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GIS Analysis of Land-Use Change in Threatened Landscapes by *Xylella fastidiosa*

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Received: 20 October 2018; Accepted: 2 January 2019; Published: 7 January 2019

Abstract: Land-use/land-cover analysis using Geographic Information System (GIS) application can describe and quantify the transformation of the landscape, evaluating the effectiveness of municipal planning in driving urban expansion. This approach was applied in the municipality of Spongano (Salento, South Italy) in order to evaluate the spatial heterogeneity and the transformations of the land use/land cover from 1988 to 2016. This approach was also used to examine the spread of *Xylella fastidiosa*, which is a plant pathogen of global importance that is reshaping the Salento landscape. The land-use maps are based on the CORINE Land Cover project classification, while the topological consistency was verified through field surveys. A change detection analysis was carried out using the land-use maps of 1988 and 2016. The most extensive land-use class is olive groves (34–36%), followed by non-irrigated arable lands and shrub and/or herbaceous vegetation associations. The main transition of land involved non-irrigated arable lands, which lost 76 ha and 23 ha to shrub and olive areas, respectively. Meanwhile, the artificial surfaces class doubled its extension, which involved mainly the transition from shrub and heterogeneous agricultural areas. However, the olive groves class is threatened by the dramatic phytosanitary condition of the area, indicating a compromised agroecosystem, which is causing a de facto transition into unproductive areas. The results highlight the inconsistency between what was planned by the urban plan in the past and how the landscape of Spongano has been changed over time. This evidence suggests that it is necessary to develop a plan based on learning by doing, in order to shape and adapt the processes of territorial transformation to the unpredictability of the ecologic, social, and economic systems, as well as ensure that these processes are always focused on environmental issues.

Keywords: land use; landscape urban planning; landscape pattern; spatial heterogeneity

1. Introduction

European landscapes are the result of human actions that transform ecosystems in order to adapt them to human needs, which can change between different generations [1–3]. The concept of landscape is also linked to the non-material values of the elements that compose it and the cultural aspects that have produced it. Landscapes continuously change, because they are the result of the dynamic interaction between natural processes and cultural forces. In this way, cultural landscapes can be defined as the result of consecutive reorganization of the land in order to adapt its use and spatial structure better to the changing societal demands [4]. Therefore, land use could be understood as the way and the aim in which human societies use the land resource, creating patterns that can alter the natural processes, modifying the natural evolution of the landscape [5].

Socio-economic changes and innovation take place independently from ecological systems and follow their own dynamics. This produces non-linear land-use transition or change in the time that refers to any change in land-use systems from one state to another, changing the structure of the landscape pattern [6]. In this way, the landscape can be defined as a social-ecological system, where the human societies co-evolve with their environment through change, instability, and mutual adaptation [6], forming relationships between human and ecological components as part of a complex system with multi-scale feedbacks and dependencies [7–11]. Therefore, the links between social, economic, and ecological processes are fundamental aspects of landscape ecology that aim to understand the main *driving forces* that produce changes in the landscape [12].

In this context, studying and quantifying landscape patterns and their transformations over time become essential in order to develop sustainable landscape urban planning and monitor landscape management [13–15].

From this perspective, a Geographic Information System (GIS) is a useful tool to support landscape ecology studies. In particular, the development of *remote sensing* provides an enormous amount of information that is useful for the study of the landscape patterns and the related ecological functions [16,17]. A relevant aspect of GIS applications is the possibility of carrying out retrospective analysis that is useful for ex-post studies that are connected to the effect of human actions at the time [18–23].

Currently, approximately 54% of the world's population lives in urban areas. Furthermore, it is estimated that by 2050, 55% of the world's population will be urban [24]. The growth of urban populations causes cities, and their suburbs, to spread, expand, and replace agricultural and natural lands [25,26]. Urbanization brings land-use change, altering the relationship between human societies and environmental resources [6,27,28]. It produces land erosion, energy flows, biogeochemical cycles, climatic conditions, habitat fragmentation, biodiversity loss, and decline in the provision of important ecosystem goods and services [6,26,29,30]. Therefore, the management of land use connected to the urban expansion has become one of the most important challenges to sustainable landscape [31,32].

Environmental considerations, including the protection of the soil, environmental heritage, and the landscape, should be integrated into planning decisions related to land use toward the objective of 'no net land take', by 2050 [33], in order to align it with population growth and not increase land degradation by 2030 [34]. Italy presents a large problem connected to urban land use; in particular, the province of Lecce, which is located in Apulia Region, Southern Italy, is among the provinces that are most subjected to the transformation of agricultural areas into residential areas [35]. Each municipality has adopted an urban plan that must regulate the development of urban and agricultural areas defining, for example, new building areas and the size of buildings. Therefore, these urban plans play a key role in determining the transformations of the landscape and limiting the urbanization.

Another threat that is affecting the agroecosystems of the province of Lecce is the presence of the plant pathogen of global importance *Xylella fastidiosa* (sequence type ST53) [36]. The destructive effect caused by the pathogen on olive trees can potentially compromise the practical and ecological purpose of olive groves. In addition, since olive groves potentially can be classified as monumental according to the characteristics established by the Apulia regional Law 14/2007 (dimension of the three; drum width; and prevalence of the monumental olive trees in the field), the spread of *X. fastidiosa* can determine the destruction of cultural olive groves, and therefore the loss of important and structural elements in the landscape pattern of the province of Lecce.

The aim of this paper is to carry out a landscape analysis in the municipality of Spongano (located in the Salento peninsula in province of Lecce) in order to identify and quantify the spatial heterogeneity and the transformations of the land use from 1988 to 2016. We also compared the current state of land use with the urban development forecasts of the urban plan of development in force from 1980. Through this analysis, we intend to verify the effectiveness of the existing urban plan in driving the processes of territorial transformation to the unpredictability of the ecologic, social, and economic systems. The assessment of urban land use in an agroecologically threatened area by the plant pathogen *Xylella fastidiosa* represents a peculiar rare case study.

2. Materials and Methods

2.1. Study Area

Spongano is a small municipality that is located in the peninsula of Salento (province of Lecce in South Italy), and is characterized by social ecological landscapes that represent the result of the strong interaction between human actions and ecological processes.

In the province of Lecce, commerce is the sector with the highest number of companies (33% of total active companies), followed by the construction sector (14.6%) and agricultural sector (14%). The tourism and manufacturing activities make up 9% of the companies in the province of Lecce respectively. The farms of the province are over 71,060; however, the agricultural sector appears to be characterized by a high degree of corporate fragmentation, and the average company size is rather small in terms of total surface area (2.4 hectares), and is decidedly lower than the average in Puglia (5.11 ha) and Italy (10.54 ha) [37]. There are 398 farms of the municipality of Spongano, with an average utilized agricultural area of 1.49 hectares.

As shown in Figure 1, Spongano is characterized by a core urban area that is mainly surrounded by olive groves and arable lands. The link between human activities, agriculture, and landscape is highlighted by the regional law 14/2007, which protects and enhances monumental olive trees because of their productive, ecological, and hydrogeological functions, as well as the peculiar and characteristic elements of the history, culture, and regional landscape.

The pathogen threat involves the reduction of crop yield, causing the wilting and death of olive trees (olive quick decline syndrome), but the side effects related to the management of the disease are not irrelevant, causing a significant alteration of the agroecosystems [36]. In particular, *X. fastidiosa* in Salento is directly impacting the environment (i.e., increment of chemical distributions for insect control or fertilization practices, uprooting of diseased plants with relevant impact on production patterns), while the indirect impacts may involve tourism, which is a significant part of the Italian gross domestic product (GDP) (i.e., due to changes in landscape) [38]. Further issues due to *X. fastidiosa* spread are related to social implications, due to the long historical and cultural connection of olive trees with the area, generating public resistance to uprooting diseased plants [38].

