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Changes in Land-Cover/Land-Use Pattern in the Fortore River Basin (Southern Italy) and Morphodynamic Implications

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Abstract: In Southern Italy, studies dealing with the analysis of multidecadal land-use/land-cover (LULC) changes at the basin scale are scarce. This is an important gap, considering the deep interrelationships between LULC, soil erosion, and river and coastal dynamics. This study provides a contribution in filling this gap by analyzing the LULC patterns and changes in an area of southern Italy, i.e., the Fortore River basin, which occurred between 1960 and 2018. To this end, we conducted a GIS-aided comparison and analysis of LULC data from 1960, 1990, and 2018, respectively. The LULC changes were analyzed at both the basin and the physiographic unit scale. The results showed that most of the LULC changes occurred between the 1960s and 1990s, while from the 1990s onward, great stability in LULC was evident in the basin. The obtained data were mostly coherent with national-, regional-, and basin-scale trends, although some scale-dependent discrepancies were noted. The river and shoreline dynamics fully reflected the duration and the amount of phases of the changes in LULC stability at the basin scale.

Keywords: landscape; GIS analysis; afforestation; physiographic units; human impacts; land degradation; soil erosion; geomorphology

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1. Introduction

Southern Italy is a "fragile," land-degradation-prone territory [1]. Among the causal factors of land degradation, land management plays a significant role [2,3]. In fact, several studies demonstrated that land-use/land cover (LULC) patterns and changes are the most important factors among those explaining the intensity of soil erosion [4–7], which is one of the main processes of land degradation [8]. Thus, the analysis of LULC patterns and/or changes is a key starting point in studies dealing with soil-erosion assessment. Because the soil represents the physical and chemical support for plants and allows the perpetuation of agricultural activity, such studies are of utmost importance, especially in areas whose economy largely or totally depends on agriculture, as is unquestionably the case in southern Italy [9–11].

At the basin scale, soil-erosion processes and intensity control the sediment supply to rivers and, thus, their sediment discharge, which is a key variable in river-channel dynamics and morphological evolution [12–15]. Because, as stated above, soil-erosion processes and intensity are, at least partly, controlled by LULC patterns and changes, the latter indirectly control river dynamics and evolution, knowledge of which is fundamental to correctly assess associated hazards and risks [16–18].

In coastal areas, shoreline variations are strictly controlled by the amount of sediment supplied by rivers to the coast, i.e., by their sediment discharge [19]. However, as stated above, the sediment discharge of rivers is indirectly controlled, among other factors, by LULC patterns and/or changes. Thus, the latter must also be considered an indirect control factor in shoreline evolution.

Few studies dealing with LULC changes in Southern Italy exist in the literature. Ellis et al. [20] found that, between the middle decades of the nineteenth century and the

1930s, diffuse deforestation affected Southern Italy, with two peaks occurring between the 1870s and 1890s and between the early 1900s and middle 1930s, respectively. Di Martino [21] showed that, among the different regions of southern Italy, deforestation was particularly intense in the Molise region. Deforestation was followed by diffuse reforestation, which lasted until 2010s [22]. Di Gennaro and Innamorato [23] analyzed the LULC changes in the Campania region (southern Italy) between 1960 and 1998. They found a marked increase in urbanized areas, especially on both mountainous reliefs and alluvial/coastal plains. The authors also observed an increase in forests in both mountainous and hilly reliefs at the expense of agricultural lands and, to a lesser extent, of grasslands and shrubs.

The studies mentioned above, however, did not provide any insights into the interrelationships between LULC patterns and changes, soil-erosion processes and rates, river-sediment discharge and channel morphological evolution, or shoreline dynamics. This is because such interrelationships are clear only when considered at the basin scale over a period of several decades. This highlights the importance of studies dealing with the analysis of LULC changes at this scale. Notwithstanding this observation, previous research on this topic in a geomorphologically dynamic and vulnerable territory such as southern Italy is extremely scarce. Only very recently, two studies [24,25] focused on LULC changes over a period of about six decades in two large-sized river basins in southern Italy (i.e., the Calore River and the Sele River basins), also exploring the implications of the detected changes in terms of soil erosion and/or protection. However, we are currently very far from providing an exhaustive framework of the multidecadal LULC dynamics at the basin scale in southern Italy, as most of the river basins in this area still remain uninvestigated from this point of view.

This study is intended to further fill this gap by analyzing the LULC changes over a period of 58 years (i.e., between 1960 and 2018) in the Fortore River basin, located in southern Italy (Figure 1). Chronologically, the analysis was split into two sub-periods, approximately 30 years long (i.e., 1960–1990 and 1990–2018). The LULC patterns and changes were analyzed at the basin, physiographic-unit, and LULC-class scale. The detected changes were interpreted in terms of variations in soil protection against erosion. The results were compared with pre-existing studies dealing with LULC changes to verify whether the detected trends were in accordance with those reconstructed at the national and/or regional scale, as well as discussing the possible causes. Finally, the obtained results were discussed in the framework of pre-existing geomorphological research data about river and coastal geomorphological changes. The aim was to test whether the influence of the detected LULC changes on morphodynamic processes was in accordance with that observed in previous studies, as well as to further check the reliability and geomorphological coherence of the obtained results.

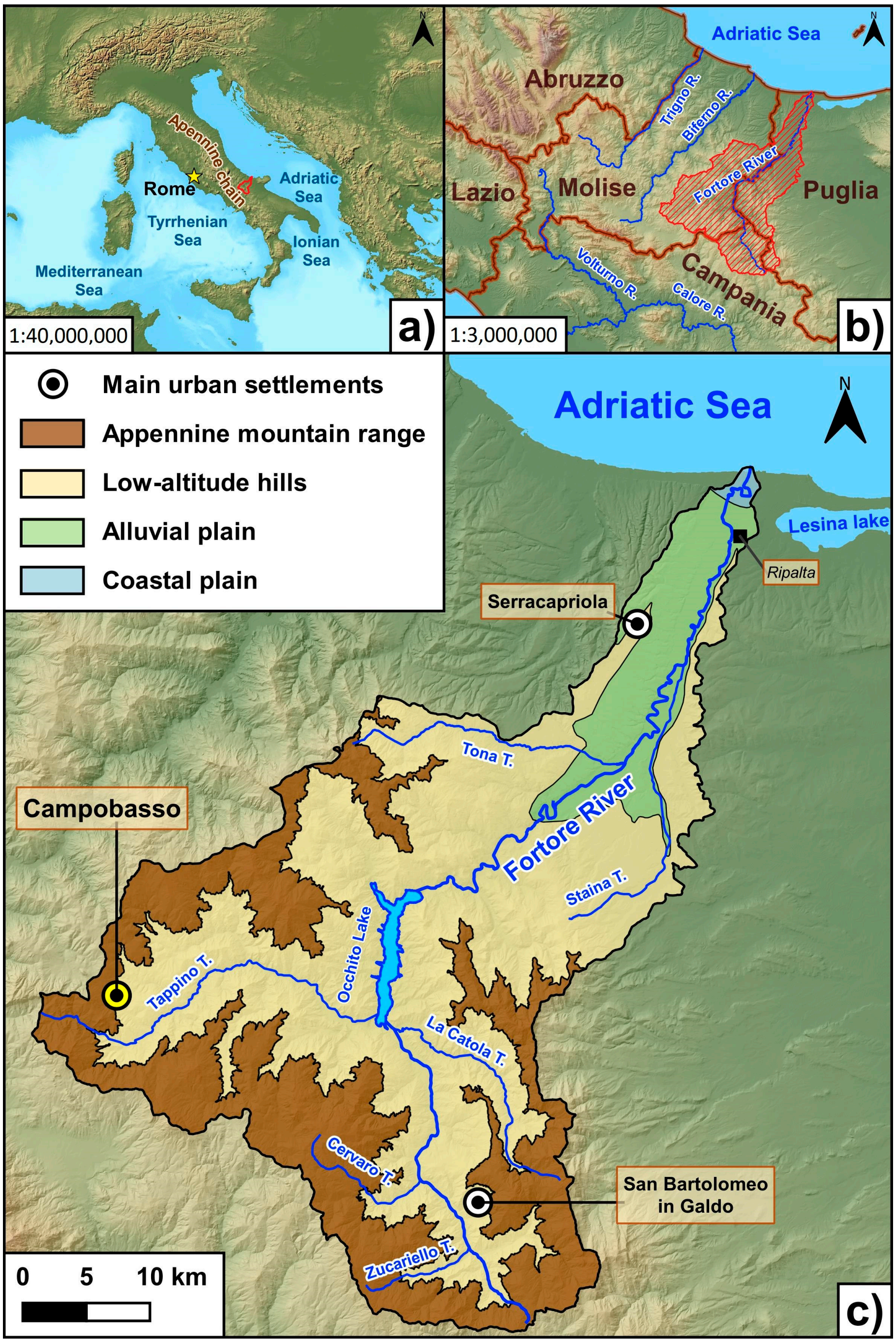

Figure 1. Location map of Fortore R., in the Italian territory (**a**) and in southern Italy (**b**). In (**c**), the main hydrographic network, urban settlements, and boundaries of the physiographic units are also reported.

