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Integrating Agriculture in Greenways: a Methodology for Planning Connected Urban and Peri-Urban Farmlands in a Mediterranean City

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Introduction and Literature Review

Cities are often threatened by a loss of environmental quality due the rapid increase of urbanized areas that fragment natural landscapes. This is particularly true at the cities' fringe where uncontrolled urbanization is often characterized by discontinuous patterns and consequent fragmentation of farmlands. These phenomena are particularly relevant in Mediterranean cities, where the high degree of land-use transitions, a consequence of urban growth with poor environmental regulations produce urban landscapes characterized by a lack of green areas and high levels of ecological fragmentation (EEA, 2006).

Greenways are one of the most powerful and widespread tools used at urban, metropolitan and regional scales. Their aim is to counteract ecological fragmentation and to integrate urban development, nature conservation and public health promotion (Ahern, 1995; Fabos & Ryan, 2006). They facilitate linkages between rural and urban spaces along the rural-urban interface through linear systems (Walmsley, 2006). As networks of linear elements they are planned, designed and managed for multiple purposes, including the provision of ecosystem services such as purification of air and water, mitigation of floods, climate regulation, generation and renewal of soil fertility, accessibility to open spaces and intellectual stimulation. Urban contexts present particular challenges for greenways development due to the complex arrangement of urban landscape features. The large number and diversity of land-cover types often produce high degrees of fragmentation of open spaces and heterogeneity of their roles and functions. For this reason a number of different types of patches of Non Urbanized Areas (NUAs) are present in urban contexts: this calls for a characterization of these spaces in order to highlight their physical features and their ecological and social functions. Particularly, they could represent a big opportunity for planning policies oriented to support new forms of urban agriculture (La Greca et al., 2011a).

When formulating planning approaches to greenways in urban contexts, new forms of agriculture have been the focus of very few studies and applications but they can significantly contribute to cities' sustainability (Zasada, 2011). Proposing an agricultural greenway that integrates different NUAs into a network of farmlands and other green spaces (parks, playgrounds and so on) could significantly improve the overall accessibility of these areas, redefining the rural-urban interface and enhancing the provision of urban ecosystem services.

Goals and Objectives

This paper presents a method to characterize and connect patches of agricultural land uses via a greenway approach. NUAs located on the urban fringe were analyzed with different parameters and criteria in order to ascertain which forms of agricultural land uses could be addressed and linked with other green spaces nearby through an Agricultural Greenway (AG). The proposed method checks the suitability of transformations of the areas toward new forms of agriculture thereby enhancing their ecological and social function, as well as accessibility and overall connectivity. This proposed method was tested in a concrete urban planning case, the revision of the *Land Use Plan* of the city of Catania, south Italy.

The Study Area and Available Geo-Data Set

Catania is one of the main cities in southern Italy, with an administrative area of 180 km^2 and a population of 293,458. The city is the centre of a large conurbation that represents the largest metropolitan area in Sicily, a settlement system characterized by extensive urban sprawl (La Greca et al. 2011b). The favourable location of the city along the coast, well connected to the motorway and railway system and the presence of a commercial port and busy airport give to the city a strategic role in the region. Existing settlement has developed around the historical center and has grown beyond the city administrative borders, incorporating existing agricultural and fishing villages into one large metropolitan area. The result is a rather heterogeneous aggregate of settlements. Rich and vital urban fragments are intertwined with poor and marginal ones, the latter often corresponding with social housing schemes or illegal settlements. The main city in characterized by a relevant shortage of public spaces and services, especially green space. Currently the amount of public green space is about 3 m^2/ inhabitant much less than the minimum amount stated by the national legislation (9 m^2/inhabitant).

At the end of 2009, the municipality of Catania started a new revision of the city land-use plan, based on the idea of achieving a more sustainable future for the city. This plan addresses several critical issues: the high level of congestion of the mobility system; concentration of residential uses in peripheral neighbourhoods; and, enhancing the number of public spaces especially greenspaces. To a high number of NUAs, located on the fringe of the city, the new zoning plan assigned a status of public green space, using a transfer of development rights program. For these green spaces, the plan defined a set of new land-uses, including urban agriculture. Despite these efforts, most of new public green spaces were planned without considering specific criteria to determine more suitable areas that could become urban agriculture. In order to overcome this limitation, this paper proposes a method to characterize NUAs patches as new forms of agriculture and proposes a design of a greenway of these identified patches.

