The broken grid: non-urbanised areas for climate change adaptation strategies in a metropolitan region

1. Planning climate changes adaptation strategies

Accelerated climate change is posing new challenges to planning. Measures to reduce emissions, known as mitigation, are only one element of these challenges. The other key issue is how to build settlements that can adapt better to the consequences of these changes, including uncomfortable high temperatures, greater incidences of flooding and strain on quantity and quality of water resources. Adapting to climate change is therefore an essential part of ensuring our communities remain desirable places to live and work (Shaw et al. 2007).

Mitigation has traditionally received much greater attention in the climate change community than adaptation, both scientifically and from a policy perspective (Fussel, 2007). However, adaptation can be considered with great attention in physical planning since it has consequences that go beyond the climate change challenges. In particular, the role of green areas within the sprawled settlements is fundamental in order to achieve high levels of quality, together with adaptation to climate change.

Sprawl is the main threat to green areas, consequently it has to be carefully considered in any climate change adaptation action. Characterized by a mix of low density land uses, mainly on the urban fringe, it is often the result of unplanned or poorly planned developments. Urban sprawl is a typical phenomenon of the United States. It began in the second half of the 20th century, stimulated by several reasons including the rapid growth of private car ownership, the preference for detached houses with gardens and public policies about road infrastructure and mortgage incentives. European cities were more compact and less sprawled in the mid 1950s than they are today, and urban sprawl is now a common phenomenon throughout Europe. Motivations for this change are similar to the ones of the USA even if there are also considerable differences. Urban areas particularly at risk are in the southern, eastern and central parts of Europe (EEA, 2006). Southern Italian regions including Sicily are increasingly exposed to the same phenomenon with some specificities (Martinico et al, 2008).

A considerable number of studies is concerned with sprawl. They span from analytical and quantitative ones (Angel et Al, 2005; Antrop and Van Eetvelde, 2000) to surveys aimed at understanding the perceptions of inhabitants (Ryan, 2002). Others are more concerned with planning tools and policies (Portnov, Pearlmutter, 1999, Kochan, 2007; Charmes, 2009). The resulting overall picture is a complex one. For instance, it emerges that suburbs are less homogenous than it is expected. They are never simple dormitories for middle class and they often include low income communities or self built housing (Kreibich, 2000). All these elements have to be carefully considered since social and economic status greatly affects the approach toward green areas of the community.

The study of sprawl is particularly relevant for the planning of green areas since there is not a widespread consensus on effective strategies for its containment or upgrading. The main focus of literature is on the built side and less on the open land that is left in between the built up patches, at neighborhood level. Green belts or green hearts have been considered as design tools, useful for separating compact city from sprawl or for integrating city regions, but they are first of all abstract constructs of planners (Kuhn, 2003). Other policies are mainly concerned with the effects of road construction (Schiller, 2002). On the contrary, open land, left within sprawled settlements has to be carefully considered as a key part of physical localities in order to propose effective planning approaches.

Several actions at different levels are concerned with these key issues, including the Green and Blue Space Adaptation for Urban Areas and Eco Towns (GRaBS) project. GRaBS is funded by European Union European Regional Development Fund (ERDF) INTERREG IVC Program. In this project a network of organizations is involved, including the University of Catania. The main aim is integrating climate change adaptation strategies into regional

planning and development across Europe.
We present a case study that is part of this project, considering that the University of Catania is involved in the definition of land use planning strategies for a municipality that is part of the Catania Metropolitan Area. The planning strategy is going to include some of the principles of climate change adaptation following the analyses here presented. In particular, this paper focuses on a method to address land-use planning issues taking into account analyses of land cover features and fragmentation of non-urbanized areas. By using land cover analysis it is possible to evaluate permeability and evapotranspiration. In addition, fragmentation analysis brings into the model the pattern of non urbanized areas, considering dimension, density, and shape of open land patches. This can be achieved by using landscape ecology metrics. Combining both these sets of data the first elements of a conceptual model for guiding land use planning of open-spaces within a sprawled settlement are suggested.

