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Anthropization Processes and Protection of the Environment: An Assessment of Land Cover Changes in Sardinia, Italy

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Abstract: Protection of the environment is implemented through preventive and mitigating measures aimed at hindering anthropization processes. These measures may possibly entail the establishment of natural protected areas and sites where conservation measures are stated under the provisions of the “Habitats” Directive (No. 92/43/EEC) and Directive No. 2009/147/EC (the so-called “Birds” Directive, which modifies Directive No. 79/409/EEC). A straightforward way of assessing widespread anthropization processes consists in analyzing land cover changes related artificialization processes concerning natural areas. In this study, we assess land cover changes by using the simplified land cover taxonomy of the Land and Ecosystem Account classes and by analyzing transition processes; in addition, we propose a comparative appraisal of land cover changes occurring in areas characterized by different protection regimes, as follows: areas protected under the provisions of national or regional acts or regulations; sites belonging to the Natura 2000 network, that is, protected under the Habitats or Birds Directives; and unprotected areas. We analyze anthropization processes that take place in Sardinia, an Italian insular region characterized by the presence of several national and regional protected areas and by a significant system of Natura 2000 sites, and assess land cover changes over a twelve-year period (2000–2012). The outcomes of our study put in evidence important lessons related to the definition and implementation of planning policies aiming at preventing anthropization processes in Sardinia. Moreover, the assessment methodology we implement in our study can be exported to other European regions to set up planning processes that fit the local features of land cover changes.

Keywords: protected areas; Natura 2000 network; land cover change; transition processes

1. Introduction

Preventing or limiting anthropization processes is one of the main objectives of environmental protection policies. Anthropization processes are in this study understood, following Martínez-Fernández et al. [1], as the sets of processes that ultimately lead to more natural to less natural land covers. Hence, they broadly comprise three groups of processes: the first group includes conversion from any types of non-artificial land covers into artificial land covers; the second group includes conversion from any type of natural land covers into agricultural land covers; and, finally, the third group includes conversion from less structured, extensive agricultural land covers into more structured, intensive ones.

According to Deguignet et al. [2], protected areas worldwide cover 3.14% and 14% of marine and terrestrial areas, respectively. The establishment of protected areas plays a significant role in protecting biodiversity and natural areas from human-induced pressures in terms of progressive artificialization [3,4]. Processes such as deforestation, agricultural expansion and urbanization bring

about the reduction and fragmentation of habitats, possible decline in the number of species and the introduction of invasive alien species [5].

An effective assessment of these processes is represented by the analysis of those land cover changes that entail a progressive increase in artificial land cover, such as urbanization starting from croplands, pastures or semi-natural areas, or generation of homogeneous agricultural areas from heterogeneous, semi-natural or natural areas.

In this essay, we assess land cover changes over a twelve-year period (2000–2012) in relation to three levels of environmental protection in the case study of Sardinia, an Italian insular region characterized by the presence of several national and regional protected areas and by a widespread system of Natura 2000 sites (N2Ss). The essay aims at assessing the role played by different levels of protection in terms of anthropization processes. In particular, we consider three different protection regimes, as follows:

1. natural protected areas (NPAs) under the provisions of national or regional acts or regulations;
2. sites belonging to the Natura 2000 network (N2Ss), that is protected under Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (“Habitats Directive”) or Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (“Birds Directive”); and
3. unprotected areas (UAs).

The essay is organized as follows. Section 2 provides the reader with an overview of recent literature that assesses the contribution of protected areas towards biodiversity conservation through methodological approaches similar to ours, i.e., based on assessments and comparisons of land cover changes. In Section 3, we explain the methodological approach and the data we use. In our analyses, we adopt a modified version of the CORINE Land Cover taxonomy, proposed by the European Environment Agency [6], where land cover classes are grouped into broader types according to the “Land and Ecosystem Accounting” (LEAC) project [7]. In Section 4, we introduce the results that are subsequently discussed in Section 5. The outcomes of our study put in evidence important lessons related to the definition and implementation of planning policies which aim to prevent anthropization processes in Sardinia. Finally, concluding remarks and directions for future research are presented in the last section.

2. Effectiveness of Protected Areas in Maintaining Biodiversity: A Literature Review

At the international and national level, policies on environmental protection pursue the maintenance [5,8] or restoration [9] of biodiversity and ecological integrity. Therefore, such policies are formally put into practice through the establishment of protected areas [10]. Article No. 2 of the Convention on Biological Diversity defines a protected area as “a geographically defined area which is designated or regulated and managed to achieve specific conservation objectives”.

The importance of the role played by protected areas is highlighted in the Strategic Plan for Biodiversity 2011–2020, where Aichi Biodiversity Target No. 11 sets at 17% and 10%, respectively, the percentage of terrestrial, and coastal and marine areas to be maintained and protected through a system of conservation measures by 2020. Despite these targets, biodiversity is declining even in protected areas [11] due to land-use changes within or outside their borders [5]. Land cover changes, resulting from deforestation, agricultural expansion and abandonment and anthropization processes, involve fragmentation and degradation of habitats [12].

According to Hansen and DeFries [13], protected areas should be planned within an integrated ecosystem where they interact with their surroundings in terms of ecological and socio-economic interrelationships. Moreover, assessing the effectiveness of protected areas could represent a precondition to improve conservation measures in terms of effectiveness and efficiency and to take appropriate management actions [8]. Therefore, measuring protected areas’ effectiveness is a still debated issue [14].

Both qualitative and quantitative methods are used to assess the effectiveness of protected areas [15]. Qualitative methods are often based on opinion of experts; they can take different forms depending on the subject under evaluation and consequently on the experts to be involved. We can identify, for instance, a first group that aims at analyzing positive and negative effects of management strategies within protected areas, thus involving, for example, park managers. A second group evaluates the effectiveness of protected areas in protecting species and habitats, involving, for instance, naturalists. A limitation of qualitative approaches concerns the experts' subjectivity, and, consequently, difficulties in comparing judgments across sites [16] and the impossibility to evaluate changes within protected areas over a time period [15].