Method

The proposed Multi Criteria Suitability Model aimed to produce different scenarios of new Prospected Land Uses (PLUs) with a view to new forms of agriculture. The model characterizes the patches of NUAs to obtain different spatial configurations of agricultural land uses with a multi-attribute approach. These criteria are intended as prerequisites such that a single patch of NUA could modify its land-use to become a new form of agricultural space. Criteria were derived by literature review and analysis of physical features of existing fabric of NUAs.
The following new forms of agriculture were prospected:

- Urban Farms. They represent the primary form of urban and multi-functional agriculture (Aubry et al., 2010) and are characterized by the production of fresh products. They clean up the city by recycling waste (Mougeot, 2005), provide landscape and socio-educational functions (Ba and Moustier, 2010) and contribute to urban employment and reduction of

inequalities (Dubbeling et al., 2010). Urban Farms are often conducted according to Community supported agriculture (CSA) model (Wells and Gradwell, 2001) and can have different sizes, starting from a minimum size of 0,8 Ha, and providing fifty shares (2-4 persons) of products per hectare (Van En, 1995).
- Allotment Gardens. They are places for leisure and integration of elder people and socially deprived groups (Rubino, 2007) where gardening is the main activity. The minimum plot area can vary from 50-100 m^2 to 200-400 m^2 (Rubino, 2007). According to NSALG (no date) a single plot of about 250 m^2 can provide food for 4 persons per year.
- Agricultural Parks. They are large farmland areas where productive uses (usually organic farming) are implemented along with rural landscape protection and enjoyment. Sizes can vary from 10 to 10,000 Ha in France (Donadieu, 1998). Other examples include of 7 Ha in the US Sunol AgPark in the US (7 ha) and Parco Agricolo Sud Milano in Italy (46,000 ha).

Each criteria was described by an indicator that calculated in GIS from the available land-use layer, following two main phases.
The **first phase** analyzed the existing fabric of NUAs in order to find a first set of areas to be addressed for new PLUs. This phase considered as main criterion the compatibility of transition from current land-use toward one PLUs. The following cases were observed:
- Farmlands and Abandoned Farmlands were considered always compatible to a transition toward one PLU, as their soil and physical characteristics of these land uses would be conserved in case of transformation.
- Bare soil was considered compatible under the condition of existence of contiguity with an existing farmland. This condition assumes that a bare soil can be transformed into new forms of agriculture if it is geographical contiguous to other agricultural land uses. This would make the transformation more feasible from an economic point of view.
- Woods and Shrubs were considered compatible under the condition of the presence of tree land cover below 20%. This condition assumes that if the amount of existing semi-natural features is below this percentage the single patch might be more susceptible of transformation toward a PLUs, while, on the contrary, for higher percentages it might be more suitable for other forms of green areas (i.e. small urban parks).
- Lava Fields were considered not compatible, because any agricultural land uses would not be appropriate on these types of land.
- Urban Greenspaces were not compatible as transformations would significantly alter the natural or semi-natural characteristics of these lands.
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According to the above criteria, two indicators were used in this phase to check the compatibility of transformation of Bare Soil and Woods and Shrubs patches, respectively Contiguity to Farmlands and Trees Land Cover.

Contiguity to Farmlands (CO_F)
This indicator verifies the existence of contiguity between patches of bare soil to each patch of farmlands. Operationally, the indicator is calculated using a spatial join function of GIS between the layers of bare soil patches and farmlands. A new binary attribute (CO_F) was added to the bare soil layer and calculated as “Y” for patches with contiguity or “N” on the contrary.

Trees Land Cover (TLC)

This indicator evaluates the percentage of land cover comprised by Wood and Shrub patches. Trees Land Covers were manually identified and digitalized by interpreting 2008 available orthophotos. A detailed feature extraction was possible thanks to the high resolution of orthophotos (0.25 meters), enabling the identify of individual trees. TLC was then calculated as the percentage of surface covered by trees and the area of the single patch.

After the calculation of the two indicators, a GIS query identified the first set of suitable NUAs to be addressed with new forms of agriculture and included in the AG according to the proposed criteria.

The **second phase** is aimed at further defining the most suitable NUAs for new forms of agriculture among the areas already selected in the previous phase. PLUs are defined according to criteria of size, accessibility of patches by people, presence of tree land cover and contiguity to farmlands. For each PLU, criteria follow the conditions listed below.