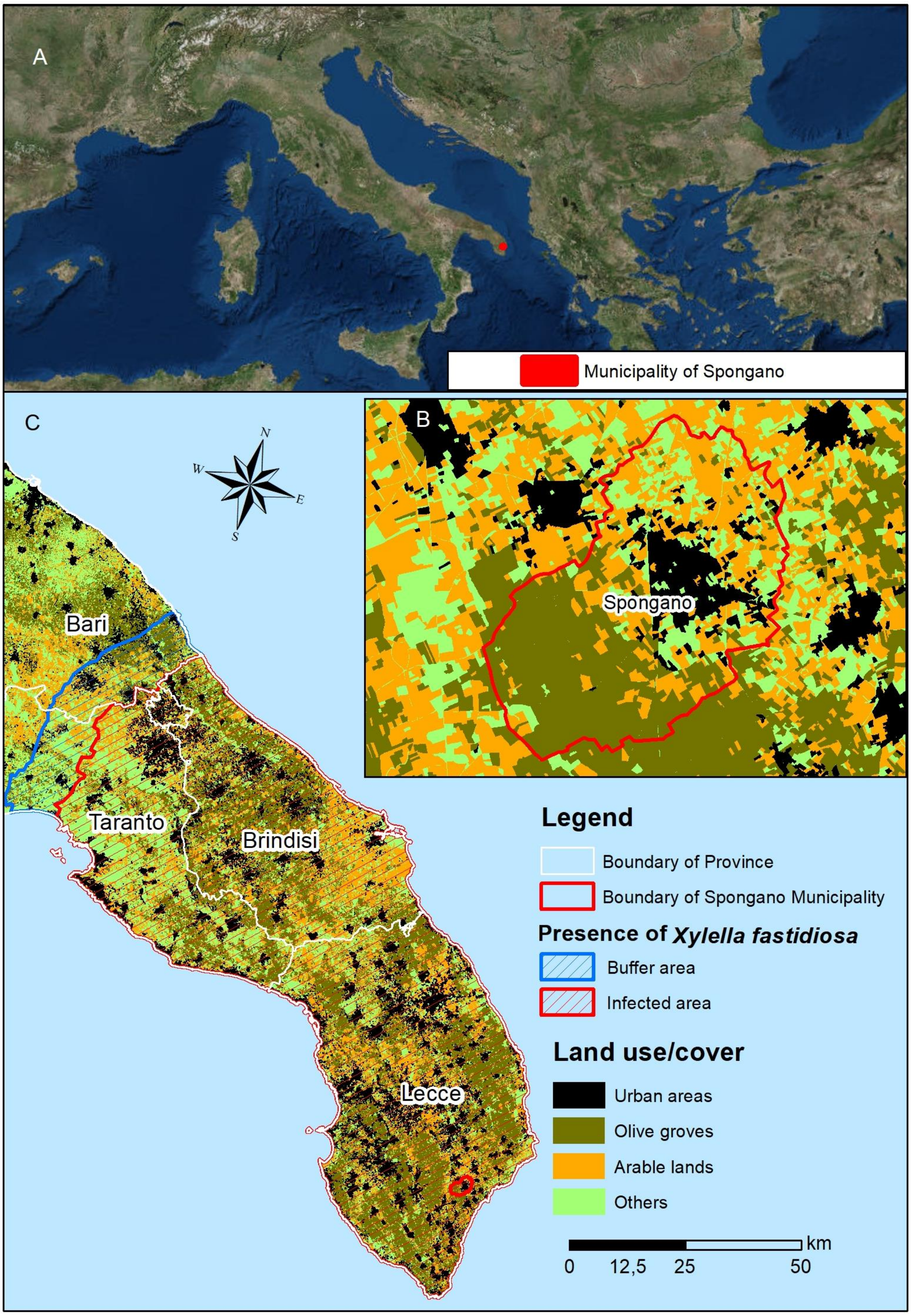

Figure 1. (**A**) Location of Spongano; (**B**) main land-use classes of the peninsula of Salento and Spongano in the year 2006 (www.sitpuglia.it); (**C**) zones bounded by the *Xylella fastidiosa* emergency for the years 2017/2018 [39].

2.2. Methods

In the first step of the analysis, we have digitized in QGIS the land-use maps for the years 1988 and 2016, interpreting and converting orthophotos to vector digital data. The year 1988 has been selected because it is the year that is closest to the approval date of the urban plan of Spongano. The year 1988 represents the year zero in our analysis.

The vector digital map of the land use of Apulia region for the year 2006 was used as a starting map for compiling land-use maps for the years 2016 and 1988. The map of 2006 was downloaded in shapefile format from the official Territorial Information System (SIT) of the Apulia region [39]. The 2016 land-use map was obtained by updating the land-use map of 2006 using the aerial ortho-photos for the year 2016 with 25 cm spatial resolution. The orthophoto is an official regional data available on the SIT of Apulia region [39]. The topological consistency of polygonal coverage in the map was verified and validated through field surveys. After that, the land-use map for 1988 was obtained by modifying the land-use map of 2016 by using the aerial orthophotos with one meter of resolution for the year 1988, which were available in the national geoportal [40]. In particular, we have redrawn in the map only the perimeters of the areas that were changed from 1988 to 2016, while the unchanged areas have maintained the same perimeter of the 2016 map. This procedure allows the overlap of the maps, avoiding the detection of non-existent changes due to the misregistration between the orthophotos, which in this case is about 3.76 m, with a standard deviation of 0.19 m [21–23,41].

Each designed polygon has been assigned to a class in the classification scheme, and some properties have been calculated, such as its area or its total perimeter. The land-use classification assumes that the identified environmental units are characterized by ecological systems that can be considered homogeneous within the boundaries of each individual environmental unit [42]. In order to realize the land-use maps, we based on the CORINE Land Cover (CLC) project classification [43], because this is the classification is used by the Apulia region for the realization of the cartography of the land use for 2006. This classification has remained unchanged throughout the years considered in the study. This aspect is important, because the differences in the landscape components over time must be due to a transition from a land use and not a different nomenclature of the same landscape element due to different classification systems.

After the completion of the 1988 and 2016 land-use maps, we simplified the classification scheme in order to make the interpretation of results easier. In particular, some urban areas have been incorporated into a single class called artificial surfaces, so in the end, a mixed classification scheme was chosen between the first and the third level of the CLC [44] (Table 1).

Table 1. Classification scheme used for land-use classes. CLC: CORINE Land Cover project.

Level	CLC	Classes
1	1	Artificial surfaces
3	1.2.2	Rail networks and associated land
3	1.2.2	Road networks and associated land
3	1.3.1	Mineral extraction sites
3	1.3.2	Dump sites
3	1.3.3	Construction sites
3	1.4.1	Green urban areas
3	2.1.1	Non-irrigated arable lands
3	2.2.3	Olive groves
2	2.4	Heterogeneous agricultural areas
2	3.1	Forest
2	3.2	Shrub and/or herbaceous vegetation associations
3	5.1.2	Water bodies
		Photovoltaic system

In the second step, a change detection (CD) analysis was carried out using the land-use maps of 1988 and 2016 (Figure 2). A space–time composite [45] was created to identify the locations of land-use changes, and also the direction and magnitude of these changes.

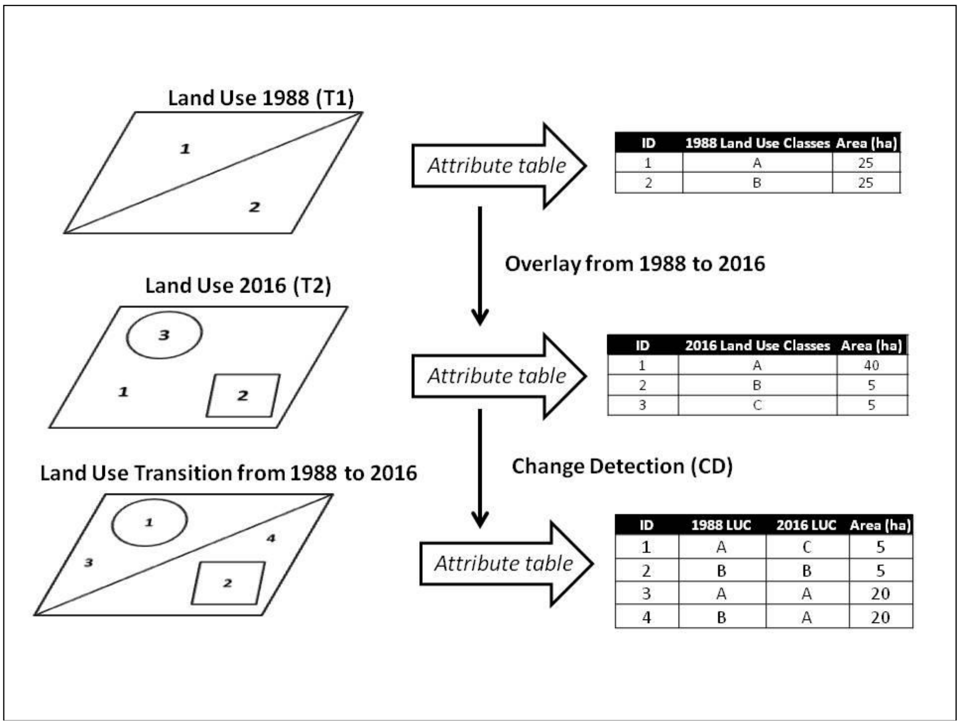

Figure 2. Representative diagram of the change detection (CD).

A transition matrix (Table 2) was obtained showing the changes in the landscape mosaic by contrasting the surface of land-cover types of the map at time T_1 (rows), and those of the map at time T_2 (columns). The totals per row and per column indicate the surface of each land-cover type at the time T_1 and at the time T_2, respectively. The main diagonal line refers to the surface of land-cover types remaining unchanged during the time window considered.

Table 2. A transition matrix based on the example of a CD reported in Figure 2.

		Land Use 2016			**Total Value**
		A	**B**	**C**	
Land use 1988	**A**	**20**	0	5	25
	B	20	**5**	0	25
	C	0	0	**0**	0
Total value		40	5	5	50

The urban development of a municipality is regulated by an urban plan that divides the municipal area into areas with different land uses. The urban plan of Spongano has been in force since 1980, and is available only in paper format. For this reason, the third step of the work has been scanning the maps of the urban plan, the georeferencing using the orthophoto of 2006 as a reference base, and the digitization of the urban plan of Spongano. In this case, to avoid the misregistration between the maps, the map of the urban plan was created by aggregating the polygonal elements of the land use of 2016, on the basis of the urban land use (e.g., residential areas, agricultural areas, etc.). To verify whether urbanization occurred as expected from the municipal planning, the urban areas mapped in 2016 and 1988 have been intersected with the residential expansion zones and the agricultural areas identified by the Urban Plan of Spongano. In addition, we analyzed official census data from ISTAT (the National Institute of Statistics) regarding the number of residents living in Spongano from 1861 to 2017, and the number of houses in 2011 to verify whether the increase of population can be a driving force that has shaped the urban areas over time. This has been fundamental to evaluate the coherence between the urban expansion with the municipal urban plan. From the comparison between the map that identifies the areas in which a land-use transition has taken place and the municipal plan for the expansion of urban areas, it is possible to evaluate the effectiveness of municipal planning in driving urban expansion.

