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Towards the Metropolitan City: adaptation strategies to climate change using new technologies and integrated approaches for e-governance and spatial planning decision-making

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In addressing the challenges posed by climate change becomes essential to promote, also at the local level, a kind of planning able to consider mitigation and adaptation measures in an integrated way. How to design and plan considering, not only, the mitigation logic but also the adaptation? And how to do this in an efficient and integrated way?

In particular, urban climate adaptation policies are more likely to be influenced by locally relevant environmental factors and conditions, and the perception of stakeholders and decision makers. To obtain such goals, the smart city's paradigm shows itself as the best possible solution. The smart city, through the opportunities provided by Information and Communication Technologies (ICT), promotes the participation of citizens in defining and implementing integrated and sustainable urban policies, in order to improve the inhabitants' quality of life. The problem of climate change is a social problem, and only by involving the population, and with their collaboration, it is possible to implement strategies for adaptation and mitigation. The new approach suggested for Public Administration (P.A.) moves away from the concept of possession, but instead it is near to the concept of sharing of resources and knowledge, cooperation; and introduce models of Governance based on participation and involvement of citizens. Therefore, to increase the urban resilience it is important, first of all, to build a framework of knowledge: innovative (for the detail of information), shared, and integrated. The Province of Venice, with the University IUAV of Venice and its PhD school, during the last years, has coordinated and supported the Covenant of Mayors for drafting the SEAP, and then the Project Partner European Seap-Alps. This collaboration has produced:

- an innovative method for analysing with the use of the techniques of Remote Sensing, oriented spatial information in order to produce valid identification and environmental vulnerability of the area to climate change;
- an enlarged working group with some P.A. local pilot, in order to develop a shared guidelines, useful for planning future Climate Metropolitan City;
- definition of strategies for use the ICT in order to share information and create a regional network for a Climate Plan on a metropolitan scale.

Index of Paper

Introduction

Until a few years ago, the main - if not the only - answer to climate change was the reduction of greenhouse gas emissions, supported mainly by the ambitious policies of the European Union[1] (Biesbroek *et al*., 2010). Nonetheless, it is widely known and accepted that climate change and its impact are inevitable even though global emissions were to be immediately reduced by a great margin (IPCC, 2007). It is with this aspect in mind that adaptation policies, plans and actions became part of the responses to climate change. Adapting to its consequences has become a need that can no longer be postponed, especially considering the increasing risks to which population, infrastructures, economic and strategic sectors, environment and ecosystems are subjected. Adaptation measures have therefore sided with mitigation measures, despite their very different characteristics. The reduction of greenhouse gases is a global challenge that cannot be complete without everyone's commitment. Therefore, mitigation measures have a global reach – they try to change the current development model and use of resources. Of course, mitigation also has localised applications such as the increase in energy efficiency of buildings, the reduction of private cars with the support of public transport etc., but it remains a global challenge in which everyone must play their part. Adaptation is instead a strictly local challenge. It is the duty of a specific territory with its inhabitants, infrastructures, municipal and ecosystem services, to find and implement adaptation measures that are suitable for the specific risks it must face without affecting the environment or lifestyle. A successful adaptation plan only depends on those who implement it and it is only able to defend a specific territory (Musco *et al*., 2014; Carmin *et al*., 2012).
More specifically, it will be the cities and urban areas as a whole, with their increasing number of inhabitants and constant need for land, water, air and green areas, which will have to adapt to climate change, because they will be the ones subjected to risks and the most vulnerable.

The objective of the article is to outline a possible adaptation approach of the cities' territorial government activities. Thanks to the experiments carried out as part of the European *"SEAP Alps"* project, we will show how the analyses and techniques produced thanks to the use of *"new technologies*[2]*" (remote-sensing*[3]*)* are useful in developing information that can support the planning of "*climate proof*" territory. The aim of the work was the drafting of guidelines to implement adaptation topics into pre-existing plans such as the SEAP, which so far had always been directed only at mitigation. In the first part, the article will explain the connection between climate change and the city, stressing its characteristics and outlining its relationship with adaptation and resilience. In the second part, the "*SEAP Alps*[4]" project will be presented and the guidelines that have been developed in cooperation with ten Municipal Administrations of the Venice metropolitan area will be described. Finally, there will be an in-depth analyses of the process employed – through the *Remote Sensing* technique, informative levels were developed, useful for analysing the vulnerability of the territory to the effects caused by climate change. Such analyses were carried out in preparation for the identification of adaptation strategies.