2. Materials and Methods

2.1. Study Area

The Fortore River basin is located in the northeastern sector of southern Italy (Figure 1a), between Molise, Campania, and Puglia regions (Figure 1b). It covers a surface area of 1604 km^2, between 41°18′ N and 41°55′ N in latitude and 14°36′ E and 15°17′ E in longitude. Altitude ranges from 0 to 1103 m a.s.l., but 68% of the basin area is located at altitudes lower than 600 m a.s.l. [22].

The climate is of a continental type in the upper sector of the basin and of Mediterranean type in the lower sector. It is characterized by mean annual precipitation ranging from 665 mm in the upper sectors to 800 mm in the lower sector. November and December are the wettest months, while July and August are the driest. The maximum mean annual temperature is 12 °C in the coastal sector [26,27].

According to the method proposed by Rinaldi et al. [28], the Fortore River basin can be subdivided into four main physiographic units, i.e., (i) Apennine mountain range (hereinafter, AMR), (ii) low-altitude hills (LAH), (iii) alluvial plain (AP), and (iv) coastal plain (CP) (Figure 1c).

The AMR physiographic unit is located between 1103 and 600 m a.s.l. and accounts for 32.5% of the basin area. The substratum mainly consists of clayey, calcareous–marly-arenaceous, and clayey–calcareous deposits, dating back to the Upper Cretaceous–Lower Miocene period [26,29]. The geomorphology of this unit is strictly controlled by the geotechnical features of the substratum. Steep slopes deeply dissected by the hydrographic network predominate where the most conservative lithotypes crop out, while wide, gently sloping valleys characterize the areas where the substratum is made up of more erodible terrains [27].

The LAH physiographic unit accounts for 57% of the study area. The substratum is very similar to that of the AMR physiographic unit, except for wide outcrops of quartzarenite [29]. Rounded and often narrow hill ridges characterize this unit [30]. Landslides of various types are extremely frequent, especially where clayey deposits crop out, on hillslope gradients between 10° and 25° and, finally, in proximity of streams that are actively incising at rates of 0.4 to 0.7 mm/y [31]. Water-induced soil erosion (sheet, rill, and gully erosion) is also intense. In the upper part of the Fortore R. basin (mostly coinciding with AMR and LAH physiographic units), Buondonno et al. [32] estimated that 42% of the area is affected by high levels of soil erosion (52–156 t/ha/year), 31% is affected by very high levels of soil erosion (229 t/ha/year), and 14% is affected by severe soil erosion (437 t/ha/year).

The AP physiographic unit accounts for 10% of the Fortore R. basin. It is dominated by a terraced morphology and characterized by prevailing NNW–SSE-oriented terraced ridges that gently slope towards the Adriatic coastal plain [30]. Terraced ridges are built on Plio-Pleistocene marine-to-continental deposits, made of clays, sands, and conglomerates [26,30].

The CP physiographic unit accounts for only 0.4% of the basin area. It is made of terrigenous sands carried to the coast by Fortore R. [33]. The sandy deposits are arranged in a complex of swamps, dune belts, and beach ridges, which are cut by short-relict fluvial channels [34].

The Fortore R. is approximately 110 km long [27]. It is characterized by a mean annual discharge of 13.5 m^3/s and a torrential regime [26]. Low flows occur during summer, with minimum and maximum monthly discharges ranging from 0.03 to 0.62 m^3/s in August. High flows occur during winter, with minimum and maximum monthly discharges ranging from 3 to 31.9 m^3/s in February. The Fortore River is dammed by one of the largest earth dams in Europe, i.e., the Occhito dam, which was built between 1958 and 1966 for irrigation purposes and regulation of flood discharges [26].

2.2. Data Source and Methodology

Figure 2 graphically summarizes the main steps of the presented study, which are described in detail below.

Three LULC maps were compared and analyzed, in GIS environment, to reconstruct the LULC pattern and changes over the considered period of ~60 years (i.e., from 1960 to 2018) in the Fortore R. basin.

The first was the map of land use in Italy (“Carta dell’Utilizzazione del Suolo in Italia,” referred to as “CNR-TC 1960” in Figure 2), at a 1:200,000 scale, produced in 1960 by the National Research Council (CNR) and published by Touring Club (TC) [35], hereinafter referred to as CNR-TC. This map graphically reports the LULC pattern of the entire

Italian peninsula, derived from cadastral data analysis and interpretation of aerial photos, generally at a 1:33,000 scale. The entire map was scanned at a resolution of 1200 dpi. We used the "Georeferencing" function of the ESRI® (Redlands, CA, USA) ArcGIS 10.4.1 software to carry out georeferencing of the CNR-TC map in the UTM-WGS84 coordinate system. The perimeter of the Fortore R. basin was manually digitized on topographic maps of greater detail (i.e., at 1:25,000 scale), in raster format, produced by the Italian Geographical Military Institute (IGMI). The portion of the CNR-TC map falling within the perimeter of the Fortore R. basin was manually digitized to obtain the LULC pattern of the study area in 1960. A geodatabase was created and compiled in ArcGIS 10.4.1 environment and the area of each polygon corresponding to land surfaces with different LULC was automatically calculated by using the "Calculate Geometry" ArcGIS tool.

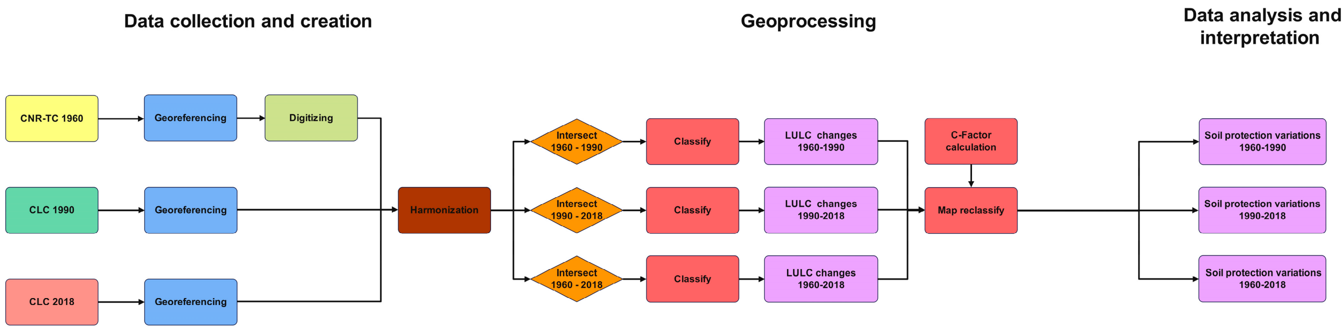

Figure 2. Flowchart illustrating the different steps of the research. Legend—CNR-TC 1960: map of the land use in Italy [31]; CLC: Corine land cover.

To obtain both the second and the third LULC maps used in this study (i.e., CLC 1990 and CLC 2018 in Figure 2), we freely downloaded the shapefiles reporting the LULC pattern in the entire EU in 1990 and 2018, according to the Corine land-cover project (hereinafter, CLC1990 and CLC2018, respectively) from the websites https://land.copernicus.eu/pan-european/corine-land-cover/clc-1990 [36] and https://land.copernicus.eu/pan-european/corine-land-cover/clc2018 (accessed on 20 February 2023) [37]. The downloaded shapefiles were originally georeferenced in UTM-WGS84, zone 32N. Thus, with the aim of re-projecting them in the same coordinate system in which the CNR-TC map was georeferenced (i.e., UTM-WGS84, zone 33N), we used the "Georeferencing" functions of the ArcGIS software. Finally, both the CLC1990 and CLC2018 maps were clipped based on the perimeter of the Fortore R. basin, previously digitized from the IGMI 1:25,000-scaled topographic maps. The nominal scale of the obtained LULC map was 1:100,000, and it was thus comparable with the scale of the CNR-TC LULC map of the study area [35], previously compiled.

The comparison between the obtained LULC maps highlighted several differences in the LULC classification between the CNR-TC and CLC systems [35–37]. To overcome this problem, a harmonization of the LULC classes was carried out based on their description in the CNR-TC and CLC legends (Table 1). This harmonization was possible only at the third level of the Corine land cover, due to the differences in scope, years, and methods of production between CNR-TC and CLC maps (Table 1). According to Magliulo et al. [24,25], the differences in the responses of the LULC classes to soil-erosion processes, widely accepted in the literature ([38,39], and references therein), were used as additional harmonization criteria. The harmonization also took into account the suggestion by Falcucci et al. [40] to reduce the former number of classes and define a few new classes that represent markedly distinct LULC types. Therefore, our harmonization led us to define seven broad LULC classes: (i) agricultural areas, (ii) forests, (iii) wetlands and water bodies, (iv) artificial surfaces, (v) fruit trees and olive groves, (vi) grasslands and pastures, and (vii) bare or sparsely vegetated areas. The harmonization carried out in this study between the CNR-TC and CLC classification systems of LULC is reported in detail in Table 1. With the aim of highlighting discrepancies in the polygon boundaries of the harmonized LULC classes not attributable to LULC changes (e.g., due to the differences in scale between the maps), the harmonized LULC maps were overlaid and the discrepancies manually corrected through digitation.

Table 1. Harmonization scheme of the LULC classes and maps. Legend—CNR-TC: Consiglio Nazionale delle Ricerche (National Research Council)–Touring Club. CLC: Corine land cover.

