This special issue collects a selection of peer-review papers presented at the 8th International Conference INPUT 2014 titled “Smart City: planning for energy, transportation and sustainability of urban systems”, held on 4-6 June in Naples, Italy. The issue includes recent developments on the theme of relationship between innovation and city management and planning.

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SMART CITY
PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM
Special Issue, June 2014

Published by
Laboratory of Land Use Mobility and Environment
DICEA - Department of Civil, Architectural and Environmental Engineering
University of Naples "Federico II"

TeMA is realised by CAB - Center for Libraries at "Federico II" University of Naples using Open Journal System

Editor-in-chief: Rocco Papa
print ISSN 1970-9889 | on line ISSN 1970-9870
Lycence: Cancelleria del Tribunale di Napoli, n° 6 of 29/01/2008

Editorial correspondence
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University of Naples "Federico II"
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80125 Naples
web: www.tema.unina.it
e-mail: redazione.tema@unina.it
TeMA Journal of Land Use, Mobility and Environment offers researches, applications and contributions with a unified approach to planning and mobility and publishes original inter-disciplinary papers on the interaction of transport, land use and environment. Domains include engineering, planning, modeling, behavior, economics, geography, regional science, sociology, architecture and design, network science, and complex systems.

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SMART CITY. PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM

This special issue of TeMA collects the papers presented at the Eighth International Conference INPUT, 2014, titled “Smart City. Planning for energy, transportation and sustainability of the urban system” that takes place in Naples from 4 to 6 of June 2014.

INPUT (Innovation in Urban Planning and Territorial) consists of an informal group/network of academic researchers Italians and foreigners working in several areas related to urban and territorial planning. Starting from the first conference, held in Venice in 1999, INPUT has represented an opportunity to reflect on the use of Information and Communication Technologies (ICTs) as key planning support tools. The theme of the eighth conference focuses on one of the most topical debate of urban studies that combines, in a new perspective, researches concerning the relationship between innovation (technological, methodological, of process etc..) and the management of the changes of the city. The Smart City is also currently the most investigated subject by TeMA that with this number is intended to provide a broad overview of the research activities currently in place in Italy and a number of European countries. Naples, with its tradition of studies in this particular research field, represents the best place to review progress on what is being done and try to identify some structural elements of a planning approach.

Furthermore the conference has represented the ideal space of mind comparison and ideas exchanging about a number of topics like: planning support systems, models to geo-design, qualitative cognitive models and formal ontologies, smart mobility and urban transport, Visualization and spatial perception in urban planning innovative processes for urban regeneration, smart city and smart citizen, the Smart Energy Master project, urban entropy and evaluation in urban planning, etc..

The conference INPUT Naples 2014 were sent 84 papers, through a computerized procedure using the website www.input2014.it. The papers were subjected to a series of monitoring and control operations. The first fundamental phase saw the submission of the papers to reviewers. To enable a blind procedure the papers have been checked in advance, in order to eliminate any reference to the authors. The review was carried out on a form set up by the local scientific committee. The review forms received were sent to the authors who have adapted the papers, in a more or less extensive way, on the base of the received comments. At this point (third stage), the new version of the paper was subjected to control for to standardize the content to the layout required for the publication within TeMA. In parallel, the Local Scientific Committee, along with the Editorial Board of the magazine, has provided to the technical operation on the site TeMA (insertion of data for the indexing and insertion of pdf version of the papers). In the light of the time’s shortness and of the high number of contributions the Local Scientific Committee decided to publish the papers by applying some simplifies compared with the normal procedures used by TeMA. Specifically:

- Each paper was equipped with cover, TeMA Editorial Advisory Board, INPUT Scientific Committee, introductory page of INPUT 2014 and summary;
- Summary and sorting of the papers are in alphabetical order, based on the surname of the first author;
- Each paper is indexed with own DOI codex which can be found in the electronic version on TeMA website (www.tema.unina.it). The codex is not present on the pdf version of the papers.
SMART CITY
PLANNING FOR ENERGY, TRANSPORTATION AND SUSTAINABILITY OF THE URBAN SYSTEM
Special Issue, June 2014

Contents

   Fabio Andreassi, Pierluigi Properzi 1-13

   Grazielle Anjos Carvalho 15-26

3. Temporary Dwelling of Social Housing in Turin. New Responses to Housing Discomfort
   Giulia Baù, Luisa Ingaramo 27-37

4. Smart Communities. Social Innovation at the Service of the Smart Cities
   Massimiliano Bencardino, Ilaria Greco 39-51

   Ivan Blečić, Dario Canu, Arnaldo Cecchini, Giuseppe Andrea Trunfio 53-63

   Ivan Blečić, Arnaldo Cecchini, Tanja Congiu, Giovanna Fancello, Giuseppe Andrea Trunfio 65-76

7. Diachronic Analysis of Parking Usage: The Case Study of Brescia
   Riccardo Bonotti, Silvia Rossetti, Michela Tiboni, Maurizio Tira 77-85