Quantitative approaches usually involve mapping land cover changes within the protected areas' boundaries and their surroundings [9,14] or inside protect areas only [10,17]. As claimed by Nagendra [18], studies carried out either within protected areas only or also including their surroundings share similar conclusions in terms of accessibility and attitude towards conversion. In relation to the first group (i.e., studies concerning protected areas only), Kamlun et al. [17] assess deforestation within the boundaries of two Malaysian protected areas between 1985 and 2013, while Sieber et al. [10] compare land cover changes in relation to forest and agricultural land in two protected areas in Russia in a given time period (1984–2010). With reference to the second group (i.e., studies also concerning bordering areas), Scharsich et al. [19] compare the rate of land cover changes within the Matobo National Park and its surroundings by analyzing 1989, 1998 and 2014 Landsat images, while Ament and Cumming [20] compare land cover changes over a ten-year time period inside nineteen national parks and their neighboring areas in South Africa. Moreover, Terra et al. [21] compare land uses changes for the years 1962, 1980, 2001 and 2007 within two protected areas in Brazil, the Despraiado Sustainable Development Reserve, and the Jureia-Itatins State Ecological Station, and within a buffer zone to analyze the impacts of legal regulations on environmental protection. Votsi et al. [22] use information provided by land uses to analyze an integrated network composed by protected areas, that is N2Ss, and quiet areas, zones characterized the absence of all those noises produced by human activities.

Finally, some quantitative approaches analyze land cover changes before and after the legal establishment of protected areas—such studies are often affected by the absence of sound baseline data [23]—while others compare land cover changes within and outside protected areas, before and after their establishment [18]. For example, Willcock et al. [24] analyze land cover changes in the Eastern Arc Mountains in Tanzania, characterized by protected and unprotected areas, using data from georeferenced maps dated before and after the establishment of protected areas in order to assess the effectiveness of protection regime.

3. Data and Methods

3.1. Study Area and Protection Levels

In this study, we look at the Italian island of Sardinia as our case study. Located in the west Mediterranean, between Italy and Spain, Sardinia has an area of around 24,000 km². In terms of European biogeographical regions [25] as used under the Habitats Directive [26] and as adopted by the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) in 2010 [27], Sardinia belongs to the Mediterranean biogeographic region. Within the region, three types of nature protection regime can be identified as follows: NPAs, N2Ss (which are to be considered as protected areas themselves, albeit of a different kind than the previous one), and, finally, UAs.

Because of the status of autonomous region granted to Sardinia, both a national law (No. 394/1991) and a regional law (No. 31/1989) rule over the system of NPAs. According to national law No. 394/1991, national NPAs can be either parks or reserves; a third type is that of marine protected areas, which are not included here because land cover changes only concern terrestrial surfaces.

In Sardinia, only two national parks (Parco Nazionale dell'Asinara and Parco Nazionale dell'Arcipelago di La Maddalena) have been established; a third one (Parco Nazionale del Golfo di Orosei e del Gennargentu) was legally established in 1998 through a Decree of the President of the Republic, but in 2008 the regional administrative court ruled that conservation measures were not in force in the area delineated in the Decree because of the lack of involvement and agreement of local communities, which should have been mandatory; hence, since conservation measures are not in place, the formal establishment of this park cannot impact on land cover change processes, and for this reason the third park is not included in our study. Pursuant to regional law No. 31/1989, regional NPAs include regional parks and reserves; four regional parks have been established so far, all of which are included in our analysis, while no regional reserves are yet in place. Finally, having regard to their special protection status, we also include among NPAs the public woods that are maintained by the Regional Agency for Forests because they are to be actively managed in such a way to guarantee the maintenance of current landscapes for future generations, the protection of the environment against natural and human-induced disasters (for example, fires), and, finally, the sustainable consumption of natural resources (there including both wood and non-wood products) below the carrying capacity of the forest.

As for the second type of protected areas, Natura 2000 is a transnational network of areas comprising currently more than 27,000 sites [28] across the European Union (EU), of which the network is the centerpiece of nature and biodiversity policies. N2Ss aim to guarantee the maintenance, in a favorable conservation status, of species and habitats that are regarded as valuable, or threatened, or typical of certain European landscapes. N2Ss can be broadly classed into two groups: on the one hand, Sites of Community Interest (SCIs) and Special Areas of Conservation (SACs), designated under the Habitats Directive; on the other hand, Special Protection Areas (SPAs), designated in compliance with the Birds Directive [29]. The establishment process varies depending on the type of site: each EU Member State has a duty to contribute to the network by designating a sufficient amount of land as SPAs and by proposing to the European Commission an appropriate number of candidate SCIs, which are next designated by the European Commission itself (by being included in a list of sites approved through a Decision of the Commission and periodically updated), and within a six-year time frame from the designation SCIs must be established as SACs. In Italy, the State delegated [30] the task of proposing candidate SCIs and establishing SPAs to the 19 regions and two autonomous provinces. As a result, over a 17-year long process, in Sardinia 124 sites have been established so far: 37 SPAs and 93 SCIs, out of which 56 have recently been designated as SACs [31]. Some of these sites also include a portion of marine area, which we do not consider in this study for the same reasons previously mentioned with reference to marine protected areas. In addition, in the event of Natura 2000 overlapping NPAs, we consider the overlapping portion as having the highest protection level (hence, as NPAs) and the remainder as Natura 2000.

Finally, concerning the third protection level, we consider as UAs those parts of the island that are not included in the first two types and that are outside a five-kilometer buffer around both NPAs and N2Ss to exclude potential boundary effects [32]. Table 1 provides some figures concerning the size of the whole region and of each protection level.

Table 1. Area and percentage of each protection level in Sardinia.

Sardinia Total Area	NPAs		N2Ss		UAs			
					Within 5-km Buffer around NPAs and N2Ss		Outside 5-km Buffer around NPAs and N2Ss	
[km ²]	[km ²]	[%]	[km ²]	[%]	[km ²]	[%]	[km ²]	[%]
24,088	2364	9.81	3502	14.54	9599	39.85	8622	35.79

3.2. Data

National land cover spatial vector datasets for the years 1990, 2000, 2006, and 2012 have been made available by the Italian National Institute for Environmental Protection and Research (Istituto Superiore per la Protezione e la Ricerca Ambientale, ISPRA) [33]; such datasets make use of the taxonomy of the European CORINE Land Cover project. Hence, they represent the national equivalent to the datasets produced by the European Environment Agency for the whole EU (the latter are available on the European Environment Agency' website).