2. Urban growth in metropolitan areas

The case study presented in the following paragraphs is a municipality included in the conurbation of Catania, a settlement system nowadays mainly characterized by a considerable amount of urban sprawl. Considering the 27 municipalities, included in the official designation of the metropolitan area, in forty years (1961 – 2001), the total population grew more than 27%, while the main city lost 16% and the other 26 municipalities increased of 107%. In 2001, about 57% of total population lived outside the main city. This process is continuing in recent years: in 2008 this percentage grew over 60%.
Taking into account a reduced number of municipalities (the 18 ones that are more related to the main city) they included 46% of total population in 2001. This percentage increased to 49% in 2008. In the same period the main city lost another 4.5% of its population (Tab. 1).
A settlement model characterized by prevailing low density corresponds to this population dynamics. From the early 1970's the new built up areas have heavily affected the rural setting typical of the slopes of Mount Etna, compromising its fragile landscape and generating relevant congestion phenomena. Almost 70% of total built up areas were built between 1964 and 1985 (Tab. 2). As usual, the reasons for sprawl include the search of new residential models, detached or semidetached housing, the diffusion of private cars and lower real estate prices outside the main city.
In addition, the lack of tight zoning regulations in smaller municipalities produced the rise of the sprawl in areas adjacent to the northern boundaries of the main city where the master plan, approved in 1969, reduced severely the opportunity for new developments.
This frantic speculative building activity produced a new urban landscape that wiped out the agricultural activities. Subdivisions took place mainly according to poorly designed master plans, just tools for distributing building consents based on mere quantitative criteria. The result was a conglomerate of mono-functional residential settlements, some with the shape of suburbia, others with higher densities, but all unified by considerable levels of inefficiency.
Non-residential functions followed the first diffusion pattern, initially commerce and after offices, services and manufacturing. In 2001, about 50% of all businesses units were located outside the main city. Within the 27 municipalities, the 12 ones around the main city show a greater complexity of functions, as they include the majority of value added services and productions (Martinico, 2005). Among these last ones there is a group of 5 municipalities (Aci Castello, Gravina, S. Agata Li Battiati, San Gregorio and Tremestieri Etneo) where, not only the built up areas, but also the social and economic profiles are almost undistinguishable from the main city. Data about household size, age, workforce and literacy are almost similar to the ones surveyed in Catania.
Land use planning is characterized by a complete lack of overall metropolitan planning. Each municipality has its own master plan based on autonomous choices as far as the amount of new developments is concerned. The only attempt to define a plan at metropolitan level failed in 1960s, (Martinico, 2005). This piecemeal approach has caused a notable erosion of the residual agricultural land, progressively substituted by new developments.

Agricultural land and other non-urbanized areas in Catania metropolitan area have never been studied systematically in spite of their strategic role. This lack of rigorous data collection and analyses is the direct consequence of the weakness of regional planning.
On the contrary, the study of these areas is strategic both for defining agricultural, urban and infrastructural policies and for proposing climate change adaptation strategies, including in the process elements like their permeable and evapotranspiring features.
Only by pursuing a planning strategy at metropolitan level, going beyond the traditional municipal plans, it is possible to envisage a way to restore the grid of non urbanised areas that has been broken by over thirty years of unwise urban development, assuming an effective stance about climate change issues.

Municipality	**Total 2001**	**Total 2008**	**2001 - 2008**	**% split in 2008**
Aci Bonaccorsi	2 549	2927	14,8%	0,50%
Aci Castello	18 272	18107	-0,9%	3,08%
Aci Catena	27 058	28434	5,1%	4,83%
Aci sant'Antonio	15 389	17188	11,7%	2,92%
Camporotondo etneo	3 007	3805	26,5%	0,65%
Gravina di Catania	27 343	27808	1,7%	4,73%
Mascalucia	**24 483**	**27482**	**12,2%**	**4,67%**
Misterbianco	43 995	47912	8,9%	8,14%
Nicolosi	6 197	6959	12,3%	1,18%
Pedara	10 062	12283	22,1%	2,09%
San Giovanni la Punta	20 850	22136	6,2%	3,76%
San Gregorio di Catania	10 366	11307	9,1%	1,92%
San Pietro Clarenza	5 863	6670	13,8%	1,13%
Sant'Agata li Battiati	10 378	9690	-6,6%	1,65%
Trecastagni	8 212	9769	19,0%	1,66%
Tremestieri Etneo	20 442	21520	5,3%	3,66%
Valverde	7 246	7588	4,7%	1,29%
Viagrande	6 591	7707	16,9%	1,31%
Catania	**313 110**	**298957**	**-4,5%**	**50,82%**
Total outside Catania	**268 303**	**289 282**	**7,8%**	**49.18**
Total 24 municipalities	**581 413**	**588 249**	**1,2%**	**100,00%**

Tab. 1 - Recent population dynamics in Catania Metropolitan Area

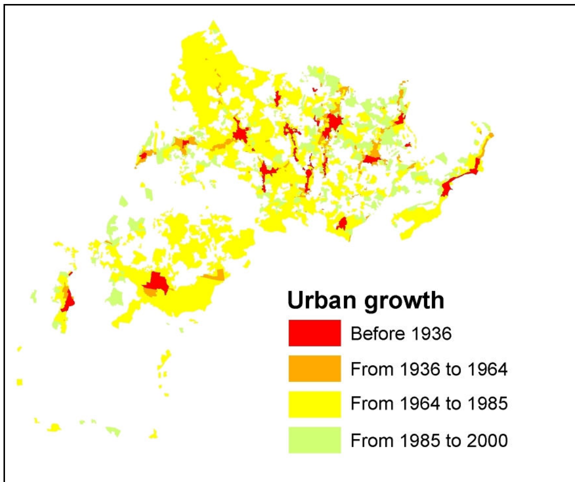


Fig. 1 – The urban growth of Catania Metropolitan Area (considering same municipalities reported in tab. 1)

Built up areas	**AREA [sqm]**	**%**	**% cumulated**
Before 1936	3353327	6,2%	6,2%
From 1936 to 1964	2867105	5,3%	11,5%
From 1964 to 1985	37249790	69,0%	80,5%
From 1985 to 2000	10550606	19,5%	100,0%
Total	**54020828**	**100,0%**	