8. Crowdsourcing. A Citizen Participation Challenge
   Júnia Borges, Camila Zyncier 87-96

   Júnia Borges, Camila Zyncier, Karen Lourenço, Jonatha Santos 97-108
<table>
<thead>
<tr>
<th>Article Number</th>
<th>Title</th>
<th>Authors</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Dilemmas in the Analysis of Technological Change. A Cognitive Approach to Understand Innovation and Change in the Water Sector</td>
<td>Dino Borri, Laura Grassini</td>
<td>109-127</td>
</tr>
<tr>
<td>11</td>
<td>Learning and Sharing Technology in Informal Contexts. A Multiagent-Based Ontological Approach</td>
<td>Dino Borri, Domenico Camarda, Laura Grassini, Mauro Patano</td>
<td>129-140</td>
</tr>
<tr>
<td>12</td>
<td>Smartness and Italian Cities. A Cluster Analysis</td>
<td>Flavio Boscacci, Ila Maltese, Ilaria Mariotti</td>
<td>141-152</td>
</tr>
<tr>
<td>13</td>
<td>Beyond Defining the Smart City. Meeting Top-Down and Bottom-Up Approaches in the Middle</td>
<td>Jonas Breuer, Nils Walravens, Pieter Ballon</td>
<td>153-164</td>
</tr>
<tr>
<td>14</td>
<td>Resilience Through Ecological Network</td>
<td>Grazia Brunetta, Angioletta Voghera</td>
<td>165-173</td>
</tr>
<tr>
<td>15</td>
<td>ITS System to Manage Parking Supply: Considerations on Application to the “Ring” in the City of Brescia</td>
<td>Susanna Bulferetti, Francesca Ferrari, Stefano Riccardi</td>
<td>175-186</td>
</tr>
<tr>
<td>16</td>
<td>Formal Ontologies and Uncertainty. In Geographical Knowledge</td>
<td>Matteo Caglioni, Giovanni Fusco</td>
<td>187-198</td>
</tr>
<tr>
<td>17</td>
<td>Geodesign From Theory to Practice: In the Search for Geodesign Principles in Italian Planning Regulations</td>
<td>Michele Campagna, Elisabetta Anna Di Cesare</td>
<td>199-210</td>
</tr>
<tr>
<td>18</td>
<td>Geodesign from Theory to Practice: From Metaplanning to 2nd Generation of Planning Support Systems</td>
<td>Michele Campagna</td>
<td>211-221</td>
</tr>
<tr>
<td>19</td>
<td>The Energy Networks Landscape. Impacts on Rural Land in the Molise Region</td>
<td>Donatella Cialdea, Alessandra Maccarone</td>
<td>223-234</td>
</tr>
<tr>
<td>20</td>
<td>Marginality Phenomena and New Uses on the Agricultural Land. Diachronic and Spatial Analyses of the Molise Coastal Area</td>
<td>Donatella Cialdea, Luigi Mastronardi</td>
<td>235-245</td>
</tr>
<tr>
<td>21</td>
<td>Spatial Analysis of Urban Squares. ‘Siccome Umbellico al corpo dell'uomo’</td>
<td>Valerio Cutini</td>
<td>247-258</td>
</tr>
</tbody>
</table>
22. Co-Creative, Re-Generative Smart Cities.  
Smart Cities and Planning in a Living Lab Perspective 2  
Luciano De Bonis, Grazia Concilio, Eugenio Leanza, Jesse Marsh, Ferdinando Trapani  
259-270

23. The Model of Voronoi’s Polygons and Density:  
Diagnosis of Spatial Distribution of Education Services of EJA in Divinópolis, Minas Gerais, Brazil  
Diogo De Castro Guadalupe, Ana Clara Mourão Moura  
271-283

Roberto De Lotto, Tiziano Cattaneo, Cecilia Morelli Di Popolo, Sara Morettini, Susanna Sturla, Elisabetta Venco  
285-295

25. Landscape Planning and Ecological Networks.  
Part A. A Rural System in Nuoro, Sardinia  
Andrea De Montis, Maria Antonietta Bardi, Amedeo Ganciu, Antonio Ledda, Simone Caschili, Maurizio Mulas, Leonarda Dessena, Giuseppe Modica, Luigi Laudari, Carmelo Riccardo Fichera  
297-307

26. Landscape Planning and Ecological Networks.  
Part B. A Rural System in Nuoro, Sardinia  
Andrea De Montis, Maria Antonietta Bardi, Amedeo Ganciu, Antonio Ledda, Simone Caschili, Maurizio Mulas, Leonarda Dessena, Giuseppe Modica, Luigi Laudari, Carmelo Riccardo Fichera  
309-320

27. Sea Guidelines. A Comparative Analysis: First Outcomes  
Andrea De Montis, Antonio Ledda, Simone Caschili, Amedeo Ganciu, Mario Barra, Gianluca Cocco, Agnese Marcus  
321-330

Studies for a Method of Analysis of Urban Periphery  
Paolo De Pascali, Valentina Alberti, Daniela De Ioris, Michele Reginaldi  
331-339

The Approach of the Transform Project  
Ilaria Delponte  
341-351

30. From a Smart City to a Smart Up-Country.  
The New City-Territory of L’Aquila  
Donato Di Ludovico, Pierluigi Properzi, Fabio Graziosi  
353-364

Interactive Tool for Urban Planning  
Enrico Eynard, Marco Santangelo, Matteo Tabasso  
365-375
The Case of Out-of-Scale Buildings  
Enrico Fabrizio, Gabriele Garnero  
377-388

