land

Article

Linking Flood Risk Mitigation and Food Security: An Analysis of Land-Use Change in the Metropolitan Area of Rome

Davide Marino [1], Margherita Palmieri [1], Angelo Marucci [1], Mariangela Soraci [2], Antonio Barone [1,*] and Silvia Pili [1]

[1] Department of Biosciences and Territory, University of Molise, 86090 Pesche, Italy
[2] Italian Institute for Environmental Protection and Research (ISPRA), 00144 Rome, Italy
* Correspondence: a.barone20@campus.unimib.it

Abstract: Land consumption and climate change have intensified natural disasters in urban areas. In response to these emergencies under the European 2030 Agenda, Sustainable Development Goals have been established to improve ecosystem protection and increase resilience and adaptation to natural disasters globally (Goal 13 "Climate action" and Goal 15 "Life on land"). In order to implement governance tools appropriately, it is necessary to know the relationships among the drivers, the changes in the state of urban ecosystems and agro-ecosystems, and the impact on the supply of goods and services at spatial and temporal scales. In this paper, Land-Use and Land-Cover Changes (LULCCs) in the metropolitan area of Rome have been investigated, with the purpose of detecting the synergistic variations in the supply of the flood mitigation and agricultural production ecosystem services (ES). The methodology is based on a GIS (Geographic Information System) analysis that identifies the transformation processes and permanencies related to land-cover. The variation in flood mitigation services was quantified through the use of the Urban Flood Risk Mitigation Model (UFRM) from the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) suite, while the variation in agricultural production through productivity coefficients was associated with changes in land-uses. Finally, an analysis of LULC-induced synergies and trade-offs between the two services was performed. The results show a net negative change in ES supply, caused mainly by urbanization at the expense of agricultural land. This decrease in ES supply is not offset by other LULCC transitions. In addition, the analysis of synergies and trade-offs between flood mitigation ES and agricultural production ES (in arable land, orchards, vineyards, and olive groves) shows that the reduction of agricultural land negatively affects both ES. The innovative contribution of this paper lies in setting an integrated methodology that is able to investigate how LULCC influences both hydraulic safety and food security. Findings can be useful to support planning of enhancing the role of agriculture in metropolitan areas.

Keywords: flood mitigation ES; runoff retention; agricultural production; food security; InVEST model; GIS

check for updates

Citation: Marino, D.; Palmieri, M.; Marucci, A.; Soraci, M.; Barone, A.; Pili, S. Linking Flood Risk Mitigation and Food Security: An Analysis of Land-Use Change in the Metropolitan Area of Rome. *Land* **2023**, *12*, 366. https://doi.org/10.3390/land12020366

Academic Editors: Alessandro Bonifazi and Carlo Rega

Received: 10 December 2022
Revised: 24 January 2023
Accepted: 25 January 2023
Published: 29 January 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Unsustainable LULCC driven by socioeconomic processes have greatly impacted the Earth system's capacity to self-regulate [1]. In fact, planetary boundaries relating to some key processes have been crossed, increasing the risk of Earth system destabilization on a planetary scale [2]. Contemporary emergencies are at the center of the European 2030 Agenda [3]. In Goal 13 (Climate action) and Goal 15 (Life on land), the Sustainable Development Goals were established to improve ecosystem protection and increase the resilience and adaptation to natural disasters. Humans have radically altered ecosystems through the indiscriminate consumption of resources and input of pollutants, conditioning the current geological era defined as the Anthropocene [4]. It is characterized by increasing natural hazards that have consequences for urban communities and ecosystems. Floods, for example, represent the natural hazard to which most of the world's population is exposed [5]. In 2019, floods accounted for 49% of all natural disasters, affecting 68% of the world's population [6]. In Italy, more than 9.8% of the territory (29,500 km^2) is vulnerable to flooding, for a total of 82% of municipalities located in six administrative regions (Calabria, Trentino Alto Adige, Molise, Basilicata, Umbria, and Valle d'Aosta) and about 3.5 million people are exposed to its consequences [7].

According to the Italian institute for environmental protection and research (ISPRA) [8], 10.9% of the Italian territory falls in low flood hazard areas, 8.4% in medium hazard zones, and 4.1% in high hazard zones. A total of 45.7% of the Emilia-Romagna territory falls in medium hazard zones, followed by Tuscany 12.1%, Lombardy 10.1%, Veneto 9.3%, and Lazio 3.3%. Regarding studies conducted in the city of Rome, Anelli et al. [9] assessed the degree of spatial exposure to natural disasters through the estimation of a synthetic natural risk index. Floods can be caused by several drivers, such as urbanization, population growth, and LULCC. These processes impact the hydrological cycle and the drainage systems [8], and therefore they impact the infiltration capacity, or rather, the maximum rate at which a given soil, in a certain condition, can absorb rain as it falls. If all the rainfall water is absorbed by the terrain, no surface runoff occurs [10]. On the contrary, if the precipitation rate overcomes the infiltration rate, the soil will become saturated and unabsorbed water will give rise to surface runoff. The specific features of each type of soil and land-cover have an influence on the infiltration capacity and, as a consequence, on the runoff. Soil texture, as fractions of the sand, silt, and clay that are present in the soil, is one of the main factors determining infiltration, together with, among others, vegetation cover and human activities [11].

High runoff rates and volumes can provoke soil erosion, damage to structures, and lives [12]. Urbanization, as a product of agricultural and forest areas conversion into anthropized areas, (i) generates land-take, which on the one hand, inhibits the natural water retention capacity and, on the other hand, (ii) increases the velocity of surface runoff, resulting in increased flooding [8]. In artificial residential areas, there is a higher probability of runoff than in agricultural and forest soils, due to the longer time it takes for rain to infiltrate into the soil [13]. Liu et al. [14], using hydrological modeling based on a simulation of scenarios, proved that urbanization is the worst scenario in terms of the produced runoff, even worse than deforestation. In rural areas, excessive mechanization, crop density, and the absence of undergrowth due to agricultural intensification can also affect the increase in surface flow and flooding [15]. In fact, the presence of vegetation cover is essential for hydrological functions stabilization, runoff regulation, and flood control [16,17]. In several studies, the relationship between deforestation and flooding has been analyzed [18–20]. Each land-use and cover, in general, differ in the capacity to provide ecosystem services [21].

The ES approach is increasingly used to inform policy-makers and land-use managers [22]. ES derive from natural ecological processes and cumulative human activities over time and space [23,24]. In order to understand the flood mitigation ecosystem service variation provided by nature, it is important to analyze the land management and transitional processes that influence runoff and flooding [25,26]. Recent studies [27–29] have suggested that flood risk assessments, especially in urban areas, requires analyses based not only on hydrological processes but also on the socioeconomic context that may affect ecosystem stability. In fact, as highlighted in the literature, there is a relationship between flooding, population growth, and urbanization [30,31]. Due to their impermeability, metropolitan urban areas are highly vulnerable to extreme pluviometric events, so-called cloudbursts, which lead to unexpected floods throughout built-up areas [25]. Therefore, research on the spatial and temporal variability of the hydrological cycle in urban areas has become one of the most important issues for land-use planning [32].

To monitor floods as a function of LULCC at spatial and temporal scales [30,33–37], researchers generally use hydrological models, remote-sensed data, and GIS. A recent flood monitoring model used in urban areas is the UFRM of the InVEST suite, generated within the Natural Capital Project [36]. Kadaverugu et al. [38] used this model to quantify the flood mitigation services of green spaces and estimated the economic damage to the built infrastructure in the Hyderabad metropolitan city (India). Quagliolo et al. [15] applicated InVEST in the urban coastal territory of the Liguria Region (Italy) to estimate the amount of runoff due to two extreme rainfall events for each watershed considered, while Salata and Arslan [39] evaluated the cloudburst vulnerability level of the Izmir Province (Turkey).

According to Apollonio et al. [40], while the correlation between land-use changes and flood risk is well-known, there is still the need to define how land-use changes might impact flood trends. In this paper, the use of the UFRM model has been experimented with in the metropolitan areas of Rome to estimate the changes in the flood mitigation ES caused by LULCCs. As pointed out by Padrò et al. [41], the creation of metropolitan areas capable of conciliating population growth and ecosystem services is a crucial issue in planning. In this direction, a rising interest in green infrastructure is detectable at institutional and social levels [42–44], as they are able to mitigate urban heat islands [45], safeguard and prevent land consumption [46], enhance human–nature interactions [47], support biodiversity and the ecosystem services [48], and ensure food security [49].

Food security is a pivotal issue that has returned powerfully to the attention of both researchers and policy-makers, in relation to the multiple environmental social health and geopolitics that are affecting the contemporary world. Food security [50] depends on sustainable natural resources use [51]. Recent land-take driven by urbanization has produced a severe impact on the agricultural sector's capabilities [52]. Soil is a non-renewable resource, it should be maintained in order to support food production and thus, ensure food security.

Several studies addressing the issue of the influence of flooding on food security can be found in the international literature. Shen et al. [53] studied the relationships between flooding durations and soybean crop yield, comparing 2011 and 2018 data of the Anhui province (China); Pais et al. [54] analyzed the potential effects of waterlogging on wheat crops; Al-Jawaldeh et al. [55] evaluated the effects of several climate change indicators, among which flooding was included, on food security in the eastern Mediterranean region; and Gaviglio et al. [56] studied the economic losses caused by flood damage on dairy farms considering the livestock sector. The aforementioned studies are based on specific agricultural productions (e.g., soya, wheat, and dairy products) affected by flooding. Links between climate change and food security are addressed by several authors [57–59]. These studies, based on a global scale, are built on a future scenario analysis, and their results enhance the importance of drawing up adaptation strategies.

The objective of our paper is to carry out an original analysis of the trade-offs between flood mitigation and food security ES. An integrated methodology has been applied in this paper to address the issue of the trade-offs between flood mitigation and food security: LULCCs and a transition categories analysis have been accomplished in the framework of a GIS diachronic analysis (1990–2018). Then, ES supply variations have been studied in relation to both the retention capacity and the agricultural productivity variation caused by LULCCs using the UFRM and production coefficients. The flood mitigation variation has thus been estimated, with special attention on the productive agricultural areas. In fact, agriculture and food systems are involved in numerous challenges, including climate change, environmental pollution, the depletion of natural capital, and the loss of ecosystem services [60–62]. The results should be considered by the policy-makers of the metropolitan area of Rome as a planning tool for land-change management in future scenarios.

2. Materials and Methods

2.1. Study Area

The study area extends over 5358 km^2 and matches with the administrative boundary of the metropolitan area of Rome, including, in addition to the municipality of Rome, 120 other municipalities. This area is administered by the "Città Metropolitana di Roma" (CMRC) institution, which replaced the province of Rome in 2014. The CMRC, through the updating of the general provincial territorial plan, also performs the function of general territorial planning and directing and coordinating municipal plans, which still retain a fundamental character in the processes of land-use change. In addition, in 2022, the CMRC approved the metropolitan strategic plan, with the aim of establishing priority areas and actions for the sustainable and integrated development of the territory. One of the main plan goals is the evaluation of policies, aiming at increasing the level of food security through, among others, the protection of areas with a higher production capacity and the conversion of production areas to local supply chains [63]. A recent study based on the metropolitan area of Rome highlighted that the theoretical capacity to meet the food needs of the population is relatively low [64].

The population of the metropolitan area of Rome amounted to 4,263,542 in 2018, more than half of which is located within the municipality of Rome (see Figure 1). Urban built-up areas have experienced a great spread during recent times, according to the contemporary processes occurring within the European metropolises [65]. An increasing displacement of the resident population toward larger distances from the inner city of Rome can be recorded [66]. Urban development transformed the agricultural landscape surrounding the city of Rome, especially in low-density residential urban areas [67]. New residential functions have progressively replaced productive agricultural lands.

