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Brief

Vulnerability assessment and Information and Communication Technology (ICT) to drive climate-proof planning

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Abstract

FEEM Policy Brief

Climate change is one of the most complex issues of the 21st century, and the magnitude of the problem is globally recognized and largely discussed both in the academic and political arena. Climate-proofing cities require substantial modifications in planning, design and management approaches. That includes the strategies to reduce climate change emissions and to make urban systems more resilient to climate change effects (Musco, 2014).
More fine-scale pieces of information are necessary to produce more detailed analysis. In particular, Remote Sensing Technologies are particularly suited to produce an information framework that can support climate-proof planning processes. The general inadequateness of the available data is the major obstacle in developing those vulnerability assessment. For this reason, Public Administration might find it worthwhile to overcome the concept of information ownership, preferring to adopt a new model based on knowledge resources sharing. This paradigm presupposes the involvement and the cooperative participation of citizens, academia and private enterprises with a common objective orientation. Therefore, building an innovative knowledge framework and a reliable network should be the first step to develop a shared and integrated climate-proof planning.

01

Introduction

Climate change is by now recognized, not only by the scientific community, as one of the main causes of a range of shocks and stresses that humankind must be prepared to address at different scales in the near future (Leichenko, 2011). Climate change issues have been treated with a focus on global and national levels through international agreements and the reduction of greenhouse gas emissions has been the only answer taken into account over a long period. The implementation of adaptation strategies and mitigation actions has now become extremely urgent, and cities are increasingly at the forefront in taking action in mitigating and adapting climate change. Considering the amount of energy-related carbon emissions produced in urban areas, cities have a central role in mitigation strategies. Still, at the same time, they are particularly vulnerable to the effects of climate change (Rosenzweig, 2011) due to the concentration of economic activities, infrastructure systems, social services, population growth, poverty, and pollution.

Planning and design of cities need to be linked to climate concerns (Rosenzweig, 2010) to produce urban settlements with less impact on the climate but resilient to its effects. The issues that connect climate change and cities are so variegated that integrated approaches, inspired by a broad range of disciplines, are required.

Two issues concerning climate change adaptation emerge very clearly in urban areas: urban heat island (UHI) and stormwater management, the latter has become a pressing topic in Italy over the last years, since the number and frequency of extreme rain events increased. Both of them, although very different in their manifestations, arise from common causes such as the high level of impermeable surfaces in the urban fabric.

Urban heat island effect is also caused by different thermal and radiative properties of the urban construction materials, and possible mitigation strategies indicate the increase of green areas to reduce the local temperature (Takebayashi and Moriyama, 2007; Susca et al., 2011). On the other hand, tackling the stormwater issue in urbanized areas often involves “hard” solutions such as improvements in drainage systems or concrete channels, but stormwater problems come up not only because of the intensity of rain events, but it is also strongly linked to surface characteristics. This means that changing land cover in strategic locations through the implementation of “soft” solutions could be a viable alternative not only to deal with stormwater but to involve a range of co-benefits as well. For example, green infrastructure uses vegetation, soil and natural processes to infiltrate and rainwater evapotranspiration(Vineyard et al., 2015) and can be implemented as an addition or as a replacement to the more traditional grey infrastructure. Green infrastructures have the potential to reduce the environmental impacts of grey infrastructure, improve water and air quality (ibidem), sequester CO2 and reduce the urban heat island effect (Odefey et al., 2012). Green infrastructures may also slow the flow of stormwater to streams to restore stream health (Vineyard et al., 2015; Stephens et al., 2012).

02 ICT and knowledge management for climate change adaptation

To study the adaptation of the territory to climate change effects (such as heat, water, erosion, etc.), we have to consider three main issues:

- Which information do we need?
- How can we build the information that we do not have?
- How can we produce spatial knowledge?

One of the main problems that emerge during the analysis of the vulnerability caused by climate change is the unsuitable knowledge on which the process is based. The data normally processed by public authorities in the processes of land management never include useful variables to identify the vulnerability produced by climate change (Maragno, Musco, 2014). To find solutions to the urban flooding problem, but also to define the urban microclimate as well, we need to increase the spatial knowledge of the city, having available information such as (Stewaed, Oke, 2006):

- m^2 of vegetation;
- height of the vegetation;
- percentage of paved grounds;
- sloping surfaces;
- sloping roof;
- Sky View Factor;

Urban adaptation solutions, as evidenced by figure 1, are not difficult to choose. Instead, problematics arise in the process of identifying the best infrastructure solution to match up with specific urban areas to obtain the greatest efficiency from the intervention.