Tab. 2 – Urban growth in Catania Metropolitan Area (considering the municipalities of Acicastello, Camporotondo, Gravina di Catania, Mascalcia, Misterbianco, Motta S. Anastasia, S.Agata li Battiati, S.Giovanni la Punta, S.Gregorio di Catania, San Pietro Clarenza, Tremestieri Etneo, Valverde)

3. Scaling down the issue: the case study of municipality of Mascalucia

Mascalucia is one of the small agricultural towns on the volcano slopes that has been absorbed into the expanding metropolis. In the late 19th century it had slightly more than

3000 inhabitants and its municipal territory is about 1600 hectares, with a height range from 320 m to almost 700 m a.s.l. Its agriculture oriented economy, mainly based on wine production, was completely swiped out, first, by holiday houses developments in the 1960 - 1970s. In the following 20 years these houses became stable dwellings and in 2008 its population reached 27482 inhabitants.

Population

According to national census data, the increase in the total population has been constant since 1936, with a sudden boost from 1971 on. Population almost doubled twice, first time between 1971 and 1981 and again in the next decade.

The population living in Mascalucia (data from National census, 2001) is mainly middle class, younger than in the main city; the average number of family components is 3.2. Workforce percentage is higher than in the main city, the one of retired people is lower. Workforce composition is a typical urban one with a percentage employed in retailing higher than the average. People working in value added services are slightly less than in the main city and the surrounding highly integrated five municipalities. Considering the average family, income Mascalucia is 12th within the official metro area designation.

Planning

Mascalucia has had three land use master plans from 1960s. The first one was approved in 1966. The second one, approved in the early 1980s, was the main cause for sprawl since it allowed a building area of 10% of the plot almost everywhere outside the existing built up area. Landowners began subdividing their properties in plots of about 500 – 1000 sqm, selling them mainly to middle class people from main city eager to have a holiday house in a place with a better climate during the hot summer season. The third one, approved in the year 2000 was an attempt to rationalize the resulting settlement system by restricting further developments and introducing services and infrastructure that were lagging behind.

4. Land use and urban growth

The first step for all further analyses was the construction of a detailed land use map that did not exist so far for this area. It is based on: the vector cartography (1:10,000) produced by regional authorities, municipal vector cartography (1:2000) and field surveys. The use of recent Google Earth (2006-2008) satellite photos was also very useful for an update of most recent changes. Land uses are mapped in fig. 2 and summarized in tab. 3. It can be seen how residential land covers almost half of the municipality, while the rest is equally divided between agriculture, both cultivated and abandoned, (more than 21%) and wood and shrubs (20,5 %). Roads surfaces also sum up almost 10 % of the total.

Residential patches have been further divided in the following categories: historical compact urban settlements, new multi-storey apartment residences, linear historical rural settlements and detached family houses. Linear historical settlement is a typical pattern of Mount Etna countryside. It is formed by rows of narrow plots of farmland with the houses aligned along the old roads that connect existing villages and small towns.

A relevant feature is the amount of small patches of abandoned farmland. They are, in many cases, the result of the progressive erosion of agricultural land by urban sprawl. This land use type, together with shrubs and a limited amount of wooden patches, represent the non urbanized areas scattered within the municipality.

Focusing on urban land use, a further analysis was conducted on the urban growth. Each patch of urban land was classified according to the time period of the settlement. Five different time thresholds were identified, on the basis of available cartographic sources (1920 Italian Army scanned maps; 1964 Provincial scanned maps; 1980-1982 scanned Regional Technical Maps; 2000 vector Regional Technical Maps and Orthophotos ECW maps). All the scanned maps needed to be preliminary georeferenced before proceeding to the digitizing on screen of urban areas.

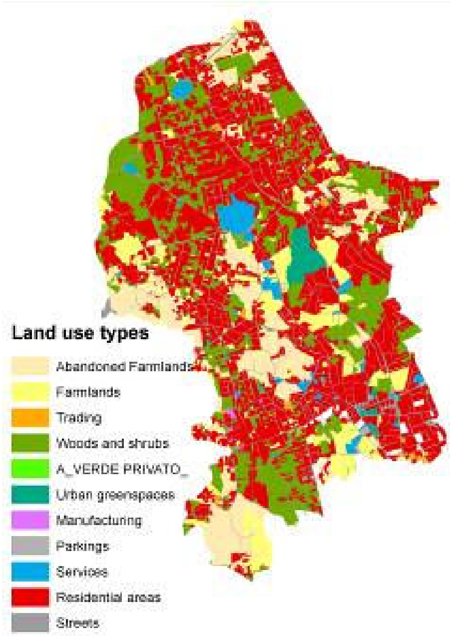


Fig. 2 – Land Uses map in Mascalucia

Land use type	Area [ha]	%
Abandoned farmland	215,1	13,2%
Farmland	135,7	8,3%
Woods and shrubs	333,4	20,5%
Parks and public gardens	24,5	1,5%
Trading	8,7	0,5%
Manufacturing	1,8	0,1%
Services and utilities	38,0	2,3%
Residential	704,4	43,2%
Private gardens	13,5	0,8%
Parkings	3,4	0,2%
Roads	150,9	9,3%
Total	**1629,5**	**100,0%**

Tab. 3 – Land use types in Mascalucia

Fig. 3 clearly shows how the growth of sprawl has affected almost all the land within the municipal borders since the 1960's. Tab. 4 reports quantitative data of this impressive urbanization process: urban land increased by more than 2,000 % between 1928 and 2008, from 35,7 ha to 718,4 ha. These growth patterns are quite similar, but even more evident, than the ones outlined for the entire Catania metropolitan, as it emerges comparing tab. 4 with tab. 2.

