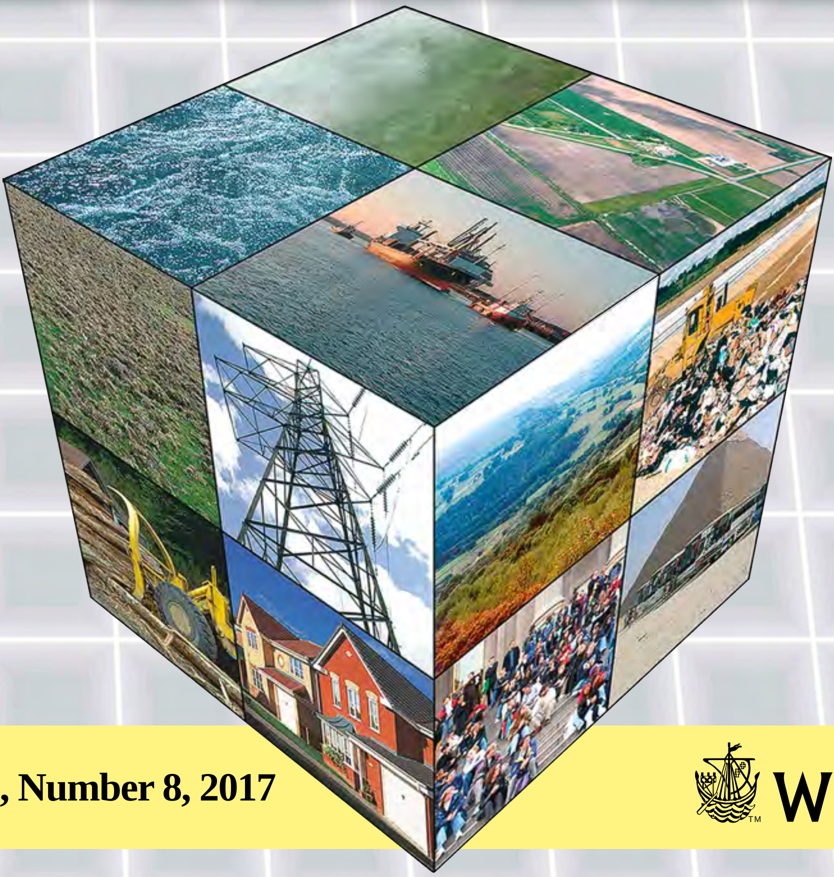
International Journal of

Sustainable Development and Planning

Encouraging a unified approach to achieve sustainability



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The International Journal of Sustainable Development and Planning responds on the necessity to relate the fields of planning and development in an integrated way and in accordance with the principles of sustainability.

The Journal covers all aspects of planning and development including environmental design, planning and management, spatial planning and sustainable development.

It is the aim of the editors of the Journal to create an interdisciplinary forum where all the issues related with the concept of sustainability (environmental, spatial, economical and social), are open for scientific discussion.

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MULTI-LAYERED DESIGN STRATEGIES TO ADOPT SMART DISTRICTS AS URBAN REGENERATION ENABLERS

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ABSTRACT

Smart City emerged as a reference concept to shape the city of the future, mainly by strengthening the connections between grids, Information and Communication Technology (ICT) tools, governance and people. 'Smart' refers to the potential benefit that is derived by adopting ICT to face the increasing complexity of city growth, which involves multiple urban scales, a number of different players and a variety of regulatory frameworks, as shown by several experiences worldwide in the past few decades. Compared to the potential that is expected to be fuelled by hyper-connected devices in delivering an efficient and optimized configuration of the urban eco-system, the architecture of the city seems to have been relegated to the background. Facilitating an integrated management of the urban dynamics on both a large and a small scale is a key challenge. This means that the cross-related effects of decisions and behaviours must be identified, mapped and analysed considering their relations, reciprocal influences and conflicts. Although an effective ICT infrastructure should facilitate this purpose, the number of variables to consider is enormous, due to both top-down and bottom-up strains, which can act simultaneously on a large palette of fields, with multiple and combined issues as well. In order to design a model on which a tool for management can be built, a simplified scale of analysis is needed: the 'district' seems to represent an acceptable intermediate portion of the whole city where local and global phenomena can be observed from a perspective of their interferences and potential synergies. It often also corresponds to an administrative entity as well as to a structured place recognized by citizens and inhabitants. This article reports on a study conducted in the city of Bologna by a team of researchers of the University of Bologna – Department of Architecture. The study aimed at supporting the municipality in defining effective strategies to implement the Smart City Vision by a set of coordinated actions of regeneration at district level. The research aimed at coupling holistic design principles and the typical ICT platform architecture into an inter-operable tool that could enable the management of the key features of a district in separate layers, supplemented by different data sets. A significant part of the research has been devoted to identifying the variables involved and defining the methodology to process them, according to the most up-to-date shared definitions and indicators.

Keywords: built environment, energy efficiency, multi-layer design, smart city, smart district, urban regeneration.

1 INTRODUCTION

In the recent past, the Smart City (SC) concept has emerged as a possible answer to world-relevant challenges most metropolitan cities are facing at different levels [1, 2]: massive urbanization, increase of demographic pressure due to migration flows, CO_2 emissions and economic and social constraints as never before [3–9]. As pointed out by several studies [1, 3, 10, 11], the smart city paradigm and the extended use of ICT tools are often adopted to facilitate coordinated and more sustainable actions [3, 5]. Despite the rapid progress achieved in this field, a shared and common definition of an SC is still missing [5, 12–16]. This prevents a clear understanding of the potential hidden behind the supporting tools to foster the transition process and to coherently create effective synergies when adopting smart building and smart city solutions to shape the architectural landscape of the future.

The article aims to identify some recurring key concepts/themes describing the SC notion in scientific literature and in recent/ongoing research projects. This provides a reference to

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define the main layers of a multi-criteria platform to be used for supporting the application of ICT tools in the design process of effective actions, especially on a district scale assumed as an intermediate scale where urban transformation and transition processes are usually carried out. The article reports on the results of a study developed by the Technology Research Team of the Department of Architecture at the University of Bologna aimed at supporting the Bologna Municipality in defining effective strategies at the district level, by performing separate but coordinated regeneration actions within the framework of the general Smart City Vision [17]. Although the district, as a pilot dimension for testing solutions, has been widely discussed [18, 19] including several potential features (geographical, social, administrative, functional) that are suitable to define it, the research assumed the district as an intermediate urban dimension that is recognizable to its citizens [19]; having a minimum physical dimension for implementing projects; having a relevance compared to the whole city and being mainly devoted to a specific function (e.g. residential, commercial, etc.). A considerable portion of the research has been devoted to delivering a state of the art – which is reported in the first part of the article – in which a comprehensive perspective of the key concept definitions has been provided, aiming at bridging the gap between their meaning and understanding. On this basis, a methodology has been developed to assess the level of ‘smartness’ that may characterize an urban situation and its potential improvement by specific regeneration actions assumed as tools to revitalize the spatial, social and economical dimensions of the site [20].

Since the research aims to couple the holistic design principles and the typical ICT platform architecture into an interoperable tool, the key district features have been referred to separate layers, fed by different data sets in order to facilitate the management of the complex interaction given by the wide range of variables involved in the process.

2 BACKGROUND AND ASSUMPTIONS

2.1 General framework

To support the fulfilment of EU directives 31/2010 (Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings) and 27/2012 (Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency) the city developed and adopted the Bologna Adaptation Plan in 2015 [21]. A number of ICT-based solutions were implemented accordingly in order to achieve the Bologna Smart City Vision. Thus, the first step in the research was to obtain a clear definition of the smart city concept [14, 16, 22].

The debate on the notion of ‘smart’ dates back to the late 1980s and early 1990s with the advent of the information age. On the one hand, it was the integration of ICT-based tools to trigger the idea and on the other defining the concept of useful, simple and cheap methods associated with the term smart [5]. According to Nam and Pardo [14], it seems to be generally accepted that the aim of smart growth is to combine economic and social issues with sustainable urban development, by a process where ICT plays the key role of enabler. Then, the smart city topic’s strong bond with technology started to be more and more coupled with sustainability issues, [3, 23] especially dealing with climatic and social challenges [2]. Some research [1, 24–27] highlights these aspects, pointing out the importance of cross-cutting strategies to meet the present urban challenges [28]. Facing the multiple dimensions of the topic, a literature and research screening appears to be a suitable reference to establish a set of assumptions and definitions that reflect coherent and shared positions.

2.2 State of art review

The state-of-art review was set up to screen research on smart cities, focusing on those that assumed environmental issues and climate change responsive strategies as key elements, which were clearly addressed as a priority by the Municipality of Bologna. A systematic review [29] has been performed on Google Scholar,-and on Cordis, the web portal where EU-funded projects are collected by adopting a methodology coherent to Cooper taxonomy (see Table 1) [30].

The Google Scholar search included all kinds of documents (reports, theoretical analysis, methodologies, research outcomes, scientific papers) in a time range between 2000 and 2015 when the smart city concept was spreading. Data from the 1990s was complemented by a recent study [31] retrospectively analysing the topic literature in that period. Within the time frame defined, the references were retrieved from the Goggle Scholar database by the following set of keywords: smart district; smart building AND indicator; smart city AND indicator AND sustainable; smart building AND refurbishment; urban regeneration AND smart city AND sustainable; smart city AND retrofitting OR renovation OR refurbishment. The listed combinations produced 4,423 results, 490 of which were selected based on the relevance assigned to the document and excluding the following: documents containing citations only; patents; slide show presentations; documents not written in English or Italian; papers focusing on specific engineering topics (i.e. heating systems, grids, etc.); papers concerning only tourist or artistic/historical or cultural heritage issues. The findings were firstly ranked in chronological order, to map their relevance in the evolution of the topic and considering the most updated trends and, secondly, in conceptual order according to the research scope.

Table 1: Cooper taxonomy applied to smart district literature review.

Characteristics	Cooper's option	Adopted selection criteria
Focus	Typologies of papers involved	*All papers involved: theoretical, conceptual, methodological, case study*
Goal	Integration (e.g. bridge the gap between theories, etc). Criticism (e.g. demonstrate a theory) Central issue	*Central issue. Coherent to the literature review scope*
Organization	Data mining: chronological, conceptual, methodological	*The data mining is developed with chronological and conceptual organization*
Perspective	Neutral position, espousal of a position	*Neutral position*
Audience	Target of the literature review	*The audience is specialized researchers, policy makers, architects acting on urban context*
Coverage	Exhaustive, exhaustive with selective citations, representative, central, pivotal	*Representative*

Time evolution of the concept – The selected references were classified according to publication date so as to analyse the emerging trends and to demonstrate that the linkage between smart city and district regeneration is quite recent. Until 2010, the topic was covered by only a few articles and papers, while a remarkable increase in publications is recorded since 2010. This can be explained by an increased demand from the EU and national regulations application. Figures 1 and 2 show the increase of relevance of papers connecting smart city and district regeneration year by year.

Thematic interpretation - According to key words listed in each document and the recurrence of the string combinations in the main text, the results were assigned to 9 main categories: 1) case studies (reporting the outcomes of application in real contexts); 2) economy and policies (i.e. stakeholder engagement, guidelines, business models, etc.); 3) ICT/technology (analysing the role in process implementation); 4) performance and indicators (descriptions of the main parameters and related derived indicators); 5) methodologies and models (describing analytical structure, design options, implementation models); 6) social involvement (i.e. creative districts, living labs, etc.); 7) theories (describing theoretical and position approaches, i.e. terms and concepts definitions, interpretation of trends, etc.); 8) low carbon transition (describing transition, adaptation, regeneration processes); 9) cousin words (including similar or related concepts, i.e. intelligent city, eco-city, digital city). Theoretical approaches are predominant, followed by methodologies and case studies. The prevalence of theory can be taken as evidence of the need for defining the boundaries of the topic and its key features.

The relevance of case studies demonstrates the need for testing the assumption in real conditions, however this can vary significantly from place to place. The large number of pilot applications is not mutually fed by each other's experiences thus reflecting the lack of a systematic development in the field due both to the early stage and the complexity of the issue.

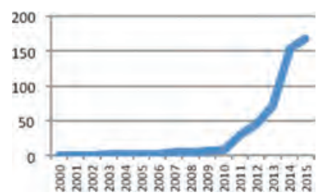

Figure 1: Time analysis of Smart City. and District refurbishment, n° of elements.

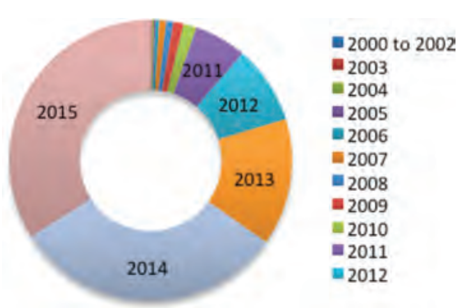

Figure 2: Time analysis of Smart City and District Refurbishment, percentage.

The share by topic is displayed in Figure 3. The analysis shows that smartness seems to have two main cores: the technological component, which includes both hard infrastructure (the enabling systems and devices: IT, web-based) and software infrastructure), combined with ecological/sustainable features. The transition towards low- carbon cities involves economic and social growth as well as the inclusion of communities [32–34].

Document typology interpretation - The selected documents were then classified according to their typology (see Figure 4): books; book chapters; EU documents (official documents, issued by EU Institutions and governmental or official bodies); EU projects; scientific papers; theses (master or doctoral). The predominant typology is the scientific paper reflecting the need to establish a consolidated background on the topic. However, some common outcomes emerged. Urban development through transition towards low-carbon sustainable districts is a growing research topic that is closely connected to smart city issues.

The Cordis portal was searched according to the following keywords: 'smart city' AND district OR retrofitting OR renovation OR regeneration OR urban; 'smart city'. The following filters were applied: research on 7th work programme AND research on H2020 work programme; research only in PROJECTS. 25 projects, were found and further filtered according to the following criteria: exclusion of projects not applied to urban or district contexts; exclusion of projects with educational purposes; exclusion of duplicated results. The outcomes were double checked with the 'Smart City Platform' database as an additional source. All the selected projects have a complex structure that was examined as a starting point for the Bologna case study and to define the multi-layer architecture of the design tool object of the study.

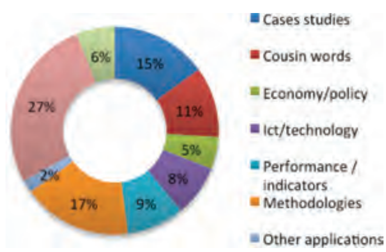

Figure 3: Thematic analysis %.

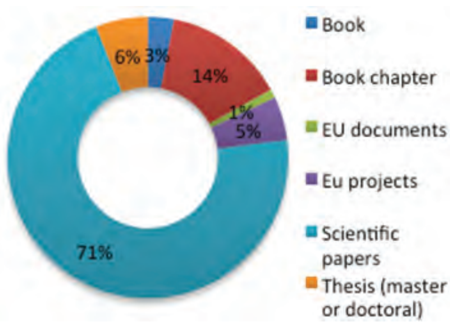

Figure 4: Product typology %.

3 METHODOLOGY AND DEFINITIONS

3.1 Applied methodology

The massive amount of information screened and the variations in terminology and meaning among themes belonging to the same category made it necessary to accept a certain level of approximation in creating some main families in order to progress further with the research.

The key objective was to support the replacement of the conventional approach to renovation of the existing stock which – being usually aimed at achieving pre-defined performance thresholds for each single building according to specific energy savings targets – assumes city regeneration processes as the collection of these single results [25, 35] and moves towards a more coordinated vision that adopts ICT tools and smart principles as the key enabler [36]. The core idea of the project is therefore to couple the holistic vision with ICT architecture in order to include in the interoperable platform a number of 'layers' representing the key themes and concepts on which the smart and sustainable city vision can be linked as shown in Fig. 5. The main problem that arose was the complexity generated by managing the whole process on a city scale and the lack of adequate connections while working on the scale of a building. Therefore, the very first task of the project was to structure the whole platform as a scalable tool and to fix its key element at the district scale. The complex interaction of variables and specific conditions, typically characterizing the dense urban environment, requires the separation of both data flows and their representation in order to provide a simplified tool to visualize possible conflicts or synergies and facilitate the understanding of phenomena for a different range of players (who are mostly non- expert users). The core idea of the research is to aggregate variables and data belonging to the same domain into a number of key layers organized into sub-categories that make it easier to filter information and browse the data-sets in separate or aggregated visualizations.

The methodology was developed as follows:

- sub-categories identification by analysing the recurrence in the screened projects and their definition accordingly;

Figure 5: The core idea is based on a multi-layer structure that aims to facilitate the management of interactions and optimize the design solutions.

- application of indicators to the parameters involved, to be used to feed graphic maps representing the related data sets;
- aggregation of sub-categories into key layers, to be used to display data on graphic maps for facilitating end-user visualization of results;
- definition of the platform architecture as a whole
- test on a demo-case and check of replicability potential.

3.2 Definition of the thematic layers

The very first problem of this approach was how to define the layers so that they could be general enough to be applied to different contexts but specific enough to adequately describe a consistent part of urban phenomena. The outcomes of the state-of-the-art review, and especially those coming from the project screening, were used to support the layer definition phase. Each source was investigated to select the categories used to describe the main issues in a smart and sustainable city perspective and definitively select the most used and recurrent thematic group so as to adopt shared definitions understandable to a wide range of potential users [24–27, 37].

Based on the different realms (mobility, energy grids, people, communication, etc.) [38] and according to the outcomes of the performed review results (recurrency of the theme in the concept definition) 5 main 'layers' were identified: *circulation*, which is closely connected to smart mobility and the physical infrastructure at the city and district level, where the smart district can be defined as an urban geographical, socio-economic unit that can be associated with a specific culture and identity [39]; *climate conditions*, which includes all the variables dealing with the specific characteristics of the environment (such as temperature, humidity, wind speed, rainfall, etc.); *buildings*, which represent the single units of the built environment and are assumed to host the ICT supported backbone controlling sensors, actuators, micro-chips, micro/nano-embedded systems used to manage the key functionalities while collecting and filtering information locally with the purpose of managing aggregated data at city level according to business functions and services [40]; *space in-between*, which represents the connective fabric where most interactions take place; *grids infrastructure*, which typically refers to services and systems associated with the so-called smart grids. Each key layer includes a number of sub-categories in order to optimize the description of the combination between the variables and the deriving phenomena. All these definitions and key layers were used to define the platform architecture and structure with the aim of managing separate data put into aggregated visualization output in order to facilitate the understanding of the potential related to alternative renovation scenarios.

3.3 Platform structure

From a methodological point of view, the layered architecture of data is the backbone of the platform while the sub-categories are assumed as a set of homogeneous information.

The platform conceptual structure is designed to be implemented with new additional layers in case the complexity of phenomena requires them. Furthermore, this responds both to the need to use existing and already available data sets and new ones whose data can be specifically collected according to new purposes. The resulting structure is displayed in Fig. 6. Each key layer aggregates information concerning the sub-categories that are fed by the

Key layer	Sub-category	Detail	Indicator
Circulation	Street		
	Cycle lanes		
	Pedestrian		
	Car park		
	Type new		
Climate conditions	Climate zone	Tertiary	
	Temperature (av)	Residential - row	
	Rain fall trend	Residential - single house	
	Wind	Residential - block	
	Type new	Commercial	
Buildings	Typology	Industrial	
	Size		
	Specific features	Building envelope	Thermal transmission
	Type new	Heating system	Time shift
Space in-between	Green areas	Cooling system	Decrement factor
	Green corridors	...	
	Courtyards		
	Squares		
	Type new		
Grids infrastructure	Energy		
	Waste		
	Heat		
	Water		
	Type new		

Figure 6: architecture of the tool with the key layers and sub-categories.

existing database or by monitoring tools already installed or to be installed in the buildings and/or in the service infrastructures. When a sub-category is filled, specific descriptors are adopted and adequate indicators are assumed accordingly. Thus, the process works in two directions, one for feeding each data set and the other for putting questions to the system using a sub-category as a filter.

An easy example of how the structure works is offered by a very common goal of regeneration processes concerning the reduction of energy demand for cooling and heating.

With the aim of defining effective solutions, the key parameters are usually displayed in a number of data sheets, like the one shown in Fig. 7, and can be represented by a map at the district level visualizing homogeneous conditions according to the selected indicators.

This can be applied to each sub-category and layer providing a facilitated access to information as well as an easy way to compare interrelated data sets. A map of the green areas can be easily associated with a map of air temperature (which is described by isolines) or of ventilation (see Fig. 8) to analyse the potential influence of green surface remodelling in the same zone with mitigation purposes. In this sense, the test phase on the demo-site was useful for studying possible interaction topics to be further developed at a future stage of the research. This is just one example of correlation processes, others can deal with circulation and mobility data, thermal behaviour of building envelopes and demand data from energy suppliers, etc. The key layers can be implemented according to needs; however, for functional reasons the easiest way to implement the tool is to add new sub-categories with related details.

The platform is expected to be integrated with already existing ICT tools and software in order to ensure the widest compatibility and to ease data collection. The tool is intended for important data gathering and analysis, to include GIS-based (geographic information system) maps and to allow smart simulations for providing fast feedback after any changes to the parameter settings.

BUILDING CATEGORY	SIZE		Specific site conditions			
residential	m^2		isolated		no vegetation	
tertiary	m^2		line		partial vegetation	
other			court		adequate vegetation	

STARTING EP [ ]

INPUT LOCAL CLIMATE

Climatic zone		January average outside temperature [°C]	
A	D	August average outside temperature [°C]	
B	E	Average global horizontal radiation [kWh/m² yr]	
C	F	Annual heating degree days [oCd/yr]	

BUILDING FEATURES

Façade/wall	U	W/ m²K	
Roof	U	W/ m²K	
Ground floor	U	W/ m²K	
Glazing	U_g	W/ m²K	
Average U-value	U_{av}	W/ m²K	
Glazing	g	total solar energy transmittance of glazing [%]	
Shading	FS	Shading correction factor	
Ventilation rate		airchanges/hr	

RENOVATION OPTIONS

Strategy	[kWh/m² yr]	Starting condition	Target reduction %	Achieved reduction %
Heating + ventilation				
Cooling + ventilation				
Ventilation				
Lighting				
Over-cladding + insulation				
Domestic hot water				
RES integration				
Other....				

INFLUENCED ENVIRONMENT

Average indoor condition after intervention		Average outdoor condition after intervention	

Figure 7: architecture of the tool with the key layers and sub-categories.

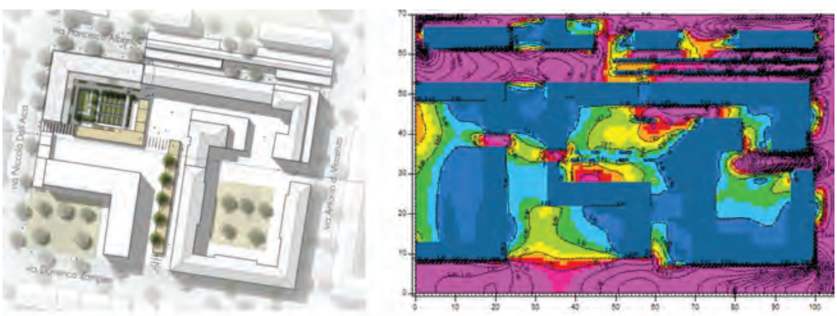

Figure 8: example of wind map (b) compared with green re-design (a) of a portion of the urban fabric on the demo-site.

4 RESULTS, IMPACTS AND REPLICATION POTENTIAL

The main results of the study deal with two different levels: on the one hand, the attempt to define thematic layers that represent the recurrent issues detected in the performed review in order to have a broad range of categories included in an easier structure to manage; on the other hand, the architecture assigned both to the methodological backbone and to the platform itself represents a promising field of work in boosting synergies and connections between initiatives and solutions. The original character of the research lies in considering the district meso-scale in terms of renovation projection, performance level, achieved results, while analysing and processing data acquired on the single elements (buildings, green areas, circulation, etc.) composing it. This approach requires a very multi-disciplinary team including experts from different domains particularly regarding ICT development and software integration.

The research is expected to have a positive impact on the city regeneration process. In the short term, it will drive innovations in energy management and control technologies in the renovation market – which is the widest field of application from the Municipality's point of view in several areas of the City – and will increase the key player awareness thus generating a greater demand for both innovative, retrofit solutions (e.g. insulation, ventilation, water saving, etc.) and training and support services for building managers [37, 41]. In the medium term, although it might be randomly replicated in different sectors of the city according to the dotted nature of investments and to the emerging needs, it will direct the processes into a coordinated vision drafted following the pattern designed by the thematic maps of each layer like pieces of a single mosaic. The main barrier to speeding up the process is the lack of resources available to plan interventions in the long-term perspective that usually lead to single isolated initiatives rather than to larger portions of the city. The ownership regime is also a critical element that hinders coordinated decision-making processes. However, the very active cooperation with the Municipality of Bologna is a promising premise in order to successfully overcome procedural and contextual barriers and to boost tool adoption and use by the key players involved.

5 CONCLUSIONS AND DISCUSSION

This multi-perspective approach is a response to what the City of Bologna, as problem owner, profiled when asked to facilitate the cooperation between all subjects – from suppliers to citizens and communities – in order to optimize energy efficiency measures, find adaptable solutions and increase the overall quality at district level according to a coordinated vision [37, 42–44]. The envisaged methodology requires a constant updating of the key parameters (i.e. building features concerning both the construction system and equipment, site features, relation with neighbouring buildings, circulation, connection to grids, etc.) as well as the protocols for data acquisition. A circular check process is used to assess the effect each technical solution to be implemented may produce according to pre-defined targets of performance and quality. The platform is therefore the first application of the methodology and, at the same time, the tool to check its coherence and reliability. The next steps will be the implementation of the demo-cases and the related extension of platform functionalities according to the envisaged multi-user perspective. The ambitious character of the research requires several intermediate evaluations to allow the development of each single phase according to a circular checking process. In addition, each single stage is planned separately according to budget availability so as to ensure the advance of the research.

The originality of the research is indeed mostly connected with its multi-criteria and multi-user dimension, which are closely connected to the core concept of scalability that was assumed in the very early phase of the project conception as the key element to satisfy the replicability of the methodology either in several parts of the city or in other cities with different contexts and size. This represents a crucial element for defining adequate pathways to replicate the process elsewhere and for driving the platform structure to further implementations – not simply referred to the potential additional layers, but mostly to new potential applications dealing with the smart dimension, which will require a constant exchange of information between the real and the virtual realm in shaping the cities of the future [45].

REFERENCES

[1] R. P. European Union, Cities of tomorrow. Challenges, visions, ways forward, 2011, available at http://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/citiesoftomorrow/citiesoftomorrow_final.pdf

[2] EIP on Smart Cities and Communities, "Strategic Implementation Plan", 2013.

[3] Hajer, M. & Dassen, T., *Visualizing the Challenge for 21st Century Urbanism*, Amsterdam, 2014.

[4] Secchi, B., *La città dei ricchi e la città dei poveri*, Laterza, 2013.

[5] Bonomi, A. & Masiero, R., *Dalla Smart City alla Smart Land*, Marsilio, 2014.

[6] Pickett, A.T.A., Boone, C.G., McGrath, B.P., Cadenasso, M.L., Childers, D.L., Ogden, L.A., McHale, M. & Grove, J.M., Ecological science and transformation to the sustainable city. *Cities*, **32**, pp. S10–S20, 2013. https://doi.org/10.1016/j.cities.2013.02.008

[7] The World Bank, "Cities and Climate change: an urgent agenda", 2010, available at http://siteresources.worldbank.org/INTUWM/Resources/340232-1205330656272/CitiesandClimateChange.pdf

[8] Ferrao, P. & Fernandex, J.E., Sustainable urban metabolism. *The MIT Press*, p. 264, 2013.

[9] European Environment Agency, "Urban adaptation to climate change in Europe", 2012, available at http://www.eea.europa.eu/publications/urban-adaptation-to-climate-change.

[10] Engelke, P., Foreign Policy for an Urban World: Global Governance and the Rise of Cities, 2015, available at https://www.ciaonet.org/attachments/28077/uploads?1446493739

[11] Espon, Territorial Dimensions of the Europe 2020 Strategy, 2013.

[12] Batty, M., The future cities agenda. *Environmental Planning B Planning and Design*, **40**, pp. 191–194, 2013. https://doi.org/10.1068/b4002ed

[13] Hall, R.E., Bowerman, B., Braverman, J., Taylor, J. & Todosow, H., The vision of a smart city. In 2nd *International Life Extension Techology Workshop*, 2000, available at http://www.osti.gov/scitech/servlets/purl/773961

[14] Nam, T. & Pardo, T.A., Conceptualizing smart city with dimensions of technology, people, and institutions. *Proceeding 12th Annual International Digital Goverment Research Conference Digital Government Innovation in Challenging Times*, pp. 282–291, 2011. https://doi.org/10.1145/2037556.2037602

[15] Roche, S., Nabian, N., Kloeckl, K. & Ratti, C., Are 'smart cities' smart enough? *GSDI World Conference*, pp. 215–236, 2012.

[16] Wolfram, M., Deconstructing smart cities: an intertextual reading of concepts and practices for integrated urban and ICT development. *Real Corp*, pp. 171–181, 2012, ISBN 978-3-9503110-2-0

[17] Antonini, E., Gaspari, J. & Boulanger, S.O.M., Multi-layered urban strategies to foster the smart cities development. *The Sustainable City X, WIT Press*, **194**, pp. 23–34, 2015, ISSN 1743-3541

[18] Balducci, A. e Fedeli, V., Quartieri che cambiano In *Territori della città in trasformazione. Tattiche e percorsi di ricerca*, Angeli, Milano, 2007.
[19] Barton, H. (eds), *Sustainable Communities: The Potential of Eco-Neighbourhood*, Eartschan, London, 2000.
[20] Foerlev, B., Urban regeneration — a role for research? Batiment International. *Building Research and Practice*, **10**(2), 1982.
[21] Municipality of Bologna, BLUE AP. *Bologna Local Urban Environment Adaptation Plan for a Resilient City*, available at http://www.blueap.eu/site/.
[22] Neirotti, P., De Marco, A., Cagliano, A.C., Mangano, G. & Scorrano, F., Current trends in smart city initiatives: Some stylised facts. *Cities*, **38**, pp. 25–36, 2014. https://doi.org/10.1016/j.cities.2013.12.010
[23] Williams, K., Burton, E. & Jenks, M., *Achieving Sustainable Urban Form*, E & FN Spoon, London, 2000.
[24] Hajer, M. & Dassen, T., *Visualizing the Challenge for 21st Century Urbanism*, Ed. naio10publisher/PBL publishers, Amsterdam, 2014.
[25] GIZ and ICLEI, Operationalizing the Urban NEXUS. Towards resource-efficient and integrated cities and metropolitan regions, 2014, available at http://www2.giz.de/wbf/4tDx9kw63gma/UrbanNEXUS_Publication_ICLEI-GIZ_2014_kl.pdf
[26] Floater, G. & Rode, P., Cities and the New Climate Economy: The transformative role of global urban growth, 2014, available at https://files.lsecities.net/files/2014/11/LSE-Cities-2014-The-Transformative-Role-of-Global-Urban-Growth-NCE-Paper-01.pdf
[27] European Commission Directorate General, LIFE and Climate change adaptation, 2015.
[28] Mattoni, B., Gugliermetti, F. & Bisegna, F., A multilevel method to assess and design the renovation and integration of smart cities. *Sustainable Cities and Society*, **15**, pp. 105–119, 2015. https://doi.org/10.1016/j.scs.2014.12.002
[29] Vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R. & Cleven, A., Reconstructing the giant: on the importance of rigour in documenting the literature search process. *ECIS 17th European Conference on Information Systems*, pp. 2–13, 2009.
[30] Cooper, H.M., Organizing knowledge synthese: a taxonomy of literature review. *Knowledge in Society*, **1**, pp. 104–126, 1988. https://doi.org/10.1007/BF03177550
[31] Cocchia, A., Smart and digital city: a systematic literature review, in smart city. In *Smart City*, eds R.P. Dameri & C. Rosenthal-Sabroux, Springer International Publishing: Switzerland, p. 32, 2014.
[32] OECD, Handbook on Constructing Composite Indicators: Methodology and User Guide, 2008, available at https://www.oecd.org/std/42495745.pdf
[33] United Nations, Indicators of Sustainable Development: Guidelines and Methodologies, Economics and Social Affairs, 3rd ed., pp. 1–90, 2007, available at http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf
[34] Directorate-General for internal policies- European Parliament, Mapping Smart Cities in the EU, 2014, available at http://www.europarl.europa.eu/RegData/etudes/etudes/join/2014/507480/IPOL-ITRE_ET%282014%29507480_EN.pdf
[35] Stafford, A., Gorse, C. & Shao, L., *The Retrofit Challenge: Delivering Low Carbon Buildings*, Centre for Low Carbon Futures: Leeds, UK, 2011.

[36] Abastante, F., Lami, I.M., Lombardi, P. & Toniolo, J., Towards Sustainable Urban district: a MACBETH approach. In: *Towards Post Carbon Cities*, Torino, pp. 134–143, 2016.
[37] Giffinger, R., Hemis, H., Weninger, K. & Haindlmaier, G., PLEEC. Planning for energy efficient cities. *Methodology for Monitoring*, 2014, available at http://www.pleecproject.eu/downloads/Reports/Work%20Package%202/wp2_d24_methodolgy_for_monitoring.pdf
[38] ISO/IEC JTC 1 Information Technology, Smart Cities. Preliminary Report, 2014, available at http://www.iso.org/iso/smart_cities_report-jtc1.pdf
[39] Jiménez, J.P., Martìn, A., Rosa, P.D.L., Aguilera, O. & Pulido, E.P., DAREED. Definition of a methodology for district modelling, FP7 project “DAREED”, 2014, available at http://www.dareed.eu/-/m/124/DAREED%20Project%20-%20WP1%20-%20D1.4.pdf
[40] European Commission – Directorate General Information Society and Media – ICT for Sustainable Growth Unit, “Smart Buildings”, 2009, available at http://ec.europa.eu/information_society/activities/sustainable_growth/docs/sb_publications/smartbuildings-ld.pdf
[41] Fertner, C., Groth, N.B., Grosse, J., Read, S. & Rocco, R., Framework for reports on urban energy planning in 6 case cities, 2014.
[42] Giffinger, R., Fertner, C., City ranking of European Medium-Sized Cities, Vienna University of Technology, University of Ljubljana, Delft University of Technology, 2007.
[43] Un Habitat, *State of The World’s Cities 2012/2013: Prosperity of Cities*, Routledge: New York, NY, USA, 2013.
[44] Erell, E., Pearlmutter, D. & Williamson, T., *Urban Microclimate: Designing the Spaces Between Buildings*, Earthscan: London, Washington, DC, p. 266, 2011.
[45] Smart City Council, Smart Cities Readiness Guide: The planning manual for building tomorrow’s cities today, 2013.

GREEN AREAS IN COASTAL CITIES – CONFLICT OF INTERESTS OR STAKEHOLDERS' PERSPECTIVES?

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ABSTRACT

Coastal zones have experienced rapid urban growth over the last 50 years and this is expected to continue. The most important reasons for rapid land-use changes are related to real estate pressure and the construction of new urban infrastructures. Coastal systems support a wide variety of social, economic and natural services and are directly affected by multiple human activities. The downside of urban increase is reflected in the change of land-use cover, and land-cover from open areas to built-up areas, especially within the metropolitan cities on the coast. The aim of the paper is to evaluate the relationship between the decrease of large green areas in coastal zones and the efficiency of planning and regulation of those areas. For this purpose, we are presenting a comparison between two case-studies from different countries: Boa Viagem Beach in Recife (Brazil) and Rocha Beach in Portimão (Portugal). These two areas have similar socio-environmental problems. The method relies on two sources: literature review (national regulation and policy documents) and 37 semi-structured interviews with stakeholders/agents responsible for urban development of the two areas of study. The interview questionnaire comprised topics such as the national planning legal framework, the process of urban growth, the impact of densification and the problems related to the lack of green areas in the coastal zones. A 3D GIS model complements the geospatial references of the research, showing the localization of green areas and their decrease over time. The comparison on different aspects of development in the two countries shows that the rules tend to be more efficient in Portugal than in Brazil. However, in both countries, it is felt that more efficient legal instruments and enforcement action is necessary to lead developers to comply with the rules. The use of semi-structured interviews proved to be very effective for comparative analysis on national policies. The paper presents a cross-national perspective with different stakeholders' points of view on the issue of the scarcity of green areas in coastal zones, which is intended to provide helpful information to planners, scholars and administration officers.
Keywords: 3D GIS model, green areas, interview, urban planning, vertical growth.

1 INTRODUCTION

Cities have always been responsible for the enormous challenges to humans in terms of the adaptations necessary to live in such environments where important ecological services (effluent dilution, clean air, thermal comfort, etc.) need to be managed to promote individual and social wellbeing. However, more recently, the possibility of climate change, demographic aging, and natural resource depletion [1, 2] have presented us with new problems. The report of the Department of Economic and Social Affairs of the United Nations in 2012, reports that cites and their surrounding regions used by humans for infrastructure and commerce facilities, require a great many resources, which cause intense pressure on the environment. This is even more worrying because nearly 51% of the global population live currently in cities and their suburbs. In developed countries like the United States, Canada, Australia, Japan and Europe the estimate is that up to 80%, or even 90% of the population live in urban centres [3].

Rapid population and urban growth have affected coastal zones around the world, especially in the last decades (from 1970s onwards) [4]. Among the prevailing stakeholders driving extreme urban growth along coastal zones is real estate speculation, which is pushing for the

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construction of more, higher, and more expensive new buildings inside these areas [5, 6]. The view of the passage is more attractive, for the biggest the people and the especial areas for the rest and the vacations.

Another aspect is noted: loss of green areas [7]. If sustainable development practices are to match the pace of rapid changes resulting from urbanisation, the urban knowledge gap must be quickly bridged [2]. Recent literature indicates that green environments within urban areas contribute with multiple benefits, and is very important for the well-being of urban populations [8–10 the provision of urban green areas is approached from a social perspective, as public spaces for recreation and sports activities, regardless of the environmental and economic benefits they can provide from a sustainable development perspective. The planning of urban green areas requires a set of conditions in order to be successful, among which are: an updated regulatory framework, adequate financial resources, technical knowledge of the appropriate plant species and the effective participation of the community. However, without a complete and classified inventory of the existing green areas, any planning is unfeasible. Therefore, this paper presents the first stage of the study of urban green areas in a city of the State of Baja California, Mexico, developing firstly, a review of the regulatory framework and a redefinition of the concept of urban green areas that takes into account the basic dimensions of sustainability, and on the other hand, it proposes a general classification of urban green areas that includes all types of open spaces with vegetation: both for public and private use, subdivided into systems and subsystems, which were the basis for the identification, classification and quantification of urban green areas, using Quickbird multispectral images of 2.6 m resolution and applying the Normalized Difference Vegetation Index (NDVI]

Rapid urbanization causes tremendous growth in buildings and population that is accompanied by environmental issues including heat islands trapped inside urban areas, including the hinterland of coastal cities. The primary reason for heat islands' formation in urban areas is the absorption of solar radiation by the mass of built-up structures, roads, etc. during daytime [11]. The absorbed heat is subsequently re-radiated to the surroundings and increases ambient temperatures at night [7]. Natural green areas within cities can thus provide a certain adaptability (resilience) to urban landscapes in coping with problems such as increased risks of heat waves and flooding [11]. Green spaces in urban areas have been found to be promising in enhancing urban life quality in many ways, but in many cases this is no longer possible, mainly because of the lack of urban planning. For example, urban-locked natural ecosystems were vastly under-represented in the world's largest assessment of ecosystems [2].

Cities are dependent on the ecosystems beyond their limits, but also benefit from internal urban ecosystems. Such is applicable to urban areas along coastal zones, where part of the city limits is a water mass (the sea or an estuary, for example). These areas are part of the city, both suffering and exerting direct influence over it [7]. Green areas are one of the many possible ecological measures used to combat the problems of urban heating that may also contribute to wider nature and biodiversity conservation. To address the challenges of ecosystems degradation, an interdisciplinary eco-social system approach is critically important and needed at this time [12]. Ecosystems play an important role in facilitating transformations needed to address urban challenges. Understanding how urban ecosystems work, how they change and what limits their performance can add to the general understanding of ecosystem change and governance in an ever more human-transformed world [8, 12].

It should also be noted that green areas provide services that include non-material benefits such as psychological and cognitive advantages to people who are in contact with nature during recreation, aesthetic, spiritual and tourist activities [2, 7, 12]. Therefore, urban-locked natural green areas should be one more of the strategies aimed at sustainable development packages of actions, since they confer liveability and resilience in urban areas [2, 7, 12].

The comparative studies between different countries were made comparing the space-temporal development of green areas within urban settlements in two different countries: Praia de Boa Viagem Beach at Recife (Brazil) and Rocha Beach at Portimão (Portugal). These two urban areas, although very far apart, have a number of similarities that encourage comparisons from different points of view [4]. In this research, Boa Viagem Beach, located in Recife, northeast region of Brazil, and the Rocha Beach of Portimão located in the southern region of Portugal, Algarve, are taken as case studies for testing the proposed methodology. Two reasons support this choice. Firstly, the findings show that the coastal urban zones of Boa Viagem Beach and Rocha Beach underwent major and rapid physical changes over the 1960–2013 period. Secondly, although these two case studies are located in such distinct geographic contexts, they exhibit similar land-use and land-cover change dynamics especially regarding transitions from non-urban land to urban land. Extensive documental and literature review was allied to 37 semi-structured interviews with stakeholders who were considered responsible for urban changes and development in the two areas of study. The interviews and questionnaire comprised topics such as the national planning legal framework, the process of urban growth, the impact of densification, and problems related to the diminishing green areas in these two coastal cities. A 3D GIS model complements the geospatial references of the research, showing the localization of green areas and their evolution over time.

2 STUDY AREAS, MATERIALS AND METHODS

2.1 Study areas

Boa Viagem Beach is situated in the coastal area of Recife City, the capital of Pernambuco State, a thriving economy in the Brazilian Northeast (Fig. 1). The study-area is 200 ha and is located in the south of Recife City, with approximately 2 km of seafront. Due to the

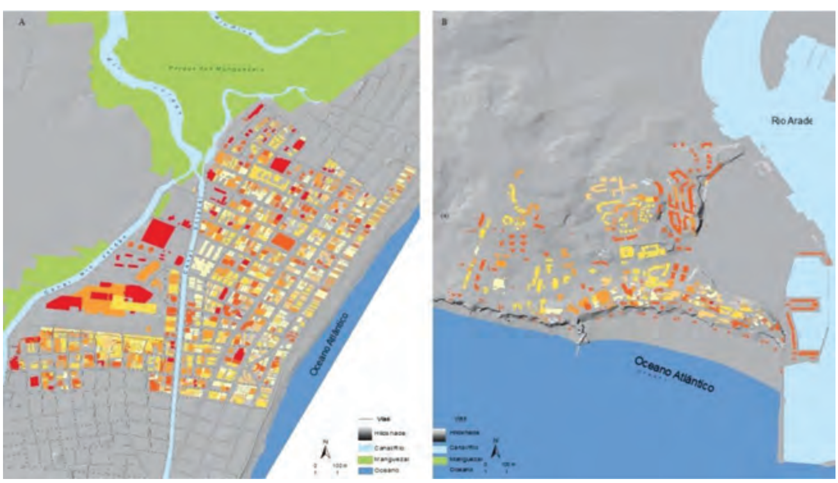

Figure 1: Study areas: (A) Boa Viagem Beach, Recife City, Brazil; (B) Rocha Beach, Portimão, Portugal.

tropical climate of the region, mangrove-flooded forests dominate the estuaries. As Recife has developed in the last 500 years, especially in the last century, only small fragments of this ecosystem remain. The most important is a park (1000 ha) that limits the landward side of Boa Viagem Beach. It is the only significant green area in the south of the city. Recife City has other green areas such as public parks, communal gardens, and internal courtyards, but the major green area is in the north of the city and is part of the Atlantic Rain Forest (Dois Irmãos Park).

Rocha Beach is situated on the coastal area of the Portimão City in Portugal, and is the capital of Barlavento – Algarve Region (Fig. 1). Located in the Atlantic South of Portugal, the study-area is characterized by a Mediterranean climate. Rocha Beach is 200 ha located in the south of Portimão, with approximately 2 km of seafront. It has arborized open squares but no public parks. Portimão has other green areas, like public parks, communal gardens, and internal courtyards, but the major quantitative green areas are spread across the city.

The green areas in both cities are diversified by the types of buildings, which include different homes, apartment buildings, commercial buildings and mixed-use buildings. Green areas are considered by UNDESA as an indicator of the quality of life. Based on official data by the town hall of Recife City that measures ‘green area per inhabitant’, a per capita value of 46 m^2/inhabitant emerges (Table 1).

The World Health Organization (WHO) recommends a minimum of 12 m^2 of green area per inhabitant, but the ideal is 36 m^2 per inhabitant [3]. The data presented in Table 1, is for the whole Recife City and considers as ‘green areas’ all types of vegetation cover (trees, grams, bush). This data will be discussed later. In 2012, the Secretariat of the Environment, together with the Environmental Policy Directorate of the Recife City, identified 25 Nature Conservation Units and two Landscape Conservation Units.

No data was found for the Portimão City, but one can follow on the map the distribution of green spaces in Rocha Beach (Fig. 2). As in the city of Recife, Portimão considers all type of vegetation cover as ‘green areas.’