33. Smart Dialogue for Smart Citizens:  
Assertive Approaches for Strategic Planning  
Isidoro Fasolino, Maria Veronica Izzo  
389-401

34. Digital Social Networks and Urban Spaces  
Pablo Vieira Florentino, Maria Célia Furtado Rocha, Gilberto Corso Pereira  
403-415

35. Social Media Geographic Information in Tourism Planning  
Roberta Floris, Michele Campagna  
417-430

36. Re-Use/Re-Cycle Territories:  
A Retroactive Conceptualisation for East Naples  
Enrico Formato, Michelangelo Russo  
431-440

37. Urban Land Uses and Smart Mobility  
Mauro Francini, Annunziata Palermo, Maria Francesca Viapiana  
441-452

38. The Design of Signalised Intersections at Area Level.  
Models and Methods  
Mariano Gallo, Giuseppina De Luca, Luca D’acierno  
453-464

Roberto Gerundo, Gabriella Graziuso  
465-476

40. Social Housing in Urban Regeneration.  
Regeneration Heritage Existing Building: Methods and Strategies  
Maria Antonia Giannino, Ferdinando Orabona  
477-486

41. Using GIS to Record and Analyse Historical Urban Areas  
Maria Giannopoulou, Athanasios P. Vavatsikos,  
Konstantinos Lykostratis, Anastasia Roukouni  
487-497

42. Network Screening for Smarter Road Sites: A Regional Case  
Attila Grieco, Chiara Montaldo, Sylvie Occelli, Silvia Tarditi  
499-509

43. Li-Fi for a Digital Urban Infrastructure:  
A Novel Technology for the Smart City  
Corrado Iannucci, Fabrizio Pini  
511-522

44. Open Spaces and Urban Ecosystem Services.  
Cooling Effect towards Urban Planning in South American Cities  
Luis Inostroza  
523-534
45. From RLP to SLP: Two Different Approaches to Landscape Planning  535-543
   Federica Isola, Cheti Pira

   Jaroslaw Kazimierczak

47. Geodesign for Urban Ecosystem Services  557-565
   Daniele La Rosa

48. An Ontology of Implementation Plans of Historic Centers: A Case Study Concerning Sardinia, Italy  567-579
   Sabrina Lai, Corrado Zoppi

49. Open Data for Territorial Specialization Assessment. Territorial Specialization in Attracting Local Development Funds: an Assessment. Procedure Based on Open Data and Open Tools  581-595
   Giuseppe Las Casas, Silvana Lombardo, Beniamino Murgante, Piergiuseppe Pontrandoli, Francesco Scorza

50. Sustainability And Planning. Thinking and Acting According to Thermodynamics Laws  597-606
   Antonio Leone, Federica Gobattoni, Raffaele Pelorosso

51. Strategic Planning of Municipal Historic Centers. A Case Study Concerning Sardinia, Italy  607-619
   Federica Leone, Corrado Zoppi

52. A GIS Approach to Supporting Nightlife Impact Management: The Case of Milan  621-632
   Giorgio Limonta

   Giampiero Lombardini

54. Social Media Geographic Information: Recent Findings and Opportunities for Smart Spatial Planning  645-658
   Pierangelo Massa, Michele Campagna

   Giulio Maternini, Stefano Riccardi, Margherita Cadei
56. Urban Labelling: Resilience and Vulnerability as Key Concepts for a Sustainable Planning
   Giuseppe Mazzeo
   671-682

57. Defining Smart City. A Conceptual Framework Based on Keyword Analysis
   Farnaz Mosannenzadeh, Daniele Vettorato
   683-694

58. Parametric Modeling of Urban Landscape: Decoding the Brasilia of Lucio Costa from Modernism to Present Days
   Ana Clara Moura, Suellen Ribeiro, Isadora Correa, Bruno Braga
   695-708

59. Smart Mediterranean Logics. Old-New Dimensions and Transformations of Territories and Cities-Ports in Mediterranean
   Emanuela Nan
   709-718

60. Mapping Smart Regions. An Exploratory Approach
   Sylvie Occelli, Alessandro Sciullo
   719-728

61. Planning Un-Sustainable Development of Mezzogiorno. Methods and Strategies for Planning Human Sustainable Development
   Ferdinando Orabona, Maria Antonia Giannino
   729-736

   Rocco Papa, Carmela Gargiulo, Gennaro Angiello
   737-747

63. Integrated Urban System and Energy Consumption Model: Residential Buildings
   Rocco Papa, Carmela Gargiulo, Gerardo Carpentieri
   749-758

64. Integrated Urban System and Energy Consumption Model: Public and Singular Buildings
   Rocco Papa, Carmela Gargiulo, Mario Cristiano
   759-770

65. Urban Smartness Vs Urban Competitiveness: A Comparison of Italian Cities Rankings
   Rocco Papa, Carmela Gargiulo, Stefano Franco, Laura Russo
   771-782

   Rocco Papa, Carmela Gargiulo, Floriana Zucaro
   783-792

67. Climate Change and Energy Sustainability. Which Innovations in European Strategies and Plans
   Rocco Papa, Carmela Gargiulo, Floriana Zucaro
   793-804
68. Bio-Energy Connectivity And Ecosystem Services. 
   An Assessment by Pandora 3.0 Model for Land Use Decision Making 805-816
   Raffaele Pelorosso, Federica Gobattoni, Francesco Geri,
   Roberto Monaco, Antonio Leone