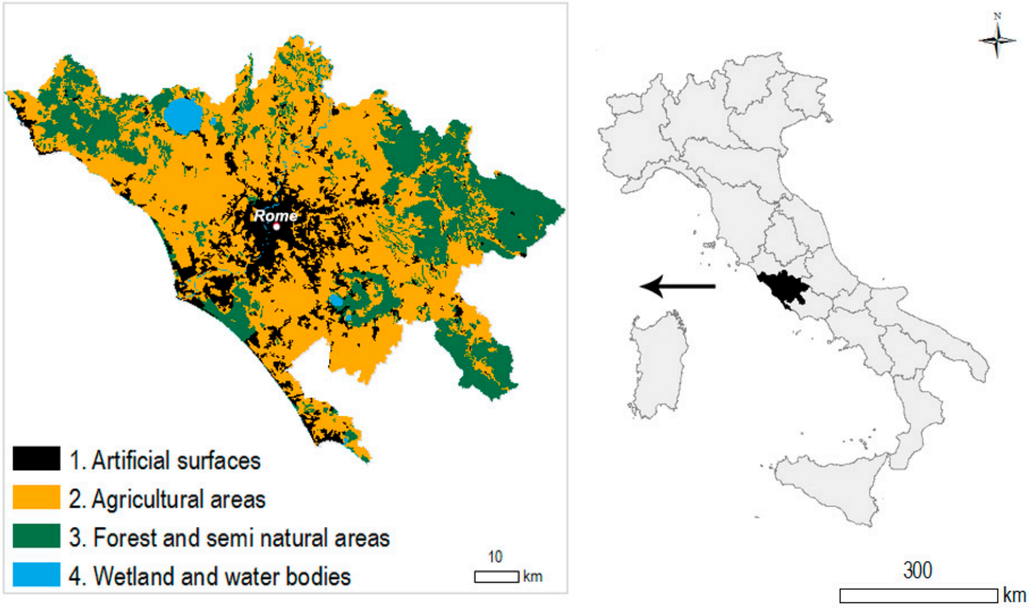

Figure 1. Location of the study area (right) and macro land-cover classes (left) in 2018: artificial surface (black), agricultural areas (orange), forest and semi-natural areas (green), and wetland and water bodies (blue). See Figure A1 in Appendix B for further information.

As Figure 1 shows, in 2018, the metropolitan's landscape is composed of 57.4% agricultural lands, 27.4% forest and semi-natural areas, 13.6% urban areas, and 1.6% wetlands and water bodies. Several studies explored the flooding phenomenon in the city of Rome [68,69] or in peri-urban municipalities [37]. Nardi et al. [70] and Recanatesi and Petroselli [37] state that anthropic transformations caused by urbanization (urban and industrial development) have significantly altered the territory, making it vulnerable to flooding. Accordingly, Di Baldassarre et al. [71] pointed out that numerous people actually live in areas potentially subject to flood events. However, none of these studies take into account the entire metropolitan area of Rome and the synergies and trade-offs between flood mitigation and agricultural production caused by LULCCs.

In the metropolitan food system, in fact, the presence of a great traditional variety of local products that have been certified as unique and inimitable as they represent the great food quality typical of this specific territory is notable. The area called Campagna Romana, which extends to the surrounding territories outside the infrastructural ring encompassing Rome, is one of the most representative agricultural landscapes of the metropolitan area, and it plays a crucial ecological role of connection [72,73]. As pointed out by Pili et al. [74], the recent LULCCs modified the natural and semi-natural landscape, producing a great fragmentation and loss of this area. In recent times, to face these dynamics, there is remarkable attention, in the territorial policies, to the agricultural management of metropolitan green spaces as a useful tool for limiting urban expansion and enhancing biodiversity [64]. As pointed out by Brunori et al. [60], during the 2006–2008 food crisis, food security became a key element in Italy: a rising interest has been dedicated to food as it is one of the most important factors of the Italian competitive assets, and for this reason, it is particularly vulnerable. The recent Atlas of Food [64] detected in the Rome metropolitan agro-food system a troubling decrease during the last decades.

2.2. Methodological Framework

The methodological approach is composed of four steps illustrated in Figure 2 and described in Sections 2.3, 2.4, 2.5 and 2.6. The first step is based on the analysis of transition and permanence processes from the LULCC analysis that interested the metropolitan city of Rome for the period 1990–2018. In the second step, we quantified the change in flood mitigation ES by runoff retention variation using the UFRM software.

This allowed us to link the flood mitigation ES variation to the transition and permanence categories in step 3. Finally, in step 4, we quantified the agricultural production of ES supply and evaluated how the transition and permanence categories affect the supply and trade-offs of flood mitigation ES and agricultural production ES.

Transition matrices have been used in the research literature [75–79] to assess the change in ES supply due to changes in LULCC. Other studies, on the other hand, use tools such as GIS to analyze the spatial and temporal distribution of ES [80–84], or INVEST to assess several ES including flood mitigation ES [15,38,39]. In our paper, we used GIS and INVEST combined to assess flood mitigation ES supply and food production ES supply as a function of transition and permanence processes.

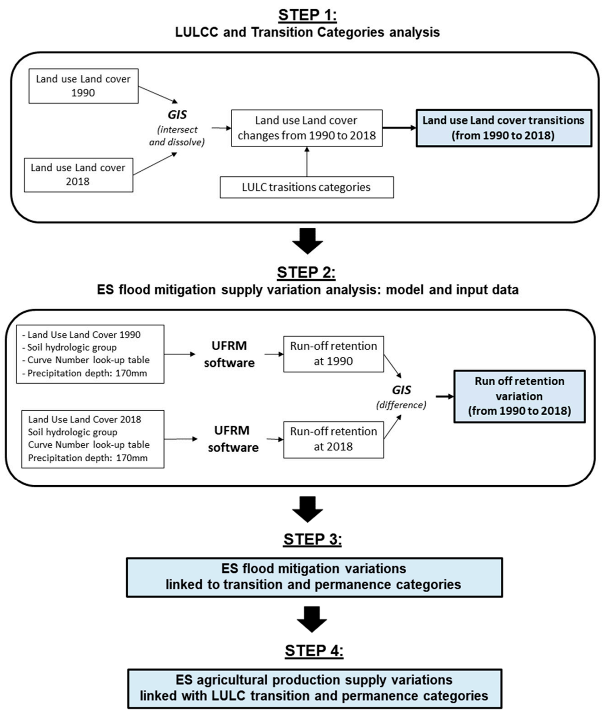

Figure 2. Methodological framework of the ecosystem services variation analysis represented by 4 steps. Sources: UFRM software [36], Land Use Land Cover [72], LULC transition categories [85], Soil hydrologic group [86], Curve Number look-up table [87].

2.3. LULCC and Transition Categories Analysis (Step 1)

LULCC analysis has a crucial role in studying ES variation due to human activities through the territory. This type of analysis can be useful to inform stakeholders and planners in order to make sustainable choices that are able to reverse negative consequences and face contemporary challenges. The III hierarchical level of the CLC [74] is the cartographic vector data at the basis of our GIS-based analysis: first, the intersect geoprocessing tool has been used to detect the LULCCs between CLC 1990 and CLC 2018 (e.g., 211 to 242 CLC class), then, LULCCs have been classified into 7 categories (see Figure 3): (i) urbanization, (ii) agricultural extensification, (iii) agricultural intensification, (iv) evolution to complex system, (v) forest expansion, (vi) forest internal transition, and (vii) permanence, according to Marino et al. [85]. The category named "other changes" has been added to the original matrix, so as to include all transitions that occurred in the study area (even if rare).

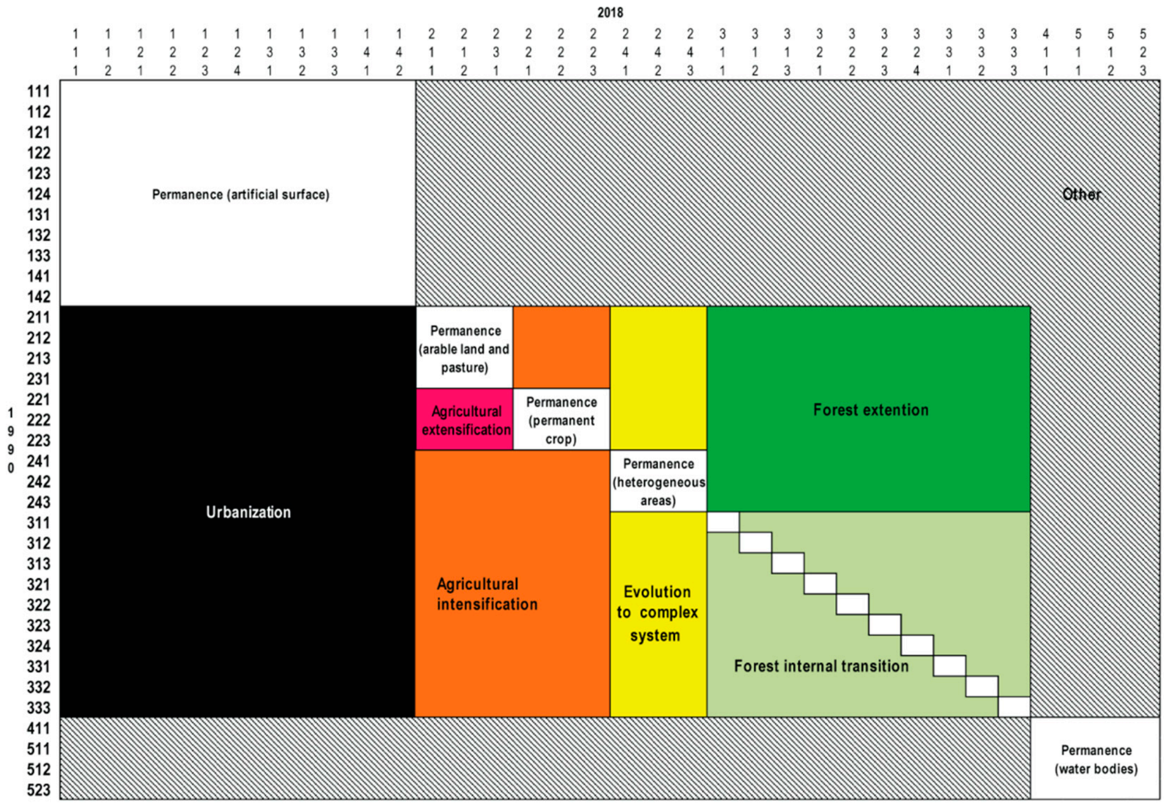

Figure 3. Land-use and land-cover (LULC) transition categories matrix (modified on [88]): urbanization (black), agricultural intensification (red), agricultural extensification (pink), evolution to complex systems (yellow), forest extension (green), forest internal transition (light green), other (gray), and permanence (white).

2.4. ES Flood Mitigation Supply Variation Analysis: Model and Input Data (Step 2)

The UFRM is one of the spatially explicit models included in the InVEST suite, developed by the Natural Capital Project of Stanford University [36]. This software for evaluating ecosystem services, as outlined in the introductory section, has been used in several other international studies [15,38,39]. Using maps as main information sources and producing maps as outputs, the UFRM calculates the amount of runoff retention and production (per pixel) for a given rainfall depth, using the established curve number rainfall-runoff method [89]. Runoff occurs when water flows over the land surface due to the saturation conditions of the soil. The curve number method is a conceptual hydrological abstraction of rainfall, which is supported by empirical data [90,91]. The curve number value, in particular, is a parameter that relies on field observations and ranges from 30 to 100, determined by the association between land-use and land-cover and the corresponding hydrological group. Increasing curve number values (mostly associated with poorly permeable soils) result in less absorption of precipitation and greater surface runoff, with a potentially increasing risk of flooding.

In order to launch the UFRM, it is necessary to enter the required data relating to the area under investigation, including the following: land-use land-cover (raster), hydrological groups of soils (raster), the association between curve number, land-use and hydrological group (table), and rainfall depth of storm design (numeric).

Below is a brief description of the input data used.

2.4.1. Land-Use and Land-Cover Raster

Among the main inputs of the UFRM is the LULC raster of the survey area. Since the aim of this paper is to perform a diachronic analysis between 1990 and 2018, two rasters (one for each year considered) have been used for each of the two modeling runs. CLC shapefiles, for 1990 and 2018, have been downloaded for the Rome metropolitan area from the online repository made available by ISPRA [72]. The shapefiles have been converted to raster with 10mx10m pixels.