VULNERABILITY	GOAL	TARGET	ACTION
Urban Heat Island	Increase natural ventilation	Reduce stored heat	Green corridors
		Reduce Stored heat/Teduce Incident Radiation	Modify building geometry (average height and canyon width ratio)
	Temperature decrease		Increase surface building reflectance and emissivity
			Increase paved surface reflectance and emissivity
		Reduce Incident Radiation	Increase green shading
		Reduce Bowen Ratio (transformation of sensible heat to latent heat)	Preserve woodlands, parks and not built areas
			Increase green surfaces - roofs and walls
			Increase Green grounds
			Reduce impermeable pavements
	Energy efficiency	Reduce anthropogenic flow	Action in Mitigation Plan
Difficult run off	Integrated storm water management (hydraulic invariance)	Increase of surfaces' permeability	Wells and infiltration trenches
			Reduce impermeable pavements
			increasing green grounds
		Increase of the concentration time of the drainage systems	Wetlands (ditches and grassy plant filter)
		Separation of the first rain water	Create storage areas
			Lagoons retention tanks
		Increase of the concentration time of the drainage system	Create artificial lake
			Monitoring Interception organs

Figure 1. *Example of the possibility of actions in high-density urban areas. (Product by Denis Maragno, Filippo Magni, Francesco Musco, 2014).*

Selecting the location for adaptation measures requires a deep knowledge of the area and the kind of information and the level of detail needed are often not available.

Proceeding with the identification and selection of adaptation strategies becomes important to make an analysis capable of identifying all the vulnerable elements to understand its resistance to external shocks.

The goal of the work is to support and facilitate the Climatic Integrated Planning in the government of the territory activities at local and metropolitan scales.

The work is then geared to the definition of innovative methodologies that can produce spatial information currently not available (such as m^2 of vegetation, the height of trees, solar incidence, sky view factor, and slope surface, etc.) utilizing remote sensing analysis and ICT (Information and Communication Technologies).

The new information produced is managed and organized by last-generation open source software focused on the processing of spatial data to maximize information sharing and to increase the analytical capacity of local governments.

The study produces a methodology that can be exportable to other cities, able to build new territorial and environmental information, to organize and encourage integrated decision-making and promote social innovation, exploiting ICT technologies.

03 The Remote Sensing Analysis to improve the urban spatial information

The study of analysis methodology was starting trough collaboration with the Metropolitan City of Venice. The Metropolitan City of Venice obtained extremely innovative data through an aerial survey (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 technique, enabled the creation of a 3D digital model of the area (Hirschmuller, 2008).

The data acquired guarantees the possibility of generating high-resolution raster images: DSM (Digital Surface Model) and DTM (Digital Terrain Model), each with a precision of 25 cm (Raster 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.

These models, and the precise information they contain, enable us to create new information, analyses and thematic visualizations 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;
- Visualization and calculation of waterproof areas;
- Assessment and mapping of urban green (public and private) and its relative height;
- Sky View Factor.

All such information layers can be converted to vector information. By GIS (geographic information system) is possible to use vector data to process, query and share information by Shapefile. For example, it is possible to create a Digital atlas that can distinguish permeable and impermeable areas every 25 cm. Furthermore, thanks to the third dimension, it is possible to calculate the volume of natural and man-made areas. On top of analyzing vulnerability, indicators such as the sky view factor, solar incidence, permeability/impermeability ratio, density, etc. will support the drafting of adaptation and mitigation strategies.