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[1] With the publication of the '*Adapting to climate change in Europe – options for EU action*' (CEC, 2007) Green Paper and of the '*Adapting to climate change: Towards a European Framework for action*' (CEC, 2009) White Paper, the European Commission has recognised the need for an adaptation strategy for all Member States.

[2] *New technologies refer to Information and Communication Technology (ICT) and modern geo-referenced information management systems, i.e. geo-databases.*

[3] *Remote Sensing is the technical-scientific discipline whose purpose is to collect qualitative and quantitative information as regards objects through a sensor that measures the electromagnetic radiations emitted, reflected and transmitted by such objects.*

[4] *SEAP_Alps (http://seap-alps.eu/hp2/Startseite.htm) is supported and implemented by 12 partner countries from the Alps area. The objective is to experiment the integration of CC adaptation dynamics within the SEAP Plan, which at the moment only includes considerations as regards mitigation.*

1. Cities and climate change

In the last few years, the relationship between climate change and cities has become increasingly closer. There are several publications that stress the close link between the activities and lifestyle of those living in the city and greenhouse gas production, i.e. the main causes of the increase of the global average temperature (Rosenzweig *et al*., 2011; Musco, 2008), but there are also many publications that identify the cities as the places most vulnerable to the effects of climate change (Bulkeley e Tuts, 2013; UFPP, 2009). The risks caused by climate change have quadrupled in the past 30 years, causing both human and economic losses (UNISDR, 2012). These risks are also known as natural hazards and are generally attributable to extreme weather events such as: storm intensity, urban heat island, drought and flooding as well as sea level rise and coastal erosion (IPCC, 2007a). Historically, cities and urban areas have been perceived as a refuge from these calamities because they are far away from nature. Nowadays, however, they have become dangerous places and sources of disasters (UNDP, 2004; Pelling, 2003). In the light of this new perspective, cities become both a problem and a solution.
Carte et al. (2015) identify three main reasons for which cities occupy a central position in the implementation of adaptation measures:

- Urbanisation is the distinctive characteristic of the twenty-first century and the population residing in urban areas is destined to increase enormously in the next few decades;
- The design and planning of cities create unique microclimates that modify important variables such as temperature and wind (think about heat islands);
- Thanks to the low resilience of infrastructures, high density of population, large number of poor people and great concentration of economic and strategic sectors, cities are particularly vulnerable to climate change.

For all these reasons, it is essential to bring the adaptation question to the foreground as well as mitigation and to plan and work on an urban scale.

2. Adaptation, risk and urban resilience

In 2010, the "Cancun Adaptation Framework" implemented under the "UN Framework Convention on Climate Change" (UNFCCC) established that adaptation to climate change must be faced with the same priority level given to mitigation to reduce greenhouse gas emissions. Since January 2013, 15 EU Member States have adopted national adaptation plans and strategies. (European Commission, 2013a, 2013b).
But what does adaptation mean? The IPCC (2007b, p.76) defines it as:
«Initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects. Various types of adaptation exist, e.g. anticipatory and reactive, private and public, and autonomous and planned. Examples are raising river or coastal dikes, the substitution of more temperature-shock resistant plants for sensitive ones, etc».
In the past few years, adaptation has therefore become intertwined with the concept of "resilience". In fact, the support for the creation of a "*climate-resilient Europe*" is among the latest European Strategy objectives concerning adaptation to climate change (European Commission, 2013a). The concept of resilience ("climate resilient", "climate-proofing" and "resilient city" are increasingly common terms) has its roots in ecology, though it has recently taken on a wider connotation and has been adopted by many research sectors and traditions. (Zhou *et al*., 2010; Leichenko, 2010). The *United Nations Office for Disaster Risk Reduction* (UNISDR, 2012, p.92) defines it as such:
«Resilience means the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of the hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions».

"Resilience", i.e. the ability of any organism, individual or organisation to face and recover from the effect of an unsettling action, is opposed to vulnerability, i.e. those elements that favour the likelihood that a system suffers from damage (Graziano et al., 2013).
This way, the concept of adaptation is linked to a wide perspective of urban resilience. The assessment of risks and of the resulting vulnerability supports an adaptation approach in urban areas, where the identification and reduction of extreme event risks caused by climate change lower the frequency and/or intensity of shocks to the urban system (Carter *et al*., 2015).

