Sustainable Cities and Society xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Sustainable Cities and Society

journal homepage: www.elsevier.com/locate/scs

An analysis of the urban heat island of Venice mainland

F. Peron, M.M. De Maria*, F. Spinazzè, U. Mazzali

Building Physics Laboratory, 30172 Università Iuav di Venezia, via Torino 153/A Venezia, Mestre, Italy

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Urban heat island
Micro-climatic simulation
Mitigation strategies

ABSTRACT

In Italy, as in the rest of Europe, serious land degradation processes are occurring, mostly due to rural abandonment, urbanization and infrastructure development. In particular Veneto, the region around Venice, has undergone considerable land use and land cover change in the last decades. This work integrates field observations and numerical simulations to study the urban heat island (UHI) effect in the mainland part of Venice. The numerical study was performed using ENVI-met, an environment and micro-climatic simulation tool. Different mitigation scenarios are evaluated in a case study area. The study aims to explore the factors that contribute to urban heat island development proposing practical, feasible and specific solutions for mitigating their effects. The focus of the analysis is, in particular, on the use of permeable surfaces vegetative soil or grassed parking instead of conventional asphalt or cement pavement as soil compensation mechanisms for soil loss. The replacement of traditional roofs with cool or green ones is also considered.

1. Introduction

In 2010, a fraction of the world's population larger than 51% was living in urban areas, with a much higher fraction (68.2%) in Italy, and these percentages are expected to rise in the future (United Nations Secretariat, 2012). This growth of urban population affects the soil use and consequently the urban climate. A recent report, presented by the Italian Institute for Environmental Protection (ISPRA), shows that the loss of rural land in Veneto Region from 1994 through 2006 amounts to 2400 km^2 and puts it in the second place in the ranking of the Italian regions with the highest rates of building (ISPRA, 2014). The Veneto Region is now a hybrid territory of countryside having a couple of cities, some towns and an incredibly wide and dense semi urban area. It is well known that in a city the atmospheric conditions are quite different compared to the surrounding rural environment. In urban areas, buildings, roads and paved surfaces store heat during the day. The surface heating throughout an entire area involves global increase in air temperature, typically on the order of 2 °C, but extremes as high as 8 °C have been recorded (Taha, 2004). This is the 'urban heat island' effect, which is usually ascribed to many physical differences between urban and rural areas (Oke, 1982): absorption of solar radiation, heat storage of structures and streets surfaces, and obstacle of re-radiation by buildings and in air circulation, insufficient evapo-transpiration of water from soil for the deficiency of vegetation.

Many studies on UHI have been conducted worldwide, and recently also in Italy, especially in the large cities as Milan, Genoa, Bologna, Florence and Rome (Bertocchi et al., 2011; Maggiotto et al., 2014; Perini & Magliocco, 2014; Zauli Sajani & Scotto, 2006; Petralli et al., 2006; Pichierri, Bonafoni, & Biondi, 2012; Zinzi & Agnoli, 2012) investigating in particular the impact of stressful meteorological conditions on health problems. The European Project UHI (UHI, 2014), launched in 2011, analyses the phenomenon in the metropolitan cluster of Bologna–Modena and in the urban corridor of Venice–Padua with the aim of preventing risks developing mitigation and management strategies. In particular, the University of Padua has been observing, since 2010, UHI effect on Padua (Busato, Lazzarin, & Noro 2014). Padua is a city located 40 km west of Venice, a bit far from the sea, and has a humid climate, with some continental characteristics: hot, humid summers and cold, wet winters. The results of a campaign of measurements performed in July and in August 2012 by a mobile meteorological station indicate UHI intensities of 1–7 °C during the night and a small effect (0–2 °C) during the day. In the mainland of Venice the climate is considered instead a climate of transition between the continental and the Mediterranean, because it is mitigated by the proximity to the sea (the minimum winter temperature is about 1 °C and the maximum in summer is about 28 °C). No studies on UHI effect have been conducted in the mainland of Venice, a territory heavily polluted by vehicular traffic and industrial emissions.

The climate effects associated with urban heat islands can adversely affect the health of the population. Therefore, a method

* Corresponding author. Tel.: +39 0412571234.
E-mail address: michela.demaria@iuav.it (M.M. De Maria).

http://dx.doi.org/10.1016/j.scs.2015.05.008
2210-6707/

of mitigating UHI known to be effective is to increase areas of green space, which lowers ambient temperatures mainly through increased evaporative cooling (Rosenfeld et al., 1995). Moreover, the albedo of a city may be increased gradually replacing dark materials surfaces with high-albedo surfaces as cool roofs and cool pavements (Prokop, Jobstmann, & Schonbauer 2011; Bowler, Buyung-Ali, Knight, & Pullin, 2010).

The aim of this study is to examine the urban heat island effect in Mestre, the part of Venice on mainland, and to evaluate the effects of the mitigation strategies. The work consists of two parts. In the first a set of climate data, collected from a range of weather stations, are analyzed and used to evidence the UHI phenomenon. In a second part a numerical analysis is performed to evaluate and quantify the possible additional benefits of large-scale use of roofs with both high reflectivity and high thermal emittance (cool roofs) and pavements that combine reflective materials and high water permeability (cool pavements). The micro scale climate model ENVI-met v3.1 (Huttner & Bruse, 2008; Bruse, 1999, 2004; Bruse & team, 2006) was used to simulate an area in Mestre that has undergone a rapid and chaotic urbanization associated with the industrial expansion in mid to late 20th century.