2.4.2. Hydrologic Soil Groups

Hydrologic soil groups are a fundamental component of the curve number method for estimating rainfall-runoff and they indicate the potential behavior of soils in generating surface water runoff. Runoff occurs when rainfall intensity exceeds the infiltration capacity of soils. The physical nature of the soils (e.g., their texture, compaction, etc.) is decisive in this respect: fine-textured clay soils, for example, have less pore spacing than sandy soils, resulting in slower water infiltration [91]. Based on similar pedoclimatic characteristics, therefore, USDA [91] divides soils into four main groups, with increasing potential runoff, named A (that usually contains 90% sand and less than 10% clay), B (10 to 20% clay and 50 to 90% sand), C (20 to 40% clay and less than 50% sand), and D (more than 40% clay and less than 50% sand). The UFRM, which is used in this work, requires as input, cartographic (raster) data on the hydrological groups in the survey area. These data have been retrieved from a global dataset [86] that is specifically intended for hydrological modeling. The raster has been subsequently resampled with 10mx10m pixels.

2.4.3. Curve Number

As mentioned above, the curve number is an empirical parameter that describes the runoff formation following a specific rainfall for each specific "soil-cover complexes", the association between hydrological groups, and the land-use land-cover classes [92,93]. Using a look-up table (see Table A1 in Appendix A), curve number values (for average antecedent wet condition) have been assigned to the association between hydrological group and soil-cover class (at III level of Corine land-cover classification). The look-up table used has been commissioned by the region of Tuscany to the Department of Environmental Engineering of the University of Florence [87]. This table is compiled on the basis of the indications of the USDA-Natural Resources Conservation Service [93] and provides curve number values associated with the land-use classes of the Corine land-cover legend. As there are no such tables available for the metropolitan area of Rome, this table has been considered to be sufficiently adequate for the purpose of our work. Of course, for complete and more precise hydrological modeling, the ideal would be to use an empirical curve number obtained from field experiments. In any case, complete and precise hydrological modeling is not the purpose of this work, which rather focuses mainly on the effect of land-use changes on water retention capacity or rather, ES supply.

2.4.4. Rainfall Depth

Another parameter required by the UFRM is the rainfall depth (mm) of the simulated weather event, namely the amount of precipitation fallen in a given period of time. To calculate the rainfall depth, the rainfall intensity–duration–frequency curves made available by the Regional Agency for Civil Protection have been considered. In particular, the arithmetic mean of the rainfall possibility values (with a 50-year return period and 24-h rainfall duration) has been calculated for seven rain gauge stations distributed throughout the metropolitan territory. The average value calculated corresponds to 170 mm of rainfall depth in 24 h. The return period used is common in modeling investigating the effect of LULC change on flood mitigation [94].

Once the required data had been collected and processed, two modeling runs were carried out using the UFRM. In particular, the only difference between the two modeling runs had been the different input data for the LULC raster: one for 1990 and the other for 2018. The other parameters have been left unchanged, to isolate the effects on runoff retention capacity, due to land-use/cover change only. As output, the software returned in raster format, the runoff retention capacity (the ES flood mitigation supply) for the two different years investigated. Lastly, in order to quantify the change in ES supply between 1990 and 2018, a subtraction between the two runoff retention capacity rasters has been elaborated, using the raster calculator tool of the spatial analysis software ArcGIS. The final raster identifies the location and extent of changes in ES supply that occurred between 1990 and 2018. It should be noted that the modeling is based on a hypothetical single meteoric event with a 50-year return period and 24-h duration (rainfall height equal to 170 mm). The change between 1990 and 2018 in the ES supply is therefore the difference in rainfall retention capacity calculated for a single event of the type described above.

2.5. ES Flood Mitigation Variations Linked to Transition and Permanence Categories (Step 3)

With the aim of exploring the role of the LULC transition categories with regard to ES supply variation, zonal statistics (in ArcGIS environment) have been used between the transition category shapefile and the ES supply difference raster. In particular, the service variations have been grouped, i.e., summed, within the same identified transition category, to obtain the total net ES supply variation associated with each transition category.

Note that since the curve number is associated with the third CLC level (see Section 2.3), the ES supply varies in some cases between changes at the third CLC level. Consequently, each transition category may include within it positive or negative changes in ES supply, which when added together, return a total net (positive or negative) ES supply variation induced by that category. For this reason, the major internal processes within the individual transition categories have been investigated in detail.

2.6. ES Agricultural Production Variation Linked to Transition and Permanence Categories (Step 4)

The way through which transition processes and permanencies between 1990 and 2018 influenced the change in ES agricultural production has been evaluated. Specifically, an estimate of which processes changed the area of some crops (arable land, vineyards, orchards, and olive groves) and the associated agricultural productivity has been produced. The software ArcGIS has been used to quantify crop area from Corine land-cover. Agricultural productivity has been estimated using biophysical coefficients (t/year) elaborated from data from Council for Agricultural Research [95]. We calculated biophysical coefficients (tons/ha) by relating the agricultural production (tons) of the main horticultural, cereal, olive, viticultural, and fruit crops to the agricultural area (ha) in Italy. To quantify the supply of the agricultural production SE, we multiplied these coefficients with the agricultural areas (period 1990–2018) of the metropolitan area of Rome. To calculate the percentage change in agricultural areas and agricultural production ES, we applied the following formulas:

$$\textit{Variation } (\Delta\%) \textit{ agricultural areas} = [(\textit{CLC value 2018} - \textit{CLC value 1990})/\textit{CLC value 1990})] \times 100$$

$$\textit{Variation } (\Delta\%) \textit{ agricultural production} = [(\textit{Supply value 2018} - \textit{Supply value 1990})/\textit{Supply value 1990})] \times 100$$

Finally, we evaluated the change (1990-2018) in flood mitigation ES and agricultural production ES according to the LULC transition categories. This aspect is important for analyzing synergies and trade-offs among the ES analyzed in this paper. When referring to relations between ecosystem services in terms of trade-offs, this indicates the occurrence of an increase in the supply of one ES while another decreases. Conversely, when the supply of two or more ecosystem services increases or decreases simultaneously, this is described as synergy [81]. Variations in the supply of ecosystem services depend on endogenous or exogenous changes in the system, referred to as drivers [96]. In our case, the drivers are the LULCCs, summarized by the transition categories described above.

3. Results

3.1. Transition Category Analysis

The transition categories analysis points out that 85% (4555 km^2) of Rome's metropolitan area territory has not undergone any transformation, while 15% (802 km^2) experienced changes. As Figure 4 shows, the most widespread transitions are (i) forest internal changes, or rather "forest transition" (4.7% of the study area), and (ii) evolutions to complex systems (4.4%). The lowest transition category rate extension corresponds to agricultural extensification (0.1%).

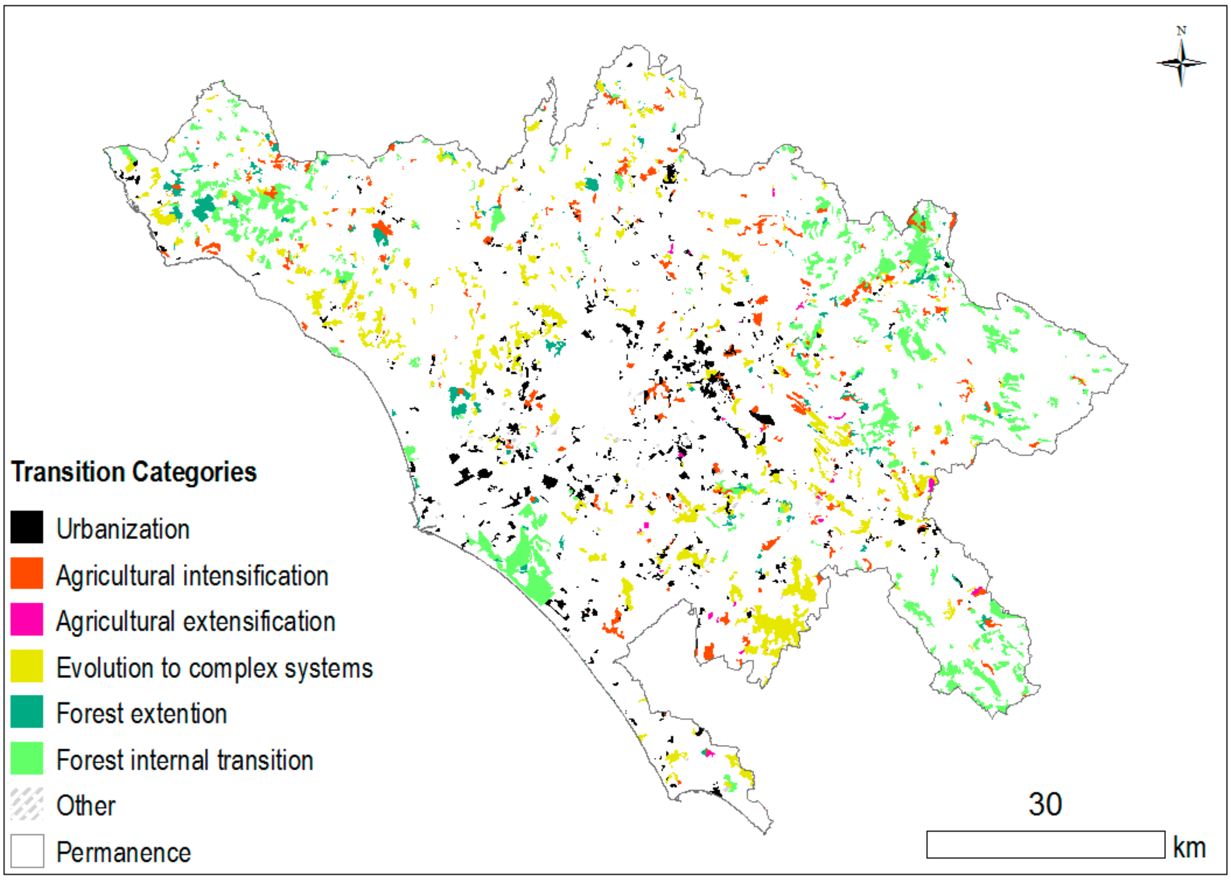

Figure 4. LULCC transition categories map: urbanization (black), agricultural intensification (red), agricultural extensification (pink), evolution to complex systems (yellow), forest extension (green), forest internal transition (light green), other (gray), and permanence (white).

New artificial areas have been built up mainly in agricultural areas. In fact, 98% of urbanization (118 km^2) occurred at the expense of arable land (67 km^2), heterogeneous agricultural areas (40 km^2), permanent crops, and pastures (10 km^2). These classes have been converted into artificial areas: the land taken from agricultural areas can be observed mainly in correspondence to Rome's urban growth directions (E and SW), especially in areas adjacent to the infrastructure of the great ring road (GRA) that surrounds the city of Rome. A small part of urbanization happened on woodland (2%).

3.2. ES Supply Variation Analysis

Through the UFRM, the flood mitigation service supply has been quantified for 1990 and 2018. InVEST has generated two rasters of the runoff retention capacity for both the two years (see Figure A2 in Appendix B). The difference between these two outputs has been calculated (via the ArcGIS raster calculator tool) in order to localize and quantify the changes in the ES supply (Figure 5). The resulting raster, generated by the difference between the two years, equals $-513{,}065$ m^3 of the runoff retention capacity. Specifically, in the entire territory, the ES supply in 1990 has been found to be 288,241,838 m^3, while in 2018 it corresponded to 287,728,777 m^3.