2.2 Materials

2.2.1 Cartographic data

Vector and matrix data were used to identify the green areas in both study areas. Being in different countries, it was necessary to take into account the specific norms and laws that affect these areas (Table 2).

The altimetry data is composed of sets from vector cartography used by the municipality, and the digital terrain model was composed of 1 m in both areas. It was collected from official sources at the two cities. The representations and digital maps of the areas were made by processing hildshade in Arcgis. Another source of altimetry information was Magarotto *et al.* (2015). The other set of elevation and contours was obtained from 1:1000 scale altimetry cartography of 1998, available.

Table 1: Total square meters of green area per inhabitant (annual average) for Recife City

City	Year	Green space in urban areas (m^2)	Total inhabitant	‘Green area per inhabitant’
Recife	2012	7156,8158	155,5039	46,0234

Source: Secretariat of Environment and Sustainability.

Figure 2: Green areas in study area of Rocha Beach.

Table 2: Vector and matrix data available for each study area.

City	Data	Year
Recife	Aerial photographic covers	1961
		1981
	Satellite images	2002
	Orthophotomaps	2013
	Vector cartographic data	2013
	Municipal land use plan	2008
Portimão	Aerial photographic covers	1958
		1986
	Satellite images	2002
	Orthophotomaps	2010
	Vector cartographic data	2010
	Municipal land use plan	2008

2.2.2 Interviews

Semi-structured interview with key participants is a research technique used with interest groups to assess the current situation of green areas in the two study areas. In conjunction with the interviews, laws and urban development plans were also analysed. These semi-structured interviews were carried out by those in charge of town planning, eligible public positions, real estate entrepreneurs, associations/residents and researchers that characterize

Table 3: Interviews with key informants.

Cities	Researchers	Municipal staff	Politician	Residents Owners	Real estate agents
Recife	4	6	2	4	2
Portimão	5	7	3	2	2

interest groups. There was a total of 37 interviews, 18 in Recife (Brazil) and 19 in Portimão (Portugal), with representatives of different groups of stakeholders acting in different aspects of stakeholder's urban growth and built-up areas (Table 3).

The interviews were coded as Interviewee Boa Viagem Beach (IBVB) followed by a number (1,2,3...); Interviewee Rocha Beach (IRB) and a number. The application of this qualitative technique of social research allowed us to identify and explore the different perceptions and opinions of the stakeholders on the problem, the potentialities and challenges associated with green areas in the two study areas, as well as their impact on urban environment as a whole. It should also be noted that analysis of different discourses has brought to light good practices, points of convergence, and possibilities for understanding the efficiency of green areas to improve the quality of life of local residents and visitors.

All the interviews were recorded in digital format and later transcribed for treatment and analysis.

2.3 Methods

The methodological proposal of this paper is the association between qualitative and quantitative research methods, a seldom-attempted approach. The quantitative aspect is the visual analysis of satellite and other images that identified the green areas within each parcel of 200 ha under investigation, and the qualitative aspect is the association of the GIS data with the interviewers' references to green areas they know of. The integration of GIS and interviews confirms the present situation of study areas in relation to changes (increase, decrease and change in quality) in the total and partial green spaces within a city.

The use of the 2D/3D GIS Model in the analysis was of great importance for the observation and mapping of the elements present in the geographic space. The data was represented dynamically, along four decades (1960–2013), through the association of data and the interpretation of clear and efficient spatial information. This processing of the quantitative data aims to create a 3D GIS model over the terrain, and locate visually the information for surface characterization. The result of this stage includes above-ground spatial objects. This first step was taken with most recent data available of Boa Viagem Beach (2013) and Rocha Beach (2010). This process is the basis for the reconstruction of the other years in this study. Through this technique it is possible to see in the previous aerial coverings whether or not the space objects of the study existed, and thus model the terrain.

Applications to verify vegetation-related variables and indexes is common within the Remote Sensing science, to quantify the spatial distribution of vegetation through the digital data of reflecting spectral bands. The surface of plants absorbs radiation in the visible range (between 0.4 and 0.7 μm) and is reflected in the Near Infrared (NIR) range (0.725 to 1.10 μm). Thus, a vegetation index may be the ratio of the difference and/or combination between the VIS and NIR reflecting values, considering there is no atmospheric interference. However, in this paper, the data acquired in the public agencies consulted for this research will be used. The interest is the use of green areas for improvement of both cities' life and environmental quality. Another aspect is the use of terminology: green areas rather than green spaces. This last term is used for the denomination of all green spaces within the city (…). Green areas are specific to gardens or public parks only.

3 RESULTS

The analysis of land use in Boa Viagem Beach and Rocha Beach shows that these two urban areas, though in different countries, have similar problems in respect to green areas. Both study areas have consolidated gardens and parks, but they are little used by the population (local residents or tourists). This analysis in large scale shows that in the two areas, streets are made to benefit the cars. The pavement does not exist or is uncomfortable for pedestrians walk. Bicycle lanes are present at the beachfront, with little planning, and were built over the pavement, reducing available space. These observations can be seen empirically in both the study areas. On the other hand, contact with the local reality shows other aspects that are not perceptible at first sight.

Boa Viagem Beach has no trees on the sand, but has some coconut trees that provide limited shade, much used by local formal and informal beach commerce (beverages and snacks). The presence of coconut trees provides some relief from the sun until the early afternoon, after which buildings shade the beach (backshore). This is the reason why green areas have been used for moderating urban climate all over the world in recent years. Also, coconut trees are responsible for providing the feeling of *tropical beach* that sellers want to associate with their products. Therefore, in addition to physical comfort, they compose a landscape in agreement with users' desires, promoting psychological well-being.

Portugal has a longer history in relation to the planning of its coast when compared to Brazil. The first instrument is the Royal Decree of December 31, 1864, which establishes the Public Maritime Domain (MPD). This is now reflected in ever-changing and evolving models for the development and management of the coast, especially in continental Portugal. At Rocha Beach, commerce is well-organized and follows norms from the Coastal Zone Management Plans (POOCs) (Decree 309/93). However, relative to green areas, there is no specific regulation, and it approaches the same vulnerable situation as Boa Viagem Beach.

The green areas in Boa Viagem Beach are small patches, and a major area of mangrove-flooded swamp that recedes rapidly at the rear of the neighbourhood. At Rocha Beach, there are four green areas (Fig. 2). These are the most representative green areas that were detected in both study areas. A more detailed work scale could reveal individual trees on the pavements, flower/grass beds along avenues and around buildings used by residents and tourists. However, the objective of achieving better urban environments does not result from individual trees and grass beds, but from the maintenance of much larger patches with full ecological services being provided to the surrounding city. In both study areas, it is shown that these significant spaces are shrinking rapidly, in the timescale of less than a lifetime, to make room for more buildings and roads (Fig. 3), which could already permanently compromise the quality of life of the present and next generation.

In relation to the interviews, the decrease in green areas and environmental quality was a transversal preoccupation across all involved from both study areas, independent of their profile in relation to urban changes.

'This is an aspect (green areas) that concerns the public sector. However, the real state sector, the population, and even researchers, agree that it does not serve public use, but the maximization of business interest' IBVB5.

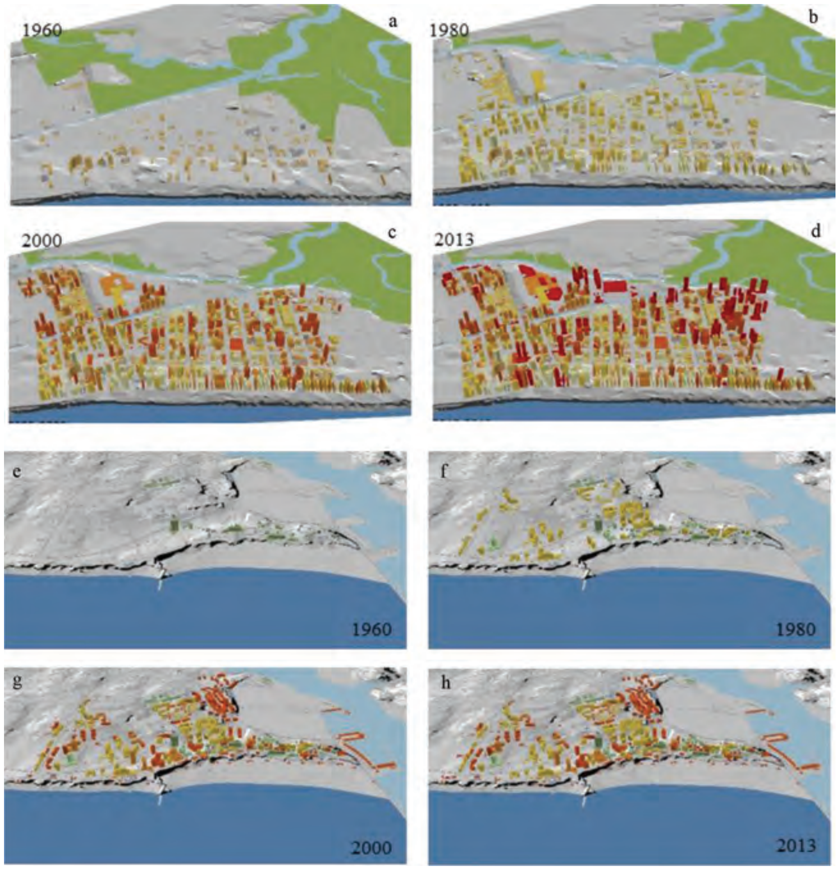

Figure 3: Evolution of vertical growth and green areas from 1960 to 2013 in (a–d) Boa Viagem Beach and (e–h) Rocha Beach. The different colours of the buildings represent their years of construction.

The common opinion is that green areas are essential to moderate air temperature change and that they are good for sports activities. Another aspect is the conviction that the creation/construction/maintenance of these green areas is the responsibility of public authorities exclusively.

The Interviewеds, in the public power, when questioned about this fact they always answered that 'the public administration should work to benefit the population, but the new administration is failing to promote change concerning green areas' IRB10, thus the government know the problem, but the actions of different administrations do not resolved the problem.

The associated question in Boa Viagem Beach answers that this is less important; for them the problem is related to public power and real estate. 'The public administration counts on the assistance of residents who seldom do the right thing about the building of green areas on their properties. They plant a couple of trees and a bit of grass where no one else has access' IBVB 07. 'Local regulation demands all new property to have at least 10% of green area' IBVB15. This shows that for the associations there is complicity relationship between the government and real estate. This work that make associate management, which is normally disregarded by planning authorities, is important for urban planning. The city organization is the result of the contribution of all those involved.

The real estate group are more pragmatic and say ‘real estate always does what is determined by public regulation… If semi-permeable pavement is more convenient for parking areas, it will be used since this type of finishing is considered a green area’ IRB01. In another place, about of the similar theme ‘we have to think better about the city. Today, Recife is going through a complicated urbanization process. The government alone is unable to manage the city. We, real estate businessmen, can help as partners. But there are many things we have to do, for example, forbid homeless people to build in green areas (over land and water) or to invade public and private property’ IBVB11. Here, the concern is of the real estate not the green areas or the comfort of the population, but that business has protection from the public power.

Local people have another consideration, because this group live with all the time. ‘The population suffers from the absence of green areas, having no place to go in the neighbourhood for a walk or a dip, the only option being the sea. I was in Barcelona last year, and walked along a reorganized area near the beach ... There was a large park with playgrounds, trees, jogging track ... I thought the same could be made here in Boa Viagem, and other areas in our neighbourhood’ IBVB13. Here the local people show disenchantment with the use of the city as a commodity. ‘It occurs because the city’s green areas are used for real estate speculation. People are often deceived when buying an apartment. The whole idea is that the surrounding landscape will never change. But, in reality, after they sell, the public administration suddenly becomes responsible for the view’ IRB14. This is happens because the real estate speculators have no control, and the interest is higher than the welfare of local residents.

Criticism of the system is interpreted by research groups: ‘Even with all the technology and space available, the public administration has no interest in building parks and taking good care of them… There are many places around Recife that are totally abandoned, or under-used as natural urban habitats, except for irregular activities and drug abuse’ IRB15.

4 DISCUSSION AND CONCLUSION

The present work created an opportunity successfully to link ground data (quantitative) and perceptions from different and relevant participants (qualitative). This is important, as a link between these two types of information needs to be made, *preferably* at the planning stage of coastal cities and their neighbourhoods. Residents, living in the urban space or studying its changes, are the best agents to spot opportunities for land use, and to translate it into social welfare. Their sensibility could be used to locate housing, infrastructure and green areas.

The continuing increase in the number and size of cities and the ensuing transformation of natural landscapes on different scales pose significant challenges for reducing the rate of biodiversity loss and related ecosystem functioning, and ensuring human welfare [2, 9the provision of urban green areas is approached from a social perspective, as public spaces for recreation and sports activities, regardless of the environmental and economic benefits they can provide from a sustainable development perspective. The planning of urban green areas requires a set of conditions in order to be successful, among which are: an updated regulatory framework, adequate financial resources, technical knowledge of the appropriate plant species and the effective participation of the community. However, without a complete and classified inventory of the existing green areas, any planning is unfeasible. Therefore, this paper presents the first stage of the study of urban green areas in a city of the State of Baja California, Mexico, developing firstly, a review of the regulatory framework and a redefinition of the concept of urban green areas that takes into account the basic dimensions of sustainability, and on the other hand, it proposes a general classification of urban green areas that includes all types of open spaces with vegetation: both for public and private use, subdivided into systems and subsystems, which were the basis for the identification, classification and quantification of urban green areas, using Quickbird multispectral images of 2.6 m resolution and applying the Normalized Difference Vegetation Index (NDVI]. The term 'green areas' in the cities this study is a mistake, the correct use this term 'green areas' should be related to gardens, parks with plants, animals and microorganisms. This biodiversity can be used by residents of the zone and the ecosystems, and the services that they can provide.

Urbanisation and soil-sealing provoke changes, predominantly a decline, in species diversity and human well-being in cities [2]. Other types of change – vegetation in urban areas – can be reoffered as green spaces (e.g. trees, grams, bush and flowers beds in avenues or private buildings). Therefore, there should be a different classification for green areas in the two studies. Certainly there would be a better notion of what use they would be to residents. For example, the study area of Rocha Beach is presented without green spaces (Fig. 4). Note that there are only four green areas for use by residents. However, only two gardens are open to residents (on the beach cliff, and to the north of the study area). The other two areas are on private land without access to inhabitants (the east) and the last was granted to the town hall to build a park with other general public facilities (soccer field, basketball, tennis, among others).

Another important aspect in that have attention is the evolution of the transformation of natural landscapes, is the fact of Boa Viagem Beach (Fig. 3). The urban vertical growth was rapid and destroyed the coastal landscape. The mangrove swamp disappeared, with the years

Figure 4: The study area of Rocha Beach whit the useful green areas.

and the construction of urban buildings. The result, as pointed out in the semi-structured interviews, was the creation of a cluster of skyscrapers that today constitute a complicated urban arrangement. The Secretariat of Environment and Sustainability of the City of Recife has classified all green spaces so that the calculations of the green areas (Table 2) obtain a high index figure; but if one looks closer, to the local reality we see that in the area of study of Praia de Boa Viagem has almost no green areas, and those that might be possible are in a very bad state of preservation.

The importance of the ‘green areas’ study is related to improving the quality of life of the inhabitants. Many point out that green areas provide ecosystem services, which include reduction of air pollution, reduction in the heat island, benefits to health (which make cities more sustainable), and with the use of the green areas inhabitants are more sociable.

Lastly, it can be emphasized that the use of the term ‘green areas’ deserves to be highlighted as note for a correct use for a better designation of these areas, in the cities and especially in the coastal zones. Thus the elaboration of the indices of green areas could be better represented and adequate the reality. Another important aspect of green areas should also include qualitative use and constant conservation.

Considering the complexity of today’s society, exposed to increasingly artificial environments, the urban planning should find seek solutions ways to prevent the decline of environmental quality in the city in general and special attention of coastal zones. Coastal areas, as pointed out by the interviewed, require regular greater environmental comfort protection, and with larger green areas for the leisure and sociability and pleasure of appreciate the views and the nature by the inhabitants and tourists. This study approaches the analysis of green areas in two different countries and contributes to the knowledge and possible improvement of the conditions quality of life of the two cities.

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REFERENCES

[1] Dasgupta, S., Gosain, A.K., Rao, S., Roy, S. & Sarraf, M.A., Megacity in a changing climate: the case of Kolkata. Clim Change [Internet]. 2012 Jun 28 [cited 2013 Aug 16]; **116**(3–4), pp. 747–766, available at http://link.springer.com/10.1007/s10584-012-0516-3 https://doi.org/10.1007/s13280-014-0504-0

[2] Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., Gomez-Baggethun, E., Gren, Å., Hamstead, Z., Hansen, R. & Kabisch, N., A quantitative review of urban ecosystem service assessments: concepts, models, and implementation. *Ambio*, **43**(4), pp. 413–433, 2014.

[3] UNDESA. World Urbanization Prospects: The 2011 Revision [Internet]. Presentation at the Center for Strategic and …. 2012, available at http://esa.un.org/unpd/wpp/ppt/CSIS/WUP_2011_CSIS_4.pdf

[4] Magarotto, M.G., Costa, M.F., Tenedório, J.A., da Silva, C.P., Vertical growth in a coastal city: an analysis of Boa Viagem (Recife, Brazil). *Journal of Coast Conservation [Internet]*, **19**(52), pp. 1–12, available at http://link.springer.com/10.1007/s11852-015-0415-7

[5] Inouye, C.E.N., de Sousa, Jr. W.C, de Freitas, D.M. & Simoes, E., Modelling the spatial dynamics of urban growth and land use changes in the north coast of São Paulo, Brazil. *Ocean Coast Management*, **108**, pp. 147–157, 2015. doi:10.1016/j.ocecoaman.2014.12.016

[6] Mikovits, C., Rauch, W. & Kleidorfer, M., Dynamics in urban development, population growth and their influences on urban water infrastructure. Procedia Eng [Internet]. Elsevier B.V.; 2014 [cited 2014 Oct 22];**70**, pp. 1147–1156, available at http://linkinghub.elsevier.com/retrieve/pii/S1877705814001295

[7] Wong, N.H. & Yu, C., Study of green areas and urban heat island in a tropical city. *Habitat Int [Internet]*, **29**(3), pp. 547–558, 2005, available at http://linkinghub.elsevier.com/retrieve/pii/S0197397504000281
https://doi.org/10.1016/j.habitatint.2004.04.008

[8] Santos, T., Tenedório, J. & Gonçalves, J., Quantifying the city's green area potential gain using remote sensing data. *Sustainability [Internet]*, **8**(12), p. 1247, 2016, available at http://www.mdpi.com/2071-1050/8/12/1247
https://doi.org/10.3390/su8121247

[9] Peña-Salmón, C., Leyva-Camacho, O., Rojas-Caldelas, R., Alonso-Navarrete, A. & Iñiguez-Ayón, P., The identification and classification of green areas for urban planning using multispectral images at Baja California, Mexico. In: Ecology and the Environment [Internet]. pp. 611–621, 2014, available at http://library.witpress.com/viewpaper.asp?pcode=SC14-051-1

[10] Balram, S. & Dragićević, S., Attitudes toward urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. Landsc Urban Plan [Internet]. 2005 Mar [cited 2015 Oct 26];**71**(2–4), pp. 147–162, 2005 available at http://www.sciencedirect.com/science/article/pii/S0169204604000520

[11] Barros HR, Lombardo MA. A relação entre ilhas de calor urbana, ocupação do solo e morfologia urbana na cidade do Recife. *Rev GEONORTE* [Internet], **2**(5 Especial 2), pp. 65–76, 2012, available at http://www.revistageonorte.ufam.edu.br/attachments/013_%2528A RELA%25C3%2587%25C3%2583O entre ilhas de calor urbana, ocupa%25C3%2587%25C3%2583o do solo e morfologia urbana na cidade do recife%2529.pdf

[12] Folke, C., Hahn, T., Olsson, P. & Norberg, J., Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* [Internet], **30**(1), pp. 441–473, 2005, available at http://www.annualreviews.org/doi/abs/10.1146/annurev.energy.30.050504.144511

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STRATEGIC ENVIRONMENTAL ASSESSMENT FOR METROPOLITAN PLANS OF COASTAL AREAS. THE CASE OF VALENCIA

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ABSTRACT

Many uses of land, such as for building and all kinds of infrastructure, are concentrated in the metropolitan areas of coastal cities. Often, urban and infrastructure uses are dispersed across the territory, generating situations of urban sprawl. In addition, especially in coastal areas, new urban expansion and new infrastructures are in conflict with other uses, such as for agrological areas, beaches or natural areas. In general, the best agricultural zones on the Mediterranean coast are next to the sea. The more important touristic areas are also next to the sea. Therefore, contradictions between sustainability and development are very intense. All these conditions take place in the metropolitan area of Valencia. Now, regional government wants to develop a metropolitan plan to generate an equilibrium between the different uses and to reserve areas for new urban use and infrastructure. In reality, the area's population is now stable but, for economic activities to be competitive, new usage is required as logistic areas or to increase the rail network. A global vision is also needed for urban transport in the metropolitan area. On the other hand, the environmental impacts of current and planned uses can be significant. Moreover, the perception of environmental impacts has changed over time. It is necessary to preserve areas, such as agricultural areas or natural areas, but it is also necessary to produce the quality of landscape perceived by visitors or to generate a green infrastructure network, according to European policy. Finally, we must integrate all these elements with current and new urban and civil infrastructure uses through a public decision-making process. The objective of this paper is to introduce a methodology to integrate the process of public environmental assessment on the works to elaborate a metropolitan plan for a coastal city such as Valencia (Spain) next to the Mediterranean Sea.

Keywords: green infrastructure, landscape and urban planning; regional planning, strategic environmental assessment.

1 INTRODUCTION

In the 21st century in particular, and during the urban expansion period of 1997 to 2007 and the period of the real estate crisis from 2008 to the present, metropolitan areas have increased in surface area and decreased in density. According to Wheeler [1], who studied the dynamics of six metropolitan regions of the US in the period 1980–2005, the dynamics were characterized by:

- A very large increase in their urbanized areas and a very large increase in the surface of metropolitan areas.
- An important decrease in density, of both population and houses, in metropolitan regions.

In Spain, between 1997 and 2007, there was an expansive economic cycle based on real estate speculation that ended with the economic crisis, which began in 2008 and still continues today [2], with special consequences for touristic coastal zones [3].

Feria and Martínez [4] studied the dynamics of metropolitan areas of Spain between 2001 and 2011. They observed that, in the case of Spain, metropolitan areas increased their populations during the period of the real estate bubble, as you can see in Table 1, but, in the crisis period, their population stopped or decreased. They think that this trend will continue. Nevertheless, the process of metropolitan area expansion and urban sprawl persists and densities

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Table 1: Population evolution of metropolitan areas of Spain. *Source: Feria and Martínez [4].*

	2001		2011	
Metropolitan area	Municipalities	Population	Municipalities	Population
Madrid	172	5,623,784	172	6,729,769
Barcelona	130	4,340,618	139	5,088,201
Valencia	74	1,594,762	80	1,935,363
Sevilla	49	1,369,708	51	1,581,798
Málaga-Marbella	29	1,000,900	25	1,239,954

continue decreasing. That is the case of the metropolitan area of Valencia, a metropolitan area next to the Mediterranean Sea.

Therefore, it is necessary to understand the new reality of metropolitan areas in order to generate policies to improve sustainability in the metropolitan territory through a new kind of planning [5]. In this situation, it is essential that environmental issues are part of the process of strategic environmental assessment.

In the metropolitan area of Valencia, different borders can be identified in function of different criteria. According to the Valencian Community's Territorial Strategy [6], that stablishes different criteria that Feria, the functional area of Valencia covers an area of 3897 km^2 with a population of 1,774,550 inhabitants in 2015. The area includes 90 municipalities. Figure 1 shows the surface occupied by the metropolitan area, according a study

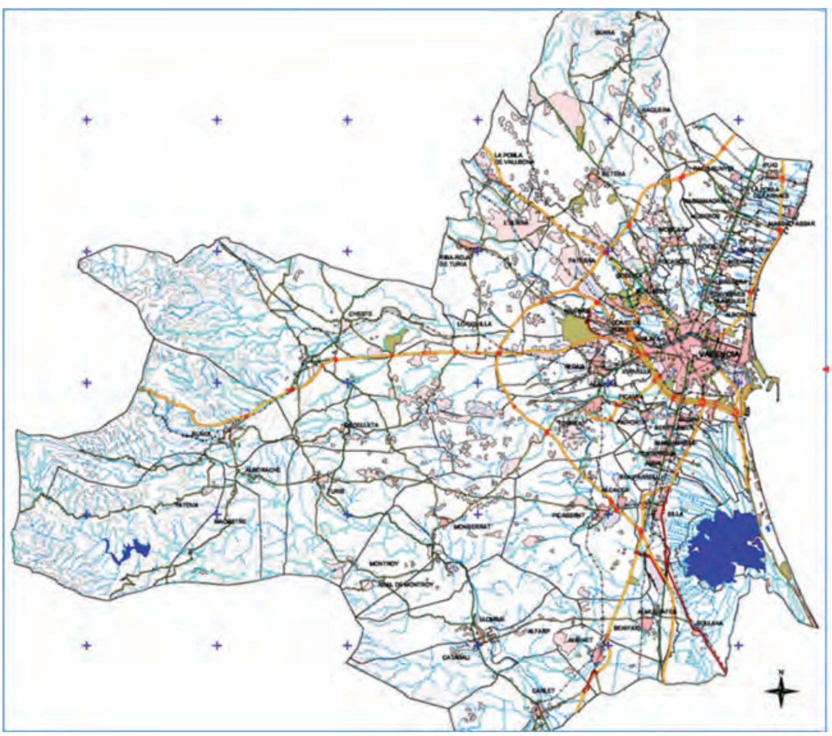

Figure 1: Metropolitan area of Valencia. *Source: UDR F. Eiximenis.*

realized by the author's research team, *UDR F. Eiximenis*, in 2003. The current surface of the metropolitan area is very similar to that of 2003.

In 2005, the population of this area was 1,740,335 inhabitants, increasing to 1,807,826 in 2015, according to the data of the Initial Document for Strategic Environmental Assessment or the Draft Plan of the Metropolitan Plan of Valencia [7]. In addition, there are 895 ha of urbanized land, with the capacity for 22,375 new homes, and 1280 ha of commercial and industrial urbanized lands, with the capacity for 51,200 new employees.

Therefore, the metropolitan area underwent a moderate increase between 2005 and 2015. However, as shown in Table 2, the artificial surface has undergone a large increase, according to Boira [8].

In addition, there is an important amount of land prepared for urban development, as shown in Table 3. With an average density of 25 homes/ha, land planned for residential developments in urban plans (*urbanizable lands*) has the capacity for about 150,000 new homes or 375,000 inhabitants. On the other hand, land for economic activities, with a ratio of 40 employees/ha, has the capacity for about 138,000 new employees.

All this means that, although population is not growing very much, urban use is increasing in a very intensive way. Urban expansion in the metropolitan area of Valencia has taken place in the form of urban sprawl, as can be seen in Fig. 1. This involves an increase in the cost of municipal public services [9, 10]. In addition, this intensive process of urban expansion and sprawl produces important environmental impacts.

2 CONFLICTS BETWEEN USES IN THE COASTAL AREA OF VALENCIA

The coastal area of Valencia, as in the case of many coastal areas, is very complex. Many uses are in clear competition with each other and, thus, generate conflict. In the following points, the most important uses are analysed in a synthetic form.

2.1 Agricultural land

Valencia is located in the centre of a large expansion of high-quality agricultural land: the Horta of Valencia [11]. The climate of the Mediterranean coast of Spain is hot and dry. With

Table 2: Population evolution and artificial land (technical terminology of the CORINE database) of Valencia Urban Region (1990–2006). *Source: Boira [8]*.

Artificial land (ha)	1990	2000	2006
Valencian Community	73,335.28	109,612.90	125,794.52
Valencia Urban Region	28,116.76	36,363.74	41,766.75

Table 3: Land for urban development. *Source: GVA [7]*.

Urbanizable land	Surface (ha)
Residential	6138.86
Public facilities	1987.26
Economic activities	4464.07
– Industrial	3468.74
– Tertiary	995.33
Total	12,590.19

this climate, if water is available for irrigation and the soil is suitable, coastal plains develop highly productive agriculture. That has been the case in Valencia for a long time. Agricultural activity is historical, and the medieval institution of the Water Court, declared a UNESCO World Heritage site, resolves problems between farmers: in general, problems about water management and irrigation. The surface of the irrigation zones has historically been extensive, covering about 23,000 ha. Nevertheless, until now, about 13,000 ha of irrigation zones have been transformed by an irreversible process of Valencia' urban expansion and the surrounding municipalities. The rest is now in the process of being protected, along with other nearby irrigated areas.

2.2 Albufera lake

On the south coast of Valencia, there is the Albufera Natural Park of Valencia. Most of this area has been protected since 1986 [12]. In the geographical area of the park, several activities coexist:

- A wetland ecosystem of international level that is a resting place for birds migrating from Europe to Africa.
- An area especially capable of cultivating rice around the lake; this involves specific management of both water and the water levels of the lake.
- Tourist activity, in general in the whole area and in particular along the coast.

2.3 Tourist activities

Tourist activity is very intense along the entire Spanish Mediterranean coast. This activity is particularly important in Valencia [13]. In the metropolitan area, tourist activity is located in Valencia City in the form of urban tourism, on the north coast and, finally, on the south coast, inside the Natural Park of Albufera. Urban tourist development can produce important environmental impacts [14], a consequence of which is the degradation of the tourist activity itself. The motorway and roads that provide access to the tourist beaches located in the park form a hard barrier for the ecosystem and produce high mortality among the fauna.

2.4 Seaport activity

The seaport of Valencia is one of the most important on the Mediterranean Sea [15]. It was the busiest Mediterranean seaport for container traffic in 2015. The port needs specific facilities located inland for managing freight, especially road and rail infrastructure to provide access to the port and its logistic areas. These demands condition the planning of the metropolitan territory. There are physical limits to the extension of the port: to the north lies Valencia's beach and to the south, the Natural Park of Albufera.

2.5 Land that is urbanized land but not built on

During the period of the real estate boom, a great deal of land was developed but not built on. In the metropolitan area of Valencia, there are 895 ha of residential land, with the entire infrastructure completed but without buildings, having the capacity for 22,375 new houses; there are also 1280 ha of commercial and industrial land with the capacity for 51,200 new employees [16]. So, the capacity for new houses and economic activity is very high.

2.6 Land planned for urban development (urbanizable land)

On the other hand, and in addition to the above figures, the municipalities of the metropolitan area have currently planned 22,637 ha of urban land (land already built) and 12,509 ha of land for urban development (*urbanizable* land) [16]. Land for urban development has the following destiny: 6138 ha are residential land with the capacity for about 150,000 new houses with an average ratio of 25 houses/ha; 3468 ha of land are for economic activity, commercial and industrial, with the capacity for about 138,000 new employees with a ratio of 40 employees/ha. Obviously, a great amount of this land planned for urban development is completely unnecessary.

2.7 The mediterranean corridor

The Mediterranean Corridor is a strategic project to connect the whole EU through transport infrastructure, for freight and passengers, from the south to the north. This corridor has been promoted by the FERRMED lobby [17] since 2004. The corridor runs along the entire Spanish Mediterranean coast and therefore goes through Valencia to connect to the seaport. Consequently, it is necessary to plan the infrastructure to support the servicing of this corridor in the future.

2.8 Land demanded for new uses (logistic areas)

Due to the global expansion of economic activities, logistics have become very important. Transport logistics demand large spaces for the transfer of goods between different transportation modes and also for their storage and distribution. It is necessary to plan these spaces in adequate locations.

3 REGARDING THE SUSTAINABILITY OF THE TERRITORY

Environmental impacts produced by urban usage in the territory may be caused by two possible processes:

- land transformation from rural usage to urban or artificial usage
- economic and social activities (residential, commercial, industrial, transport…)

The main characteristic of urban or artificial usage taking place in the territory is irreversibility. So, when rural land is transformed into urban or artificial land, the possibility of reversing the action is extremely low and, usually, very expensive. As a result, in fact, it is impossible to reverse the destruction of rural usage when it is transformed into urban usage.

On the contrary, economic and social activities produce environmental impacts that, in general, can be corrected or reversed by the appropriate technology.

Thus, from the point of view of regional planning, to achieve sustainability, society must achieve a distribution of land usage to keep natural resources that produce the goods and services necessary for social and economic activities and not destroy them by irreversibly transforming these rural uses into urban usage. These natural resources are the so-called Natural Capital.

According to the well-known theory of the ecological footprint and the Living Planet Report, published by the World Wildlife Fund every 2 years [18], social and economic activities consume the natural resources produced by a certain surface of the planet and produce pollutants that are absorbed by a certain surface of ecosystems. The total surface is the ecological footprint. Now then, it is possible to consider the same concept from another point of view. It is possible to consider that the surface of the ecological footprint is also the surface needed for society to maintain its level of social and economic activity. In this sense, the ecological footprint is also the *ecological larder*. If we want to maintain social and economic activities, we must maintain the surfaces that produce the environmental goods and services necessaries for activities of society, that is, the ecological larder or Natural Capital. Not all territory produces environmental goods and services nor the same intensity. The vulnerability of a certain zone against a concrete urban use (such as general urban use, facilities or industries) measures the destruction of Natural Capital if that use is located in that zone.

On the other hand, to consider the sustainability of uses in the territory, it is also necessary to consider the economic costs necessary to build safely against risks. In this case, the problem is not the destruction of environmental values but the destruction of buildings if they are built in these zones, or the construction costs. The capability of a certain zone of territory for a concrete urban use (such as general urban uses, facilities or industries) refers to its suitable conditions for building safely without excessive costs.

From the two previous points of view, for the conservation of Natural Capital and for safety, a third option can be added: the green infrastructure. The green infrastructure adds the idea of a network.

The European Commission [19] defines *Green Infrastructure (GI) — Enhancing Europe's Natural Capital*, as a *strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings.*

In fact, green infrastructure produces a system of interconnected open spaces and, consequently, ecosystems are not isolated. This implies the necessity to identify the connections of areas between open spaces and to plan them as undevelopable land.

And finally, it is still possible to consider another point of view: that of the landscape. People look at the territory and have a view of the landscape. This view is important because people often value the territory according to the landscape. It is possible to design the landscape based on the three perspectives previously mentioned. In this sense, the landscape will be an integration of all the territory's sustainability points of view.

4 OBJECTIVES

The author's research team, UDR F. Eiximenis of Universitat Politècnica de València (Spain), developed in 1996 a method for the evaluation of the aptitude of the territory for urban uses, named the Method of Aptitude for Sustainable Urban Development (hereafter, method ASUD).

The research team is now working to update the method [20]. The objective of this article is to show a proposal for the planning of metropolitan coastal areas in order to optimize the territorial environment in the Strategic Environmental Assessment process developed for the case of Valencia.

5 PLANNING METROPOLITAN COASTAL AREAS TO OPTIMIZE THE ENVIRONMENT IN THE PROCESS OF STRATEGIC ENVIRONMENTAL ASSESSMENT

In the European Union, the Strategic Environmental Assessment (SEA) is a public participation process in decision-making about the environmental consequences of programmes and plans [21]. The general SEA procedure, after the screening process, is as follows:

The SEA procedure can be summarized as follows: an environmental report is prepared in which the likely significant effects on the environment and the reasonable alternatives of the proposed plan or programme are identified. The public and the environmental authorities are informed and consulted on the draft plan or programme and the environmental report prepared.

The environmental report and the results of the consultations are taken into account before adoption. Once the plan or programme is adopted, the environmental authorities and the public are informed and relevant information is made available to them. In order to identify unforeseen adverse effects at an early stage, significant environmental effects of the plan or programme are to be monitored.

According to Valencian laws, the process has the following phases:

- Declaration of the start process for the elaboration of a plan or programme
- Elaboration of the initial document of the plan or programme or draft plan/programme
- Elaboration of the plan/programme
- Elaboration of the environmental report of the plan/programme
- Public participation in decision-making
- Analysis of public participation process, modification of the plan or programme, if necessary, according to suggestions, and response to stakeholders
- Elaboration of the final document of the plan/programme
- Elaboration of the Environmental Declaration
- Communication and public exposition of final documents.

In this process, the Environmental Report must focus on the likely significant effects on the environment produced by the plan. Depending on the type of plan, the significant environmental effects will be one or the other.

In the case of territorial plans, most of the significant environmental effects are produced by the transformation of rural to urban land usage. The Method of Aptitude for Sustainable Urban Development (ASUD) allows the identification of rural lands that must not be transformed into urban or artificial land, from a sustainable point of view.

This method allows the measurement of the aptitude of each homogeneous zone for different urban uses, depending on the zone's capability for and vulnerability to different uses. In Valencia, capability is a function of the variables that can condition or determine the location of the use in the zone: slope, soil resistance, flood risk, landslide risk. For all variables, the homogeneous zones are classified into three groups:

A. Zones that do not present limitations for urban use, according to the variable considered.
B. Zones that present limitations for urban use, according to this variable, but can be corrected at reasonable cost.
C. Zones that present strong limitations for urban use, according to this variable; the problem cannot be corrected or its correction is too expensive.

These situations can be mapped for each variable. If different maps are overlapped, the result will be an integrated map of capability with all situations A, B or C.

On the other hand, vulnerability is a function of environmental variables that can be impacted if the urban or artificial use is located in the zone: agricultural lands, forest, vulnerability of aquifer and protected areas. In fact, all those variables are part of the Natural Capital. Also, for all variables, the homogeneous zones are classified into three groups:

A. Zones that are not part of the Natural Capital.
B. Zones in which some environmental variable can be impacted, but the impact can be corrected at reasonable cost.
C. Zones in which the transformation to urban land implies the irreversible destruction of the Natural Capital.

These situations can also be mapped for each variable. If different maps are overlapped, the result will be an integrated map of vulnerability variables with all situations A, B or C.

The final aptitude of each zone for each urban use will be obtained by overlapping the capability and vulnerability maps for each urban use. This final map identifies the zones that must be preserved from urban development. That is, a map of open spaces or a map of a system of open spaces with different functions, such as an ecological larder or safety. All this analysis is performed by using Geographical Information System (GIS).

This map will be completed by functional and ecological corridors which also must be part of green infrastructure. The main hydrological network is a good lineal space, free of urbanization, to connect the open spaces between that.

It is also possible to use algorithms to identify better points to connect open spaces. For example, it is possible to calculate an 'index of permeability' of points of the territory, based on land use, orography and distance to roads. When a zone has a natural or similar use, the slope is medium or high and the distance to roads is high, the theoretical permeability for the connection of zones is higher. According to these variables, it is possible to create numerical criteria about the degree of compliance of each variable and, in consequence, the theoretical grade of connection between the different zones. Of course, these resulting zones must be contrasted with real experience. These must be protected and added to the protected areas and open spaces to generate a network.

Finally, it will be necessary to integrate the perception of the landscape by the consideration of two issues:

- Identification of landmarks and scenic views (elements observed).
- Identification of viewpoints and scenic ways (observation points).

These perceptions must be considered in order to protect the views.

The integration of all concepts will produce a complete green infrastructure. All integrated analyses are performed by the use of GIS. This green infrastructure will be the basis for protecting the territory from new urban and artificial usage. Of course, these new uses or the renovation of old uses will create new landscapes.

6 CONCLUSIONS

Sustainability is a general and complex concept. Therefore, it is possible to study the sustainability for different elements or activities. Particularly, it is possible to apply the concept to the territory. In fact, all human activities are produced in the territory. The study of territory always requires a geographical vision. Historically, the society have used the territory like object to extract profit. However, at present the territory is very artificial or urbanized, especially in metropolitan areas, and often makes degraded landscapes. On the other hand, the expansion of urbanized lands and the stop of population' growth forces to act on urbanized land to implement new urban uses and to avoid more expansion of urban sprawl. Accordingly, it is necessary the application of a new territorial quality concept in planning processes and Strategic Environmental Assessment.

Green infrastructure is a very useful concept. In current metropolitan areas situation, green infrastructure must be considered prior to metropolitan planning of urban and artificial uses in order to maintain historical landscapes but also to make new quality landscapes.

As a result of research, Green infrastructure can be determined as the integration of the land's aptitude for different urban and artificial uses (capability + vulnerability), functional and ecological corridors and landscape-views (elements observed + observation points). Note you that vulnerability concept includes the Natural Capital to preserve for the future. Therefore, this key aspect is integrated in the methodology.

The whole analysis is essentially geographic. Because of this, the use of Geographic Information Systems is especially indicated as operational instruments.

Determination of the green infrastructure is an objective process to apply sustainability concept on land transformation from rural into urban and artificial usage through regional planning.

This process of determining the green infrastructure allows the creation of an alternative to the territorial model with sustainability criteria in the Strategic Environmental Assessment process.

Finally, as it is known, regional planning have as objectives, among others, maintain natural resources (as a part of green infrastructure) and design new urban uses in zones already urbanized or not. Well, the concept of green infrastructure also allows to design new landscapes specially in border areas between new urban and artificial uses and natural areas or when green infrastructures crosses urban areas.

REFERENCES

[1] Wheeler, S.M., The evolution of built landscapes in metropolitan regions. *Journal of Planning Education and Research*, SAGE Publications: New Jersey, **27**, pp. 400–416, 2008. available at www.//jpe.sagepub.com/cgi/content/abstract/27/4/400 (accessed 20 February 2017).

[2] Miralles i Garcia, J.L., *El darrer cicle immobiliari al País Valencià. O el progrés de la misèria*. Fundació Nexe: València, 2014.

[3] García-Ayllón, S., Retrospective analysis of urban development in the Spanish Mediterranean Coast. *WIT Transactions on Ecology and the Environment*, WIT Press: Southampton, **179**, pp. 291–302, 2013.

[4] Feria Toribio, J.M. & Martínez Bernabeu, L., La definición y delimitación del sistema metropolitano español: permanencias y cambios entre 2001 y 2011. *Revista Ciudad y Territorio. Estudios Territoriales*, Ministerio de Fomento: Madrid, **187**, pp. 9–24, 2016.

[5] Miralles i Garcia, J.L., Revising the basis for planning a new kind of progress: the case of Valencia's city. *WIT Transactions on The Built Environment*, WIT Press: Southampton, **148**, pp. 3–14, 2015.

[6] Generalitat Valenciana (GVA)., Conselleria d'Habitatge, Obres Públiques i Vertebració del Territori. Estrategia Territorial de la Comunitat Valenciana. Website, Valencia, available at http://www.habitatge.gva.es/web/planificacion-territorial-e-infraestructura-verde/estrategia-territorial-de-la-comunitat-valenciana-77496 (accessed 20 February 2017).
[7] Generalitat Valenciana (GVA)., Conselleria d'Habitatge, Obres Públiques i Vertebració del Territori. Documento de Inicio del proceso de Evaluación Ambiental y Territorial Estratégica del Plan de Acción Territorial Metropolitano de Valencia. Website, Valencia, available at http://www.habitatge.gva.es/web/planificacion-territorial-e-infraestructura-verde/plan-de-accion-territorial-metropolitano-de-valencia-pateval- (accessed 20 February 2017).
[8] Boira, J.V., Urbanismo expansivo: de la utopía a la realidad. *Proceedings of XXII Congreso de Geógrafos Españoles*, pp. 79–90, 2011.
[9] Gielen, E., *Costes del "Urban Sprawl" para la administración local*. Publicacions de la Universitat de València: València, 2016.
[10] Gielen, E., Riutort-Mayol, G., Palencia-Jiménez, J.S. & Cantarino, I., An urban sprawl index based on multivariate and Bayesian factor analysis with application at the municipality level in Valencia. *Environment and Planning B: Analytics and City Science*, 2017.
[11] Miralles i Garcia, J.L., Environmental management of peri-urban natural resources: L'Horta de València case study. *WIT Transactions on Ecology and the Environment*, WIT Press: Southampton, **192**, pp. 99–110, 2015.
[12] www.albufera.com (accessed 20 February 2017).
[13] Miralles i García, J.L., Green infrastructure in Mediterranean Valencian Coast. *International Journal of Sustainable Development and Planning (Online)*, **3**(11), pp. 227–235, 2016.
[14] Miralles i García, J.L., Díaz Aguirre, S. & Altur Grau, V.J., Environmental impact on the Mediterranean Spanish coast produced by the latest process of urban developments. *WIT Transactions on Ecology and the Environment (Online)*, **155**, pp. 379–389, 2012.
[15] www.valenciaport.com (accessed 20 February 2017).
[16] Generalitat Valenciana (GVA)., Conselleria d'Habitatge, Obres Públiques i Vertebració del Territori. Documento de Inicio del proceso de Evaluación Ambiental y Territorial Estratégica del Plan de Acción Territorial Metropolitano de Valencia. Website, Valencia, available at http://www.habitatge.gva.es/web/planificacion-territorial-e-infraestructura-verde/plan-de-accion-territorial-metropolitano-de-valencia-pateval- (accessed 20 February 2017).
[17] www.ferrmed.com (accessed 20 February 2017).
[18] World Wildlife Fund. Living Planet Report 2016., available at http://wwf.panda.org/about_our_earth/all_publications/lpr_2016/ (accessed 20 February 2017).
[19] European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Green Infrastructure (GI) — Enhancing Europe's Natural Capital. available at http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0249 (accessed 20 February 2017).
[20] Miralles i García, J.L. & Altur Grau, V.J., Updated method of aptitude to sustainable urban development for including green infrastructure. *International Journal of Sustainable Development and Planning (Online)*, **6**(11), pp. 970–979, 2016.
[21] European Commission., available at http://ec.europa.eu/environment/eia/sea-support.htm (accessed 20 February 2017).