A specific field survey was carried out in 2018 in order to evaluate the vegetative and productive status of the olive groves class, due to the *X. fastidiosa* outbreak in 2013. Thus, data about analytical tests retrieved from an institutional database (www.emergenzaxylella.it) were integrated with a 16-spot survey in the olive grove area, selecting random geographic positions in which disease symptoms were assessed (10 plants per spot) [46]. Symptoms that were mainly related to leaf scorching and wilting of the canopy were assessed by visual inspection, estimating disease severity. The presence of symptoms was recorded and scored using the following severity scale: 0 = symptomless; 1 = leaf scorching on few branches or few desiccated branches affecting the portion of the canopy; 2 = leaf scorching on several branches or desiccation affecting a large part of the portion of the canopy; and 3 = canopy with desiccated branches uniformly distributed [46].

3. Results

3.1. Land-Use Description

We have identified the main land-use classes of Spongano for the years 1988 and 2016 and their extent and the percentage changed from 1988 to 2016 (Table 3). In 1988, agricultural areas (non-irrigated arable lands, olive groves, and heterogeneous agricultural areas) occupy over 68% of the total surface considered. Olive grove is the most extensive land-use class, covering 34% of the total municipal area. The natural vegetation occupies a limited area of about 237 ha (19% of the total municipal area), and it consists mainly of shrub and/or herbaceous vegetation associations. Artificial surfaces have an extent of 4.5 ha.

In 2016, non-irrigated arable lands, olive groves, and heterogeneous agricultural areas cover 59% of the total area; in particular, olive groves remain the dominant class, with 36%. The land-cover class covering shrub and/or herbaceous vegetation associations has an extent of about 253 ha, while the artificial surface class covers an area of 117.36 ha. In 2016, the water bodies and photovoltaic systems classes were identified, constituting two new elements in the landscape that were not present in 1988.

Table 3. Extent of land-use classes and percentage changed from 1988 to 2016.

Classes	1988 (ha)	1988 (%)	2016 (ha)	2016 (%)	Percentage Changed (%)
Artificial surfaces	56.1	4.5%	117.136	9.5%	Over 100%
Rail networks and associated land	4.0	0.3%	4.0427	0.3%	1
Road networks and associated land	31.0	2.5%	39.0	3.2%	27
Mineral extraction sites	0.2	0.001%	0.6	0.0%	Over 100%
Dump sites	1.5	0.1%	2.6	0.2%	77
Construction sites	37.5	3.0%	34.0	2.7%	−9
Green urban areas	20.4	1.6%	50.2	4.1%	Over 100%
Non-irrigated arable lands	290.8	23.5%	184.5	14.9%	−36
Olive groves	426.1	34.4%	450.5	36.4%	6
Heterogeneous agricultural areas	133.1	10.8%	95.3	7.7%	−28
Forest	0.9	0.1%	0.9	0.1%	0
Shrub and/or herbaceous vegetation associations	236.7	19.1%	252.7	20.4%	7
Water bodies	0	0.0%	0.1	0.0%	new class
Photovoltaic systems	0	0.0%	6.0	0.5%	new class

3.2. Land-Use Change

The land-use change from 1988 to 2016 is shown in Figure 3. The total extent of the changed areas is 328 ha, which corresponds to 27% of the total municipal area. These changes are located in the northeast of Spongano, in the agricultural area mainly concerned with non-irrigated arable lands.

Examining the transition matrix (Table 4), the main transition of land use is characterized by the change of 76 ha from non-irrigated arable lands to shrub and/or herbaceous vegetation associations; this conversion is probably due to the abandonment of agricultural lands. The second big land-use transition is characterized by 23 ha from non-irrigated arable lands to olive groves. The surface losses by non-irrigated arable lands are partly offset by a conversion of some parcels of shrub and/or herbaceous vegetation associations and heterogeneous agricultural areas into non-irrigated arable lands. Considering the area gained and lost for each land-use class (Figure 4), the land-use class non-irrigated arable lands showed a negative balance, while the classes shrub and/or herbaceous vegetation associations and olive groves have a positive balance. The heterogeneous agricultural areas land-use class has a negative balance. The main losses of heterogeneous agricultural areas occurred with the following classes: green urban areas with 17 ha; artificial surfaces with 13 ha; non-irrigated arable lands with 13 ha, and the shrub and/or herbaceous vegetation associations class with 14 ha.

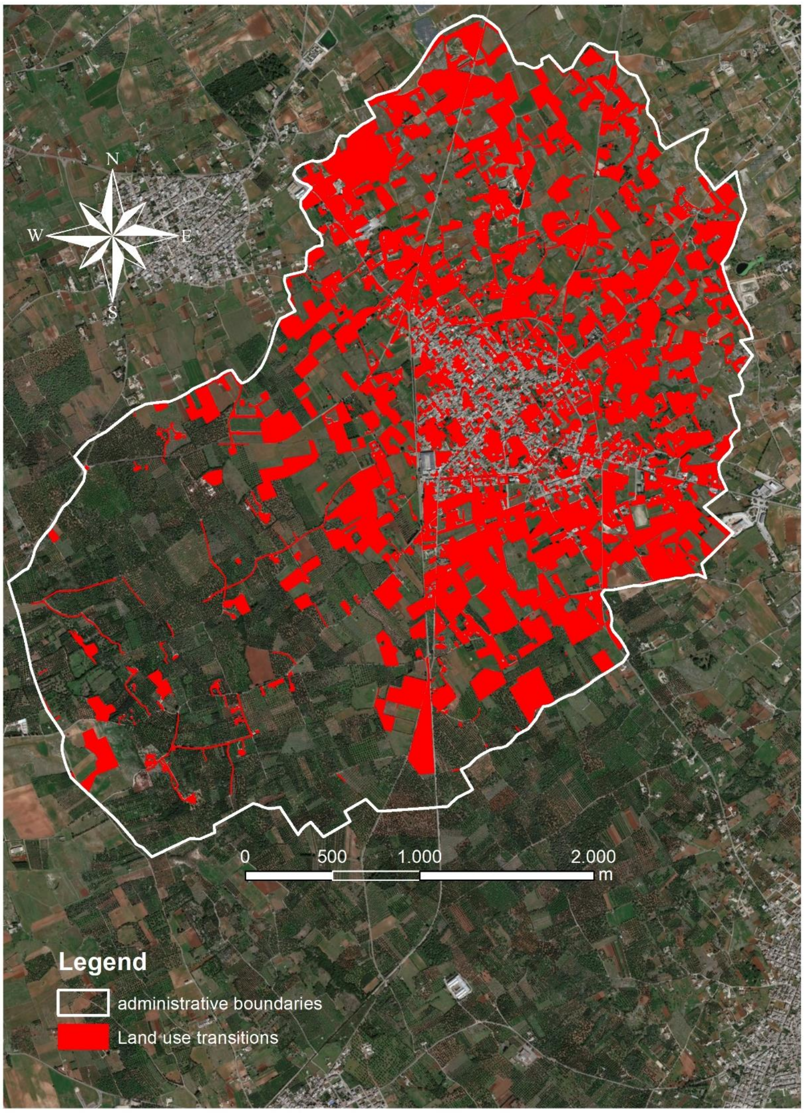

Figure 3. Spatial representation of the change detection analysis.

The gain registered by the artificial surfaces class is interesting, because it doubled its extension from 1998 to 2016. This change involved mainly the transition of about 20 ha from shrub and/or herbaceous vegetation associations; 13 ha from heterogeneous agricultural areas; 8 ha from non-irrigated arable lands, and 7.1 ha from green urban areas. While the 10 ha concerning the class construction sites are areas that were already in transformation in 1988 and that have been brought to completion.

The photovoltaic systems class was absent in 1988, while it is characterized by an area of 6 ha in 2016. It has gained about 1.3 ha from non-irrigated arable lands and 4.7 ha from shrub and/or herbaceous vegetation associations.

About 413 ha of olive groves, comprising about 33% of the total surface area of Spongano, did not change during the period under investigation. They represent a big and a continuous olive grove located in the southeast of Spongano. From the field survey, it emerged that this large olive grove is an important element of the cultural landscape of Spongano, because it is characterized by a large number of monumental plants (regional law 14/2007) (Figures 5 and 6). However, as visible in Figure 6, most of the plants have the symptoms of desiccation caused by *Xyella fastidiosa*, estimating a disease severity of level 2.