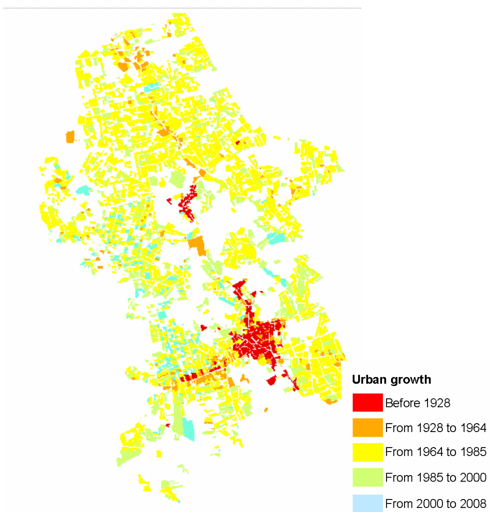


Fig. 3 – Urban areas growth map for Mascalucia

Layer	Sum_area	**Area Ha**	**%**
00_1928	357481	35,7	4,74%
00_1964	476947	47,7	6,32%
00_1985	4543156	454,3	60,24%
00 2000	1737788	173,3	23,04%
00_2008	425903	42,1	5,65%
TOT	**7115372**	**753**	**100,00%**

Tab. 4 - Urban areas growth at the different time thresholds considered

5. From land use to land cover: permeability and evapotraspiration assessment

The traditional land use categories are generally not able to provide indication about land cover features. Each patch of a single land use type can infact be composed by a complex mix of land covers. In order to cope with problems posed by climate change adaptation, it becomes crucial the characterization of land uses type by different land covers.

In the next step of our study, this was done by aerial photograph interpretation on sample areas for every land use type. The methods allowed the detection of different land cover surfaces and the assessment of their contribution to evapotranspiration and permeability.

A geographic sampling

In the evaluation of evapotranspiring and permeable surfaces, surveys have to be conducted at a very small scale, in order to take into account those land cover surfaces (i.e trees, small grass or urban gardens) that contribute to these phenomena.

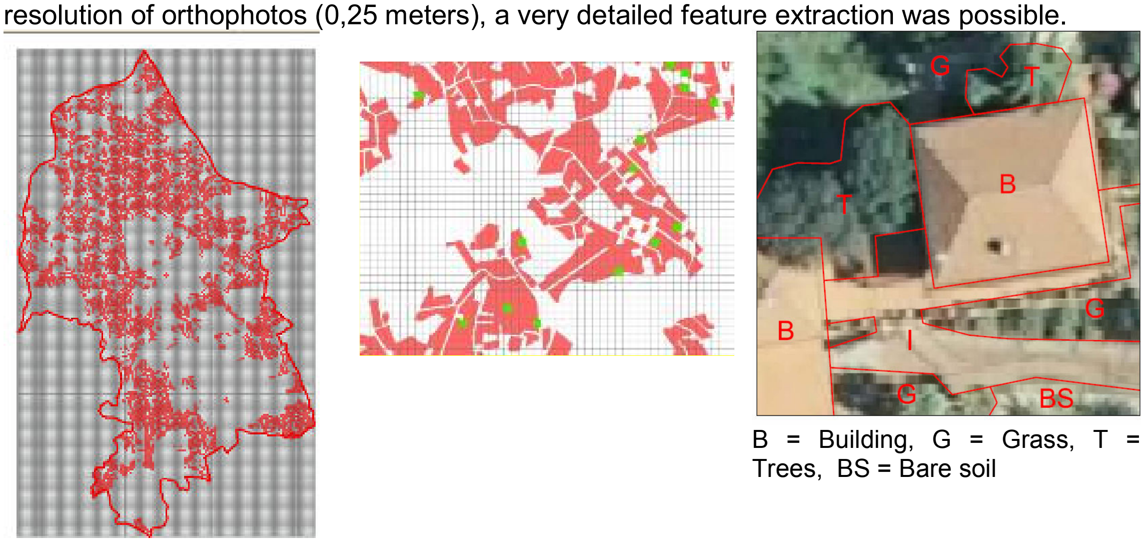
In our research, eight land cover types were chosen, in order to distinguishing impervious, permeable and evapotranspiring surfaces: buildings, impervious surfaces (roads driveways, sidewalks, parking areas), grass, farmland, abandoned farmland, tree, shrubs and bare soil.