In this study, the 2000 and the 2012 datasets are used. National and regional parks in Sardinia were established at the very end of the 1990s, while N2Ss were first officially listed in an Italian decree in the year 2000 [34]; hence, the 2000 release of the national land cover map was chosen because it represents land covers at the initial stages of the establishment of protected areas in the island. The 2012 release was chosen because it is the most recent and available one.

Both datasets share some main characteristics, such as the scale (1:100,000), the minimum mapping unit (25 hectares), the geometric accuracy (100 m), the taxonomy (CORINE Land Cover, three levels, 44 classes), because of the need to build consistent, hence comparable, datasets across the years, notwithstanding some improvements such as the use of multi-temporal satellite images in the 2012 version [35].

3.3. Methodology: Identifying Processes of Land Cover Change

A preliminary reclassification of the two spatial datasets was performed in ArcGIS ESRI (release 10.1) to group the 44 (third-level) land cover classes into eight broad groups, following the LEAC scheme proposed by the European Environment Agency [7], as detailed in Table 2.

As outputs of such reclassification, two datasets concerning the spatial distribution of LEAC land cover groups in Sardinia in 2000 and 2012 were obtained. These were used as input data to quantify the significance of land cover change processes in the 2000–2012 time interval through geoprocessing operations in a GIS environment.

Land cover processes are listed in Table 3; this classification builds on [1] who, in turn, developed a reduced version of a previous classification by [36]. The right hand-side column provides the full list of land cover changes that contribute to a given process; each land cover change is provided as "X-Y", which signifies the change from land cover X (in 2000) to land cover Y (in 2012). Land cover persistence, understood as the absence of changes in land cover (which would be represented as "X-X", meaning that a given parcel of land in 2012 had the same land cover as in 2000), is therefore not included in the table.

Table 2. CORINE land cover classes and groups.

LEAC Groups		CORINE Land Cover Classes ¹			
A	Artificial surfaces	1. *			
ARA	Arable land and permanent crops	2.1. *	2.2. *	2.4.1	
PMF	Pastures and mosaic farmland	2.3. *	2.4.2	2.4.3	2.4.4
FOR	Standing forests	3.1. *			
TRW	Transitional woodland and shrub	3.2.4			
GRSH	Natural grassland, heathland, sclerophyllous vegetation	3.2.1	3.2.2	3.2.3	
OPEN	Open space with little or no vegetation	3.3. *			
WAT	Wetlands and water bodies	4. *	5. * (except 523-sea)		

Note: ¹ The asterisk (*) marks any sub-classes of a given class, or any sub-sub-classes of a given sub-class.

As Table 3 shows, four main land cover change processes can occur: type 1, anthropization processes; type 2, processes that lead to higher naturalization; type 3, internal changes in natural areas; and, finally, type 4, processes that produce an increase in water surfaces.

Table 3. Land cover change processes.

Code	Land Cover Change Processes	Land Cover Changes Included in the Process			
1	Anthropization processes				
11	Urbanization				
111	Urbanization and artificialization from crops, pastures and semi-natural areas	ARA-A	PMF-A		
112	Urbanization and artificialization from natural areas	FOR-A OPEN-A	TRW-A WAT-A	GRSH-A	
12	Agrarian creation from natural areas				
121	Creation of new predominantly homogeneous agrarian areas	FOR-ARA OPEN-ARA	TRW-ARA WAT-ARA	GRSH-ARA	
122	Creation of new heterogeneous or semi-natural agrarian areas	FOR-PMF OPEN-PMF	TRW-PMF WAT-PMF	GRSH-PMF	
13	Homogenization or simplification of agrarian areas	PMF-ARA			
2	Processes to higher naturalization				
21	Conversion and restoration from artificial area				
211	Conversion from artificial to agrarian areas predominantly homogeneous	A-ARA			
212	Conversion from artificial to heterogeneous or semi-natural agrarian areas	A-PMF			
213	Restoration from artificial to natural areas	A-FOR A-OPEN	A-TRW	A-GRSH	
22	Heterogeneization or semi-naturalization of agrarian areas	ARA-PMF			
23	Agrarian abandonment				
231	Abandonment of “homogenous” agrarian areas	ARA-FOR ARA-OPEN	ARA-TRW	ARA-GRSH	
232	Abandonment of “heterogeneous or semi-natural” agrarian areas	PMF-FOR PMF-OPEN	PMF-TRW	PMF-GRSH	
3	Internal changes in natural areas				
31	Successional processes (e.g., recovery, densification, shrub encroachment)	TRW-FOR WAT-FOR WAT-TRW WAT-OPEN	GRSH-FOR GRSH-TRW OPEN-GRSH	OPEN-FOR OPEN-TRW WAT-GRSH	
32	Processes derived from disturbances, conducive towards higher simplification or degradation or less dominance and density	FOR-TRW TRW-GRSH	FOR-GRSH TRW-OPEN	FOR-OPEN GRSH-OPEN	
4	Processes leading to increase in water surfaces	A-W FOR-W OPEN-W	ARA-W TRW-W	PMF-W GRSH-W	

4. Results

Table 4 provides the percentage area (of the whole region, of NPAs, of N2Ss, of UAs) concerned by a given land cover change process between 2000 and 2012.

Table 5 also represents quantitatively the results of the analysis. In this table, the size of the land characterized by a given land cover group is provided, again as a percentage of the total area for the whole of Sardinia and for each of the protection levels here analyzed. Moreover, for each LEAC group, Table 5 quantifies the relative net change, which is defined as the ratio of absolute net change (i.e., the difference between the size of the land belonging to a given group in 2012 and that in 2000) to its initial size in 2000:

$$NC_i = [(S_{i,2012} - S_{i,2000})]/(S_{i,2000}), \quad (1)$$

where i is a land cover group, NC_i is the relative net change of land cover group i , S_i is the area of land cover group either in 2000 or in 2012.