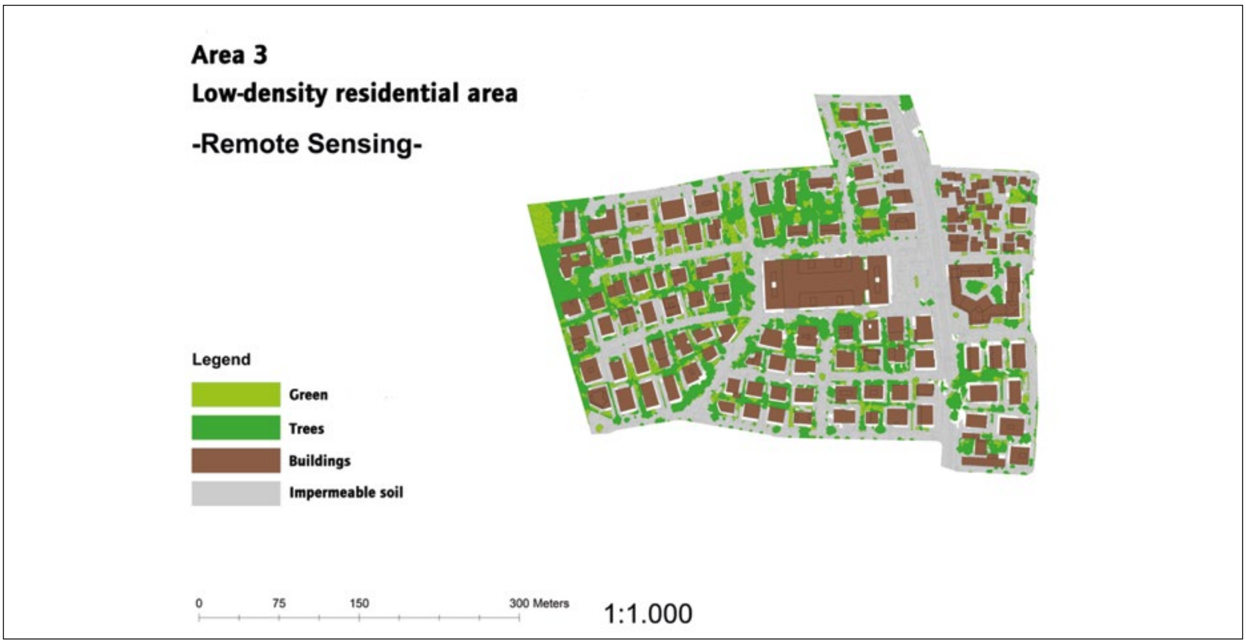

Figure 2. *Map of permeability and waterproof zones. The technique used has allowed dividing the surface area through an automated process. The remote sensing analysis has enabled the creation of a detailed atlas of surfaces useful not only for studies on the Urban Heat Island but also suitable to support the analyzes of the hydrological risk and evaluate urban ecosystem services; to facilitate multi-functional adaptation actions (Elaborated by D. Maragno)*

04 Remote sensing, ICT, and knowledge management for the climate change adaptation

Land development and urbanization alter and inhibit the natural hydrologic processes of surface water runoff patterns, infiltration, percolation to groundwater and evapotranspiration. In undeveloped land, up to half of the annual rainfall infiltrates through the soil and percolates downward where portions of it can recharge the groundwater or provide base flow to streams (Dorman 2013). In contrast, developed areas can generate up to five times the annual runoff and allow one-third of the infiltration of natural areas (USEPA 2005). One of the main indicators of this change is the permeability rate: cities and their surroundings are almost totally covered by impervious surfaces. Fine-grained spatial mapping identifies these clusters of impervious surfaces to be able to shape strategies tackling specific vulnerabilities of the urban fabric and of the watershed. Layers of information such as vegetation coverage and height can be interlaced with fabric elevation, land use and soil characteristics to shape a model that simulates predicted precipitations patterns.

Conventional stormwater management systems rely on hard infrastructures that convey runoff rapidly from developed surfaces into drainage systems, discharging large volumes of stormwater and pollutants to downstream water bodies. As a result, stormwater runoff from developed land is a significant source of many water quality, stream morphology, and ecological impairments (Dorman 2013).

While in rural areas impervious surfaces represent only 1% or 2%, in denser residential areas increases from about 10% in low-density suburban areas to over 50% in multi-family housing communities. In industrial and commercial areas, impervious coverage rises above 70%, and in dense metropolitan areas, it is over 90%. (Schueler 2000) Reducing the overall imperviousness and using the natural drainage features of a site are fundamental objectives when developing or retrofitting urban portions to enhance the site's hydrologic characteristics. This can be achieved by applying Low Impact Development (LID) stormwater management strategies. LID, which works to replicate predevelopment, natural hydrologic processes and reduce the impacts of urban development on runoff patterns, has emerged as an alternative stormwater management approach that is complementary to conventional stormwater management measures. (Dorman 2013) LID strategies are structural stormwater and planning techniques to reduce impervious surfaces and infiltrate, evaporate, and store stormwater runoff directly on-site. They use native or improved soils, vegetation, and bioengineering. The ideal solution is often made up of several methods appropriately linked (Woods-Ballard 2007), aiming to manage stormwater as close to the source as possible, taking advantage of site-specific characteristics and vulnerabilities.