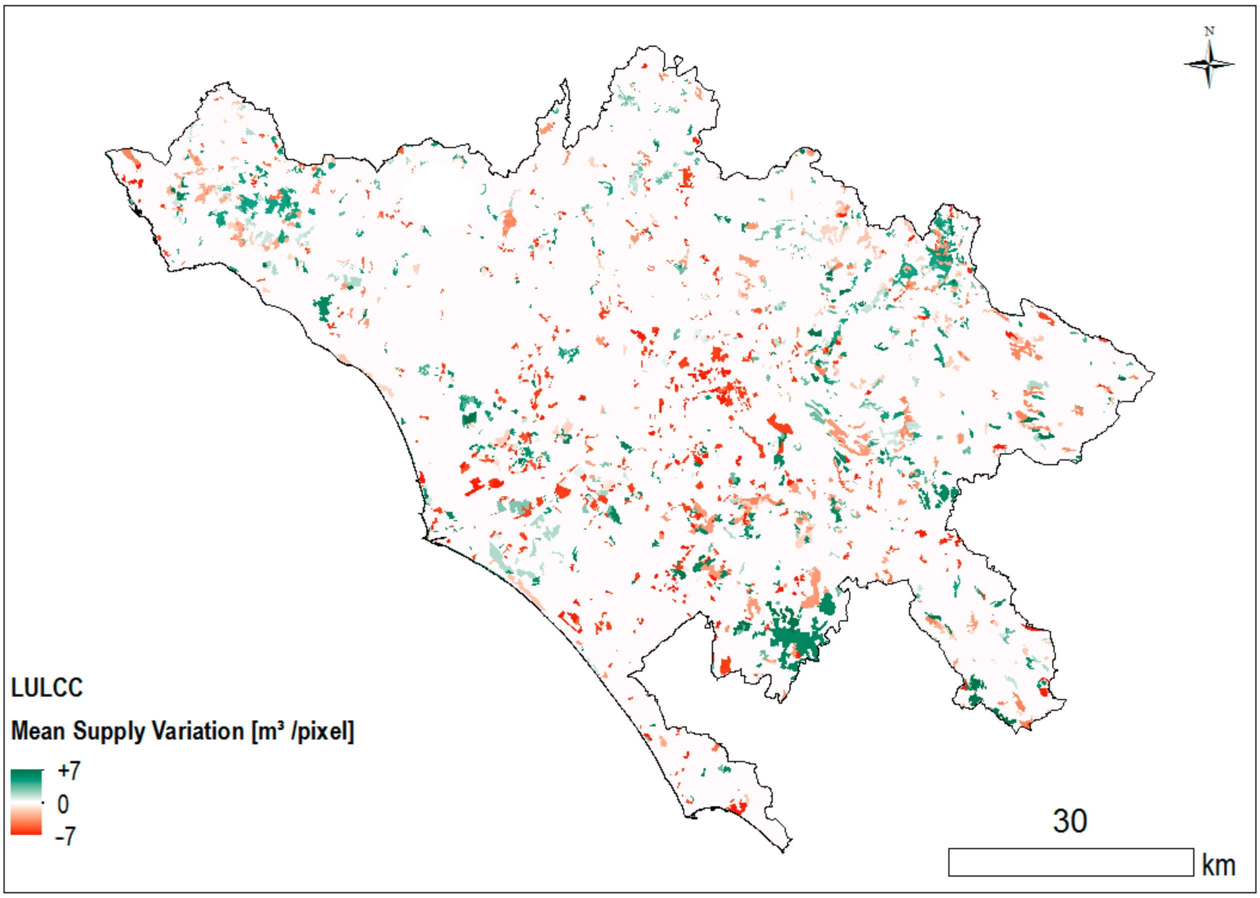

Figure 5. ES flood mitigation supply variation (1990–2018). This map represents the values of the ES supply variation at pixel level, obtained through the raster calculator tool. Gradations of red represent negative variations from the least pronounced (shaded red) to the most pronounced (full red), while gradations of green represent positive variations from the least pronounced (shaded green) to the most pronounced (full green).

The results record a marked spread of reduced levels of runoff retention (Figure 5). This trend can be especially observed in three directions branching out from the center of Rome that are E–SE, S, and W directions: they correspond to the recent urban growth (urbanization transition category) of the Rome metropolitan area. Rome is the municipality that recorded major decreases in the supply service, followed by Pomezia, Guidonia Montecelio, Cervara di Roma, Nettuno, Fiumicino, Fiano Romano, and Colleferro. As the positive variation concerns, comparing the two UFRM outputs (see Figure A2 in Appendix B section), the results reflect an improvement of the ES supply in correspondence with the municipalities of Velletri in the southern part of the study area and in Genazzano in the area linked to the transition category of evolution to complex systems, which corresponds, at least in part, to agriculture abandonment.

3.3. ES Supply Variation Associated with LULC Transition Categories

Using ArcGIS zonal statistics between the transition categories shapefile and the ES supply variation raster, the role of LULC transitions concerning the ES supply changes has been further investigated. Specifically, for each transition category, the total net (m^3) and average (m^3/ha)-induced variation in the ES supply have been deduced (Table 1). The most relevant processes within the first two transition categories in terms of impact on flood mitigation ES have been delved.

Table 1. Total and average change in ES flood mitigation supply for each LULC transition category.

LULCC Transition Categories	Area (ha and %)	ES Supply Variation (m^3)	ES Supply Mean Variation (m^3/ha)
Agricultural extensification	694 (0.1%)	46,903	68
Agricultural intensification	9419 (1.9%)	206,716	22
Evolution to complex system	23,460 (4.4%)	410,830	3
Forest extension	5965 (1.1%)	805,628	135
Forest internal transition	25,333 (4.7%)	685,310	27
Urbanization	12,126 (2.3%)	−3,236,852	−267
Other changes	3257 (0.6%)	684,360	212
Permanence	455,538 (85.0%)	217,675	0.4
Total	535,792 (100%)	−513,065	-

Urbanization is the only transition category that results in a total net negative change in the flood mitigation ecosystem service. The induced change is so significant that it is not fully offset by the total net positive changes of the other LULC transitions. Our results indicate that on average, for each hectare of sealed soil, 267 m^3 of runoff retention capacity has been lost in the area of study. As for the positive changes in the ES supply, these are primarily attributable to forest extension (with an average per hectare of +135 m^3/ha), followed by internal transitions between forest areas (+22 m^3/ha). Followed in descending order are the categories: other changes, evolution to complex system, permanence, agricultural intensification, and agricultural extensification.

Urbanization is not the most significant process in terms of area involved (2.3%), but it is the process with the greatest weight in terms of the negative changes of ES supply. Within this category, urbanization that occurred at the expense of agricultural areas (98%) and at the expense of forest areas (2%) can be distinguished. Urban expansion has mostly affected agricultural areas and most of the negative changes in the ES supply are attributable to this process. Although on average, urbanization of agricultural areas results in a lower loss of service (−266 m^3/ha), compared to the urbanization of forest areas (−347 m^3/ha), the former (given the preponderance in terms of area involved) has had a very important impact on ES supply variation and contributes to defining the final average ES supply variation for this category.

Going into even greater detail, it should be noted that the largest LULC changes in this category, in terms of both area and negative change induced on ES supply, concern:

1. Transformations from arable land (211 CLC class) to urbanized land-uses, such as discontinuous residential areas (112 CLC class) and industrial/commercial areas (121 CLC class) (5464 ha);
2. Transitions from complex agricultural systems (242 and 243 CLC classes) to discontinuous urban areas (112 CLC class) (3336 ha).

The processes listed above account for 71% of all the negative changes and 73% of the area involved in the urbanization category.

Forest extension occurs in only 1.1% of the area, but it is the category that resulted in the highest ES supply variation. Notably, just as with urbanization processes, it occurs in 95% of the cases at the expense of agricultural land, and 5% of the cases involve reforestation in formerly urban soils (incorporated into the "other changes" category). Our results indicate that afforestation of agricultural land led to an average increase in ES supply of 135 m^3/ha, while afforestation in urban areas led to an average increase in ES supply of 316 m^3/ha, or more than double. It is clear that the reforestation of urban areas has the greatest benefit in terms of runoff retention and thus the ES supply, but in the case of this study, almost all reforestations took place at the expense of agricultural land (5965 ha). In fact, transformations from heterogeneous agricultural areas with important natural spaces (243 CLC class) to broadleaf forests (311 CLC class) and transitional woodlands (324 CLC class) accounted for 50% of the positive changes in ES supply for this category and weighed 38% (2398 ha) in terms of area.

3.4. Variation of ES Agricultural Production

According to our results in the area of study, the transition processes produced a loss of 11% in agricultural land, or rather, about 20,000 hectares (Table 2). The reduction in vineyard areas in the metropolitan area is in line with the national data. Factors that may have had an effect are both structural (downsizing of the sector) and political–financial, due to the reconversion and restructuring of vineyards through CMO wine (Common Market Organization for wine) policies [97]. Despite the cross-compliance rules of the Common Agricultural Policy (CAP), which prohibit the feeling of olive groves and maintaining them in a good vegetative state, the olive grove areas decreased by 1,329 hectares. Possible reasons for this include excessive urban sprawl and the presence of mixed crops, in which olive trees are intercropped with other crops. The intercropping with other crops may have induced a change in the land-cover. The reduction in the agricultural area proportionally resulted in a loss of agricultural productivity, estimated at 249,838 tons (−11%).

Table 2. Agricultural areas (expressed in hectares and percentage) and related agricultural production (expressed in tons and percentage) changes between 1990 and 2018.

Corine Land-Cover Class	Area				Supply			
	1990	2018	Δ 2018–1990 (ha)	Δ 2018–1990 (%)	1990	2018	Δ 2018–1990 (t)	Δ 2018–1990 (%)
211	162,394	148,701	−13,693	−9	2,252,571	2,062,638	−189,932	−8
221	14,557	9620	−4937	−51	154,540	102,127	−52,413	−34
222	28,423	28,282	−141	0	41,184	40,980	−204	0
223	4495	3166	−1329	−42	24,657	17,368	−7289	−30
Total	209,869	189,769	−20,099	−11	2,472,952	2,223,114	−249,838	−11

Finally, synergies and trade-offs between the ES of agricultural production and flood mitigation have been analyzed. Agricultural production has been considered a proxy indicator for food security. The results are shown in Table 3. In this case, the variations considered for the two ES depend on the processes of the LULC transition on agricultural soils only, and in particular, non-irrigated arable land (211 CLC class), vineyards (221 CLC class), orchards (222 CLC class), and olive groves (223 CLC class).

Table 3. Agricultural production (ton/ha) and flood mitigation (m^3) variation in arable land, vineyard, olive groves, and orchards, between 1990 and 2018. The percentage was calculated by dividing the variation of individual transition processes by the total sum of each ES variation.

Transition	Agricultural Productionvariation (ton/ha)	Agricultural Production Variation (%)	Flood Mitigation Variation (m^3)	Flood Mitigation Variation (%)
Agricultural extensification	+4,325	+2	+46,903	+6
Evolution to complex system	−214,596	−86	+461,793	+61
Agricultural intensification	+55,410	+22	+218,151	+29
Other changes	+12,728	+5	+227,198	+30
Permanence of permanent crop	−9,311	−4	+218,095	+29
Permanence of arable land and pasture	+14,054	+6	−45,396	−6
Forest extension	−16,014	−6	+119,850	+16
Urbanization	−96,436	−39	−2,005,228	−264

4. Discussion

In line with other studies, this paper highlights how changes in LULC have led to changes in the provision of ecosystem services [98–100]. The results should be considered as an innovative tool for diachronic studies and for future scenario analysis informing planning. As Horton states [10], if planning cannot directly change the features of the rainfall and floods, it can improve land-use practices toward increasing infiltration and crop production. According to Morano et al. [101], specific and adequate urban plannings are needed in order to reduce natural risks. Agricultural land should be provided and maintained because of its importance for both flood mitigation and food production services.

Consistent with the national and international literature [8,14,37,102], our diachronic analysis pointed out that urbanization produces the most worsening effects affecting flood mitigation ES supply. This is confirmed both by studies using the UFRM and by studies using different methodologies. Salata et al. [39], for example, using the UFRM, find that in Turkey, more than half of the precipitation that falls onto soils that have become urbanized is not absorbed, and thus, becomes runoff. Sugianto et al. [13], through infiltration experiments in Indonesia, found that the infiltration time of water in residential soils was 9 min compared to 4 min in forest and agricultural soils. In the metropolitan area of Rome, the negative urbanization impacts have not been compensated by positive effects generated by forest expansion and the other LULC transitions analyzed. In fact, while urbanization averagely generates a −267 m^3/ha water retention, forest extension gives rise to a +135 m^3/ha. Thus, even if forest expansion brings the highest observed average rise of the ES provision, the negative effects of urbanization amount to twice the positive effects of woodland expansion. Additionally, the other LULC transitions analyzed, although involving, in some cases, relatively large areas (see forest internal transition and evolution to complex systems), on average, do not have a considerable positive effect on the change in ES flood mitigation supply and consequently, have not compensated for the loss of the ES due to urbanization. Land-use strategies should take into account the results of our study, encouraging the maintenance of agriculture and forests in metropolitan areas rather than land-take. In this sense, for example, the environmental compensation provided by the urban planning system cannot repair the decrease in the flood mitigation services caused by urbanization. Overall, the mean variation associated with each transition category could contribute to estimating ES supply variation in a scenario analysis of the land-use transformation, allowing, for example, the ES fluctuation estimation in metropolitan green infrastructure planning.