We describe land cover changes through the LEAC taxonomy and quantify their transitions as the size of the area whose classification changes across the LEAC macrocategories. The LEAC macrocategories are the following (see Table 2): artificial areas (A); agricultural zones, which include permanent crops and arable areas (ARA), and mosaic farmland and pastures (PMF); and natural zones,

which include transition woodland and shrubs (TRW), standing forests (FOR), open space (OPEN), sclerophylus vegetation (GRSH), and water bodies and wetlands (WAT).

The figures in Table 4 point out that NPAs, N2Ss and UAs are characterized by a comprehensive steadiness as regards the twelve-year period of our analysis.

N2Ss and UAs show the most significant transitions. Changes related to UAs are characterized by an increase in artificial areas (8%) and a less important increase in agricultural surfaces, whereas N2Ss reveal a much more evident growth concerning agricultural areas (15%) and a slight decrease in artificial surfaces (2%). Natural surfaces decrease in UAs and N2Ss by similar rates (5–6%), which puts in evidence that land cover changes in N2Ss have a marked attitude towards agriculture, whereas transitions in UAs feature a trend towards land-taking processes and urbanization. The 8% rate of artificialization of UAs is high in relative terms, but corresponds to about 1650 hectares, which limits the quantitative size of the share of the urbanized land located outside NPAs and N2Ss.

NPAs are characterized by a steady state, since the amount of urbanized, agricultural and natural surfaces remains almost the same.

Land cover changes regarding the whole Sardinian region can be compared to the correspondent figures related to NPAs, N2Ss and UAs. Table 5 shows that, in relative terms, the regional transitions are included in the (−5%, +7%) range. They entail an increase in artificial (+7%) and agricultural (+5%) surfaces and a decrease in natural areas (−5%). These figures are quite close to those concerning UAs, even though the share of natural surfaces prevails over the agricultural surfaces as for Sardinia, whereas a dual situation characterizes UAs.

The share of artificial areas related to N2Ss (0.65% in 2012) is lower than those related to UAs (2.49%) and the Sardinian region (2.96%), and slightly higher than those related to NPAs (0.48%). Moreover, N2Ss and NPAs do not show any trend towards artificialization in the period 2000–2012, since artificial land decreases in both cases (−6% and −2% respectively). The steadiness of artificial areas in NPAs and N2Ss can be due to the strict conservation-oriented rules in force in the two types of protected areas with respect to the rest of the regional land.

Agricultural land is quantitatively less important (2.70% in 2012) and steady in NPAs, whereas its share is higher in N2Ss (about 30%) and even greater in UAs (about 57%). Trends towards increase of the share of agricultural surfaces are evident in N2Ss (15%), UAs (4%), and in the whole region (5%).

As expected, the shares of natural surfaces mirror the agricultural surfaces. Their values in 2012 are about 97% (NPAs), 70% (N2Ss) and 40% (UAs). Trends towards decrease of the share of natural surfaces are evident in N2Ss (5%), UAs (6%), and in the whole region (5%).

Table 4. Land cover change processes: results for the whole Sardinia and for each protection level.

Code	Land Cover Change Processes	Sardinia [%]	Protection Level		
			NPAs [%]	N2Ss [%]	UAs [%]
1	Anthropization processes	5.16	0.52	6.26	5.49
11	Urbanization	0.41	0.04	0.13	0.39
111	Urbanization and artificialization from crops, pastures and semi-natural areas	0.30	0.01	0.05	0.32
112	Urbanization and artificialization from natural areas	0.11	0.03	0.08	0.07
12	Agrarian creation from natural areas	3.95	0.45	5.63	4.19
121	Creation of new predominantly homogeneous agrarian areas	0.41	0.05	0.23	0.46
122	Creation of new heterogeneous or semi-natural agrarian areas	3.54	0.40	5.40	3.73
13	Homogenization or simplification of agrarian areas	0.80	0.03	0.50	0.91
2	Processes to higher naturalization	1.99	0.63	2.09	2.24
21	Conversion and restoration from artificial area	0.22	0.06	0.14	0.21
211	Conversion from artificial to agrarian areas predominantly homogeneous	0.08	0.00	0.02	0.09
212	Conversion from artificial to heterogeneous or semi-natural agrarian areas	0.07	0.00	0.02	0.08
213	Restoration from artificial to natural areas	0.07	0.06	0.10	0.04
22	Heterogeneization or semi-naturalization of agrarian areas	0.30	0.09	0.52	0.31
23	Agrarian abandonment	1.47	0.48	1.43	1.72
231	Abandonment of "homogenous" agrarian areas	0.42	0.05	0.35	0.55
232	Abandonment of "heterogeneous or semi-natural" agrarian areas	1.05	0.43	1.08	1.17
3	Internal changes in natural areas	3.07	9.52	3.98	1.74
31	Successional processes (e.g., recovery, densification, shrub encroachment)	1.49	3.22	2.25	1.02
32	Processes derived from disturbances, conducive towards higher simplification or degradation or less dominance and density	1.58	6.30	1.73	0.72
4	Processes leading to increase in water surfaces	0.11	0.01	0.38	0.08
	Total area with change	10.33	10.68	12.71	9.55
	Total area without changes (persistence)	89.67	89.32	87.29	90.45

Table 5. Surface of land cover types (classified according to LEAC groups as in [7]) in 2000 and 2012 and relative net change (NC) for Sardinia and for each protection level. Relative net change is calculated as per Equation (1).