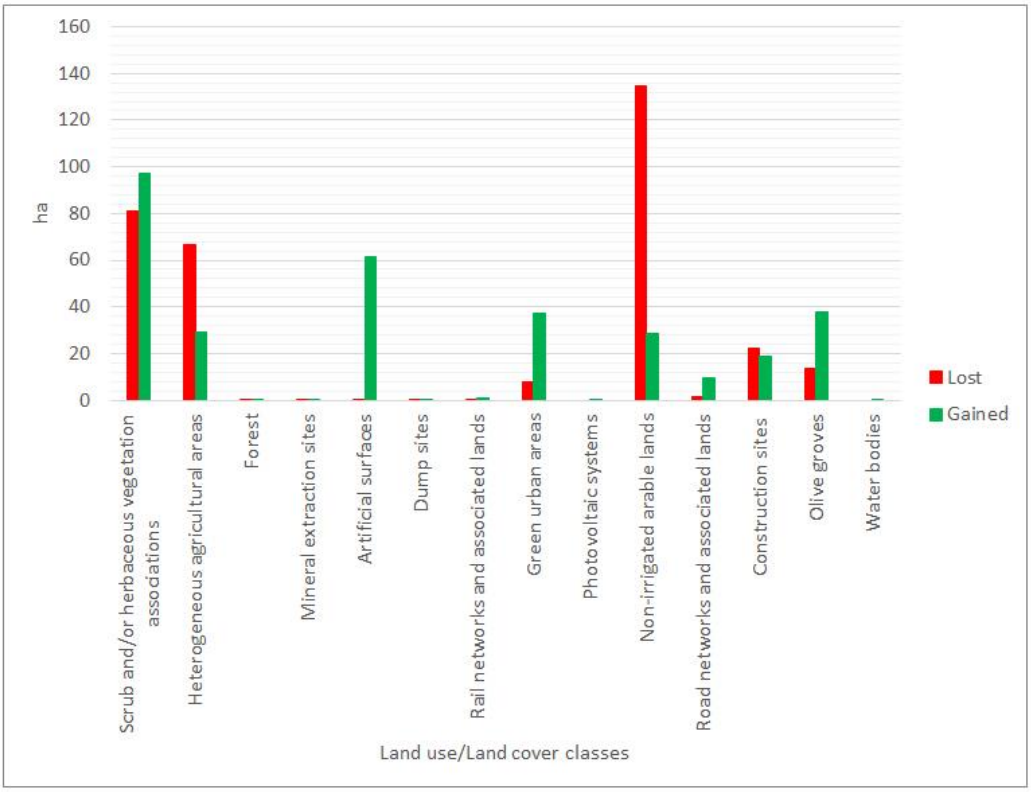

Figure 4. Graphical comparison between gains and losses of surface for each land-use class.

Table 4. Transition matrix that quantitatively and qualitatively describes the transitions between land-use classes.

		Land Use/Land Cover 2016 (ha)														
	Classes	**Artificial Surfaces**	**Construction Sites**	**Dump Sites**	**Forest**	**Green Urban Areas**	**Heterogeneous Agricultural Areas**	**Mineral Extraction Sites**	**Non-Irrigated Arable Lands**	**Olive Groves**	**Photovoltaic Systems**	**Rail Networks and Associated Lands**	**Road Networks and Associated Lands**	**Shrub and/or Herbaceous Vegetation Associations**	**Water Bodies**	**Total 1998**
Land use/Land cover 1998 (ha)	Artificial surfaces	55.5	0.1	-	-	0.1	0.0	-	0.1	0.0	-	-	0.2	0.0	-	56
	Construction sites	10.4	15.0	0.5	-	1.0	2.6	-	0.2	0.4	-	-	5.9	1.5	-	37
	Dump sites	0.0	-	1.5	-	-	-	-	-	-	-	-	-	-	-	1
	Forest	0.0	0.0	-	0.9	-	-	-	-	-	-	-	-	-	-	1
	Green urban areas	7.1	0.1	-	0.0	12.8	0.0	-	-	0.2	-	0.1	0.0	0.1	-	20
	Heterogeneous agricultural areas	13.1	2.6	-	-	17.2	66.4	-	13.3	6.0	-	-	0.1	14.4	-	133
	Mineral extraction sites	0.0	-	-	-	0.0	-	0.1	-	-	-	-	-	0.1	-	0.2
	Non-irrigated arable lands	7.8	4.1	-	-	7.3	14.8	0.0	155.8	**23.4**	1.3	-	0.2	**75.6**	0.0	290
	Olive groves	2.8	2.5	-	-	0.6	1.8	-	0.5	412.5	-	-	0.1	5.4	-	426
	Photovoltaic systems	-	-	-	-	-	-	-	-	-	0.0	-	-	-	-	0
	Rail networks and associated lands	0.0	0.0	-	-	0.0	-	-	-	-	-	4.0	0.0	-	-	4
	Road networks and associated lands	0.7	0.6	-	-	0.0	-	-	0.0	-	-	-	29.6	0.0	-	31
	Shrub and/or herbaceous vegetation associations	19.5	8.8	0.7	-	11.0	9.7	0.4	14.6	8.1	4.7	-	3.4	155.7	0.1	237
	Water bodies	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0	0
	Total 2016	117	34	3	1	50	95	1	185	451	6	4	39	253	0	1238

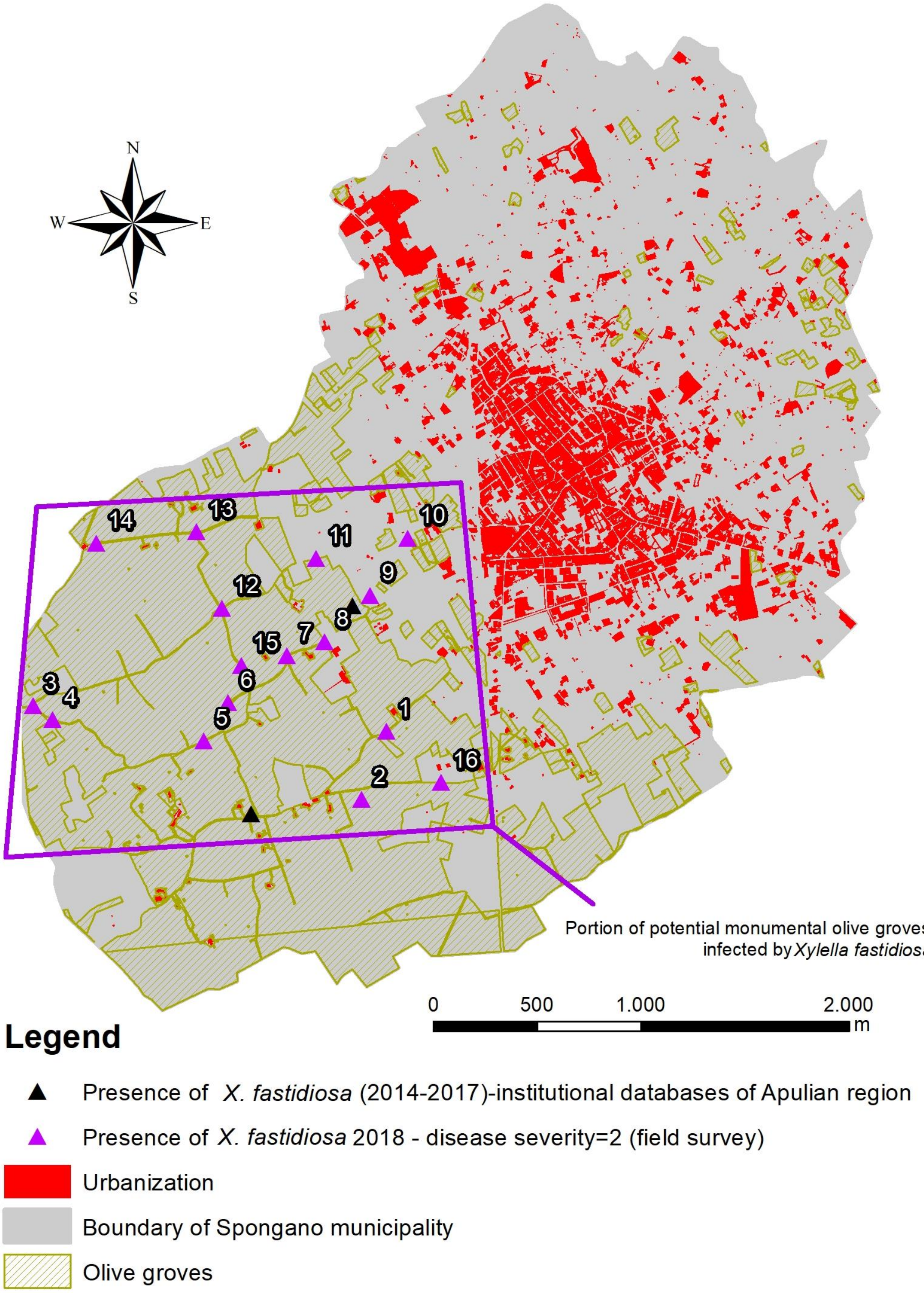

Figure 5. Presence of the olive quick decline syndrome, mixing the institutional database and field surveys.