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APPLICATION OF ARTIFICIAL NEURAL NETWORKS TO FORECASTING MONTHLY RAINFALL ONE YEAR IN ADVANCE FOR LOCATIONS WITHIN THE MURRAY DARLING BASIN, AUSTRALIA

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ABSTRACT
Much of Australia regularly experiences extremes of drought and flooding, with high variability in rainfall in many regions of the continent. Development of reliable and accurate medium-term rainfall forecasts is important, particularly for agriculture. Monthly rainfall forecasts 12 months in advance were made with artificial neural networks (ANNs), a form of artificial intelligence, for the locations of Bathurst Deniliquin, and Miles, which are agricultural hubs in the Murray Darling Basin, in south-eastern Australia. Two different approaches were used for the optimisation of the ANN models. In the first, all months in each calendar year were optimised together, while in the second approach, rainfall forecasts for each month of the year were made individually. For each of the three locations for most months, higher forecast skill scores were achieved using single-month optimizations. In the case of Bathurst, however, for the months of November and December, the root mean square error (RMSE) for all-month optimisation was lower than for single-month optimisation. The best overall rainfall forecasts for each site were obtained by generating a composite of the two approaches, selecting the forecast for each month with the lowest forecast errors. Composite model skill score levels of at least 40% above that of climatology were achieved for all three locations, whereas skill level derived from forecasts using general circulation models is generally only comparable to climatology at the long-lead time of 8 months.
Keywords: artificial neural network, flooding, forecast, Murray Darling Basin, rainfall, skill score.

1 INTRODUCTION

The Murray Darling Basin (MDB) covers 1,059,000 square kilometres, or 14% of Australia's land area, and contains a large proportion (65%) of the irrigated land. The MDB accounts for more than half of Australia's total water use, of which more than 80% is used by agricultural industries [1], generating nearly 40% of the value of agricultural production of Australia. Over the past several decades, competing requirements of agriculture and the environment have led to difficulties in formulating water policies for the region [2, 3]. This issue is exacerbated because the natural climate of the region is characterized by periods of extreme drought, followed by periods of heavy rainfall [4]. It would be beneficial for both policy makers and farmers if more accurate medium-term rainfall forecasts were available, particularly at long lead times [5–8]. However, most attempts to forecast rainfall with long lead times have resulted in models with poor predictive skill [9, 10] often only comparable to, or below, climatology.

Two principle approaches have been applied to medium-term rainfall forecasting: statistical models [11, 12] and general circulation models (GCMs) [13]. These approaches have been more commonly used to produce seasonal forecasts, and less extensively for monthly rainfall forecasts. Statistical models typically use a set of lagged input variables to compute desired output rainfall, usually large-scale climate variables or indices [14–17].

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Artificial neural networks (ANN), a form of machine learning, can be classified as a type of statistical model that offers several important advantages over the more simple statistical models traditionally used. ANNs have the capacity to accommodate non-linear relationships, and the flexibility in testing multiple inputs, particularly where their influences may be due to combinations of drivers that interact in poorly understood ways. Preliminary research suggests ANNs have the potential to produce skilful seasonal and monthly rainfall forecasts in many parts of the world [18, 19] including Australia [20–23]. Forecasts from GCMs, however, are used to produce the operational medium-term rainfall forecasts issued by the Australian Bureau of Meteorology (BOM), despite evidence that these forecasts are typically less skilful, and despite substantial efforts to enhance performance over many years [24, 25].

Currently operational medium-term seasonal rainfall forecasts issued by the BOM use output from a GCM, the Predictive Ocean Atmosphere Model for Australia (POAMA) [10, 13]. Prior to May 2013, operational rainfall forecasts generated by the BOM were produced by simple statistical models that used only four input values for the entire continent. These inputs were derived from two lagged sea surface temperatures, SST1 and SST2 [11, 12] relating to the Pacific and Indian oceans respectively. Both of these sea surface temperature model inputs were lagged by one and three months. In reviewing the performance of this simple statistical model, Fawcett and Stone [12] described the skill level demonstrated for seasonal rainfall forecasting as “only moderate, better than climatology or randomly guessed forecasts”.

Risbey *et al.* [16] examined concurrent relationships between seasonal rainfall over Australia with individual ENSO-related drivers additional to Southern Oscillation Index (SOI), including the ENSO Modokai Index (EMI) Niño 3, Niño 3.4 and Niño 4, which are all measures of sea surface temperature (SST) difference in the equatorial Pacific. Other non-ENSO indices considered were the Indian Ocean Dipole (DMI), the Southern Annular Mode (SAM) and the Madden-Jullian Oscillation (MJO). Risby *et al.* [16] found that analysis based on linear correlations between rainfall and individual drivers could only generate crude indications of the relative importance of individual climate indices, and did not account for possible interactions. Nevertheless, their results indicate which individual driver might be more significant for determination of seasonal rainfall throughout Australia. SOI was most the influential in northern parts of Queensland. For south east Queensland, the identity of the dominant index was more variable, and depended on the season. Many other studies have reported on the relationships of ENSO-related indices to rainfall in eastern Australia [15, 26–28]. There is also evidence that the relationship between ENSO and rainfall is modulated by the phases of the Inter-decadal Pacific Oscillation (IPO) [29–31] and when the IPO is in a negative phase, the impact of ENSO on rainfall is enhanced [32].

A strong concurrent relationship between rainfall and a particular input variable does not necessarily translate into a strong lagged relationship [14]. It is lagged relationships that are essential for forecasting. Chiew *et al.* [33] examined linear correlations between rainfall and ENSO indices (SOI and SSTs) for the Queensland region, including lagged relationships. The strongest linear correlations, r above 0.4, were found for spring rainfall. The geographical coverage and intensity of the strongest correlations declined as lags were progressively increased from 0 to 1, 2 and 3 months. Correlations with summer rainfall were less expansive geographically, and these also diminished with lag time. Kirono *et al.* [34] investigated linear correlations between 12 individual climate indices, lagged for 1 or 2 months, and seasonal rainfall across Australia including SOI, Niño 3, Niño 4, DMI, SAM. Results for south-east Queensland exhibited the sporadic influence of individual lagged climate indices.

Schepen *et al.* [14] estimated the influence of 13 individual lagged climate indices on seasonal rainfall for geographical grid areas across Australia. The indices studied included SOI, Niño 3, Niño 3.4, Niño 4, DMI, EMI, and also the Indian Ocean East Pole index (EPI) at lag periods of 1, 2 and 3 months. The variability in the strengths of relationships between lagged climate indices, and rainfall was calculated by using the pseudo-Bayes factor that can accommodate non-linear relationships. This factor is probably more useful in providing a measure of the strength of rainfall–input relationships than the Pearson correlation coefficient (r). However, evaluations using the pseudo-Bayes factor are still potentially limited in that they evaluate each rainfall–input relationship in isolation from the effect of other inputs. This may not give a true indication of a specific input's influence when introduced in combinations with other inputs.

This study builds on a previous investigation using ANNs [35] where monthly rainfall forecasts were made for Miles in Queensland with lead times between 1 and 9 months. In this study, two additional sites in the Murray Darling are considered, Bathurst and Deniliquin, both in New South Wales. This study also presents results for optimisation of ANNs for individual months, whereas the previous study was limited to optimisation of all months together.

2 DATA AND METHODS

The three stations forecasted for in this study included Bathurst Agricultural Station, Denilquin, and Miles Post Office all of which began collecting data in 1908, 1858, and 1885 (respectively). Each site is also in close proximity to a 250 km × 250 km grid area where comparative monthly forecasts have been published using the GCM POAMA [10].

Each location is still operating as a weather station today, and data from these stations located within the Murray Darling Basin (Fig. 1) was used in the ANNs.

Figure 1: Map showing locations of Bathurst, Deniliquin and Miles within the Murray Darling Basin.

Local minimum and maximum temperatures and a set of climate indices were input as monthly values to the ANNs. Previous investigations have shown that local temperatures and rainfall contribute as significant inputs to monthly rainfall forecasts for eastern Australia [20]. The climate indices used as inputs were the SOI, DMI, Niño 4, Niño 3.4, Niño 3, Niño 1.2 and the IPO. As discussed above, each of these has been shown to have potential value as a predictor of future rainfall over eastern Australia, and because monthly values are available over a long historical period extending back as far as the observational rainfall records considered. Other climate indices that may be influential in the prediction of rainfall in south-east Australia were not used as inputs in this study because their availability is restricted to a shorter time period. For example, monthly values of the SAM are only available from the Climate Explorer website from 1957 onwards, whereas the other inputs used extend back for more than a century. The forecasts were run with the full set of inputs, and also local rainfall, with each lagged up to 12 months.

The total input data sets of monthly data used comprised: Bathurst (July 1909 to June 2014); Deniliquin (January 1877 to June 2014); Miles (January 1888 to July 2011), (Table 1). The dataset considered for Miles was taken to mid-2011 because of gaps in the corresponding temperature series. For each site, the data were divided into training (75%), evaluation (15%) and test sets (10%). Test data sets used in training were not used in testing.

Values for DMI and the four Niño indices were sourced from the Royal Netherlands Meteorological Institute Climate Explorer – a web application that is part of the World Meteorological Organisation and European Climate Assessment and Dataset project. Values for IPO were provided by the UK Met Office. Values of SOI, and also local minimum and maximum temperatures, were obtained from from the Australian Bureau of Meteorology.

All of the above climate indices with local rainfall and temperatures were provided as input to *Neurosolutions Infinity* software and used to build ANN models. Many different architectures of ANNs have been used to make forecasts of rainfall [18–23]. A common approach in the selection of an ANN architecture is through simple trial and error of candidate models [20–23] using a limited set of input data, and select the ANN that produced the minimum error. This model is then applied in the investigation with all the data input sets. This selection process can be a very time-consuming. The recently available software *Neurosolutions Infinity* gives access to many different ANN architectures, but has the facil-

Table 1: Initial input data sets used for ANN models and sources.

Input	Lags (months)	Source
Rainfall	12-24	Australian BOM
Maximum Temperature	12-24	Australian BOM
Minimum Temperature	12-24	Australian BOM
SOI	12-24	Australian BOM
IPO	12-24	UK Met Office
DMI	12-24	Climate Explorer
Nino 1.2	12-24	Climate Explorer
Nino 3	12-24	Climate Explorer
Nino 4	12-24	Climate Explorer
Nino 3,4	12-24	Climate Explorer

ity to automate both selections of ANN architecture and input data. This offers a great advantage in terms of arriving at an optimum ANN configuration for every data set of interest without a prohibitive time outlay. The *Infinity* program uses a pre-set formula incorporating RMSE, mean absolute error (MAE) and correlation coefficient (r) to evaluate the accuracy for each neural network model and a corresponding set of selected inputs tested. Based on this formula, the program determines which ANN model and set of inputs is optimal. For the datasets used in this investigation, the optimal ANN configuration automatically selected by *Neurosolutions Infinity* was a probabilistic neural network (PNN). A PNN has four layers, an input layer, one hidden layer, a summation layer and an output layer. Each attribute considered was lagged up to 12 months. The data were divided into training (75%), evaluation (15%) and test sets (10%). RMSE and Pearson correlation coefficients are used to compare the skill of rainfall forecasts generated by the ANNs, POAMA and also climatology [20, 36].

Two approaches were used for ANN optimization. With the first approach, designated as "all-month optimization", data for all 12 months of the year was included as input and optimised together, as in our previous studies [10, 11]. With the second approach, designated as "single-month optimisation", forecasts corresponding to each calendar month were performed individually, so that 12 optimisations were carried out to produce forecasts for the entire year.

Equation (1) was applied to give a forecast skill score relative to climatology:

$$\text{Skill score} = \frac{[\text{RMSE (climatology)} - \text{RMSE (model)}]}{\text{RMSE (climatology)}} * 100\% \quad (1)$$

This is analogous to an equation used in studies where a skill score has been calculated for forecasts based on POAMA [10]. Applying this equation, it follows that if the calculated values of RMSE from climatology and for a particular model are equal, the forecast skill score will be zero. For a perfect model forecast, the RMSE for the model will be zero, and the calculated skill score will be 100%. Any negative values calculated from eqn (1) indicate a forecast skill score below that of climatology.

3 RESULTS AND DISCUSSION

Optimizations performed with *Neurosolutions Infinity* software to generate forecasts at the three sites produced optimised models regarding both the neural network architecture and the associated inputs. In each case, there were initially 120 lagged input variables available to relate to each required output rainfall value (Table 1). In all cases, the fraction of these input retained by the *Infinity* software in the optimised model was a small subset of the initial input set made available, typically only 5% to 10%. This is illustrated for single-month optimisations for Deniliquin in Tables 2 and 3, where each numerical entry corresponds to the lag period for the particular retained attribute.

RMSE values were calculated corresponding to each month of the year for test data using (i) all-month optimisation and (ii) single-month optimisation for Bathurst (January 2005 to June 2014), Deniliquin (July 2004 to June 2014) and Miles (August 2004 to July 2011) respectively (Table 4). Inspection of these values shows that for each location, for the majority of months, higher skill was achieved using the single-month optimisation. Only in the case of Bathurst, for the forecast months of November and December did the all-month method produces lower errors, while for Miles and Deniliquin the single-month optimisations produced lower errors for all 12 calendar months.

Table 2: Retained input data for optimal neural networks for Deniliquin for single-month optimizations (January to June).

Input	Jan	Feb	Mar	Apr	May	Jun
Rainfall				12	12	
Max T	20, 22, 24	19, 20, 23			14, 17	12, 13, 16, 18, 21, 23
Min T	19	17	12, 22, 23			
SOI		15, 17, 18, 20				
IPO	19		13, 15, 18			
DMI			13, 23, 24			
Nino 1.2		13, 14, 24				
Nino 3		12				
Nino 4			13			
Nino 3.4				12, 13, 14		

Table 3: Retained input data for optimal neural networks for Deniliquin for single-month optimizations (July to December).

Input	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall						21
Max T	12, 13, 19			16	19, 20, 24	
Min T	21	16	13, 15, 21	16, 18, 24	15	
SOI		12		17, 19, 20		13, 14
IPO		12		15, 19, 21		13, 23
DMI			13, 15			
Nino 1.2		16		14, 21, 22		20, 21, 24
Nino 3	23	24	14	16, 19		13
Nino 4				21		14, 16
Nino 3.4		12	14			13, 18

Composite forecasts were constructed by taking the best forecasts for each month from both methods. Therefore, composite and single month forecasts for Miles and Deniliquin are equivalent, whereas for Bathurst the composite forecast incorporates two months from the all-month optimisation.

Values of forecast skill were calculated using eqn (1) for Bathurst, Deniliquin and Miles corresponding to the composite forecasts (Table 5). Skill scores were above climatology for all forecast months at each of the three locations. Average skill levels, relative to climatology, in the range 42–48% are achievable for rainfall forecasts with 12 month lead time. Table 6 shows the corresponding Pearson correlation coefficients between observed and ANN forecast rainfall are in the range 0.80 to 0.98.

Table 4: Root mean square errors for monthly rainfall forecasts for Bathurst, Deniliquin and Miles using all-month and single month optimisation.

	All-month RMSE (mms)			Single-month RMSE (mms)		
Month	Bathurst	Deniliquin	Miles	Bathurst	Deniliquin	Miles
January	27.0	13.8	37.9	11.4	11.8	31.5
February	23.7	28.1	43.8	19.5	9.4	28.8
March	34.2	30.8	35.5	31.1	7.8	30.3
April	21.4	16.3	24.3	12.5	12.2	14.2
May	22.5	19.5	27.1	7.9	13.2	15.2
June	25.8	17.3	57.6	15.7	20.1	28.7
July	19.5	11.5	21.8	13.1	7.5	11.8
August	21.3	20.0	29.4	15.5	9.4	19.0
September	35.5	17.1	28.2	18.5	14.4	12.6
October	24.5	21.1	28.2	22.4	11.2	16.7
November	36.2	16.1	33.7	47.9	16.8	13.0
December	36.2	17.0	55.7	38.7	9.3	44.8

Table 5: Forecast skill score (%) for rainfall forecasts at 12 months lead for Bathurst, Deniliquin and Miles using a neural network.

Month	Bathurst	Deniliquin	Miles
January	70.4	35.9	42.3
February	50.8	71.3	33.2
March	41.5	80.6	42.9
April	59.2	22.9	35.1
May	60.7	43.3	37.6
June	29.3	57.4	45.4
July	36.4	17.9	53.8
August	56.3	53.4	34.6
September	44.6	18.7	62.3
October	39.2	66.3	50.6
November	42.8	35.4	31.8
December	45.4	67.8	49.0

Figures 2, 3 and 4 show plots of observed and forecast monthly rainfall for each site for the composite for Bathurst, Deniliquin and Miles respectively. In each case the test period is shown which corresponds to 10% of the total rainfall period used in the ANN model. Of particular interest is the prominent forecast peak in January 2010/January 2011 for Miles in Fig. 4, when extremely heavy rainfall was experienced in Queensland.

Table 6: Correlation coefficients for rainfall forecasts at 12 months lead for Bathurst, Deniliquin and Miles using a neural network.

Month	Bathurst	Deniliquin	Miles
January	0.96	0.96	0.94
February	0.92	0.97	0.80
March	0.89	0.98	0.90
April	0.92	0.91	0.83
May	0.97	0.91	0.94
June	0.84	0.94	0.87
July	0.94	0.94	0.72
August	0.98	0.95	0.80
September	0.96	0.94	0.96
October	0.77	0.98	0.91
November	0.89	0.84	0.90
December	0.99	0.98	0.88

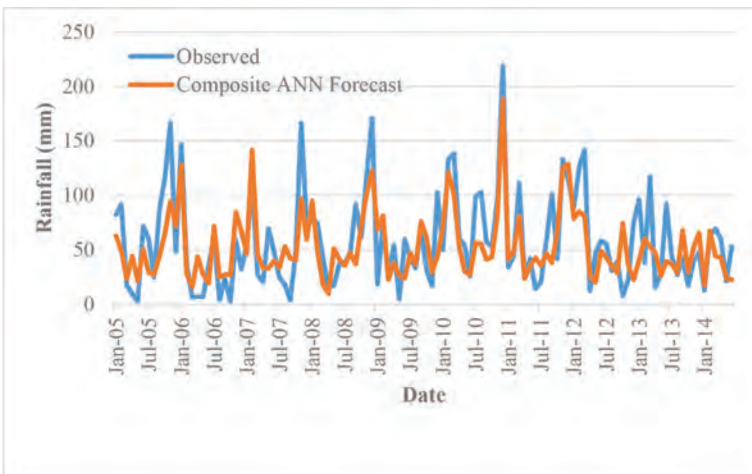

Figure 2: Forecast and observed monthly rainfall for Bathurst using the composite neural network. Test period January 2005 to June 2014.

In previous reported studies using ANNs to forecast monthly rainfall in Queensland [20–23], the approach used was to optimise forecasts for the 12 calendar months together, for a given set of inputs. This approach consistently produced results with better skill than either climatology or POAMA. However, the present study shows that the monthly rainfall forecast skill can in most instances be improved when individual months are optimised. This is because single-month optimization enables the variability in the influence of specified lagged climate indices at different times during the year to be considered [14].

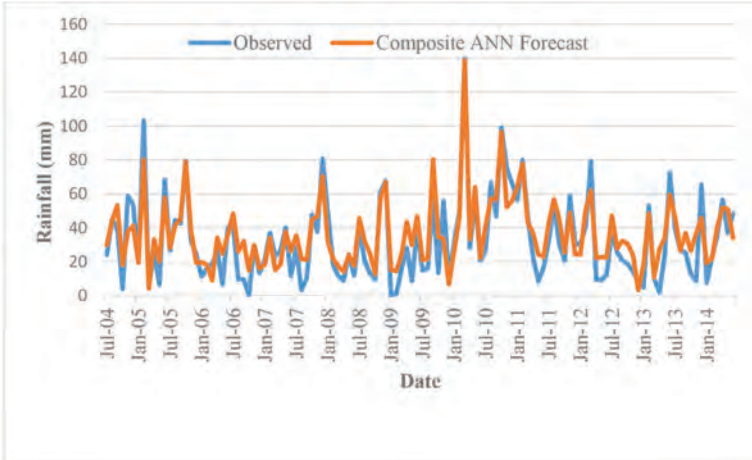

Figure 3: Forecast and observed monthly rainfall for Deniliquin using the composite neural network. Test period July 2004 to June 2014.

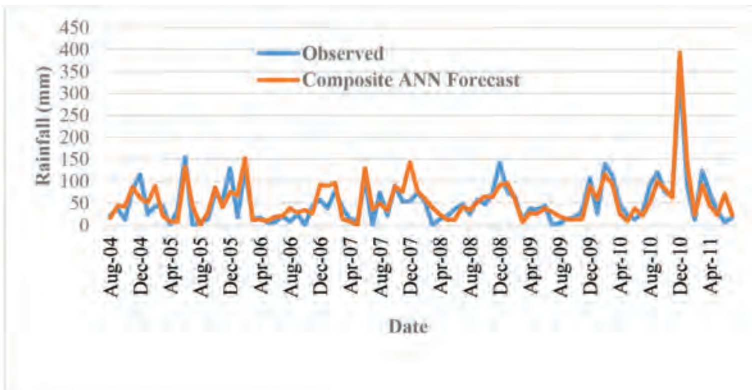

Figure 4: Forecast and observed monthly rainfall for Miles using the composite neural network. Test period August 2004 to July 2011.

Ideally, the output from the ANNs would be compared directly with output from POAMA, using identical lead times, locations and test periods. However, only very limited results from POAMA have been made available by the BOM to enable comparative skill analysis. Comparisons based on the limited data directly provided by the BOM, and also published studies, show that the ANN method has superior skill for monthly rainfall forecasting in the Murray Darling Basin region of Australia at the long lead times of 12 months. Table 7 shows a comparison of results using a lead time of 12 months from this study using an ANN, with results from POAMA at a lead time of 8 months. These results from POAMA corresponded to the longest lead time available in the published literature. Bearing in mind that results from POAMA generally decrease with longer lead times, so the comparison made is not biased against the GCM. In particular, Table 7 shows that applying the composite ANN approach gives skill levels above climatology for all 12 months of the year, with values between 22% and 69%. In contrast, for forecasts derived from POAMA, results for 9 months of the year

Table 7: Forecast skill as a percentage for monthly rainfall forecasts for Miles with reference to climatology for the composite ANN model and POAMA. The test period was August 2004 to December 2010.

Month	ANN (lead 12 months)	POAMA (lead 8 months)
January	30.2	6.0
February	22.2	–1.7
March	49.3	–6.3
April	39.3	–40.6
May	33.1	–5.9
June	43.3	–1.2
July	62.1	–3.4
August	30.6	0.0
September	69.0	–2.0
October	43.0	–8.0
November	22.0	8.1
December	48.6	–16.1

have skill levels at, or below, climatology, and results for 4 months have skill between 0 and 5%, with no results above 10%. Taking the averages over 12 months, the results from POAMA have a skill level of –3.9% with reference to climatology, while the average for results from the composite neural network is 42.5%.

The measure of the forecast skill score expressed in eqn (1) is analogous to the formula applied by Hawthorne *et al.* [10] to evaluate monthly rainfall forecast skill using POAMA. In that study, results for various lead times and 250km × 250km grid regions in Australia were presented along a skill spectrum with reference to climatology based on RMSE, extending between –20% and 20%. To facilitate quantitative forecast skill comparisons, those published results have been translated into numerical ranges of values (Table 8). This gives the number of calendar months of the year where the POAMA forecast skill falls into particular ranges. Three geographical grid locations are considered, identified as H, E and G [10] as these are in the geographical proximity of the three locations Bathurst, Deniliquin and Miles, respectively.

Using the composite ANN model for Bathurst, all 12 forecast months showed a forecast skill above climatology, with skill levels in the range 24% to 70%. The results from POAMA for grid region H at 6 and 8 month lead, gave 7 and 8 months, respectively, with skill levels below climatology (0%). Only 1 forecast month at lead 8 months lead reached the 16–20% skill score level.

Using the composite neural network approach, for Miles with a lead time of 12 months, Table 5 shows that all 12 forecast months have a skill above climatology, falling in the range between 32% and 62%. In contrast, examining the results POAMA grid region E for lead times of 6 and 8 months, there are 5 and 6 forecast months respectively where skill is below climatology (0%), and only 1 forecast month where skill reaches the 16–20% level.

For Deniliquin, all 12 forecast months showed a forecast skill above climatology using the composite model, with skill levels in the range 17% to 80%. In contrast, examining the results

Table 8: Forecast skill scores for monthly rainfall for three different grid regions produced by POAMA [10].

	Skill relative to climatology (%)					
Lead (months)	–20 to 0	0 to 4	4 to 8	8 to 12	12 to 16	16 to 20
Grid region H (proximity to Bathurst)						
8	8	1	0	0	2	1
6	7	2	1	1	1	0
0	6	0	2	1	1	2
Grid region G (proximity to Deniliquin)						
8	9	2	1	0	0	0
6	7	2	1	2	0	0
0	4	4	1	3	0	0
Grid region E (proximity to Miles)						
8	5	2	2	2	0	1
6	6	4	1	0	1	0
0	2	2	5	2	1	0

POAMA for grid region G for lead times of 6 and 8 months, there are 6 and 8 forecast months respectively where skill is below climatology (0%), and no forecast months where skill reaches the 16–20% level.

Shao and Li [9] reported results of a downscaling technique to produce monthly rainfall forecasts for 35 sites in the Murray Darling basin based on results from POAMA 1.5 over the period 1980–2006. The sites were concentrated in the region between Bathurst and Deniliquin. Detailed analysis of forecasts for individual sites was not reported, and forecast accuracy reported only as correlation coefficients. For lead times of 1, 2 and 3 months the mean correlations between observed and downscaled monthly rainfall were: 0.381, 0.287 and 0.192 respectively. Correlations for individual months fell in the range between 0.1 and 0.6. This can be contrasted with correlation coefficients for the composite neural network approach in Table 3, where correlation coefficients fall in the range from 0.80 to 0.98. These results suggest that the predictive skill of POAMA for monthly rainfall is very low, particularly at long lead times.

The demonstrated skill of GCMs in predicting seasonal or monthly rainfall is low for many regions of the world including India, the United States and Australia [37–40] often with little enhancement in forecast skill above climatology. A number of different approaches have been investigated to improve the skill of GCMs in predicting rainfall, including using weighted multi-model ensembles [41] and developing hybrid statistical models [42–44]. Post-processing of the output of the GCM POAMA using statistical models has been reported in attempting to improve skill of rainfall forecasts for Australia [39, 40].

Operational seasonal rainfall is currently produced by the BOM in Australia, use a combination of dynamical and statistical modeling. The dynamical model used is POAMA [40], while the statistical model makes use of the climate variables derived from POAMA [45].

Effectively, this amounts to using the GCM to forecast parameters, particularly concurrent large scale climate indices, such as sea surface temperatures, for the input statistical model. While this approach may have some merit, the question then arises as to whether the input parameters generated by the GCM might be generated more skilfully using a statistical model such as a neural network, rather than the GCM. Halide and Ridd [46] have suggested that, despite their complexity and the superior computational power of the super computers used to run them, GCMs are no better at forecasting parameters associated with ENSO than very simple statistical models. It has been shown [47] that forecasts of the Niño indices can be performed more skilfully by ANNs than by GCMs, and do not suffer from the limitations imposed by the "Spring Predictability Barrier" [48, 49].

In addition to the low skill in the operational seasonal rainfall [44] forecasts generated by the BOM, there are a number of other important issues regarding the form in which the forecasts are provided to the public. The operational seasonal forecasts are provided to the public only in a probabilistic, as opposed to a deterministic form. This means the information provided is only the probability that rainfall will be above the median value, rather than as a quantitative estimate of the rainfall to be anticipated. Surveys have shown that end-users of probabilistic forecasts, such as farmers, often find this concept difficult to interpret and apply in practical terms [50]. For example, a forecast that there is a probability of 60% that rainfall will be above median gives limited information about the amount of rainfall to anticipate – the forecast is very limited because it does not differentiate between, for example, being 1% higher than the median or 400% higher than the median.

This shortcoming in probabilistic operational forecasts can be illustrated with a recent example, In May 2016 the BOM issued a 3 month rainfall forecast for Australia [51] indicating that there was a 70–80% chance of above median rainfall over much of the Murray Darling Basin during the period June to August 2016. This would have delighted many farmers in the region, who would have enthusiastically planted their crops with the expectation of bumper harvests, following years of comparative drought and widespread depression in farming communities. In fact, record rainfalls in the three month forecast period in parts of the MDB caused extensive flooding, washing away about 30% winter crops such as wheat, barley and chickpeas. The New South Wales Department of Primary Industries (DPI) said it had been the third wettest winter on record [52]. The extreme rainfall resulted in extensive flooding leaving the town of Deniliquin devastated [53]. Although it can be argued the BOM operational seasonal forecast was "correct" it did not provide the information many end-users required to make appropriate decisions regarding crop management.

Other limitations on the operational forecasts are the comparatively long duration (seasonal as opposed to monthly) and the short forecast lead times (limited to the next three months). The ANN approach, in contrast, is very flexible in generating forecast with different forecast periods and lead times to suit the need of different end-users. Output from the GCM also corresponds to large geographical areas corresponding to grid areas of 250 km × 250 km, rather than more localised forecasts that are easily generated by the ANN approach.

4 CONCLUSION

This study builds on previous investigations that used ANNs for monthly rainfall forecasting with lead-times up to three months [19–21]. This study indicates that it is possible to make skilful monthly rainfall forecasts with a 12 month lead time for locations in the Murray Darling Basin. Our previous approach of forecasting has also been refined by examining the skill corresponding to the optimization of individual months, as well as the overall performance of multi-month optimization. In the majority of cases, forecast skill using the "single-month" optimisation is higher than the "all-month" optimisation. A composite forecast was constructed for each site by taking the best results from each method.

Comparisons of the predictive skill of the composite ANN model with rainfall forecasts derived from the GCM POAMA show that the ANN approach has significantly superior skill at the three locations in the Murray Darling Basin investigated. At the long lead time of 12 months the ANN approach has skill of 40% above that of climatology, whereas skill levels derived from forecasts using POAMA at long lead times are generally only comparable to climatology (Tables 4 and 7). There remains scope for future improvement, for example, through the introduction of other input parameters that have been associated with rainfall, such as blocking [16] and SAM [16, 34], although there may be an offsetting impact of increased numbers of attributes against shorter data sets due to more limited availability of historical values.

Despite intensive research efforts and heavy investment over the past two decades, the skill of operational rainfall forecasts reliant on the GCM POAMA remains low, and provides information in a format that is often not useful to the public. This study and others show that more skilful rainfall forecasts can be generated using ANNs, and these have flexibility in forecast periods and lead times. Recognising that GCMs perform poorly in prediction of rainfall, much of the recent efforts have been directed towards skill improvement by combining their output with statistical models. Although some improvement in skill has resulted, it may now be time to accept that the public would be better served by developing medium-term rainfall forecasts focussing on machine leaning and artificial intelligence technologies such as neural networks.

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REFERENCES

[1] Australian Bureau of Statistics, Water and the Murray–Darling Basin – a statistical profile, 2008, available at http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0.55.007

[2] Ashton, D. & Oliver, M., Irrigation technology and water use on farms in the Murray-Darling Basin 2006–2007 to 2011–2012. ABARES Research Report 14.03, 2014.

[3] Gell, P., Mills, K. & Grundell, R., Challenges to management of environment and agriculture: A legacy of climate and catchment change: the real challenge for wetland management. *Hydrobiologia,* **708**(1), pp. 133–144, 2013. doi:10.1007/s10750-012-1163-4

[4] Gallant, A.J.E., Reeder, M.J., Risbey, J.S. & Henessey, K.J., The characteristics of seasonal-scale droughts in Australia, 1911–2009. *International Journal of Climatology,* **33**(7), pp. 1658–1672, 2013. doi:10.1002/joc.3540

[5] Pook, M., Lisson, S., Risbey, J., Ummenhofer, C.C., McIntosh, P. & Rebbeck, M., The autumn break for cropping in southeast Australia: trends, synoptic influences and impacts on wheat yield. *International Journal of Climatology,* **29,** pp. 2012–2026, 2009. doi:10.1002/joc.1833

[6] Vizard, A.L., & Anderson, G.A., The resolution and potential value of Australian seasonal rainfall forecasts based on the five phases of the Southern Oscillation Index. *Crop & Pasture Science,* **60,** pp. 230–239, 2009. doi:10.1071/CP08277

[7] Hammer, G.L, Holzworth, D.P. & Stone, R., The value of skill in seasonal climate forecasting to wheat crop management in a region with high climatic variability. *Australian Journal of Agricultural Research*, **47,** pp. 717–737, 1996. doi:10.1071/AR9960717

[8] Ash, A., McIntosh, P., Cullen, B., Carberry, P. & Stafford Smith, M., Constraints and opportunities in applying seasonal climate forecasts in agriculture. *Australian Journal of Agricultural Research,* **58,** pp. 952–965, 2007. doi:10.1071/AR06188

[9] Shao, Q. & Li, M., An improved statistical analogue downscaling procedure for seasonal precipitation forecast. *Stochastic Environmental Research and Risk Assessment,* **27,** pp. 819–830, 2013. doi:10.1007/s00477-012-0610-0

[10] Hawthorne, S., Wang, Q.J., Schepen, A. & Robertson, D., Effective use of general circulation model outputs for forecasting monthly rainfalls to long lead times. *Water Resources Research*, **49,** pp. 5427–5436, 2013. doi:10.1002/wrcr.20453

[11] Drosdowsky, W. & Chambers, L.E., Near-Global Sea Surface Temperature Anomalies as Predictors of Australian Seasonal Rainfall. *Journal of Climate,* **14,** pp. 1677–1687, 2001. doi:10.1175/1520-0442(2001)014<1677:NACNGS>2.0.CO;2

[12] Fawcett, R.J.B. & Stone, R.C., A comparison of two seasonal rainfall forecasting systems for Australia. *Australian Meteorological and Oceanographic Journal,* **60,** pp. 15–24, 2010. doi:10.22499/2.6001.002

[13] Schepen, A., Wang, Q.J. & Robertson, D.E., Seasonal forecasts of Australian rainfall through calibration and bridging of coupled GCM outputs. *Monthly Weather Review,* **142,** pp. 1758–1777, 2014. doi:10.1175/MWR-D-13-00248.1

[14] Schepen, A., Wang, Q.J. & Robertson, D., Evidence for using lagged climate indices to forecast Australian seasonal rainfall. *Journal of Climate,* **25,** pp. 1230–1246, 2012. doi:10.1175/JCLI-D-11-00156.1

[15] Murphy, B.F. & Ribbe, J., Variability of Southeastern Queensland Rainfall and climate indices international. *Journal of Climatology,* **24,** pp. 703–721, 2004. doi:10.1002/joc.1018

[16] Risbey, J.S., Pook, M.J., Mcintosh, P.C., Wheeler, M.C. & Hendon, H.H., On the remote drivers of rainfall variability in Australia. *Monthly Weather Review,* **137,** pp. 3233–3253, 2009. doi:10.1175/2009MWR2861.1

[17] Ramseyer, C.A. & Mote, T.L., Atmospheric controls on Puerto Rico precipitation using artificial neural networks. *Climate Dynamics*, **47**(7)**,** pp. 2515–2526, 2016. doi:10.1007/s00382-016-2980-3

[18] Dahamsheha, A. & Aksoy, H., Artificial neural network models for forecasting intermittent monthly precipitation in arid regions. *Applied Meteorology*, **16**, pp. 325–337, 2009. doi:10.1002/met.127

[19] Nayak, D.R., Mahapatra, A. & Mishra, P., A survey on rainfall prediction using artificial neural network. *International Journal of Computer Applications,* **72**(16), pp. 32–40, 2013. doi: 10.5120/12580-9217

[20] Abbot, J. & Marohasy J., Input selection and optimisation for monthly rainfall forecasting in Queensland, Australia, using artificial neural networks. *Atmospheric Research,* **138,** pp. 166–178, 2014. doi:10.1016/j.atmosres.2013.11.002

[21] Abbot, J. & Marohasy, J., The potential benefits of using artificial intelligence for monthly rainfall forecasting for the Bowen Basin, Queensland, Australia. Water Resources Management VII. *WIT Transactions on Ecology and the Environment,* **171,** pp. 287–297, 2013. doi:10.2495/WRM130261

[22] Abbot, J. & Marohasy, J., Using lagged and forecast climate indices with artificial intelligence to predict monthly rainfall in the Brisbane Catchment, Queensland, Australia. *International Journal of Sustainable Development and Planning,* **10**(1), pp. 29-41, 2015. doi:10.2495/SDP-V10-N1-29-41

[23] Abbot, J. & Marohasy, J., Application of artificial neural networks to rainfall forecasting in Queensland, Australia. *Advances in Atmospheric Sciences,* **29**(4), pp. 717–730, 2012. doi:10.1007/s00376-012-1259-9

[24] Vaze, J., Teng, J. & Chiew, F.H.S., Assessment of GCM simulations of annual and seasonal rainfall and daily rainfall distribution across south-east Australia. *Hydrological Processes,* **25,** pp. 1486–1497, 2011. doi:10.1002/hyp.7916

[25] Langford, S. & Hendon, H.H., Improving reliability of coupled model forecasts of Australian Seasonal Rainfall. *Monthly Weather Review,* **141,** pp. 728–741, 2013. doi:10.1175/MWR-D-11-00333.1

[26] Chowdhury, R.K. & Beecham, S., Australian rainfall trends and their relation to the southern oscillation index. *Hydrological Process*es, **24,** pp. 504–514, 2010. doi:10.1029/2007GL030854

[27] Power, S.B. & Smith, I.M., Weakening of the walker circulation and apparent dominance of El Nino both reach record levels, but has ENSO really changed? *Geophysical Research Letters,* **34**, L18702, 2007.

[28] Cai, W., Whetton, P.J. & Pittock, A.B., Fluctuations of the relationship between ENSO and northeast Australian rainfall. *Climate Dynamics* **17,** pp. 421–432, 2001. doi:10.1007/PL00013738

[29] Cai, W., et al., Asymmetry in ENSO teleconnection with regional rainfall, its multidecadal variability, and impact. *Journal of Climate,* **23,** pp. 4944–4955, 2010. doi:10.1175/2010JCLI3501.1

[30] Power, S.B., et al., Interdecadal modulation of the impact of ENSO on Australia. *Climate Dynamics,* **15,** pp. 319–324, 1999. doi:10.1007/s003820050284

[31] Power, S.B., et al., The predictability of interdecadal changes in ENSO activity and ENSO teleconnections. *Journal of Climate,* **19,** pp. 4755–4771, 2006. doi:10.1175/JCLI3868.1

[32] Verdon, D.C. & Franks, S.W., Long-term behaviour of ENSO: interactions with the PDO over the past 400 years inferred from paleoclimate records. *Geophysical Research Letters,* **33,** L06712, 2006. doi:10.1029/2005GL025052

[33] Chiew, F.H.S., et al., El Nino/Southern oscillation and Australian Rain, streamflow and drought: links and potential for forecasting. *Journal of Hydrology,* **204,** pp. 138–149, 1998. doi:10.1016/S0022-1694(97)00121-2

[34] Kirono, D.G.C., Chiew, F.H.S & Kent, D.M., Identification of best predictors for forecasting seasonal rainfall and runoff in Australia. *Hydrological Processes,* **24,** pp. 1237–1247, 2010. doi:10.1002/hyp.7585

[35] Abbot, J. & Marohasy, J., Forecasting of monthly rainfall in the Murray Darling Basin, Australia: Miles as a case study. River Basin Management VIII Book Series: *WIT Transactions on Ecology and the Environment,* **197,** pp. 149–159, 2015. doi:10.2495/rm150141

[36] Mekanik, F., Imteaz, M.A., Gato-Trinidad, S. & Elmahdi, A., Multiple regression and Artificial Neural Network for long-term rainfall forecasting using large scale climate modes. *Journal of Hydrology,* 503, pp. 11–21, 2013. doi:10.1016/j.jhydrol.2013.08.035

[37] Zimmerman, B.G., Vimont, D. J. & Block, P. J., Utilizing the state of ENSO as a means for season-ahead predictor selection. *Water Resources Research,* **52**(5), pp. 3761–3774, 2016. doi:https://doi.org/10.1002/2015WR017644
[38] Tiwari, P.R., Kar, S.C., Mohanty, U.C., et al., Skill of precipitation prediction with GCMs over north India during winter season. *International Journal of Climatology,* **34**(12), pp. 3440–3455, 2014. doi:10.1002/joc.3921
[39] Schepen, A. & Wang, Q. J., Ensemble forecasts of monthly catchment rainfall out to long lead times by post-processing coupled general circulation model output. *Journal of Hydrology,* **519,** pp. 2920–2931, 2014. doi:10.1016/j.jhydrol.2014.03.017
[40] Schepen, A. & Wang, Q. J., Toward accurate and reliable forecasts of Australian seasonal rainfall by calibrating and merging multiple coupled GCMs. *Monthly Weather Review,* **141**(12), pp. 4554–4563, 2013. doi:10.1175/MWR-D-12-00253.1
[41] Acharya, N., Chattopadhyay, S., Mohanty, U.C. & Ghosh, K., Prediction of Indian summer monsoon rainfall: a weighted multi-model ensemble to enhance probabilistic forecast skills. *Meteorological Applications,* **21,** pp. 724–732, 2014. doi:10.1002/met.1400
[42] Lang, X. & Wang, H., Improving extraseasonal summer rainfall prediction by merging information from GCMs and observations. *Weather and Forecasting,* **25**(4), pp. 1263–1274, 2010. doi: 10.1175/2010WAF2222342.1
[43] Ying, L. & Ke, F., Improve the prediction of summer precipitation in the Southeastern China by a hybrid statistical downscaling model. *Meteorology and Atmospheric Physics,* **117**(3–4), pp. 121–134, 2012. doi:https://doi.org/10.1007/s00703-012-0201-0
[44] Sun, J. & Chen, H., A statistical downscaling scheme to improve global precipitation forecasting. *Meteorology and Atmospheric Physics,* **117**(3), pp. 87–102, 2012. doi:10.1007/s00703-012-0195-7
[45] Wang, Q.J., Schepen, A. & Robertson, D.E., Merging seasonal rainfall forecasts from multiple statistical models through Bayesian model averaging. *Journal of Climate,* **25**(16), pp. 5524–5537, 2012. doi:ttps://doi.org/10.1175/JCLI-D-11-00386.1
[46] Halide, H. & Ridd, P., Complicated ENSO models do not significantly outperform very simple ENSO models. *International Journal of Climatology,* **28**, pp. 219–233, 2008. https://doi.org/10.1002/joc.1519
[47] Abbot, J. & Marohasy, J., Forecasting monthly rainfall in the Bowen Basin of Queensland, Australia, using neural networks with Niño Indices for El Niño-Southern Oscillation. *Lecture Notes in Artificial Intelligence,* **9992**, pp. 88-100, 2016.
[48] Duan, W. & Zhang, R., Is model parameter error related to a significant spring predictability barrier for El Nino events? Results from a theoretical model. *Advances in Atmospheric Science,* **27**(5), pp. 1003–1013, 2010. https://doi.org/10.1007/s00376-009-9166-4
[49] Yan, L. & Yu, Y., The spring prediction barrier in ENSO hindcast experiments using the FGOALS-g model. *Chinese Journal of Oceanology Limnology,* **30**(6), pp. 1093–1104, 2012. available at: https://doi.org/10.1007/s00343-012-1271-z
[50] Coventry, W.L. & Dalgleish, L.I., Farmers' accuracy interpreting seasonal climate forecast probability. *International Journal of Climatology,* **34**(6), pp. 2097–2107, 2014. https://doi.org/10.1002/joc.3825
[51] http://www.bom.gov.au/jsp/sco/archive/index.jsp?map=rain&outlook=probmedian&period=season1&year=2016&month=05&day=26

[52] Woodburn, J., Rain wipes out NSW crops in third wettest winter on record, ABC News, available at http://www.abc.net.au/news/2016-09-02/rain-wipes-out-nsw-crops-in-third-wettest-winter-on-record/7810722, September 2, 2016.

[53] Hoerr, K., NSW flooding leaves rural town of Deniliquin devastated, community set to feel impact for months, ABC News, available at http://www.abc.net.au/news/2016-10-16/nsw-flooding-leaves-rural-town-of-deniliquin-devastated/7935136, October 16, 2016.

PROJECTED CHANGES IN TEMPERATURE AND PRECIPITATION IN SARAWAK STATE OF MALAYSIA FOR SELECTED CMIP5 CLIMATE SCENARIOS

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ABSTRACT

This article explores the projected changes in precipitation, maximum temperature (T_{max}) and minimum temperature (T_{min}) in the Malaysian state of Sarawak under Representative Concentration Pathways (RCPs) with the CanESM2 Global Circulation Model. The Statistical Downscaling Model (SDSM) was used to downscale these climate variables at three stations in Sarawak. The model performed well during the validation period and thus was used for future projections under three RCPs with the CanESM2 General Circulation Model. It is noted that the T_{max} will increase by 1.94°C at Kuching, 0.09°C at Bintulu and 1.29°C at Limbang, when comparing the period of 2071–2100 with the baseline period of 1981–2010, under the most robust scenario of RCP8.5. T_{min} is also expected to increase by 1.21°C at Kuching, 0.15°C at Bintulu and 2.08°C at Limbang, under the RCP 8.5 projection for the same period. The precipitation at Kuching and Bintulu is expected to increase slightly to 1.6% and 1.4% at Kuching and Bintulu respectively; however, the seasonal shift is projected as follows: lesser precipitation during the December–February period and more during the June–August season. On the other hand, precipitation is expected to increase at Limbang during all seasons, when compared with the period of 1981–2010; it is expected that under RCP4.5 the annual precipitation at Limbang will increase by 10.5% during the 2071–2100 period.