- Agricultural Parks: minimum patch size of 20,000 m^2 to allow productive uses and other functions (landscape protection and leisure). Moreover, contiguity of patches to farmlands was required for ensure economic feasibility and accessibility.
- Urban Farms: size ranking from 5000 to 20,000 m^2 and accessibility of 2,000 inhabitants for 1 ha of land within a pedestrian distance buffer of 500 m. Considering that 1 ha of land can produce food for 200 people - 50 shares of food for 4 persons (Van En, 1995) -, the condition of 2000 inhabitants per hectare would ensure the economic feasibility of Urban Farms, even if only 10% of the population would be interested in purchasing products. Moreover, a minimum percentage of tree land cover is required as an indicator of agricultural productive potential of current Farmlands patches or vegetation features for Woods and Shrubs.
- Allotment Gardens: maximum patch size of 5000 m^2 and accessibility of 100 inhabitants for 1,000 m^2 of land within a pedestrian distance buffer of 250 m. Considering that 1000 m^2 of land can be accessed by 20 people - 1 lot of 50 m^2 for 1 person (NSALG, no date) -, the condition of 100 inhabitants per 1000 m^2 ensure the accessibility to Allotment Gardens because they are mainly oriented to elder people and socially deprived groups. Moreover, the above mentioned criteria of contiguity to farmlands and % of tree land cover are requested.

Table 1 shows all possible transitions between current land uses (farmlands, abandoned farmlands, woods and shrubs, bare soil) and prospected one (urban Farms, allotment gardens, agricultural park),. Each transition is considered to be suitable if each patch presents particular values of indicators. The same table also contains a first indication of indicators’ values for suitable transitions. As an example, in order to be transformed into an Urban Farm, a patch of farmlands must have the following indicators’ values, according to the above discussed criteria: size between 2000 m^2 and 5000 m^2, more than 2000 people in a buffer of 500 m from the patch.

Current Land Uses	Prospected Land Uses	A	PR_Res	CO_F	TLC
F	UF	Min 5000 m^2, max 20000 m^2	Min 2000 inhab. within 500 m buffer for each 1ha of land	/	/
	AG	**Not suitable**			
	AP	min 20000 m^2	/	Yes	/
AB F	UF	Min 5000 m^2, max 20000 m^2	Min 2000 inhab. within 500 m buffer for each 1ha of land		Min 30 %
	AG	max 5000 m^2	Min 100 ab di UF in raggio di 250 m		/
	AP	min 20000 m^2	/	Yes	Min 50%
WS	UF	Min 5000 m^2, max 20000 m^2	Min 2000 inhab. within 500 m buffer for each 1ha of land		/
	AP	**Not suitable**			
	AG	max 5000 m^2	Min 100 ab di UF in raggio di 250 m		/
BS	UF	Min 5000 m^2, max 20000 m^2	Min 2000 inhab. within 500 m buffer for each 1ha of land		/
	AG	**Not suitable**			
	AP	min 20000 m^2	/	/	/

Table 1. Possible transition between current land use and PLUs with relative criteria and indicators.

All these conditions are represented by one or more indicators that are calculated with GIS.
Size (A) records the area of the single patch.
Proximity to residential areas (PR_Res) accounts for the total number of people that can access each patch of NUAs. The indicator is weighted with patch size, as the bigger a patch is, the higher can be its influence in "attracting" people. Two distance thresholds are fixed: 500 m for Urban Farm and 250 m for Allotment Gardens. Operationally, the indicator is calculated using GIS functions of overlay analysis and spatial join. The number of people inside each buffer area was derived by a census data layer. A geographical intersection of census tracts and buffer area was performed to estimate the population. Finally, the indicator is calculated as: Pop_buf/A, where Pop_buf is the total population estimated in the buffer area and A is the patch size.

Trees Land Cover (TLC) is calculated for Woods and Shrubs and Abandoned farmlands as reported in the first phase of the methodology. The tree surface cover that represents in the first case the natural or semi-natural vegetation, while in the second case represent the last remnants of agricultural trees once present in patches of abandoned farmlands.
Contiguity to Farmlands (CO_F) is calculated for Bare Soil as reported in the previous phase of the methodology.

Sensitivity and Scenarios analysis for Prospected Land Uses

Since these criteria are represented with indicators' values, different scenarios of new forms of agriculture - in terms of number of PLUs - can be defined as planning alternatives. Fixing different indicators' thresholds, the number of occurrence for each PLU will vary according to thresholds' values. Operationally, scenarios are produced with GIS multi attributes queries that seek the satisfaction of requested indicators' values. ArcGis model builder environment was used to parameter these values.