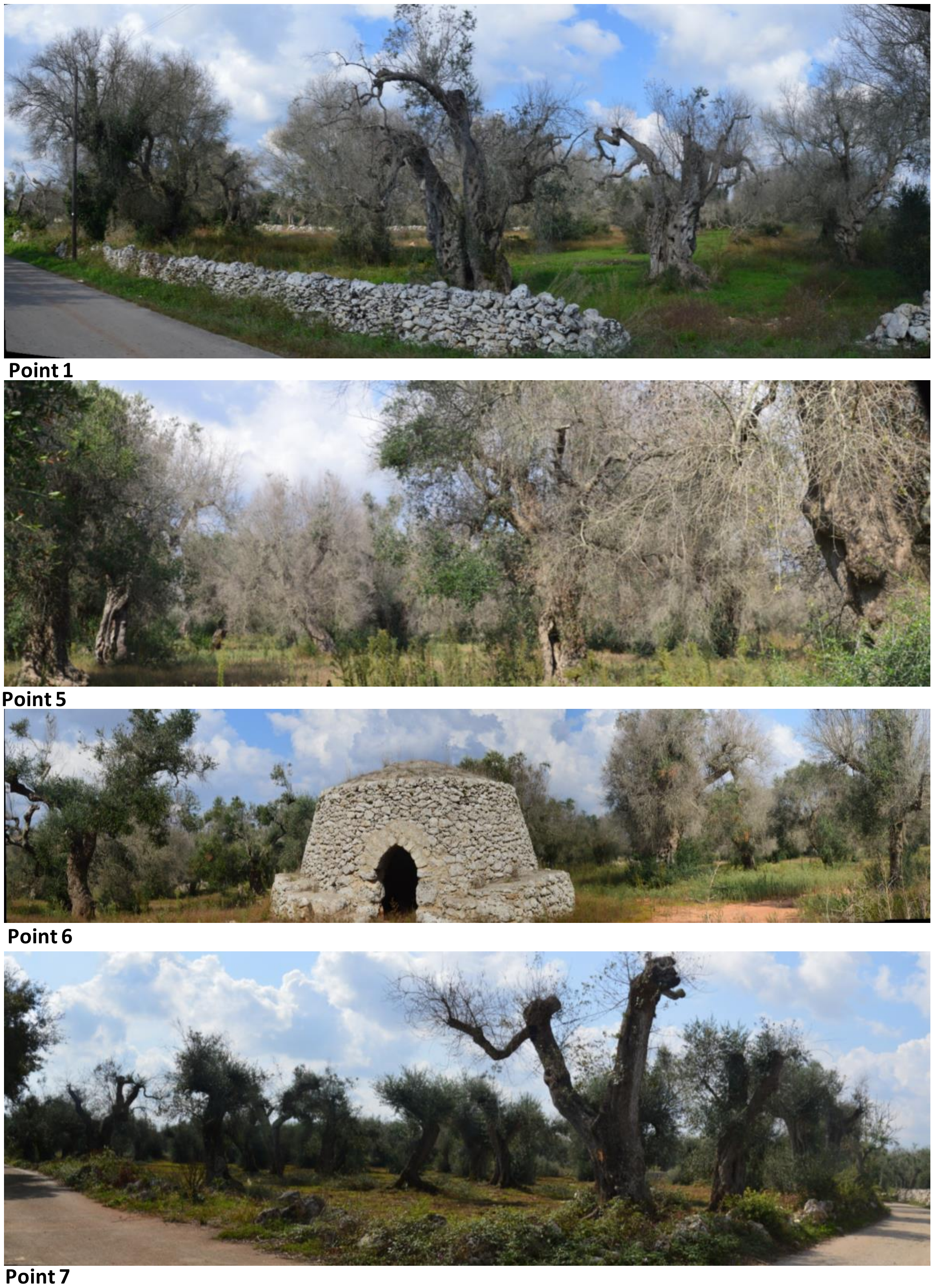

Figure 6. Landscape view of the olive grove affected by olive quick decline syndrome.

3.3. Spongano Urban Plan

The urban plan (Figure 7) shows the municipal areas with different urban land uses. In particular, the zoned areas C are those destined to the expansion of new residences. In the agricultural areas, a limited use is foreseen for the realization of warehouses.

The urban plan provides an expansion of the urban core and a decentralization of a limited number of warehouses in order to support the development of agricultural activities.

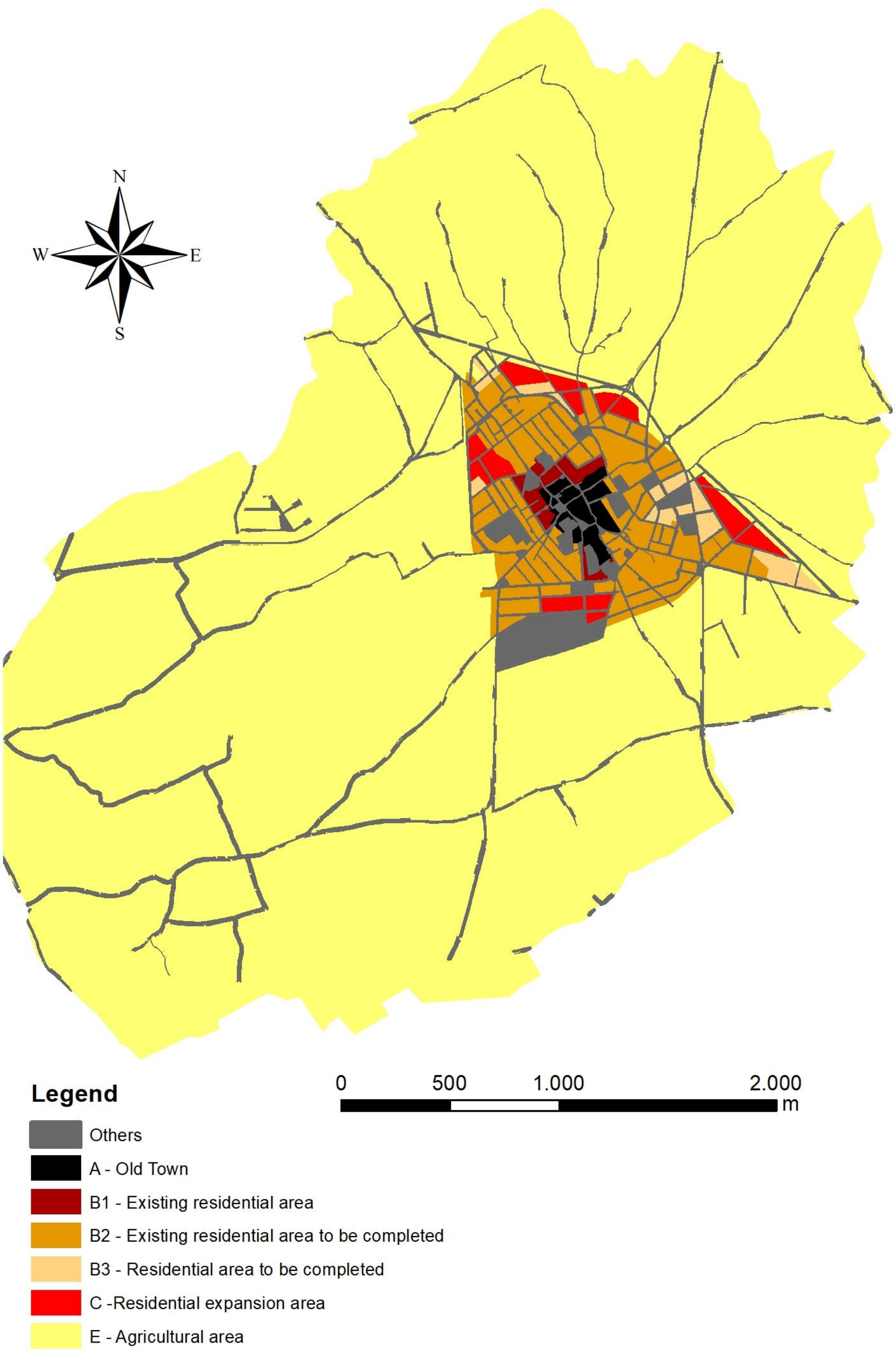

Figure 7. Urban plan of Spongano.

The analysis shows how the urban areas of Spongano have had a considerable expansion from 1988 to 2016. In particular, Figure 8 shows how urban expansion has strongly affected the agricultural areas, while the residential expansion zones have remained partly unused for urban development (Figure 9). It is interesting to observe that the perimeter of the residential expansion areas cut the fields without using criteria or structural elements of the landscape, for example, roads, fences, etc.

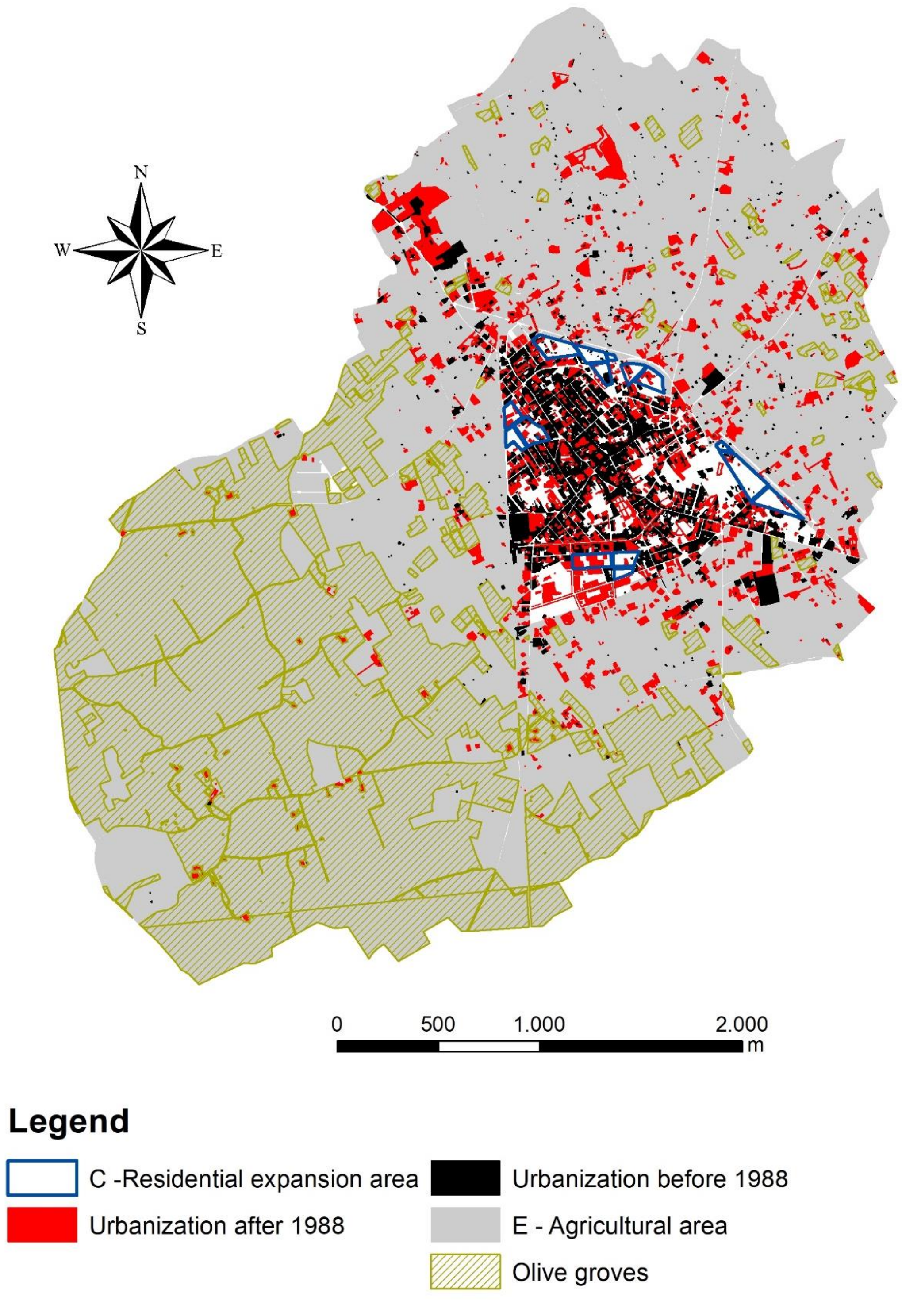

Figure 8. Comparison between the urban development of Spongano from 1988 to 2016 and the urban plan.