Furthermore, our results show that urbanization has occurred mainly at the expense of agricultural land, and in particular, on arable land and complex agricultural systems. This trend is common to many areas of the planet and, according to Bren d'Amour et al. [103], will continue for the foreseeable future. These projections make our findings even more relevant, because as we have observed, urbanization in agricultural areas is confirmed to be a crucial factor in both flood mitigation and food production reduction. In fact, urbanization represents a severe cause of ES flood mitigation reduction in the studied period: this transition produces an overall great decrease (−264%) of the flood mitigation ES in arable lands, vineyards, olive groves, and orchards. At the same time, urbanization at the expense of agricultural areas has caused a 39% reduction in agricultural production.

The reforestation of agricultural areas leads instead to a trade-off between the two services. There is in fact a negative change in agricultural production (−6%) and an increase in runoff retention (+16%). Other factors being equal, the greater potential of woodlands to intercept and absorb precipitation is confirmed by several international studies [14,104]. Examining the other trade-offs found, we note that regarding the negative agricultural production variation, urbanization is exceeded only by the evolution to complex system category, that results, at least in part, in agricultural land abandonment. Nevertheless, this transition does not even come close to repairing a quarter of the decrease in flood mitigation ES produced by urbanization in these productive areas. These findings confirm the need to maintain and enhance agricultural productive areas as they can play a relevant role in supporting both flood mitigation ES and food production.

The innovative contributions of this work lie in an integrated methodology that is able to investigate past LULCC transformations considering the influence on ES variations. If applied to future scenario analyses, it can inform planners in order to predict transformations impacts. This article has relevance as it concerns the issue of the trade-off between flood mitigation and food security in the metropolitan area of Rome. Several works on the analysis of ecosystem services in this area focus just on the municipality of Rome alone (or on a part of it) [37,70,71]. As already stated, the metropolitan area of Rome is governed by a public institution with planning jurisdiction over the entire territory under investigation. Integrated analyses at this scale are needed to inform territorial governance (e.g., strategic plan). The analysis of synergies and trade-offs between ecosystem services is a hot topic and will probably continue to be so in the near future [105]. Currently, there are no studies analyzing synergies and trade-offs induced by LULCCs on the ecosystem services supply of flood regulation and food production. Conversely, several studies focus on flood-induced damage at the expense of agricultural production [106–110]. In this sense, it is possible to state that the ES of agricultural production is threatened not only by a reduction in productive agricultural areas, but also by a decrease in the ecosystem service of flood mitigation. Indeed, the reduction of this service increases the potential risk of fluvial and pluvial flooding, also at the expense of agricultural production.

The limits of our study can be overcome by bridging the gap of data availability, i.e., with in-depth, local-based studies on curve numbers through direct observation. Lengthy field experiments and accurate sampling designs are required, and they are particularly needed for cultivated systems where past management practices represent an additional factor [111]. Furthermore, with regard to the availability of cartographic bases, it is desirable to have maps at a local level. The Corine dataset, in fact, has several limitations (e.g., geometric resolution), as noted by several studies [112–114]. Agricultural production data presented in this study are intended to be indicative and offer potential. The use of coefficients does not take into account certain factors such as fertility, soil tillage, management, water availability, etc. This study would be improved and expanded by also considering other ES provided by nature. Moreover, in addition to the ES supply, the spatial and temporal variation in demand should be analyzed. This would assess the ecosystem services balance [115], facilitating the identification of areas where it is desirable to increase natural capital [116,117]. Furthermore, for proper urban planning, it is useful to combine mapping with tools that can integrate both spatial mapping methods and human-based assessment tools [118]. Models analyzing land-use changes and spatial trends are largely used in assessments, in order to provide useful tools for decision-making. To this end, in flood risk planning, assessment is therefore a necessary approach to explore possible scenarios based on transition processes and permanencies.

The results of our paper should be used to predict trends and simulate scenarios of land-change dynamics. The quantification of ecosystem services may be useful to define governance policies at the metropolitan city level. As pointed out by the analysis, agricultural productive areas would be straightened as they play a pivotal role in implementing metropolitan strategies in order to face both the effect of floods [119] and food insecurity [120].

5. Conclusions

Despite the inherent limitations of the materials used for the study, the results can be considered as useful elements for planning agricultural land-use transformations in front of the need to cope with the current challenges as, among others, climate change and the consequent flood risks are increasing. Our original analysis underlines the trade-offs between hydraulic safety (flood mitigation ES) and food security (food production ES) induced by LULCCs. LULCC is one of the phenomena that has the greatest impact on biodiversity loss and global changes affecting the environment, at both global and local scales. Analyzing transformations in land-use make possible the identification of areas that are relevant to ensuring the ES supply on which economic and social well-being depends. Acknowledging these areas is essential to protecting biodiversity and contributing to the global goals of the European Agenda 2030, the European Biodiversity Strategy for 2030, and the CAP. In metropolitan areas, the consumption of land in agricultural and rural areas can negatively affect the provision of ecosystem services for the population residing in more densely populated areas. In other cases, such as for the renaturation phenomenon, there is evidence of a trade-off between essential ecosystem services, such as food supply and protection from hydrogeological disruption. However, the dynamics in land-use change are complex, and the recent increase in potential extreme weather events can negatively affect the safety of urban populations in relation to both flooding and food production loss. In this regard, metropolitan areas play a relevant role in defining and implementing a land governance model that includes socioeconomic and environmental needs. Integrating ES into the planning tools of metropolitan cities can be a useful action to strengthen the resilience of urban and agricultural ecosystems. Strengthening the resilience of metropolitan areas, including through the use of nature-based solutions, enables the establishment of conditions for sustainable and long-term development that is in line with the European 2030 Agenda.

In this paper, through the quantification of land-use transitions in the metropolitan area of Rome, the changes in the ecosystem services provision of flood mitigation and agricultural production have been analyzed. The findings underline that urbanization can have synergistically negative effects on both physical security and food security. The latter represents an element that is even riskier in light of the potential disruptions in food supply chains at the international level. Environmental, health, and food security are thus, according to the UN-developed concept of One Health, intimately linked, which highlights the need for a place-based and integrated approach for environmental, social, and economic policies in metropolitan areas.

Author Contributions: Conceptualization, D.M. and A.B.; methodology, D.M., M.P. and A.M.; software, A.B. and S.P.; data curation, M.P., A.M., A.B., S.P. and M.S.; writing original draft preparation, A.B. and S.P.; writing—review and editing, D.M., M.P., A.M., A.B. and S.P.; visualization, A.B., M.P. and S.P.; supervision, D.M., A.M. and M.P. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been supported by the research-action project "Construction of the Food Plan of the metropolitan City of Rome Capital" followed by the University of Molise working group under a collaboration agreement with the metropolitan City of Rome Capital (project code F39F19000410001).

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Curve number values (average wet condition) assigned to III level Corine land-cover (CLC) classes. Source: Castelli F. [87].

CLC Classes	Hydrologic Soil Groups			
	A	**B**	**C**	**D**
111 - Continuous urban fabric	89	92	94	95
112 - Discontinuous urban fabric	77	85	90	92
121 - Industrial or commercial units	81	88	91	93
122 - Road and rail networks and associated territories	98	98	98	98
123 - Port areas	98	98	98	98
124 - Airports	98	98	98	98
131 - Mineral extraction sites	76	85	89	91
132 - Landfills	81	88	91	93
133 - Construction sites	77	86	91	94
141 - Urban green areas	49	69	79	84
142 - Sport and leisure facilities	68	79	86	89
211 - Non-irrigated arable land	61	73	81	84
212 - Permanently irrigated land	67	78	85	89
213 - Rice paddies	62	71	78	81
221 - Vineyards	76	85	90	93
222 - Orchards and minor fruits	43	65	76	82
223 - Olive groves	43	65	76	82
231 - Pastures	49	69	79	84
241 - Annual crops associated withpermanent crops	61	73	81	84
242 – Complex cultivations patterns	61	73	81	84
243 - Land principally occupied by agriculture, with significant areas of natural vegetation	61	73	81	84
244 - Agro-forestry areas	43	65	76	82
311 - Broad-leaved forests	36	60	73	79
312 - Coniferous forests	36	60	73	79
313 - Mixed forests	36	60	73	79
321 - Natural grassland	49	69	79	84
322 - Heathland and scrubland	49	69	79	84
323 - Sclerophyllous vegetation	35	56	70	77
324 - Transition woodland/shrubs	35	56	70	77
331 - Beaches, dunes, and sand flats	46	65	77	82
332 - Bare rock	96	96	96	96
333 - Sparsely vegetated areas	63	77	85	88
334 - Burnt areas	63	77	85	88
335 - Glaciers and perennial snows	98	98	98	98
411 - Inland marshes	98	98	98	98
412 - Bogs	98	98	98	98
421 - Salt marshes	98	98	98	98

Table A1. *Cont.*

CLC Classes	Hydrologic Soil Groups			
	A	**B**	**C**	**D**
422 - Salines	98	98	98	98
423 – Intertidal flats	98	98	98	98
511 – Water courses	98	98	98	98
512 – Water bodies	98	98	98	98
521 – Coastal lagoons	98	98	98	98
522 – Estuaries	98	98	98	98
523 – Sea and ocean	98	98	98	98

Appendix B

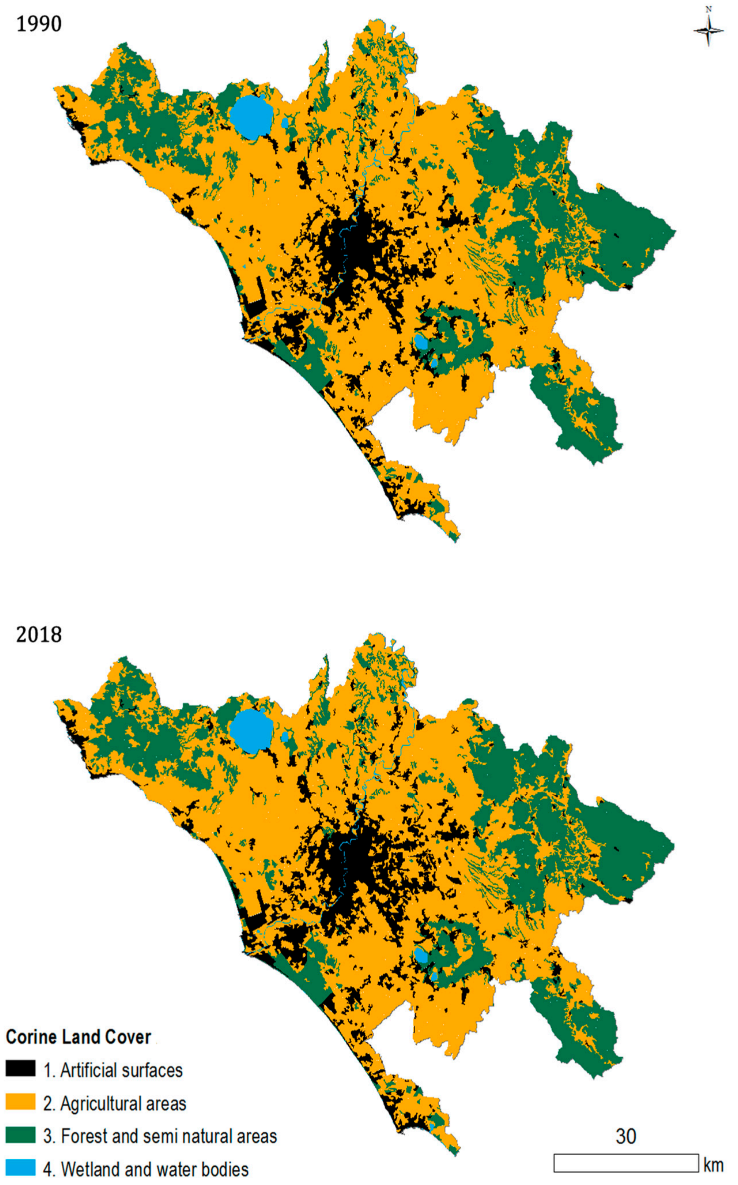

Figure A1. Land-cover and -use in 1990 and 2018. Source: CLC [72].