CNR-TC (1960)	CLC (1990; 2018), Third Level	Harmonized LULC Class	C-Factor [41,42]	Harmonized Class C-Factor
Mixed forests	Mixed forests	Forests	0.0011	0.0012
Tall-tree forests	Coniferous forests Broad-leaved forests		0.0011 0.0013	
Coppice woodlands	-		-	
Pastures and natural grasslands	Pastures Natural grasslands	Grasslands and shrubs	0.0903 0.0435	0.0520
Wooded grasslands (dry)	Transitional woodland and shrub		0.0219	
-	Sclerophyllous vegetation Moors and heathland		0.0623 0.0420	
Dry arable lands Irrigated arable lands	Annual crops associated with permanent crops Complex cultivation patterns	Agricultural areas	0.2323 0.1384	0.1869
Wooded arable lands (dry)	Land principally used for agriculture, with significant areas of natural vegetation		0.1232	
Wooded arable lands (irrigated)	Agro-forestry areas		0.0881	
Vineyards	Vineyards		0.3527	
Hazelnut groves Chestnuts Fruit trees plantations	Fruit trees and berry plantations	Fruit trees and olive groves	0.2188	0.2231
Olive groves Olive trees and vines associations	Olive groves		0.2273	
Barren areas	Sparsely vegetated areas Beaches, dunes, sands	Bare or sparsely vegetated areas	0.2652 -	0.2652
Water bodies	Water bodies Water courses	Wetlands and water bodies	- -	N.D.
Settlements and other utilization forms	Continuous urban fabric Discontinuous urban fabric Industrial or commercial units Road and rail networks and associated land Mineral extraction sites Dump sites Construction sites Green urban areas	Artificial surfaces	- - - - - - - -	N.D.

With the aim of quantifying the areal variation in each LULC class, expressed in percentage form, the following formula was used:

$$AV(\%) = \frac{ClassArea_{-j} - ClassArea_{-i}}{ClassArea_{-i}} \times 100 \quad (1)$$

where AV (%) was the areal variation of a given LULC class, expressed in percent, $ClassArea_{-j}$ was the area of the LULC class on the more recent LULC map, and $ClassArea_{-i}$ was the area of the LULC class on the older LULC map.

The next step (Figure 2) consisted of two-by-two intersections, in GIS environment, between the three LULC maps of the study area listed above (i.e., CNR-TC vs. CLC1990; CLC1990 vs. CLC 2018; CNR-TC vs. CLC2018). The results consisted of digital maps in which each polygon represented areas that experienced LULC changes or persistence. Each polygon, i.e., each LULC change or persistence, was classified according to Di Gennaro et al. [37] and Magliulo et al. [24,25] (Figure 3). Finally, the extension of each polygon was automatically calculated by means of the "Calculate Geometry" ArcGIS® tool.

		Subsequent LULC						
		Forests	**Grasslands and shrubs**	**Agricultural areas**	**Fruit trees and olive groves**	**Bare or sparsely vegetated areas**	**Water bodies and wetlands**	**Artificial surfaces**
Previous LULC	**Forests**	FoP	Pde	ADe	ADe	CBl	OFL	Ude
	Grasslands and shrubs	FoG	Gpe	ATi	ATi	CBl	OFL	Urb
	Agricultural areas	FoA	Gex	AgP	AgP	CBl	OFL	Urb
	Fruit trees and olive groves	FoA	Gex	AgP	AgP	CBl	OFL	Urb
	Bare or sparsely vegetated areas	BLa	Gex	ATi	ATi	BLp	OFL	Urb
	Water bodies and wetlands	FoW	Gex	AgE	AgE	CBl	WeP	Urb
	Artificial surfaces	FoAS	Gex	ATi	ATi	CBl	OFL	Urp

Figure 3. Classification matrix of the detected LULC changes (modified from Di Gennaro et al. [37] and Magliulo et al. [24,25]). The legend for each acronym is reported in detail in Figure 7.

As stated in Section 1, the deep influence of LULC changes on soil protection against erosion is widely demonstrated by a vast body of scientific research (e.g., [38,39] and references therein). Thus, the LULC changes we detected in the Fortore R. basin were interpreted in terms of increase or decrease in soil protection. To this end, we took into account the fact that land-cover-type C-factors in the USLE equation [41] expresses the different degrees of soil protection against diffuse water erosion in different land-cover types. Quantitatively, soil loss is expressed due to diffuse water erosion from a standard plot with a given land-cover by the soil loss from a bare standard plot. The higher the C-factor, the lower the soil protection. To interpret the LULC changes detected in the Fortore R. basin in terms of variations in soil protection, we first collected the C-factors calculated by Panagos et al. [42] for each CLC land-use class; the latter were estimated for the entire European Union (EU) by using pan-European datasets. According to the harmonization reported in Table 1, we assigned a C-factor to each harmonized LULC class used in this study. The assigned C-factor was the arithmetical average of the C-factors estimated by Panagos et al. [42] for the CLC LULC classes in each class we used in this study and reported in Table 1. Next, the harmonized LULC classes were ordered in terms of decreases in "degree of protection" of soil against water erosion, i.e., in terms of increases in C-factor. The final step (Figure 2) was the classification, according to Magliulo et al. [24,25], of each type of LULC change (e.g., afforestation, deforestation, agricultural extensification, and so on) in terms of increase or decrease in soil protection (Figure 4). For example, the authors assigned to the class with highest increase in soil protection (i.e., "very high increase" class) the LULC change from the "less protective" LULC class (i.e., bare or sparsely vegetated areas, characterized, according to Table 1, by the highest C-factor) to the "most protective" class (i.e., forests, with the lowest C-factor).

Previous LULC / Subsequent LULC	Forests	Grasslands and shrubs	Agricultural areas	Fruit trees and olive groves	Bare or sparsely vegetated areas	Wetlands and water bodies	Artificial surfaces
Forests	Unchanged (very high protection)	Low decrease	Moderate decrease	High decrease	Very high decrease	No soil areas	No soil areas
Grasslands and shrubs	Low increase	Unchanged (high protection)	Low decrease	Moderate decrease	High decrease	No soil areas	No soil areas
Agricultural areas	Moderate increase	Low increase	Unchanged (moderate protection)	Low decrease	Moderate decrease	No soil areas	No soil areas
Fruit trees and olive groves	High increase	Moderate increase	Low increase	Unchanged (low protection)	Low decrease	No soil areas	No soil areas
Bare or sparsely vegetated areas	Very high increase	High increase	Moderate increase	Low increase	Unchanged (very low protection)	No soil areas	No soil areas
Artificial surfaces	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas
Wetlands and water bodies	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas	No soil areas

Figure 4. Classification matrix of the detected LULC changes in terms of expected variations in soil protection (modified from Magliulo et al. [24,25]).

3. Results

3.1. LULC Patterns

The LULC patterns in the Fortore R. basin in 1960, 1990, and 2018 are shown in Figure 5a–c, respectively. Figure 6 shows the extension of each LULC class in the entire Fortore R. basin and in each physiographic unit (Figure 1), expressed as a percentage of the total area, in the investigated years (i.e., 1960, 1990, and 2018). Finally, Table 2 reports the area of each LULC class, expressed in hectares, in the considered years and the areal variation, expressed as percentage of the former area, in the three considered sub-periods (i.e., 1960–1990, 1990–2018, and 1960–2018).

Both Figures 5 and 6 clearly show the high level of agricultural activity in the studied area. In particular, Figure 6a highlights that the percentage of the total area used for agriculture ranged between 78.6% (in 1990) and 77.5% (in 2018), remaining stable in the period of 1960–1990 and undergoing a negligible decrease (i.e., just over one percentage point; Table 2) in the period of 1990–2018.

The forests were almost exclusively located in the AMR and, to a lesser extent, LAH physiographic units (Figures 5 and 6). The forested areas underwent a clear increase in the investigated period in both the entire basin (Figure 5a) and in almost all the investigated physiographic units (Figure 6b–e), except for the coastal plain, where forests were absent (Figure 5b). At the basin scale, forests accounted for 9% of the total area in 1960, 11.9% in 1990 and, finally, 14.2% in 2018. The increases in the forested areas were calculated as 32.4% in the period 1960–1990, 19.5% in the period 1990–2018, and 58.3% in the entire investigated period (1960–2018; Table 2).

The grasslands and shrubs underwent decreases in their extension at both the basin and physiographic-units scale (Figure 6a–e). At the basin scale (Figure 6a), the percent of the total area used as grassland decreased from 8.5% in 1960 to 4.8% in 1990 (−43.8%; Table 2), and to 3.1% in 2018 (−36.4%; Table 2). Grasslands and shrubs totally disappeared from the Coastal Plain from at least 1990 (Figure 6b). The visual comparison between Figure 5a,b clearly shows that, in 1960, the lower Fortore R. was almost completely bordered by grasslands and shrubs, while, from 1990, the grasslands mostly disappeared. This is confirmed by Table 2, which highlights a dramatic decrease in the area occupied by grasslands and shrubs, of 89.6%, in the AP physiographic unit (in which the lower Fortore R. flows).