69. Entropy and the City, GHG Emissions Inventory: 
   a Common Baseline for the Design of Urban and Industrial Ecologies 817-828
   Michele Pezzagno, Marco Rosini

70. Urban Planning and Climate Change: Adaptation and Mitigation Strategies 829-840
   Fulvia Pinto

71. Urban Gaming Simulation for Enhancing Disaster Resilience. 
   A Social Learning Tool for Modern Disaster Risk Management 841-851
   Sarunwit Promsaka Na Sakonnakron, Pongpisit Huyakorn, Paola Rizzi

72. Visualisation as a Model. Overview on Communication Techniques 
   in Transport and Urban Planning 853-862
   Giovanni Rabino, Elena Masala

73. Ontologies and Methods of Qualitative Research in Urban Planning 863-869
   Giovanni Rabino

74. City/Sea Searching for a New Connection. 
   Regeneration Proposal for Naples Waterfront Like an Harbourscape: 
   Comparing Three Case Studies 871-882
   Michelangelo Russo, Enrico Formato

75. Sensitivity Assessment. Localization of Road Transport Infrastructures 
   in the Province of Lucca 883-895
   Luisa Santini, Serena Pecori

76. Creating Smart Urban Landscapes. 
   A Multimedia Platform for Placemaking 897-907
   Marichela Sepe

77. Virtual Power Plant. Environmental Technology Management Tools 
   of The Settlement Processes 909-920
   Maurizio Sibilla

78. Ecosystem Services and Border Regions. 
   Case Study from Czech – Polish Borderland 921-932
   Marcin Spyra

79. The Creative Side of the Reflective Planner. Updating the Schön’s Findings 933-940
   Maria Rosaria Stufano Melone, Giovanni Rabino
80. Achieving People Friendly Accessibility. 
   Key Concepts and a Case Study Overview 941-951
   Michela Tiboni, Silvia Rossetti

81. Planning Pharmacies: An Operational Method to Find the Best Location 953-963
   Simona Tondelli, Stefano Fatone

82. Transportation Infrastructure Impacts Evaluation: 
   The Case of Egnatia Motorway in Greece 965-975
   Athanasios P. Vavatsikos, Maria Giannopoulou

83. Designing Mobility in a City in Transition. 
   Challenges from the Case of Palermo 977-988
   Ignazio Vinci, Salvatore Di Dio

84. Considerations on the Use of Visual Tools in Planning Processes: 
   A Brazilian Experience 989-998
   Camila Zyngier, Stefano Pensa, Elena Masala
ABSTRACT
Open space (OS) is a key element in the provision of ecosystem services (ES) in urban environments. Under a land cover-land use perspective, cities are incorporating into the expansion process to different types of surfaces: sealed, paved surfaces and OS. The first corresponds to a land cover change while the second, which includes bare soil, grass, forest or any other type of non-sealed surface, corresponds to a land use change, without physical transformations. As a land use change OS is able to keep fundamental pre-existing ecological properties. However, besides specific ecological characteristics, the overall capacity to provide ES depends also on the size, number and spatial distribution of OSs within the urban fabric. Those aspects which can determine the very ecological performance of urban ecosystem services (UES) are not yet included in the current urban planning in Latin America. OS is still understood mainly as green infrastructure and related mostly with aesthetic and cultural benefits. On the contrary, under an ecological point of view, OS is capable to provide fundamental UES, which can be spatially assessed and analyzed. In this paper the provision of cooling services (CS) is assessed in 2 South American cities: Lima and Santiago de Chile. The provision of CS is measured by means of a Remote Sensing-GIS-based method. Two aspects of CS are explored: (1) the current amount of existing OS; and (2) the trend of increasing/reducing CS within the urban tissue, in a dynamic assessment of spatial distribution and rates of OS incorporation to the continuous urban tissue. The aim is to analyze the CS generated by OS in those two cities. The analysis discusses the role of OS in the provision of CS, considering the current urban development trends and planning practice in these specific Latin American cities, highlighting the need to keep unsealed surfaces and increase in trees coverage, to retain the CS provision in certain levels.

KEYWORDS
Open space, Urban ecosystem services, Cooling effect, Santiago, Lima
1 INTRODUCTION

The global future will be dominated by urban development and driven by urban systems. On the regional scale, urban systems are a powerful force which transforms landscapes and affects the provision of ecosystem services (ES), both out and within urban areas. Cities evolve in a world pervasive urban expansion context, where the urban expansion is not likely to be put under control. Under the identified trends of expansion (Inostroza et al. 2010; Inostroza et al. 2013) Latin-America will be inevitably and deeply transformed at fast rate. The urban sprawl, fragmentation and discontinuity will impact on several scales. Under market conditions and without an adequate regional planning, these impacts can be even intensified (Inostroza et al. 2013), and several ES like water infiltration, carbon sequestration and cooling effect are might be lost. As a result of the process of rapid urbanization the urban heat island (UHI) arises as a relevant – hybrid – ecological urban phenomenon. Urban areas tend to have higher air temperatures than their rural surroundings as a result of gradual surface modifications that include replacing the natural vegetation with buildings and roads.