		Sardinia			NPAs			N2Ss			UAs		
		2000 [%]	2012 [%]	NC	2000 [%]	2012 [%]	NC	2000 [%]	2012 [%]	NC	2000 [%]	2012 [%]	NC
<i>(Artificial types)</i>	A	2.76	2.96	0.07	0.51	0.48	−0.06	0.66	0.65	−0.02	2.30	2.49	0.08
<i>(Agricultural types)</i>	ARA	24.42	24.79	0.02	0.81	0.73	−0.09	14.09	13.90	−0.01	30.78	31.16	0.01
	PMF	19.50	21.38	0.10	1.92	1.96	0.02	11.87	15.95	0.35	24.12	26.01	0.08
<i>(Natural types)</i>	FOR	16.42	17.03	0.04	53.37	50.20	−0.06	18.26	19.00	0.04	11.67	12.82	0.10
	GRSH	33.73	30.03	−0.11	37.18	37.32	0.00	46.00	40.18	−0.13	29.73	25.80	−0.13
	OPEN	1.46	1.48	0.01	4.79	4.51	−0.06	3.59	3.59	0.00	0.46	0.47	0.01
	TRW	0.57	1.19	1.09	0.76	4.13	4.47	0.43	1.50	2.48	0.53	0.77	0.47
	WAT	1.13	1.14	0.03	0.66	0.67	0.01	5.09	5.22	0.03	0.41	0.48	0.18
Total artificial surfaces		2.76	2.96	0.07	0.51	0.48	−0.06	0.66	0.65	−0.02	2.30	2.49	0.08
Total agricultural surfaces		43.92	46.17	0.05	2.73	2.70	−0.01	25.96	29.85	0.15	54.90	57.17	0.04
Total natural surfaces		53.31	50.87	−0.05	96.76	96.82	0.001	73.38	69.49	−0.05	42.80	40.34	−0.06

4.1. Land Cover Changes in NPAs

In NPAs, land cover changes amount to a 6% decrease in artificial areas, to a 1% decrease in agricultural surfaces and to a 0.1% increase in natural areas (see Table 5).

Table 5 shows that FOR and OPEN decreased in the 2000–2012 period (−6%), whereas TRW increased more than four times. A 6% decrease in FOR implies a 3.17% decrease of the share of FOR with respect to the total area of NPAs, which is an important impact on the land cover structure of NPAs, whereas a 6% decrease in OPEN entails a 0.28% decrease of the share of OPEN, which is negligible. Moreover, a 447% increase in TRW entails a 3.37% increase of the share of TRW, which is an important impact as well. The other land cover types, namely A, ARA, PMF, GRSH and WAT, remained almost stable. Consequently, the 2012 structure of land cover types in NPAs is different from the 2000 structure, since it shows an important increase in the share of TRW (3.37%) and a significant decrease in FOR (3.17%). These figures correspond to a land cover change of about 7500–8000 hectares.

The results put in evidence that the dominant process regarding land cover changes in NPAs is FOR-TRW, that is a process derived from disturbances, conducive towards higher simplification or degradation or less dominance and density, namely an internal change in natural areas (see Table 3). This is consistent with the steadiness of the three LEAC macrocategories, since the only significant land cover change process concerns internal changes in natural areas, which do not imply any land cover change regarding the LEAC macrocategories. Thus, we conclude that, in NPAs: (i) the three macrocategories of the LEAC in NPAs, namely artificial, agricultural and natural surfaces, are steady; and (ii) FOR-TRW is the most outstanding process of land cover transition.

4.2. Land Cover Changes in N2Ss

In N2Ss, land cover changes amount to a 2% decrease in artificial areas, to a 15% increase in agricultural surfaces and to a 0.1% increase in natural areas (see Table 5).

Table 5 shows that GRSH decreased in the period 2000–2012 (−13%), whereas PMF (35%) and TRW (more than two times) increased. A 35% increase in PMF implies a 4.08% increase in the share of PMF with respect to the total area of N2Ss, whereas a 248% increase in TRW entails a 1.07% increase of the share of TRW. Moreover, a 13% decrease in GRSH indicates a 5.82% decrease of the share of GRSH. The other land cover types, namely A, ARA, FOR, OPEN and WAT, remained almost stable. Consequently, the 2012 structure of land cover types in N2Ss is different from the 2000 structure, since it shows important increases in the shares of PMF (4.08%) and TRW (1.07%), and a significant decrease of GRSH (−5.82%). These figures correspond to a land cover change of about 18,000–20,000 hectares.

The results put in evidence that the dominant processes related to land cover changes in N2Ss are GRSH-PMF and GRSH-TRW, that is processes derived from, respectively (see Table 3): (i) creation of new heterogeneous or semi-natural agrarian areas, that is a kind of agrarian creation from natural areas, a process of anthropization; and (ii) successional processes, namely recovery, densification, and shrub encroachment, which are processes of internal changes in natural areas. Thus, we conclude that, in N2Ss: (i) agricultural and natural surfaces are the LEAC macrocategories which reveal significant changes, namely, agricultural surfaces grow and natural surfaces decrease by 3.89% of the N2Ss total area, which corresponds to about 13,600 hectares; and (ii) GRSH-PMF and GRSH-TRW are the most outstanding land cover transition processes.

4.3. Land Cover Changes in UAs

In UAs, land cover changes amount to an 8% increase in artificial areas, to a 4% increase in agricultural surfaces and to a 6% decrease in natural areas (see Table 5).

Table 5 shows that the transitions concerning A, OPEN, TRW and WAT were negligible, either because very low in terms of relative change (ARA and OPEN: 1%), or as regards the transition size (A: about 1600 hectares, 0.19% of the UAs total area; TRW: about 1400 hectares, 0.16%; WAT: about 600 hectares, 0.07%).

Table 5 also puts in evidence that GRSH decreased in the period 2000–2012 (−13%), whereas PMF (8%) and FOR (10%) increased. An 8% increase in PMF implies a 1.89% increase of the share of PMF with respect to the total area of UAs, whereas a 10% increase in FOR entails a 1.15% increase of the share of FOR. Moreover, a 13% decrease in the share of GRSH indicates a 3.93% decrease of the share of GRSH. Hence, the 2012 structure of land cover types in UAs is different from the 2000 structure, since it shows a significant growth of the shares of PMF (1.89%) and FOR (1.15%), and an important decrease of GRSH (3.89%). These figures entail a land cover change of about 30,000–32,000 hectares.