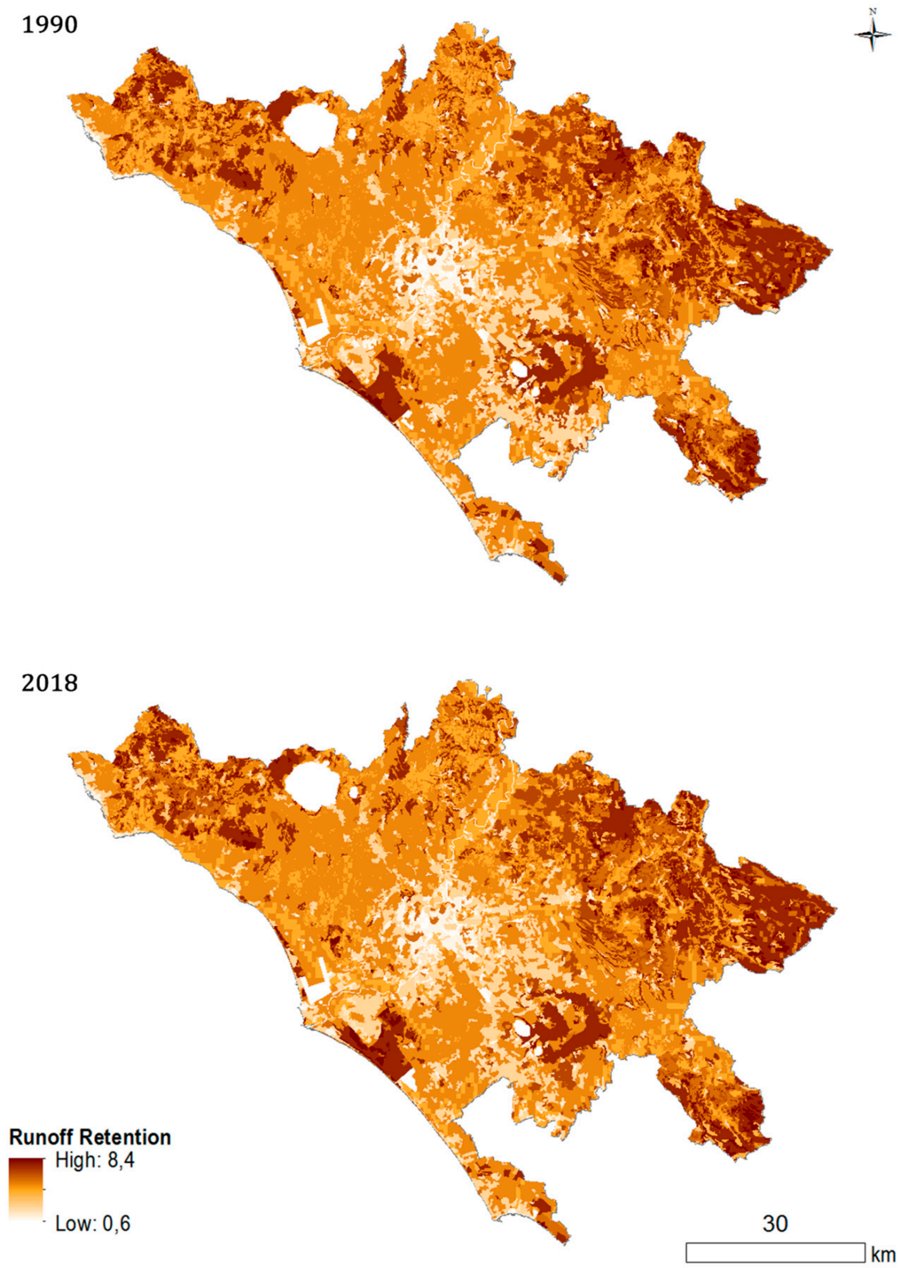

Figure A2. Runoff retention in 1990 and 2018.

References

1. Rockstrom, J.; Steffen, W.; Noone, K.; Persson, A.; Chapin, F.S., III; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. A safe operating space for humanity: Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue Johan Rockstrom and colleagues. *Nature* **2009**, *461*, 472–476. [CrossRef] [PubMed]
2. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.M.; De Vries, W.; De Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. [CrossRef] [PubMed]
3. UN DESA. *The Sustainable Development Goals Report 2022*; UN DESA: New York, NY, USA, 2022.
4. Ruddiman, W.F. The Anthropocene. *Annu. Rev. Earth Planet. Sci.* **2013**, *41*, 45–68. [CrossRef]
5. United States Nations Office for Disaster Risk Reduction (UNISDR). *Words into Action Guidelines: National Disaster Risk Assessment Hazard Specific Risk Assessment 4, Flood Hazard and Risk Assessment*; UNISDR: Geneva, Switzerland, 2017.
6. Centre for Research on the Epidemiology of Disasters (CRED). *Disaster Year in Review 2019*; CRED: Bengaluru, India, 2020.
7. Data. Available online: https://www.preventionweb.net/news/mitigating-impact-climate-change-and-flooding-italy (accessed on 11 December 2022).

8. ISPRA. *Landslides and floods in Italy: Hazard and Risk Indicators*; Summary Report. 287bis/18; ISPRA: Rome, Italy, 2018; ISBN 978-88-448-0934-8.
9. Anelli, D.; Tajani, F.; Ranieri, R. Urban resilience against natural disasters: Mapping the risk with an innovative indicators-based assessment approach. *J. Clean. Prod.* **2022**, *371*, 133496. [CrossRef]
10. Horton, R.E. Analysis of runoff-plat experiments with varying infiltration-capacity. *Eos Trans. Am. Geophys. Union* **1939**, *20*, 693–711. [CrossRef]
11. Mangala, O.S.; Toppo, P.; Ghoshal, S. Study of infiltration capacity of different soils. *Int. J. Trend Res. Dev.* **2016**, *3*, 388–390.
12. Huffman, R.L.; Fangmeier, D.D.; Elliot, W.J.; Workman, S.R.; Schwab, G.O. Chapter 5: Infiltration and Runoff. In *Soil and Water Conservation Engineering*, 7th ed.; Copyright American Society of Agricultural and Biological Engineers; ASABE: St. Joseph, MI, USA, 2013; pp. 81–113. ISBN 1-892769-86-7. [CrossRef]
13. Sugianto, S.; Deli, A.; Miswar, E.; Rusdi, M.; Irham, M. The Effect of Land Use and Land Cover Changes on Flood Occurrence in TeunomWatershed, Aceh Jaya. *Land* **2022**, *11*, 1271. [CrossRef]
14. Liu, Y.B.; De Smedt, F.; Hoffmann, L.; Pfister, L. Assessing land use impacts on flood processes in complex terrain by using GIS and modeling approach. *Environ. Model. Assess.* **2005**, *9*, 227–235. [CrossRef]
15. Quagliolo, C.; Comino, E.; Pezzoli, A. Experimental Flash Floods Assessment Through Urban Flood Risk Mitigation (UFRM) Model: The Case Study of Ligurian Coastal Cities. *Front. Water* **2021**, *3*, 663378. [CrossRef]
16. Levavasseur, F.; Bailly, J.S.; Lagacherie, P.; Colin, F.; Rabotin, M. Simulating the effects of spatial configurations of agricultural ditch drainage networks on surface runoff from agricultural catchments. *Hydrol. Process.* **2012**, *26*, 3393–3404. [CrossRef]
17. Irham, M.; Ilhamsyah, Y.; Deli, A.; Syahreza, S. Is flash flood cycle? A preliminary climate study on Teunom fluvial system. *Conf. Ser. Earth Environ. Sci.* **2019**, *273*, 012001. [CrossRef]
18. Abdullah, H.M.; Islam, I.; Miah, M.G.; Ahmed, Z. Quantifying the spatiotemporal patterns of forest degradation in a fragmented, rapidly urbanizing landscape: A case study of Gazipur, Bangladesh. *Remote Sens. Appl. Soc. Environ.* **2019**, *13*, 457–465. [CrossRef]
19. Bradshaw, C.J.; Sodhi, N.S.; Peh, K.S.H.; Brook, B.W. Global evidence that deforestation amplifies flood risk and severity in the developing world. *Glob. Chang. Biol.* **2007**, *13*, 2379–2395. [CrossRef]
20. Antonio, P.; Carandang, L.A.B.; Dolom, P.C.; Garcia, L.N.; Magdalena, M.; Villanueva, B.; Espiritu, N.O. *Analysis of Key Drivers of Deforestation and Forest Degradation in the Philippines*; Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: Manila, Philippine, 2013.
21. Burkhard, B.; Kroll, F.; Müller, F.; Windhorst, W. Landscapes' Capacities to Provide Ecosystem Services—A Concept for Land-Cover Based Assessments. *Landsc. Online* **2009**, *15*, 1–22. [CrossRef]
22. Clark, C. Deforestation and floods. *Environ. Conserv.* **1987**, *14*, 67–69. [CrossRef]
23. Barral, M.P.; Laterra, P.; Maceira, N. Flood mitigation ecosystem service in landscapes of Argentina's Pampas: Identifying winning and losing farmers. *J. Environ. Manag.* **2019**, *240*, 168–176. [CrossRef]
24. Barbedo, J.; Miguez, M.; Van Der Horst, D.; Marins, M. Enhancing ecosystem services for flood mitigation: A conservation strategy for peri-urban landscapes? *Ecol. Soc.* **2014**, *19*, 54. [CrossRef]
25. Eigenbrod, F.; Bell, V.A.; Davies, H.N.; Heinemeyer, A.; Armsworth, P.R.; Gaston, K.J. The impact of projected increases in urbanization on ecosystem services. *Proc. R. Soc. B Biol. Sci.* **2011**, *278*, 3201–3208. [CrossRef]
26. Kahane, R.; Hodgkin, T.; Jaenicke, H.; Hoogendoorn, C.; Hermann, M.; Hughes, J.D.A.; Padulosi, S.; Looney, N. Agrobiodiversity for food security, health and income. *Agron. Sustain. Dev.* **2013**, *33*, 671–693. [CrossRef]
27. Li, X.; Siddique, K.H.M. Future Smart Food: Harnessing the Potential of Neglected and Underutilized Species for Zero Hunger. *Matern. Child Nutr.* **2020**, *16*, e13008. [CrossRef]
28. Taromideh, F.; Fazloula, R.; Choubin, B.; Emadi, A.; Berndtsson, R. Urban Flood-Risk Assessment: Integration of Decision-Making and Machine Learning. *Sustainability* **2022**, *14*, 4483. [CrossRef]
29. Wijayarathne, D.B.; Coulibaly, P. Identification of hydrological models for operational flood forecasting in St. John's, Newfoundland, Canada. *J. Hydrol. Reg. Stud.* **2020**, *27*, 100646. [CrossRef]
30. Unduche, F.; Tolossa, H.; Senbeta, D.; Zhu, E. Evaluation of four hydrological models for operational flood forecasting in a Canadian Prairie watershed. *Hydrol. Sci. J.* **2018**, *63*, 1133–1149. [CrossRef]
31. Barredo, J.I.; Engelen, G. Land use scenario modeling for flood risk mitigation. *Sustainability* **2010**, *2*, 1327–1344. [CrossRef]
32. Woolley, R.; Marsell, R.; Grover, N. *Cloudburst Floods in Utah. 1850–1938*; US Government Printing Office: Washington, DC, USA, 1946. Available online: http://pubs.usgs.gov/wsp/0994/report.pdf (accessed on 15 December 2022).
33. Brunetta, G.; Ceravolo, R.; Barbieri, C.A.; Borghini, A.; de Carlo, F.; Mela, A.; Beltramo, S.; Longhi, A.; De Lucia, G.; Ferraris, S.; et al. Territorial resilience: Toward a proactive meaning for spatial planning. *Sustainability* **2019**, *11*, 2286. [CrossRef]
34. Faisal, A.A.; Kafy, A.A.; Roy, S. Integration of Remote Sensing and GIS Techniques for Flood Monitoring and Damage Assessment: A Case Study of Naogaon District, Bangladesh. *Remote Sens. GIS* **2018**, *7*, 236. [CrossRef]
35. Liping, C.; Yujun, S.; Saeed, S. Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China. *PLoS ONE* **2018**, *13*, e0200493. [CrossRef]
36. Natural Capital Project. InVEST. University of Stanford. Available online: https://naturalcapitalproject.stanford.edu/software/invest (accessed on 30 September 2022).
37. Recanatesi, F.; Petroselli, A. Land Cover Change and flood risk in a peri-urban environment of the Metropolitan area of Rome (Italy). *Water Resour. Manag.* **2020**, *34*, 4399–4413. [CrossRef]