A geographical sampling strategy was chosen (Gill, 2003; Akbari et al, 2003; Tappan et al, 2004) considering that mapping these small features is a time consuming task. The proposed sampling method is based on the overlaying of 30 meter square grid over the land use map (fig. 4, left) and on a random choose of cells of the grid (fig. 4, middle). Within each of them the land cover types were identified by aerial photo interpretation. Random sampling is usually carried out when the area under study is very large, or time available is limited. When using random sampling techniques, large numbers of samples are taken from different positions within the area. The advantage of this approach is that no human is involved in the sample selection process.

An important and crucial step was the choose of the appropriate sample size (Bartlett et al., 2001). Particularly, since land use types have different geographic distribution and amount of covered areas, it appeared important to sample each of them with samples of different size.

For each land use type the sample size was calculated, using Cochran formulas for categorical data (Bartlett et al., 2001). Confidence level and interval were fixed respectevely at 85 % and 5%. A numbered vector grid was overlaid over the area and for each land use type the sample cells were randomly generated with the Random Selection ArcMap tool (fig. 4, middle).

Inside every sampled cell, land cover surfaces were manually identified and digitalized by photo interpretation of orthophotos from 2007, as shown in fig. 4, right. Thanks to the good resolution of orthophotos (0,25 meters), a very detailed feature extraction was possible.



B = Building, G = Grass, T = Trees, BS = Bare soil

Fig. 4 – The overlayed sampling grid on semi-detached house land use (left), the random generated sampling cell (middle) and an example of the land cover surfaces extraction (right).

Results of Land Cover Analysis

The results of Land Cover Analysis are shown in Table 5, where for each land use type the composition of land cover surfaces is reported.

		LAND COVER TYPES								
		Trees	Shrubs	Cultivated	Grass	Herbaceous vegetation	Bare soil	Buildings	Impervious	**TOT**
LAND USE TYPES	Detached houses	25%	6%	7%	25%	0%	4%	13%	20%	**100%**
	Historical compact settlements	15%	0%	0%	18%	0%	1%	38%	29%	**100%**
	Multi-storey apartment residences	15%	0%	0%	13%	0%	0%	39%	34%	**100%**
	Linear historical rural settlements	32%	0%	0%	18%	0%	0%	38%	13%	**100%**
	Private gardens	30%	11%	6%	24%	8%	2%	10%	9%	**100%**
	Retail	4%	0%	0%	9%	0%	14%	24%	49%	**100%**
	Manufacturing	2%	0%	0%	6%	0%	10%	20%	61%	**100%**
	Services and utilities	8%	7%	3%	12%	6%	14%	16%	34%	**100%**
	Farmland	6%	15%	50%	2%	9%	10%	1%	5%	**100%**
	Abandoned Farmland	12%	36%	11%	0%	18%	19%	1%	2%	**100%**
	Parks and public gardens	85%	0%	0%	5%	2%	0%	1%	7%	**100%**
	Woods and shrubs	13%	33%	5%	2%	20%	19%	2%	7%	**100%**

Tab. 5 –Results from land cover surface analysis

The highest *buildings* surface cover type is found in historical compact settlements (38%), in multi-storey apartment residences (39%) and in linear historical rural settlements (38%). Detached houses have only 13%, less than Retail (24%), Manufacturing (20%) and Services & Utilities (16%). All other cover types are below 2%.
Impervious surfaces are high in Manufacturing (49%) and Retail (61%). Residential land use types present a heterogeneous distribution of this land cover, ranking from 13% in linear historical rural settlement, followed by Detached family houses (20%), Historical compact urban areas (29%), multi-storey apartment residences and Services & Utilities (34%).
Trees surface cover percentage (85%) in Parks and public gardens is considerably affected by a new large suburban park, characterized by natural woodland. Residential land use types show the highest proportion of *trees* cover surface: from 15% in historical compact settlements and multi-storey apartment residences to 25% in detached houses. The 32% value is quite remarkable for linear historical rural settlements. Farmland (6%), abandoned farmland (12%), woods and shrubs (13%) show less percentages of *trees* cover.
The highest *grass* cover surfaces cover is found in Detached family houses (25%), followed by historical compact settlements and linear historical rural settlements (18%), slightly more than the one of multi-storey apartments residences (13%). Retailing (9%), Manufacturing (6%) and Services and Utilities (12%) show an higher percentage than Parks and public gardens (5%) and Woods and Shrubs (2%). Finally, Grass is very low in farmlands (less than 2%), due to the features of local agriculture. On the contrary, the high value found for Detached family houses is related to the fact that lawns are socially appreciated by suburbanites, in spite of high maintenance costs in Sicilian climate.
Shrubs surface cover is surprisingly higher in Abandoned Farmland (36%) than in Woods and Shrubs (33%). This last value reveals as this land use is more characterized by shrubs vegetation than by trees.
Bare soil surface cover is diffused in Abandoned Farmland (19%) and Woods and Shrubs (19%). Retails and Services and Utilities have 14% bare soil cover, slightly more than Manufacturing and Farmland (10%).
Excepted from Woods and Shrubs (20%), Abandoned Farmland (18%), Farmland (9%), *Herbaceous vegetation* surface cover is almost absent in all the other land use types.
The proposed method allows to diversify land-use types, especially non-urbanised areas, by the percentage of their evapotranspiring and impervious surfaces. This is derived by summing surfaces of evapotranspiring land cover types (Trees, Shrubs, Cultivated, Grass, Herbaceous Vegetation), impervious land cover types (Buildings and Impervious) and

calculate their percentage for each land-use type (tab. 6). Fig. 6 (left) shows the % of evapotranspiration for the all considered land use types. Non urbanised areas have been than extracted and divided into 2 classes, with reference to the average evapotranspiring surface value (fig. 6, right).