Open space (OS), understood as areas free of development left behind by the process of urbanization, with or without vegetation coverage and including or not green infrastructure, arises as an important ecological asset of cities, in terms of their capacity to provide ES and reducing the UHI effect. Connecting this positive ecological effect with the ES framework, in this paper the cooling service (CS) of OS is analyzed for two Latin American cities: Lima and Santiago de Chile. The aim is to understand the CS generated by OS within those urban areas. In the first part a dynamic assessment of urban expansion is provided to calculate the relevance of OS within the urban areas of 10 important South American cities in 20 years period of time. This analysis gives an overview of the dynamic spatial process affecting OS in the continent. In the second part land surface temperatures (LST) was calculated for both cities. Provision of CS provided by OS was explored in terms of their spatial distribution in both cities. Using LST as UHI proxy the thermal difference between open spaces and their surrounding urbanized areas was estimated. In the conclusion some recommendations for urban planning and policy making, looking specifically to green infrastructure in Latin American cities, are proposed.

1.1 THE UHI: AN HYBRID URBAN ECOSYSTEM FUNCTION

The UHI effect is a global regularity present in almost every cities. UHI it has been recognized as important negative effect of urbanization on local weather. Within the urban fabric temperature varies mainly due to two important reasons: (1) differences in the thermal properties of impervious surfaces and (2) a decreased rate of evapotranspiration (Streutker 2002).

Urban blue and green space regulates local temperatures (Hardin and Jensen 2007). Water areas absorb heat in summer time and release it in winter (Chaparro and Terradas 2009) and vegetation absorbs heat from the air through evapotranspiration, particularly when humidity is low (Hardin and Jensen 2007). Urban trees moderate local temperatures by providing humidity and shade (Bolund and Hunhammar 1999). The share of impermeable surface is the most important factor determining urban sensitivity to heat. Large water bodies are important as well. Less important factors include the vegetation index (NDVI), the share of traffic infrastructure and shade. As such UHI emerges as the combination of preexisting geographical conditions, i.e. local climate conditions, altitude, etc. and artificial conditions resulting from the urbanization process, i.e. land cover, morphology of urban tissues, percent cover of buildings, etc. As it is depending on both types of factors, UHI can be characterized as hybrid ecosystem function. This is an ecological property and will constraint the possible control over the UHI effects. The concept it has been used to describe the
phenomenon of altered temperatures in urban areas compared to their rural hinterlands. The UHI effect is characterized as the influence of urban surfaces on temperature patterns in urban areas as opposed to surrounding areas (Oke 1982). The increase in the urban temperature shows higher temperatures in urban than in rural areas (e.g., Jin i 2005) and depends on a variety of factors, such as latitude, height above sea level, topography, city size (Wienert and Kuttler 2005) and atmospheric stability (Tomlinson et al. 2010; Sun et al. 2011).

Remote sensing is one of the most common techniques to map magnitude and spatial extent of UHI, allowing assessments without expensive and time demanding in situ measurements. Remote sensing techniques are focused on the surface urban heat island (SUHI), i.e. the surface temperatures of the emitting materials and not the air temperature as in situ measurements often are. Remotely sensed data and above ground air temperatures are not identical, but related (Mostovoy et al. 2006; Prihodko and Goward 1997). Thus, a very high correlation between surface temperatures and temperature comfort exists (Inostroza and Csaplovics 2014). The term SUHI is often used to explicitly distinguish SUHIs measured using land surface temperatures (LST) from air temperature patterns (e.g., Voogt and Oke 2003). LST modulates the air temperature of the lower layer of the urban atmosphere and is a primary factor in exploring surface radiation and energy exchange, the internal climate of buildings, the spatial structure of urban thermal patterns and their relation to urban surface characteristics, surface-air temperature relationships, and human comfort in cities (Liang et al. 2012).

Remote sensing data use the thermal emissivity of land surfaces to derive land surface temperatures (LSTs). Remotely sensed LST records the radiative energy emitted from the ground surface, including building roofs, paved surfaces, vegetation, bare ground, and water (Arnfield, 2003; Voogt and Oke 2003). Therefore, the pattern of land cover in urban landscapes may potentially influence LST (Arnfield 2003; Forman 1995). The percent cover of buildings arises as the most important land cover feature increasing the magnitude of LST. From the side of mitigation, percent of woody vegetation is the most important factor (Zhou et al. 2011).

1.2 STUDY AREAS

Lima is the capital and the largest city of Peru situated in the central coastal part of the country in front of the Pacific Ocean (Fig. 1). The city is located in the 12°2’36”S Latitude and 77° 1’42”W Longitude, in the valleys of the Chillón, Rímac and Lurín rivers. With a population of over 7 million, Lima is the most populated city of Peru, and the fifth largest city in the Americas.

Lima has two distinct seasons, summer and winter. The Peruvian Humboldt Current, cold water, giving rise to the phenomenon of inversion defined as the increase in temperature with increasing altitude. Hence the presence of cloud type layers (not give rise to precipitation) throughout the year. The inversion height varies between 1,000 m and 1,500 m in winter and summer, respectively, for which Lima is a city with the presence of clouds all year (SENAMHI 2009).