The outcomes indicate that the dominant processes concerning land cover changes in UAs are GRSH-PMF and GRSH-FOR, that is processes derived from, respectively (see Table 3): (i) creation of new heterogeneous or semi-natural agrarian areas, that is a kind of agrarian creation from natural areas, or, in other words, a process of anthropization; and (ii) successional processes, namely recovery, densification, shrub encroachment, which are processes of internal changes in natural areas. Thus, we conclude that, in UAs: (i) agricultural and natural surfaces are the LEAC macrocategories which reveal significant changes; namely, agricultural surfaces grow by 2.27% of the total area of UAs, which corresponds to about 19,600 hectares, and natural surfaces decrease by 2.44%, which corresponds to about 21,200 hectares; and (ii) GRSH-PMF and GRSH-FOR are the most outstanding land cover transition processes. Although these outcomes are qualitatively consistent with the results concerning N2Ss, however a substantial difference has to be stressed, which regards transition processes related to internal changes in natural areas. In N2Ss internal changes are mainly related to transitions from GRSH to transition woodland and shrubs, whereas in UAs such changes are connected to afforestation.

5. Discussion

Land cover change processes related to N2Ss and UAs are very close to one another. In either case, anthropization equals about 6% (see Table 4), mostly due to process “122”. This process is more important in N2Ss (5.63%) than in UAs (4.19%). Moreover, process “11”, that is urbanization, influences anthropization more in UAs than in N2Ss. This result is consistent with conservation rules related to N2Ss, where a special protection regime is in force, which cannot be implemented into UAs. Demand for anthropization generated by pressures related to profits coming from productivity of land [37] can possibly be better satisfied through new urbanized areas in UAs, than in N2Ss, where new urbanization is almost totally forbidden, and where every proposal of land transformation needs to pass an appropriate assessment, which is much more likely to be obtained in the case of process “122”, agrarian transformation, than in the case of process “11” (see Table 3).

This complies with the main goals of Natura 2000, which identifies urbanization, including new housing settlements, urban expansion and city and metropolitan sprawl, as the most dangerous global risk factors concerning biodiversity and natural habitats [38,39].

The process of generation of agricultural from natural areas is a global threat to biodiversity conservation as well (see, for example, [40]). Nonetheless, transition “122” is just a part of this generation, which implies the creation of heterogeneous, semi-natural and non-intensive agricultural areas, where many wild-fauna populations can find their habitats. Consequently, positive appropriate assessments are likely to be granted in the case of “122” land cover change processes.

Transitions towards naturalization are more significant in UAs (2.24%) than in N2Ss (2.09%). In either case, these processes are mainly caused by transition “232” (1.17% and 1.08%), that is a naturalization caused by the abandonment of former agrarian areas. A second, and less important, process which is involved in higher naturalization of UAs and N2Ss is transition “22” (0.31% and 0.52%), which implies agrarian areas that are converted into semi-natural or heterogeneous areas. A more important naturalization in UAs, due to the abandonment phenomenon, is coherent as regards the size of semi-natural agricultural and heterogeneous areas located in N2Ss, which amount to about one fifth of semi-natural agricultural and heterogeneous areas located in UAs, which entails a minor propensity to naturalization.

Dangerous processes which take place in N2Ss are related to the abandonment of agrarian activities such as grazing and cultivation of semi-natural and heterogeneous rural areas [41], which entails new bush, scrub and forest developments because of successional processes. These processes may generate the impoverishment of the diversity of habitats and of the habitat mosaics [42,43] and can eventually weaken semi-natural habitats of community interest which depend upon light agricultural activities [44]. Consequently, a lesser incidence of the abandonment rate related to naturalization of former agrarian areas in N2Ss with respect to UAs can be positively considered. This can be possibly due to the schemes concerning the agri-environmental support of the EU related to N2Ss. These schemes fund low-intensity, traditional farming [45], since such activity protects community interest habitats and species depending on agriculture [44,46,47], and, by doing so, it maintains and enhances biodiversity conservation [48], and eventually contributes to the comprehensive objectives of Natura 2000.

Natural areas in NPAs are characterized by greater internal changes than in N2Ss and in UAs. The “3” transition is equal to 9.52% in NPAs versus 3.98% and 1.74% in N2Ss and UAs respectively. Moreover, internal changes in N2Ss amount to more than double the correspondent transition in UAs. Successional processes (transition “31”) prevail over degradation and simplification transitions (“32”) in either case. This finding highlights that transitions “31” characterize NPAs, where enhancements concerning agriculture techniques can hardly take place because of very strict rules in place, which may possibly make almost impossible to implement innovative practices. Prevention of technical enhancement in agriculture may result in land abandonment, and, consequently, in degeneration and downgrading. Therefore, the areas where these deterioration processes take place should be identified and prioritized [49] as regards the implementation of public policies concerning environmental improvement [50].

An important feature of land cover changes in Sardinia in the targeted period is the lack of changes in a significant fraction of the region (see Table 4). Nevertheless, changes in N2Ss are more significant than in the areas corresponding to the other two protection regimes: 12.71% versus 10.68% (NPAs) and 9.55 (UAs). This can be explained with reference to the structural framework of the regional land cover defined by the LEAC in the context of each regime of natural protection. Table 5 reports that the most changing LEAC category, in absolute terms, is GRSH, whose N2Ss size is greater than in the NPAs and UAs cases (46.00% in N2Ss versus 37.32% and 29.18% in NPAs and UAs respectively). The decline of GRSH in N2Ss (−13%) is greater than that in NPAs (0.00%) and almost equal to the decrease in UAs, but much larger in size. This is consistent with a larger propensity to decline as a consequence of a larger size of the GRSH LEAC category, which, that being so, is comparatively more sensible to land cover change-related pressures. As we put in evidence in the previous section, internal changes in natural areas are mainly characterized by the FOR-TRW (NPAs), GRSH-TRW (N2Ss) and GRSH-FOR (UAs), which entail conversions into transition woodland and shrubs which can be considered as an environmental improvement in the case of GRSH-TRW and GRSH-FOR (transition “31”), whereas FOR-TRW represents a “32” transition, namely a process derived from disturbances, conducive towards higher simplification or degradation or less dominance and density (see Table 3). The outcome concerning NPAs stresses a generalized lack of maintenance of forests which implies degradation and, in the long run, desertification. A possible explanation is that NPAs are characterized by a very large share of the forest LEAC type (more than 50%), whose maintenance entails the availability of huge amounts of public funds, which is very difficult to achieve in times of generalized public budget cuts.