LAND COVER TYPES	% evapotranspiring surface	% impervious surface
Detached houses	62,1%	33,7%
Historical urban areas	32,3%	67,1%
Multi-storey apartment residences	27,6%	72,4%
Linear historical rural settlements	49,4%	50,6%
Private gardens	79,0%	19,0%
Trading	12,2%	73,4%
Manufacturing	8,3%	81,5%
Services and utilities	35,9%	50,5%
Farmland	83,1%	6,6%
Abandoned farmland	77,8%	2,9%
Urban greenspaces	92,2%	7,7%
Woods and shrubs	72,1%	8,7%

Tab. 6 – Percentage of evapotranspiring surfaces for the land use type

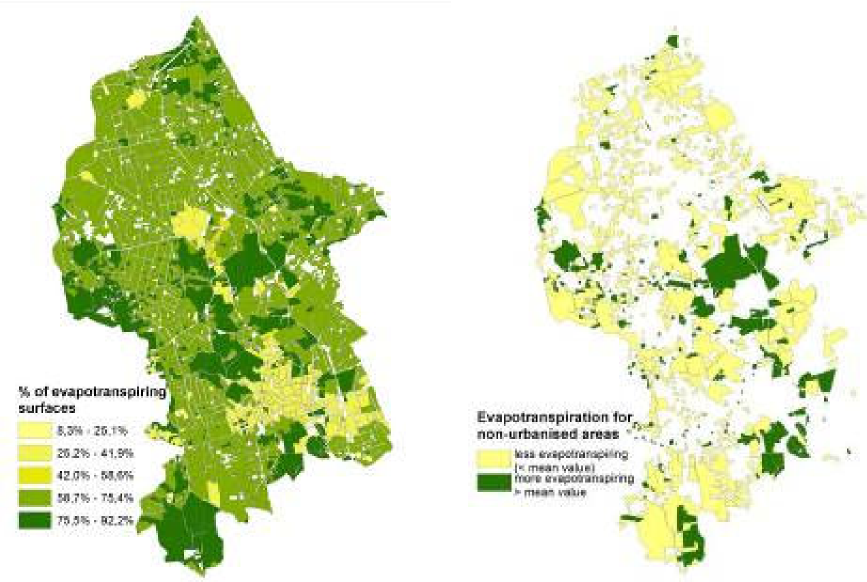


Fig. 6 – Percentage of evapotranspiring surface for land use types (left) and classification of non urbanised area by degree of evapotranspiration

This approach is useful for suitability analysis of land use allocation of non urbanized areas. Different percentages of evapotranspiring surfaces can be taken into account in deciding new land uses or safeguard measures (see par. 7). Nevertheless,, the method shows a possible evolution. Weighting each land cover type with a coefficient that takes into account the different potential of evapotranspiration and permeability, may allow getting larger range of behaviours. Tree cover type, for instance, may provide a higher evapontraspiration potential than cultivated cover type: a comparative coefficient may therefore be used to try to asses this difference. This would allow the distinction of different classes of evapotranspiration and permeability.

6. The fragmentation of non urbanised areas

On an ecological point of view, fragmentation involves dividing up contiguous ecosystems into smaller areas called patches. A patch is an area with relatively homogeneous conditions relative to other patches (Forman 1995). The term class typically represents the different categories of possible patches, e.g. land cover/land use classes, habitat classes, or vegetation classes. The division of natural ecosystems into smaller patches is very often the result of human activities, such as the development of agricultural or urban areas in places once covered by forests or other natural land uses. Consequences of fragmentation processes, including the increasing number of patches, the decreasing of the mean patch size, the increasing of the total amount of edges, are various and known (Rutledge, 2003).

Focusing on non urbanized areas, we have considered not only the natural land uses like woods or shrubs but also the agricultural land, since they play an important role in controlling surface run-off and evapotranspiring processes inside an highly urbanized settlement. Another reason is that the metropolitan area is not well endowed with wooden areas, so the conservation of agriculture land appears quite strategic for the management of non urbanized areas and climate change adaptation strategies.

We evaluate non urbanized areas fragmentation extracting patches belonging to land uses type of Farmland, abandoned Farmland, Woods and Shrubs and Urban greenspaces. These land use types sum up about 44% of the total municipal area of Mascalucia.