3. The "SEAP Alps" Project

"SEAP Alps" is a European project co-financed within the "Alpine Space 2007-2013" Operative Programme with 12 partners from Italy, Austria, France, Germany and Slovenia. Its main objective is to promote the planning of sustainable energy at a local level sharing a common methodology among all partners. More in detail, the project aims to integrate adaptation into Sustainable Energy Action Plans[5] (SEAP) through the following actions:

- raise awareness of the long-term political component to produce and use energy in a sustainable manner and manage the consequences of climate change;
- favour the integration of different tasks in territorial government activities;
- develop a phase to analyse the vulnerability to climate change and combine it to the Baseline Emission Inventory (BEI);
- identify actions to manage and reduce vulnerability and combine them with actions to support energy saving and renewable energy;
- monitor the implementation and effects produced by such actions.

In this way, new SEAP countries will be able to consider actions to decrease CO2 production and increase renewable energy as well as to evaluate strategic actions to adapt their cities and improve their resilience to climate change.

3.1 Methodology

The project implements the "*SEAP Alps Methodology: Integration of adaptation in SEAPs"*, which contains the guidelines agreed upon by the partners to integrate the existing procedure - which only considers mitigation - with considerations on adaptation. The document defines mitigation as all those activities that can limit the effects produced by human activities on climate change[6], and adaptation as all those actions suitable to reduce the possible impact of climate change on the territory.
A specific methodology[7] was developed for the Venice province[8] starting from the general indications, in order to implement the integrated mitigation and adaptation approach on a local scale[9]. This methodology is based on 6 phases (tab. 1):

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[5] In 2008, after having adopted the "Climate and Energy" Package with which a reduction of greenhouse gas emissions by 20% by 2020 with respect to 1990 values was undertaken, the European Commission launched the new Covenant of Mayors project. Local signatory bodies undertake to reduce emissions and must draft a SEAP, a plan that outlines the actions and policies to develop to reach the objective established. For further information on SEAP in Italy and Europe, please refer to Magni e Musco, 2014.
[6] The IPCC (2007b, p.84) defines mitigation as: *«Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to Climate Change, mitigation means implementing policies to reduce greenhouse gas emissions and enhance sinks»*
[7] The methodology was developed by a working team from the Università Iuav di Venezia and the Envionmental Service of the Venice province with the active cooperation of 10 local municipal administration.
[8] The Venice province which, just like other nine provinces in Italy, is facing an institutional reorganisation towards a Metropolitan City.

- Phase 1: Analysis of PAT strategies. In this phase, the political agenda of the municipal administration is analysed using PAT strategic guidelines.
- Phase 2: summary of existing projects/actions. The projects/actions initiated on the territory by other public or private/public bodies are also briefly analysed in addition to the PAT strategies.
- Phase 3: Analysis of "new vulnerabilities". In this phase, the municipal territory is analysed to identify main/new vulnerabilities.
- Phase 4: new adaptation actions. In this phase, new actions to reduce vulnerability emerged during the analysis phase are proposed and built.
- Phase 5: identification of the planning tools that can best implement such actions. This is a very delicate phase – in addition to identifying the most suitable planning tool for each single action, the most suitable regulation system (bonus or restrictive) must also be selected.
- Phase 6: monitoring. The results of the implemented actions are monitored using suitable tools and technologies.

RECAP OF THE PROCESS						
STEP	1 ANALYSIS OF PAT STRATEGIES	2 SUMMARY OF EXISTING PROJECTS/ACTIONS/REGULATIONS	3 ANALYSIS OF 'NEW' VULNERABILITIES	4 NEW PROPOSED ACTIONS	5 TOOLS CONNECTED TO THE NEW ACTIONS	6 TYPE OF MONITORING/ MONITORING TOOLS
CONTENT	This phase considers the political agenda of the municipal administration put into effect in PAT general strategies.	In addition to PAT strategies, all projects/actions/regulations that other public or public/private bodies implemented are also listed.	Thanks to the technological support from the Venice Province, the municipal territory is analysed to highlight the main/new vulnerabilities.	Drafting of new actions to deal with the vulnerabilities identified by the new analyses.	Selection of the tools available to implement the new actions. - If needed, integration of the tools with bonus or restrictive systems	If possible, drafting of solutions to monitor the actions.