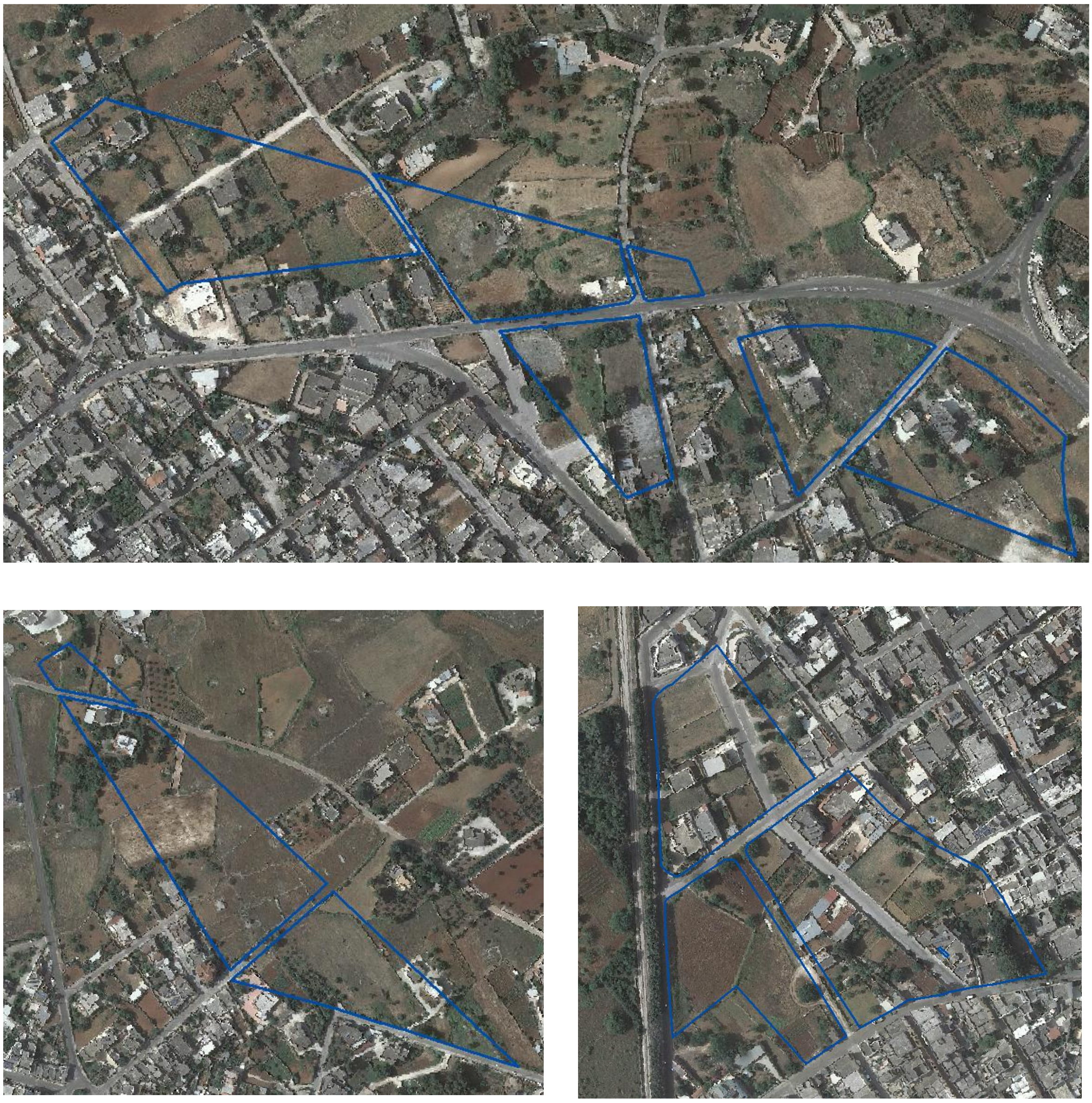

Figure 9. Overlapping of the areas indicated in the urban plan as C: residential expansion areas, with the orthophoto of 2016.

Concerning the number of residents living in Spongano from 1861 to 2017, it remains almost constant in the interval time analyzed, settling at around 3869 inhabitants (Figure 10).

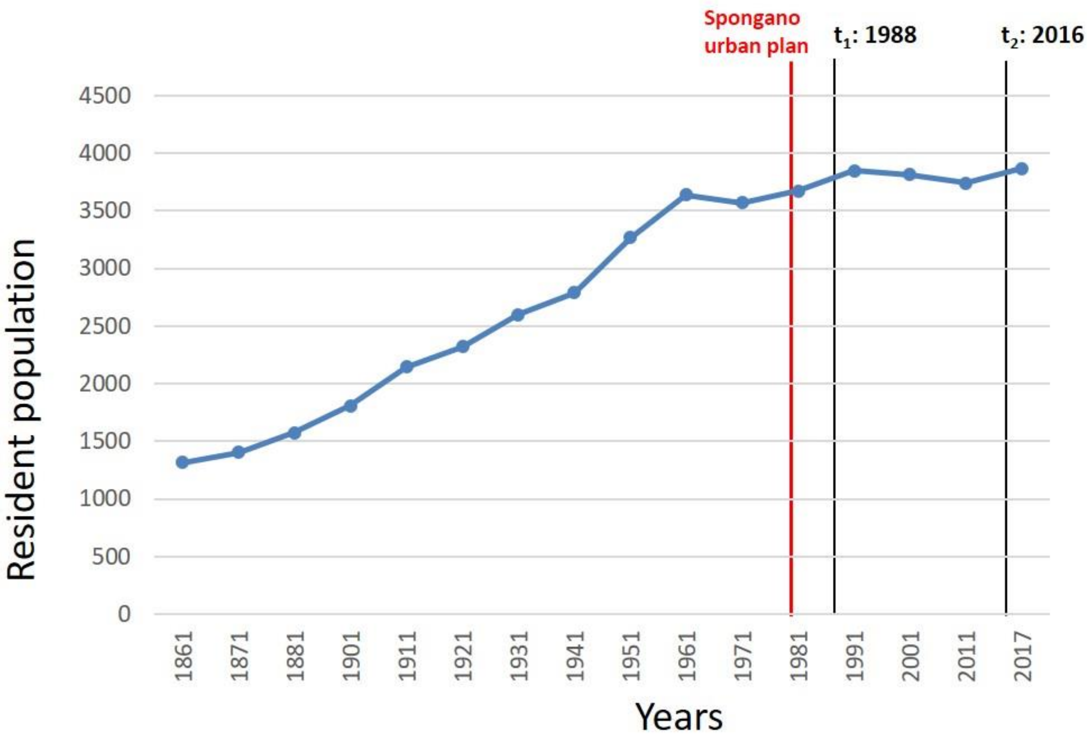

Figure 10. Demographic trend of the population of Spongano.

4. Discussion

Past and Future Role of Olive Groves

Olive groves represent an important structural element in the landscape pattern of Spongano, covering about 1/3 of the area. This highlights the major role of olive oil production in the area and the dimension of *X. fastidiosa* threat to the local economy and landscape preservation. However, the land-use/land-cover changes observed in Spongano for olive groves and other classes can be traced to territorial policies conducted at different administrative levels. For example, the transition from non-irrigated arable lands to olive groves was pushed by the policy of decoupling of direct payments, which drove to extensive production (economic aids are linked to land assigned to cultivation, not to production). However, the increased surface of orchards that was observed in 2016 cannot be considered positive due to the dramatic phytosanitary condition of the area. The data retrieved in institutional databases confirm the presence of the pathogen in two different sites, while field surveys indicate a severe symptomatic status (level 2) in all checked plants (Figures 5 and 6). These observations in orchards of Spongano, as well as similar health status in neighboring municipalities, suggest a completely compromised agroecosystems, which is causing a de facto transition from olive groves to shrub and/or herbaceous vegetation associations or non-irrigated arable lands. In fact, the assessment of symptoms carried out in the field survey indicated the well-established status of the pathogen, the presence of which in Salento is considered as not eradicable [47]. This evidence and its correlation to the epidemiology of the bacteria—which is scattered by a common insect vector such as *Philaenus spumarius* from infected plants to novel hosts—suggests that the olive groves areas in Spongano had reached a high level of risk, in which the productivity and survival of trees is compromised. Another example of the effect of territorial policies is the introduction of photovoltaic systems in the landscape pattern. This change was pushed by international (2001/77/CE) and national (D.Lgs. 387/2003) policies, as well as tax breaks (D.M. 19/02/2007) and regional policies (L.R. 31/2008). This has produced competition for the use of land between agriculture and renewable energy production [32].