Some landscape ecology metrics (McGarigal, Marks, 1995) widely used in many applications for landscape assessment have been calculated. In particular, for describing fragmenation on patch and landscape levels (McGarigal, Marks, 1995), the following indeces have been used:

- *Percentage of Non Urbanised* areas (PNU): as the percentage of non urbanised area inside each cell of the grid
- *Number of Patches* (NP): the number of patches inside each cell of the grid
- *Mean Patches Size* (MPS): the mean patch size inside each cell of the grid
- *Largest Patch Index* (LPI): the % of the total landscape made up by the largest patch
- *Edge Density* (ED): the ratio between the edges length and the area of the patches.

Many approaches in metrics calculation use to provide a single value for the entire study areas, but in many situations indices calculated over the entire region are not accurate enough to describe the fragmentation patterns within the region. Infact a spatial calculation unit able to get fragmentation patterns at a sub-comunal scale was needed. When indices are used to describe landscape pattern at regional scale, appropriate spatial unit has to be decided before starting with the calculation of indices (Liu, 1999). The choice of a correct area is a crucial factor in landscape metrics calculations, also known as modifiable areal unit problem (Openshaw, Taylor, 1981).

We used a vector grid with 500 m x 500 m cells, where fragmentation metrics were calculated. Obviously, scores from metrics must be read as relative values along the different cells of the grids. The four indeces were calculated using the Patch Analyst tool with ArcGis.

Indeces are mapped in fig. 7. PNU has very eterogeneous values, reaching almost 100% of cell coverage (dark brown cells) but also showing how cells with high density of non-urbanized patches are not close to one another. Thus it may be difficult to work out re-connection strategies. NP shows very well the higly fragmentation of non urbanised areas, particoular in blue cells where there are up to 35 patches. This is strictly related to growing of urban detached houses areas, especially in the western part of the municipality. MPS values result highly correlated with the ones of NP, showing, in the areas previously mentioned, an average size of patches of less than 1 ha. LPI presents a spatial distribution of values quite similar than MPS; there is only a couple of cells with a 50% of the total cell size made up by the largest patch. ED values give different results, being heavy influenced by the patch size. Small patches are caracterized by higher index values: This is affecting the most central ones, where predominant residential land uses tend to heavily fragmentate agriculture areas.

Further adjustments of the fragmentation assessment are needed. Firstly, in all landscape metrics a high dependency of index values from the size of the chosen grid was found, so that it may be worth testing different grid meshes. Furthermore, pre-defined sub-zones may be used as spatial units to calculate metrics, in order to try to minimize the "cookie-effect" of the overlaid grid on the patches. Development of a simple aggregated fragmentation index may also be very useful to use a single metric in the further step of the study (see. par. 7).