Tab.1. The table sums up the methodological steps identified in cooperation with the Venice Province and 10 Municipal Administrations (political and technical staff) of the future Venetian Metropolitan City.
Processed by Denis Maragno, Filippo Magni, Michele Dalla Fontana, Sara Verones, Giulia Lucertini, Francesco Musco.

The new process will be implemented alongside the existing procedure to draft SEAPs. This will make it possible to follow activities both during the drafting of SEAPs as well as where they have already been implemented. Technically, the territory vulnerability analyses will be added to the CO2 baseline emission inventory (BEI), which is useful to identify mitigation strategies. The aim of our methodology is to develop evidence-based climatic planning to help policy-makers during the decision phase. In fact, thanks to the risk and vulnerability assessment, a territory is zoned according to the possible impact of

[9] In April 2014, the need for an approach that combined mitigation and adaptation strategies was met at a Community level thanks to the Mayors Adapt initiative, which integrates the Covenant of Mayors.

climate change on the various urban areas. In this way, areas are ranked according to their vulnerability level, to highlight those where intervention is a priority (Maragno *et al*., 2014).
Special attention was paid during their development to favour the cooperation and integration between the tasks and actors who live in the territory.

3.2 New technologies for territorial analysis

The main problem during the analysis of the vulnerability to climate change of a territory is posed by an unsuitable knowledge base to support the process. Usually the Public Administration does not have the necessary information bases because it is not included in current planning tools. Information such as m2 of vegetation, height of plants, solar incidence, private and public soil permeability, etc. is hardly available at a municipal level. To solve this problem, it is possible to use *new technologies*, which can be classified as *ICT* (Information and Communication Technology) as they enable the creation of suitable territorial and environmental information.
As part of the project, the Province of Venice obtained extremely innovative data through an aerial survey[10] (covering 3000 Km^2 i.e. the entire province). The survey made it possible to collect 4,000 high-resolution images that, thanks to the *Dense Image Matching*[11] technique, enabled the creation of a 3D digital model of the area (Hirschmuller, 2008).
The data acquired guarantee the possibility of generating high-resolution raster images - DSM (*Digital Surface Model*) and DTM (*Digital Terrain Model*) – with a precision of 25 cm (Pixel 0.25 m). The DSM reports the altimetric data of all natural and man-made elements in a specific area, while the DTM reports the morphology of the territory without man-made creations and vegetation. This process allows us to collect information at a cost that is 10-fold less than with other methods such as LiDAR.
These models and the precise information they contain enable us to create new information, analyses and thematic visualisations such as:

- Surface composition (distinguishing whether it is permeable or not every 0.25 m), height and volume of urban buildings;
- Energetic potential of buildings with renewable sources (Wilson *et al*., 2000);
- Roof slope and orientation;
- Potentially floodable areas;
- Visualisation and calculation of waterproof areas;
- Assessment and mapping of urban green (public and private) and its relative height;
- *sky view factor*[12].

These technologies make it possible to create a digital atlas that can distinguish permeable and impermeable areas every 25 cm. In addition, thanks to the third dimension, it is possible to calculate the volume of natural and man-made areas. Furthermore, on top of analysing vulnerability, indicators such as the Sky View Factor, solar incidence, permeability/impermeability ratio, density etc. will support the drafting of adaptation and mitigation strategies.
Urban classification divides the urban fabric into classes using a hexagonal grid, which highlights which hexagons are subject to water vulnerability and heat accumulation (figure 1).
If you look at fig. 1, you can clearly see how well vulnerability is highlighted (hexagons with a well-defined perimeter).

[10] Survey carried out by UniSky, spin-off of the Università Iuav di Venezia.
[11] Before a 3D model using “Dense Image Matching” (*DIM*) is produced, an aerial survey overlapping the images both transversally and lengthwise is created. In the second phase, a state-of-the-art software (based on the DIM algorithm) can be used to extract 3D points through the identification of correspondences between the primitives extracted in two or more images.
[12] The Sky-View Factor (SVF) indicates the fraction of sky visible from an observation point. The higher the SVF the greater the heat loss. For example, a narrow and deep valley has a low SFV and therefore reduced night-time cooling, whereas a plain has a high SVF and is subjected to greater cooling.