To understand how the scenarios can produce a different numbers and types of PLUs, a sensitivity analysis was carried out. Simulating a change in indicators' values and fixing different thresholds, it is possible to explore the change in number and types of resulting PLUs, as well as their spatial configuration. For each transition from current land-use to prospected one, a number of finite combinations of thresholds values was tested in order to understand whether one indicator was more influential than another, or, to establish within which value range the number of resulted PLUs remained stable.

Three planning Scenarios were tested. The first one was the *Mixed Land Use Scenario* (S1), aimed at minimizing the difference of resulted occurrences of patches belonging to the 3 PLUs and producing a more differentiated spatial configuration. This scenario was obtained by finding the indicators' values that respect the condition *Min (Std_Dev (#UF, #AP, #AG)*, where *#UF*, *#AP*, *#AG* are the number of occurrences respectively for Urban Farms, Agricultural Parks and Allotment Gardens and *Std_Dev* is the standard deviation.
The second scenario is the Max Urban Agriculture (S2) that maximises the number of occurrences of patches of UF and AG, that are more related to urban forms of agriculture. S2 was obtained with the condition *Max (#UF + #AG)*.

The third scenario was the Max Agriculture (S3), aim to maximize the number of occurrences of Farmlands and Agricultural Park. The following condition was required *Max (#F + #AP), where #F* is the number of occurrences of Farmlands.

All scenarios were derived in GIS by iteratively changing indicators thresholds in the multi attributes queries.

The Agricultural Greenway (AG) approach
In the last phase cycle-pedestrians connections were chosen among the areas identified in the Scenario 2 of mixed uses. The AG approach was based on the main concept of creating a network of PLUs involving existing farmlands, public greenspaces and currently unmanaged NUAs. The design proposal follows a greenway multifunctional approach for urban contexts (Walmsley, 1995; Ahern, 1995). AG aimed to enhance the role of agriculture in urban contexts (Thornton, 2008) re-designing the urban fringe to ensure the congruence with the city form and urban landscape and thereby enhancing of city's accessibility, safety and attractiveness.
According these aims, the AG definition followed 5 qualitative steps:
1.Selection of most accessible and large patches of PLUs as the first elements of the AG.
2.Selection of secondary elements of the AG, including other NUAs and greenspaces.
3.Selection of the linear connecting elements, taking into account geometrical features of roads, abandoned rail tracks and other linear spaces beside roads.
4.Verification of connections' limitations (slope, physical barriers, road features).
5.Design of a main greenway connection and other secondary corridors.
6.Verification of the attractiveness and safety of the greenway, considering road crossings, unprotected pedestrian, cycling lanes, landscape features.

Results

Within the study area of the municipality of Catania, 201 patches of NUAs are present (fig. 1). The first phase of the methodology assessed the compatibility between current land-use and PLUs. 127 patches were found to be compatible: 43 Farmlands, 57 Abandoned Farmlands, 23 Woods and Shrubs and 4 Bare soils. These patches represent the first set of PLUs to be used as PLUs in for the Greenway design. Even if the main characterizing element is the very different size of these patches (with relative high standard deviation), it is interesting to see how also very large patches (more than 5 ha) are present in the area, considering that all patches are generally close to dense urban fabric boundary or to the city center.

As introduced in the previous section, results of the second phase produce spatial configurations of PLUs. This configuration was dependent on the applied criteria, indicators used to describe these criteria and consequently the indicator's values. Overall the most influential indicators in number of occurrences of the PLUs were A and TLC, while less significant was the PR_RES. The contiguity condition described by indicator CO_F was not significant as the relative condition was always verified. However, these results were different according to the land-use transitions reported in Table 1: for instance, variation of A thresholds were highly relevant for the transitions from Far and Abandoned Farmlands to Urban Farm, but less relevant from Bare Soil and Agricultural Park.

The three proposed scenarios produced different configurations in terms of number of involved patches and spatial localization. Figure 1 shows the relative maps and table 2 summarizes the number and typologies of PLUs for each Scenario.

PLUS	**Scenario 1**	**Scenario 2**	**Scenario 3**
UF	26	36	17
AG	7	7	3
AP	23	23	32
F	11	4	13
TOT	**67**	**70**	**65**

Tab. 2 – Number of patches for each PLU in the 3 proposed Scenario.