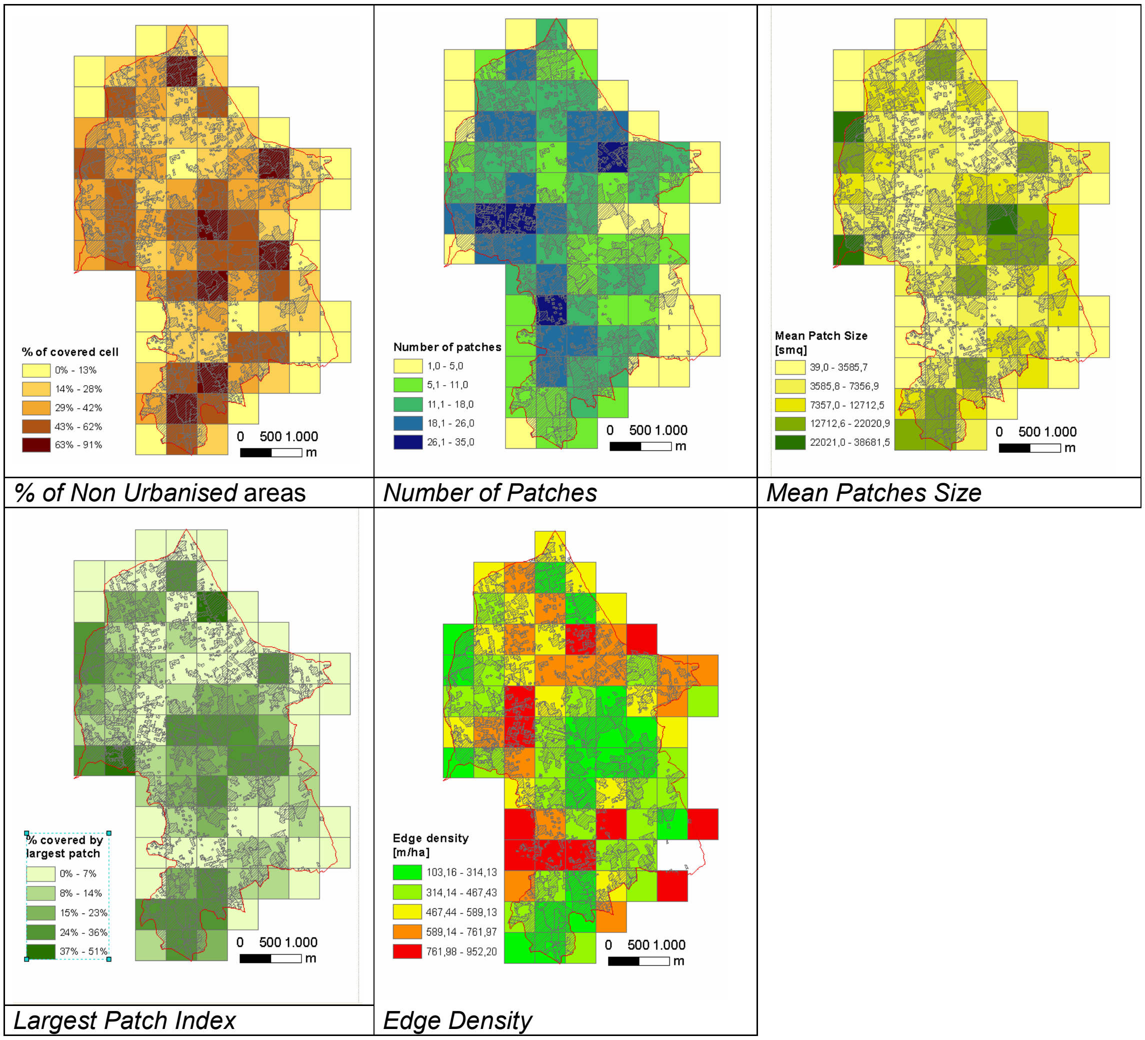


Fig. 7 – Results of fragmentation metrics

7. A conceptual model for a multidimensional use of non-urbanised areas

Non-urbanized areas in Catania Metropolitan area are under constant pressure from urban development. Neglecting them in land use planning may endanger the future of the entire metropolitan system, considering how much these areas are becoming residual both for their quantity and quality.

Decisions about land uses for a specific location depend on the suitability of the land for specific use types. A suitability analysis predicts the potentials and constraints for a defined use (Steiner et.al., 2000). Data presented in the previous paragraphs show the importance of addressing allocation of land uses by considering evapotranspiring, and fragmentation features of land cover types. The following considerations are based on a specific case study but they can be extended to similar settlement patterns, as well as to wider areas.

The examined area presents a complex picture of non-urbanised areas, where productive and abandoned farmland, woods, shrubs, parks and public gardens are closely mixed to both traditional and new urban uses. Non urbanised areas have been summarized into two categories: high evapotranspiring, low evapotranspiring. Fragmentation assessment also

allows to diversify patches of the same land use type which are characterized by the same percentage of evapotranspiration surfaces, this resulting in more differentiated geographical behaviours.
From the combination of the results of the analyses the following categories for future uses of non-urbanised areas emerge.

- Areas with high evapotranspiring values, combined with low level of fragmentation, are eligible for environmental protection, especially if associated to a low level of mixed-use in the surrounding patches. Their size and the presence of existing natural vegetation is a prerequisite for an effective protection.
- High evapotranspiration and fragmentation levels, characterized by the presence of small wood patches or high density of shrubs, may suggest their use for recreational purposes, i.e. small gardens or playgrounds.
- In low evapotranspiring areas, appropriate uses could be oriented toward agriculture. This applies mainly with high values of fragmentation. Considering that the size of these patches will engender the economic feasibility of these activities, new form of periurban-agriculture should be envisaged. They will be based on a combination of support actions and innovative management approaches to be carried out with the involvement of local communities. There are examples where small agriculture patches have been cultivated by retired people, or other groups, on voluntary bases as kitchen gardens for the adjacent dwellings. One of these examples is the Parco Agricolo Sud Milano.

Furthermore, not evapotraspiring land, i.e. permeable bare soils, should be used mainly to minimize water run-off, especially when close to built areas. Considering that in the examined area there are mainly residual lava fields, their use will depend by their level of alteration. The ones maintaining their natural condition should be preserved in order to allow the natural colonization cycle by wild species. Others that have been altered by uses as gravel or basalt stone quarries or junkyards can be reclaimed introducing a considerable amount of plants in order to give them an evopotraspiring function.
The previous considerations tell us only a part of the story. Decisions about future land uses or protection including recreational and agricultural uses or ecological protection or upgrading development must be evaluated with respect to their significance for future perspectives. Planner evaluation can add all other elements that are not descending from mere analytical studies.
Applying sound planning principles like the ones proposed by the Smart Growth Movement. requires a set of innovative tools that goes beyond the traditional ones applied in Italy. They are referred both to design and management. Latter ones includes conservation easements or agreements that remove development rights but provide for continued private ownership for such uses as farming and forestry granting compensations similar to the Purchase of Development Rights (PDR), applied in USA.
Land use allocation problems are complex. Typically, the analysis of land cover surfaces is based on the biophysical characteristics, and the spatial configuration of different land uses. Considering these aspects from the climate change adaptation point of view, opens up a more comprehensive approach useful for fostering a sustainable land use policy.
Challenges posed by climate change adaptation require a comprehensive approach where the costs related to the containment of new developments should be compensated by shared or individual benefits. These include the advantage of living in a higher quality settlement where recreation and open air activities are favored by the settlement pattern. Moreover, it should be considered that several social, economic and cultural benefits can derive from urban agriculture.

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