38. Kadaverugu, A.; Rao, C.N.; Viswanadh, G.K. Quantification of flood mitigation services by urban green spaces using InVEST model: A case study of Hyderabad city, India. *Model. Earth Syst. Environ.* **2021**, *7*, 589–602. [CrossRef]
39. Salata, S.; Arslan, B. Designing with Ecosystem Modelling: The Sponge District Application in Izmir, Turkey. *Sustainability* **2022**, *14*, 3420. [CrossRef]
40. Apollonio, C.; Balacco, G.; Novelli, A.; Tarantino, E.; Piccinni, A.F. Land use change impact on flooding areas: The case study of Cervaro Basin (Italy). *Sustainability* **2016**, *8*, 996. [CrossRef]
41. Padró, R.; La Rota-Aguilera, M.J.; Giocoli, A.; Cirera, J.; Coll, F.; Pons, M.; Pino, J.; Pili, S.; Tarik, S.; Gara, V.; et al. Assessing the sustainability of contrasting land use scenarios through the Socioecological Integrated Analysis (SIA) of the metropolitan green infrastructure in Barcelona. *Landsc. Urban Plan.* **2020**, *203*, 103905. [CrossRef] [PubMed]
42. Magnaghi, A.; Fanfani, D. *Patto Città Campagna: Un Progetto di Bioregione Urbana Per la Toscana Centrale*; Alinea Editrice: Firenze, Italy, 2010.
43. Evans, D.L.; Falagán, N.; Hardman, C.A.; Kourmpetli, S.; Liu, L.; Mead, B.R.; Davies, J.A.C. Ecosystem service delivery by urban agriculture and green infrastructure—A systematic review. *Ecosyst. Serv.* **2022**, *54*, 101405. [CrossRef]
44. Russo, A.; Escobedo, F.J.; Cirella, G.T.; Zerbe, S. Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. *Agric. Ecosyst. Environ.* **2017**, *242*, 53–66. [CrossRef]
45. Marando, F.; Salvatori, E.; Sebastiani, A.; Fusaro, L.; Manes, F. Regulating Ecosystem Services and Green Infrastructure: Assessment of Urban Heat Island effect mitigation in the municipality of Rome, Italy. *Ecol. Model.* **2019**, *392*, 92–102. [CrossRef]
46. Colantoni, A.; Pili, S.; Mosconi, E.M.; Poponi, S.; Cecchini, M.; Doria, P.; Salvati, L. Metropolitan Agriculture, socio-demographic dynamics and the Food-City relationship in southern Europe. *Curr. Policy Econ. Eur.* **2017**, *28*, 301–324.
47. Landor-Yamagata, J.L.; Kowarik, I.; Fischer, L.K. Urban foraging in Berlin: People, plants and practices within the metropolitan green infrastructure. *Sustainability* **2018**, *10*, 1873. [CrossRef]
48. Lin, B.B.; Philpott, S.M.; Jha, S.; Liere, H. Urban Agriculture as a Productive Green Infrastructure for Environmental and Social Well-Being. In *Greening Cities*; Springer: Singapore, 2017; pp. 155–179.
49. Khan, M.M.; Akram, M.T.; Janke, R.; Qadri, R.W.K.; Al-Sadi, A.M.; Farooque, A.A. Urban horticulture for food secure cities through and beyond COVID-19. *Sustainability* **2020**, *12*, 9592. [CrossRef]
50. Food and Agriculture Organization. *State of World Food Insecurity*; Food and Agriculture Organization: Rome, Italy, 2006; ISBN 92-5-105580-7.
51. Richardson, R.B. Ecosystem services and food security: Economic perspectives on environmental sustainability. *Sustainability* **2010**, *2*, 3520–3548. [CrossRef]
52. Gardi, C.; Panagos, P.; Van Liedekerke, M.; Bosco, C.; De Brogniez, D. Land take and food security: Assessment of land take on the agricultural production in Europe. *J. Environ. Plan. Manag.* **2015**, *58*, 898–912. [CrossRef]
53. Shen, T.; Jiao, P.; Yuan, H.; Su, H. Effects of Flooding Duration and Growing Stage on Soybean Growth Based on a Multi-Year Experiment. *Sustainability* **2022**, *15*, 738. [CrossRef]
54. Pais, I.P.; Moreira, R.; Semedo, J.N.; Ramalho, J.C.; Lidon, F.C.; Coutinho, J.; Maçãs, B.; Scotti-Campos, P. Wheat Crop under Waterlogging: Potential Soil and Plant Effects. *Plants* **2022**, *12*, 149. [CrossRef] [PubMed]
55. Al-Jawaldeh, A.; Nabhani, M.; Taktouk, M.; Nasreddine, L. Climate Change and Nutrition: Implications for the Eastern Mediterranean Region. *Int. J. Environ. Res. Public Health* **2022**, *19*, 17086. [CrossRef]
56. Gaviglio, A.; Marescotti, M.E.; Demartini, E.; Corradini, A. Flood Damage on Dairy Farms: A What-If Analysis to Assess Economic Losses. *Water* **2022**, *14*, 3984. [CrossRef]
57. Douglas, I. Climate change, flooding and food security in south Asia. *Food Secur.* **2009**, *1*, 127–136. [CrossRef]
58. Gregory, P.J.; Ingram, J.S.; Brklacich, M. Climate change and food security. *Philos. Trans. R. Soc. B Biol. Sci.* **2005**, *360*, 2139–2148. [CrossRef] [PubMed]
59. Schmidhuber, J.; Tubiello, F.N. Global food security under climate change. *Proc. Natl. Acad. Sci. USA* **2007**, *104*, 19703–19708. [CrossRef] [PubMed]
60. Brunori, G.; Malandrin, V.; Rossi, A. Trade-off or convergence? The role of food security in the evolution of food discourse in Italy. *J. Rural Stud.* **2013**, *29*, 19–29. [CrossRef]
61. Vaarst, M.; Escudero, A.G.; Chappell, M.J.; Brinkley, C.; Nijbroek, R.; Arraes, N.A.; Andreasen, L.; Gattinger, A.; De Almeida, G.F.; Bossio, D.; et al. Exploring the concept of agroecological food systems in a city-region context. *Agroecol. Sustain. Food Syst.* **2018**, *42*, 686–711. [CrossRef]
62. Millennium Ecosystem Assessment (MEA). *Ecosystems and Human Well-Being: Synthesis*; Island Press: Washington, DC, USA, 2005.
63. AAVV. *Roma, Metropoli al Futuro. Innovativa, Sostenibile, Inclusiva. Piano Strategico Metropolitano di Roma Capitale 2022–2024*. 2022. Available online: https://static.cittametropolitanaroma.it/uploads/Trasp_Delibera_76-15_14_12_2022_DPT0400.pdf (accessed on 20 January 2023).
64. Marino, D.; Bernaschi, D.; Cimini, A.; D'Amico, G.; Gallo, G.; Giovanelli, G.; Giustozzi, D.; Kollamparambil, A.; Lirosi, L.; Mazzocchi, G.; et al. Atlante del Cibo. Uno Strumento per le Politiche locali del Cibo. In *Città metropolitana di Roma Capitale*; CURSA: Roma, Italy, 2022; ISBN 9788894227239.
65. Pili, S.; Grigoriadis, E.; Carlucci, M.; Clemente, M.; Salvati, L. Towards sustainable growth? A multi-criteria assessment of (changing) urban forms. *Ecol. Indic.* **2017**, *76*, 71–80. [CrossRef]
66. Cellamare, C. *Fuori Raccordo: Abitare L'altra Roma*; Donzelli: Rome, Italy, 2016.