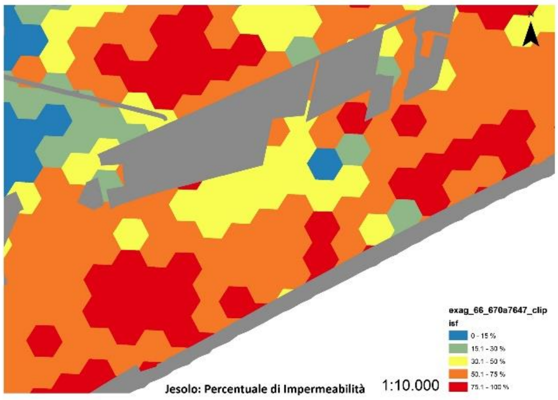

Fig. 1-2. The images show the results obtained with the remote sensing technique. The information obtained via the processing of DIM data (Dense Image Matching, with a precision of 75 cm) has been processed and integrated into hexagonal grids (of different sizes, ranging from 6 to 130 metre-long sides, divided using an automated calculation process). This way, it is possible to visualise and obtain environmental and territorial information for every single cell in different scales. The technique was studied to make it easier to read information (using a colour-coded grid) and to help the decision process.
In the example, part of the urban impermeability analysis.
Processed by Denis Maragno

These kind of outputs are available for the entire municipal area. Thus, we are able to represent, with easily understandable maps, the territorial areas with a high impermeability percentage (fig.3), useful to identify where actions are required firstly in order to handle issues related to runoff. Figure 4 instead portrays the opposite information, which is the areas classified by the permeability percentage. Figures 3-4-5 provide us with information helpful to deal with water issues, whereas maps such as one in figure 5, which describes the urban volumetric concentration, is useful to identify areas with possible cases of overheating (Urban Heat Island). This kind of phenomena is indeed more frequent in areas with high concentration of buildings.
This kind of knowledge is provided by a public administration, the Province of Venice in this case, therefore any information are available to the public and particularly to the local authorities operating in the provincial territory. The layout (grid of colours) of the vulnerabilities analysis it was thought to be easily understandable by a wide public, not only technicians.