2. Methods

2.1. Study area

This study is conducted on an urban zone of Mestre (45.49° N, 12.24° E), the town located in the northeast of Italy on the mainland opposite the islands of Venice. The municipality of Venice covers the historic city centre, a number of islands in the lagoon, and Mestre-Marghera, a large urbanized and industrial area on the mainland, where most of services and trade centres are located and most of the population lives. Mestre, connected to Venice by rail and road bridges over the lagoon, is administratively a part of Venice: despite of this, it has history as a separate town, and it has a very different character. The history of Mestre goes back to the Middle Age, though it was always overshadowed by its powerful neighbour Venice. In 1791, Carlo Goldoni described Mestre as a little Versailles,[1] as it was a fashionable country resort, site of middle class's country estates for their annual excursion from the city of Venice. Then, since the eighteenth century, the site has undergone a series of dramatic transformations. After the Second World War, the whole mainland area around Mestre underwent a massive, rapid and disordered process of economic and urban growth. This development reached its maximum between the 1950s and 1970s due to the proximity of Porto Marghera, the port and petrochemical complex that lies on the northwest side of the lagoon, and for the demographic shift of many Venetians to the mainland (due to the high cost of housing and consequent evictions). In Mestre the modernization has been hasty, heavy and widespread: in the 1970s the urban population increased dramatically reaching a peak of 210,000 inhabitants in 1975 – they were 20.597 in 1901 and 97,000 in 1951 (Comune di Venezia, Servizio Statistica e Ricerca 2013); the industrial plants area expanded to 20 km^2 giving job to more than 30,000 people; the ring road, a 6-lane motorway, 8 km long, passes through the urban centre and became the most heavily travelled stretch of motorway in Europe (about 150,000 vehicles a day and peaks during summer of over 170,000); finally, the airport grew to be the third largest in Italy for passenger volume. Invisible on maps, Mestre has been marked as "Venice's suburb" or "the ugliest city in Italy". Nowadays, mainly because of the decline of the industrial site, the population has dropped to 180,000, about two thirds of the entire population of Venice municipality. In 2009 a widened motorway was opened diverting the congested European flow of east–west traffic. There is a very strong transformation underway in the area. The territory is undergoing some development and renovation projects combined with a new ecological trend (36 m^2 of parkland per inhabitant) could be an opportunity to provide sustainable regenerative solutions for helping urban areas to adapt to climate change, to weather events, and improve public health and well-being.

The climate of Venice has a seasonal pattern: temperature rises in summer and contributes to increasing levels ambient temperatures, demands on cooling systems, and health problems related to both mixing and dispersion of pollutants. Several studies have shown that the local topography and meteorological conditions, natural and anthropogenic emissions and regional transport processes, make this area one of the most polluted in Europe (Pecorari et al., 2013).

2.2. Experimental analysis

Mestre is limited on the southeast by the lagoon, while in the north and north-western part the limit is given by a series of suburban centres. For the southern part, the border is marked by the Northern Industrial Channel of Porto Marghera. A satellite view of the area is shown in Fig. 1. With the aim to determine the spatial extent of the urban heat island in Mestre, temperature data collected by meteorological stations in the area (managed by ARPAV, the Regional Agency for Environmental Protection, and by the Italian Air Force) are analyzed. The location of each station is marked with a push pin.

Fig. 2 shows the behaviour of air temperature in the area of Mestre over the period from July 1st to August 31st 2012 using data from 3 weather stations distributed in the city centre (Parco Bissuola, via Torino and Marghera), and from one in a rural area (Favaro, 4 km east of Mestre) (ARPAV Dipartimento per la Sicurezza del Territorio Centro Meteorologico 2012). The weather station of via Torino is installed on the roof of the two-store edifice of the Building Physics Laboratory of University Iuav di Venezia (Laboratorio di Fisica Tecnica Ambientale 2012). The lowest and highest mean daily temperature of 19.3 °C and 28.9 °C is observed at Favaro and Mestre respectively. Moreover there are two periods of high temperatures (above 26 °C), one on late July to early August, another lasting ten days in the middle of August, each one followed by a rapid temperature drop of 5 °C and 8 °C. To better visualize the temperature differences among the sites and highlight the heat island effect, the rural Favaro station was used as reference to calculate the difference of mean daily temperature ΔT. Results are plotted in Fig. 3. The difference ΔT between the rural site and urban sites is highest (2.5 °C on August 28th) at via Torino. Via Torino is in the centre of Mestre and this area is mostly covered by buildings and thermally-absorbent artificial materials, confirming the "urban heat island effect". The difference is most of the time lower between Favaro and Marghera, a low-density residential area.

As the UHI effect exhibits diurnal variations, most intense at night (Oke, 1982), this analysis focused on the data of mean temperature collected at night-time in the range between 9:00 pm and 3:00 am (Fig. 4). In this case, the temperature difference ΔT (°C) between urban areas in Mestre (Parco Bissuola and via Torino weather stations) and the surrounding suburban or rural areas of Favaro Veneto, is on average always greater than 4 °C, and sometimes reaches values greater than 7 °C (Fig. 5). In particular the highest temperature difference $\Delta T = 7.33$ °C is recorded on August 21st in via Torino weather station. The lowest temperature difference ΔT, about 0.53 °C, is on August 6th in Marghera weather station.

[1] in La cameriera brillante, "The Brilliant Maidservant".

Please cite this article in press as: Peron, F., et al. An analysis of the urban heat island of Venice mainland. Sustainable Cities and Society (2015), http://dx.doi.org/10.1016/j.scs.2015.05.008