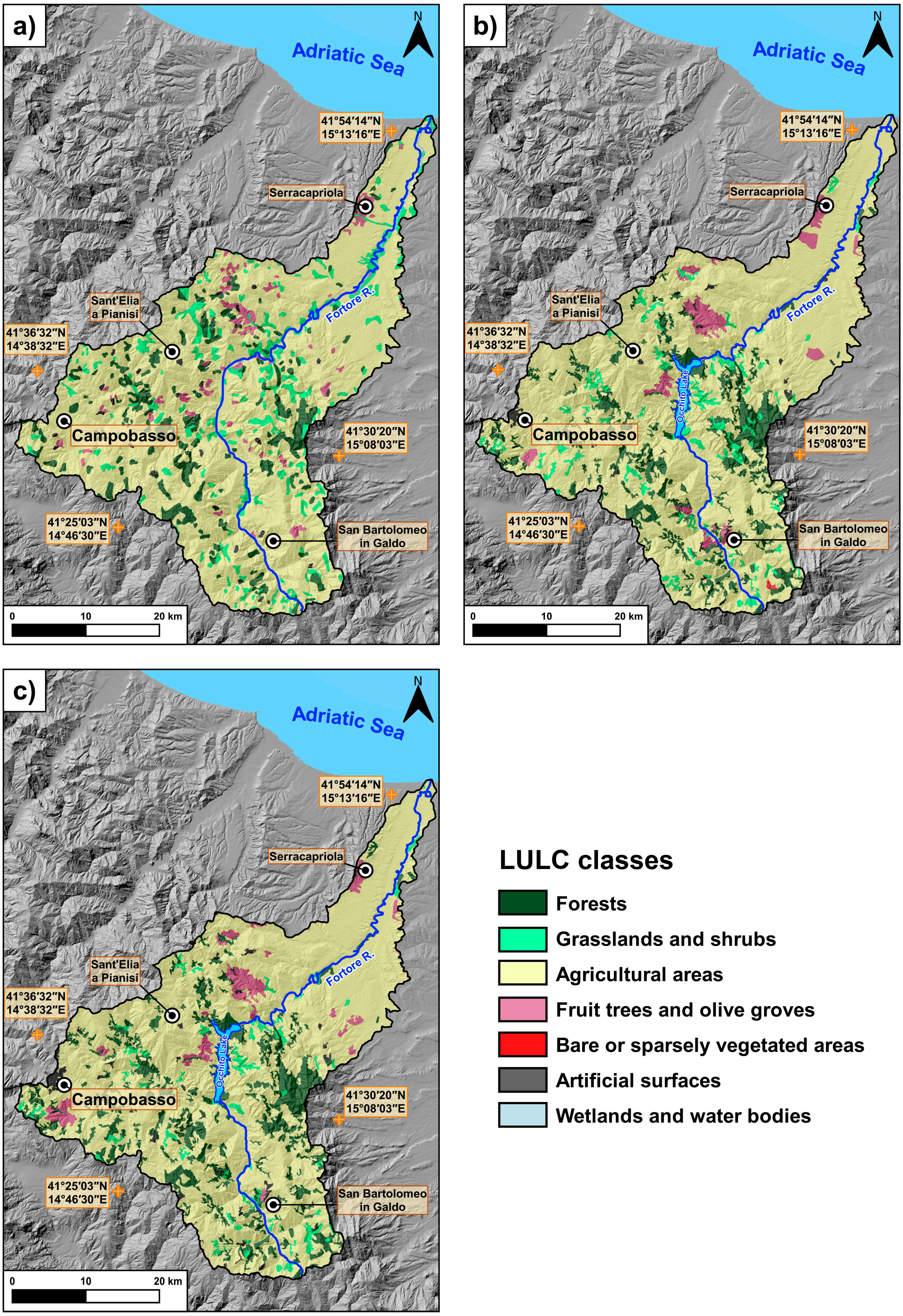

Figure 5. LULC patterns in the Fortore R. basin in 1960 (**a**), 1990 (**b**), and 2018 (**c**).

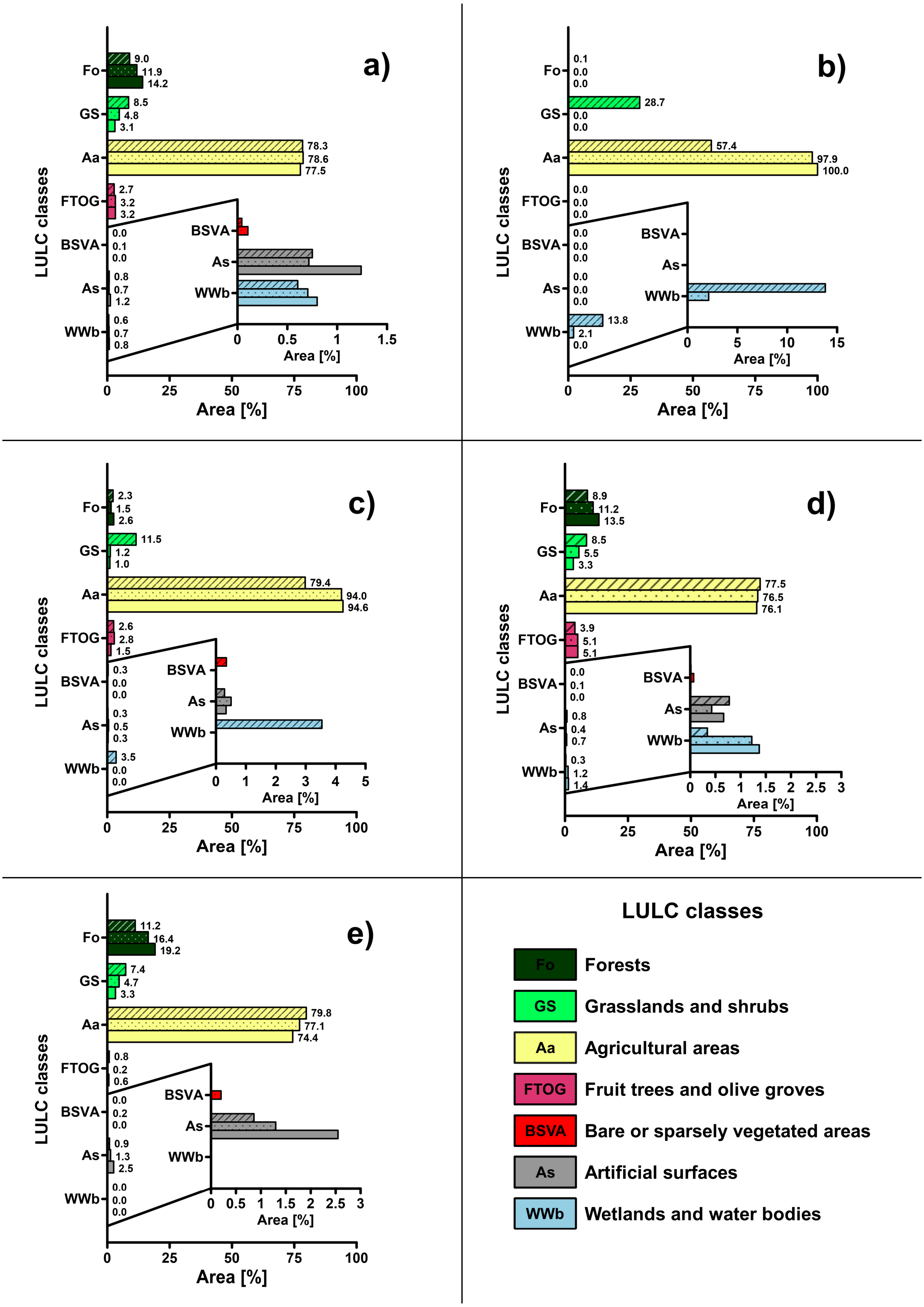

Figure 6. Extension of the LULC, expressed as percentage of the total area, in 1960 (bars with diagonals), in 1990 (dotted bars) and in 2108 (empty bars) in the Fortore R. basin (**a**), coastal plain (**b**), alluvial plain (**c**), low-altitude hills (**d**), and Apennine mountain range (**e**).

Table 2. Extension of the LULC classes, expressed in hectares, in the investigated years and areal variation, expressed as a percentage of the total area, in the entire considered period and in the two sub-periods in the whole Fortore R. basin and in the detected physiographic units.