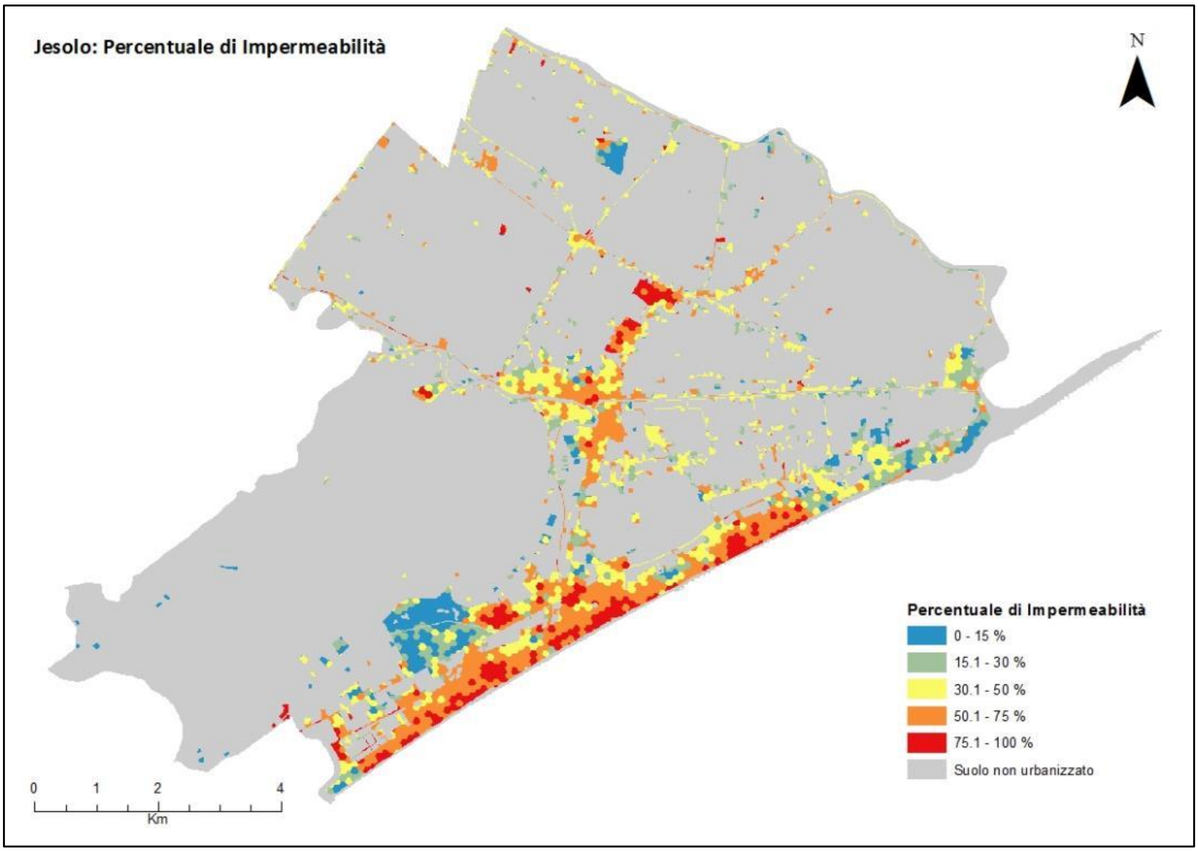

Fig. 3. Urban impermeability map - Processed by Denis Maragno

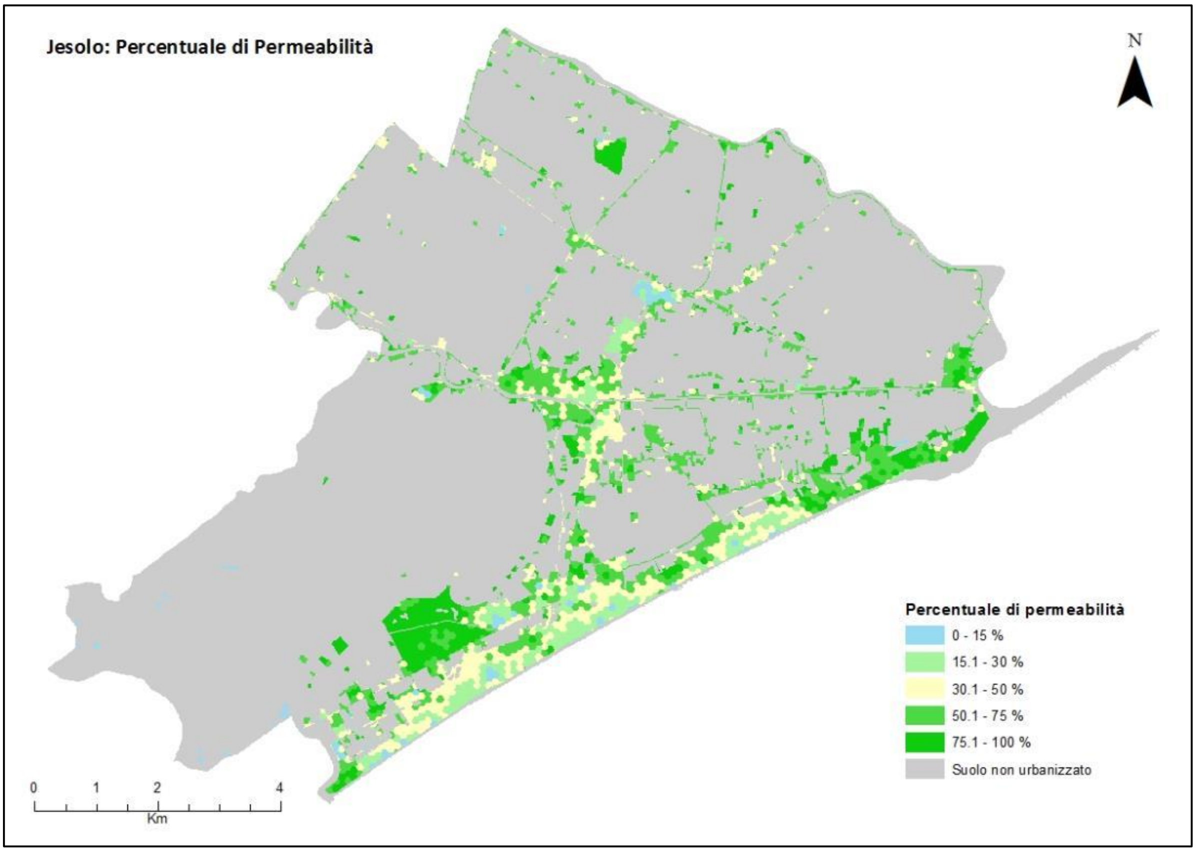

Fig. 4. Urban permeability map - Processed by Denis Maragno