Keywords: Borneo, CanESM2, climate change, CMIP5 scenarios, Malaysia, NCEP, precipitation and temperature projection, Sarawak, statistical downscaling.

1 INTRODUCTION

Increased greenhouse gas (GHG) emissions and positive radiative forcing are the evidence of human impact on the global climate system. GHG emissions caused global surface warming, ranging from 0.5°C to 1.3°C during the years from 1951 to 2010; continued GHG emissions will cause further warming and change the equilibrium of the climate system, according to IPCC [1]. Under the projected future climate, it is plausible that grievous and extreme weather events (i.e. severe floods and droughts) will occur in global monsoon areas [2–5].

Temperature and precipitation are two main climate variables that influence the hydrological cycle as an impact of climate change. Global Climate Models, also called Global Circulation Models (GCMs), are the main tools for projecting the changes in temperature and precipitation. These models interpret global systems such as sea-ice, oceans and the atmosphere [6]. Although GCMs are very useful for the projection of future climate changes, the outputs of these models are based on a large grid scale (i.e. 250 to 600 km). Because of their coarse resolution, the outputs cannot be used directly to investigate the environmental and hydrological impacts of climate change on a regional scale [7]. Therefore, for climate change impact studies, it is necessary to downscale GCMs' output to a regional or local scale.

Two main approaches are used to downscale the GCM output: statistical downscaling (SD) and dynamical downscaling (DD). The SD methods are much simpler than the DD methods;

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in the SD global scale, GCM climate variables, such as mean sea-level pressure, zonal wind, temperature, precipitation, geo-potential height etc., are linked with local-scale variables, such as observed temperature and precipitation, through various regression techniques for the controlled historical period. Then the future changes in local-scale temperature and precipitation are derived by forcing the future simulated data for selected GCM variables into the developed regression equations [8–11].

Many statistical models have been developed during recent years and have been used in various regions. The statistical downscaling model (SDSM) is also widely used to downscale the most important climate variables such as temperature and precipitation [12–16]. The objectives of this study are to derive an SD model using the SDSM toolbox for downscaling the precipitation, maximum temperature (T_{max}) and minimum temperature (T_{min}) in Sarawak and to assess the projected changes in precipitation, T_{max} and T_{min} under the representative concentration pathways (RCPs) of CanESM2 for the periods, 2011–2040, 2041–2070 and 2071–2100.

2 STUDY AREA AND DATA DESCRIPTION

Sarawak is the largest state of Malaysia (124,450 Km^2), located on Borneo Island in South East Asia. It experiences a wet and humid tropical climate throughout the year, with annual precipitation of between 2800 mm and 5000 mm and temperature variations between 20°C and 36°C. In this study, three cities, i.e. Limbang, Bintulu and Kuching, in the northern, central and western regions, respectively, have been selected for the exploration of potential changes in temperature and precipitation. Most of the state's population is settled along the coast, and therefore the historical temperature record is only available at the airports in these coastal cities. The observed daily data of precipitation, T_{max} and T_{min} was collected from the Department of Irrigation and Drainage, Sarawak (DID) for three climate stations, as described in Table 1 and shown in Fig. 1.

The Canadian Centre for Climate Modelling and Analysis (CCCma) has developed a number of climate models. These are used to study climate change and its variability and to

Table 1: Geographical location, altitude and climate variables used for the selected meteorological stations in the Malaysian state of Sarawak.

	Location			
Station	Latitude (D, M, S)	Longitude (D, M, S)	Altitude (masl)	Climate Variables
Kuching	001 29 27	110 20 57	25	Precipitation T_{max} T_{min}
Bintulu	003 07 15	113 01 17	34	Precipitation T_{max} T_{min}
Limbang	004 44 46	114 59 58	15	Precipitation T_{max} T_{min}

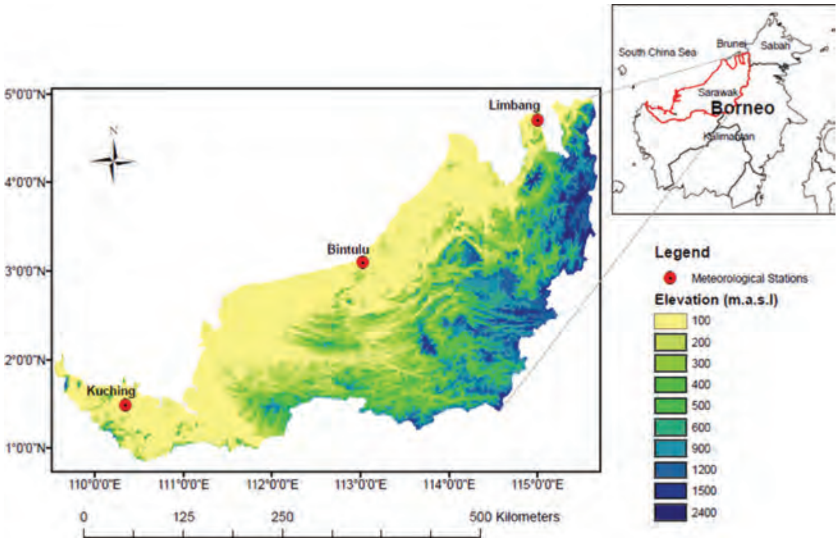

Figure 1: Location map of the selected meteorological stations in the Malaysian state of Sarawak.

understand the various processes that govern the global climate system. These models are also used to make quantitative projections of future long-term climate change under various GHG and aerosol forcing scenarios. In this study, two types of daily climate variables were obtained from the Canadian Climate Data and Scenarios website (http://ccds-dscc.ec.gc.ca/?page=dst-sdi): (a) 26 variables of the National Center of Environmental Prediction (NCEP) for the period 1981–2005, and (b) 26 variables of CanESM2 from CCCma for the historical period 1981–2005, as well as for the future period, 2006–2100, for three RCPs, i.e. RCP2.6, RCP4.5 and RCP8.5. These RCPs were developed by different modelling groups and address the different scenarios of future GHG emission scenarios. The RCP2.6 scenario leads to a very low level of GHG concentration. The RCP4.5 is a stabilization scenario, in which total radiative forcing is stabilized before 2100 by adopting various technologies and policies for minimizing the GHG emissions. The RCP8.5 scenario is categorized by increasing GHG emissions over time, leading to a high level of GHG concentration levels. The list of the NCEP and CanESM2 climate variables used in this study is shown in Table 2. All data used is available at a grid resolution of 2.8125° × 2.8125° (Latitude × Longitude).

3 METHODOLGY

3.1 Statistical downscaling model (SDSM)

The SDSM is a downscaling tool developed by [17]; it combines multiple linear regression (MLR) with a stochastic weather generator (SWG). MLR establishes a statistical relationship between GCM predictor variables and local-scale predictands' variables to produce regression parameters. These calibrated regression parameters are further used with NCEP and GCM predictor variables in SWG to simulate daily time series to create a better correlation with the observed predictands' time series.

Table 2: List of NCEP and CanESM2 climate variables used in this study.

Sr. No.	Predictor	Description	Sr. No.	Predictor	Description
1	temp	Mean temperature at 2m	14	p1_zh	Divergence at surface
2	mslp	Mean sea level pressure	15	p5_f	Geostrophic air flow velocity at 500 hPa
3	p500	500 hPa geopotential height	16	p5_z	Vorticity at 500 hPa
4	p850	850 hPa geopotential height	17	p5_u	Zonal velocity component at 500 hPa
5	r500	Relative humidity at 500 hPa height	18	p5_v	Meridional velocity component at 500 hPa
6	r850	Relative humidity at 850 hPa height	19	p5_th	Wind direction at 500 hPa
7	shum	Near surface specific humidity	20	p5_zh	Divergence at 500 hPa
8	prec	Total precipitation	21	p8_f	Geostrophic air flow velocity at 850 hPa
9	p1_f	Geostrophic air flow velocity at surface	22	p8_z	Vorticity at 850 hPa
10	p1_z	Vorticity at surface	23	p8_u	Zonal velocity component at 850 hPa
11	p1_u	Zonal velocity component at surface	24	p8_v	Meridional velocity component at 850 hPa
12	p1_v	Meridional velocity component at surface	25	p8_th	Wind direction at 850 hPa
13	p1_th	Wind direction at surface	26	p8_zh	Divergence at 850 hPa

There are three kinds of sub-models – monthly, seasonal and annual sub-models – that comprise the statistical/empirical relationship between the regional-scale variables (temperature and precipitation) and large-scale variables. Annual sub-models derive a single regression equation for all months in the year, seasonal sub-models derive a regression equation for each season, and the monthly sub-model represents a separate regression equation for each month.

There are also two options within sub-models: conditional and unconditional sub-models. The conditional sub-models are used for the parameters that are dependent on the occurrence of other climate parameters, i.e. precipitation, evaporation, etc., while the unconditional models are used for independent climate parameters, i.e. temperature [15, 17]. SDSM also contains a tool to normalize the input climate data prior to its usage in the regression equations.

3.2 Screening of predictors

In SDSM, the most suitable variables from the atmospheric predictors are selected through a MLR model, utilizing the combination of the correlation matrix, partial correlation, P-value, histograms, and scatter plots. In the current study, a correlation analysis was applied between predictands and NCEP predictors; each predictor was selected based on the highest correlation, partial correlation and least P-value with the predictand (precipitation, T_{max} and T_{min}). At Kuching, prec was the super predictor with higher rank for precipitation, temp for T_{max} and shum for T_{min}. At Bintulu, prec was the super predictor for precipitation, p1_z for T_{max} and p500 for T_{min}. At Limbang, prec was the super predictor for precipitation, temp for T_{max} and p500 for T_{min}. In general, the selection of predictor variables in this study was performed in a similar way to those applied in other studies, for example [14, 18].

3.3 Model calibration and validation

Based on the available observed data, two daily data sets, 1981–1995 and 1996–2005, were selected for the model calibration and validation, respectively. Daily downscaling models were developed in SDSM for precipitation, T_{max} and T_{min} to generate the separate regression equation for each month. The conditional sub-model is used for T_{max} and T_{min} without any transformation and the unconditional sub-model, for precipitation. Optimization of the best fit is performed by the ordinary Least Squares (OLS) method. The correlation coefficient (R) and root mean square error (RMSE) of simulated data to observed data were used as performance indicators during the calibration and validation. With the calibrated model for the period of 1981–1995, 20 daily ensembles for precipitation, T_{max} and T_{min} were simulated for the period of 1996–2005, feeding the NCEP and CanESM2 predictors, and the mean ensemble of these 20 ensembles was used for validation with the observed data for the same period (1996–2005).

During the calibration, at all stations, the model simulated daily precipitation, T_{max} and T_{min} well; however, it overestimated the daily precipitation at all stations. The performance of the model during the calibration period simulated by SDSM (using the NCEP variables) is shown in Table 3. This over-estimation of precipitation was addressed during the validation period, when these biases were calculated and daily precipitation was de-biased as explained in Section 3.4. Kuching's temperature and precipitation have better correlation during the calibration period, as compared to Bintulu and Limbang, the latter of which shows the lowest correlation. For the coefficient of correlation, the model performed better for T_{max} as compared to T_{min} and precipitation. During the calibration period, while comparing the coefficient of correlation, the SDSM performance is similar to that shown in [14], when applied to Peninsular Malaysia.

During the validation period, the precipitation, T_{max} and T_{min} were simulated using the NCEP data, as well as the CanESM2 historical data, to evaluate the model performance with both data sets. Table 4 shows the model's performance during the validation period. The model simulated average daily and monthly T_{max} and T_{min} very well at all stations. Compared to the observed daily/monthly precipitation, the simulated monthly precipitation was slightly higher at Kuching and Bintulu and slightly lower at Limbang. In order to remove the errors, during validation, the biases were adjusted by the bias-correction method, as shown in Fig. 2. The model performed well for temperature downscaling at all three stations in Sarawak; however, for the precipitation downscaling, the model performance was fairly satisfactory and could be improved further with some alternative methods/models.

3.4 Bias correction

Bias correction (BC) has been used in several studies, such as [12, 13], to remove biases from the daily precipitation and temperature series of downscaled data. The techniques for bias

Table 3: Performance of model for daily and monthly time series of T_{max}, T_{min} and precipitation during the calibration period (1981–1995).

	T_{max}			T_{min}			Precipitation		
	X (°C)	R	RMSE	X (°C)	R	RMSE	X (mm)	R	RMSE
Western Region (Kuching)									
Daily									
Obs	31.60			23.09			11.26		
NCEP	31.59	0.66	1.24	23.16	0.49	0.55	13.48	0.28	19.85
Monthly									
Obs	31.60			23.09			342.6		
NCEP	31.60	0.87	0.50	23.09	0.74	0.21	406.5	0.74	115.4
Central Region (Bintulu)									
Daily									
Obs	30.90			23.61			9.94		
NCEP	30.98	0.54	1.25	23.70	0.34	0.75	12.22	0.18	20.08
Monthly									
Obs	30.89			23.61			302.3		
NCEP	30.90	0.73	0.35	23.60	0.58	0.26	361.1	0.59	110.3
Northern Region (Limbang)									
Daily									
Obs	32.30			23.30			7.33		
NCEP	32.41	0.28	1.70	23.28	0.20	1.03	8.95	0.19	14.78
Monthly									
Obs	32.30			23.23			222.9		
NCEP	32.29	0.49	0.76	23.22	0.38	0.53	260.1	0.49	85.59

correction for temperature differ from those for precipitation, and the following equations are used to correct the biases in the daily time series of temperature and precipitation:

$$T_{deb} = T_{SCEN} - \left(\overline{T_{CONT}} - \overline{T_{obs}}\right) \tag{1}$$

$$P_{deb} = P_{SCEN} \times \left(\frac{\overline{P_{obs}}}{\overline{P_{CONT}}}\right) \tag{2}$$

where T_{deb} and P_{deb} are the de-biased (corrected) daily time series of temperature (in °C) and precipitation (in mm/day), respectively, for future periods. SCEN represents the scenario data downscaled by SDSM for future periods (e.g., 2011–2040 etc.), and CONT represents data downscaled by SDSM for the historical controlled period (e.g. 1981–1995). T_{SCEN} and P_{SCEN} are the daily time series of temperature and precipitation generated by SDSM for future

Table 4: Performance of SDSM models for simulating T_{max}, T_{min} and precipitation during validation (1996–2005).

	T_{max}			T_{min}			Precipitation		
	X	R	RMSE	X	R	RMSE	X	R	RMSE
	°C			°C			mm		
Western Region (Kuching)									
Daily									
Obs	31.60			23.37			11.46		
NCEP	31.60	0.60	1.27	23.37	0.38	0.59	11.48	0.17	22.28
CanESM2	31.60	0.51	1.37	23.38	0.18	0.69	11.49	0.15	22.85
Montly									
Obs	31.60			23.37			348.9		
NCEP	31.74	0.87	0.55	23.03	0.62	0.45	375.9	0.66	166.5
CanESM2	31.36	0.83	0.64	22.94	0.48	0.55	385.5	0.61	176.2
Central Region (Bintulu)									
Daily									
Obs	31.19			23.84			10.26		
NCEP	31.19	0.30	1.89	23.84	0.27	0.83	10.28	0.15	20.57
CanESM2	31.19	0.30	1.89	23.84	0.12	0.90	10.29	0.02	21.15
Monthly									
Obs	31.19			23.84			312.4		
NCEP	30.89	0.76	0.60	23.54	0.50	0.40	313.0	0.48	135.2
CanESM2	30.89	0.77	0.60	23.64	0.43	0.45	325.3	0.28	150.4
Northern Region (Limbang)									
Daily									
Obs	33.14			23.54			9.34		
NCEP	33.14	0.29	1.25	23.54	0.07	0.92	9.34	0.10	17.79
CanESM2	33.14	0.29	1.26	23.55	0.18	0.90	9.34	0.01	18.17
Montly									
Obs	33.13			23.54			284.2		
NCEP	32.35	0.53	1.04	22.97	0.13	0.73	245.1	0.37	138.1
CanESM2	32.19	0.55	1.17	23.24	0.60	0.46	233.4	0.19	150.4

periods, respectively. T_{CONT} and P_{CONT} are the mean monthly values for temperature and precipitation, respectively, for the control period (historical) simulated by SDSM. T_{obs} and P_{obs} represent the long-term mean monthly observed values for temperature and precipitation. The bar on T and P shows the long-term average. Table 5 presents the monthly standard deviation of observed and simulated data at Kuching for the period, 2071–2100. It demonstrates that the model successfully generated the future time series of temperature and precipitation realistically.

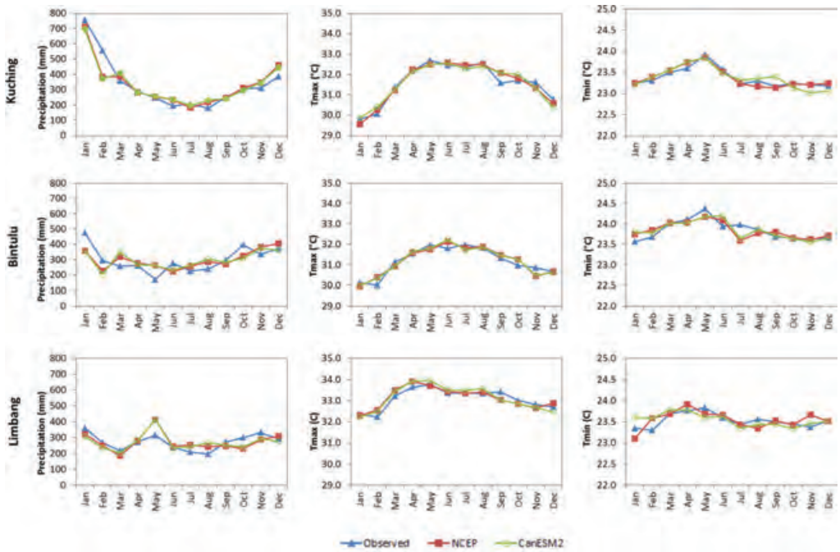

Figure 2: Comparison of monthly precipitation, T_{max} and T_{min} simulated by SDSM with observed dataset during validation period (with bias correction) in the Malaysian state of Sarawak.

Table 5: Standard deviation of observed and simulated monthly precipitation, T_{max} and T_{min} at Kuching.

	Historical	RCP2.6	RCP4.5	RCP8.5
Variable	1981–2010		2071–2100	
Precipitation	194	134	135	134
T_{max}	1.6	1.12	1.16	1.30
T_{min}	0.6	0.31	0.35	0.50

4 RESULTS AND DISCUSSIONS

4.1 Annual changes in precipitation and temperature

Feeding the selected CanESM2 predictors of three future scenarios, i.e. RCP2.6, RCP4.5 and RCP8.5 into developed SDSM models, daily precipitation, T_{max} and T_{min} were simulated for three future periods: 2011–2040, 2041–2070 and 2071–2100. BC was applied as calculated during the control period (1981–2005) to remove biases in the projected data. Future changes in precipitation, T_{max} and T_{min} were calculated by comparing them to the baseline period. In this study, the period from 1981 to 2010 was selected as the baseline period because this 30-year period has been used in the majority of climate change studies across the world [5, 19, 20]. A 30-year period is considered sufficient to define the local climate, as it is anticipated that it will comprise different situations such as dry, wet, cool, and warm years or sub-periods.

As the RCP8.5 is the scenario considering a high concentration of GHG emissions, it is noted that the mean annual T_{max} at Kuching would be expected to increase by 1.94°C during 2080's under the RCP8.5 scenario. At Bintulu, T_{max} is expected to increase by 0.09°C during the 2080s. At Limbang, the T_{max} would also increase by 1.29°C during the 2080s. The T_{min} also followed the same pattern as of that of the T_{max} and would be expected to increase by 1.21°C at Kuching, 0.15°C at Bintulu and 2.08°C at Limbang during the 2080s, when compared with the baseline period. In future, the annual precipitation at Kuching, Bintulu and Limbang is expected to increase by 0.3%, 1.4% and 4.5%, respectively, during the 2080s, as shown in Table 4. The projection of precipitation, T_{max} and T_{min} during the 2020s, 2050s and 2080s under the RCP2.6, RCP4.5 and RCP8.5 is detailed in Table 6.

4.2 Seasonal changes in precipitation and temperature

The temperature in Sarawak has the same pattern throughout the year, with December to February (DJF) having heavy rainfall and slightly lower temperatures, as compared to the other seasons. The precipitation changes over the seasons; during DJF, Sarawak receives its highest rainfall due to the north-west monsoons, while June to August (JJA) are the lowest precipitation months. The other two seasons, i.e. March to May (MAM) and September to November (SON), are the inter-monsoon months and give average precipitation. The changes in future seasonal precipitation, T_{max} and T_{min} were calculated under the three RCPs of CanESM2, and the future period of 2071–2100 was compared with the baseline period of 1981–2010.

During the drier season of JJA, it is noted that, during 2071–2100, surface T_{max} would increase to 1.06°C, 1.44°C and 2.21°C at Kuching, to 0.17°C, 0.18°C and 0.18°C at Bintulu

Table 6: Future changes in annual precipitation, T_{max} and T_{min} with respect to the baseline (1981–2010) under CanESM2 runs for possible future RCP scenarios.

	Kuching			Bintulu			Limbang		
	2020's	2050's	2080's	2020's	2050's	2080's	2020's	2050's	2080's
T_{max} (°C)									
RCP2.6	0.68	0.88	0.85	0.08	0.10	0.10	0.71	0.79	0.78
RCP4.5	0.66	1.04	1.20	0.09	0.10	0.09	0.70	0.87	0.94
RCP8.5	0.76	1.27	1.94	0.09	0.09	0.09	0.75	0.98	1.29
T_{min} (°C)									
RCP2.6	0.51	0.60	0.58	0.13	0.15	0.14	0.64	0.88	0.83
RCP4.5	0.51	0.70	0.78	0.13	0.14	0.15	0.66	1.02	1.19
RCP8.5	0.54	0.84	1.21	0.14	0.14	0.15	0.72	1.36	2.08
Precipitation (%)									
RCP2.6	1.3	1.3	–0.1	1.0	–0.6	–0.3	10.1	8.2	9.9
RCP4.5	0.5	0.9	1.6	–0.4	0.3	1.0	9.3	9.5	10.5
RCP8.5	1.4	1.1	0.3	0.1	1.6	1.4	10.0	7.6	4.5

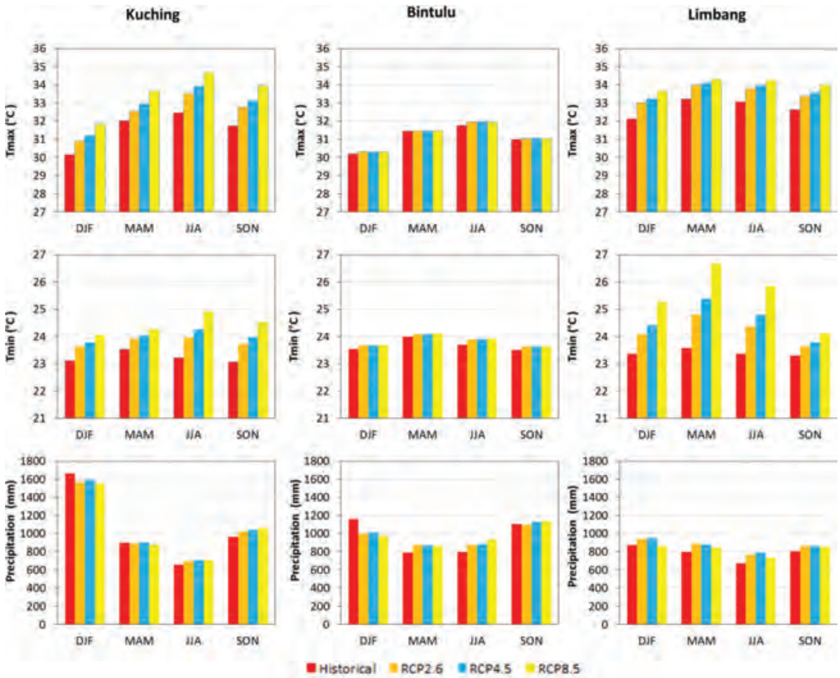

Figure 3: Seasonal changes in T_{max}, T_{min} and precipitation at three stations for the period of 2071–2100, compared to the baseline period of 1981–2010.

Table 7: Future projected changes in seasonal precipitation, T_{max} and T_{min} during the period, 2071–2100, with respect to the baseline (1981–2010) under CanESM2 runs for possible future RCP scenarios.

	RCP2.6				RCP4.5				RCP8.5			
	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
T_{max} (°C)												
Kuching	0.74	0.54	1.06	1.04	1.03	0.92	1.44	1.39	1.68	1.63	2.21	2.23
Bintulu	0.13	0.02	0.17	0.06	0.10	0.01	0.18	0.07	0.10	0.01	0.18	0.07
Limbang	0.89	0.74	0.76	0.73	1.11	0.86	0.90	0.90	1.53	1.06	1.22	1.38
T_{min} (°C)												
Kuching	0.53	0.40	0.73	0.66	0.67	0.50	1.05	0.90	0.94	0.76	1.69	1.46
Bintulu	0.14	0.11	0.20	0.13	0.14	0.10	0.21	0.13	0.16	0.11	0.23	0.12
Limbang	0.72	1.24	1.01	0.35	1.05	1.80	1.43	0.48	1.91	3.10	2.49	0.81
Precipitation (%)												
Kuching	−5.6	−0.6	5.5	6.1	−4.4	0.4	7.3	7.7	−6.8	−2.2	6.8	9.1
Bintulu	−14.2	10.4	9.8	−0.7	−14.5	9.0	10.1	2.3	−18.7	8.3	15.9	2.9
Limbang	7.7	11.4	14.4	7.2	8.0	9.2	15.0	6.7	−1.3	5.1	7.9	5.2

and to 0.76°C, 0.90°C and 1.22°C at Limbang, under the RCP2.6, RCP4.5 and RCP8.5 scenarios, respectively, when compared with the baseline period of 1976–2000. The T_{min} is also projected to increase in future under the all RCPs, as shown in Table 5. Precipitation at Kuching is projected to decrease during DJF, increase during JJA and SON but to remain the same as the historical period during MAM. At Bintulu, the precipitation is also projected to decrease during DJF, increase during MAM and JJA but to remain the same during SON. At Limbang, the precipitation is projected to increase during all seasons under all RCPs by the end of the twentyfirst century, as shown in Fig. 3 and Table 7.

5 CONCLUSIONS

Sarawak is the wettest state in Malaysia and receives up to 5 m of precipitation per year. In the present study, the impact of climate change on temperature and precipitation was assessed at three different locations in the state. The study concluded that the surface temperature is projected to increase in future in all selected places in Sarawak under all selected RCPs. This coincides with the findings of other regional studies, i.e. [14, 21].

The annual precipitation at Kuching and Bintulu is projected to remain unchanged under all future climate scenarios; it coincides with [22] who studied future precipitation changes over Batang Ai catchment in Sarawak, where projected future precipitation is likely to be unchanged. However, a seasonal shift is expected at these locations, with a projection of less precipitation during DJF and more during JJA. On the other hand, Limbang is projected to have more precipitation during every season under all RCPs in future, when comparing the period of 2071–2100 with that of 1981–2010.

This study used precipitation and temperature data from three stations in different regions of the Malaysian state of Sarawak. It is recommended that more stations from each region be included to investigate any uncertainty associated with the data used. The temperature projection is limited by the unavailability of data across the state; however, the precipitation projection could be further expanded with the inclusion of more rainfall stations in each region.

In this study, only CanESM2 GCM output from the Coupled Model Intercomparison Project Phase 5 (CMIP5) was used for the future projection of precipitation, T_{max} and T_{min}. It is recommended to include a few other CMIP5 models for projection and to adopt a mean ensemble of selected models to minimize the uncertainty associated with a single model projection.

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REFERENCES

[1] IPCC, Summary for policymakers. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, eds T.F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex & P.M. Midgley, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2013.

[2] Hsu, P.C., Li, T., Luo, J.J., Murakami, H., Kitoh, A. & Zhao, M., Increase of global monsoon area and precipitation under global warming: A robust signal? *Geophysical Research Letters*, **39**(6), 2012. doi:10.1029/2012GL051037

[3] Lau, W.K.M., Wu, H.T. & Kim, K.M., A canonical response of precipitation characteristics to global warming from CMIP5 models. *Geophysical Research Letters*, **40**(12), pp. 3163–3169, 2013. doi:10.1002/grl.50420

[4] Lee, J.Y. & Wang, B., Future change of global monsoon in the CMIP5. *Climate Dynamics*, **42**(1), pp. 101–119, 2012. doi:10.1007/s00382-012-1564-0

[5] Hassan, M., Du, P., Jia, S., Iqbal, W., Mahmood, R. & Ba, W., An assessment of the South Asian summer monsoon variability for present and future climatologies using a high resolution regional climate model (RegCM4.3) under the AR5 scenarios. *Atmosphere*, **6**(11), pp. 1833–1857, 2015. doi:10.3390/atmos6111833

[6] Hasson, S.U., Pascale, S., Lucarini, V. & Böhner, J., Seasonal cycle of precipitation over major river basins in South and Southeast Asia: a review of the CMIP5 climate models data for present climate and future climate projection. *Atmospheric Research*, **180**, pp. 42–63, 2016. doi:10.1016/j.atmosres.2016.05.008

[7] The Second National Communication to the Republic of Malawi to the Conference of the Parties (COP) of the UNFCCC. *Ministry of Natural Resources and Environment, Malaysia*, 2011.

[8] Ahmed, K.F., Wang, G., Silander, J., Wilson, A.M., Allen, J.M., Horton, R. & Anyah, R., Statistical downscaling and bias correction of climate model outputs for climate change impact assessment in the U.S. northeast. *Global and Planetary Change*, **100**, pp. 320–332, 2013. doi:10.1016/j.gloplacha.2012.11.003

[9] Cañón, J., Domínguez, F. & Valdés, J.B., Downscaling climate variability associated with quasi-periodic climate signals: a new statistical approach using MSSA. *Journal of Hydrology*, **398**(1–2), pp. 65–75, 2011. doi:10.1016/j.jhydrol.2010.12.010

[10] Yin, C., Li, Y., Ye, W., Bornman, J.F. & Yan, X., Statistical downscaling of regional daily precipitation over southeast Australia based on self-organizing maps. *Theoretical and Applied Climatology*, **105**(1), pp. 11–26, 2010. doi:10.1007/s00704-010-0371-y

[11] Timbal, B., Fernandez, E. & Li, Z., Generalization of a statistical downscaling model to provide local climate change projections for Australia. *Environmental Modelling & Software*, **24**(3), pp. 341–358, 2009. doi:10.1016/j.envsoft.2008.07.007

[12] Hussain, M., Yusof, K.W., Mustafa, M.R. & Afshar, N.R., Application of statistical downscaling model (SDSM) for long term prediction of rainfall in Sarawak, Malaysia. *WIT Transactions on Ecology and the Environment*, **196**, pp. 269–278, 2015. doi:10.2495/wrm150231

[13] Mahmood, R. & Babel, M.S., Future changes in extreme temperature events using the statistical downscaling model (SDSM) in the trans-boundary region of the Jhelum river basin. *Weather and Climate Extremes*, **5–6**, pp. 56–66, 2014. doi:10.1016/j.wace.2014.09.001

[14] Hassan, Z., Shamsudin, S. & Harun, S., Application of SDSM and LARS-WG for simulating and downscaling of rainfall and temperature. *Theoretical and Applied Climatology*, **116(**1), pp. 243–257, 2014. doi:10.1007/s00704-013-0951-8

[15] Chu, J.T., Xia, J., Xu, C.Y. & Singh, V.P., Statistical downscaling of daily mean temperature, pan evaporation and precipitation for climate change scenarios in Haihe River, China. *Theoretical and Applied Climatology*, **99**(1), pp. 149–161, 2010. doi:10.1007/s00704-009-0129-6

[16] Dibike, Y.B. & Coulibaly, P., Validation of hydrological models for climate scenario simulation: The case of Saguenay watershed in Quebec. *Hydrological Processes*, **21**(23), pp. 3123–3135, 2007. doi:10.1002/hyp.6534

[17] Wilby, R.L., Dawson, C.W. & Barrow, E.M., SDSM – a decision support tool for the assessment of regional climate change impacts. *Environmental Modelling and Software*, **17**(2), pp. 147–159, 2002. doi:10.1016/S1364-8152(01)00060-3

[18] Mahmood, R. & Babel, M.S., Evaluation of SDSM developed by annual and monthly sub-models for downscaling temperature and precipitation in the Jhelum basin, Pakistan and India. *Theoretical and Applied Climatology*, **113**(1), pp. 27–44, 2012. doi:10.1007/s00704-012-0765-0

[19] Huang, J., Zhang, J., Zhang, Z., Xu, C., Wang, B. & Yao, J., Estimation of future precipitation change in the Yangtze River basin by using statistical downscaling method. *Stochastic Environmental Research and Risk Assessment*, **25**(6), pp. 781–792, 2011. doi:10.1007/s00477-010-0441-9

[20] Mahmood, R., Jia, S. & Babel, M., Potential impacts of climate change on water resources in the Kunhar River Basin, Pakistan. *Water*, **8**(1), p. 23, 2016. doi:10.3390/w8010023

[21] Amin, M.Z.M., Shaaban, A.J., Ohara, N., Kavvas, M.L., Chen, Z.Q., Kure, S. & Jang, S., Climate change assessment of water resources in Sabah and Sarawak, Malaysia, based on dynamically-downscaled GCM projections using a regional hydroclimate model. *Journal of Hydrologic Engineering*, **21**(1), 2016. doi:10.1061/(ASCE)HE.1943-5584.0001242

[22] Hussain, M., Nadya, S., Yusof, K.W. & Mustafa, M.R., Potential impact of climate change on inflows to the Batang Ai reservoir, Malaysia. *International Journal on Hydropower & Dams*, pp. 44–48, 2017.

OPTIMIZING THE URBAN THERMAL ENVIRONMENT AT LOCAL SCALE: A CASE STUDY IN WUHAN, CHINA

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ABSTRACT

The urban thermal environment deteriorates with increasing frequency of extreme heat events in cities. Conventionally, the Urban Heat Island (UHI) effect only reflects the temperature difference between the city and its rural surroundings. This scale of analysis is often too broad to help devise mitigation strategies, which are typically implemented at a more local scale within the sphere of urban planning and design. In this research, the city of Wuhan, China, is taken as an example. Through quantitative measurements, a workflow is proposed to mitigate the surface UHI of Wuhan, locally. Also, the satellite images of the MODerate-resolution Imaging Spectroradiometer and Landsat-7 ETM+ are used for technical purposes, and the K-means clustering is applied to classify the Local Climate Zone (LCZ). Further, the Local Scale Urban Heat Island (LSUHI) is captured through morphological parameters, such as Multi-Scale Shape Index (MSSI) based upon the latent Land Surface Temperature (LST) pattern. The mitigation process is organized hierarchically and prioritized by the combination of LCZ and LSUHI. Based on this, Wuhan is divided into seven LCZs and the LSUHI, in the mean time, can be detected by morphological parameters. We present the corresponding quantitative planning advice for places with higher heat threats in the city. This research is conducted on urban microclimate and urban planning on at least two levels: (1) the reduced study scale of urban thermal environment and (2) a planning-driven workflow of urban thermal environment optimization.
Keywords: climate zone, heat island, hotspot, land surface temperature, local scale, morphology.

1 INTRODUCTION

Global temperature continues to rise and cities may possess higher warming rates than natural land covers [1]. The phenomenon of higher temperature in urban areas is known as the Urban Heat Island (UHI). The physical mechanisms through which the UHI effect is driven are well documented. Primary constituents of urban construction, such as asphalt, cement, and roofing tiles, have a much greater heat capacity than forest vegetation and other natural features [2]. The enhanced anthropogenic heat emissions, reduced evaporative cooling, increased surface roughness, lower surface albedos and narrow urban canyon geometry associated with cities also results in the formation of UHIs [3].

Tragic socio-economic consequences of urban heat events have been realized and addressed only lately. Most cities are reported to be without any form of regulations for temperature mitigation in terms of land surface management [4]. Even at the local level, some climate action plans that only considered greenhouse gas emission control were insufficient to address the problem [1].

1.1 The land surface specification in the local climate zones

One of the significant weaknesses of current research on microclimate is the lack of standards, which impedes both the quantitative measurement of meteorology phenomenon at a local scale and the development of local meteorological research of urban climate [5]. Most planning and design concepts are restricted by lack of quantitative standards that can mitigate and adapt climate uncertainties [1]. The weakness is quite intuitive in the study of

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temperature patterns and variations at the local scale [6]. Building upon the concept of Urban Climate Zone (UCZ) and Local Climate Zone (LCZ) initiated by Oke's (2011) research team, the research applies the idea to an entire city [7]. The LCZ is proposed such that the study of microclimate can be set into a standard background. The framework of LCZ recommends that the land surface should be classified into zones quantitatively according to their meteorological responses. The classification indicators include the surface material and meteorological properties. This can be further defined according to the surface configuration of a natural and a built environment, such as Impervious Surface Fraction (ISF) or Pervious Surface Fraction (PSF) [8–10], albedo [11–13], Sky View Factor (SVF) [14–16], the vegetation fraction [8, 17–19], and building density [2, 20].

The LCZ is a framework that has been proposed recently, and has been validated through circling places with radius of hundreds of meters in few cities [21]. The application of the concept is rarely found. Szeged, Hungary, began to apply the framework to the whole city in 2014 [22]. More applications and tests of the framework are needed to bring insights of the dynamics of local climate at the local scale.

1.2 Characterizing the surface urban heat Island

Conventionally, UHI is defined as the temperature difference between urban and rural areas. The investigations are largely influenced by the conventional 'urban-rural' dichotomy at the city scale [5]. The analyses of UHI aim at urban surface with remote sensing data and the findings of the specific relation between Land Surface temperature (LST) and air temperature [20]. LST became the primary concern because it governs the energy balance at the lowest layer of the atmosphere in the urban areas and controls the air temperature within the Urban Canopy Layer (UCL) [23]. When the temperature study boils down to investigate the LST within the UCL, UHI accordingly became the Surface Urban Heat Island (SUHI). A milestone is the characterization of the city scale SUHI of Houston, Texas, USA, by applying the unimodal Gaussian surface to the fitting of the Advanced Very High Resolution Radiometer (AVHRR) image data [24]. An extension of the methodology is employing the non-parametric kernel method to model the LST and SUHI patterns in Indianapolis, Indiana, USA [25].

1.3 Research framework

Since the classification of LCZs is based upon a set of indicators that reflect certain meteorological properties of the study area, the LCZs provide a configuration of climatic ingredients of the area and depict how the climatic patterns of the area distribute locally. Based on the modified version of the Stewart's (2011) LCZ scheme with a focus on LST, 9 LST-sensitive indicators are extracted from land surface factors and are used as the basis of classification for climate zones in Wuhan.

Based on the previous research of SUHI, the LST is further delineated with a combination of spatial and morphological information. In order to find out the prioritized areas with high temperature locally, the parameters are used as indicators to identify Local Scale Urban Heat Island (LSUHI).

LCZ provides the framework to mitigate LSUHI from the perspective of planning domains in two aspects. Firstly, the scope of LSUHI is limited to a single LCZ, rather than to the whole city. Secondly, the mitigation approaches for LSUHI are based on the classification indicators of LCZ. Then, the quantitative planning strategy is proposed by combining LCZ and LSUHI in hierarchies and priorities (Fig. 1). The research provides a workflow for the improvement

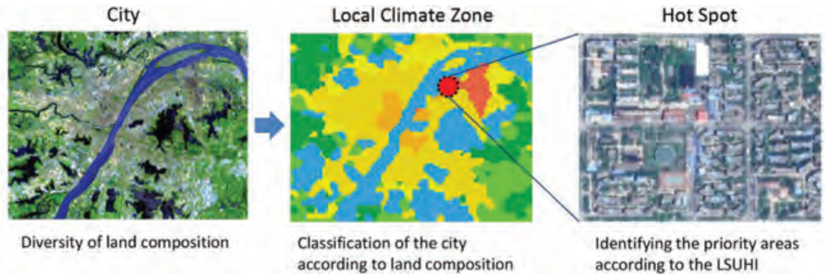

Figure 1: The hierarchical structure and priority for optimizing urban thermal environment.

of urban climate in terms of planning and implementation. The workflow includes the classification of the climate zone, the detection of the *hotspot*, and the adjustment of relevant land surface parameters.

2 METHODOLOGY

2.1 Study area and data

Wuhan, China, is selected as the case study. The city is located in central China. It is the fifth most populous city in the nation. Wuhan is characterized by its heterogeneity of land cover. The water bodies scatter within and around the urban area highlighting the diversity of land composition. The extent of the study area is 45×36 km, which covers entire downtown Wuhan and extends to the surrounding rural area. The upper-left and lower-right coordinates are '30°43′53″N, 114°4′49″E' and '30°24′0″N, 114°32′34″E', respectively. This coverage is sufficient to exhibit the land composition of the city (Fig. 2a). The L1T product with the resolution of 30 meters in 2012 captured by Landsat-7 ETM+ is employed to measure the land surface indicators, including PSF, ISF, albedo, Vegetation Index (VI), Water Index (WI), etc. The indicators including SVF, Building Density (BD), Building Volume Density (BVD), and Building Height (BH), are measured through shapefile of building data in 2012 according to the relevant Wuhan governmental departments. The MODIS/Terra (MOD11A2) and

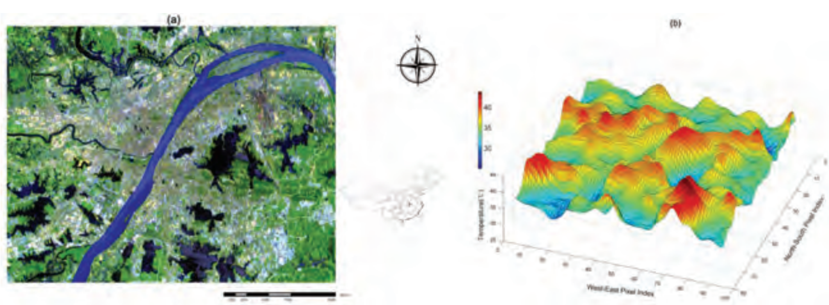

Figure 2: Study area and its latent LST. (a) The study area represented by false color image. SWIR2, NIR, and Green bands of Landsat ETM+ are combined to highlight the land surface heterogeneity of built environment, vegetation, and water bodies. (b) The latent LST at 13:30h, July 27th, 2012, extracted by using Gaussian Process model.

MODIS/Aqua (MYD11A2) V5 Daily L3 Global 1 km Grid products in 2012 are used to represent the LST pattern at a particular time point. The MYD11A2 data is acquired at 01:30h and 13:30h local time, and the MOD11A2 data is acquired at 10:30h and 22:30h local time. The accuracy of the LST data is better than 1K (0.5K in most cases). The LST is converted to Celsius degrees in this research. Before analyzing the morphology of LST, the Gaussian Process (GP) model [26] is used to extract the smooth and continuous latent pattern of LST as shown in Fig. 2b.

In the study of Wuhan, the variogram of LST at the phenomenon level and multi-scale analysis together define the operational scale of the LST–ISF interaction to be in the range of 500–650 m. The value is reasonable considering the characteristics of Chinese cities [10]. So, the scale of this research for LST and LCZ is set at 500 m.

2.2 The indicators and classification for the LCZs

The LCZs are classified in terms of temperature-sensitive indicators extracted from land surface factors. The indicators are selected empirically according to previous investigations of the land surface–LST relationships. For illustration, altogether 9 most frequently used LST sensitive land surface indicators extracted from vegetation, buildings, and land covers are used for classification. The indicators are SVF [27], BD, BVD [28], BH [17], PSF, albedo, VI, ISF, and WI [29]. Specifically, SVF is computed using vector databases based on methodology from Gál [27]; VI is coverage of vegetation and WI is coverage of water, respectively.

The indicators are all unified to the same raster resolution with pixel size of 500 m. The indicators are considered as properties of a certain area of the land surface, which means for each pixel, its properties can be taken as a multi-dimensional vector. In this situation, the K-means clustering is applied for the reason that such classification approach utilizes the intrinsic structure of the data as opposed to artificial partition by using empirical values. In this study, the pixels can be viewed as n observations, and for each observation the properties is a d dimensional vector P. All the pixels are in a d dimensional space (P_1, $P_2 \dots P_n$). The K-means clustering separates the pixels into k sets to minimize the within-cluster sum of squares. Thus it tries to find

$$\arg\min \sum_{i=1}^{k} \sum \left\| \mathbf{p} - \mu_i \right\|^2 \quad (1)$$

where μ_i is the mean of cluster i.

2.3 The morphological indicators

The conventional parameters characterizing UHI are restricted to the city or regional scale by the ‘urban-rural’ dichotomy. This research identifies LSUHI through the morphology of LST at a local scale. The morphological indicators are based on the smooth and continuous latent pattern of the LST, which is derived by the Gaussian Process (GP) model [26]. The MSSI is an extension of Koenderink’s Shape Index (SI) [30] that evaluates shapes at the optimal scale. It thus contains two steps: 1) scale selection, and 2) the SI evaluation.