Urban areas of Spongano have had a considerable expansion from 1988 to 2016, affecting the agricultural areas such as the heterogeneous agricultural areas class, non-irrigated arable lands class, and shrub and/or herbaceous vegetation associations class. All of these classes are located in areas defined as agricultural areas in the Spongano urban plan (Figure 8). On the other hand, the residential expansion zones have remained partly unused for urban development (Figure 9). This urban expansion is not justified by a need for new residences for the population, which has remained almost constant in recent years (Figure 10), and this may suggest that the building construction in agricultural areas may be due to the development of summer houses or houses for holidays. Furthermore, according to the 2011 census data, there are 1427 houses inhabited by residents, compared to 1773 houses registered. Thus, it can be assumed that 20% of the buildings that are classified as residences are not used, and could even be abandoned. This percentage may have also grown over the years. Unfortunately, it was not possible to register the abandoned buildings, but we can assume that Spongano is undergoing a double phenomenon of urbanization; on the one hand, there is urban expansion toward the countryside, while on the other hand, there is an abandonment of parts of the city in which there are no economic or social advantages to exploit.

The transformation of agricultural areas into urban areas with low density or isolated residences may be due to a municipality urban plan that is not able to regulate the relationship between urban areas and agricultural areas. Although the plan clearly demarcates agricultural areas from newly expanding urban areas, it is not effective in limiting urban spillage into agricultural areas. Probably one of the critical points of the urban plan is the minimum size that is required to create a new building in an agricultural area that is 0.5 ha. Therefore, the analysis highlights the inconsistency between what was planned by the urban plan and how the landscape of Spongano has been changed over time, highlighting how landscape and urban planning can be ineffective, if not adequately realized considering the territorial needs. This creates problems of a practical nature in the governance of the landscape, because there are urban areas that are currently planned and legally bound that are no longer suitable for fulfilling the role for which they were intended, thus creating holes in the planned landscape.

Fortunately, until now, the olive grove seems to have limited the spread of residences in the agricultural area. In addition, the portion of Spongano occupied by olives groves has been only slightly affected by land-use transition or urban land uses, keeping the landscape unchanged (Figure 8). Furthermore, many olive trees are secular plants with a high cultural value recognized and protected by the regional law of Apulian Regional law 14/2007. Olive groves have a big role in reducing changes in the landscape, mainly land-use transition in artificial surfaces. Unfortunately, the olives trees have been affected by the bacterium of the *X. fastidiosa* that produces the desiccation and death of infected plants, even if some resistant cultivars were identified [48,49]. However, sensitive cultivars are the most spread in the area. Thus, the whole Salento area was classified as infected by the bacteria, and most of the orchards are threatened, unless a solution for this problem will be found. This dramatic situation also involves Spongano, in which productive orchards are decaying. The analysis of the vegetative and productive status of the "olive groves" was carried out with field surveys, which showed the diseases and damages that characterize the monumental olive groves. The disease causes the withering and desiccation of terminal shoots, producing the collapse and death of the trees. These plants should be eliminated, as they are destroying an important cultural element of the landscape of Spongano. Therefore, the pathogen *Xylella fastidiosa* will introduce a future change in the landscape pattern of Spongano

In particular, from this study, it is possible to highlight that the time scale in which urban or landscape plans are developed is not the same time scale with which ecological processes (e.g., the spread of *Xyella fastidiosa*) or the economic processes (e.g., the spread of residential areas in agricultural areas) drive transformations in the landscape. In social-ecological systems, a hierarchy of institutions can be distinguished [50,51], and they reflect the different levels at which decisions of the landscape plan are taken [52]. Ecological and institutional boundaries seldom coincide [53] (Figure 11). The planning at a different institutional scale influences the evolution of a landscape, because it can alter the relationship between urban land use, agricultural land use, and natural land use. However, the presence of ecosystems of important conservation value (such as the presence of a monumental olive groves) can influence the landscape planning at different institutional scales. The establishment of new conditions and interactions between different ecological and institutional scales can introduce unpredictable and not planned transformations.

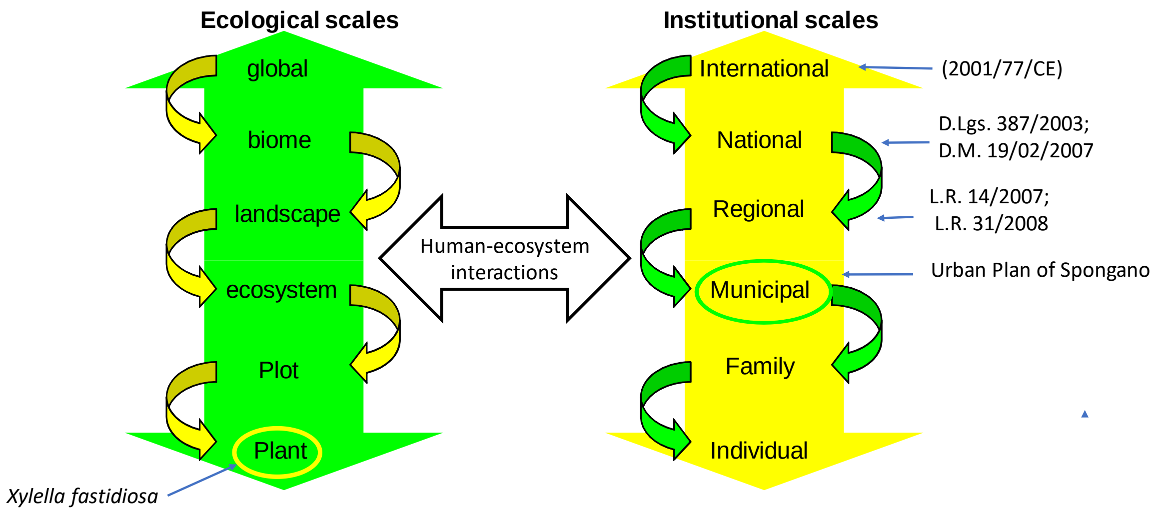

Figure 11. Schematic example of ecological and institutional scales (adapted from [54]).

Spongano represents an interesting case study, which can be considered representative of the whole area effected by *Xylella fastidiosa*, because it allows highlighting how ecological processes such as the spread of the pathogen can be connected with anthropic processes that can lead to the increase of urbanization in the presence of urban planning that is not adequate to the needs of the territory. The spread of the bacterium is of interest throughout the region. The olive groves of Spongano have been impacted and will likely change, with resulting social, economic, and ecological effects. It will probably be impossible to eradicate the *X. fastidiosa* from the Salento Peninsula. It is necessary to consider that the host range of the sequence type ST53, the one found in Salento, includes several other species, including other trees (such as *Laurus nobilis*, *Prunus avium*, *P. dulcis)* and shrubs (such as *Acacia saligna*, *Asparagus acutifolius*, *Catharanthus roseus*, *Cistus creticus*, *Dodonaea viscosa purpurea*, *Euphorbia terracina*, *Grevillea juniperina*, *Lavandula angustifolia*, *Myoporum insulare*, *Myrtus communis*, *Nerium oleander*, *Polygala myrtifolia*, *Rhamnus alaternus*, *Rosmarinus officinalis*, *Spartium junceum*, *Vinca minor*, *Westringia fruticosa*, and *W. glabra*). However, due to novel host finding in the last years, the effective host range of ST53 may be larger. Furthermore, *X. fastidiosa* host shifts are predictable, while the adaptation of the pathogen to new hosts that include mutations, whether homologous or not homologous gene flow, are reported [36]. This suggests a severe situation in the years to come, and a potential further shift in the composition of classes not only in Spongano, but also in other affected areas.

Therefore, considering the adaptive cycle in social-ecological systems [55], the presence of *Xylella fastidiosa* can be considered like a "revolt" process that has affected the "monumental olive groves", making it pass from a "conservation (K)" phase in the adaptive cycle, into a collapse or release (Ω) phase (Figure 12). Naturally, the system will jump into a new adaptive cycle, with new environmental, social, and economic characteristics, because the growth or exploitation (r) phase that has developed the monumental olive groves will no longer be reproducible, especially in the short term [56,57]. Therefore, the system will undergo a reorganization (α) phase that creates situations for innovation that will be conditioned by economic and social processes, and planning in this case plays a crucial role in determining the new pattern of the landscape [55].