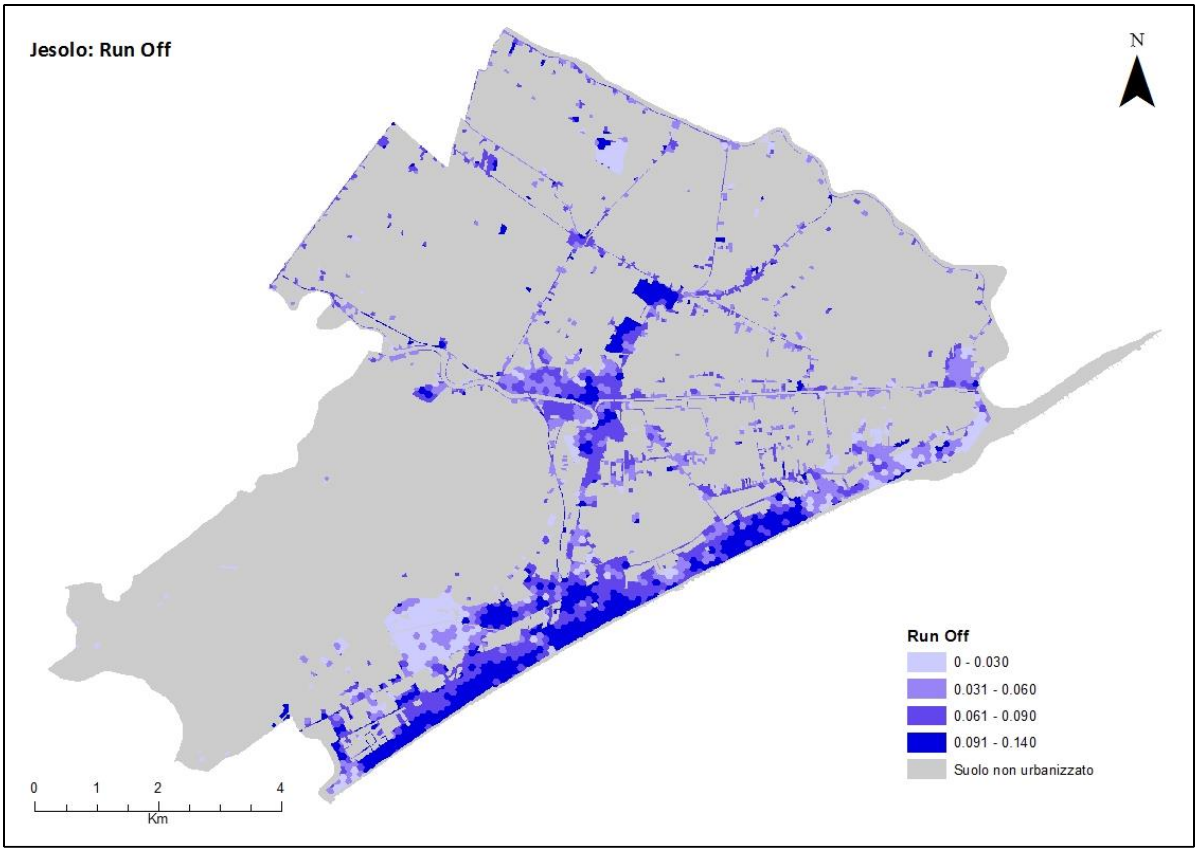

Fig. 5 / Map of the possible run-off with a precipitation of 75 mm of rain in half an hour - Processed by Denis Maragno