The SI of each pixel should be calculated at its appropriate scale. The scale selection adopts the scale space [31]. The characteristic scale can be found in terms of the kernel size that produces the maximum normalized distance in the scale space. The optimal scale can be identified by the maxima normalized distance [32]. Then the MSSI is the SI evaluated at each point on a surface at the optimal scale, which is represented as

$$MSSI = \frac{2}{\pi}\arctan\frac{\kappa_2+\kappa_1}{\kappa_2-\kappa_1},\ SI \in [-1,1], \tag{2}$$

where κ_1 and κ_2 ($\kappa_1 \geq \kappa_2$) are the principle curvatures. The principle curvatures can be easily evaluated from a noiseless continuous latent LST surface through eigenvalues of the Hessian matrix. The MSSI measures how a point varies relative to its surroundings as shown in Fig. 3. The deformations are encoded within the interval [-1, 1]. The value indicates the extent of the deformation along the principle curvatures. Typical shapes such as cup, rut, saddle, ridge, and cap can be measured along the interval. It thus captures both the geometry and the magnitude.

2.4 Selecting the LSUHI and the local *hotspot*

The selection criteria of LSUHI in this research are as follows. The temperature threshold set in each of the LCZs is a 2-standard-deviation from the zonal mean, determining whether LSUHI is excessively hot, and the MSSI>0 helps to select the raised LSUHIs. The 8-day MODIS image data represents the daily average monthly LST in 2012. LSUHIs can be selected by the criteria from every latent LST pattern. While four sets of LST images are acquired each day, there is a total of 48 distribution diagrams of LSUHIs during the whole year. The local *hotspots* are detected, whose frequency is the highest among LSUHIs in each LCZ throughout the year.

2.5 The LST-responsive land surface indicators

It is necessary to examine the relationship between LST and land surface indicators in each zone for mitigating the *hotspots*. The examination may concretely support the existence of the indicator–LST interactions and gives information about how the relationship varies through space. It also indicates the potential LST change by modifying a specific indicator at the percentage level. The examination provides two modules. The temperature responses of SVF, BD, BVD, BH, albedo, VI, and WI are first considered. Then, the temperature response of ISF is considered independently from the rest of the indicators to avoid collinearity [9]. PSF is left out also for its collinearity with ISF. This study applies Ordinary Least Squares (OLS) to inspect the interactions. It is in the form of:

$$T_{LST} = X\beta + e, \tag{3}$$

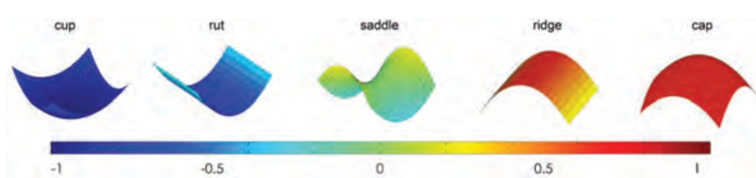

Figure 3: The surface morphology in the range of Shape Index.

where T_{LST} is the LST as the response or dependent variable, **X** is the vector of multiple explanatory or independent variables, β is the regression coefficient indicating the relationship between the T_{LST} and **X**, and e is the intrinsic residual.

3 RESULTS

3.1 The classification of climate zones

By applying the K-means clustering for sufficient repetitions, a 7-category classification is found to be best suited for the study area, which means that the classification is neither complicated nor simple. Figure 4 is an illustration of the classification. The shape of the climate zones outlines the distribution of a built environment meaning that artificial manipulation of land surface imposes significant impacts on climate. The details of the land surface indicator specifications are listed in Table 1. All indicators are normalized to the percentage level. The means of ISF, BD, and BVD increase along LCZ 1 through 7 implying that the artificial

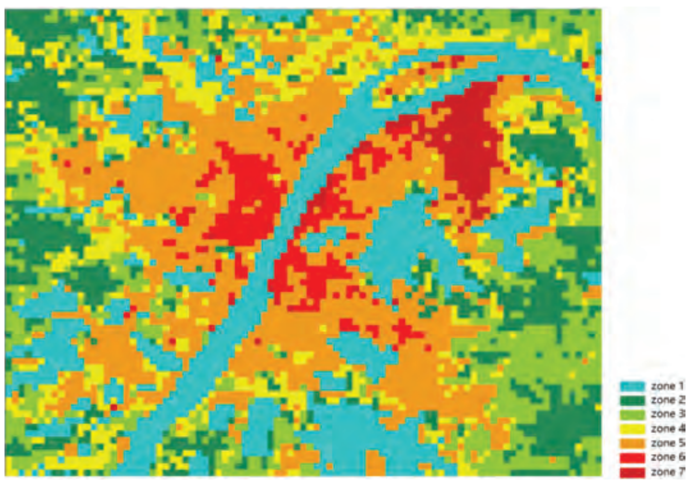

Figure 4: An illustration of the classification.

Table 1: The mean of the land surface indicator specifications in each of the LCZs (%).

LCZ	SVF	BD	BVD	BH	PSF	Albedo	VI	ISF	WI
1 Water Bodies	99.52	2.28	1.60	4.03	81.21	17.48	4.57	6.51	58.16
2 Vegetation	99.71	3.43	1.92	5.60	71.68	22.64	38.26	10.07	21.95
3 (Vegetation and rural areas)	99.80	2.50	1.20	5.88	78.55	24.75	38.14	8.99	11.42
4 (Rural Areas)	99.17	7.99	3.57	5.61	66.89	22.69	28.75	16.94	22.50
5 (Built-up Areas)	94.83	15.36	14.58	12.21	71.17	23.35	25.20	25.31	15.95
6 (Downtown)	83.92	29.21	42.91	18.78	52.59	20.29	17.17	43.61	20.35
7 (Industrial District)	99.14	18.70	7.59	6.26	51.15	20.66	18.74	39.98	22.59

modification of natural environment intensifies. The increase of BH is pre-eminent in LCZ 5 and 6 as high-rise residential communities and office buildings are clustered in downtown within these LCZs. The traditional low-rise and dense residential communities also enhance BD and BVD in LCZ 6. These dense buildings and apartments also substantially block visible sky and make LCZ 6 the only zone with SVF below 90%. Those indicators such as VI, PSF, and WI depicting the abundance of natural land surface decrease from LCZ 1 to 7 only except for the deficiency of VI in water bodies of LCZ 1. Albedo is roughly uniform along all LCZs with values around 23%. The traditional deteriorating communities and factory buildings with dark roofs lead to lower albedo in LCZ 6 and 7. The albedo values are 20.34% and 20.60%, respectively.

For the convenience of cross-sectional comparison among LCZs, the mean values in Table 1 are plotted column-wise (Fig. 5). Same indicators in each of the seven LCZs are compared based on the overall mean of the study area. BD, BVD, PSF, ISF, and VI exhibit more prominent opposite deviations from the overall mean for rural and built-up areas.

3.2 The situation of LSUHI around one year

Figure 6a gives the frequencies of being LSUHI at each pixel location for all of the 48 time points. The LSUHIs with high frequency are distributed across the whole study area, especially in the southwest. These areas with serious thermal environment problems are called Wuhan Economic & Technological Development Zone in the southwest, Jinyin Lake Industrial Zone in the northwest, and WISCO Industrial Zone in the northeast. Then, the central area is mainly alongside the Yangtze River and lies at the north of the Ink Lake. To the southwest, the LSUHIs in a developed industrial zone are more apparent thanks to the

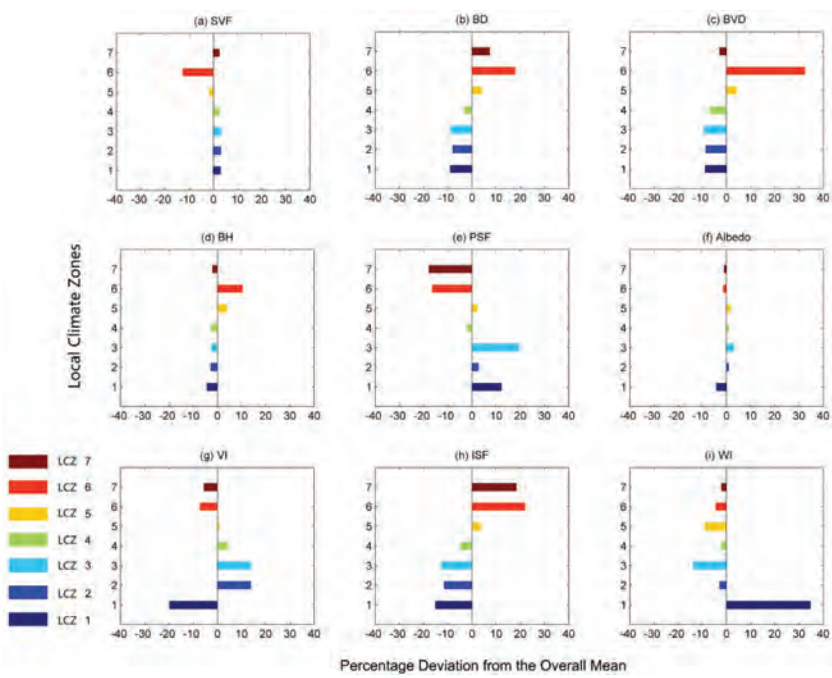

Figure 5: Comparison of LCZs in terms of indicators.

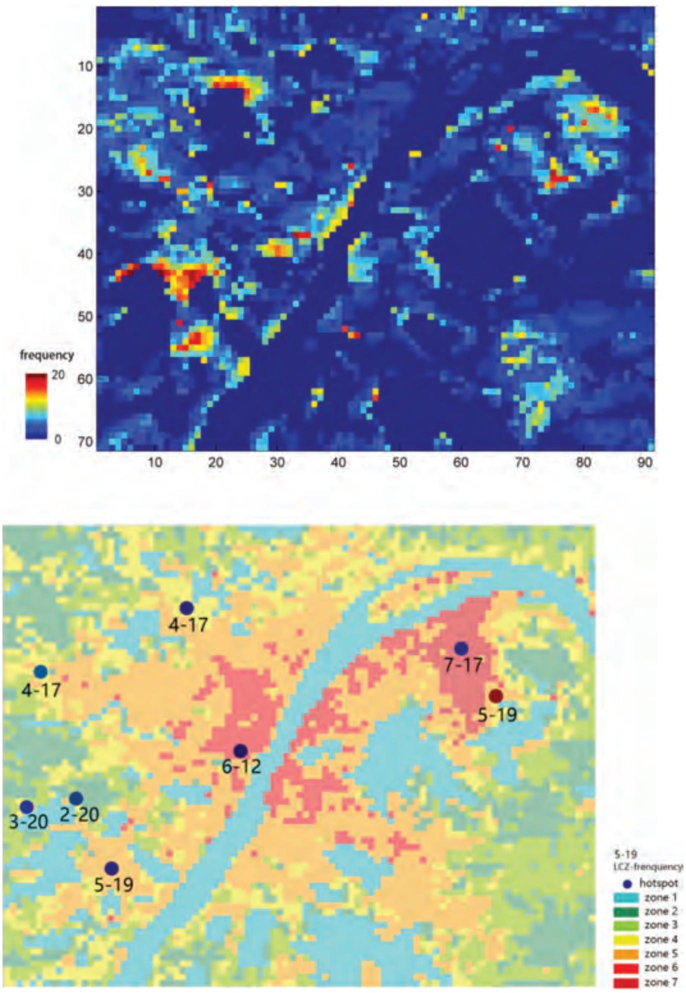

Figure 6: (a) The frequency distribution of LSUHI and (b) the selected *hotspots* in each LCZ (5-19: LCZ-LSUHI frequency), and the red *hotspot* is selected as the example in this case study.

development of low intensity. It can be found that the LSUHIs with high frequency are mainly industrial zones around the city and urban center with dense population. Eight *hotspots* are selected with the highest frequency as the LSUHI in LCZs.

3.3 The land surface–LST interactions

Table 2 shows the impacts of the land surface indicators on LST in each LCZ at the pixel level in this research, which are all statistically significant (p>0.01). Take the ISF–LST relationship for instance, the regression coefficient β varies across zones in different places and scales. While a previous study has found that the coefficient is around 0.21°C in the whole study area [10], the table shows that the zonal coefficient fluctuates around this value. Higher

Table 2: The interactions between the land surface indicators and LST in each LCZ.

Multi-variable OLS Regression Parameters	**Indicators**	**LCZ 1**	**LCZ 2**	**LCZ 3**	**LCZ 4**	**LCZ 5**	**LCZ 6**	**LCZ 7**
β	**SVF**	-0.040	-0.032	-0.037	-0.015	-0.004	-0.001	-0.005
	BD	0.025	0.039	0.082	0.067	0.061	-0.064	0.148
	BVD	0.013	0.003	0.014	0.067	-0.023	-0.027	0.227
	BH	0.064	0.017	0.002	0.036	0.001	-0.006	0.204
	Albedo	-0.325	-0.014	-0.019	-0.026	-0.107	-0.247	-0.226
	VI	-0.062	-0.082	-0.109	-0.093	-0.142	-0.097	-0.196
	WI	-0.116	-0.076	-0.110	-0.079	-0.033	-0.024	-0.023
$\mathbf{R^2}$		0.761	0.566	0.494	0.708	0.667	0.778	0.583
p		**	**	**	**	**	**	**

Single-variable OLS Regression Parameters	**Indicators**	**LCZ 1**	**LCZ 2**	**LCZ 3**	**LCZ 4**	**LCZ 5**	**LCZ 6**	**LCZ 7**
β	**ISF**	0.390	0.440	0.227	0.185	0.188	0.190	0.192
$\mathbf{R^2}$		0.577	0.326	0.381	0.687	0.704	0.752	0.780
p		**	**	**	**	**	**	**

** indicates p>0.01 and thus the relationship is statistically significant with a confidence level of 99%

values are found in zone 1 and 2. It means that LST is more sensitive to ISF change in these well-vegetated LCZs with lower ISF. For instance, increasing 1% of ISF in LCZ 1 may cause LST to rise to about 0.39°C within a pixel. The coefficient β tends to be smaller in LCZ 3 to 7, which means that the change of the ISF in built-up areas imposes less impact on LST. In contrast, ISF increasingly captures information of LST variations toward more intensive built-up LCZs according to the R^2. Specifically, the R^2 rises from 0.33 to 0.78 through LCZ 2 to 7. It means that although LST is less sensitive to the change of ISF, such seemingly weak interactions may dominate the LST patterns as built-up areas are mostly impervious.

The multi-variable OLS regression suggests that SVF, albedo, VI, and WI are negatively correlated to LST while BD, BVD, and BH possess less clear relationships to LST. Especially for those more intensively built LCZs, BD, BVD, and BH can be negatively correlated to the LST which seems to be counterintuitive. A previous study has shown that this is because urban surface can be well shaded by high and dense building clusters and thus with lower surface temperature [28]. Although SVF maintains to be negatively correlated to LST in LCZ 5, 6, and 7, its impact tends to be minimal and below -0.01. Among all the indicators involved in the multi-variable regression, albedo and VI possess the highest regression coefficients with LST. The R^2 is relatively low in LCZ 2 and 3 for both the multi-variable and single-variable regressions. Such low R^2 reflects the limitation of using several built environment indicators in the interpretation of the LST variation in rural areas.

3.4 The strategy to mitigate the *hotspots*

The *hotspot* as a study case is located in the northeast of the city in LCZ 5 with a frequency of 19 as being LSUHI. The *hotspot* is near the Yanxi Lake and lies at the southeast of the WISCO Industrial District. The overall mean of the study area is the benchmark. The largest discrepancy between the *hotspot* and LCZ is found in BD with 54.05%. The indicator specifications at this *hotspot* are mostly less desirable than the level of LCZ 5, while this LCZ is a less desirable zone in the study area (Fig. 7a). The counterintuitive negative relationship between LST and BVD makes the strategy relatively subtle. The buildings are dense enough to shade the land surface as mentioned in Section 3.3. Thus, modification of building geometries may be less promising. Indicators such as PSF, albedo, VI, ISF, and WI are all clearly indicated in Fig. 5. These indicator values should be first modified to the zonal level and not the average level of the study area based on priority. Considering the relationships between the land surface indicators and LST, increasing 1% of albedo may reduce 0.11°C of LST at

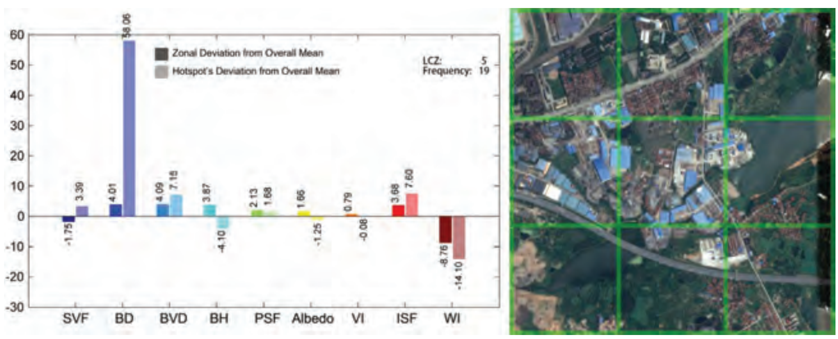

Figure 7: The land surface indicator specifications of *hotspot* and LCZ 5. (a) The indicator discrepancy between the *hotspot* and the LCZ benchmarked against the overall mean of the study area. (b) The QuickBird aerial image of the *hotspot* with its eight neighboring pixels on May 20th, 2012.

Table 3: The indicator values of *hotspot* and mean of indicator for LCZ 5.

	SVF	**BD**	**BVD**	**BH**	**PSF**	**Albedo**	**VI**	**ISF**	**WI**
mean of the study area	97.56	8.57	7.43	7.72	61.07	21.89	27.61	16.70	26.53
hotspot	99.98	69.41	17.63	4.24	70.71	22.45	17.41	29.23	10.60
LCZ 5	94.83	15.36	14.58	12.21	71.17	23.35	25.20	25.31	15.95
Hotspot-LCZ Discrepancy	5.15	54.05	3.05	-7.97	-0.46	-0.90	-7.79	3.92	-5.35
Surface–Temperature Relationship	-0.004	0.061	-0.023	0.001	-	-0.107	-0.142	0.188	-0.033
Potential Optimization(°C)	-	-	-	-	-	0.10	1.11	0.74	-

the pixel level. It means that if albedo at *hotspot* increases by 0.9% to reach the corresponding zonal level, LST can potentially be 0.1°C lesser. Similarly, modifying VI to the zonal level can reduce 1.11 of LST in a pixel. Approximating ISF at the *hotspot* to the zonal level leads to a reduction of 0.74°C. The details are shown in Table 3. In a word, the indicator values of *hotspot* are adjusted to an approximate mean of the indicator for LCZ 5 to relieve LSUHI.

As this study focuses on the concept and framework, further examples are not explored. The mitigation strategies for other *hotspots* can be formulated in the same way as shown above.

4 DISCUSSION

4.1 The completeness and dynamic of indicators

The completeness of indicators means to characterize the climatic or meteorological property of the surface factor with enough details. Besides thermal and airflow pattern, others such as humidity, moisture, and pollution are also expected to be captured by the indicators. Only then can the indicators be considered to be complete.

The *hotspot* is selected from a one-year cycle without considering the diurnal or seasonal variation of land surface specification. The dynamic difference of these indicators would affect the distribution of LSUHI. More specific improvement strategies and suggestions would be proposed, if the distribution of the *hotspots* is further explored with land use and diurnal variation of indicators being taken into account.

4.2 The priority of planning and implementation

This research only adjusted the land surface parameters, whereas specific implementation approaches are different when carrying out the adjustment. The complexity and cost of each strategy is different in terms of planning and implementation. For example, the cost of reducing building density is normally higher than that of increasing vegetation cover. Meanwhile, the complexities in mitigation strategies also vary because of land use variance. The vegetation cover of public land is usually easier to adjust than that of residential land. The *hotspot* with high population density should be taken into consideration at day one, especially in urban centers. The high-frequency LSUHIs in city suburbs are mostly industrial zones, regarded as a secondary consideration due to low population density. It is therefore reasonable to say that the priority of planning strategy should be considered in terms of land use, population density, complexity of adjusting specifications, and the correlation between the indicators and LST.

5 CONCLUSIONS

A framework of mitigating excessive heat in urban areas is proposed. The mitigation is at a local scale and helps to facilitate planning and design strategy selection with detailed guidelines. The mitigation is operated within zones and conforms to planning and design conventions. It avoids radical modifications of land surface configuration and enhances feasibility and practicability. The mitigation thus attenuates in a hierarchical and incremental manner. The hierarchy manifests by priority based on two aspects: (1) problem identification, and (2) strategy recommendation. The incrementality is reflected by zonal level mitigation that ensures more achievable goals.

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REFERENCES

[1] Stone, B., Vargo, J. & Habeeb, D., Managing climate change in cities: will climate action plans work? *Landscape and Urban Planning*, **107**(3), pp. 263–271, 2012. doi:10.1016/j.landurbplan.2012.05.014

[2] Brian Stone, J. & Michael, O.R, Urban form and thermal efficiency: how the design of cities influences the Urban Heat Island effect. *Journal of the American Planning Association*, **67**(2), pp. 186–198, 2001. doi:10.1080/01944360108976228

[3] Debbage, N. & Shepherd, J.M., The urban heat island effect and city contiguity. *Computers, Environment and Urban Systems*, **54**, pp. 181–194, 2015. doi:10.1016/j.compenvurbsys.2015.08.002

[4] Wheeler, S., State and municipal climate change plans: the first generation. *Journal of the American Planning Association*, **74**(4), pp. 481–496, 2008. doi:10.1080/01944360802377973

[5] Stewart, I.D., A systematic review and scientific critique of methodology in modern urban heat island literature. *International Journal of Climatology*, **31**(2), pp. 200–217, 2011. doi:10.1002/joc.2141

[6] Arnfield, A.J., Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island. *International Journal of Climatology*, **23**(1), pp. 1–26, 2003. doi:10.1002/joc.859

[7] Stewart, I.D. & Oke, T.R., Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, **93**(12), pp. 1879–1900, 2012. doi:10.1175/BAMS-D-11-00019.1

[8] Yuan, F. & Bauer, M.E., Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. *Remote Sensing of Environment*, **106**(3), pp. 375–386, 2007. doi:10.1016/j.rse.2006.09.003

[9] Song, J., Du, S., Feng, X. & Guo, L., The relationships between landscape compositions and land surface temperature: Quantifying their resolution sensitivity with spatial regression models. *Landscape and Urban Planning*, **123**, pp. 145–157, 2014. doi:10.1016/j.landurbplan.2013.11.014

[10] Wang, J., Qingming, Z., Guo, H. & Jin, Z., Characterizing the spatial dynamics of land surface temperature–impervious surface fraction relationship. *International Journal of Applied Earth Observation and Geoinformation*, **45**, pp. 55–65, 2016. doi:10.1016/j.jag.2015.11.006

[11] Myneni, R.B., Maggion, S., Iaquinta, J., Privette, J.L., Gobron, N., Pinty, B., Kimes, D.S., Verstraete, M.M. & Williams, D.L., Optical remote-sensing of vegetation - modeling, caveats, and algorithms. *Remote Sensing of Environment*, **51**(1), pp. 169–188, 1995. doi:10.1016/0034-4257(94)00073-V

[12] Schaaf, C.B., Gao, F., Strahler, A.H., Lucht, W., Li, X., Tsang, T., Strugnell, N.C., Zhang, X., Jin, Y., Muller, J.P. & Lewis, P., First operational BRDF, albedo nadir reflectance products from MODIS. *Remote Sensing of Environment*, **83**(1–2), pp. 135–148, 2002. doi: 10.1016/S0034-4257(02)00091-3

[13] Larsen, L., Urban climate and adaptation strategies. *Frontiers in Ecology and the Environment*, **13**(9), pp. 486–492, 2015. doi: 10.1890/150103

[14] Chudnovsky, A., Ben-Dor, E. & Saaroni, H., Diurnal thermal behavior of selected urban objects using remote sensing measurements. *Energy and Buildings*, **36**(11), pp. 1063–1074, 2004. doi:10.1016/j.enbuild.2004.01.052

[15] Unger, J., Intra-urban relationship between surface geometry and urban heat island: review and new approach. *Climate Research*, **27**(3), pp. 253–264, 2004. doi:10.3354/cr027253

[16] Giannopoulou, K., et al., The impact of canyon geometry on intra urban and urban: suburban night temperature differences under warm weather conditions. *Pure and Applied Geophysics*, **167**(11), pp. 1433–1449, 2010. doi:10.1007/s00024-010-0099-8

[17] Weng, Q.H., Lu, D.S. & Schubring, J., Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment*, **89**(4), pp. 467–483, 2004. doi:10.1016/j.rse.2003.11.005

[18] Wu, H., Ye, L.P., Shi, W.Z. & Clarke, K.C., Assessing the effects of land use spatial structure on urban heat islands using HJ-1B remote sensing imagery in Wuhan, China. *International Journal of Applied Earth Observation and Geoinformation*, **32**, pp. 67–78, 2014. doi:10.1016/j.jag.2014.03.019

[19] Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M. & Williams, N.S., Planning for cooler cities: a framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, **134**, pp. 127–138, 2015. doi:10.1016/j.landurbplan.2014.10.018

[20] Schwarz, N., Schlink, U., Franck, U. & Großmann, K., Relationship of land surface and air temperatures and its implications for quantifying urban heat island indicators—an application for the city of Leipzig (Germany). *Ecological Indicators*, **18**, pp. 693–704, 2012. doi:10.1016/j.ecolind.2012.01.001

[21] Stewart, I.D., Oke, T.R. & Krayenhoff, E.S., Evaluation of the 'local climate zone' scheme using temperature observations and model simulations. *International Journal of Climatology*, **34**(4), pp. 1062–1080, 2014. doi:10.1002/joc.3746

[22] Lelovics, E., Unger, J. & Gál, T., Design of an urban monitoring network based on local climate zone mapping and temperature pattern modelling. *Climate Research*, **60**(1), pp. 51–62, 2014. doi:10.3354/cr01220

[23] Voogt, J.A. & Oke, T.R., Thermal remote sensing of urban climates. *Remote Sensing of Environment*, **86**(3), pp. 370–384, 2003. doi:10.1016/S0034-4257(03)00079-8

[24] Streutker, D.R., A remote sensing study of the urban heat island of Houston, Texas. *International Journal of Remote Sensing*, **23**(13), pp. 2595–2608, 2002. doi:10.1080/01431160110115023

[25] Rajasekar, U. & Weng, Q.H., Urban heat island monitoring and analysis using a non-parametric model: A case study of Indianapolis. *Isprs Journal of Photogrammetry and Remote Sensing*, **64**(1), pp. 86–96, 2009. doi:10.1016/j.isprsjprs.2008.05.002

[26] Rasmussen, C.E. & Nickisch, H., Gaussian Processes for Machine Learning (GPML) Toolbox. *Journal of Machine Learning Research*, **11**, pp. 3011–3015, 2010.

[27] Gál, T., Lindberg, F. & Unger, J., Computing continuous sky view factors using 3D urban raster and vector databases: comparison and application to urban climate. *Theoretical and Applied Climatology*, **95**(1–2), pp. 111–123, 2008. doi:10.1007/s00704-007-0362-9

[28] Zhan, Q., Meng, F. & Xiao, Y., Exploring the relationships of between land surface temperature, ground coverage ratio and building volume density in an urbanized environment. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, **XL-7/W3**, pp. 255–260, 2015. doi:10.5194/isprsarchives-XL-7-W3-255-2015

[29] Chen, X.-L., Zhao, H.M., Li, P.X. & Yin, Z.Y., Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. *Remote Sensing of Environment*, **104**(2), pp. 133–146, 2006. doi:10.1016/j.rse.2005.11.016

[30] Koenderink, J.J. & Vandoorn, A.J., Surface shape and curvature scales. *Image and Vision Computing*, **10**(8), pp. 565–565, 1992. doi:10.1016/0262-8856(92)90076-F

[31] Lindeberg, T., Feature detection with automatic scale selection. *International Journal Of Computer Vision*, **30**(2), pp. 79–116, 1998. doi:10.1023/A:1008045108935

[32] Wang, J., Zhan, Q. & Guo, H., The morphology, dynamics and potential hotspots of land surface temperature at a local scale in urban areas. *Remote Sensing*, **8**(1), p. 18, 2015. doi:10.3390/rs8010018

PRODUCTION AND UTILIZATION OF ENERGY AND CLIMATE ADAPTATION: GLOBAL TASKS AND LOCAL ROUTES

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ABSTRACT

Nowadays, when the energy, industry and transport sectors are adapting to climate change and need to reduce their environmental impact, it is vital that the optimal solutions are found for individual countries and their different circumstances. Territories, which have a hydrocarbon deficit, should use non-conventional energy sources while the countries with substantial resources of hydrocarbons should be focused on the strategy of raising the energy efficiency, i.e. to reduce the specific consumption of fuel consumed. The paper discusses these scenarios and describes some innovative technologies for both cases. Energy production from biomass is encouraged in some European countries by the granting of generous economic subsidies so that renewable energy plants, such as anaerobic digestion plants that produce biogas for use in internal combustion engines, in particular, are receiving much funding. An alternative technology for biogas valorisation could be that of biomethane (so called green gas) production through biogas purification and upgrading processes to remove CO_2, H_2S and water vapour. Different technologies have been proposed to remove CO_2 from gas streams, such as physical absorption, absorption by chemical solvents, cryogenic and membrane separation and CO_2 fixation by chemical or biological methods. Production of biomethane and its introduction into the natural gas grid or its use as a fuel for vehicles could increase the energy efficiency and reduce specific emissions (combined cycle gas turbines, district heating of CHP units, methane powered vehicles). A simple and low-cost method of improving energy efficiency and environmental safety of transport by introducing into hydrocarbon fuels micro doses of a universal multifunctional additive is proposed. The method will make a significant contribution towards solving the problems of adapting to global climate change and improving the environment. It is capable of reducing specific fuel consumption by up to 12% and the requirements for a gasoline octane number by 10 points. It significantly reduces emission levels of greenhouse gases and toxic substances and provides complex improvement of the properties of fuels and the condition of engines.

Keywords: biogas, biomethane, climatic adaptation, energy efficiency, environmental safety, hydrocarbon fuels, multifunctional additive.

1 INTRODUCTION

According to the assessment of the International Resource Panel [1] the annual global use of material reached 70.1 billion tonnes in 2010, up from 23.7 billion tonnes in 1970. Thereby, over the past four decades, global material use has tripled and this has led to an acceleration of the processes of climate change and air pollution.

This creates serious challenges concerning the sustainability of modern civilization. Priorities and national solutions in terms of climate protection and the reduction of the overall environmental risk should be individualized in accordance with local conditions and opportunities [2, 3]. In particular, the situation with the generation of electricity and transport development in Europe, a hydrocarbon deficient region, is different from that of Russia, the world's largest producer of oil and gas. Table 1 shows the total proven Russian hydrocarbon reserves in comparison with the values of reserves in the world as a whole and those in Europe and Eurasia.

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Table 1: Total proved reserves of oil, natural gas, and coal*.

Reserves	Total World		Europe and Eurasia		Russia		
	Billion tonnes**	Share of total, %	Billion tonnes	Share of total, %	Billion tonnes	Share of total, %	Share of Europe and Eurasia, %
Oil	239.4	100.0	21.0	9.1	14.0	6.0	67.0
Natural Gas	186.9	100.0	56.8	30.4	32.3	17.3	56.8
Coal	891,531	100.0	310,538	34.8	157,010	17.6	50.6

*Based on the data from Ref. [4].
**The data for natural gas are indicated in trillion cubic metres.

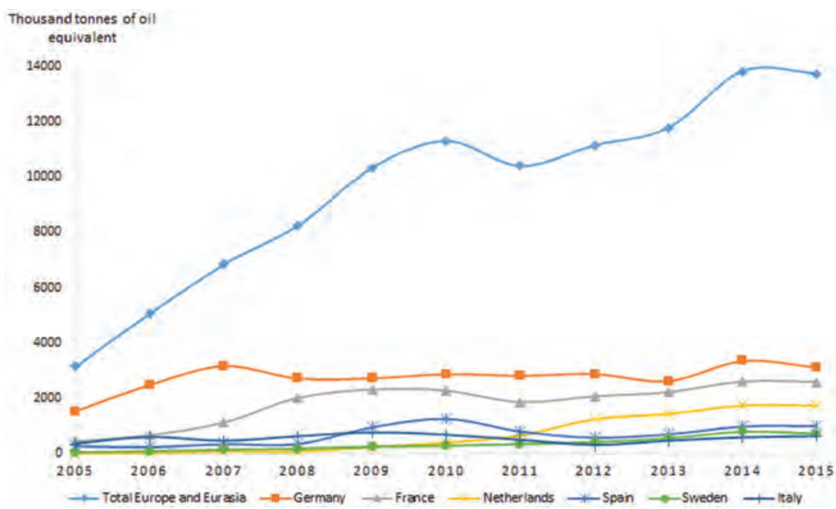

Figure 1: Dynamics of biofuel consumption (based on the data from Ref. [4]).

Therefore, the task of selecting the optimal technologies must take into account the local conditions. For the countries with substantial hydrocarbons resources an important task is the overall increase in energy efficiency, which will contribute to the growth of competitiveness of the national economy. It is important for European countries to focus their efforts on progress in technology that will reduce the cost of alternative energy. Figure 1 shows the dynamics for the consumption of biofuels (except for fuel ethanol and biodiesel) for some European countries.

It is necessary to direct investment flows to projects that improve energy efficiency and develop new technologies in energy, industry and transport. In addition, there is a requirement for the immediate implementation of low-cost measures that take into account the local conditions. Such measures can have a significant impact in the short term.

2 AN APPROACH TO BIOGAS VALORISATION

In order to reduce and minimize the effect of greenhouse gas (GHG) emission the European Union with the Directive 2009/28/EC has promoted the use of renewable sources, for the energy production, instead the fossil fuel. In this context the use of biomasses is an interesting example of this application.

In the field of biomasses conversion to energy we can identify two different possibilities mostly connected to the molecular structure and to the water content of the biomasses [5, 6]:

- Thermochemical processes (in particular direct combustion, gasification and also pyrolysis): these processes are convenient for biomass with carbon to nitrogen ratio (C/N) higher than 30 and with a moisture content lower than 30%. In this category we find all the vegetable biomasses;
- Biochemical processes (in particular anaerobic digestion): these processes are suitable for biomass with carbon to nitrogen ratio (C/N) lower than 30 and with moisture higher than 30%. In this category we find the aquatic cultures, some agricultural by products, municipal and industrial effluents.

In this study the authors analyzed in particular the biochemical processes with the anaerobic digestion of different biomasses (agricultural products such as for example maize silage, sorghum and organic waste), which in fact is today the most widespread technology used in order to obtain bioenergy. According to research performed by the Fraunhofer Institute [7], there were about 10,000 biogas units in Europe in 2012 with the expected increase to 13,500 by 2016.

The biogas produced from anaerobic digestion of different biomasses is in general valorized from the energetic point of view using internal combustion engines [8]. In this way the production of electric energy or combined electric and thermal energy is possible.

Biogas produced by anaerobic digestion is composed mainly by methane (40%–65%) and carbon dioxide (25%–60%). Trace amount of other components such as water (2%–8%), hydrogen sulphide (0.005%–1.5%), nitrogen (<2%), ammonia (<1%) and carbon monoxide (<0.6%) can be present. In account of the great amount of methane present an alternative use of biogas is the production of biomethane [9, 10]. Biomethane, if adequately compressed, could be used as fuel for vehicles or injected into natural gas pipeline. In order to obtain the biomethane the biogas treatment processes are divided into:

- biogas cleaning to remove trace components harmful to the natural gas grid through chemical physical and biological processes;
- biogas upgrading, where CO_2 is removed to meet the purity and calorific value required for natural gas use.
- Biogas upgrading techniques could be [9–11]:
- physical absorption with pressurized water;
- physical absorption with pressurized organic solvent;
- chemical absorption with aqueous alkanolamine solutions (MEA/DEA etc.);
- pressure and Vacuum Swing Adsorption (PSA/VSA);
- membrane separation;
- cryogenic separation.

The most applied techniques in Europe are absorption with pressurized water and PSA.

2.1 Biogas plant

In the present study some results reported in a previous work [12] are reported and analyzing. In particular the study analyzes an anaerobic digestion plant (mesophilic condition) fed with cattle slurry and maize silage.

From the energetic point of view the available thermal energy of the produced biogas is 2.5 MW [13]. Table 2 and Figure 2 show the specifics of the studied biogas plant.

2.2 Environmental evaluation and comparison between the production and use of biogas and the production of biomethane

In this section the results of the implementation of the dispersion model for the two alternative solutions: anaerobic digestion plant and valorization of the biogas with combustion (Fig. 2) and production of biomethane (Fig. 3) are reported and analyzed. The pollutants analyzed are NO_x and PM (particulate matter) (that are the two main contaminants responsible to the local impact) [12].

In order to evaluate the pollutant dispersion a Gaussian model was used. The meteorological data was supplied by the Piedmont Regional Agency for the Environmental Protection (ARPA).

Table 2: Specific features of the analyzed plant.

Substrates	Input (t/d)	Dry matter mass fraction	Volatile solids/ dry matter mass fraction	Volatile solids (VS) (t VS/d)	Biogas yield/ volatile solids (m^3/t VS)	Biogas production (m^3/d)	Biogas production (t/d)
Cattle manure	48.5	0.22	0.75	8.0	400	3200.3	3.52
Maize silage	47.5	0.35	0.95	15.5	700	10850.5	11.94
Total	96	0.56	-	23.5	-	14050.9	15.46

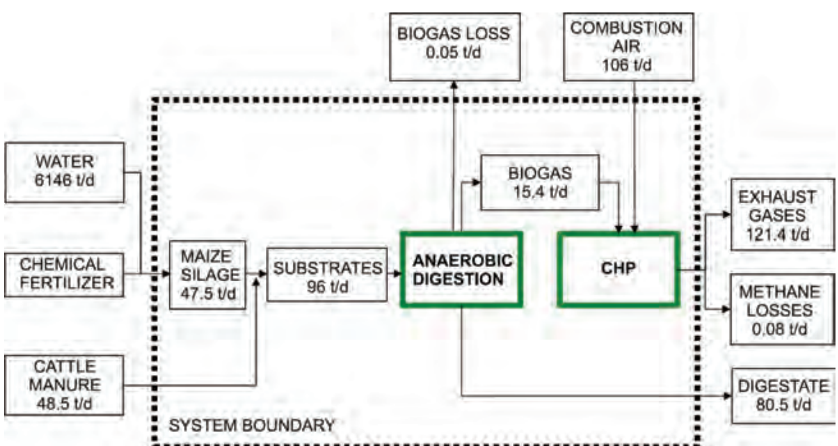

Figure 2: Scheme of the analysed process.

In order to define the turbulence the six 'stability classes' defined from Pasquill are used: A, B, C, D, E, and F [14]; in particular class A means the most unstable or most turbulent conditions, instead class F means the most stable or least turbulent conditions.

In the simulations the two stability classes A (unstable condition) and F (stable condition) are used. The results for the two scenarios are reported on the iso-concentration maps of Figures 4 and 5 for NO_x and Figures 6 and 7 for PM.

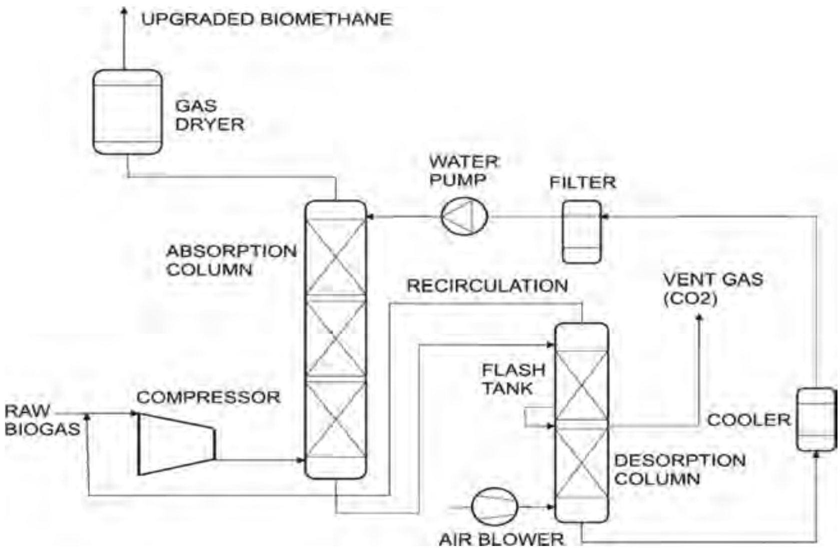

Figure 3: Scheme of the biogas upgrading process.

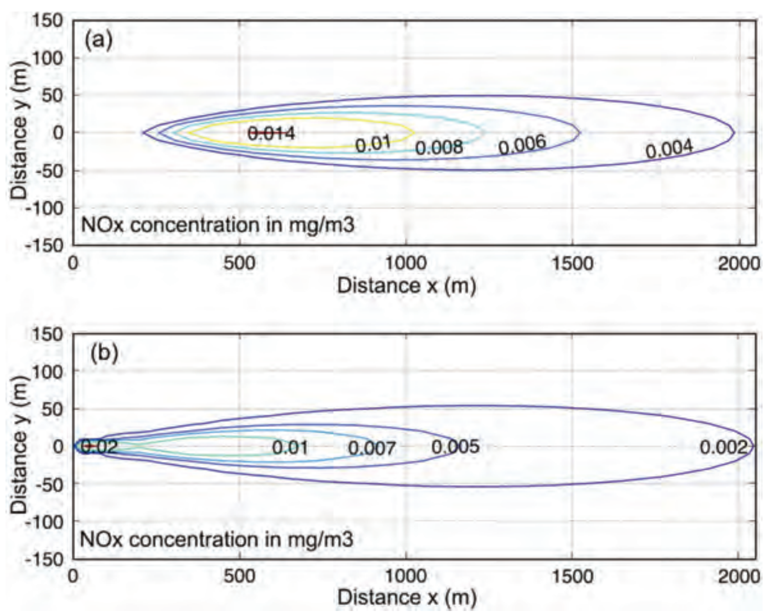

Figure 4: NO_x dispersion for biogas plant (a) and methane boiler (b) – stability class: F.

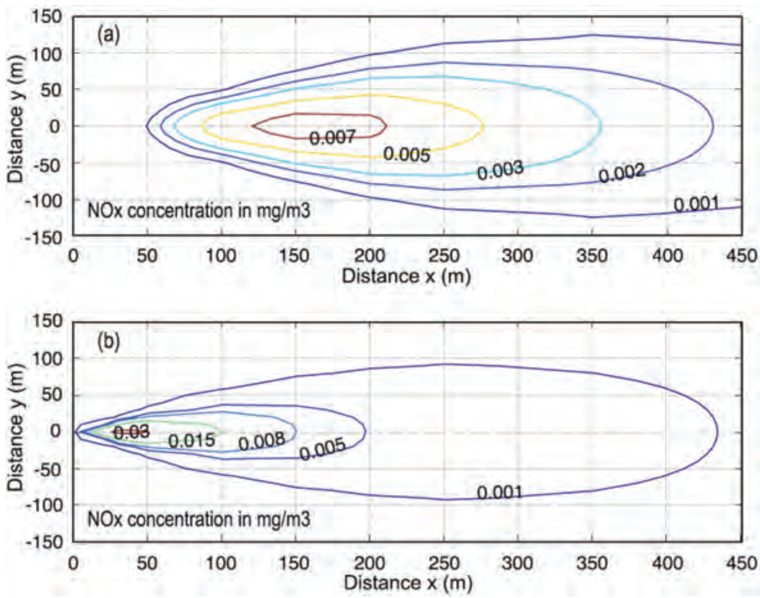

Figure 5: NO_x dispersion for biogas plant (a) and methane boiler (b) – stability class: A.

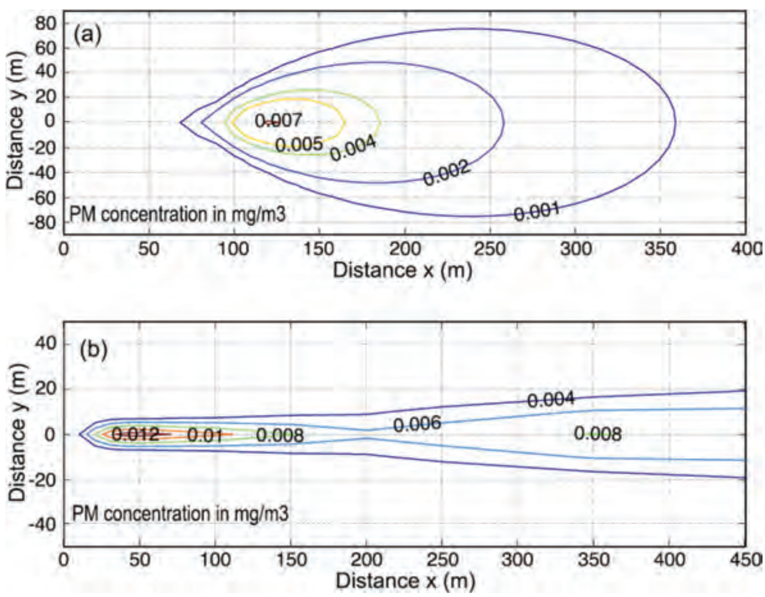

Figure 6: PM dispersion for biogas plant (a) and methane boiler (b) – stability class: F.