Fortore R. basin						
LULC Class	Area (ha)			Variation (%)		
	1960	1990	2018	1960–1990	1990–2018	1960–2018
Agricultural areas	125,680.6	126,027.4	124,282.0	0.3	−1.4	−1.1
Artificial surfaces	1203.9	1148.0	1988.9	−4.6	73.3	65.2
Bare or sparsely vegetated areas	68.8	167.1	2.3	142.9	−98.6	−96.6
Forests	14,368.1	19,027.0	22,737.6	32.4	19.5	58.3
Fruit trees and olive groves	4410.1	5199.1	5212.6	17.9	0.3	18.2
Grasslands and shrubs	13,709.1	7709.6	4905.1	−43.8	−36.4	−64.2
Wetlands and water bodies	968.9	1131.2	1280.9	16.7	13.2	32.2
Coastal plain						
LULC class	Area (ha)			Variation (%)		
	1960	1990	2018	1960–1990	1990–2018	1960–2018
Agricultural areas	358.5	611.4	624.6	70.6	2.2	74.2
Artificial surfaces	-	-	-	-	-	-
Bare or sparsely vegetated areas	-	-	-	-	-	-
Forests	0.8	-	-	-	-	-
Fruit trees and olive groves	-	-	-	-	-	-
Grasslands and shrubs	179.0	-	-	-	-	-
Wetlands and water bodies	86.3	13.2	-	−84.7	-	-
Alluvial plain						
LULC class	Area (ha)			Variation (%)		
	1960	1990	2018	1960–1990	1990–2018	1960–2018
Agricultural areas	12,821.7	15,175.7	15,269.7	18.4	0.6	19.1
Artificial surfaces	46.1	81.5	54.6	76.6	−32.9	18.4
Bare or sparsely vegetated areas	571.9	-	-	-	-	-
Forests	374.8	243.8	418.7	−34.9	71.7	11.7
Fruit trees and olive groves	414.1	452.2	236.9	9.2	−47.6	−42.8
Grasslands and shrubs	1862.7	194.3	167.6	−89.6	−13.8	−91.0
Wetlands and water bodies	571.9	-	-	-	-	-
Low-altitude hills						
LULC class	Area (ha)			Variation (%)		
	1960	1990	2018	1960–1990	1990–2018	1960–2018
Agricultural areas	70,891.8	70,033.9	69,653.0	−1.2	−0.5	−1.7
Artificial surfaces	709.2	390.1	606.6	−45.0	55.5	−14.5
Bare or sparsely vegetated areas	12.6	62.4	-	395.8	-	-
Forests	8159.1	10,227.6	12,323.7	25.4	20.5	51.0
Fruit trees and olive groves	3602.3	4625.3	4652.3	28.4	0.6	29.1
Grasslands and shrubs	7822.8	5051.4	3019.8	−35.4	−40.2	−61.4
Wetlands and water bodies	310.7	1118.0	1253.2	259.8	12.1	303.3
Apennine mountain range						
LULC class	Area (ha)			Variation (%)		
	1960	1990	2018	1960–1990	1990–2018	1960–2018
Agricultural areas	70,891.8	70,033.9	69,653.0	−1.2	−0.5	−1.7
Artificial surfaces	709.2	390.1	606.6	−45.0	55.5	−14.5
Bare or sparsely vegetated areas	12.6	62.4	-	395.8	-	-
Forests	8159.1	10,227.6	12,323.7	25.4	20.5	51.0
Fruit trees and olive groves	3602.3	4625.3	4652.3	28.4	0.6	29.1
Grasslands and shrubs	7822.8	5051.4	3019.8	−35.4	−40.2	−61.4
Wetlands and water bodies	310.7	1118.0	1253.2	259.8	12.1	303.3

Figure 6a also shows a marked increase in the artificial surfaces in the period 1990–2018 (+55.5%; Table 2). This increase mainly occurred in the AMR physiographic unit (Figure 6e), where the main urban settlement of the study area (i.e., Campobasso) is located.

The visual comparison between Figure 6a,b clearly demonstrates the formation of the Occhito reservoir, which followed the closure of the Occhito dam in 1966 [26]. Notwithstanding the significant extension of the Occhito reservoir (i.e., ~14 km^2; [26]), the area of the corresponding LULC class (i.e., wetlands and water bodies) increased, at the basin scale, by 16.7% only (Table 2) in the period in which the Occhito Dam was closed (i.e., 1960–1990). This is because there was a significant decrease in the extension of the "wetlands and water bodies" LULC class in both the CP and the AP physiographic units, as highlighted in Figure 6b,c. These decreases partly compensated the significant increase in the "wetlands and water bodies" class (+259.8%; Table 2) in the LAH physiographic unit (Figure 6d), in which the Occhito reservoir is located, due to the closure of the dam.

Figure 6a also highlights that the "bare or sparsely vegetated areas" always occupied a negligible portion of the basin (less than 0.1%), with a relative peak in 1990. The latter were mainly located in the LAH physiographic unit (Figure 6d).

Finally, the percentage of the basin area occupied by fruit trees and olive groves remained almost constant in the three considered years, with values of 3.2% (in both 1990 and 2018) and 2.7% (in 1960; Figure 6a).

3.2. LULC Changes ("Transitions")

The analysis of the LULC changes ("transitions") provided new insights into the LULC dynamics in the study area in the considered periods. The spatial distribution of the LULC transitions is graphically reported in Figure 7.

Figure 8 shows the percentages of both the Fortore R. basin and physiographic-unit area affected by the detected LULC changes.

To ensure readability, both Figures 7 and 8 report only the main types of LULC change. More precisely, the different sub-types (e.g., the different types of afforestation) of each class of LULC change are shown with the same color, as in Figure 3. The percentages of the total area of both the Fortore R. basin and each physiographic unit affected by the different sub-types of LULC changes (e.g., the different types of afforestation) in both the 1960–1990 and 1990–2018 sub-periods and in the whole investigated time-span (1960–2018) are reported in Table 3.

Figure 7 clearly shows that the LULC changes mainly affected the upper part of the Fortore R. basin (i.e., LAH and AMR physiographic units), while the LULC remained substantially unchanged in the lower part of the basin (i.e., AP and CP physiographic units).

Figure 8 shows that most of the LULC changes occurred in the period of 1960–1990. However, they affected only 25.2% of the total area, while the remaining 74.8% experienced various forms of LULC persistence (i.e., agricultural, forestry, urban and grassland persistence; Figure 8A; Table 3). Agricultural persistence was the dominant form, as it affected 70% of the basin area. About 11.8% of the study area was reclaimed for agriculture (i.e., conversion to farmlands in Figure 8) through deforestation (4.5% of the basin area), agricultural extensification (0.5%%), and agricultural tillage (6.7%; Table 3). The conversion to farmland was particularly intense in the CP physiographic unit, accounting for 40.4% of the total area. Because 57.4% of the CP area experienced agricultural persistence, agriculture occupied 98% of the coastal plain in 1990. Compared with CP, the conversion to farmland was less intense in the AP physiographic unit, as it affected 16.6% of the unit through deforestation (2.1%), extensification (3.1%), and tillage (11.4%; Table 3). However, because 80.2% of the AP experienced agricultural persistence, 96.8% of the AP was used for agriculture in 1990. This percentage decreased to 76.9% in the LAH and to 72.2% in the AMR physiographic units, respectively (Figure 8A; Table 3).

Afforestation affected 8.1% of the Fortore R. basin between 1960 and 1990 (Table 3). It was particularly intense in the AMR and, to a lesser extent, LAH physiographic unit, as it affected 10.7% and 7.8% of the unit area, respectively. This afforestation mainly occurred at the expense of agricultural lands and, to a lesser extent, in both the entire basin and in all the physiographic units. Forestry persistence occurred on 3.8% of the basin area and was relatively frequent in the AMR physiographic unit, accounting for 5.1% of the unit area.

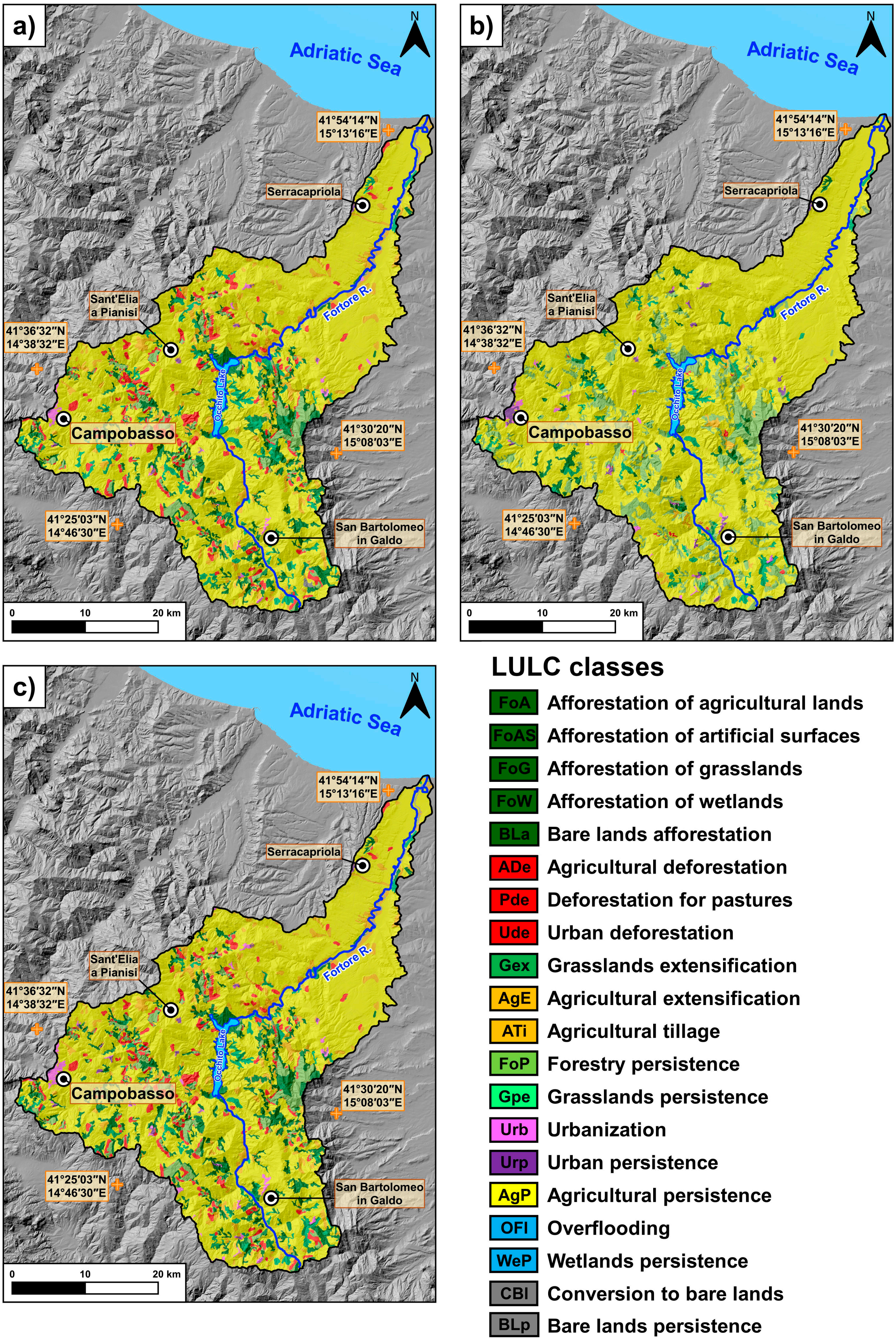

Figure 7. Spatial distribution of the LULC changes ("transitions") in the periods of 1960–1990 (**a**), 1990–2018 (**b**), and 1960–2018 (**c**). See also Figure 3 for details.