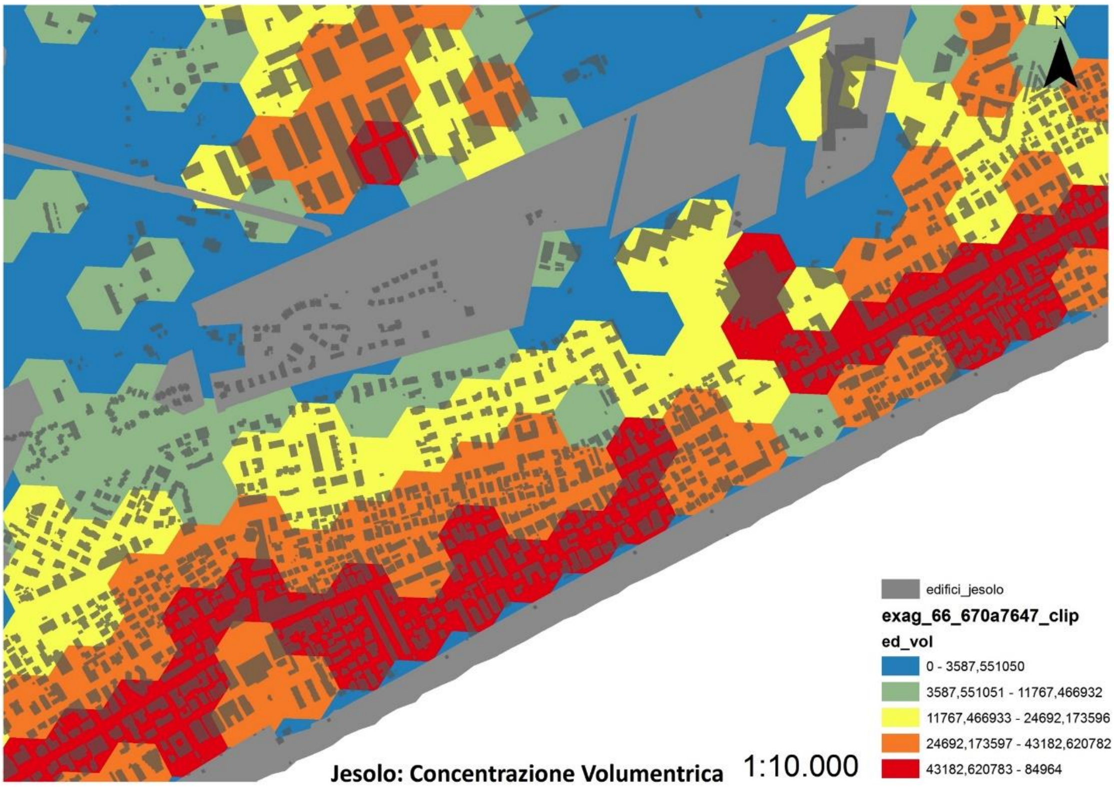

Fig. 6 / Urban volumetric concentration map - Processed by Denis Maragno

3.3 Expected Results

The new SEAP must and will consider strategies to reduce risk exposure and increase urban resilience to risks connected to climate change. These kind of analyses, as well as almost all initiatives related to climate change, are not compulsory. It is therefore important the sensitivity to the topic by local governments and their willingness to cooperate. This type of analysis is important also to make local authorities aware of possible vulnerabilities affecting their territory. At this point, the actions will be divided into:

- structural or steering actions, aimed at avoiding or reducing risk exposure (building standards, green roofs for the protection against global warming and to re-use water, green infrastructures, etc.);
- actions to raise awareness and involve citizens;
- actions deriving from the use of the ICT technology, useful to increase the collection, analysis and sharing of information.

The project has now reached its conclusive phase. The working group is now involved in working tables with the Province of Venice and the Municipalities of the metropolitan areas to draft the first technical attachment concerning the adaptation to climate change.

4. Conclusions

Climate change and the adaptation to its consequences are destined to remain among the most urgent questions in cities and urban areas over the next decades (Carter *et al*., 2015). It is therefore essential to develop systems and methodologies that can analyse, assess and support policy-makers in the development of policies, plans and actions to counter not only climate change in general, but also its most immediate effects. To do so, an in-depth knowledge of the territory and its socio-economic systems is essential as well as the tools currently in use. Mitigation and, even more so adaptation measures, will be more effective with a higher integration of existing regulation and strategic frameworks, with no need for radical changes or additional bureaucracy. Mitigation and adaptation actions are usually not compulsory; the aim of this project was indeed to draft a process in which specific actions to contrast climate change are integrated into the regular planning tools. New technologies played a key role to make visible the vulnerabilities and risks to the local authorities.
Thanks to the cooperation among technicians, the scientific apparatus (university) and public administration, the experience gained during the project has indicated that there is a way to adapt to climate change. Municipalities, institutions and associations welcomed the work carried out, so much so that we can hope for future collaboration. By continuing on this path, it will be possible to encourage sensitivity towards an integrated approach to climate change more effectively which, now more than ever, needs the direct involvement of local administrations and the population.

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