The climate is characterized as semi-warm and moderate humidity conditions (SENAMHI, 2009). The average annual temperature ranges between 18.6° C and 19.8° C, with temperatures ranging between 15° C and 20° C in the winter months and between 19° C and 27° C during the summer (SENAMHI 2009). The humidity varies between 81% and 85% for the year, which intensifies the thermal sensation of heat or cold, depending on the season. The temperature is sinusoidal, varying from low temperatures in the months of June to September with peaks from December to April, causing the city to register two well defined, one cold and one warm. Minimum temperatures vary between 15° C and 21° C, depending on the season and recorded in the areas closest to the coast. In the summer ranges from 17.1° C and 20.5° C in the winter between 10.7° C and 15.4° C. The maximum temperatures ranging between 17° C and 29° C, recorded
lower values during winter (June to August) and higher during summer. In turn, the maximum temperatures are lower in areas close to the coast, while in the areas closest to the Andes with values of 25° C to 30° C.

Santiago is located in the central valley of Chile in the coordinates 33°26′16″S latitude and 70°39′01″O longitude, is the capital of the country concentrating the economic and political power (Fig. 2). It concentrates more than 43% of the countries’ population and more than 40% of the GDP is produced in the
city. With an estimated population of 6.5 millions it has been suffering a strong process of urban expansion during the last decades, adding more than 1,300 ha per year to the continuous urban fabric (Inostroza et al. 2013). Politically administrative speaking the city contains 40 municipalities, which represent the local administrative level (commune).

2 MATERIAL AND METHODS

The methodology is spatially explicit and quantitative at city scale. An important aspect to consider is the spatial delineation of the urban area under study and its rural counterpart. For the purposes of this research the spatial scope of the analysis is the continuous urban fabric (red line in Fig. 1 and Fig. 2). For the definition of this area see (Inostroza et al. 2013). Calculation of sizes gains and loses and spatial distribution of the incorporated OS in a 20 years time period was performed. Over that basis, the provision of CS was explored under an Ecosystem Services perspective.

2.1 LAND SURFACE TEMPERATURE (LST) ESTIMATION

In order to determine the SUHI within the continuous urban fabric, LST was calculated using the thermal band of the Landsat 5 TM. Even though the spatial resolution of the thermal band is 120m x 120m, resampled to 60 m x 60 m per pixel, a rescaling to 30 x 30 m. was performed. The extension of the image was fitted to the extension of the continuous urban fabric.

The Landsat -5 & Landsat-7 Thematic Mapper sensor systems contain a thermal band that collects data in the wavelength interval of 10.40 – 12.50 \( \mu \text{m} \). This band can be converted to temperature by using the calibration information from the Landsat manual. LANDSAT 5TM band 6 is produced by a 120 m resolution thermal detector capable of sensing radiant temperature differences of approximately 0.6°C (Avery and Berlin, 1985; Aniello et al. 1995).

At-satellite temperature can be determined for TM thermal data in a two step process (Markham and Barker, 1987; Sun et al. 2009). The first step is to convert the digital number (DN) into spectral radiance \( \lambda \). In the original LANDSAT image pixels are converted to units of absolute radiance using 32 bit floating point calculations. Pixel values are then scaled to byte values prior to media output. The spectral radiance \( \lambda \) of each DN value is calculated using the following equation:

\[
\lambda = \text{Grescale} \times \text{QCAL} + \text{Brescale}
\]

\( \lambda \) - Spectral Radiance at the sensor's aperture in watts/(meter squared * ster * \( \mu \)m).

Grescale - Rescaled gain (the data product "gain" contained in the Level 1 product header or ancillary data record) in watts/(meter squared * ster * \( \mu \)m)/DN.

Brescale - Rescaled bias (the data product "offset" contained in the Level 1 product header or ancillary data record ) in watts/(meter squared * ster * \( \mu \)m).

Which is also expressed as:

\[
\lambda = \left( \frac{(LMAXL - LMINL)}{(QCALMAX-QCALMIN)} \right) \times (QCAL-QCALMIN) + LMINL
\]

QCAL - the quantized calibrated pixel value in DN

LMINL - the spectral radiance that is scaled to QCALMIN in watts/(meter squared * ster * \( \mu \)m)

LMAXL - the spectral radiance that is scaled to QCALMAX in watts/(meter squared * ster * \( \mu \)m)

QCALMIN: the minimum quantized calibrated pixel value (corresponding to \( L_{\text{MIN}} \)) in DN
1 for LPGS products
1 for NLAPS products processed after 4/4/2004
0 for NLAPS products processed before 4/5/2004
QCALMAX: the maximum quantized calibrated pixel value (corresponding to \( L_{\text{MAX}} \)) in DN
255

QCAL, LMIN, LMAX, and QCAL, are obtained directly from EOSAT for each LANDSAT sensor system.
LMIN and LMAX values for conversion to radiance units are in the metadata file (header file) of each image.
The second step is to convert the spectral radiance as described above to at-sensor brightness temperature.
This is the effective at-satellite temperatures of the viewed Earth-atmosphere system under an assumption
of unity emissivity and using pre-launch calibration constants listed in Tab. 1. It is carried out by using the
following conversion formula:

\[
T = \frac{K_2}{\ln \left( \frac{K_1}{L_\lambda} + 1 \right)}
\]

\( T \): Effective at-satellite temperature in Kelvin
\( K_2 \): Calibration constant 2 from Tab. 1
\( K_1 \): Calibration constant 1 from Tab. 1
\( L_\lambda \): Spectral radiance in watts/\( \text{meter squared} \times \text{ster} \times \mu \text{m} \)