Italian regulations impose an annual concentration limit for NO_x of 40 μm/m^3, for PM_{10} of 40 μm/m^3 and for $PM_{2.5}$ of 25 μm/m^3.

The emissions derived from the two scenarios analyzed are lower than the maximum value indicated from the Italian regulation; anyway, the additional contribution to the normal presence of pollutants may be significant. In fact the background situation concerning these

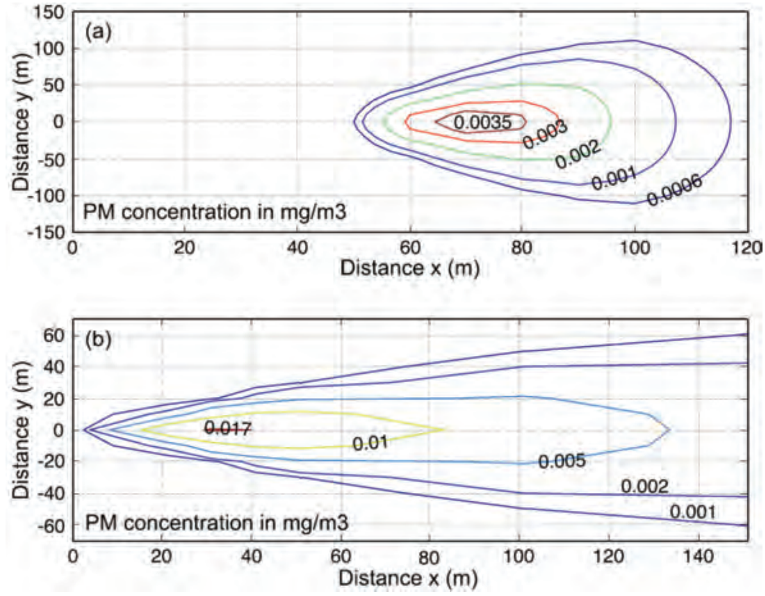

Figure 7: PM dispersion for biogas plant (a) and methane boiler (b) – stability class: A.

contaminants (in particular for the NO_x) is already critical and so the higher NO_x and PM concentrations may cause negative effects for the possible recipients (human or vegetable).

3 CLIMATIC ADAPTATION AND SUSTAINABILITY OF TRANSPORT CONSUMING TRADITIONAL MOTOR FUELS

3.1 Problems of improving the energy efficiency and environmental safety of transport operation

Modern problems of transport sustainability represent the critical comprehensive environmental and economic challenge to civilization. This is due to the rapid growth of a world vehicle fleet adapted to liquid petroleum fuel whose consumption is also continually increasing while oil and gas resources are rapidly depleting. Vehicles are one of the major consumers of oil products and consequently, the generators of greenhouse gases and toxic byproducts of combustion into the atmosphere, as illustrated in Figure 8. This exacerbates both the problem of global climate change and the environmental situation. Traditional fuels and the products of combustion bring increased risk to the environment the solution to which requires a systematic approach [15]. Adapting transport to climate change requires a reduction in specific fuel consumption. Energy efficiency and environmental safety of vehicles' operation are highly dependent on the quality of the fuel used [16–21]. An improvement in the design of vehicles and engines, as well as other methods for reducing the negative effects of transport operation for the environment are inefficient when using poor quality fuel. In this way, the improvement of the quality of motor fuels should be considered as a priority task.

The importance of improving the energy efficiency and environmental safety of vehicles require the rapid implementation of innovative and highly efficient technological solutions. Despite efforts to develop and deploy the alternative fuels and energy for transport, they have

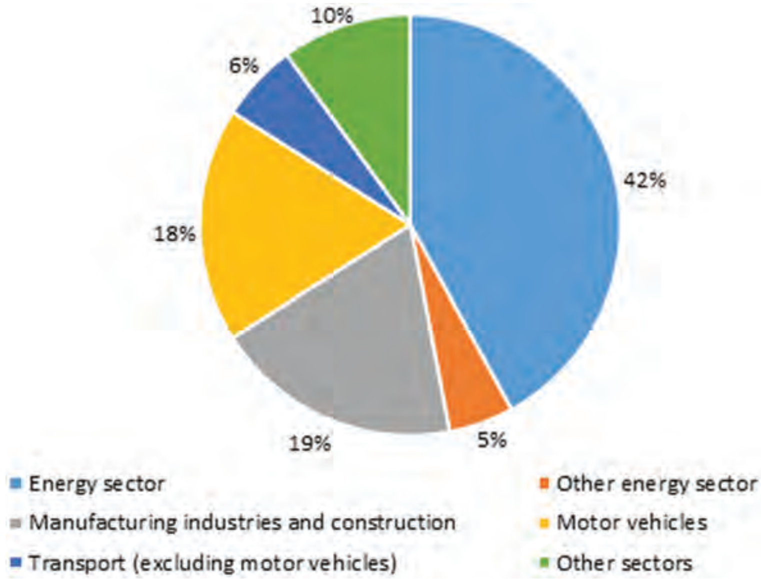

Figure 8: Total world greenhouse gases emissions by sectors (2014) (on the basis of Ref. [27]).

not yet contributed significantly to the structure of the world's growing vehicle fleet. In addition, carbon footprint calculations have shown that in some cases the advantages that can be derived from rejecting traditional fuels are not at all obvious. For example, by switching to electric cars we will get the local benefits, a rehabilitated urban environment, but in terms of overall emission reduction – the electricity itself can be generated from 'dirty' sources, and the process of creating electric vehicles themselves also is accompanied by harmful emissions into the atmosphere. The most rapidly implemented and low-cost way to improve the environmental and operational characteristics of cars is through the use of highly effective fuel additives [22–25]. Therefore, this method is of interest to both developed and developing countries.

3.2 Universal multifunctional fuel additive for improving the energy efficiency and environmental safety of vehicles

A method improving the quality of traditional motor fuels using a universal multifunctional additive has been developed [24, 26]. The proposed additive combines the properties of a surfactant and a gasification catalyst.

The application of the additive in gasoline and diesel fuel in minor quantities (9.25 ppm for gasoline and 27.75 ppm for diesel fuel) has a comprehensive positive impact on the properties of the fuel and the performance of the engine. A single introduction of the additive into the engine eliminates carbon formation, keeping the engine clean [28, 29], and substantially reducing specific fuel consumption, which, in turn, significantly contributes to the solution to the problem of adapting transport to climate change. Figure 9 shows the exclusion of carbon deposit in the engine after the additive application. Constant use of the additive provides additional positive effects including improved detergency, which

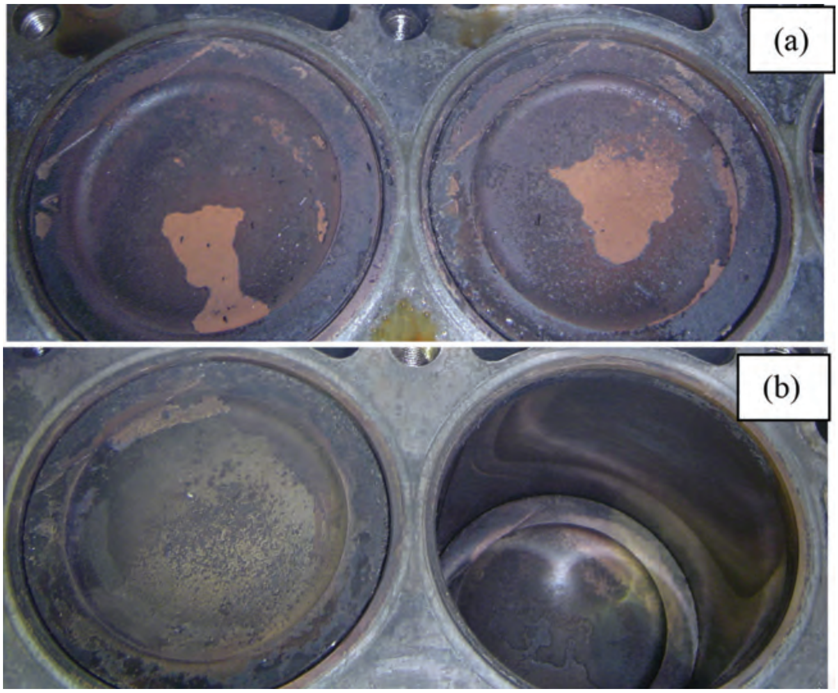

Figure 9: The cylinder faces of internal combustion engines after the test run: (a) control car (without the additive); (b) testing car after application of the additive.

ensures the engine fuel system is kept clean, lubricating properties, reduced loss of gasoline through evaporation and improved mixture formation when injecting the fuel into the engi*n*e. Table 2 demonstrates the results of the developed multifunctional additive application (the laboratory, test bench, traffic operation and experimental-industrial checkout). Compulsory application of the additive will reduce dependence on a gasoline octane rating [28, 29]. Consumption of gasoline and diesel fuels by engines will also be reduced. Unique in its simplicity, efficiency and low cost, the method integrates the characteristics and capabilities of the nanotechnology and effects equivalent to the use of package of the effective additives to the fuel. Use of the multifunctional additive significantly reduces the emission of greenhouse gases and toxic substances during the operation of vehicles and improves the condition of the engines. The emission of benzo(α)pyrene, which is the strongest carcinogen, is reduced by 95%. Using fuel that contains the additive produces no additional toxic substances in the exhaust gases that were not observed without the additive.

The high efficiency of the developed additive was confirmed by its application in the production of approximately 360,000 tons of gasoline and 40,000 tons of diesel fuel, which were used in the experimental-industrial checkout. The additive is synthesized from obtainable, low-cost substances. Its production does not require highly qualified engineers and complicated facilities. The additive can be introduced into the during the production of the fuel, into the finished product, at the petrol station and directly into the vehicle's fuel tanks.

Table 3: Effects of the additive application (concentration of the additive 9.25 ppm in gasoline and 27.75 ppm in diesel fuel)*.

Characteristics	Gasoline engines, gasoline	Diesel engines, diesel fuel
Fuel consumption	–5%–12%	–4%–7%
Reduction of carbon deposits	~ −95%–100%	~ −95%–100%
Detergent properties, decrease of cleaning time, times	2.33	2.33
Emissions:		
Carbon monoxide	–15%–30%	–15%–17%
Nitrogen oxides	–20%–26%	–20%–22%
C_mH_n	–8%–35%	–35%–37%
benzo(a)pyrene and its homologues	–95%–96%	–
soot	–	–40%–50%
Requirements to octane number	–7–12 items	–
Cetane number	–	+3 items
Lubricating properties (coefficient of static friction)	–	–25%
Saturated vapor pressure	−15%–25%	–
Vaporization loss of gasoline	−17%–30%	–

*Cost of the additive 1$/ton of gasoline, 3$/ton of diesel fuel.

4 CONCLUSIONS

The problems of the energy, industrial and transport sectors adapting to climate change and the need to mitigate their environmental hazards cannot be overemphasized in the context of modern civilization and its future development and efforts to achieve this must be integrated. However, the implementation of the global strategy and the selection of the optimal technological solutions depend on the specific conditions in different countries.

The priorities should be increasing the energy efficiency of the technological processes and transport operation and the development of competitive alternative fuels and energy.

The study evaluated the biogas production process while considering different end-use solutions with particular reference to limiting atmospheric pollution and also reducing GHG emissions (the main reason for climate change). In this specific case, the present study points out that upgrading biogas to biomethane may represent an environmentally friendly alternative to the on-site combustion of biogas in CHP units, especially in the cases where the energy content of the gas is not fully cogenerated and all or part of the thermal energy produced is not capitalized.

The proposed method for improving the energy efficiency and environmental safety of transport operation using the universal multifunctional additive creates not only environmental benefits but also high economic motivation for its use. The fuel producers are motivated due to lower requirements for the octane number of gasoline, which dramatically reduces the cost of gasoline production. The consumers will get improved fuel economy for their vehicles. Widespread implementation of the method will significantly mitigate the negative environmental impact of transport operation and contribute to the process of adapting transport to climate change.

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REFERENCES

[1] Global Material Flows and Resource Productivity: Assessment Report for the UNEP International Resource Panel, 2016.

[2] Genon, G., Panepinto, D. & Viggiano, F., Sustainability in energy production. *International Journal of Energy Production and Management*, 1(1), pp. 16–32, 2016. doi:10.2495/EQ-V1-N1-16-32

[3] Ragazzi, M., Ionescu, G. & Cioranu, S.I., Assessment of environmental impact from renewable and non-renewable energy sources. *International Journal of Energy Production and Management*, 2(1), pp. 8–16, 2017. doi:10.2495/EQ-V2-N1-8-16

[4] BP Statistical Review of World Energy, 2016.

[5] Cherubini, F., GHG balances of bioenergy systems - overview of key steps in the production chain and methodological concerns. *Renewable Energy*, 35(7), pp. 1565–1573, 2010. doi:10.1016/j.renene.2009.11.035

[6] Blengini, G.A., Brizio, E., Cibrario, M. & Genon, G., LCA of bioenergy chains in Piedmont (Italy): a case study to support public decision makers towards sustainability. *Resources, Conservation and Recycling*, 57, pp. 36–47, 2011. doi:10.1016/j.resconrec.2011.10.003

[7] Fraunhofer Insitute, Biogas to Energy. Cologne/Oberhausen. Report, 2012.

[8] Patterson, T., Esteves, S., Dinsdale, R. & Guwy, A., Life cycle assessment of biogas infrastructure options on a regional scale. *Bioresource Technology*, **102**(15), pp. 7313–7323, 2011. doi:10.1016/j.biortech.2011.04.063

[9] Bakonyi, P., Nemestothy, N., Simon, V. & Belafi-Bako, K., Review on the start-up experiences of continuous fermentative hydrogen producing bioreactors. *Renewable and Sustainable Energy Reviews*, **40**, pp. 806–813, 2014. doi:10.1016/j.rser.2014.08.014

[10] Panepinto, D., Brizio, E. & Genon, G., Atmospheric pollutants and air quality effects: Limitation costs and environment advantages (a cost-benefit approach). *Clean Technologies and Environmental Policy*, **16**(8), pp. 1805–1813, 2014. doi:10.1007/s10098-014-0727-6

[11] Makaruk, A., Miltner, M. & Harasek, M., Membrane biogas upgrading processes for the production of natural gas substitute. *Separation and Purification Technology*, **74**(1), pp. 83–92, 2010. doi:10.1016/j.seppur.2010.05.010

[12] Ravina, M. & Genon, G., Global and local emissions of a biogas plant considering the production of biomethane as an alternative end- use solution. *Journal of Cleaner Production*, **102**, pp. 115–126, 2015. doi:10.1016/j.jclepro.2015.04.056

[13] Panepinto, D., Genon, G., Brizio, E. & Russolillo, D., Production of green energy from co-digestion: perspectives for the province of Cuneo, energetic balance and environmental sustainability. *Clean Technologies and Environmental Policy*, **15**(6), pp. 1055–1062, 2013. doi:10.1007/s10098-012-0568-0

[14] Ratnesh, T., Chakraborty, M.K. & Tewary, B.K., Generation and dispersion of total suspended particulate matter due to mining activities in an indian opencast coal project, monitoring, control and effects of air pollution, Prof. Andrzej G. Chmielewski (Ed.), ISBN: 978-953-307-526-6, InTech, available at http://www.intechopen.com/books/monitoring-control-and-effects-of-air-pollution/generation-and-dispersion-oftotal-suspended-particulate-matter-due-to-mining-activities-in-an-india

[15] Magaril, E.R., Abrzhina, L.L. & Belyaeva, M.A., Environmental damage from the combustion of fuels: Challenges and methods of economic assessment. *WIT Transactions on Ecology and the Environment*, **190**(2), WIT Press: Southampton and Boston, pp. 1105–1115, 2014.

[16] Boulter, P.G. & Latham, S., Emissions factors 2009: Report 5 – a review of the effects of fuel properties on road vehicle emissions. TRL Report PPR358, TRL Limited, Wokingham, 2009.

[17] Karonis, D., Lois, E., Stournas, S. & Zannikos, F., Correlations of exhaust emissions from a diesel engine with diesel fuel properties. *Energy and Fuels*, **12**(2), pp. 230–238, 1998. doi:10.1021/ef9700588

[18] Magaril, E., The solution to strategic problems in the oil refining industry as a factor for the sustainable development of automobile transport. *WIT Transactions on Ecology and the Environment*, **190**(2), pp. 821–832, 2014. doi:10.2495/eq140762

[19] Magaril, E., Increasing the efficiency and environmental safety of vehicle operation through improvement of fuel quality. *International Journal of Sustainable Development and Planning*, **10**(6), pp. 880–893, 2015. doi:10.2495/SDP-V10-N6-880-893

[20] Magaril, E. & Magaril, R., Fuel quality: challenges to the sustainable development of automobile transport and approach to solution. *E3S Web of Conferences*, **6**, p. 03001, 2016.

[21] Zannis, T.C., Hountalas, D.T., Papagiannakis, R.G. & Levendis, Y.A., Effect of fuel chemical structure and properties on diesel engine performance and pollutant emissions: review of the results of four European research programs. *SAE International Journal of Fuels and Lubricants*, **1**(1), pp. 384–419, 2009. doi:10.4271/2008-01-0838

[22] Bennett., J., Advanced fuel additives for modern internal combustion engines. *Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance*. *Towards Zero Carbon Transportation*, ed. R. Folkson, Woodhead Publishing Ltd: UK, pp 165–194, 2014. doi:10.1533/9780857097422.1.165

[23] Magaril, E., Improving the efficiency and environmental safety of gasoline engine operation. *WIT Transactions on the Built Environment*, **130**, pp. 437–485, 2013. doi:10.2495/UT130341

[24] Magaril, E. & Magaril, R., Improving the environmental and performance characteristics of vehicles by introducing the surfactant additive into gasoline. *Environmental Science and Pollution Research*, **23**(17), pp. 17049–17057, 2016. doi:10.1007/s11356-016-6900-1

[25] Srivastava, S.P. & Hancsók, J., *Fuels and Fuel-Additives*, John Wiley & Sons Inc: Hoboken, New Jersey, 2014. doi:10.1002/9781118796214

[26] Magaril, E., Improving car environmental and operational characteristics using a multifunctional fuel additive. *WIT Transactions on Ecology and the Environment*, **147**, pp. 373–384, 2011. doi:10.2495/air110351

[27] IEA CO_2 Emissions from Fuel Combustion, OECD/IEA, Paris, 2016.

[28] Magaril, E., The influence of carbonization elimination on the environmental safety and efficiency of vehicle operation. *International Journal of Sustainable Development and Planning*, **8**(2), pp. 231–245, 2013. doi:10.2495/SDP-V8-N2-231-245

[29] Magaril, E., Carbon-free gasoline engine operation. *International Journal of Sustainable Development and Planning*, **10**(1), pp. 100–108, 2015. doi:10.2495/SDP-V10-N1-100-108

THOUGHTFUL RECOVERY OF MEDIEVAL SHIPYARDS IN CONTEMPORARY CULTURE SITES

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ABSTRACT

There is architecture that could be called "timeless": places built by ancient civilizations where transformative human interventions have been successful; in fact, despite making small changes related to new needs, they have allowed the preservation and maintenance of this architecture. The shipyards of the Mediterranean can certainly be connoted as "timeless" places; they are characterized by simple structures, as they are factories and buildings without value; at the same time, they are imposing buildings, as they include other minor construction yards for the construction of vessels. They became an economic and social way to develop the culture of a site. These buildings are witnesses of an architectural monumentality that, although medieval, nevertheless displays a contemporary conception of space: great depth, good perspective and arches that seem to chase each other. This is the reason why, despite time, these buildings have always managed to perpetuate in new and different functions. This research analyzes the role that these places currently perform; the redevelopment and recovery processes that are submitted to ensure that this architecture continues to dialogue with the historically consolidated urban contexts, responding to the needs of contemporary living (i.e. from naval factories to factories for culture). The project of "controlled modification", to which this architecture is now subjected in order to go on living, belongs to the knowledge or methodological approach which allows space and time to be given to these places and also to their particular production and commercial importance.
Keywords: mediterranean basin, recover & valorization, shipyard, space versatility.

1 INTRODUCTION

In the Middle Ages, the buildings that defined urban complexes were formed, on the one hand, by a scattered and varied domestic architecture and, on the other, by fine architecture marked by the centers of political power – the castle and then the palace – and of religion: the cathedral; these construction sites become, for a period, the economic driving force of a city or even of an entire region. It was in this period, in fact, that new techniques were developed that allowed the construction of majestic buildings.

The architectural majesty, however, belongs not only to these categories but also in buildings of purely industrial character. Naval arsenals undoubtedly belong to this further class, in fact they are group of buildings characterizing urban centers developed in the Mediterranean coastal areas or on the banks of navigable waterways.

The shipyards are generally composed of a simple structure, marked by elementary arch and truss systems, which, however, outline ample and powerful spaces. Construction sites like this should certainly appear similar to their contemporary counterparts; Spanish historian, Pablo Pérez Mallaína, describes the shipyard of Seville as being like a mosque, for its *mudéjar* style [1]. In this era, the development took place of the most important projects in respect of military and commercial vessels, which transformed the Mediterranean Sea into the main location for naval engineering.

The way in which this era ended and the time at which it ceased differed from arsenal to arsenal for individual reasons; with its end you see the cessation of the activities for which these buildings were designed. In spite of this, the facilities have come down to us, after

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almost 800 years of history, in which they saw kaleidoscopic changes of use. These places, which seem to be bestowed with an anonymous spatial conception, are like skeletons, on which different uses took turns and which new uses seem to want to adapt.

2 NAVAL FACTORY ON THE MEDITERRANEAN BASIN

The arsenals have been responsible for the devolopment of the major port cities that are currently in the western Mediterranean countries: Italy, Spain, France, and the eastern Mediterranean countries, such as Croatia or Turkey, as well as all those on the coast of Africa, dominated in the Middle Ages by the various Arab dynasties that gave strong impetus to the construction of these industrial facilities.

The port cities constituted strategic points throughout the territory in question, so as to create a network of connections to facilitate communication by sea, thus marking the trade routes that favored the exchange of goods that the various populations were interested in exporting or importing. In this way, the arsenals, as well as being constructed to acquire military fleets, represented the starting point of a political and socio-economic process that involved much of the population of these cities, whose members held different tasks and roles, depending on the competencies and skills they possessed. In this sense, the arsenals, both during construction and with the subsequent practice of the shipping industry, were able to create a larger and more complex system than what we understand today by a medieval factory. They saw, in fact, the involvement of all those craft activities associated firstly with wood, but also with the production of ropes, fabrics for sails, tools to produce all those elements in iron (ranging from smaller items, e.g. nails for junctions, up to anchors or large guns), in addition to the preparation of foodstuffs to be cooked on each vessel to ensure nourishment in the face of long and risky travel.

In relation to all these activities, also, in each city, the various naval powers provided mutual agreements in order that they might own the areas inside the walls to install buildings, called *fondachi*, for the storage and sale of goods, in addition to granting accommodation for the foreign merchants [2].

Arsenals found in key locations, however, more or less distant from the urban center, usually presented themselves as an extended complex of buildings. Although, from the architectural point of view, the type is similarly repeated across the entire Mediterranean, reproducing the Greeks' *neoria* and the Romans' *navalia*, the configuration varies, depending on the importance and magnificence the port acquired over the centuries.

To the *Serenissima* belongs, without doubt, the most vast and articulated arsenal of the time. At the height of its splendor, Venice saw an extension on its eastern end of a real neighborhood, the result of additions of different buildings for morphology, type and function, around a polygonal dock connected by two gates, one leading towards the inside of the city (*Porta di Terra*) and the other towards the Adriatic Sea (*Porta d'Acqua*) [3]. Smaller, but very important, are the arsenals of the Republic of Pisa (Fig. 1 left); these were arranged around an artificial harbor, connected, in this case, through a gate (called *delle Galee*) to the right bank of the Arno River. Of ancient *Terzana*, the name given to that place by the people of Pisa, only four of the original 60 to 80 aisles remain; built against the wall for the storage of galleys, they fortified the city for half the 13th century on the other sides [4]. Further south, still on the Italian peninsula, on the Tyrrhenian coast, Amalfi was also equipped with a shipyard (Fig. 1 right). Originally composed, according to a hypothesis, of only threeaisles, which stretched toward the coast with its facade in direct contact with the water [5], it now has two, divided by ten pillars.

Figure 1: Republican Pisa (left) and Amalfi (right) dockyards.

Similar industrial complexes were built in the Iberian territories. In Valencia, there are five aisles in the Grao district. Grao was originally a settlement near the sea that depended on the city, built away from the coast due to the hostility of the territory. Around the 14th century, with the growing naval activities, it was decided to provide this settlement with an arsenal (Fig. 2 left). This was not just made up of the aisles but also of other structures, such as large tanks of water for the preparation of wood for the construction of boats, warehouses and a noble house, typical of the residence of the inspector of the yard's activities [6]. In Andalucia, on the west bank of the *Guadalquivir* river, also in Seville, *las Reales Atarazans* can be found (Fig. 4): an entire block that today is heterogeneous mixture because of the transformations that the arsenal has suffered over the centuries. It is an arsenal that at its completion consisted of 17 aisles, perpendicular to the watercourse, of which the five southernmost were torn down in the middle of the last century, those in the center having been transformed and adapted for a hospital complex and a church in the modern age, while, in the seven northernmost aisles, one can still perceive the appearance, although altered in part, it had in medieval times [7]. Another arsenal belong to the city of Barcelona (Fig. 2 right). Consisting of a great complex of eight aisles, currently seven because the two central were merged into one, it represented the most important shipyard in the kingdom of Aragon and one of the leading arsenals in the western Mediterranean [8].

If you travel on the Eastern Front you encounter other examples of naval arsenals; one such is *Tersane* of Alanya (Fig. 3 left), located on the east coast of the Gulf of Antalya, Turkey. A peculiar model of a yard, its five aisles are in direct contact with the water [9]. Thanks to this

Figure 2: Interiors of Valencia (left) and Barcelona (right) dockyards.

Figure 3: Alanya (left) and Hvar (right) dockyards.

configuration, it allowed easy and convenient maneuvering for entry to and exit from the arsenal of boats; although modest in size, this made it unique. In Croatia, in the main center of the island of Hvar, in the late 13th century, Venice ordered the construction of a shipyard for the galleys; this fell to ruin through the wear and tear of time. It was replaced in the 16th century by a shipyard (Fig. 3 left) with a single large nave, spaced out by seven majestic arches, surmounted by a further elevated space enclosed by a wooden truss structure [10].

As can clearly be seen, there are many factories of this kind, more or less large and articulated, that are still located today across the entire territory of the Mare Nostrum.

3 ANONYMOUS STRUCTURES WITH VERSATILE SPACES

Bricks and blocks of stone and small-sized elements, ingeniously arranged and fastened to create rows of massive piers, connected by arches: elements that follow one another repeating in parallel series, blending together with complementary substantial wooden structures. Traditional elements of architecture, built with expert and ancient techniques of construction have generated sites that to any eye appear charming and fascinating. Thus appear naval arsenals: simple and essential structures, defined, in most cases, by an orthogonal grid of pillars that develops in a longitudinal sense to form rectangular areas, in which commercial or war boats took shape.

Although structurally simple, the configuration of a naval arsenal, without any decoration, makes the rhythmic and repetitive succession of arches and pillars produce exemplary perspective games in any direction. It is this feature, that of greater formal value attributable to these buildings, which makes them, therefore, unique and exciting. The spaces, thus generated, although unconsciously, are an absolutely contemporary concept, compared to the architectural theme that is in search of more and more spaces that are versatile and adaptable to different purposes. The test of time, in fact, is the demonstration of how such structures, even after the loss of their principal function and despite the low aesthetic value, have not undergone demolition but have seen a succession of transformations and changes of use, to which it seems they are always well adapted.

From their origins as naval factories, the spaces have been used as warehouses for wheat, for wool, for mercury, etc. In the case of Seville, the first aisle, the northernmost, was converted into a fish market [11], dividing it into multiple small stores, arranged on the long sides by creating a central passage: a real covered market. Many of the arsenals were converted from naval to military use, providing for the manufacture of artillery with annexed places for military training, as is the case of the arsenals of Barcelona or Pisa. The latter, for a period, was identified as the *"cittadella"*, because of its military function. The uses to which the arsenals have been put, however, are not only in the area of productive activities but also cultural; in fact, an aisle of the arsenals of Valencia was used as a cinema room, while, since the beginning of the 19th century, the upper floor of the arsenal of Hvar has housed a small theater, consisting of an auditorium with loggias.

Today, the project directives seem to be changing, thanks to a strong process of awareness of historical architectural heritage; this is definitely converting these factories from industrial to cultural centers.

4 NEW PROJECTS FOR *ANCIENT* PLACES WITH *CONTEMPORARY* SPACES

The transformations and changes in usage suffered by these arsenals, in some cases, have been consolidated in the present day, while, others, especially after the two world wars, have been lost, causing improper use of the sites or even abandonment. Only when the concept of historical and artistic heritage extends not only to the main monuments of the city but also to buildings with a historical-technological and socio-cultural value, will naval arsenals return to the center of attention in historical port cities. These were greatly impaired buildings, obsolete and altered in morphology, so much so that, in some cases, the result was that it was difficult to read the original structure.

As techniques and technologies of naval architecture have evolved so much, changing the logistics of production and trade, we have seen the need to move industrial facilities outside residential areas. So, the historical buildings, which now present themselves as modest and unsuitable spaces for today's naval techniques, remain huge and interesting for the parallel activities of the new way to experience the city: the city which belongs not only to those who live here but also to all those tourists and travelers who journey in search of knowledge and to discover different cultures, visions, perceptions and ideas.

According to this logic, historic urban centers, dense and intricate plots, are forced to adopt large containers for use as city museums [12]. In the case of port cities, however, it was thought good to convert the grand spaces of the arsenals. Now, incorporated into the historic urban fabric, besides themselves telling the story of the city, within, they host exhibitions and cultural activities at the local, national and even international level.

The modern uses for historical, naval arsenals as destinations depends on both the size of the spaces and their potential and, finally, on the social and economic policies that characterize the individual cities in which they are located. It is certain that the original function could not be restored; with this in mind, these classifications can be found, according to the new destinations:

- Naval museum and museum of the city-harbor;
- Cultural center, art exhibitions and workshops;
- Specialized centers for boating and marine innovation;
- Spaces still unused and waiting to be recovered.

In particular, the arsenals of Amalfi, Barcelona and Alanya have been converted into museums with replicas of ancient galleys, tools and objects related to the art of shipbuilding, as well as documents that can relate and clarify to visitors the evolution of maritime knowledge during the Middle Ages. The arsenals of Pisa, Valencia and Hvar have been restored and are used as versatile spaces, alternating as exhibition centers for various art and cultural initiatives, interactive workshops, or as tourist information centers. Despite the many failed

Figure 4: Interior space of *Reales Atarazans* in Seville.

attempts to construct a cultural center, *Las Atarazanas* of Seville remains at the center of a controversy because of a debate regarding the definition of the floor surface.

Because of the vastness and the complex set of arsenals and following a recovery and renovation process, although slow, the case of Venice is characterized by ingenious and original architectural interventions. Besides making the spaces of the *Corderie*, *Artiglierie*, *Tese* of the XVI and *dell'Isolotto* usable and functional, through the *Biennale*, among the most famous and prestigious cultural institutions in the world (with several cultural activities like shows and exhibitions), they are putting in place projects with the goal of reconnecting the arsenal to the city. MAP Studio's project (2009–2011) for the *Porta Nuova* Tower hoisting machine, in addition to ensuring the preservation and enhancement of the building, combines the need for further exhibition and cultural center space in the *Darsena Novissima* area. The key objective of the project was the introduction of a modern vertical path in Cor-Ten steel, alternating stairs, ramps and walkways, parallel to the ancient wooden ones recalling *Piranesi*'s drawings, which links the conference room on the ground floor and an exhibition space at the top, also treated and coated with the same material (Fig. 5).

Also, among the most advanced projects are included those of the *Tesa 105* recovery, which is the new entrance to the north of the arsenals, where there are facilities for a research center (the work of architects Holguin - Morales - Solis, realized in 2012). In the inner space of *Tesa*, considered as empty, a steel and glass autonomous structure has been created in contrast to the brick that surrounds it. The new building is designed in the same way as that by which the boats were realized: raised on a few supports. Small spaces on the lower level

Figure 5: Elevation and plan of a "hoisting machine", Paris, Archives Nationales and Torre Porta Nuova recovery project (pictures from http://www.map-studio.it/).

Figure 6: Recovery project of Tesa 105, Venice (pictures from http://www.studioglass.it/).

support those of larger size in which the offices are distributed. On the top level, two glass spaces embrace the covering structure of the iron truss, defining the meeting rooms (Fig. 6).

The *Lamierini* shed was designed as a center specializing in marine and coastal technologies (made by Alberto Cecchetto in 2002); instead, a kind of vessel of a contemporary curved shape, whose base is predominantly matte, coated steel, polycarbonate and glass, has been inserted, while the upper body is transparent, allowing a view of the interior space of the shed. The whole structure is placed close to one side of the brick wall, leaving free an open space for the movement of materials and laboratory machinery (Fig. 7).

Finally, we consider the transformation of a structure in the arsenal station of Venice's harbor door control (project conceived and developed by C+S Architects in 2011). Here, the place that most thought would be dedicated to the operators has been reshaped to accommodate the computer terminals for the management of marine traffic. This is an ambitious project that means that, due to the constant updating, the Venetian arsenals are still capable of continuing their naval activities in a new technological way. The room is occupied by a single cuboid building for sanitary facilities, also in this case in Cor-Ten steel, called *Relitto*, accompanied by a fissure on the floor; a staircase leads to the data processing center. Moreover, all of the glass cover systems are equipped with sophisticated technologies for the production of energy, showing that interventions for the recovery of historic buildings can be combined with those for environmental sustainability (Fig. 8).

Figure 7: The new structure built into the Lamierini warehouse, Venice (pictures from http://www.studiocecchetto.com/).

Figure 8: Harbor Brain Building in Venice's *Arsenale* (pictures from http://web.cipiuesse.it/).

5 NAVAL ARSENALS: ARCHITECTURAL STRATEGIES FOR CONSERVATION AND VALORIZATION

The contemporary interventions performed on the arsenals' structures range from pure restoration, to works of consolidation and maintenance, up to a recovery of the interior spaces; in any case, they are carried out so that the arsenals maintain their identity, independent of any new use. The tendency is to free the interior of any partitions that are incongruous, restore the missing parts of the original structure, preferably using original materials found in situ, and clean up the elements, bringing to light the fairfaced stone materials, and, where necessary, deciding on the replacement or repair of wooden roofs, which in most cases are damaged and strongly degraded. In so doing, one tries to obtain a picture, which is, as far as possible, uniform and clear, so that the majestic feel of the place can be perceived, consistent with what the original shipbuilding factory was supposed to look like.

Restoring the formal image, one also tries to suggest the scenic atmosphere of all the activities carried out in the yards. It is for this reason that many of the historical arsenals have been converted into naval museums; large vessels, from archaeological excavations or mere reproductions, are inserted into the aisles, returning the authentic feel of the ancient art of shipbuilding. The goal is to return the arsenal in its entirety to life, although users-to-be are not masters or *arsenalotti* but visitors who immerse themselves in the past to discover the medieval world of navigation.

However, recently, in the great and mighty arsenals of Venice, they have experienced real recovery operations, which, in addition to providing maintenance, are intended to redevelop the entire complex so that it can come back, brimming with life. In this case, it is unthinkable to convert the entire *Arsenale* into a museum; the idea is to transform this structure into a suitable space for the community [13].

This strategy leads to the addition of new elements to the old structures: autonomous objects, with new structures, independent from the originals, distinct and recognizable materials and technologies with respect to masonry walls. Consisting of steel elements, coated glass and Cor-Ten, they are assembled dry, according to the logic of reversibility. They are structures, designed with the same concept as that of the boats: assembled through joints, they remain independent from the architecture that protects them.

6 CONCLUSIONS

There is some architecture that could be called "timeless": places built by ancient civilizations that have won over man, who, although making small changes according to the new requirements, has allowed their preservation and maintenance.

There is no doubt that the arsenals can be denoted as "timeless" places; conceived as shipyards for shipbuilding, it was with this purpose in mind that simple structures had to be designed, because they were industrial rather than prestigious buildings. At the same time, however, they were impressive, because their interiors had to accommodate many minor sites for the construction of boats.

Despite the construction techniques in masonry, the arsenals are still defined by serial elements: slender pillars and arches draw "frameworks", in brick or stone ashlars, which mark an architectural rhythm, as the Perret and Le Corbusier buildings in reinforced concrete, in which the main character is just the framework structure, which allows complete flexibility of space.

In the arsenals, in fact, we can find, paradoxically, some of the famous five points of Le Corbusier:

- the most obvious is that of the "free plan", which is free of structural walls and consists only of pillars that allow, on the one hand, the full perception of space and, on the other, an easy subdivision of it, according to the various needs;
- the facade is "free"; in fact, if the arches were originally kept open to allow the passage of boats, then they were, in many cases (Seville, Valencia), walled up, not only by simple closings that would allow the use of the interior space but also by imposing facades. Today the arches are once again gutted and left empty or even equipped with huge windows (the arsenals of Pisa, for example) running from pillar to pillar: another Le Corbusier point (*la fenêtre en longueur*);

The reason why these medieval buildings seem right to us today is their structures, which allowed functional versatility, and that is why we continue to protect them and try once again to recover them and give them new splendor.

REFERENCES

[1] Pérez-Mallaìna, P.E., La maestranza de artilleria y las atarazanas del azogue en los siglos XVIII y XIX. In: *Boletín de la Real Academia Sevillana de Buenas Letras*, **40**,pp. 507–547, 2012.

[2] Bernardini, P.L., Fondaco Come Fondamento Di Civiltà: Rileggendo Olivia Remie Constable. Mediterranea - Ricerche storiche, 31, August 2014.

[3] Relazione Storico-Artistica/Venezia/Castello/Complesso dell'Arsenale, Ministero per i bene e le Attività Culturali, Soprintendenza per i Beni Architettonici e Paesaggistici di Venezia e Laguna (contents consulted on January 7, 2017 through the website available at http://arsenale.comune.venezia.it/)

[4] Quirós Castillo, J.A., La lettura stratigrafica dell'Arsenale Repubblicano di Pisa, in Scienza e Beni culturali XII (1996). *Dal sito archeologico all'archeologia del costruito, Padova,* pp. 133–143

[5] Gargano, G., Arsenali e scaria di Amalfi nel contesto del Meridione medievale. In *Ricoveri per navi militari nei porti del Mediterraneo antico e medievale: atti del Workshop, Ravello*, 4-5 novembre 2005, EDIPUGLIA, Bari, 2010

[6] Iborra, F. & Miquel, M., La Casa de las Atarazanas de Valencia y Joan del Poyo. *Anuario de Estudios Medievales*, **37**(1), pp. 387–409, 2007.
https://doi.org/10.3989/aem.2007.v37.i1.43

[7] Aa.VV., Recuperando las Atarazanas/Un monumento para la Cultura, Junta de Andalucia, Sevilla, 1999.

[8] Nadal, E., La Drassana Reial de Barcelona. Evolució d'unaedificació cabdal del litoral barceloní. *Barcelona Quaderns d'Història*, **21**, pp. 95–112, 2014.

[9] Johns, J., The tersāneat Alanya and the galleys of Charles d'Anjou. In *Ricoveri per navi militari nei porti del Mediterraneo antico e medievale: atti del Workshop, Ravello*, 4-5 novembre 2005, EDIPUGLIA, Bari, 2010

[10] Hvar Heritage Portal (contents consulted on January 9, 2017 through the website available at http://www.hvarheritage.com/it/cultural-heritage/arsenal)

[11] AA.VV., Recuperando las Atarazanas/Un monumento para la Cultura, Junta de Andalucia, Sevilla, 1999.

[12] Colletta, T., Arsenali navali marittimi e Musei delle città potuali mediterranee. In rivista TRIA, n° **46**, pp. 135–150, 2008.

[13] This is the key objective of the Office Venice Arsenal (contents consulted on January 14, 2017 through the website available at http://www.comune.venezia.it)

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TOURISTIC DESTINATIONS AND COASTAL CITIES: EVALUATION OF THE INTEGRALLY PLANNED CENTER LOS CABOS, MEXICO FORTY YEARS FROM ITS FOUNDATION

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ABSTRACT

Tourism constitutes the more dynamic activity in some coastal areas of Mexico. This paper has as a goal to describe and analyse touristic development and to value its economic, environmental and social impact in the coastal area of the “Integrally Planned Center of Los Cabos”. Descriptive analytic statistical techniques are applied, based on the methodology of indicators of sustainable development for touristic destinations of the World Tourism Organization. The research descriptive considering two analysis periods: the year 2000, when the destination reaches maturity or consolidation, and 2015, year that represents an inflection point in the touristic, economic and social matters, this because of the effects of the “Odile” hurricane, situation that propitiate a relative process of resilience in Los Cabos. The document incorporates three sections; first the analytic and contextual framework is exposed which describes the Los Cabos evolution since its creation as an international touristic destination and the impact that such activity has propitiated on the local sustainable development in the coastal touristic cities belonging to the conurbation of San Jose del Cabo-Cabo San Lucas. Afterwards, we present the methodology and techniques on which the research is based on, highlighting the calculation of the touristic competitiveness indicators, and urban, social and environmental development. In the third section, the results refer that –economically- the destinations has reached certain competitiveness, however, the urban, social and environmental indicators in the cities being studied, showed a relative regression on the comparative evaluation of 2000 and 2015.
Keywords: coastal areas, los cabos, touristic sustainability indicators.

1 INTRODUCTION

One of the most significant challenges facing tourism planning and management in coastal cities is associated with the achievement of results that relate the models of sustainable tourism development with the private use of natural resources put into value

Today, the Municipality of Los Cabos is a consolidated international tourist destination, a situation that has led to a great economic growth in the region of the extreme south of the peninsula of Baja California. However, like other tourist-coastal cities in Mexico, this destination is characterized by a high spatial segregation, with marked differences in access and availability of public services and urban infrastructure, social marginalization and low identity and rootedness of immigrants to the region [1]. The coastal cities that concentrate the tourist attraction in the Municipality of Los Cabos are Cabo San Lucas, San José del Cabo and the so-called tourist corridor that links both cities, leaving out of this development the northern and rural areas of the Municipality. The disorderly growth experienced by these cities and their conurbation has led to the marginalization of large sectors of the population. For example, more than 30% of households do not have basic urban services in contrast to the exclusivity of the classification of this destination at international level, which represents a major challenge for the future competitiveness of tourism in Los Cabos [2].

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In this context, the objectives of this paper are to describe and analyze the tourist development and to evaluate its economic, environmental and social influence in the coastal cities of the municipality of Los Cabos. The first part of the document sets out the methodology of the research, followed by presentation of demographic, economic and tourist indicators that show the impact that tourism has generated in the area. The third section presents the results and the evaluation of 26 sustainable tourism development indicators applied to Los Cabos for the years 2000 and 2015. The results - according to the methodology of the WTO - are interpreted from five different approaches: quality of life, tourism competitiveness, institutional development, urban development and environmental sustainability.

2 METHODOLOGY

The methodological framework of this article is based on the UNWTO's "Practical Guide for the Development and Use of Sustainable Tourism Indicators" [3]. This is complemented by the information obtained by consulting experts in research topics, in order to validate the importance of each indicator in Los Cabos. The UNWTO sets out a very broad set of criteria for the selection of sustainability indicators to be considered in a tourist destination, a part of these was selected to be applied in the case of Los Cabos. Firstly, the relevance of the most important problems associated with destination planning and management was considered. A second aspect was the viability of its generation and use, as well as the availability of information from official sources (frequently periodic), in addition to simplicity and ease of interpretation. These criteria were taken into account to establish the universe of 26 indicators that are presented in this paper and refer to the case of tourism in the coastal cities of San José del Cabo, Cabo San Lucas and the tourist corridor.

The selected indicators were classified into five broad areas, which - according to the group of experts - correspond to the factors and areas in which tourism (with associated services) generates impacts on sustainable development in the area of study. The research is descriptive, at the same time as the source of information was documentary, based on official sources, highlighting: INEGI [4], DATATUR [5], Secretary of Tourism, as well as some governmental instances at local level, such as: Municipal Institute of Planning Los Cabos (IMPLAN) [6], Los Cabos Drinking Water Operator (OOMSAPALC) [7] and Los Cabos City Council [8]. In addition, information was provided by various business organizations, such as Business Coordinating Council of Los Cabos, Hotel Association and Timeshare Units Association, among others.

The areas considered for the ranking of indicators are:

1. Quality of life: its objective is to measure the benefits generated by the tourist activity in the destination, in particular in the resident population.
2. Tourism competitiveness: it includes the indicators that allow to evaluate the tourist activity and to compare, at national and international level, the competitiveness of the destination.
3. Institutional Development: they are related to the measurement of the financial capacity and administrative efficiency of the local authority, to face the challenges posed by the urban and tourist development of the municipality.
4. Urban development: they evaluate the functioning and efficiency of the city and the public services granted by the municipality; allow establishing if the population has the adequate coverage of public services, housing and regional urban infrastructure.
5. Environmental sustainability: they allow measuring the impact of the urban-tourist activity of the destination on the environment of the region.

Table 1: Ranking of values of sustainable tourism indicators.