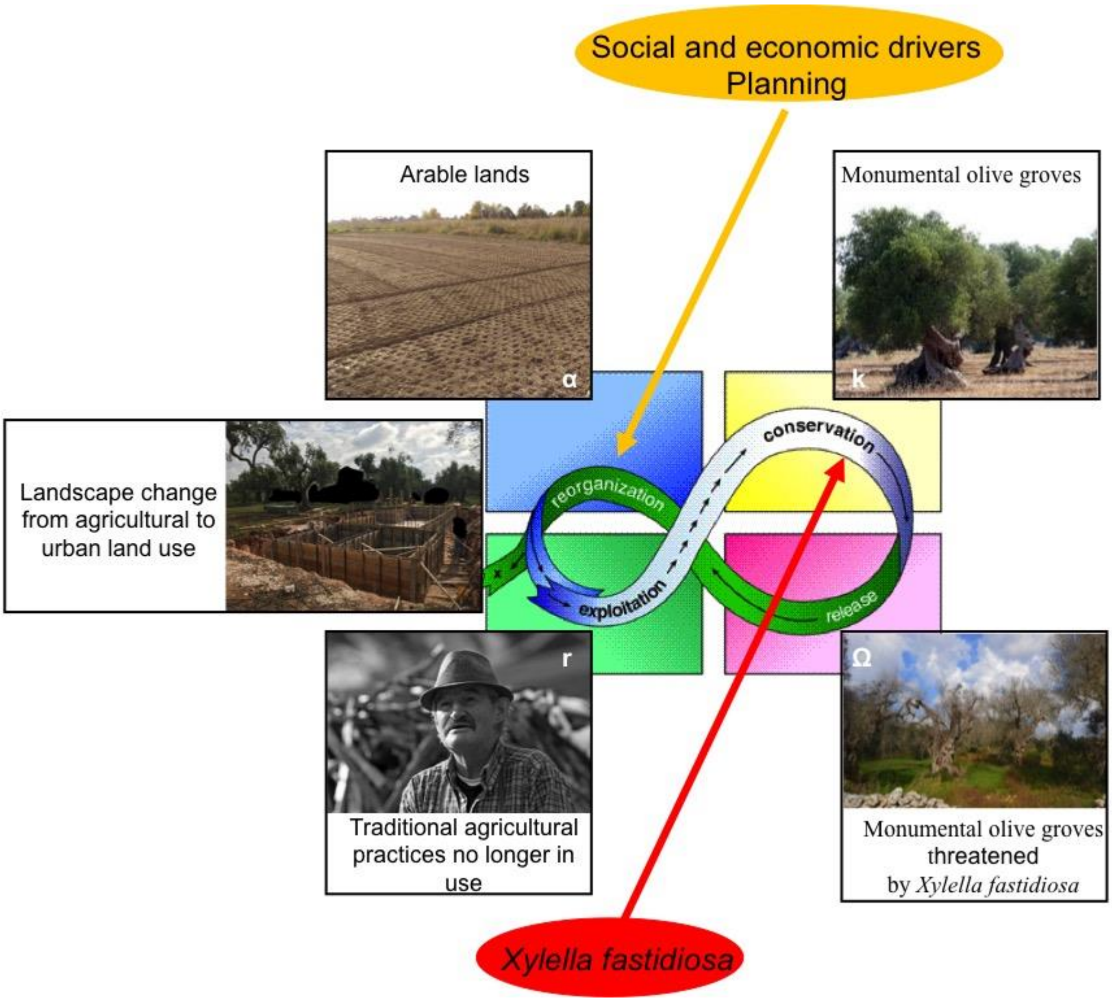

Figure 12. Adaptive cycle in monumental olive groves infected by *Xylella fastidiosa.*

In the case of the municipality of Spongano, where the urban plan is not effective in limiting the change from the use of agricultural land to urban land use, *X. fastidiosa* will produce new spaces where urbanization could be developed. A practical example is represented in Figure 13 that shows centuries-old olive groves infected with the bacterium of the *X. fastidiosa* with a sign for the sale of the agricultural area. This area, if sold, could be transformed, for example, by planting new young olive trees that are resistant to *X. fastidiosa*, or changing the crop (if allowed throughout legal disposal) and, therefore, obviously changing the landscape pattern.

In the future, it is possible that the agricultural area occupied by monumental olive groves affected by *Xylella fastidiosa* will lose its protection status guaranteed by the regional law 14/2007. In addition, a spatial and temporal comparison of the land registry of the property subdivision of 2018 with those of 1911 shows that in recent years, the fragmentation of property has increased strongly (Figure 14). This situation also impedes the management of olive groves affected by *X. fastidiosa*, because multiple notifications for uprooting are requested, and properties of plants are not always clearly defined. The presence of small owners that do not have an agricultural income would imply little interest in investing money in requalifying the infected olive groves in productive terms. This could lead, over time, to a risk of developing new residences in areas that are now protected by the presence of the monumental olive grove.

In the future, it will be necessary to develop territorial governance actions or policies that will have to be combined with the different needs of the many stakeholders of the territory, or, worse, with the limited interest of the stakeholders in investing economic resources and time in the landscape.

Figure 13. Example of centuries-old olive grove infected with the bacterium of the *Xylella fastidiosa* with a sign for the sale of the agricultural area.

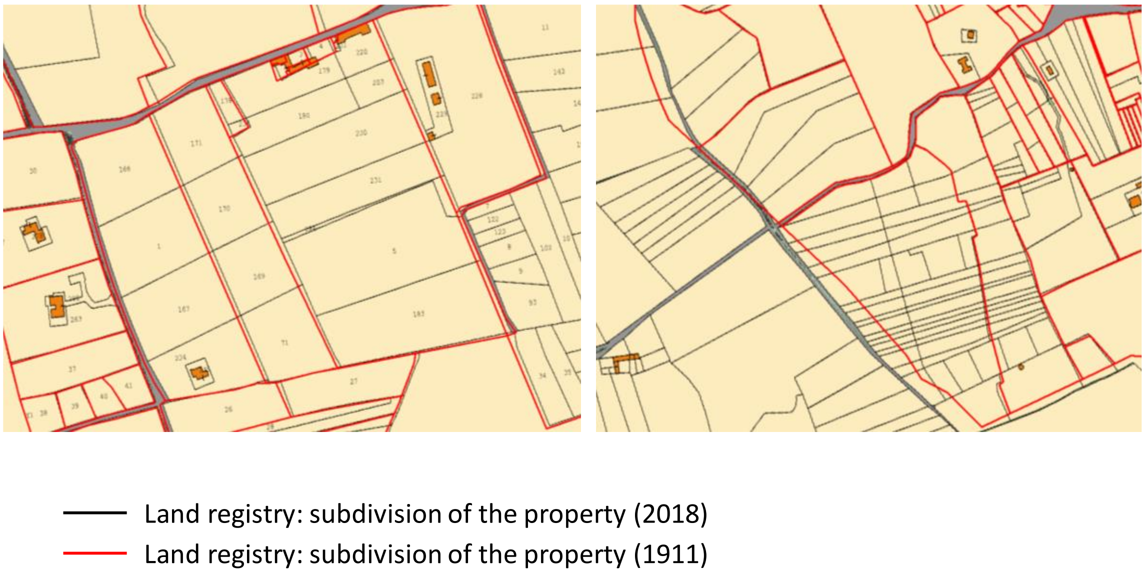

Figure 14. Comparison of the land registry from 1911 to 2018.

5. Conclusions

Landscape and urban planning need methodological, procedural, and technical indications that are able to monitor the compatibility of planning tools with the evolution of the landscape driven by social and economic aspects [58,59]. This requires a transdisciplinary approach that goes from plant physiology to urban planning, and is able to identify and correlate the interactions between ecological and anthropic processes and between the different ecological scales and institutional levels, allowing the development of a holistic vision of the evolution of the landscape.

In particular, in the case of the municipality of Spongano, for example, it emerges how the urban planning and agricultural planning of the territory cannot develop as separate elements, but rather must be developed in synergy in order to prevent the transformation of the agricultural landscape into areas urban areas, following new opportunities that may arise over time.

Spongano can be considered as a case study of reference for many other municipalities characterized by old urban plans and monumental olive groves affected by *Xylella fastidiosa* or other ecological diseases. It will probably be impossible to eradicate the *X. fastidiosa* from the area of study and, currently, national and regional political choices and economic efforts have been proposed to eliminate the bacterium, but not to rehabilitate a destroyed cultural landscape. The main actions are aimed at strengthening the agricultural activity affected by the bacterium with replanting of new olive trees, but without considering the social, ecological, and cultural context of reference.

We need a strategic planning, which is not limited to contrasting the *X. fastidiosa* and the simple replacement of the sick plants with new plants, but that is able to encourage the development of new projects and private initiatives of territorial development, which are able to involve the various carriers of interest ranging from individual farmers to simple landowners.

The new urban plan should not be limited to develop simple land-use indexes, but must develop strategies that lead to the development of farms or farmhouses through the unification of funds. It will be necessary to impose the minimum size that is required to create a new building much higher than 0.5 ha. Probably, we could think of an index between three and five ha as the minimum area of a farm that can produce an income that allows the access to public funding, and therefore can attract funding to the territory of Spongano.

Further considerations are related to the widespread of *X. fastidiosa* in agroecosystems other than those located in Salento peninsula. The confirmed the spread in the Mediterranean basin (France, Spain) and the worrisome interceptions in European countries (Germany, Czech Republic, Switzerland) (https://gd.eppo.int/taxon/XYLEFA/distribution), which could lead to drastic changes in European landscapes. This threat could challenge many agroecosystems other than those based on olive trees, because the strains retrieved in other countries are related to subspecies that can infect many cultivated plants as well as forestry or wild herbaceous species, threatening the sustainability of European ecosystems and urban green/forestry.

Therefore, it is necessary to develop an urban plan based on learning by doing in order to shape and adapt the processes of territorial transformation to the unpredictability of the social and economic systems, as well as ensure that these processes are always focused on environmental issues.

In addition, it is necessary to integrate local and regional policies in order to develop policies that discourage the development of residential activities in agricultural areas and encourage the development of farms, which can guarantee positive management of the agricultural area.

Author Contributions: G.M.: conceptualization of the research, realization of the maps for 1988 and 2016, interpretation of the results and writing of the manuscript. T.S.: conceptualization of the research, formal analysis, methodology, development of the change analysis; interpretation of the results and writing of the manuscript. R.A.: conceptualization of the research, methodology, social data analysis; interpretation of results and writing and editing of the manuscript. A.L.: conceptualization of the research, evaluation of olive quick decline symptoms; writing of the paragraph related to the plant disease. L.D.B.: conceptualization of the research, editing of the manuscript.

Funding: This research received no external funding.

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

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