67. Pili, S.; Serra, P.; Salvati, L. Landscape and the city: Agro-forest systems, land fragmentation and the ecological network in Rome, Italy. *Urban For. Urban Green.* **2019**, *41*, 230–237. [CrossRef]
68. Lentini, A.; Meddi, E.; Galve, J.P.; Papiccio, C.; La Vigna, F. Preliminary identification of areas suitable for Sustainable Drainage Systems and Managed Aquifer Recharge to mitigate stormwater flooding phenomena in Rome (Italy). *Acque Sotter. Ital. J. Groundw.* **2022**, *11*, 43–53. [CrossRef]
69. Calenda, G.; Mancini, C.P.; Volpi, E. Selection of the probabilistic model of extreme floods: The case of the River Tiber in Rome. *J. Hydrol.* **2009**, *371*, 1–11. [CrossRef]
70. Nardi, F.; Annis, A.; Biscarini, C. Urbanization impact on flood hydrology within the city of Rome. *J. Flood Risk Manag.* **2018**, *11*, S594–S603. [CrossRef]
71. Di Baldassarre, G.; Saccà, S.; Aronica, G.T.; Grimaldi, S.; Ciullo, A.; Crisci, M. Human-flood interactions in Rome over the past 150 years. *Adv. Geosci.* **2017**, *44*, 9–13. [CrossRef]
72. ISPRA. (n.d.) SINAnet—Uso, Copertura e Consumo di Suolo. 2022. Available online: https://groupware.sinanet.isprambiente.it/uso-copertura-e-consumo-di-suolo/library/copertura-del-suolo/corine-land-cover/ (accessed on 28 September 2022).
73. Battisti, C.; Mandolini, R. La comunità ornitica nidificante in un settore residuale della Campagna romana (corridoio tra le Riserve naturali 'Valle dei Casali' e 'Tenuta dei Massimi'; Roma, Italia centrale). *Alula* **2018**, *25*, 1–9.
74. Pili, S.; Mavrakis, A.; Santeriano, A.; Serra, P.; Salvati, L. Metropolitan agriculture: Socio–demographic dynamics, urban growth and food–city relationship in the Mediterranean Basin. *Boll. Della Soc. Geogr. Ital.* **2017**, *10*, 77–91.
75. Assefa, W.W.; Eneyew, B.G.; Wondie, A. The impacts of land-use and land-cover change on wetland ecosystem service values in peri-urban and urban areas of Bahir Dar City, Upper Blue Nile Basin, Northwestern Ethiopia. *Ecol. Process.* **2021**, *10*, 39. [CrossRef]
76. Gashaw, T.; Tulu, T.; Argaw, M.; Worqlul, A.W. Evaluation and prediction of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. *Environ. Syst. Res.* **2017**, *6*, 17. [CrossRef]
77. Berihun, M.L.; Tsunekawa, A.; Haregeweyn, N.; Meshesha, D.T.; Adgo, E.; Tsubo, M.; Masunaga, T.; Fenta, A.A.; Sultan, D.; Yibeltal, M. Exploring land use/land cover changes, drivers and their implications in contrasting agro-ecological environments of Ethiopia. *Land Use Policy* **2019**, *87*, 104052. [CrossRef]
78. Kindu, M.; Schneider, T.; Teketay, D.; Knoke, T. Changes of ecosystem service values in response to land use/land cover dynamics in Munessa-Shashemene landscape of the Ethiopian highlands. *Sci. Total Environ.* **2016**, *547*, 137–147. [CrossRef] [PubMed]
79. Kavhu, B.; Mashimbye, Z.E.; Luvuno, L. Detecting Connectivity and Spread Pathways of Land Use/Cover Change in a Transboundary Basin Based on the Circuit Theory. *Geomatics* **2022**, *2*, 518–539. [CrossRef]
80. Grêt-Regamey, A.; Brunner, S.H.; Kienast, F. Mountain Ecosystem Services: Who cares? *Mt. Res. Dev.* **2012**, *32*, S1. [CrossRef]
81. Rodriguez, J.P.; Beard, T.D., Jr.; Bennett, E.M.; Cumming, G.S.; Cork, S.; Agard, J.; Dobson, A.P.; Peterson, G.D. Trade-offs across space, time, and ecosystem services. *Ecol. Soc.* **2006**, *11*, 28. Available online: http://www.ecologyandsociety.org/vol11/iss1/art28/ (accessed on 15 November 2022).
82. Talukdar, S.; Singha, P.; Mahato, S.; Praveen, B.; Rahman, A. Dynamics of ecosystem services (ESs) in response to land use land cover (LU/LC) changes in the lower Gangetic plain of India. *Ecol. Indic.* **2020**, *112*, 106121. [CrossRef]
83. Sharma, E.; Molden, D.; Rahman, A.; Khatiwada, Y.R.; Zhang, L.; Singh, S.P.; Yao, T.; Wester, P. Introduction to the Hindu Kush Himalaya Assessment. In *The Hindu Kush Himalaya Assessment: Mountains, Climate Change, Sustainability and People*; Wester, P., Mishra, A., Mukherji, A., Shrestha, A.B., Eds.; Springer Nature: Cham, Switzerland, 2019; pp. 1–16.
84. Arowolo, A.O.; Deng, X.; Olatunji, O.A.; Obayelu, A.E. Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria. *Sci. Total Environ.* **2018**, *636*, 597–609. [CrossRef]
85. Marino, D.; Nofroni, L.; Savelli, S. Trasformazioni e Permanenze dei Paesaggi Agrari Tradizionali Alla Scala Nazionale. Un'indagine Diacronica 1960–2012. In *Congresso Scientifico SIEP-IALE*; SIEP - IALE Italian Society of Landscape Ecology: Asti, Italy, 2016.
86. Ross, C.W.; Prihodko, L.; Anchang, J.Y.; Kumar, S.S.; Ji, W.; Hanan, N.P. *Global Hydrologic Soil Groups (HYSOGs250m) for Curve Number-Based Runoff Modeling*; ORNL DAAC: Oak Ridge, TN, USA, 2018. [CrossRef]
87. Castelli, F. Modellazione Idrologica Caso Pilota. Implementazione Modello Distribuito per la Toscana MOBIDIC. Addendum: Parametrizzazione HMS. Relazione Tecnica Finale. 2014. Available online: https://www.regione.toscana.it/documents/10180/12745809/Parametri_HMS.pdf/fd3b35dc-98d9-463b-aa87-ede3eaf6da89 (accessed on 5 November 2022).
88. USDA—Natural Resources Conservation Service. Hydrologic Soil Groups. In *National Engineering Handbook*; USDA: Washington, DC, USA, 2009; Chapter 7, Part 630. Available online: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba (accessed on 15 November 2022).
89. USDA. Soil Conservation Service National Engineering Handbook. In *Section 4: Hydrology, Chapters 4–10*; USDA: Washington, DC, USA, 1972; pp. 15-7–15-11.
90. Moglen, G.E.; Sadeq, H.; Hughes, L.H.; Meadows, M.E.; Miller, J.J.; Ramirez-Avila, J.J.; Tollner, E.W. NRCS Curve Number Method: Comparison of Methods for Estimating the Curve Number from Rainfall-Runoff Data. *J. Hydrol. Eng.* **2022**, *27*, 04022023. [CrossRef]
91. Ponce, V.M.; Hawkins, R.H. Runoff curve number: Has it reached maturity? *J. Hydrol. Eng.* **1996**, *1*, 11–19. [CrossRef]

92. USDA—Natural Resources Conservation Service. Hydrologic Soil-Cover Complexes. In *National Engineering Handbook*; USDA: Washington, DC, USA, 2004; Chapter 9, Part 630. Available online: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17758.wba (accessed on 15 November 2022).
93. USDA—Natural Resources Conservation Service. Urban Hydrology for Small Watersheds. In *Technical Release 55 (TR-55)*, 2nd ed.; Natural Resources Conservation Service, Conservation Engineering Division; USDA: Washington, DC, USA, 1986.
94. Stürck, J.; Poortinga, A.; Verburg, P. Mapping ecosystem services: The supply and demand of flood regulation services in Europe. *Ecol. Indic.* **2014**, *38*, 198–221. [CrossRef]
95. CREA. *Annuario Dell'agricoltura Italiana, In CREA—Consiglio per la Ricerca e in Agricoltura e L'analisi Dell'economia Agraria*; Centro di Ricerca Politiche e Bio-Economia: Roma, Italy, 2021; Volume LXXIV.
96. Bennett, E.M.; Peterson, G.D.; Gordon, L.J. Understanding relationships among multiple ecosystem services. *Ecol. Lett.* **2009**, *12*, 1394–1404. [CrossRef]
97. Sansone, L.; Carroni, A.M.; Fedrizzi, M.; Santilli, E.; Pipitone, G.; Pagano, M.; Sperandio, G.; Guerrieri, M.; Puri, D.; Zaffina, F.; et al. Evaluation of environmental and economic effectiveness of the Cross Compliance 4.3 Standard 'Maintenance of olive groves and vineyards in good vegetative conditions'. *Ital. J. Agron.* **2015**, *10*. [CrossRef]
98. Marino, D.; Palmieri, M.; Marucci, A.; Pili, S. Long-term land cover changes and ecosystem services variation: Have the anthropogenic transformations degraded human well-being in Italy? *Ital. Rev. Agric. Econ.* **2022**, *77*, 7–23. [CrossRef]
99. Marucci, A.; Marino, D.; Palmieri, M.; Pili, S. Il ruolo delle aree agroforestali nella fornitura potenziale di servizi ecosistemici: Il caso della Regione Molise. *L'Italia For. Mont.* **2022**, *77*, 153–163. [CrossRef]
100. Hasan, S.S.; Zhe, L.; Miah, G.; Ahamed, T.; Samie, A. Impact of land use change on ecosystem services: A review. *Environ. Dev.* **2020**, *34*, 100527. [CrossRef]
101. Morano, P.; Guarini, M.R.; Sica, F.; Anelli, D. Ecosystem Services and Land Take. A Composite Indicator for the Assessment of Sustainable Urban Projects. In *Computational Science and Its Applications – ICCSA 2021: 21st International Conference, Cagliari, Italy, September 13–16, 2021, Proceedings, Part VI*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 210–225. [CrossRef]
102. Nagarajan, M.; Basil, G. Remote sensing-and GIS-based runoff modeling with the effect of land-use changes (a case study of Cochin corporation). *Nat. Hazards* **2014**, *73*, 2023–2039. [CrossRef]
103. d'Amour, C.B.; Reitsma, F.; Baiocchi, G.; Barthel, S.; Güneralp, B.; Erb, K.-H.; Haberl, H.; Creutzig, F.; Seto, K.C. Future urban land expansion and implications for Global Croplands. *Proc. Natl. Acad. Sci. USA* **2016**, *114*, 8939–8944. [CrossRef]
104. Potić, I.; Mihajlović, L.M.; Šimunić, V.; Ćurčić, N.B.; Milinčić, M. Deforestation as a cause of increased surface runoff in the catchment: Remote Sensing and Swat Approach—A case study of southern Serbia. *Front. Environ. Sci.* **2022**, *10*, 896404. [CrossRef]
105. Deng, X.; Xiong, K.; Yu, Y.; Zhang, S.; Kong, L.; Zhang, Y. A Review of Ecosystem Service Trade-Offs/Synergies: Enlightenment for the Optimization of Forest Ecosystem Functions in Karst Desertification Control. *Forests* **2023**, *14*, 88. [CrossRef]
106. Wang, X.; Liu, Z.; Chen, H. Investigating Flood Impact on Crop Production under a Comprehensive and Spatially Explicit Risk Evaluation Framework. *Agriculture* **2022**, *12*, 484. [CrossRef]
107. Atanga, R.A.; Tankpa, V. Climate change, flood disaster risk and Food Security Nexus in northern Ghana. *Front. Sustain. Food Syst.* **2021**, *5*, 706721. [CrossRef]
108. Reed, C.; Anderson, W.; Kruczkiewicz, A.; Nakamura, J.; Gallo, D.; Seager, R.; McDermid, S.S. The impact of flooding on food security across Africa. *Proc. Natl. Acad. Sci. USA* **2022**, *119*, e2119399119. [CrossRef]
109. Pacetti, T.; Caporali, E.; Rulli, M.C. Floods and food security: A method to estimate the effect of inundation on crops availability. *Adv. Water Resour.* **2017**, *110*, 494–504. [CrossRef]
110. Warner, B.P.; Schattman, R.E.; Hatch, C.E. Farming the Floodplain: Ecological and Agricultural Tradeoffs and Opportunities in River and Stream Governance in New England's Changing Climate. *Case Stud. Environ.* **2017**, *1*, 1–18. [CrossRef]
111. Leonard, J.; Andrieux, P. Infiltration characteristics of soils in Mediterranean vineyards in Southern France. *Catena* **1998**, *32*, 209–223. [CrossRef]
112. Diaz-Pacheco, J.; Gutiérrez, J. Exploring the limitations of CORINE Land Cover for monitoring urban land-use dynamics in metropolitan areas. *J. Land Use Sci.* **2014**, *9*, 243–259. [CrossRef]
113. Varga, O.G.; Kovács, Z.; Bekő, L.; Burai, P.; Szabó, Z.C.; Holb, I.; Ninsawat, S.; Szabó, S. Validation of Visually Interpreted Corine Land Cover Classes with Spectral Values of Satellite Images and Machine Learning. *Remote Sens.* **2021**, *13*, 857. [CrossRef]
114. González, P.B.; Cascón, V.G.; Sendra, J.B. Detección de errores temáticos en el CORINE Land Cover a través del estudio de cambios: Comunidad de Madrid (2000–2006). *Estud. Geográficos* **2012**, *73*, 7–34. [CrossRef]
115. Marino, D.; Palmieri, M.; Marucci, A.; Tufano, M. Comparison between Demand and Supply of Some Ecosystem Services in National Parks: A Spatial Analysis Conducted Using Italian Case Studies. *Conservation* **2021**, *1*, 4. [CrossRef]
116. Schirpke, U.; Marino, D.; Marucci, A.; Palmieri, M. Positive effects of payments for ecosystem services on biodiversity and socioeconomic development: Examples from Natura 2000 sites in Italy. *Ecosyst. Serv.* **2018**, *34*, 96–105. [CrossRef]
117. Marino, D.; Palmieri, M. Investing in nature: Working with Public Expenditure and Private Payments for a New Governance Model. In *Re-Connecting Natural and Cultural Capital Contributions from Science and Policy*; Paracchini, M.L., Zingari, P.C., Blasi, C., Eds.; Office of Publications of the European Union: Luxembourg, 2016.
118. Marino, D.; Mazzocchi, G.; Pellegrino, D.; Barucci, V. Integrated Multi-Level Assessment of Ecosystem Services (ES): The Case of the Casal del Marmo Agricultural Park Area in Rome (Italy). *Land* **2022**, *11*, 2055. [CrossRef]

119. Carter, J.G.; Handley, J.; Butlin, T.; Gill, S. Adapting cities to climate change–exploring the flood risk management role of green infrastructure landscapes. *J. Environ. Plan. Manag.* **2018**, *61*, 1535–1552. [CrossRef]
120. Ochoa, C.Y.; Jiménez, D.F.; Olmo, R.M. Green infrastructure planning in metropolitan regions to improve the connectivity of agricultural landscapes and food security. *Land* **2020**, *9*, 414.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.