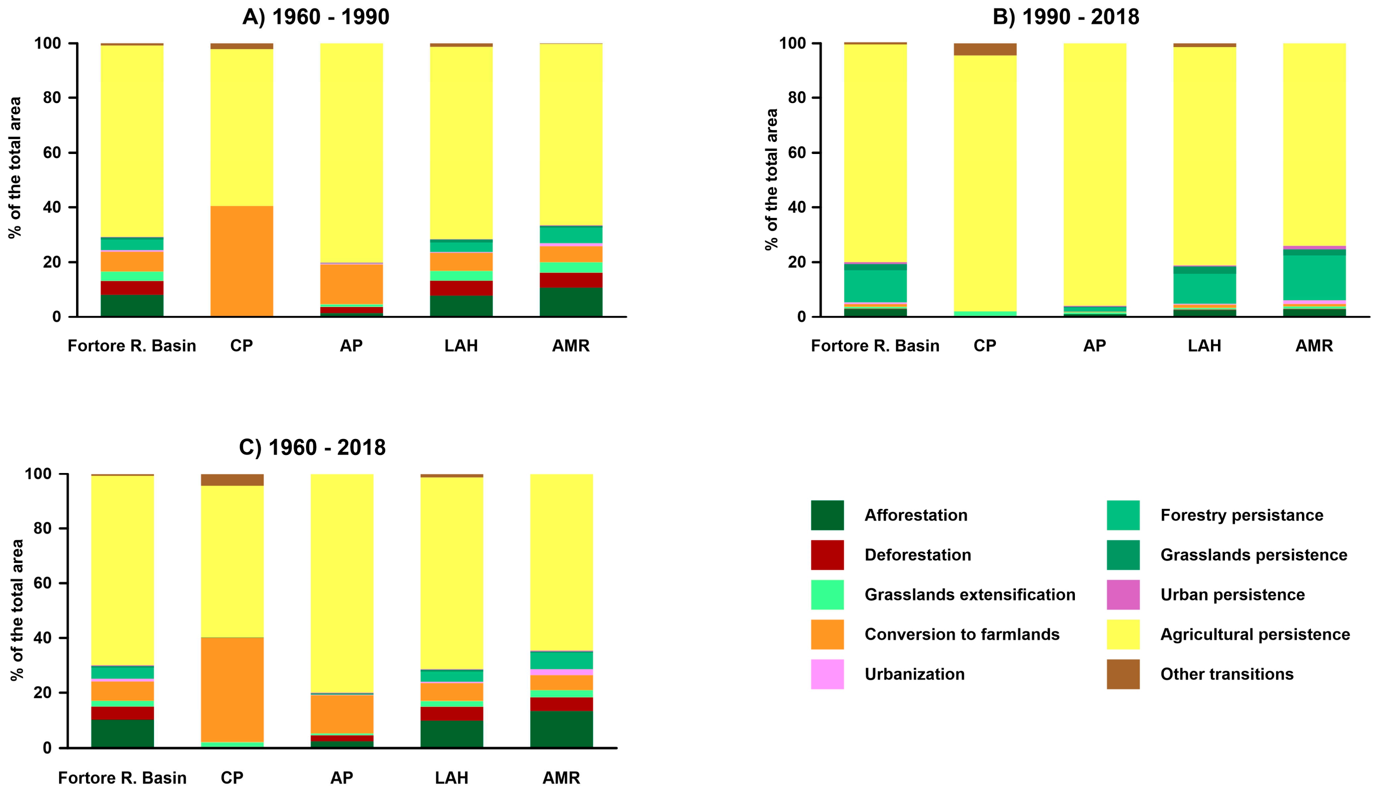

Figure 8. Percentages of the Fortore R. basin and of the detected physiographic-unit extensions affected by the different LULC changes in the sub-periods 1960–1990 (**A**) and 1990–2018 (**B**) and in the whole investigated time-span (1960–2018) (**C**). Legend–CP: coastal plain; AP: alluvial plain; LAH: low-altitude hills; AMR: Apennine mountain range. See also Figure 3 for details.

Table 3. Percentage of the total area of the Fortore R. basin and of each physiographic unit affected by the different sub-types of LULC changes in the 1960–1990 and 1990–2018 sub-periods and in the whole investigated period (1960–2018).

LULC Change	1960–1990 (%)					1990–2018 (%)					1960–2018 (%)				
	Fortore R. Basin	CP	AP	LAH	AMR	Fortore R. Basin	CP	AP	LAH	AMR	Fortore R. Basin	CP	AP	LAH	AMR
Afforestation of agricultural lands	6.6	-	0.8	6.1	9.1	1.0	-	0.2	0.9	1.3	8.2	-	1.6	7.7	11.2
Afforestation of artificial surfaces	0.0	-	-	0.0	0.0	0.0	-	-	0.0	0.0	0.1	-	-	0.1	0.1
Afforestation of grasslands	1.5	-	0.3	1.6	1.5	1.5	-	0.9	1.7	1.6	1.7	-	0.4	1.9	1.9
Afforestation of wetlands	0.0	-	0.3	0.0	-	0.0	-	-	0.0	-	0.0	-	0.4	0.0	-
Afforestation of bare lands	0.0	-	0.0	-	-	0.0	-	-	0.0	0.0	0.0	-	0.0	-	-
Agricultural deforestation	4.5	0.1	2.1	4.7	5.1	0.1	-	0.0	0.2	0.1	4.5	0.1	2.1	4.7	4.9
Deforestation for pastures	0.5	-	0.1	0.7	0.3	0.0	-	0.0	0.0	0.1	0.3	-	-	0.5	0.2
Urban deforestation	0.0	-	-	0.0	0.0	0.0	-	-	0.0	0.0	0.0	-	-	0.0	0.1
Grassland extensification	3.4	-	1.0	3.6	3.8	0.7	2.1	0.7	0.6	0.9	2.2	2.0	0.7	2.2	2.7
Agricultural extensification	0.5	13.8	3.1	0.3		0.0	-	-	0.0	-	0.5	13.5	2.8	0.3	-
Agricultural tillage	6.7	26.5	11.4	6.2	5.8	1.0	-	0.2	1.2	0.9	6.6	24.5	11.1	6.2	5.5
Urbanization	0.5	-	0.3	0.3	1.0	0.6	-	0.0	0.3	1.3	0.9	-	0.1	0.4	2.1
Forestry persistence	3.8	-	0.1	3.4	5.7	11.7	-	1.5	10.9	16.3	4.1	-	0.2	3.8	6.0
Grassland persistence	0.8	-	0.1	1.1	0.6	2.3	-	0.4	2.7	2.3	0.6	0.1	0.4	0.7	0.4
Urban persistence	0.2	-	0.2	0.1	0.2	0.7	-	0.3	0.4	1.3	0.3	-	0.2	0.2	0.3
Agricultural persistence	70.0	57.4	80.2	70.3	66.4	79.6	93.5	95.9	79.8	74.0	69.2	55.4	80.0	70.0	64.6
Bare-land persistence	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overflooding	0.7	2.1	-	1.2	-	0.1	2.3	-	0.1	-	0.8	4.1	-	1.4	-
Wetland persistence	0.0	-	-	0.0	-	0.7	2.1	-	1.2	-	0.0	0.3	-	0.0	-
Conversion to bare lands	0.1	-	-	0.1	0.2	0.0	-	-	-	0.0	0.0	-	-	-	0.0

Deforestation occurred in 5.1% of the basin in the 1960–1990 period. It was more intense in the AMR and LAH physiographic units, as it affected 5.5% and 5.4% of the unit area, respectively. As stated above, the deforested areas were mainly converted to farmland, while negligible percentages were occupied by pasture.

Both grassland extensification and urbanization were negligible. The former affected 3.4% of the basin area, and it was relatively intense in the AMR and LAH physiographic units, where it accounted for 3.8% and 3.6% of the unit area, respectively. Urbanization affected 0.5% of the study area and mainly occurred in the AMR physiographic unit, where the main settlement (i.e., the city of Campobasso) is located.