Area	Core topics	Parameter or reference standart		
		Sustain-able	Preventive	Cor-rective
Life Quality	1. Housing connected to the potable water network/ total (%)	>80%	[50,80]	<50
	2. Wastewater treatment capacity (%)	>60	[40, 60]	<40
	3. Educational expenditure / students enrolled, basic education (millions $MXN per pupil)	>200	[130,200]	<130
	4. Resources for health (doctors per 1000 population)	>1.5	[1, 1.5]	<1
	5. Incidence of property offenses per 1000 population	<25	[25, 30]	>30
Tourism Competitiveness	6. Economically active population /total (%)	>55	[35, 55]	<35
	7. Average Occupancy Factor (%)	>45	[30,45]	<0.3
	8. Increase in the annual supply of rooms (number of rooms)	<1500	[1500,2000]	>2000
	9. Average tariff rate in GT and 5 stars ($US)	>135	[100,135]	<100
	10. Matrix of supply by category and type of operation. Core Indicator: % of supply in All Inclusive of 4* or less/total supply (%)	<20	[20,35]	>35
Institutional Development	11. Own income/ Total (%)	>50	[20,40]	<20
	12. Municipal public works / total expenditure (% without debt)	>11	[2, 10]	<2
	13. Current expenditure/total expenditure (%)	<30	[30, 45]	>50
	14. Public Municipal Investment ($ MXN)	>8000	[6000,8000]	<6000
Urban Development	15. Inventory of territorial reserve en urban zones/5 years (%)	>40	[0,40]	<0
	16. Number of houses with earth floor, walls and roof of sheet, cardboard and waste materials / total of houses (%)	<3	[3, 7]	>7
	17. Need for housing / existing housing (%)	<11	[11,16]	>16
	18. Surface of green areas (m^2 per inhabitant)	>5	[0, 5]	<0
	19. Paving coverage / total roads (%)	>60	[30, 60]	<30
	20. Composite indicator on the lag of urban equipment (%)	<50	[50, 70]	>70

(*Continued*)

Table 1: (*Continued*)

Area	Core topics	Parameter or reference standart		
		Sustain-able	Preventive	Cor-rective
Environmental Sustainability	21. Total annual average recharge - value of the natural discharge committed - volume of groundwater granted and registered in the REPDA (million m3/ year) (availability of drinking water in the San José del Cabo aquifer)	>0.5	[−6,−0.5]	< −6
	22. Water consumption per capita (liters / day / inhabitant)	<317	[317,350]	>350
	23. Water supply per room (liters per day)	<1260	[1260,1600]	>1600
	24. Generation of solid waste per capita (kg per day)	<0.65	[0.65,1]	>1
	25. Solid waste collected from other sources such as hotels, restaurants and commerce, per visitor (kg / visitor / day) (Generation of solid waste in tourism by hotel room)	<0.25	[0.25,0.25]	>0.5
	26. Area with vegetation cover / total area to be used (Natural vegetation cover in useable areas) (in %)	>0.5	[0.2,0.4]	<0.2

The evaluation of each of the indicators was weighted based on qualification obtained according to the reference parameter or standard. The results generated for 2015 was compared to those of 2000. The year 2000, was selected because that's when Los Cabos was consolidated as an international tourist destination. The year 2015 was taken into account for two reasons: the availability of most recent official statistics and because in this year initiated a process to create resilience because of the disasters caused by hurricane "Odile" (September 2014). The comparison is expressed in a system of traffic lights that reflects three levels of performance: state of sustainability, in process of sustainability, and sustainability at risk.

3 CONCEPTUAL ASPECTS OF TOURISM

It is considered that tourism is one of the main sources of wealth and economic growth in some regions, but also generates impacts on environment, social issues and cultural resources of the receiving community. In order to minimize negative impacts, a number of international organizations, including the World Tourism Organization (UNWTO) and a number of specialists in the field, have expressed their support to development model framed in the concept of "sustainable tourism". This must consider the interrelationship between tourism development and the sustainability of the environment. UNWTO stresses that the guidelines for tourism development, in relation to sustainable management practices, apply to all forms and / or segments of tourism. The principles of sustainability refer to the environmental, economic and socio-cultural aspects of tourism development, and a balance must exist between the three dimensions to ensure sustainability in the long term.

The relationship between tourism development and environmental issues has been analyzed under two main approaches: firstly, tourism as an alternative for economic and socially sustainable development; Secondly, tourism as the origin of socio-environmental deterioration processes [9]. In this context, it should be considered that tourism can generate adverse effects on the environment, but this economic sector is also an opportunity for local development. Tourism explores regional vocations, at the same time fostering and integrating other sectors to the local and regional economic development. Tourism can generate multiplying effects on local economy, fostering value chains based on natural resources [10].

As mentioned above, the effects of tourism (as an economic activity) can positively or negatively affect a destination, but it will depend on the quality of the territorial planning (and the existence of adequate public policies). To obtain positive and tangible for the society results, the multiple dimensions included in sustainable tourism development must be incorporated (economic, social, environmental, cultural and institutional), because only balancing these dimensions would be possible to guarantee long-term sustainability [11].

However, attempting a sustainable tourism activity may not make sense without the existence of objective ways of assessing sustainability. The UNWTO states that in order to achieve an efficient process of planning and management of tourism, and to assess its evolution, it is advisable to use sustainability indicators that identify changes and possible alarm signals over time. These indicators provide sufficient and reliable information to define when it is necessary to modify public policies or to implement new actions. In addition, with these indicators, it is possible to generate a set of data on actual situation of tourism development, particularly regarding aspects related to sustainability. This database should facilitate the decision-making performed by various stakeholders involved in planning, so that the sustainable practices define the future actions.

According to UNWTO, the indicators that refer to the development of sustainable tourism correspond to the set of formally selected data regularly used to measure the changes caused by the development and management of tourist activities in a locality. These can serve as instrument to detect repercussions of these changes on tourist structures and on external factors influencing tourism. Through the mentioned sustainability indicators, it is possible to synthesize previously selected information, which facilitates processing and analysis of data in order to implement objective and effective policies. At the same time, instruments and programs focused on solving problems and recognizing areas of risk, can be established or designed.

At present, the development of coastal cities with a tourist vocation in Mexico faces a series of conflicts due to factors as poor planning and territorial organization, high immigration processes, heavy lags in social infrastructure, lack of public policies to control the development of tourism, and irregular settlements. Added to this, the authorities adopt decisions with political criteria rather than social criteria. However, the most important factor in tourism is the prioritization of the value of natural resources to the detriment of cultural, social and environmental aspects, which - from our perspective - represent the true capital of the tourist destinations.

The intensive use of the coasts, particularly when it is oriented to the second-home property market or mega tourist developments (tourist enclaves) framed in the “sun and beach” model, has been an important topic of research, controversies and demands. That is because the growing spatial intervention by the tourism and real estate sectors has contributed (to a great extent) to disrupting the sustainable development of coastal cities [12].

In the last decades, mass tourism or “Fordism model” has consolidated in the tourist destinations of sun and beach in Mexico, focusing on those territorial spaces with “natural capital” like beaches, vegetation, flora, fauna, as well as areas of privacy or remoteness from large cities. That generated accelerated growth of tourist enclaves along the coasts, affecting the environmental, cultural and social value of coastal cities such as Cancun, Acapulco, Puerto Vallarta and Los Cabos [13].

The creation of the National Tourism Fund (FONATUR) in 1974 focused on the development of tourism projects based on the "Integrally Planned Centers" (CIP) model, whose strategy was to create tourist complexes and provide them with basic infrastructure in relatively remote coastal areas, with little economic and demographic development, but with a great availability of natural resources. In this way, seven CIPs arose, presenting Cancun and Los Cabos the most important economic results [14], based on "sun and beach" tourism.

4 SOCIAL CONTEXT AND TOURISM ACTIVITY INDICATORS IN LOS CABOS

From the political-administrative point of view, Los Cabos is located at the southern end of the state of Baja California Sur. Unlike the rest of the state, its rapid economic growth (supported by investments in tourism and associated services) has led to a rapid increase in the number of inhabitants (between 1980 and 2015 the population increased by 1.405%) [15] that represents 40.4% of the state population. This situation has caused heavy lags in urban and social infrastructure, as well as marginalization and poverty. In fact, based on the 2015–2018 Municipal Development Plan [10], in 2015, 28.5% of the population was in poverty, 40.3% were vulnerable due to social deficiencies, 2.6% were vulnerable to income, 5.6% were in extreme poverty and only 28.6% of the population was non-poor and not vulnerable.

Because of the aforementioned economic growth, the social inequalities to access to the minimum wellbeing generate a conspicuous contrast between the exclusive mega resorts and big hotels of the tourist zone associated with the coast and oriented to isolate the tourist, and the lack of urban and social infrastructure in poor colonies and irregular settlements. This requires the urgent creation of mechanism for distribution of the economic benefits of tourism, thus reducing the inequalities and making the tourist cities of Los Cabos more homogenous, equitable, comprehensive and democratic.

In contrast, tourism has also favored job creation. In fact, in 2014 the population employed in the tourist activity in Los Cabos (considering the classification of INEGI of jobs in the sector of lodging and preparation of food and beverages) represented 30.5% of the economically active population (EAP) of the entire state of Baja California Sur.

Table 2: Demographic and Demand Indicators (Source: DATATUR, 2015)

Year	Population of Los Cabos	EAP of Tourism	Foreign Tourists	Domestic Tourists	Total Tourists
1980	19,117	n.d.	39,200	70,300	109,500
1985	29,279	n.d.	105,500	134,800	240,300
1990	43,920	3,348	228,000	77,167	305,167
1995	71,031	5,346	390,355	91,580	481,935
2000	105,469	7,821	577,548	127,824	705,372
2005	164,162	11,435	1,006,963	221,873	1,228,836
2010	238,487	24,320	842,606	382,504	1,225,110
2015	287,671	39,295	1,277,250	425,750	1,703,000

It is evident that from an economic and commercial point of view, Los Cabos represents a successful destination, considering how attractive it is for foreign tourists. However, it is necessary to mention that -historically- demand is what marks the increase in the supply of rooms and tourist services. As shown in the attached tables, the ratio of foreign and national visitors was 3 to 1 in 2015 (in 2005, prior to the crisis in US property markets, this ratio was 4.5 to 1). This situation has been a common denominator in Los Cabos and one of the factors that have led to large investments in hotel infrastructure, commerce and services to meet growing demand.

Based on available information, we recognize a series of factors that have been basic in tourism development and that have influenced the competitiveness of Los Cabos:

1. The closeness to the market with states of greater purchasing power in the United States, such as the western and southwestern states, particularly California.
2. The development of a hotel infrastructure and time share units of high quality and market value, as well as a wide range of properties for second residence of foreigners.
3. Natural resources that can be used to produce value.
4. The installation of basic external economies in the competitiveness of the destination, such as the airport, telecommunications services, roads, marinas, marketing and promotion programs (expenditure-for the most part is covered by the federal government of Mexico).
5. The peso / dollar exchange rate has always been a variable that favors foreign tourists.
6. Unlike other economic sectors, tourism, commerce and the services associated to their supply do not require a great work specialization, which makes labor costs relatively low.

5 RESULTS

When comparing the indicators of sustainable tourism for the two evaluation periods, it is clear that - with the exception of the area of tourism competitiveness - Los Cabos presents a setback in the areas of quality of life, institutional development and urban development. As can be observed in Table 4, some indicators went from a range of: “in process of sustainability” to “sustainability at risk”. For example, the decline in the indicator for municipal public

Table 3: Tourist Indicators of Los Cabos, (Source: DATATUR, 2015).

Year	Rooms Inventory	Hotel Occupancy (%)	Economic Income ($US)	Total International Flights	Total National Flights
1980	544	61.90	$20,948.0	907	380
1985	1,219	53.00	$56,204.0	1,373	696
1990	2,531	49.00	$148,885.0	2,957	1762
1995	3,710	61.40	$245,492.0	4,480	998
2000	4,842	59.70	$378,628.0	5,961	1714
2005	7,849	64.10	$779,940.0	9,955	3,548
2010	11,762	62.20	$690,373.0	8,599	4,793
2015	12,465	65.43	n. d.	13,268	5,598

investment per capita, as well as the high ratio of current expenditure to total expenditure, is striking. Even though the municipality's revenues reflect a good index of own income with respect to total revenues (between 2010 and 2015 municipal revenues increased from $ 1,041.4 to 1,614.1 million pesos, reflecting a nominal increase of 55%), the largest part is intended for current expenditure, transfers and subsidies. In terms of urban development, there are lags and deficits in urban infrastructure, with high demand for basic education, health and recreation. The precarious housing index rises from 6 to 9.5%, as well as the index that values the demand for new housing. There are irregular settlements that accelerate the processes of marginalization by lack of infrastructure, which also leads to a deterioration of the environment coupled with the fact that the municipality doesn't have territorial reserves for properly planned urban settlements.

The critical variables that endanger the sustainability of the destination are from the environmental area, a situation frequently reflected in the coastal cities with tourist vocation in Mexico. The indicators express the problems and deficits that exist in the availability of drinking water, a factor that - according to the Mexican Institute of Competitiveness (IMCO) and IMPLAN - limits the possible growth of tourism in Los Cabos. At the same time, the final disposal of solid waste and the management of wastewater also register deficits, since there is not enough coverage of these services, but it is no public investments to overcome these problems. There is also a decrease in the natural vegetation cover in areas exploited, as an economistic and short-term criterion has prevailed over the environment and natural resources.

Table 4: Indicators of sustainable tourism in Los Cabos.

Area	Core topics	Year 2000	Rank-ing	Year 2015	Ranking
Life Quality	1. Housing connected to the potable water network / total (%)	79%		82%	
	2. Wastewater treatment capacity (%)	45%		51%	
	3. Educational expenditure / students enrolled, basic education (millions $MXN per pupil)	$225		$185	
	4. Resources for health (doctors per 1000 population)	1.5%		0.98%	
	5. Incidence of property offenses per 1000 population	20		n.d.	
	6. Economically active population / total (%)	29%		47%	
Tourism Competitiveness	7. Average occupancy factor (%)	59%		64%	
	8. Increase in the annual supply of rooms (number of rooms)	521		1,110	
	9. Average tariff rate in GT and 5 stars ($US)	165		260	
	10. Matrix of supply by category and type of operation. Core Indicator: % of supply in All Inclusive of 4* or less / total supply (%)	13%		19%	

(*Continued*)

Table 4: (*Continued*)

Area	Core topics	Year 2000	Rank-ing	Year 2015	Ranking
Institutional Development	11. Own income/ Total (%)	60.3%	Green	58.4%	Green
	12. Municipal public works / total expenditure (% without debt)	11.1%	Yellow	8.6%	Yellow
	13. Current expenditure / total expenditure (%)	74.0%	Red	75.0%	Red
Urban Development	14. Public Municipal Investment ($ MXN)	$739.2	Yellow	$432	Red
	15. Inventory of territorial reserve en urban zones / 5 years (%)	2%	Yellow	0%	Red
	16. Number of houses with earth floor, walls and roof of sheet, cardboard and waste materials / total of houses (%)	6.2%	Red	9.5%	Red
	17. Need for housing / existing housing (%)	16%	Red	19%	Red
	18. Surface of green areas (m^2 per inhabitant)	4.1	Red	2.17	Red
	19. Paving coverage / total roads (%)	32%	Yellow	41%	Yellow
	20. Composite indicator on the lag of urban equipment (%)	38%	Yellow	45%	Yellow
Environmental Sustainability	21. Availability of drinking water in the San José del Cabo aquifer	−5.24%	Red	−6.90%	Red
	22. Water consumption per capita (liters/day / inhabitant)	220.7	Yellow	369.0	Red
	23. Water supply per room (liters per day)	1,574	Red	3,423	Red
	24. Generation of solid waste per capita (kg. per day)	1.13	Yellow	5.2	Red
	25. Generation of solid waste in tourism by hotel room	14.5	Red	21.4	Red
	26. Natural vegetation covers in useable areas (%)	60%	Green	50%	Yellow

Yellow: Sustainable level; Green: In process of sustainability; Red: Sustainability at risk

The results of the area of tourist competitiveness generate economic information related to the performance of the tourist activity. The data obtained reflect that in the period between 2000 and 2015, there was a considerable increase in the hotel, timeshares and properties for second residence. The hotel occupancy rate exceeds the national average, being above other destinations of the same category, such as Cancun and Puerto Vallarta, registering average rates that place Los Cabos as an exclusive international destination and with an important supply for high-income foreign tourism. The supply focuses on hotels and resorts of Gran Tourism and Five Star categories. Therefore, the indicators of tourism competitiveness place this destination at the sustainable level and of great success for the investors and economic agents of the area. However, it's worth mentioning that the pending task is located in the indicators that measure or evaluate the areas of environmental sustainability and urban development.

CONCLUSIONS

The analysis based on the indicators of tourist sustainability in Los Cabos, confirms that, the destination has experienced a great dynamism and growth in tourism. The increase in the supply of rooms, timeshare units and second homes residence, reflect the boom that this tourism center experienced in the international market. This entails constant raise of demand and investments that place Los Cabos as a competitive tourist destination with significant multiplier effect on sectors directly related to this economic activity (e.g. trade, services, transport and construction). However, despite the economic strength of tourism today, this sector has not been able to integrate into the local economic development of the area. It is recommendable for local authority to design development programs and to foster a greater linkage of local productive systems with tourism, considering that this sector is the predominant economic activity in the coastal cities of Los Cabos.

The accelerated urban growth, because of the impetus given by the federal government to Los Cabos since its creation as an integrally planned center in 1976, has created a series of problems related to environmental sustainability, urban development and social segregation. The indicators that evaluate these areas do not present the general signs of a positive evolution. In the reference years 2000 and 2015, most of the indicators of urban and environmental sustainability are in the range of parameter of sustainability at risk (a difference of the positive results presented by the item related to tourism competitiveness). The disorderly growth in the urban areas of San José del Cabo and San Lucas, resulting from the boom in tourism and real estate, has had a strong impact on the reduction of the water resources needed by tourist cities (for tourism infrastructure, public services, urban infrastructure and economic growth). The results show that between 2000 and 2015, these variables represent a challenge and jeopardize the competitiveness of the destination in the long term.

The analysis and the results presented here, can be used by local authorities to generate proposals for public policies, tending to reduce (or at least attenuate) the problems of urban development and environment, recognizing that tourism as an important economic sector, but it's development is based on the natural resources.

Forty years have passed since the creation of the CIP in Los Cabos, economic growth is evident, from a relatively isolated area, with small towns focused on self-consumption the area evolved to cities with a dynamic economy, recognized as international tourism centers. However, critical variables such as urban development and environmental sustainability (which were not included in the CIP Master Plan in 1976) threaten the development of this already consolidated destiny. According to the theory, these must be reconsidered. How long will the supportive capacity of the destiny withstand the pressure to the critical variables? What kind of actions, works and services are required for the rethinking of the model applied in Los Cabos? These questions are open and all local stakeholders have to be part in finding the right answer.

REFERENCES

[1] Montaño, A. & Pérez, J.C., Diversificación de la oferta a partir del turismo de naturaleza: un análisis de la percepción de los actores del desarrollo económico turístico en Los Cabos, en Ivanova, A. & Serrano, R. (Coord): Areas Naturales Protegidas: Vías para un desarrollo sustentable, ed. CONANP-SEMARNAT pp. 169–196, 2015.

[2] IMCO, *Instituto Mexicano para la Competitividad, Nueva política turística para recuperar la competitividad del sector y detonar el desarrollo regional*, IMCO: México, D.F, 2013.

[3] OMT. Indicadores de Desarrollo Sostenible para Los Destinos Turísticos, Vol. 1, Madrid España, 2005.

[4] INEGI., Anuario Estadístico y Geográfico de Baja California Sur, La Paz Baja California Sur México, 2016.

[5] DATATUR., Compendio estadístico del sector Turismo de México, Secretaría de Turismo, México D.F, 2015.

[6] IMPLAN, Segunda Actualización del Plan Director de Desarrollo Urbano San José del Cabo y Cabo San Lucas, San José del Cabo, México, 2013.

[7] OOMSAPAS Los Cabos., Indicadores de Gestión, available at http://aguapotabledeloscabos.gob.mx/ (accesed 20 February 2017)

[8] XII Ayuntamiento de Los Cabos., Plan de Desarrollo Municipal Los Cabos 2015–2018, San José del Cabo, México, 2017.

[9] Macário de Oliveira, V., Pasa Gómez, C. & Ataide Cândido, G., Indicadores de Sustentabilidad para La Actividad Turística Una propuesta de monitoreo usando criterios de análisis, Estudios y Perspectivas en Turismo, **22**, pp. 177–197, 2013.

[10] Poudel, S., Nyaupane, G.P. & Budruk, M., Stakeholders' perspectives of sustainable tourism development: a new approach to measuring outcomes. *Journal of Travel Research Sage Journal*, **55**(4), pp. 465–480. doi:10.1177/0047287514563166

[11] Namhyun, K., HakJun, S. & Hyun, P.J., The relationship among tourism, poverty, and economic development in developing countries: A panel data regression analysis. *Tourism Economics Sage Journal*, **22**(6), pp. 1174–1190, 2016. https://doi.org/10.1177/1354816616669038

[12] Rodrigo, H., Herrera, C., Carreño, M. & Casaubon, C., La Urbanización del borde costero en la región de Valparaíso: entre el ideal de justicia espacial y la inequidad socioterritorial. *En las costas del neoliberalismo Naturaleza, Urbanización y Producción Inmobiliaria: experiencias en Chile y Argentina*, pp. 238–259, 2016.

[13] Fitch Ratings., Municipio de Los Cabos, Baja California Sur reporte de calificación, available at http://www.fitchratings.mx/default.aspx (accesed 20 February 2017)

[14] Montaño, A., Pérez, J.C. & de la, O.V., Reposicionamiento para destinos turísticos consolidados: el caso de Los Cabos, México, Cuadernos de Turismo, **33**, pp. 271–295, 2014.

[15] INEGI, Instituto Nacional de Estadística y Geografía. Directorio Estadístico Nacional de Unidades Económicas, available at http://www.inegi.org.mx/default.aspx (accesed 20 February 2017)

PROACTIVE MANAGEMENT IN THE POWER INDUSTRY: TOOL SUPPORT

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ABSTRACT

Increasingly dynamic, non-linear and all too often chaotic changes in the global environment and tougher competition, including at the geopolitical level, call for radical transformations in strategic management of the power industry. The article provides the results of a study into proactive actions of energy company management, which are becoming increasingly important. The article offers a framework of concepts relating to proactive management and sums up ideas of a number of authors on diagnostics of weak signals as possible harbingers of threats to sustainable power industry development. The authors have determined a general approach to mechanisms of threat identification and developed methodological principles of shaping a corporate management model capable of reacting to new challenges. The article provides a thorough study of some components of the model and an assessment of factors that ensure successful implementation of the authors' conceptual solutions in energy companies.
Keywords: advanced warning, challenges, proactive management, the power industry, threats, weak signals.

1 INTRODUCTION

Global challenges and threats of accelerating changes in the environment, environmental uncertainty and aggressiveness, a growing number of new tasks which cannot be solved based on experience, call for management's proactive actions in the power industry and are shaping a new model of management of energy companies' development. This model brings in the spotlight the issue of developing a corporate system of early diagnostics of threats and opportunities.

The concept of proactive management [1–3] is a methodological framework for solving this problem; moreover, it ensures sustainable development and increases business' strategic flexibility. At the same time, theoretical aspects of proactive management, including the framework of concepts, basic models and tools, are still under development.

2 FRAMEWORK OF CONCEPTS FOR PROACTIVE MANAGEMENT IN THE POWER INDUSTRY

Proactive management in the power industry is a set of technical, organizational, resource and economic measures implemented at all levels of management and aimed at advanced prevention of the negative impact of internal and external factors (including environmental turbulence and resources restrictions), which threaten stability, integrity, economic efficiency of the industry, energy companies' competitiveness and power supply reliability.

We suggest defining the main terms and correlations between concepts in the proactive management theory.

Trend (synonym: tendency) is a direction actively developing for a certain period of time which can significantly affect relevant fields of work.

Challenges are new conditions and factors of environment that require adequate managerial decisions at all levels of management. They can either offer new sources of development and growth for the industry's efficiency or transform into relevant threats.

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Challenges tend to arise from time to time as a result of rather powerful financial and economic, scientific and technical factors as well as factors relating to resources, energy and even nature and climate ("shifts"). For example, an increase in the share of renewable energy sources in the structure of generating capacities in a number of countries; creation of renewable energy storage systems; development of small-scale (distributed) power generation; smart grid systems; nuclear power units of small and medium capacity with intrinsically safe reactors.

The growing number of challenges and their critical role in the development of the electric power industry have resulted in a relevant intellectual reaction: the role of proactive management as a response to these challenges has grown.

Threats are a possibility of an event with consequences that are unfavourable for a particular energy company; it is a probabilistic characteristic.

Correlations between challenges and threats are outlined in Fig. 1.

A threat alert is information about the nature (kind) of the threat and its source obtained with the help of continuous monitoring of some sectors of the external micro-environment.

Threat identification is an important element of the proactive management process which includes expert (probabilistic) assessments:

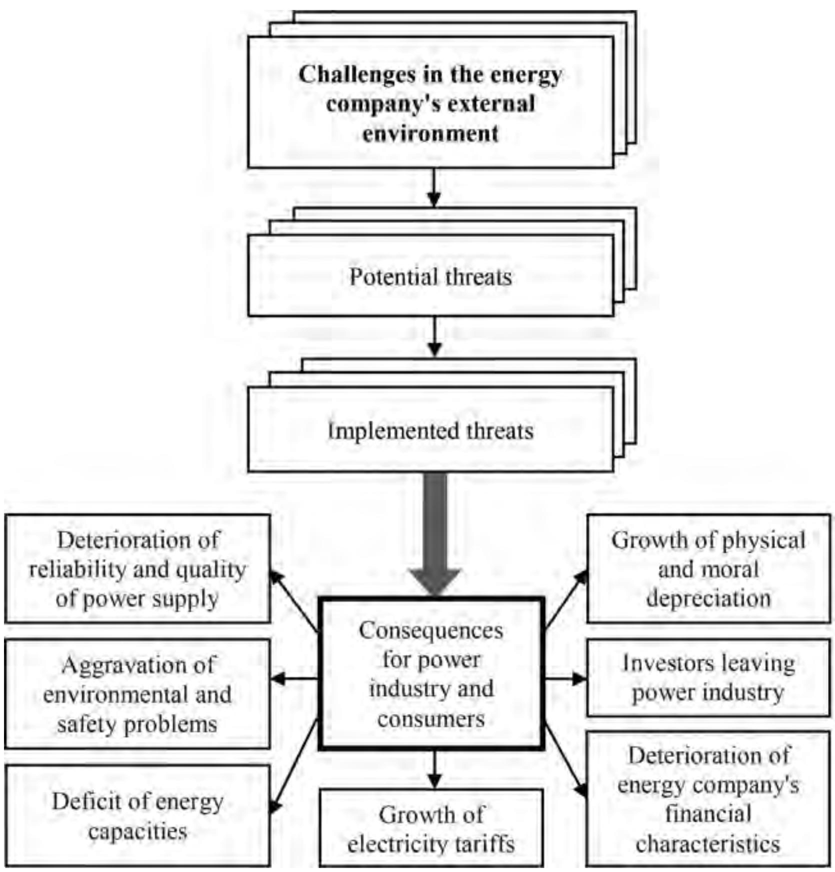

Figure 1: Correlations between "challenges - threats - consequences" for the power industry.

- The likelihood of the threat implementation (as the probability of a relevant event taking place).
- The maximum surge in parameters of the sector of the external micro-environment.
- The time frame of the surge in parameters (which determine the event duration and its impact on the existing trend).

  An event (in this context) is a sharp ("out-of-trend") change ("a surge") of parameters mediating energy company's ties with subjects of the external micro-environment, which can cause deterioration of key financial and economic characteristics of this particular energy company.
- *Key Performance Indicators (KPI)* are indicators that characterize the efficiency of the energy company's activities in the financial sphere and fields relating to customers, business processes, human resources and innovations.

Limit (or threshold) of key indicators criticality is the maximum level of deterioration of specific indicators set for a particular energy company, below which there begins a zone of event unacceptability from the point of investment appeal and competitiveness, that calls for urgent organizational-technical or economic decisions to eliminate the threat.

Depending on the completeness of information obtained as a result of observations, signals are divided into two categories: strong and weak. Problems revealed by strong signals are so obvious and specific that one can assess their significance and take relevant measures in order to eliminate threats or seize opportunities.

Weak signals are early and vague signs of emerging important events which are difficult to grasp and assess in the course of monitoring. They give a feeling about an emerging problem (threat, opportunity) but cannot be used to confidently forecast where and when they will emerge and what exactly they will be like.

In the course of time weak signals can turn into strong ones and, if the level of instability does not exceed the company's ability to timely react to changes, managers can postpone making the decision until they get a strong signal. If the instability of the environment is high, managers who choose to wait for a strong signal may end up being late to solve the problem or being incapable of making the decision under the conditions of time pressure and lack of resources. That is why, if the level of instability is high, it is essential to begin working on a decision once one gets weak signals.

Adequate management based on weak signals requires a well-adjusted monitoring system sensitive to warning signals and readiness of energy company managers and personnel for changes and making risky decisions.

3 WEAK SIGNALS AS OBJECT OF ANALYSIS OF ENERGY COMPANIES' POSSIBLE PROBLEMS

I. Ansoff [4–8] introduced the idea of weak signals and their use for early identification of threats and opportunities in strategic management. P. Schoemaker and G. Day [9–16] developed the concept and detailed a general scheme of weak signal monitoring, their interpretation and integration in the management process. Schoemaker P. and Day G. summarized their outlook in the article [10] published in the *Harvard Business Review* in November 2005 and then presented it as a more extended version in the book [11]. The book substantiates the need to broaden organizational outlook and proposes a structured approach to management which makes it possible to track weak signals coming from the periphery (areas outside the strategic focus).

In the articles written after the book was published the authors elaborate the idea of peripheral vision. The article “Seeing Sooner: How to Scan for Weak Signals from the Periphery” [12] focuses on conditions for successful tracking of weak signals and details areas and relevant methods of scanning. The article “How to Make Sense of Weak Signals” [13] looks at individual and organizational prejudices that impede timely and correct assessment of weak signals and reaction to them. It also offers solutions to this problem and rules which allow for arranging the process of scanning and processing of weak signals in the best possible way.

The last article published on the issue, “Integrating Organizational Networks, Weak Signals, Strategic Radars and Scenario Planning” [16] expands the area under study further. It links weak signal processing to scenario planning and proposed a scanning process from a variety of sources. It looks at various kinds of external networks and assesses their importance for broadening organizations’ outlook and developing periphery vision. In the article the authors suggest a tool of strategic management called “Strategic Radar”. The tool is based on developed external networks and scenario planning technologies and consists of three major functional subsystems: 1) the monitoring of external signals; 2) the assessment of strategic actions in the changing external environment; 3) the scanning for additional weak signals. The interrelation between the subsystems makes it possible to form and maintain strategic flexibility.

In the 1990s the issue of weak signals was developed in the context of studies of complex adaptive systems (CAS). This direction is most extensively covered in the works of B.S. Coffman [17] who proposed a process model for weak signals.

Yet another direction of in the study of weak signals is being actively developed by futurologists in the context of studies of the future, and sociologists for the purposes of organizational training. This direction is based on the publications by Ansoff as well as the works of G.T.T. Molitor [18–20] who studied “emerging issues”. When studying changes, Molitor paid special attention to the phase preceding changes and, consequently, weak signals detected at the beginning of this phase. He pointed out that the changes that seem sudden are in fact an expected result of lengthy processes and by scanning emerging problems one can timely reveal upcoming drastic changes.

At present this direction is being actively developed by various groups of researchers. An article by Jari Kaivo-Oja [21] suggests a model that combines knowledge management technologies and weak signal analysis that can be used when developing new future studies and foresight methodologies. In the article [22] the authors look at weak signals in the context of the foresight theory and practice and show how weak signals analysis in addition to trends monitoring enables an organization to effectively develop and implement its strategy. The article [23] looks at conceptual frameworks and applications, problems and methods of weak signal analysis in early threat detection systems. The article [24] studies the influence of interactions existing in the external environment, stereotypes and the context in which signal interpretation is carried out on weak signals. The article [25] deals with analysis of distributed, heterogeneous, open and continuous data which can be used for early detection of problems. In the paper [26] the authors suggest a tool for weak signal filtration in the strategic process the application of which contributes to pro-active decision-making. The article [27] looks at the use of improvisation in strategic studies. By combining improvisation with planning and implementation an organization gets paradoxical forms of “real time foresight” which enables it to timely detect and use emerging opportunities.

Additionally, one can cite a number of articles published by E. Hiltunen [28–32]. The article [28] offers a thorough study of the Wild Card concept (seemingly unlikely but suddenly occurring events with rather serious consequences). The article shows that in many cases closer examination reveals that the events classified as Wild Cards are in fact links in the chain of gradual changes and weak signals enable one to see the signs of Wild Cards hidden in these changes. The article [29] discusses the use of weak signals in futures studies: it offers the term “Future Signs” and a conceptual model based on it. The article [30] provides a thorough study and assessment of various data sources and offers the most suitable data sources for weak signal scanning. The article [31] proposes a new method (the Futures Window) for visualization of weak signals and choosing a direction for futures thinking and innovation in organizations. The Futures Window could be used as a central component in Creative Foresight Spaces (CFS) to enhance innovation in organizations.

Hiltunen used these and a number of other studies for her PhD thesis called “Weak signals in organizational futures learning” [32] in which Hiltunen places primary emphasis on an approach that combines views developed in studies on organizational training with weak signals concept. The issue of weak signals, their significance and processing methods are covered in the works by other Finnish researchers: Tuomo Kuosa [33] and Kimmo Laakso [34]. Mika Korhonen (2014) in his work entitled “Tacit knowledge and weak signals in organizational learning” [35] and Pia Adibe (2015) in “Competence foresight” [36] also developed the concept of weak signals.

Yet another direction of research in weak signal scanning and interpreting, which is relevant for energy management, is linked to risk reduction and prevention of accidents and catastrophes [34, 37].

The issues of inadvertent changes in the environment and system stability to such changes are closely connected with weak signals. Despite some differences as to the terms (wild cards), researchers study similar processes and phenomena. For example, the authors in the article [38] suggest an analytical approach to management of surprising and potentially damaging events which is based on up-to-date conceptual and empirical studies. For that purpose the authors use the wild card management system. Wild cards refer to sudden and unique incidents that can become turning points in the evolution of a certain trend or system. As the first of the two components of the proposed wild card management system, the authors use a weak signal methodology to get warning about possible surprising events in the course of environment scanning. The second component is nurturing improvisation capabilities for activities amid an ongoing crisis.

Among publications relating to weak signal scanning and interpretation the work of Korean researchers [39] also claims attention. The researchers introduce the NEST (New & Emerging Signals of Trends) model which provides for systematic collection and assessment of weak signals of emerging technologies by scanning expert network worldwide.

4 CORPORATE SYSTEM OF ADVANCED THREAT WARNING AND DETECTION OF NEW OPPORTUNITIES

In Fig. 2 proactive management in energy companies is presented in the form of a process consisting of a number of consequent experts and analytical operations.

To illustrate the application of the proactive management method we suggest looking at a grid (distribution) company.

Sector: energy monopolies’ regulation.

Monitoring: regulator’s pricing policy.

Threat alert: expected restriction of electricity transmission prices.

Threat identification: likelihood of the regulator making the decision, %; relative reduction of price (in comparison with the current regulation method), %; time before the introduction of the price cap, months or years; duration of restriction (assessment), years.

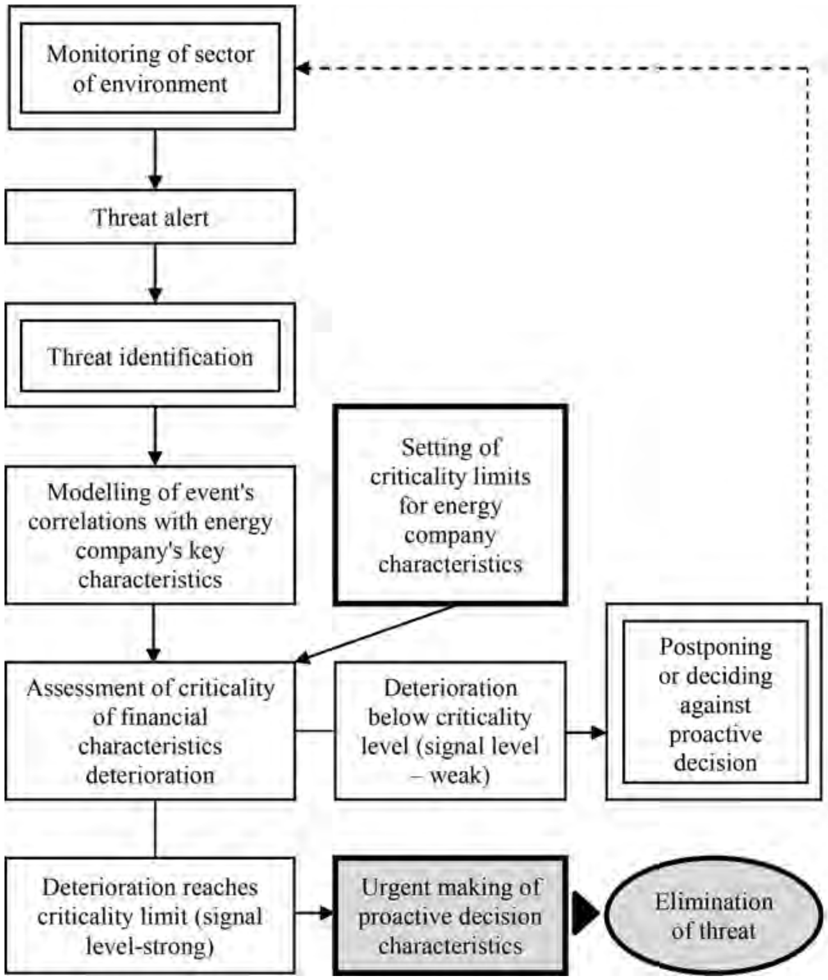

Figure 2: Structure of proactive management in energy companies.

Assessment of consequences and their criticality for the energy company: proactive solutions are required.

Proactive solutions (variants): organizational and technical measures aimed at reducing fixed costs; organizational and technical measures aimed at reducing technical and commercial losses in the grid; adjustment of customers' load in order to increase transmission capability in the existing grid; interaction with customers as regards reactive power compensation; creation of small-scale power generating units (a comprehensive feasibility study is necessary).

Using the outlined plan an energy company has an opportunity to timely and adequately react to emerging threats. However, monitoring usually applies to the area of the energy company's strategic focus and weak signals emerging in the periphery may be missed. New technologies emerging far beyond the visual range of the company's clients may have a decisive influence on their business. Consequently, their demand for electricity may drastically drop or grow. For example, a mass switch over from incandescent lamps to LED lamps will result in a significant decrease in demand for electricity used for lighting. Such changes occur everywhere but only some of them are spotted by monitoring.

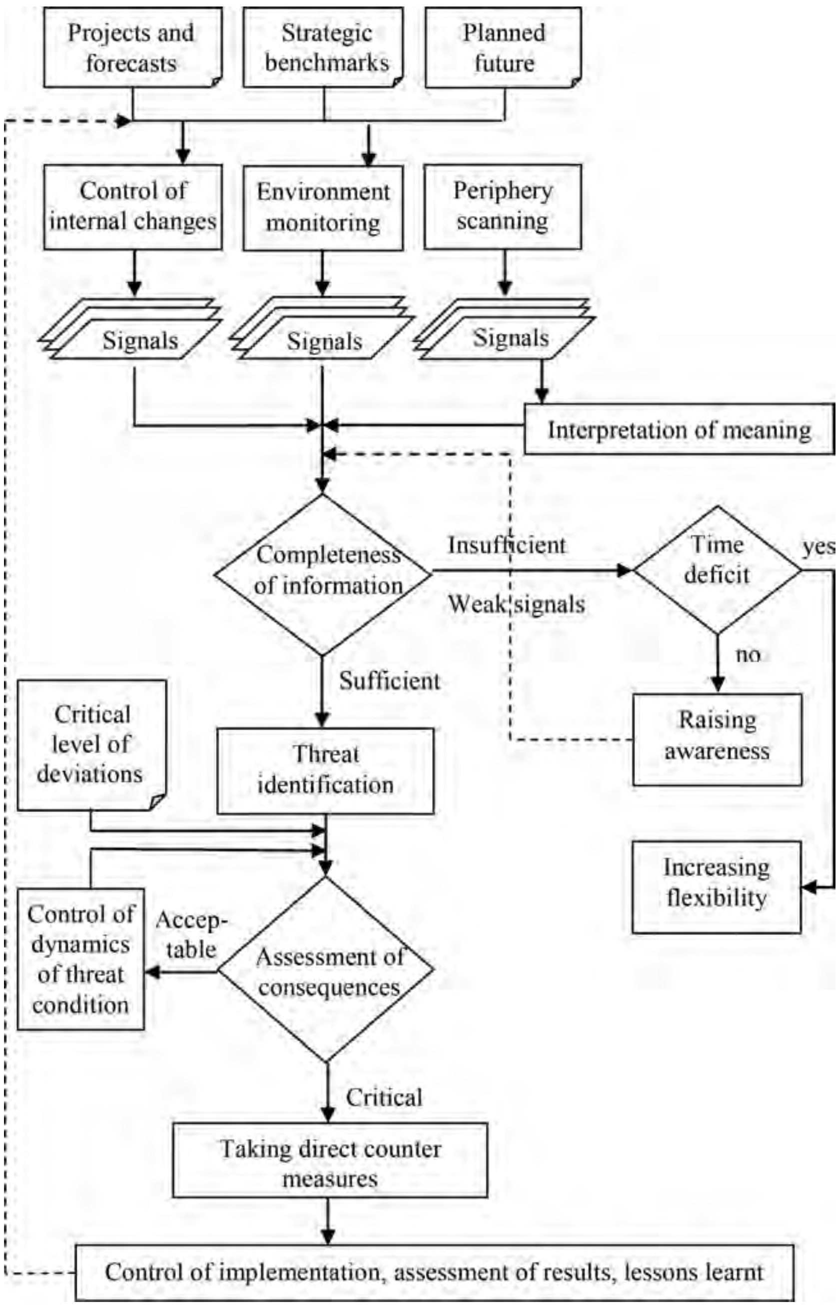

Figure 3: Proactive management model with weak signals taken into account in energy company.

It is even more dangerous not to take into account weak signals which are the harbingers of catastrophes or serious accidents. As a rule, such signals are most perceptible in the places of potential emergencies. But as people manage to prevent most of the accidents at a local level the information about a potential threat does not reach the upper level. However, when the situation gets out of hand the consequences can be disastrous. It is impossible to develop an exhaustive instruction for processing such signals, but advanced training, gaining experience, practicing interaction during drills and simulated events, active information exchange inside the energy company enables managers to reduce risks and teach employees to detect dangerous signals and act efficiently in order to prevent accidents.

Proactive management model with weak signals is presented in Fig. 3.

The testing of this model with energy companies' staff showed that the blocks Periphery Scanning and Interpreting the Meaning of Obtained Weak Signals turned out to be the most difficult ones. Moreover, 76 percent of specialists and managers participating in the project considered the demand for periphery scanning to be low and thought that the identification of threats detected by specialists and managers in their fields of work would be enough.

Yet another hindrance in the way of weak signals is limited exchange of information between the energy company's departments. Moreover, neither specialists nor managers feel the need to intensify internal information exchange and to create a single information space. Only 12 percent of managers and 9 percent of specialists support the enhancement of information exchange. At the same time, both managers and specialists are in favor of closer interaction in the functional hierarchy.

Finally, the most serious problem in the processing of weak signals is the problem of interpretation of the information contained in the signal or the second filter in Ansoff's classification [6]. Researchers have repeatedly pointed at the conservatism of mental models and difficulties connected with attempts to change them, which is essential for understanding the importance of weak signals for companies [13, 21, 26, 38]. As for the power sector, the specific character of the industry determined by heavy regulation of processes and reliability being a priority add to psychological difficulties.

Under the circumstances, it is reasonable to form a cross-functional team in an energy company to focus on futures planning and scanning for weak signals from the periphery. This group should be headed by a top manager and its members should be broad-minded and sensitive to novelties and have good communication skills. Their tasks should include intense communication with employees of different departments, active scanning of the periphery, detection of weak signals and assessment of their possible impact, arranging a broad exchange of information and monitoring of potential threats and opportunities.

5 CONCLUSION

The conducted research shows that the development of the theory and methodology of proactive management in the power industry, which is characterized by longer response time, high capital intensity and risks of catastrophic man-made and environmental consequences, is extremely important.

For advanced prevention of threats in big energy companies, it is necessary to introduce a new system that can foresee scientific, technical and organizational innovations with certain probabilistic characteristics and promptly adjust energy companies' strategies. This problem can be solved only through specialized research focused on forecasting the technological development of the power industry, forming a vision of the future and new competences. It is obvious that it will require a stronger partnership of the power industry with leading universities and research centers.

The authors propose the following issues for further studies: principles of planning the future of the power industry and management systems based on weak signals; methodology of foresight in the power industry; methodology of study of complex energy systems and risk assessment amid uncertainty; management of the corporate environment generating new knowledge and innovations.

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REFERENCES

[1] Fuerth, L.S., Foresight and anticipatory governance. *Foresight*, **11**(4), pp. 14–32, 2009. http://dx.doi.org/10.1108/14636680910982412

[2] Guston, D.H., Anticipatory governance of emerging technologies. *Journal of the Korean Vacuum Society*, **19**(6), pp. 432–441, 2010. http://dx.doi.org/10.5757/JKVS.2010.19.6.432

[3] Ramos, J.M., Anticipatory governance: traditions and trajectories for strategic design. *Journal of Futures Studies*, **19**(1), pp. 35–52, 2014.