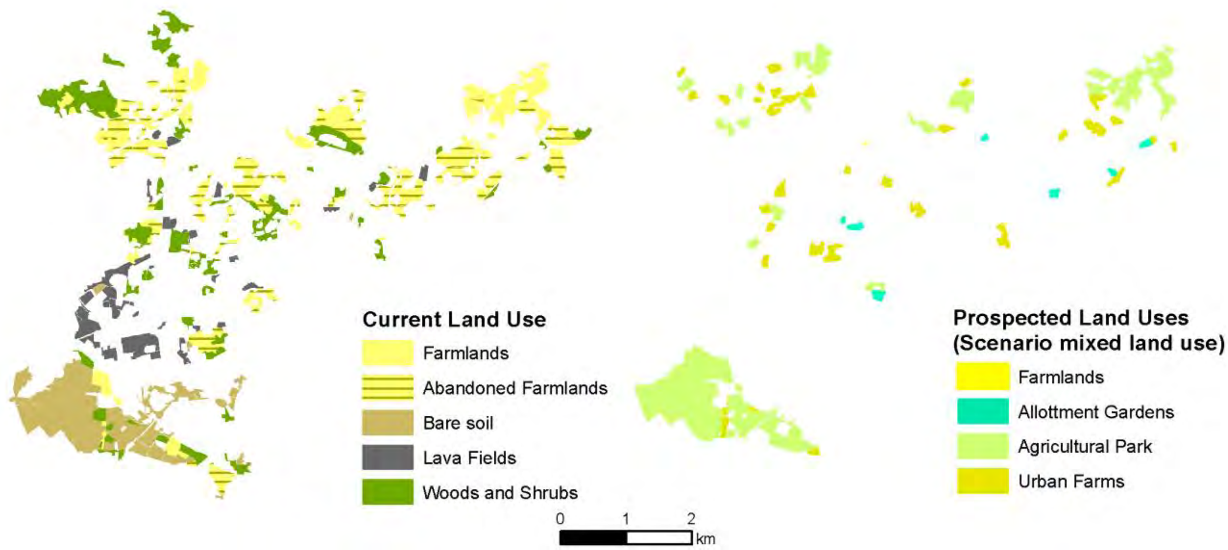

Fig. 1 – Existing Land Use and Prospected Land Use for Scenario 2

Figure 2 shows the final configuration of AG as a network of PLUs, NUAs and other greenspaces. It is composed of a main track of 20 km and four secondary tracks 11.7 km in length. Most of the segments of the main track are located inside the PLUs patches (44%) and other green areas (42%). While only 14% of AG is designed along existing roads. The maximum slope value is 4% with a mean value of 2%. Most of the segments of the secondary tracks are mainly located along roads (55%) and railway (14%). Only 25% and 6% are located within PLUs and other greenspaces areas. The maximum slope value is 2% with a mean value of 1%. The comparison between main and secondary tracks shows that the former is located along the urban fringe and mainly involves PLUs, while the latter are located inside the urban core and mainly involve existing roads. Interestingly, most of the AG network (65%) is based on existing or available green corridors.

Discussions and Conclusions

Obtained results offer different considerations both on the method and planning outcomes. Although not numerous, existing patches of agricultural NUAs present an overall medium-large size. This is partly due to their peri-urban location, resulting in low number of patches that have the best size to be addressed as Allotment Gardens. On the contrary, Urban Farms resulted the more frequent PLU according to the patch size. Accessibility of patches was not a significant indicator in dense urban contexts, as almost all patch can be reachable from a high number of people living within a buffer area of about 250-500 m. Results also showed that Scenario 2 (Urban Agriculture) was the scenario involving the highest number of patches: this was related to the high number of patches suitable for Urban Farms (more than half of involved patches of the Scenario).

The method also produced scenarios with a differentiated number of patches: this might be useful for small local municipalities that have restricted financial resources to develop projects for green areas and can now prioritise from different possibilities for greenway implementation. Another important consideration of the Agricultural Greenway Design was that not all the proposed patches to be included in the Greenway were linkable, mainly because of morphology features of the Catania area. This result can have some relevant planning consequence, as it might be preferable to assign disconnected patches the role of node with functions such as leisure where overall accessibility are more important than connectivity.