Furthermore, another outstanding process that takes place in N2Ss is GRSH-PMF, which implies a comparatively higher increase in pastures and mosaic farmland with respect to the regional land characterized by the other two protection regimes (35% versus 2% in NPAs and 8% in UAs). N2Ss show a comparatively lower PMF endowment than UAs, whereas this kind of agricultural uses is almost totally prevented in NPAs. The comparatively higher increase in PMF which takes place in

N2Ss can be explained in terms of the under endowment of PMF in 2000 in N2Ss with respect to UAs, which implies a greater size of propensity to transition towards PMF than in UAs.

The low value of PMF in 2000 is because the establishment of N2Ss is stated by the Habitats and Birds Directives. Proposals concerning the identification of N2Ss were first introduced in the late 1990s, and, because of this, the ruling context under the provisions of the two Directives was not operational until the first years of the new century. SPAs and SCIs were pinpointed in terms of zones featured by a high level of wilderness, where objectives were identified in terms of conservation of habitats of community importance and protection of wild species and habitats. These zones were characterized by a comparatively low concentration of PMF areas. Furthermore, under the provisions of the Habitats Directive, an Appropriate assessment is mandatory whenever a project or plan is proposed, whose implementation may possibly generate negative impacts on N2Ss [51], which entails that LEAC transitions consisting in anthropization processes are usually bound to the delivery of a positive Appropriate assessment. A positive Appropriate assessment concerning plans or projects related to N2Ss occurs more frequently if land cover changes which entail growth in ARA are minimized. Consequently, it is quite likely that land cover changes due to plans and projects aimed at increasing agrarian productivity in N2Ss have generated an increase in PMF areas higher than the regional mean value. Another reason concerning the increasing trend of PMF areas in N2Ss can be recognized in the schemes concerning the agri-environmental support of the EU related to N2Ss, as we put in evidence above as regards the higher loss in historically-rooted agricultural techniques which characterizes N2Ss with respect to UAs.

Transitions in NPAs are mainly related to transition “3”, namely internal changes in natural areas (9.52% out of 10.68%). Table 4 shows that transition “32” is higher than transition “31”, that is, land cover simplification and downgrading prevail over successional transitions (6.30% vs. 3.22%).

This finding is coherent with the LEAC structure of NPAs, since forests (53.37% in 2000 and 50.20% in 2012) and GRSH areas (37.18% in 2000 and 37.32% in 2012), exceed 85% of the NPAs total area. Values of FOR and GRSH are much more significant in NPAs than in UAs and N2Ss because environmental-protection-oriented rules are more rigid as regards these LEAC categories. This is consistent with expectations and with previous essays concerning the effectiveness of forest conservation policies implemented in NPAs, through measures related to direct control and monitoring of the NPAs borders (see, for example [20,52,53]).

Land cover change which implies land cover simplification and downgrading (“32”) is the dominant process in NPAs. As we remarked in Section 4.1, this is mainly due to the FOR-TRW transition. This land cover change process is characterized by comprehensive degradation of the land quality, and it shows that public policies concerning NPAs are somewhat inadequate and should be considered with attention. Public policies oriented towards nature conservation should be projected in a proactive way to involve the local communities in a long-term public–private cooperative effort to implement durable and effective management processes related to NPAs [53–56]. Land downgrading in NPAs will keep on and increasingly develop as a dramatic phenomenon if public–private partnership concerning environmental protection will not be implemented so as to become the ordinary approach to conservation of nature and natural resources.

Another land cover change process which features NPAs is the transition from ARA to PMF (“22”). This transition is somewhat less important than FOR-TRW in quantitative terms (from Table 5: ARA: 0.81% in 2000, 0.73% in 2012; PMF: 1.92% and 1.96%); however, this is another signal of the tendency towards shutdown of agricultural productive activities and the increase of land degradation in NPAs. Conversion of arable land into pastures is mainly caused by the decrease in profits from agricultural uses generated by rigid rules related to agrarian production. This land cover change process can be interpreted in two ways as regards the effectiveness in terms of environmental protection. On the one hand, it can be considered as an adequate supportive approach to restore ecosystem services [57] and as an opportunity to make available habitats for indigenous fauna [58]. On the other hand, ARA-PMF can be seen as a negative transition as well, since it might increase risks of floods and fires, as well

as desertification and erosion, and, ultimately, might spur environmental downgrading; moreover, it is likely to weaken the local economic development opportunities due to decreased agricultural production [45].

The most important artificialization process which takes place in UAs is ARA-A. Even though this process is not relevant in quantitative terms, it is a signal of a significant tendency towards land take in UAs, which is not a feature of NPAs and N2Ss (from Table 4, transition “111”: 0.32% in UAs vs. 0.01% in NPAs and 0.05% in N2Ss respectively). ARA-A is a “111” transition which implies urbanization and artificialization from crops, pastures and semi-natural areas, and it refers to the conversion from agrarian productive areas into newly-urbanized zones, which entails soil sealing and decrease in rural production.

Anthropization processes which do not imply artificialization in N2Ss and UAs are mostly related to the PMF-ARA transition, which is a process with a low quantitative relevance characterized by homogenization or simplification of agrarian areas (transition “13” in Table 4: 0.50% in N2Ss and 0.91% in UAs, vs. 0.03% in NPAs). In the case of transition “13”, anthropization is generated by demand for conversion of pastures into productive land, which is characterized by new arable areas, which are much more profitable than pastures and mosaic farmlands [37]. As we discussed above, a positive Appropriate assessment concerning plans or projects related to N2Ss is granted more frequently if land cover changes which entail growth in ARA are minimized. That is why in N2Ss anthropization processes consisting in conversion from pastures to productive agrarian land are less important than in UAs, where Appropriate assessment procedures are not implemented for conversion projects, even though demand for the availability of new productive land is present as well. As we stressed above, the most significant land cover change processes related to N2Ss are GRSH-TRW and GRSH-PMF. As we have already discussed, GRSH-TRW entails a comprehensive environmental improvement represented by successional processes from degraded areas, characterized by natural grassland, heathland and sclerophyllous, towards transition woodland and shrubs. Likewise, we highlighted above that the anthropization transition GRSH-PMF (conversion from natural grassland, heathland and sclerophyllous into pastures and mosaic farmland), mainly related to land cover changes due to plans and projects aimed at increasing agrarian productivity in N2Ss, are more likely to occur than transitions towards arable land since agrarian transformation plans and projects can hardly obtain a positive Appropriate assessment.