<table>
<thead>
<tr>
<th></th>
<th>Constant 1 - ( K_1 ) watts/(meter squared \times \text{ster} \times \mu \text{m})</th>
<th>Constant 2 - ( K_2 ) Kelvin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 5</td>
<td>607.76</td>
<td>1260.56</td>
</tr>
</tbody>
</table>

Tab. 1: ETM+ and TM Thermal Band Calibration Constants

Now the ETM+ Band 6 imagery was converted to a more physically useful variable. Last step is to transform
temperature from Kelvin to Celsius degrees. Once calibrated, surface temperatures can be determined at
any LANDSAT pixel location. Temperatures were grouped into appropriate ranges and color-coded to
generate a thermal pattern distribution map of both studied areas (Fig. 3 and Fig. 6).

3 RESULTS

3.1 URBAN EXPANSION AND THE INCORPORATION OF OPEN SPACE

Cities are expanding as a matter of fact. The pace of urban expansion in South American cities is fast. An
average of 360 ml/year growth rate has been observed in main cities during the last 20 years, this means
around 40 m²/minute as average for the continent (Inostroza et al. 2013).
Under a land cover-land use perspective, cities are incorporating into the expansion process to different
 Types of surfaces: sealed, paved surfaces and OS. The first corresponds to a land cover change, suitable to
be detected by remote sensing techniques. The second one, OS, corresponds to a land use change, without
physical transformations. It could be bare soil, grass, forest or any other type of not-sealed surface.
However, OS not necessarily correspond to green infrastructure; part of it is the result of the
suburbanization process, not sealed surfaces within new urban plots or the passive inclusion of fragmented large areas without development. In some cases those areas are targets for infilling urban development. If land surface is not sealed, OS is able to keep most of their pre-existing ecological properties.

The ecological value of OS it has to be assessed regarding specific urban ecosystem services (UES) it provides. There are at least three UES provided by OSs: rainfall infiltration, carbon sequestration and cooling effect (UHI mitigation). The provision of each ES is determined by the type of land coverage of the area.

OS as remaining land within the urban expansion process can be, in some cases transformed into formal green areas. However in the context of Latin America this is not the common situation; many OSs remain in initial conditions for decades and or they are urbanized (sealed). If not sealed, OS keeps its potential provision of UES, which can hardly be substituted by other urban elements without increasing vulnerability to other hazards, such as floods or heat.

In quantitative terms, the incorporation of OS into the urban areas is a key factor considering the fast expansion process of South American cities. In table 2 an overview of the overall incorporation of OS in 10 South American cities is presented. The incorporation of OS is relevant in all cities.

In average core areas (continuous urban fabric) increased in 200 km² between T1 and T2; 50 km² where of OS, this is 24%. There is a net increase in the overall average surface of OS in the 10 cities, from 140 in T1 up to 190 in T2, which represents a net increase of 35%. However, in relative terms, this is considering the growth of core urban areas, the overall percentage has decreased from 34% to 31%. This because despite the increase in OS's surface, the increase in core areas and built up areas has been faster, 47% and 52% respectively. This means that in 2010 most of those cities they have less open space in proportion to the urban area, than they had in 1990.

<table>
<thead>
<tr>
<th>CITY</th>
<th>YEARS</th>
<th>CORE T1</th>
<th>CORE T2</th>
<th>BUILT T1</th>
<th>BUILT T2</th>
<th>OS T1</th>
<th>OS T2</th>
<th>OS T1 %</th>
<th>OS T2 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asunción</td>
<td>23</td>
<td>336</td>
<td>534</td>
<td>190</td>
<td>327</td>
<td>146</td>
<td>207</td>
<td>43%</td>
<td>39%</td>
</tr>
<tr>
<td>Bogota</td>
<td>22</td>
<td>297</td>
<td>362</td>
<td>224</td>
<td>281</td>
<td>74</td>
<td>81</td>
<td>25%</td>
<td>22%</td>
</tr>
<tr>
<td>Brasilia</td>
<td>21</td>
<td>406</td>
<td>718</td>
<td>140</td>
<td>370</td>
<td>265</td>
<td>348</td>
<td>65%</td>
<td>48%</td>
</tr>
<tr>
<td>Buenos Aires</td>
<td>21</td>
<td>1577</td>
<td>2,103</td>
<td>1,127</td>
<td>1517</td>
<td>450</td>
<td>587</td>
<td>29%</td>
<td>28%</td>
</tr>
<tr>
<td>Cordoba</td>
<td>24</td>
<td>252</td>
<td>337</td>
<td>164</td>
<td>230</td>
<td>88</td>
<td>107</td>
<td>35%</td>
<td>32%</td>
</tr>
<tr>
<td>La Paz</td>
<td>23</td>
<td>113</td>
<td>236</td>
<td>83</td>
<td>169</td>
<td>31</td>
<td>67</td>
<td>27%</td>
<td>28%</td>
</tr>
<tr>
<td>Lima</td>
<td>22</td>
<td>446</td>
<td>695</td>
<td>374</td>
<td>547</td>
<td>71</td>
<td>149</td>
<td>16%</td>
<td>21%</td>
</tr>
<tr>
<td>Montevideo</td>
<td>24</td>
<td>291</td>
<td>310</td>
<td>167</td>
<td>201</td>
<td>124</td>
<td>109</td>
<td>43%</td>
<td>35%</td>
</tr>
<tr>
<td>Santa Cruz</td>
<td>25</td>
<td>88</td>
<td>287</td>
<td>61</td>
<td>186</td>
<td>27</td>
<td>101</td>
<td>31%</td>
<td>35%</td>
</tr>
<tr>
<td>Santiago</td>
<td>24</td>
<td>479</td>
<td>710</td>
<td>353</td>
<td>568</td>
<td>126</td>
<td>142</td>
<td>26%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Tab 2 Overall urban core values and open space in 10 South American cities for circa 1990 and circa 2010. Values are in km²