Site analysis, site planning, and on-site stormwater management guide the implementation of sustainability even in denser urban settings. Managing stormwater with green infrastructures also addresses positive effects on the city's local climate, increasing infiltration and evaporation that tackles Heat Island Effects.

Figure 3. *Example: Tree Box, Portland, Oregon, US*

Policy Conclusion

How to make our cities more resilient to the effects of climate change is one of the main challenges of the 21st century. Planning properly new urban areas and retrofitting what already exists will play a key role. Concerning urban solutions to the climate change effects, and particularly dealing with stormwater management, we highlight the benefits arising from a variety of “soft” non-invasive measures, which work together in a systemic way, rather than revolutionary changes in the infrastructure system. Green infrastructure can be a valid alternative, or at least a complementary option, to more traditional grey infrastructure in managing stormwater. Additionally, Low Impact Development strategies have several co-benefits that allow solving different problems with the same unique action. For instance, issues deriving from stormwater management and urban heat island both are related to a high rate of impermeable surface in the urban texture: greening the city, already proven as a valid solution to reduce urban heat problems, can be shaped and locate to infiltrate and store urban stormwater runoff. To make these solutions work as their best, it is fundamental to analyse spatial data to take action as close as the cause as possible. Unfortunately, detailed territorial information useful to spatially identify these causes is usually not available. This gap can be filled with the aid of new technologies through which we can obtain an integrated framework of knowledge useful to point out priority areas on which to intervene. Data acquired by new technologies help to tailor the right solution for each vulnerable area identified. Besides, it allows establishing a methodology of territorial analysis replicable in different contexts, and that produces a set of information useful for a constant monitoring process and comparison with other cases.

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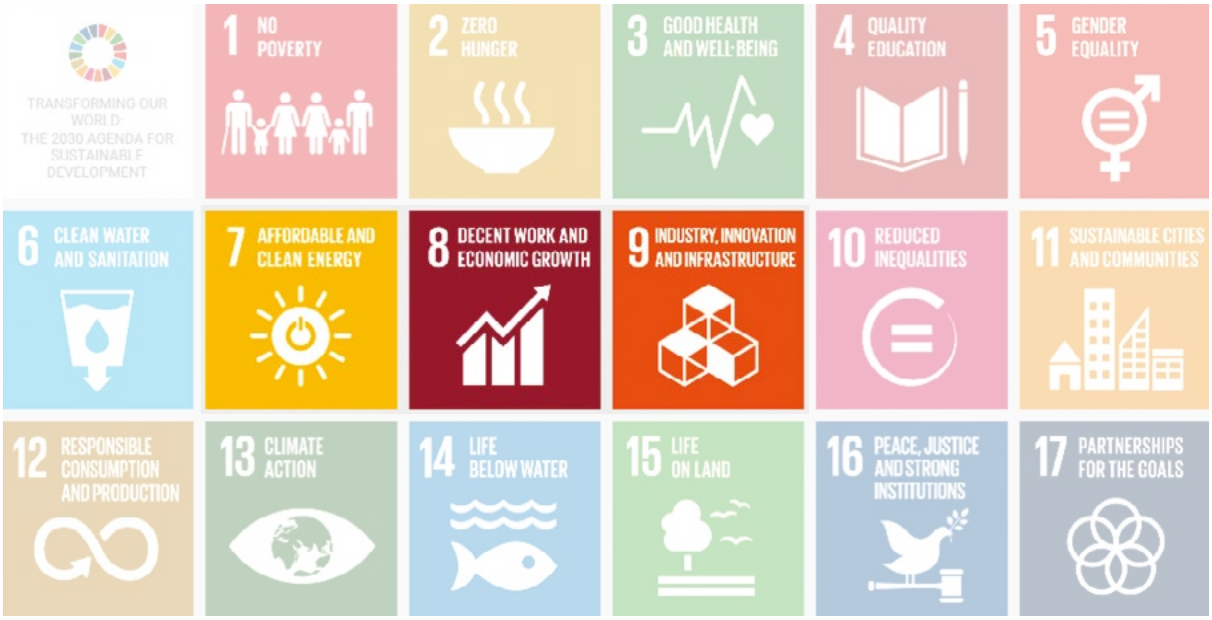

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