The discussion proposed so far entails that environmental enhancement through proactive protection of natural areas should be based on the involvement of local societies and landowners in the definition and implementation of policies based on shared long-term visions concerning the most desirable futures, which imply land take mitigation and gradual transitions towards land uses consistent with the improvement of the comprehensive environmental quality of regional spatial contexts.

6. Conclusions

Our study concerns the assessment of the effectiveness of protected areas with a specific focus on protection and regulation measures that are implemented in these areas. In fact, the effectiveness of protection measures of protected areas is influenced by regulation regimes [15] and, therefore, by their management framework [59]. For example, in our assessments, the presence of processes of degradation and simplification within N2Ss and NPAs emphasizes a problem of the management framework of protected areas. Public authorities should manage protect areas by combining objectives concerning biodiversity protection with economic, social and cultural aspects that, if not adequately managed, could support land use changes.

Moreover, although artificialization processes appear not significant from a quantitative point of view, from a qualitative perspective, they highlight the presence of human-induced pressures. The quantitative irrelevance of urbanization processes in both NPAs and N2Ss is not surprising due to the restriction measures that govern these areas; however, it is important to remark that artificialization

processes take different forms in NPAs and N2Ss, since they concern the urbanization of natural areas in NPAs and N2Ss, and of crop, pasture and semi-natural zones in UAs.

The public sector plays a key role in terms of strategies and policies aimed at protecting natural areas and limiting human-induced pressures at regional, national and supra-national levels; hence, our study highlights some issues that need a more careful consideration.

The first issue concerns land-taking processes (transition “11”) that may be limited through the enlargement of protected areas (NPAs and N2Ss), either designating new areas or expanding existent ones. However, the process of establishing new protected areas or broadening the size of existent ones entails different political, administrative and scientific commitments in relation to the typology of protected areas. In the case of NPAs, their establishment or enlargement requires strong cooperation and collaboration between local and regional authorities in terms of scientific and administrative expertise. The coordination issue is of outmost importance in the implementation of these processes, and it would call for a significant revision of the Italian regulatory framework [60]. In the case of N2Ss, the enlargement of protected surface is less critical than in NPAs due to more flexible rules that characterize the normative framework established by Habitats and Birds Directives. As a result, the establishment of new N2Ss or the increase in the size of the existing ones is likely to bring about fewer problems in terms of public consensus. On the other hand, in this second case the collaboration process is more complex because it involves local, national authorities as well as the EU Commission (namely, the Directorate-General for Environment). This process entails a significant effort for local, regional and national governments that must implement a proactive participatory process where different scientific, technical and administrative expertise work together [61,62]. Although national authorities play a purposeful role within the process of establishing a new site because they propose new SCIs and are in charge of designating SACs, the EU takes the lead role, in that it is responsible for establishing the SCIs. In Italy, regions are in charge of both proposing new SCIs to the State (who, in turn, is in charge of proposing the sites to the EU Commission) and for managing N2Ss, there including defining conservation measures. In particular, in the Sardinia region, conservation measures, integrated within management plans, are proposed by local authorities and afterwards approved by the regional government. On this basis, SCIs are next designated as SACs through a ministerial decree. This multilayered, inclusive process, which involves the EU, national, regional and local authorities, would represent an important opportunity for Sardinian planning processes that have been negatively affected by coordination problems in the past decades. Consequently, coordination between several public bodies is a strategic issue in the implementation of plans concerning protected areas. In fact, effective coordination between different tiers of government (EU, national, regional and local) may promote more efficient public policies that reflect a more coherent and effective normative framework concerning environmental and spatial planning.

The second issue concerns the absence of multidisciplinary expertise within local, provincial and regional planning offices where experts in biodiversity and environment protection should work together with planners and developers to define appropriate conservation and management measures in relation to protected areas. This issue is particularly critical in Sardinian region at the local scale [63].

Third, Strategic environmental assessment (SEA) processes may play a key role in the identification of new protected areas or in the enlargement of existent ones [64]. SEA procedures in relation to local plans are carried out, in Italy, in compliance with Legislative Decree No. 152/2006 (which transposes the European Directive 2001/42/EC “on the assessment of the effects of certain plans and programmes on the environment” into the Italian legislation) and aim at integrating environmental issues into plans and programs. Within this process, conservation measures that are particularly significant in limiting land-taking processes, as highlighted in our results, could be extended to UAs. However, this further step requires detailed information on the spatial distribution of habitats and species and a significant effort of national, regional and local governments.

A final issue concerns potential conflicts in terms of public consensus between conservation measures, aimed at maintaining and protecting biodiversity, and those traditional land uses (such as

pasture and agriculture) that may negatively impact species and habitats [63,65]. Local communities should be actively involved in the decision-making processes concerning protected areas in order to build consensus on the importance of protection policies.

Moreover, our results emphasize how within spatial plans, such as management plans, protected areas are conceived as separate entities from their surrounding areas. In reality, protected areas and their surroundings represent a complex and dynamic system characterized by different behavioral patterns and by mutual influences in terms of landscape dynamics and local communities' expectations.

Future directions of our research could include the use of the taxonomy of the CORINE Land Cover Project, where the third level accounts for 44 land cover classes. However, although the use of the CORINE Land Cover taxonomy allows for a more detailed analysis, the evaluation of transitions starting from 44 land cover classes rather than 8, as in the case of the LEAC methodology used in this essay, might make the identification of evident patterns quite complex.

Our methodology can be easily generalized in other EU contexts or within the Pan-European Ecological Network. Hence, a further step forward could test our methodology in other cases within the EU, both at national and at supra-national levels. For example, following Martínez-Fernández et al. [1], the methodology could be applied to a national case study, or, as in Calvache et al. [12], case studies from different European countries could be compared to understand the influences of management and normative issues on land cover transitions within protected areas and their surroundings.

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