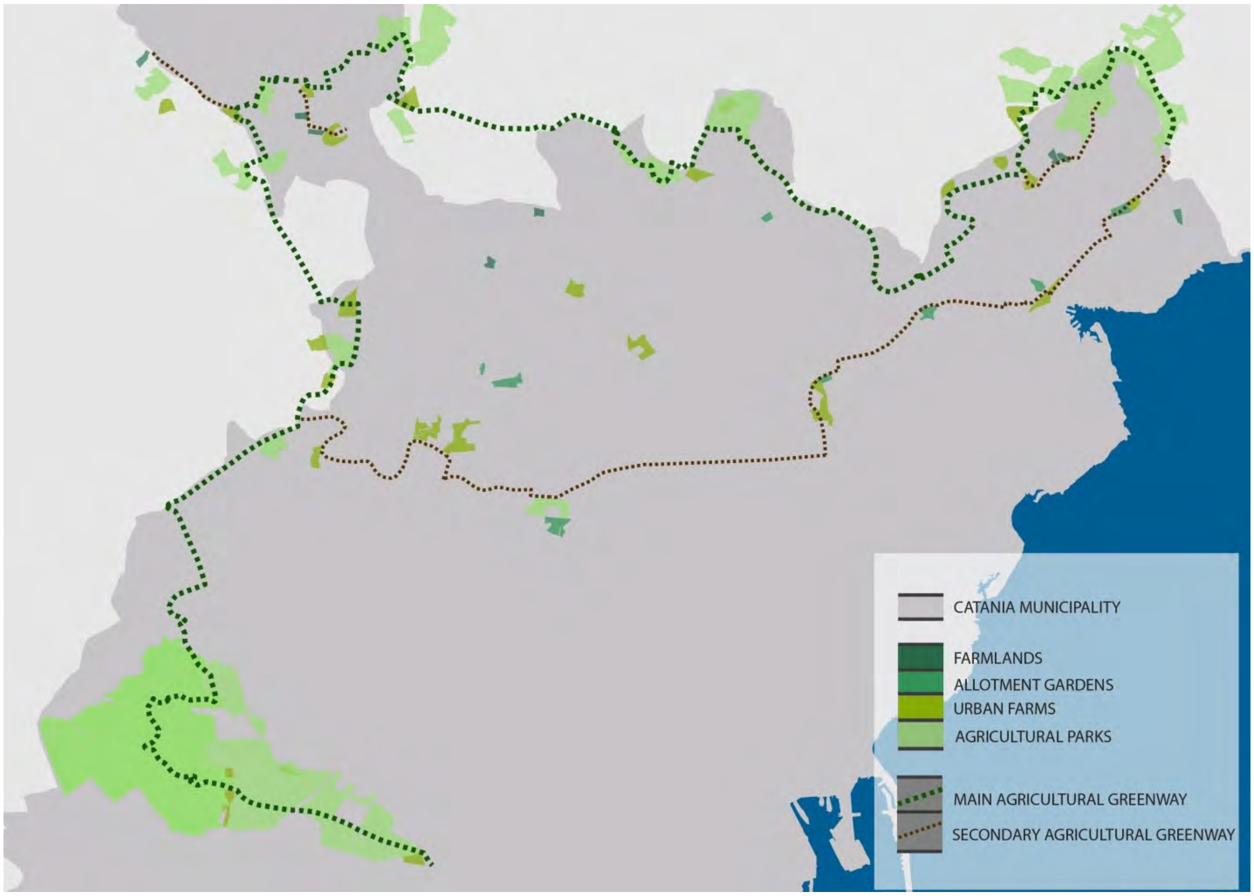

Fig. 2 – The proposed Agricultural Greenway

Improvements of the methodology may involve the inclusion of additional criteria and indicators such as terrain morphology; land ownership and parcels fragmentation. This is dependent upon the inclusion of NUA ecosystem services in the assessment (La Rosa and Privitera, 2013) in order to further characterize their nature and more suitable transformations toward PLUs.

The proposed AG allowed the integration of different and abandoned farmlands to produce new spatial configurations of NUAs with the ability to increase the provision of urban ecosystem services such as accessibility to greenspaces for leisure and food production in urban contexts. Furthermore by creating a new cycle-pedestrian urban network the overall accessibility to urban open spaces was dramatically increased. Moreover the proposed scenario of new land uses of urban and peri-urban farmlands was considered useful to protect existing productive farmlands from urban development as well as increasing productive agricultural uses (preferably organic farming) that could be implemented along with rural landscape protection and enjoyment. Finally, the scenario might enhance the overall quality of urban landscape, support climate change adaptation policies, increase economic values of parcels involved with the AG. The proposed scenario delineates a more liveable and healthy urban environment, in comparison with the current condition.

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