As a result of the persistent expansion process fundamental ecological functions are changed or eventually lost. Thus an important question for urban planning and policy making is to determine how much of this surface has to be maintain free of development to ensure the provision of certain Ecosystem Services eventually lost due to the urbanization process. To ensure the maintenance – ideally the increase – in the environmental quality of new urbanized areas, a portion of this open space has to be kept free of development in the long term, under an ecosystem services perspective. Open space is a passive incorporation of areas with higher ecological value than standard urbanized areas.
3.2 SANTIAGO

There is a pattern in the spatial distribution of LST in Santiago. Lower temperatures follow the Cordillera in the east part of the city. Higher temperatures are concentrated in the centre and in the western part as well. Big OS are playing an important cooling role (Fig. 3). Municipalities in the west part of the city they have higher values of LST, while municipalities located at piedmont they have lower LST values. Considering that western municipalities are poor while eastern municipalities are richer, it is clear that the LST has an uneven socioeconomic spatial pattern as well. In some cases the cooling islands are associated with higher shares of vegetation, i.e. the presence of consolidated green areas, parks or other historical green areas. In some others cases the dismissing in the amount of sealed surfaces accounts for the lower LST (Fig. 3). At smaller scale the spatial correlation between big OSs, and lower LST (Fig. 4) is more evident. On the contrary, lack of green areas is correlated with higher LST, like in the central and western areas of the city.

Fig. 3 Land Surface Temperature (LST) patterns and green areas in Santiago de Chile. Cooling islands within the continuous urban fabric are clear.
3.3 LIMA

Higher LST values are located in the north and south part of the city (Fig. 6), related to the presence of hills and barren soils. This is a typical pattern of a desert city. Presence of green areas, but mostly the presence of river basins (Rimac, Chillón, and Lurín) are helping to decrease the LST in the central parts of Lima (Fig. 5). Higher temperatures within the urban fabric in the central part of the city respond to barren soils and hills, as is shown in Fig. 5, where San Cristobal hill shows the highest temperatures.
4 DISCUSSION AND CONCLUSIONS

UHI is a typical effect of urbanization present in most cities. There is a growing awareness to develop strategies to cool urban areas (Mackey et al. 2012), specially when it is expected that the urban temperature will increase due to climate change. Vulnerability to heat waves is high in Latin American cities. However, UHI remain out of the scope of urban adaptation strategies. New spatially explicit approaches are needed to cope with the expected impacts of heat waves (Inostroza and Csaplovics 2014).

To understand the relevance of the OS regarding the CS, it is necessary to understand not only the specific mitigation it can be provided. The locally generated UES have a substantial impact on the quality-of-life in urban areas and should be addressed in land-use planning (Bolund and Hunhammar 1999). It is also important to account for specific ecological features of such spaces. To produce large cooling effects, grass – or lawn – is not effective, as other studies have also shown (Mackey et al. 2012). Vegetation must be dense and include shrubs/trees in order to have an affect on an urban scale (Mackey et al. 2012; Bowler et. al. 2010; Chang et. al. 2007; Potchter et. al. 2006). This is a fundamental consideration for urban planning not yet well accounted for the design of green areas in Latin America. But at the same time open space is under strong pressure. Due to increasing urbanization, combined with a spatial planning policy of densification, more people face the prospect of living in less green residential environments, especially people from low economic strata. This may lead to environmental injustice with regard to the distribution of (access to) public green space (Groenewegen et. al. 2006).

The exploration of the potential roles in the provision of UES it is also being done considering urban form properties, specifically those regarding compactness. In terms of Latin American cities the aim of a compact urban development is highly necessary (Inostroza et al. 2010). How this aim will not negatively affect the
current provision of CS in targeted OS’s is an important question for planners. When developing such OS’s, UES assessment has to be done to ensure that current provision will be maintained. However planning practice in Latin America has been largely overcome by the contingency of urban development: fast growing rates, poverty, informality and land markets. It is necessary to ensure that the passive provision of UES of OS’s is not threatened by lack of awareness and appropriated assessments. If the provision of CS will be included in cost-benefit analysis, the positive impact would be of great interest. For instance 17 municipalities in Santiago with the highest temperatures they reach over 2 million persons. The direct CS benefits of those populations it can be determined in economic terms by using available spatial methods. Normally it has been accepted that parks and lawns they have positive impact in terms of reducing the effects of the UHIs. However looking at NDVI the stronger and valuable CS resides on trees, but not in green areas in general and not at all in lawns in particular. This is an important fact to keep in mind for the design of green infrastructure and the identification of the very CS of existing OS.

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**IMAGES SOURCES**

All images are own elaboration.

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