As stated above, the LULC changes in the period 1990–2018 were less intense compared to those that occurred between 1960 and 1990, as the LULC remained unchanged in 94.3% of the basin area (Figure 8A; Table 3). In particular, agricultural persistence affected 79.6% of the Fortore R. basin area, but this percentage increased to 93.5% and 95.9% in the CP and AP physiographic units, respectively. The forestry persistence was also quite diffuse, as it occurred in 11.7% of the basin area. The forests persisted mainly in the AMR (16.3% of the physiographic unit area) and LAH (10.9%). Other forms of persistence, such as grassland and urban persistence, were less frequent, as they accounted for the 2.3% and 0.7% of the basin area, respectively.

Of the LULC changes in the 1990–2018 period, afforestation was the most widespread. However, it affected 2.9% of the basin area only and mainly occurred in the AMR and LAH physiographic units (2.9% of the physiographic unit area). Deforestation was negligible, as it affected 0.2% of the basin area only. Grassland extensification affected 2.1% of the coastal plain but, at the basin scale, it was negligible (i.e., 0.7% of the basin area), as was urbanization (0.9% of the basin area).

As a result of the LULC changes that occurred during the 1960–1990 and 1990–2018 sub-periods, described above, in the entire investigated period (1960–2018) the Fortore R. basin experienced LULC persistence in 74.2% of the total area (Figure 8C; Table 3). Agricultural persistence was the dominant form, as it affected 69.2% of the basin area, while forests persisted in 4.1% of the basin, grasslands and shrubs persisted in 0.6%, and artificial surfaces persisted in 0.3%.

Afforestation affected 10.1% of the basin area (increasing to 13.1% in the AMR physiographic unit) and mainly occurred at the expense of agricultural lands and, to a lesser extent, grasslands and shrubs, while 4.8% of the basin area was deforested. The areas reclaimed for agriculture accounted for 11.6% of the basin and were mainly located along the coastal and alluvial plain. Grassland extensification and urbanization were negligible (2.2% and 0.9% of the basin area, respectively).

3.3. Variations in Soil Protection Induced by LULC Changes

According to the method described in Section 2.2, the detected LULC changes were reclassified in terms of variations in soil protection against erosion in the considered period and sub-periods, based on both the C-factor values calculated for the harmonized LULC classes and reported in Table 1 and the matrix shown in Figure 4. The results are summarized in Figure 9, and they are quantified in terms of the percentage of the Fortore R. basin area in Figure 9d.

Most of the changes in soil protection occurred in the sub-period of 1960–1990 (Figure 9a), when most of the LULC transitions occurred (Figures 7a and 8A). Figure 9d shows that, in this sub-period, the protection of soil against erosion remained unchanged in 71.3% of the basin, due to the wide diffusion of the different types of LULC persistence (i.e., agricultural, forestry, grassland, and urban persistence; Figures 7a and 8A). However, Figure 9d also shows that 12.8% of the basin was affected by LULC transitions inducing increases in soil protection. These increases, as shown in Figure 4, were low in 6.1% of the basin area, moderate in 6.5%, and high in 0.2% only. Conversely, the LULC changes inducing decreases in soil protection against erosion affected a slightly higher percentage of the study area, i.e., 13.3% (Figure 9d). A low decrease in soil protection affected 8.5% of the study area, a moderate decrease affected 4.6%, and a high decrease affected only 0.1% of the basin. Finally, 2.6% of the Fortore R. basin consisted of no-soil areas.

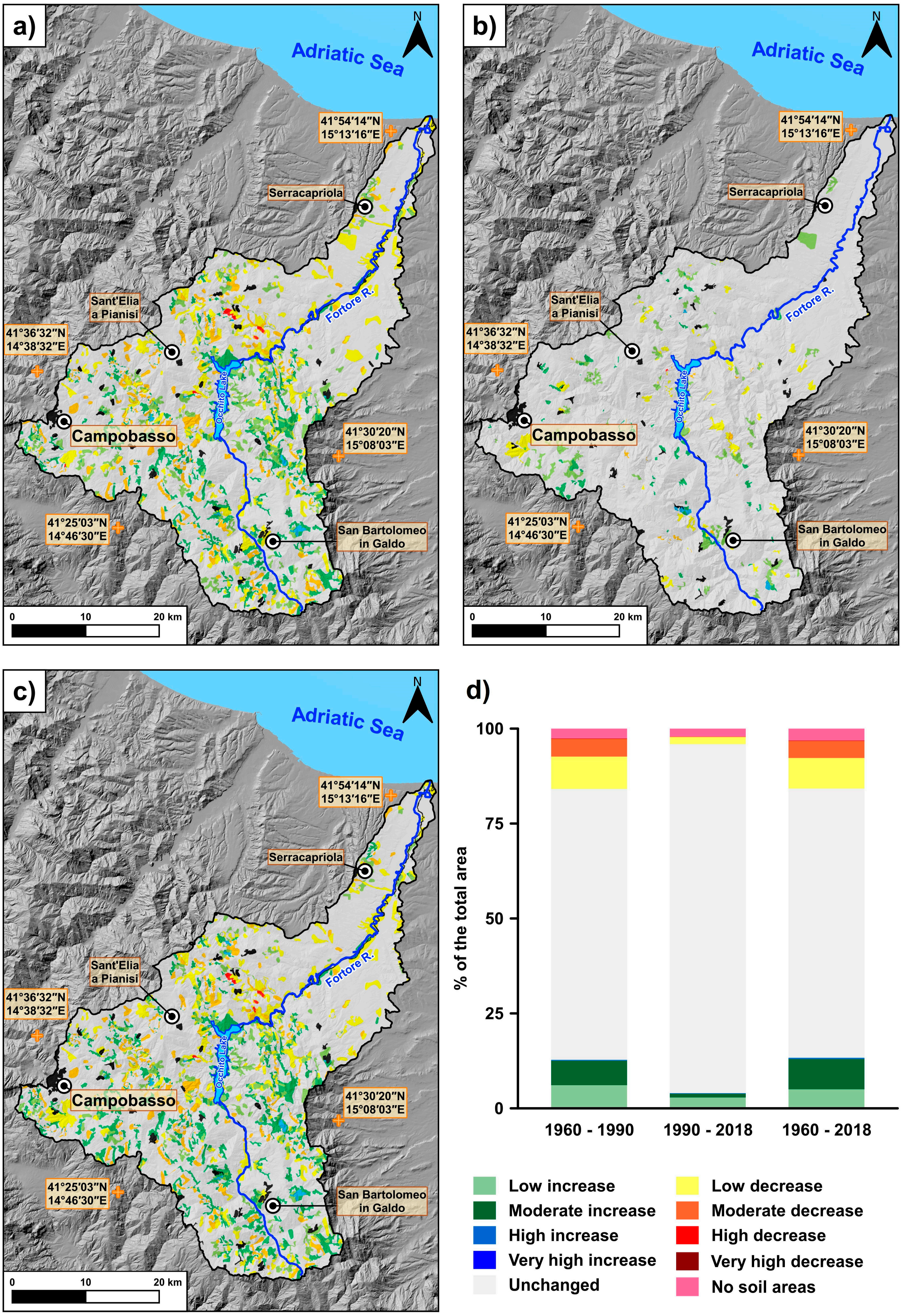

Figure 9. Spatial distribution of the variations in soil protection induced by LULC changes in the periods 1960–1990 (**a**), 1990–2018 (**b**), and 1960–2018 (**c**). In (**d**), the variations are quantified in terms of percentage of the basin area. See Figure 4 for further details.

In the sub-period of 1990–2018, the percentage of the study area in which no variations in soil protection induced by LULC changes occurred increased to 91.9%, reflecting the striking dominance of LULC persistence. Only 4% the basin area experienced an increase in soil protection induced by LULC changes, which was low in 2.9% of the basin area, moderate in 1%, and high in 0.1%. Conversely, a lower percentage of the study area (i.e., 2%) was affected by a decrease in soil protection induced by LULC changes, which was almost totally low (1.9%) No-soil areas covered 2.1% of the river basin.

4. Discussion

4.1. Trends of LULC Changes

The analysis of the LULC changes we carried out clearly showed that, over a period of 58 years, three quarters of the Fortore R. basin remained unchanged from the LULC-changes standpoint (Figures 7c and 8C). Furthermore, the LULC changes almost exclusively occurred during the first thirty years (i.e., from 1960 to 1990; Figures 7a and 8A), as in the remaining part (i.e., 1990–2018) of the investigated period, more than 94% of the study area did not experience any LULC changes (Figures 7b and 8B). These results are fully coherent with those obtained by Magliulo et al. [25] for another large-sized river basin in southern Italy, i.e., the Calore R. basin, which borders, to the south, the study area.

The obtained results also showed excellent coherence with those published by Scorpio and Rosskopf [26], who carried out an analysis of LULC changes for the period of 1990–2012 only, at a more detailed scale, in the Fortore R. basin. The results obtained by those authors highlighted, among other observations, the substantial stability of the forest coverage. This result was in good agreement with our data, which showed a negligible increase (i.e., just over 2%) in the basin area and over a slightly longer period (i.e., 1990–2018) in the land surfaces occupied by forests (Figure 6a). Scorpio and Rosskopf [26] also found that 14% of the upper part of the basin, approximately coinciding with the LAH and AMR physiographic units defined in this study, was occupied by forests. This percentage is close or very close to the values we obtained for the LAH physiographic unit (13.5%; Figure 6d) and the AMR physiographic unit (19.2%; Figure 6e). The results also converge in their highlighting of the substantial stability of agricultural land extension in the upstream portion of the basin. Scorpio and Rosskopf [26] found percentages of the total surface occupied by agricultural lands ranging from 77.8% in 1990 to 79.1% in 2012. The percentages we obtained in this study for both the LAH and the AMR physiographic unit in 1990 and 2018 (Figure 6d,e) were fully comparable with those values. Finally, the same authors also found almost total stability in the agricultural land in the downstream portion of the basin [26], coinciding with AP and CP physiographic units defined this study, which was fully confirmed by our results (Figure 6b,c).

The comparison of our results with the LULC-change data at the national scale in the same period [40] showed both discrepancies and agreements. In particular, the increase in both the forested areas and the artificial surfaces that we found in the Fortore R. basin (Figure 6a) reflects the trend of these classes at a national scale [40]. Also, the decreasing trend in the extension of grasslands and shrubs and the dominance of agricultural areas that we observed in the Fortore R. basin (Figure 6a) was confirmed at a national scale [40].

The main discrepancies between the national and local LULC trends were observed at the physiographic-unit scale. In particular, for the entire Apennine area, Falcucci et al. [40] found a decrease in the extension of the agricultural lands in the period 1960–2000, which was not confirmed by our data. However, it should be noted that, due to the national scale of the study, the “Apennines” physiographic unit defined by Falcucci et al. [40] comprised the AMR, LAH, and AP physiographic units defined in this study. This discrepancy suggests the need for a more detailed definition of the physiographic units at a less detailed scale (e.g., at a national scale) by separating the mountainous and hilly reliefs from the alluvial plains based on their elevation and geological/geomorphological features [28]. Conversely, the decrease in grasslands and shrubs and the increase in both forests and artificial surfaces in the study area (Figure 6a) were in agreement with the general trend of the “Apennines” area defined by Falcucci et al. [40], albeit with much lower percentages, which further confirms the need for a more precise delineation of the physiographic units.

The comparison of the data we obtained in this study for the Fortore R. basin (hereinafter FRB) with those provided by other, similar studies at the basin scale in southern Italy (i.e., the Sele River basin, hereinafter SRB [24]; and the Calore River basin, hereinafter CRB [25]) in the same timespan (i.e., 1960–2010s) also highlights some similarities and discrepancies. The forests markedly increased in all the investigated basins, with high percentages of the former class area (i.e., +51% in FRB; +117% in CRB; +146% in SRB). In all the study cases, they were mainly located in the AMR physiographic units. The forests mainly expanded, at the basin scale, at the expense of agricultural lands in FRB and CRB and of grasslands and shrubs in SRB. Also, grasslands were mainly located in the mountainous portions of the three basins and decreased everywhere, with percentages ranging from −49% in CRB to −64% in FRB, and up to −91% in SRB. The agricultural lands underwent negligible or moderate decreases in all the basins, ranging from −1% in FRB to −13% in CRB, and up to −18% in SRB. Finally, the artificial surfaces also markedly increased, with percentages ranging from +65% in FRB to +184% in CRB, and up to +219% in SRB. All the described trends are in agreement with those reported by Falcucci et al. [40] at the national scale, and by Di Gennaro et al. [37] at the regional scale (i.e., for the Campania region; Figure 1).

Regarding the causes of the observed LULC changes, most previous studies associated them with changes in human-population density and, in particular, with the depopulation process of Apennine marginal lands after World War II, which caused a decrease in total population of 26% from 1971 to 2010 [40,43,44]. In the Fortore valley, the resident population decreased in all the municipalities, with the overall density declining from 82 to 51 inhabitants/km^2 between 1951 and 2011 [3]. Despite this process, the Fortore R. basin demonstrated persistent results in terms of LULC changes, especially from 1990 onwards (Figures 7 and 8). In this framework, Smiraglia et al. [3] observed that the depopulation process causes the fragmentation of large farm holdigs and the downfall of family-run farms. However, this does not lead to major LULC changes, but rather to land abandonment, which, in turn, leads to less controlled and conservative land-management practices. Notwithstanding the negligible changes in soil protection induced by the LULC changes we observed in the study area (Figure 9), non-conservative farming practices can enhance the level of hydrogeological risk in a territory which is already susceptible to various types of landslide [31], as well as exposing soils to water erosion [45].

4.2. LULC Changes and Landscape Morphodynamics

As stated in Section 1, the deep interrelationships at the basin scale between the LULC changes (particularly afforestation/deforestation), river-channel adjustments, and shoreline dynamics has long been known [12–19]. Regarding the Fortore R. channel adjustments, Scorpio and Rosskopf [26] recognized two main evolutionary phases.

The first phase occurred from the 1950s until 1990s and was characterized by channel narrowing ranging between 51% and 98%, channel-bed lowering of 1 to 5 m, and pattern changes from multithread to single-thread channel morphologies. In this phase, the shoreline and, in particular, the Fortore R. delta, underwent strong erosion [46], although it is well known that coastal dynamics are not controlled only by fluvial sediment supply, but also by longshore transport. This phase almost perfectly coincided with the sub-period (i.e., 1960–1990) of relatively major changes in LULC that we observed in the Fortore R. basin (Figure 7a). By protecting the slopes from erosion [5,6,15,19,46], the increase in the forested-area extension by 32.4% (Table 2) certainly supported the reduction in the sediment supply from the slopes to the Fortore R. channel and from the latter to the coast. It is true that, at the basin scale, the forested areas increased by only ~3% (Figures 6a and 8A), but it is worth noting that the afforestation started long before the study period, i.e., in 1929 [20,21]. Furthermore, this phase was characterized by a decrease in average annual rainy precipitation, which was particularly marked between 1977 and 1998 [26]. The decrease in rainfall probably reduced the runoff on the slopes and, thus, the sediment supply to the river–coast system. Finally, during this phase, another local LULC change occurred, i.e., the closure of the Occhito dam, with the associated overflooding of the upstream areas (Table 2; Figure 5a,b, Figures 6d and 7b). This further reduced the sediment supply both to the river reaches located downstream of the dam through discharge regulation and sediment trapping, inducing more severe channel changes than those that occurred upstream [26], and to the Fortore R. delta [46].

The second phase occurred from 1998 to 2014. The downstream reaches of the Fortore R. appeared completely stable, while the upstream reaches showed some widening, which was accompanied by the increase in the surface and number of bars [26]. No research data were found about the shoreline dynamics during this phase, although a visual inspection of multitemporal Google Earth imagery suggested then overall stability of the Fortore R. delta; nevertheless, more detailed data, which are beyond the scope of this paper, are unquestionably needed. This phase of overall stability in the Fortore R. channel (and, probably, in the river delta) almost perfectly coincided with the phase of overall stability (i.e., 1990–2018) in terms of LULC changes that we observed in the Fortore R. basin (Table 2; Figures 6 and 7b). In this phase, the extension of forested areas continued to increase compared to the previous phase, but the increase was lower (i.e., 19% vs. 32%), chronologically shorter, and negligible if considered at the basin scale (~2%). From a climatic standpoint, the average annual rainy precipitation increased during this phase [26]. Although the increase in soil erosion with increasing precipitation was not simple, it is likely that runoff also increased, together with associated sediment supply to the Fortore R. This could explain, concurrently with other factors (e.g., the banning of the gravel extraction from the riverbed), both the widening and the increase in number of the fluvial bars observed by Scorpio and Rosskopf [26].

A quantification of the volumes of soil and/or sediments eroded from the slopes in the studied period is currently not possible, notwithstanding the presence of the Occhito reservoir, which forms a perfect sediment trap to control the flow of sediment into the upper Fortore River. The only available data are those published by Bazzoffi and Vanino [47], which report a total volume of sediment trapped within the reservoir of 14,768,681 m^3 over a period of 42 years (i.e., 1966–2008). This confirms the intense soil erosion occurring in the upper Fortore R. basin, previously highlighted by Buondonno et al. [32].

Finally, the visual comparison between Figure 5a,b clearly showed that, in 1960, the lower Fortore R. was almost constantly bordered by grasslands and shrubs, which, from 1990 onwards, were almost totally replaced by agricultural areas. These LULC changes unquestionably increased the flood risk though an increase in vulnerability.

5. Conclusions

This study allowed the reconstruction of the multidecadal LULC patterns and changes at a basin scale, contributing to filling the current lack of this kind of study for southern Italy. Once again, GIS proved to be a key tool in landscape analysis.

The LULC-change trends observed at the basin scale were coherent with those observed in other basins in southern Italy, creating a basis on which to recognize, in the future, a common trajectory in LULC changes. This study also highlighted the need for a more detailed delineation of the physiographic units in studies at a national scale.

Most of the LULC changes occurred between 1960 and 1990, while the LULC remained practically unchanged in the subsequent 28 years. The depopulation process often invoked as the main cause of the LULC changes induced variations in the land-management practices rather than variations in the extension of the agricultural areas, at least in the investigated basin.

This study also confirmed the interrelationships between multidecadal LULC changes at the basin scale and fluvial and coastal dynamics. The latter seem to be controlled by the intensity and duration of the phases of overall LULC changes or stability at the basin scale rather than by variations in the extension of single LULC classes (e.g., forested areas).

In conclusion, the analysis of multidecadal LULC patterns and changes at the basin scale proved their importance in the understanding of the landscape dynamics, which is fundamental in the management of land-degradation-prone territories, as is unquestionably the case in southern Italy.

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