[4] Ansoff, I.H., Managing strategic surprise by response to weak signals. *California Management Review*, **18**(2), pp. 21–33, 1975. http://dx.doi.org/10.2307/41164635

[5] Ansoff, I.H., Strategic issues management. *Strategic Management Journal*, **1**(2), pp. 131–148, 1980. http://dx.doi.org/10.1002/smj.4250010204

[6] Ansoff, I.H., *Implanting Strategic Management*, Prentice-Hall International, Englewood-Cliffs: New Jersey, p. 510, 1984.

[7] Ansoff, I.H., *Strategic Response in Turbulent Environments*, European Institute for Advanced Studies in Management, 1982.

[8] Ansoff, I.H., Conseptual underpinnings of systematic strategic management. *European Journal of Operational Research*, **19**, pp. 2–19, 1985. http://dx.doi.org/10.1016/0377-2217(85)90303-0

[9] Day, G.S. & Schoemaker, P.J.H., Peripheral vision: sensing and acting on weak signals. *Long Range Planning*, **37**(2), pp. 117–121, 2004. http://dx.doi.org/10.1016/j.lrp.2004.01.003

[10] Day, G.S. & Schoemaker, P.J.H., Scanning the periphery. *Harvard Business Review*, pp. 135–148, 2005.

[11] Day, G.S. & Schoemaker, P.J.H., *Peripheral Vision: Detecting the Weak Signals that Will Make or Break Your Company*, Harvard Business School Press: Boston, 2006.

[12] Day, G.S. & Schoemaker, P.J.H., Seeing sooner: how to scan for weak signals from the periphery. *Rotman Magazine*, pp. 64–68, 2008.

[13] Schoemaker, P.J.H. & Day, G.S., How to make sense of weak signals. *MIT Sloan Management Review*, **50**(3), pp. 81–89, 2009.

[14] Day G.S. & Schoemaker, P.J.H., Are you a ‘Vigilant Leader’? *MIT Sloan Management Review*, **49**(3), pp. 43–51, 2008.

[15] Day, G.S., Schoemaker, P.J.H. & Snyder, S.A., The vigilant organization: minding and mining the periphery. *Rotman Magazine*, pp. 34–40, 2010.

[16] Schoemaker, P.J.H., Day, G.S. & Snyder, S.A., Integrating organizational networks, weak signals, strategic radars and scenario planning. *Technological Forecasting & Social Change*, **80**, pp. 815–824, 2013. http://dx.doi.org/10.1016/j.techfore.2012.10.020

[17] Coffman, B., Weak signal research, Part I-V: Introduction, available at: http://www.mgtaylor.com/mgtaylor/jotm/winter97/wsrintro.htm

[18] Molitor, G.T.T., Molitor forecasting model: key dimensions for plotting the patterns of change. *Journal of Future Studies*, **8**(1), pp. 61–72, 2003.

[19] Molitor, G.T.T., How to anticipate public-policy changes. S.A.M. *Advanced Management Journal*, pp. 4–13, 1977.

[20] Molitor, G.T.T., Consumer police issues: global trends for the 1980's. *Advances in Consumer Research*, **8**, pp. 458–466, 1981.

[21] Kaivo-Oja, J., Weak signals analysis, knowledge management theory and systemic socio-cultural transitions. *Futures*, **44**(3), pp. 206–217, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.003

[22] Mendonca, S., Cardoso, G. & Carca, J., The strategic strength of weak signal analysis. *Futures*, **44**(3), pp. 218–228, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.004

[23] Rossel, P., Early detection, warnings, weak signals and seeds of change: A turbulent domain of futures studies. *Futures*, **44**(3), pp. 229–239, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.005

[24] Jorgensen, U., Design junctions: spaces and situations that frame weak signals – the example of hygiene and hospital planning. *Futures*, **44**(3), pp. 240–247, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.006

[25] Glassey, O., Folksonomies: spontaneous crowd sourcing with online early detection potential? *Futures*, **44**(3), pp. 257–264, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.008

[26] Ilmola, L. & Kuusi, O., Filters of weak signals hinder foresight: monitoring weak signals efficiently in corporate decision-making. *Futures*, **38**(8), pp. 908–924, 2006. http://dx.doi.org/10.1016/j.futures.2005.12.019

[27] Pina e Cunha, M., Clegg, S.R. & Kamoche, K., Improvisation as "real time foresight". *Futures*, **44**(3), pp. 265–272, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.009

[28] Hiltunen, E., Was it a wild card or just our blindness to gradual change? *Journal of Futures Studies*, **11**(2), pp. 61–74, 2006.

[29] Kuusi, O. & Hiltunen, E., The signification process of the future sign. *Journal of Futures Studies*, **16**(1), pp. 47–66, 2011.

[30] Hiltunen, E., Good sources of weak signals: a global study of where futurists look for weak signals. *Journal of Futures Studies*, **12**(4), pp. 21–44, 2008.

[31] Heinonen, S. & Hiltunen, E., Creative foresight space and the futures window: using visual weak signals to enhance anticipation and innovation. *Futures*, **44**(3), pp. 248–256, 2012. http://dx.doi.org/10.1016/j.futures.2011.10.007

[32] Hiltunen, E., Weak signals in organizational futures learning, Helsinki School of Economics, available at: http://epub.lib.aalto.fi/pdf/diss/a365.pdf

[33] Tuomo, K., Towards the dynamic paradigm of futures research. How to grasp a complex futures problem with multiple phases and multiple methods, available at: http://www.researchgate.net/publication/228727621_Towards_the_dynamic_paradigm_of_futures_research_how_to_grasp_a_complex_futures_problem_with_multiple_phases_and_multiple_methods
[34] Laakso, K., Management of major accidents – communication challenges and solutions in the preparedness and response phases for both authorities and companies, available at: http://www.researchgate.net/publication/269995668_MANAGEMENT_OF_MAJOR_ACCIDENTS__Communication_challenges_and_solutions_in_the_preparedness_and_response_phases_for_both_authorities_and_companies
[35] Korhonen, M., Tacit knowledge and weak signals in organizational learning, available at: https://publications.theseus.fi/bitstream/handle/10024/71711/Korhonen_Mika.pdf?sequence=1
[36] Adibe, P., Competence foresight: linking the identification of HR competences and competence management alignment with business strategy, available at: http://www.doria.fi/handle/10024/104884
[37] Guillaume, E.M.E., Identifying and responding to weak signals to improve learning from experiences in high-risk industry, available at: https://www.foncsi.org/fr/recherche/axes/facteurs-reussite-REX/identifying-and-responding-to-weak-signals-to-improve-learning-from-experiences-in-high-risk-industry
[38] Mendonça, S., Cunha, M.P., Kaivo-Oja, J. & Ruff, F., Wild cards, weak signals and organizational improvisation. *Futures*, **36**(2), pp. 201–218, 2004.
[39] Kim, S., Kwon, Y., Jeong, Y., Choi, S.-B., Park, J.-K. & Hong, S.-W., NEST: a model for detecting weak signals of emerging trends using global monitoring expert network, available at: http://ceur-ws.org/Vol-674/Paper114.pdf

SUSTAINABILITY FOR THE ACTORS OF A FOOD VALUE CHAIN: HOW TO COOPERATE?

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ABSTRACT

To tackle sustainability issues, food value chain actors have to study the nature and objectives of the sustainable performance they want to achieve, both individually and also for the value chain as a whole. But they have different interests, goals and strategies. Consequently, if they want to cooperate on a shared device because this represents a possible solution to improve the value chain sustainability, they need to find a way to meet a minimum level of each actor expectations. This case study is about possibilities for actors of a pork value chain representative of one type of French production to cooperate in sharing sustainability improvement solutions. The sustainable impacts of the value chain comprising a shared methanation plant with externalization of 3% of heat and 1% of electricity produced are described and analyzed. The multicriteria evaluation of the value chain is based on a life cycle analysis model with associated environmental and social indicators. The behavior of the methanation plant is simulated using *Methasim* tool and the input/output flows of the software are bridged to the LCA model. A focus is made on comparing the sustainable performance of two scenarios (standard i.e. without methanation plant and with shared methanation plant) and on confronting results with respective expectations of various players of the value chain in terms of sustainable performance. Is sharing a methanation plant a good solution for the economic actors of the value chain? How to create cooperation between the actors of a value chain in order to increase sustainability of their products and practices? The results and analysis will focus on each actor's contribution to the sustainable footprint and values destroyed or created. New intermediate solutions can be then proposed. The discussion is about methodological ways to facilitate the cooperation and the data flows to be exchanged between value chain actors.

Keywords: actors, assessment, cooperation, food, indicators, sustainability, value chain.

1 INTRODUCTION

In the food value chains, it is the transformer's or the distributor's practice which casts a decision-making power over all actors [1–2]. The growing demand for organic, local, 'free' (antibiotics, GMO, etc.) products indicates the willingness of consumers and producers to favor alternative systems development. If labels and designations adapted to these offers are now a way to reduce the complexity of the consumer's decision, they propose a limited response for the actors of food value chains. Indeed, they constitute some specifications aimed at obtaining very specific characteristics (fed with grain, source of omega-3, rich in fiber, low in fat, etc.) and for which the global sustainability is not guaranteed. Indeed, the sustainability issues are multiple and the solutions adopted to meet them not only can generate other impacts, but also move some impacts from one phase to another of the life cycle. Therefore, if the implementation of labels or claims may be the starting point for the coordination of value chain actors, it cannot be sufficient to go beyond simple specifications. Moreover, the notion of a label potentially carries the same power exercised by one actor on the others as what was identified in the dominant food systems. It is precisely to meet the objective of offering a multicriteria framework and limiting the risks of transfer of impacts that Life Cycle Analysis has been developed [3–4]. In this paper, two assumptions are made: first modeling a

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value chain and its environmental, economic and social assessment offers a systemic framework that is superior to what labels offer. Indeed, it is more valuable to the value chain actors even if the complexity of its reading makes it inaccessible to the end users/consumers. The second hypothesis exposes that this kind of model offers a common basis to the value chain actors to consider a wider reality than what their usual paradigm offers and from which new cognitive knowledge will be built. For these actors to be in a position to design together improved value chain sustainability, they need to co-design their solutions. In this perspective, the associated design and decision-making activities are considered from a socio-cognitive point of view. The construction of a solution is then not only objectified for the creation of a response to technical needs but also as a process of negotiation between different parties [5]. In his works, Bucciarelli [6] defined these parties as the different disciplines that intervene in a design process. As part of this article, it is the pluralism of the various actors in the value chain that give rise to a space for negotiation. The representations offered by the value chain modeling and the assessment of its sustainability performance are then supported to create a common space for actors in the creation and coordination of knowledge, beliefs and mutual hypotheses. These two hypotheses are discussed here in the framework of an experiment that we conducted on the modeling of a French pork value chain. Its stakeholders seek to identify solutions to improve its sustainability performance. One of the solutions resulting from one of their brainstorming was the pooling of a methanation plant from a circular economy perspective within this value chain. Chapter 2 presents a synthesis of the physico-chemical phenomena involved in methanation and the socio-technical development of this technology in France. Chapter 3 illustrates the model created and the alternative scenarios considered with the integration of a methanation plant. In this chapter, we also provide the indicators used to perform the performance evaluation. Chapter 4 is the synthetic presentation of the results compared with and without methanation plant in the value chain. Chapter 5 allows us to discuss the contribution of these results to the two hypotheses. The conclusion synthesizes the contribution of this work to the validation of our hypotheses and defines the future research needs to complement the contribution presented in this article.

2 PHYSICO-CHEMICAL PHENOMENON RELATED TO BIOGAS PRODUCTION AND SOCIO-TECHNICAL DEVELOPMENT IN FRANCE

Methanation is a technique for the production of energy and heat by the valorization of biomass [7–8]. The organic bacteria present in the material allow the fermentation of this biomass and the production of biogas [9]. The biogas produced is a gas saturated with water and made of 50 to 70% methane, 20 to 50% carbon dioxide and a few trace compounds (NH3, N2, H2S) [10]. This biogas can then be recovered in the form of biomethane fuel, for the production of electricity and heat by cogeneration, in heat production alone using a boiler, or injected into the natural gas network after purification. During hydrolysis and acidogenesis, the complex organic matter (proteins, lipids and sugars) is first degraded to the simpler molecules (amino acids, fatty acids, glucose, nitrogenous bases) by the cellular enzymes present in the material. This step is sometimes limiting in the case of compounds that are difficult to hydrolyse, such as cellulose, starch or fats. These simple substrates are used at the time of acidogenesis by the so-called acidogenic microbial species which produce alcohols and organic acids, as well as hydrogen and carbon dioxide. Then, the methanogenesis step is carried out by microorganisms which operate under strictly anaerobic conditions [11]. They belong to the reign of the archaea and some fifty strict methanogenic species are described, all anaerobic. The production of methane is carried out by two possible routes: one from hydrogen and carbon dioxide by the hydrogenophilic species and the other from the acetate by the acetoclastic species.

2.1 Performance of methanation plants: factors of variability related to technologies and practices deployed

Organic fermentable inputs derived from biomass can be classified according to their methanogenic power: waste from the food industry, livestock effluents such as manure, straw, slaughter-house water loaded with organic matter or sludge from sewage treatment plants, fermentable fraction of household refuse, etc [12]. If the slurry has a low methanogenic power, it is a substrate rich in bacteria that promotes methanation [13–15]. To ensure a satisfactory yield, it is necessary to add a mix of products with high methanogenic power, such as vegetables, the fat collected as scrap from the food industry [16–17]. Agricultural installations reuse among other things, their waste, and are based on territorial pooling models between several farms. Other inputs are added in order to obtain the best possible return in terms of electricity and heat. The nature of these inputs, which are solid or in the form of sludge, determines the dry or wet orientation of the methanation [18–19]. The technologies used differ according to the type of methanation (one or two stages, continuous or discontinuous, dry or liquid). The liquid or solid residue obtained from the fermentation can be upgraded as an organic fertilizer in substitution or in addition to conventional chemical fertilizers or in direct spreading when the spreading plan allows it (soil composition, geographical location and capacity of the soil). Beforehand, a standardization and homologation stage is necessary. If, however, the digestate cannot be recovered, it is destroyed: buried or incinerated. Cogeneration is the production of heat and electricity from biogas through a module consisting of a motor that drives an alternator [20–21]. Electrical efficiency can rise by up to 5%, and heat output allows an overall efficiency of 85%.

2.2 Economic organization of a methanation process

The main interest of cogeneration is the resale of electricity to the grid, which has to acquire electricity at a regulated price. It can be sold to supply households, businesses or local authorities, or it can be consumed whole or in part by production sites linked to methanation. Heat is recovered by heat exchangers and can be carried by hot water pipes to industries, public buildings, hospitals, collective dwellings or offices. It can also be directly used on the spot for feeding pig farms for example. As a result, cogeneration facilities are often located near areas where there is a need for heat energy to avoid the loss of transport energy. By reducing the use of fossil fuels, heat recovery leads to a reduction in pollutant emissions such as Sulphur dioxide and greenhouse gases. Finally, unlike other renewable energies that are sensitive to climatic variations, the cogeneration energy capacity is stable over time and space, and is subject to the stability of inputs. Fuels are easily stored and potentially available: waste from bio-industries, livestock effluents. It is therefore reasonable to assume that this is a reliable response to part of the electrical demand. As for heat, which is more difficult to transport, its use requires a physical approximation of the user activity in order to make the installation cost-effective. On the other hand, and even if rates act as incentives, the relative economic profitability of cogeneration systems depends heavily on the prices of fuels and competing energies. Under good conditions, cogeneration makes it possible to recover 35% of the primary energy from biogas in the form of electricity and up to 85% in total, taking into account the heat produced by the system. In France, the cost of the investment was estimated at around € 5700 per electric kilowatt for an average power of 250 kW. The Légifrance rate order of 14 December 2016 provides for the purchase of electricity for installations with a maximum electrical power of 80 kW or less, at a price of 175 € / Mwh; For those with an electrical power between 80 kW and 500 kW, at a price of 155 € / Mwh. Beyond that, an invitation to tender is required. The buyback contracts are established over 20 years now and no longer 15. There is no longer any obligation to recover the heat.

3 PRESENTATION OF THE STUDIED SYSTEM

3.1 Perimeters of the compared models

The value chain considered as a reference model describes an existing sector in which the actors involved are working to improve the sustainable characteristics of their activities and products by working on animal feed (content and proximity of supply), non-use of GMO foods, animal and human health, reduction of antibiotics and stress, increase in the cost of purchasing pigs from the farmer to take into account the efforts made and sharing the economic value created. The territorial scale considered is that of the western region of France which comprises of five administrative regions. Figure 1 shows the activities considered in our model for both scenarios: without (Scenario 1) and with methanation plant (Scenario 2). The addition of the methanation plant is represented in the Fig. 1 by the boxes colored pink. For the study, the hypothesis was made that in a sense of circular economy, the electricity and heat produced by the methanation plant are reinjected at the stages of the farm and the slaughterhouse; first because of their need for heat, and second because these two installations are supposed to be close to the methanation plant for the exchange of heat. However, the modeled methanation plant produces more electricity and more heat than necessary. Also, in the scenario 2, these flows in excess are sold at prevailing rates and used outside of our system.

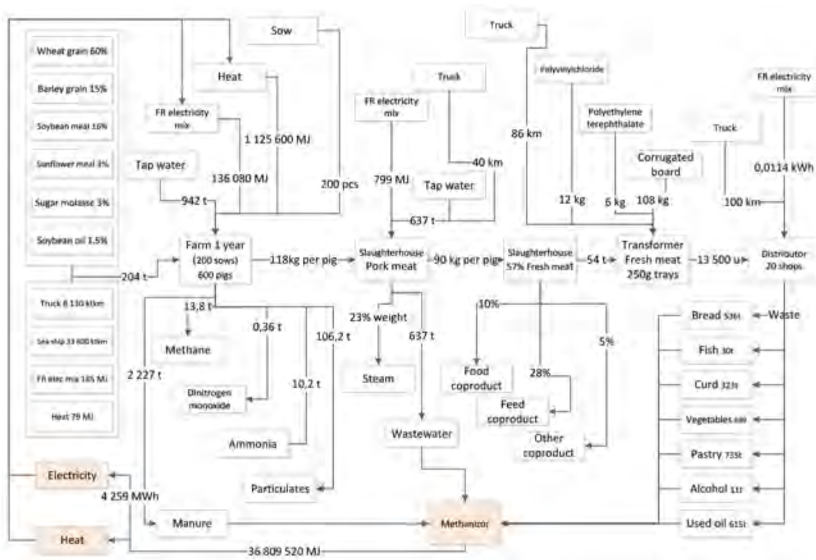


Figure 1: Perimeters of systems modeled with and without methanation plant.

The environmental advantages of these flows production is valued as follows: in the scenario 2, the impacts associated with the production of electricity and heat (by an average source representative of the French (mostly nuclear) energy mix) were modeled then subtracted from the impacts associated with the methanation plant scenario in order to take into account the impact avoided by the production of our facility.

The functional unit that sizes our model is the quantity of pig meat required for the production of 13,500 tray units of 6 chipolatas which involves breeding 600 pigs. The share of the activities and impacts related to the pig meat used in these chipolatas is dimensioned by the proportion of meat used per pig for their production.

3.2 Modeling tools used

Two modeling tools were used to conduct this study. The first one is life cycle analysis software (Simapro 8.0.5.), which allowed to evaluate and compare the environmental performance of the two scenarios. In this study, the inventory phase was carried out with real stakeholders of the French pork industry. For example, zootechnical or economic information have been collected on the ground. In order to complete this collection, the database present directly within the software databases such as EcoInvent 3 (the Swiss database) or Agri-footprint (Dutch database) were used. Finally, scientific articles and technical documentation were consulted to complete the dataset. The impact calculation phase, carried out using the Recipe 1.12 Midpoint method, widely used in the living world, made it possible to calculate specific sustainability indicators. In addition, the Methasim [22] software made it possible to size the methanation plant and its efficiency. The latter is a decision-making tool for pre-diagnosis of anaerobic digestion: it is possible to calculate the technical and economic interest of anaerobic digestion according to the choice of inputs, methanation process, purchase cost of electricity, etc. Particular attention has been paid to the nature of valuation methods of thermal energy to target the improvement provided in the tariff policy. For the purposes of this article, a minimum of data has been imposed on the tool so as to allow the latter to suggest the solutions most suited to the system studied. The characteristics chosen for the methanation plant considered in this study are: continuous liquid, the destination of the biogas: dual-fuel engine, the power of the co-generator (546 kW elec), the volume of the main digester (1807 m^3). Figure 4 presents a synthesis of the project carried out thanks to the support of Methasim. These data are then used to calculate some of the indicators suggested by this study in the following sections.

3.3 Repository used to assess the sustainability of scenarios

The framework used in this study was developed by the authors in the context of work carried out prior to this study. Presentations of these papers have been made: [23]. The authors do not have the space required to go into details on the methodology implemented and therefore propose to consider these evaluation criteria simply as a reference allowing the comparison of the two scenarios.

3.4 Data used in the model

Breeding, slaughtering and cutting phase (common to Sc1 et 2)
In this study, the inventory phase was carried out with stakeholders in the French pork industry. In addition, the database hosted by the Simapro 8.0.5 software. EcoInvent 3 (Swiss database)

and Agri-footprint (Dutch database) were used. Finally, scientific articles and technical documentation were consulted to complete this dataset. The impact calculation phase, carried out using the Recipe 1.12 Midpoint method, widely used in the living world, made it possible to calculate specific sustainability indicators.

Sizing of incoming methanation plant streams (Sc2)

The size of the methanation plant is defined by the nature and quantities of inputs available for its operation.

1. Determination of supply volumes from distribution
   A model was constructed to establish the wastes in stores on the territory in question. In our model, we retained the losses due to the partner distributor brand of our value chain (in proportion to the area of its stores in relation to the total sales area on the territory). From the INSEE (http://www.bdm.insee.fr/bdm2/index) and FranceAgrimer (https://www.rnm.franceagrimer.fr/prix?SAINOMPRODUIT; https://observatoire-prixmarges.franceagrimer.fr/resultats/Pages/ResultatsFilieres.aspx?idfiliere=6) databases, the volumes of French consumption and waste [24], by product categories, were defined and reported proportionally to the territory concerned and to the types of Shops located in this area [25].
2. Complementary inputs of the methanation plant
   - The manure of a swine operation of 200 pigs.
   - The frying oil returned to the store by consumers after use (http://www.oliobox.be/en/solution).
   - The fatty waters of a specialized porcine slaughterhouse processing 3,400 head a week.

4 RESULTS

Table 1 shows the values of indicators for each scenario. The Methane column expresses the gross impacts of our system for the scenario 2 while the Methane column with defalcation expresses the same impacts but alleviates the avoided impacts. It is therefore logical to find negative values.

Contributions of each actor of the value chain to the environmental performance are highlighted in the Tables 2 (scenario 1) and 3 (scenario2). The indicators, called Env1 to Env10, refer to those in Table 1.

As for Table 3, Table 4 shows the contributions per actor, but for the methanation plant scenario this time. A large number of values are common, except for electricity and heat indicators that have been replaced at farm level and the slaughterhouse by the production of the methanation plant modeled.

Finally, Tables 5 and 6 show the values of the two scenarios, control and methanation plant, but this time as a percentage of the total value of each indicator. Values may be common except for the flow of electricity and heat for the farm and the slaughterhouse, all the contribution rates change and this for all the actors.

The indicators in Table 1 show a very large disparity, particularly for environmental indicators, between the control scenario and the methanation scenarios. Impact reduction is important only when excess energy and heat are resold and used outside the perimeter. Some impacts are negative for the methanation with defalcation scenario; they correspond to a compensation of impacts related to energy and heat production by the methanation plant for the slaughterhouse and pig exploitation needs, plus the avoidance of impacts

Table 1: Numerical results of each scenario by indicator.

Indicator	Unity	Control	Methane	Methane with deduction
Soc1. Carcass pH	#	5,4	5,4	5,4
Soc2. Transport duration	h	8	8	8
Soc3. Foodmiles / localness (local cultures)	%	91,0	91,0	91,0
Soc4. Breeder's welfare (survey)	Score 1 to 5	2	2	2
Soc5. Employees' welfare (survey)	Score 1 to 5	2	2	2
Soc6. Biodiversity (number component /formula)	#	5,3	5,3	5,3
Soc7. Sensory evaluation score	Score 1 to 10	6,02	6,02	6,02
Soc8. Omega 6 / Omega 3 ratio	%	10,7	10,7	10,7
Soc. 9. OGM ratio	%	7,5	7,5	7,5
Soc10. Water losses after cooking (Technol quality)	%	15,45	15,45	15,45
Eco1. Additional income paid to breeder	€	0	0	0
Eco2. Production valorisation (losses)	%	5,9	5,9	5,9
Eco3. Muscles rate (economical quality)	%	60,9	60,9	60,9
Eco4. Waste (losses)	%	5,9	5,9	5,9
Eco5. Number of hires	#	0	0	0
Eco6. Additional work hours (-)	h	0	0,5	0,5
Eco7. Variation of labor cost	€	0	0	0
Eco8. Short-term investment	€/t	0	0	0
Eco9. Long-term investment	€/t	0	20	20
Eco10. Variation of manuf. cost per product	€	0	43,5	43,5
Env.1. Climate change	kg CO_2 eq	132 162	128 418	-1 558 775
Env2. Terrestrial acidification	kg SO_2 eq	5 034	5 023	943
Env. 3 Freshwater eutrophication	kg P eq	53	53	47
Env4. Human toxicity	kg 1,4-DB eq	225 389	220 041	-1 825 380
Env5. Freshwater ecotoxicity	kg 1,4-DB eq	766	762	-934
Env6. Marine ecotoxicity	kg 1,4-DB eq	102 937	101 246	-530 181
Env7. Agricultural land occupation	m^2a	325 076	325 076	325 076
Env8. Urban land occupation	m^2a	192	192	192
Env9. Water depletion	m^3	2 582	3 170	-4 220
Env10. Fossil depletion	kg oil eq	20 134	18 905	-512 980

Table 2: Contribution results (absolute values) by actor, by indicator, control scenario.

Control scenario	Sum	Distribution	Transformation	Slaughterhouse	Pigs to slaughter	Feed
Env1	132,162	1186	3230	3812	53,637	70,298
Env2	5034	5	14	12	3600	1404
Env3	53	0	0	0	10	42
Env4	225,389	6959	20,849	5041	22,698	169,841
Env5	766	8	21	4	299	434
Env6	102,937	6159	17,482	1707	7213	70,376
Env7	325,076	16	148	0	37,380	287,531
Env8	192	51	85	0	0	56
Env9	2582	4	18	247	921	1392
Env10	20,134	424	1087	1128	4759	12,736

Table 3: Contribution results (absolute values) by actor, by indicator, methanation plant scenario.

Methanation plant scenario	Sum	Distribution	Transformation	Slaughterhouse	Pigs to slaughter	Feed
Env1	128,418	1186	3230	719	52,986	70,298
Env2	5023	5	14	3	3598	1404
Env3	53	0	0	0	10	42
Env4	220,041	6959	20,849	175	22,217	169,841
Env5	762	8	21	0	299	434
Env6	101,246	6159	17,482	167	7062	70,376
Env7	325,076	16	148	0	37,380	287,531
Env8	192	51	85	0	0	56
Env9	3170	4	18	836	919	1392
Env10	18,905	424	1087	121	4538	12,736

related to the production of surplus heat and energy. This energy produced comes out of our system; it is resold and used outside our system that is not produced by an average French mix. In consequence, the difference is expected to be much less striking between the control and the simple methanation scenario than between the control and the methanation with defalcation scenario. Some indicators remain unchanged. This is the case, for example, with the occupation of urban land. The size of the various installations in the value chain does not vary between the control and methanation plant scenarios because the methanation plant is installed on existing farms and does not necessarily require an expansion of agricultural areas or new urban areas. A very large part of the social and economic indicators remain the same between the different scenarios. For example, the

Table 4: Contribution results (percentage) by actor, by indicator, scenario 1.

Control scenario	Sum (%)	Distribution	Transformation	Slaughterhouse	Pigs to slaughter	Feed
Env1	100	0.9	2.4	2.9	40.6	53.2
Env2	100	0.1	0.2	0.2	71.5	27.9
Env3	100	0.2	0.5	0	18.2	80.7
Env4	100	3.1	9.2	2.2	10	75.3
Env5	100	1.1	2.8	0.5	39	56.5
Env6	100	6	17	1.7	7	68.5
Env7	100	0	0	0	11.5	88.4
Env8	100	26.8	44.1	0	0	29.1
Env9	100	0.1	0.7	9.6	35.7	53.9
Env10	100	2.1	5.3	5.6	23.5	63.2

Table 5: Contribution results (percentage) by actor, by indicator, scenario 2.

Methanation plant scenario	Sum (%)	Distribution	Transformation	Slaughterhouse	Pigs to slaughter	Feed
Env1	100	0.9	2.5	0.6	41.3	54.7
Env2	100	0.1	0.2	0.1	71.6	27.9
Env3	100	0.2	0.5	0	18.2	80.7
Env4	100	3.1	9.5	0.1	10.1	77.1
Env5	100	1.1	2.8	0	39.2	56.8
Env6	100	6.1	17.2	0.2	7.1	69.5
Env7	100	0	0	0	11.5	88.4
Env8	100	26.8	44.1	0	0	29.1
Env9	100	0.1	0.5	26.4	29	44
Env10	100	2.2	5.2	0.6	24.1	67.3

pH of the carcass used here to characterize animal welfare does not vary between the two scenarios. The introduction of the methanation scenario does not necessarily imply an improvement in animal welfare compared to control. The same applies to the transport of live animals between the pig exploitation and the slaughterhouse. With the introduction of the methanizer, the model considered the same agricultural exploitation, located at the same distance from the slaughterhouse compared to the control scenario. In this case, the indicator does not change. Among the economic indicators, the waste rate remains the same for the actors in the value chain, such as the slaughterhouse and the processing plant. The line losses are the same whether or not there is methanation plant on the farm in the considered value chain. Finally, the contribution analysis Tables (2 to 5) show that all the values of environmental indicators are lowered thanks to the introduction of the methanation plant, in particular upstream at the level of the farm. However, since the indicators are lowered for all players in the value chain, the share allocated to farmers increases while they are responsible for 85% of the environmental impacts in our model (control scenario). We discuss in the next section how this argument can be used in favor of the farmer in the negotiation between the actors in the context of a methanation scenario introduction.

5 DISCUSSION

The aim of this study was to discuss two hypotheses: first how modeling a value chain and its environmental, economic and social assessment offers a systemic framework and secondly how this kind of model offers a common basis to build new cognitive knowledge. The results show that, within the scope of our study and within the limit of the indicators chosen, the methanation plant solution decreases the impact on a large majority of environmental indicators. When these indicators are not diminished, at worst they are unchanged. On the other hand, a large majority of social and economic indicators remain unchanged. A small share is worsened at the breeder step: additional working time, investments and the cost of production per product. The investment is inevitable in the case of the installation of a methanation plant but depending on the case, the return on investment can be more or less long and the investment more or less subsidized. The question of return on investment will be difficult to discuss to validate our assumptions. The ROI is not presented in this table and will be effectively dependent on each scenario. However, it is an argument to be exchanged in the context of negotiation among the partners. This provides the elements that can eventually be incorporated into the content of the contracts that will be established between the actors. The indicator ‘Working time’ must be analyzed in that sense: in our perimeter, its modification is related to the farmer’s activity, which implies that he must no longer be paid only for the finished product which he helps to put into market but also for the services he rendered to the society. The type of sustainability assessment promoted here makes it possible to go further than with eco-labels. It can help to apprehend socio-economic services that extend and are justified considering the added value created by the farmer and its exploitation as superior than just meat production. It should also be noted that when the energy produced in the system is taken into account and sold and used off-system, the impacts are downright negative. In other words, the methanation plant solution makes it possible to compensate for certain impacts. This is also a service to the society which cannot appear in an eco-label but which is expressed in the model proposed in this article. The information provided by this case study allows going beyond a simple specification transmitted from the downstream to the upstream. The search for a solution seems to be facilitated when it goes through a co-reflection rather than a cascade of instructions. The sharing of these representations can also enable the downstream stakeholders to better understand how they can value the work carried out by the operators upstream. It was shown how services rendered to society make it possible to extend the reflection beyond what was initially envisaged in the perimeter of the value chain alone. The contribution results Tables (2 to 5) show us that the relative contributions change enormously when a new methanation solution is put in place in a value chain. In particular, the shares allocated to the farm are increasing sharply. However, the jobs associated with crops and livestock are already undergoing a serious economic, environmental and image crisis in society. It seems inequitable to bring costs, additional impacts to actors who are already weakened, while the solution benefits everyone in terms of image and cumulative impacts. Let us assume that the sustainability impacts of a product are brought to the attention of the consumer by means of direct or indirect traceability (on the product, the packaging, via a related website, a flashcode, a promission, etc.):

the entire chain will be promoted, including the processor and the distributor. The benefit is not the farm but the entire value chain. It is therefore important that the risks and costs associated with setting up the scenario are shared by all players in the chain. It is reasonable to assume that, as part of the implementation of a shared methanation plant between the actors of a value chain, as in the setting up of any shared project, the responsibility of reducing the sustainability impact of this chain, costs, investments must be shared equally. Depending on the calculation of impact allocations, it is the responsibility of some of the most fragile actors to negotiate with the strongest players, often those at the downstream level, to share the benefits of image among all.

6 CONCLUSION

This study has shown that, in the context of the implementation of a shared methanation solution among stakeholders in a value chain, sustainability impacts are indeed reduced or maintained overall. However, on a case-by-case basis, the different contributions vary greatly with the implementation of the new scenario. The type of model developed in this article can offer a common reference framework for the actors of the value chains analyzed in order to understand the sustainability of their products and their practices from a broader perspective than they are used to. Their perimeter of responsibility is extended and this meets the expectations of consumers. It is important for the actors to co-design their improvement solutions and to associate a negotiation process between different parties and the common reference that this type of study represents thus making it possible to create and coordinate mutual knowledge. However, within the framework of the implementation of a real project and no longer a theoretical one, finer studies requiring more data are necessary in order to refine the hypotheses, and the results. On the other hand, future research remains necessary to know the prospects of mutualisation according to the type of actors studied: here the actors already work together on the sustainability of their products. One may think that this preliminary cooperation facilitated the proper introduction of the methanation plant. Would this have been the case with two actors who have never worked together or worse, with competitors? What are the limits of this work of mutualisation and structuring of the sectors?

REFERENCES

[1] Grimm, J.H., Hofstetter, J.S., Sarkis, J., Critical factors for sub-supplier management: A sustainable food supply chains perspective. *International Journal of Production Economics*, **152**, 159–173. doi : 10.1016/j.ijpe.2013.12.011

[2] Meynard, J.-M., Jeuffroy, M.-H., Le Bail, M., Lefèvre, A., Magrini, M.-B., Michon, C., Designing coupled innovations for the sustainability transition of agrifood systems. *Agricultural Systems*, 2016. doi: 10.1016/j.agsy.2016.08.002

[3] Jolliet, O., Müller-Wenk, R., Bare, J., Brent, A., Goedkoop, M., Heijungs, R., Itsubo, N., Peña, C., Pennington, D., Potting, J., The LCIA midpoint-damage framework of the UNEP/SETAC life cycle initiative. *The International Journal of Life Cycle Assessment,* **9**, p. 394, 2004. doi: 10.1007/bf02979083

[4] UNEP/SETAC, Lignes Directrices pour l'Analyse Sociale du Cycle de Vie des Produits. *Programme des Nations Unies pour l'Environnement* (PNUE), 2009.

[5] Fréard, D., Barcellini, F., Détienne, F., Baker, M., Burkhardt, J-M, Comprendre l'activité collaborative dans des communautés épistémiques en ligne: une approche socio-cognitive. *SELF*, 2012.

[6] Bucciarelli, L.L., An ethnographic perspective on engineering design. *Design Studies*, **9**, pp. 159–168, 1988. doi: 10.1016/0142-694x(88)90045-2

[7] Moletta, R., Procédés biologiques anaérobies - La digestion anaérobie des effluents. *Gestion des problèmes environnementaux dans les industries agroalimentaires*, ed. René, M. Tec et Doc, pp. 247–290, 2006.

[8] Bernet, N., Buffière, P., Caractérisation de la mise en œuvre de la méthanisation. *Chapitre 3. La méthanisation*. Editions Tec & Doc Lavoisier, pp. 39–68, 2015.

[9] Kapseu c., Nzie w., Nso e., Sieliechi j., Ngomo h., Ngaoundéré, pp. 11–17.

[10] Godon, J.-J, Aspects biochimiques et microbiologiques de la méthanisation. *Chapitre 2. La méthanisation*. Editions Tec & Doc Lavoisier, pp. 12–37, 2015.

[11] Ghouali, A., Sari, T., Harmand, J., Maximizing biogas production from the anaerobic digestion. *Journal of Process Control*, **36**, pp. 79–88, 2015.

[12] Rivas, I.D.R., Modélisation de la diversité microbienne dans les procédés de digestion anaérobie. Univ. Montpellier 2 (Sciences et Techniques), p. 247, 2008.

[13] Rouillé, B., Teinturier, C., Chaabouni, R., Eudier, S., Lucas, M., Le Cozler, Y., Les coproduits en méthanisation: quel intérêt et quelle compétition avec l'alimentation animale?, *Collection Résultats IDELE*, p. 39, 2015.

[14] Battimelli, A., Carrere, H., Delgenes, J.P., *Saponification of fatty slaughterhouse wastes for enhancing anaerobic biodegradability*. 2. International Conference on Engineering for Waste Valorisation, WasteEng 2008, Patras, 2009.

[15] Rousseau, P., Etude, Modélisation et optimisation d'un procédé de traitement des lisiers de porcs par couplage de la digestion anaérobie et du traitement biologique de l'azote. *Université de Rennes*, **1**, p. 215, 2009.

[16] Sialve, B., Bernet, N., Carrere, H., Prétraitements thermiques des lisiers : impact sur la cinétique et le taux de conversion en méthane. *XIIIème Congrès de la Société Française de Génie des Procédés*. Lavoisier Editions, Lille, pp. Axx1–Axx7, 2011.

[17] Jeannequin, B., Plénet, D., Carlin, F., Chauvin, J.-E., Dosba, F., *Réduire les pertes alimentaires dans les filières Fruits, Légumes et Pomme de terre. CIAG 2014 : Carrefours de l'Innov*. Agro. «Associations Végétales», Paris, p. 138, 2015b.

[18] Rouille, B., Le Cozler, Y., Chaabouni, R., Eudier, S., Lucas, M., Thual, J., *Recensement des pratiques d'utilisation des coproduits par les éleveurs méthaniseurs en France. Rencontres autour des Recherches sur les Ruminants*. IDELE - INRA, Paris, p. 188, 2015.

[19] Buffière, P., Frédéric, S., Les technologies de la méthanisation des résidus solides. *Eau, l'Industrie, les Nuisances*, pp. 14–19, 2008.

[20] Abbassi-Guendouz, A., Trably, E., Dumas, C., Brockmann, D., Steyer, J.-P., Delgenès, J.-P., Escudié, R., *Rôle du transfert de matière dans la limitation de la digestion anaérobie par voie sèche. XIVe congrès SFGP 2013*. SFGP, Société Française de Génie des Procédés, Lyon, pp. 1–7, 2013.

[21] Bernet, N., Buffière, P., *Caractérisation de la mise en œuvre de la méthanisation. La méthanisation*. Editions Tec & Doc Lavoisier, pp. 87–113, 2011.

[22] Levasseur, P., Aubert, P., Berger, S., Charpiot, A., Damiano, A., Meier, V., Quideau, P., Développement d'un calculateur pour déterminer l'intérêt technico-économique de la méthanisation dans les différents systèmes de productions animales: Méthasim, 2011.

[23] Petit, G., Bertoluci, G., Trystram, G., Lecomte, C., Chapdaniel, A., *Innovations in attractive and sustainable food for health*. 28th EFFoST International Conference, 7th International Food Factory for the Future Conference, 2014.

[24] Agence Française De L'environnement Et De La Maîtrise De L'énergie (Ademe), Pertes et gaspillages alimentaires : L'etat des lieux et leur gestion par etapes de la chaine alimentaire – Rapport. p. 164, 2016.
[25] Nielsen, 2014. Nielsen trends résultats au 26 janvier 2014.

SUSTAINABLE CITY 2016

OVERVIEW

The 11th International Conference on Urban Regeneration and Sustainability (The Sustainable City) took place at the University of Alicante in Spain. The meeting was the occasion to award the 13th Prigogine Medal.

The Conference addressed all aspects of urban environment, aiming to provide solutions leading towards sustainability. The meeting originated in Rio (2000), followed by Segovia (2002), Siena (2004), Tallinn (2006), Skiathos (2008), A Coruña (2010), Ancona (2012), Kuala Lumpur (2013), Siena (2014) and Medellin (2015). The 2016 Conference was co-organised by the University of Alicante, represented by Professor Antonio Galiano-Garridos, and the Wessex Institute, represented by Professor Carlos A. Brebbia.

Most of earth's population now lives in cities and the process of urbanisation still continues generating many problems deriving from the drift of the population towards them. These problems can be resolved by cities becoming efficient habitats, saving resources in a way that improves the quality and standard of living. The process however, faces a number of major challenges, related to reducing pollution, improving main transportation and infrastructure systems. New urban solutions are required to optimise the use of space and energy resources leading to improvements in the environment, i.e. reduction in air, water and soil pollution as well as efficient ways to deal with waste generation. These challenges contribute to the development of social and economic imbalances and require the development of new solutions.

The challenge of planning sustainable cities lies in considering their dynamics, the exchange of energy and matter, and the function and maintenance of ordered structures directly or indirectly, supplied and maintained by natural systems.

The Conference addressed the multi-disciplinary aspects of urban planning; a result of the increasing size of the cities; the amount of resources and services required, and the complexity of modern society.

OPENING OF THE CONFERENCE

The Conference was opened by Professor Carlos A. Brebbia who referred to the excellent and long-established links between several research groups at the University of Alicante and his own Wessex Institute. Alicante – Carlos explained – is a comparatively young and dynamic University committed to a programme of excellence in all its areas of research. The city itself combines a rich history with a lovely coastline and beaches. The old centre, in particular, contains many historic churches and buildings. The most representative site in the city is the Castle of Santa Barbara, situated in an imposing elevated location from where the whole city and surrounding coastline can be fully appreciated. The Castle itself was a defence fort since prehistoric times. It became a major defence site during Moorish times and was considerably enlarged after that by the Christian reign of Spain. Its rich and varied history parallels that of Alicante itself.

Carlos then explained the importance of this Conference for the programme. Sustainable City is one of the most important meetings organised by the Wessex Institute and in many ways indicative of its interdisciplinary type of activities. WIT – Carlos explained – encourages the dissemination of knowledge at international level and fosters interdisciplinary collaboration.

Sustainable City is part of WIT's international conference programme, which consists of 20 to 25 meetings per year. In addition, the Institute carries out a variety of training and research activities on its own Campus in the New Forest National Park, located near Southampton.

Professor Carlos A. Brebbia opening the conference

WIT – Carlos explained – is renowned throughout the world for its pioneering work on setting up the basis of the Boundary Element Method (BEM), a computational method used for solving engineering and science problems. The basis of the method – and indeed its name – originated in the research group at Southampton University, before the work moved to the Wessex Institute.

Research and Development work continues at the Wessex Institute campus on further advances and applications of BEM. Carlos then proceeded to show a series of representative examples demonstrating the use of BEM as a simulation tool in aerospace, energy engineering, hydrocarbon problems, medical studies, mechanical applications, electromagnetics, and others.

Another important objective of WIT is the dissemination of knowledge. In this regard the Institute has taken an important step in making all its papers – such as those presented at this conference – freely available on its website. Colleagues from all over the world can download this PDF. This gives greater visibility and large numbers of citations to papers presented at WIT conferences, which are also listed in Google Scholar and other important databases.

Consistent with its aim of bringing together different disciplines and exploring new areas of research, WIT has launched a series of International Journals which are now becoming well established. Of particular interest to this conference is the one on Sustainable Development and Planning. Others related to this meeting are Design & Nature and Ecodynamics, and Safety and Security Engineering (all these papers are also freely available in the Institute eLibrary site http://www.witpress.com/elibrary).

During a recent conference that also took place at the University of Alicante – Carlos said – a new Journal was launched, Heritage Architecture. The publication, in spite of its short history, has proved to be highly popular and has attracted numerous contributions.

Carlos ended his welcoming address by thanking the delegates for their participation in this important meeting and, in particular, to the University of Alicante for hosting the conference.

ADDRESSES FROM THE UNIVERSITY OF ALICANTE

Professor Juan Llopis, Vice Rector for International Relations, welcomed the participants in the name of the University of Alicante and thanked them for having participated in the Conference. He also expressed his appreciation to the Wessex Institute for having arranged for the meeting to be held at the University.

Juan explained the importance of Urban Development for Spain where the construction industry is of primary importance. Alicante has been impacted by the recession of the building industry with relation to tourism.

The University of Alicante carries out research on different aspects of urban sustainability. The University Campus itself, which is new, has been developed with a large number of open green spaces.

The University, in spite of its recent foundation, has grown considerably in the last few years, reaching now a number of 30,000 or so students, 4,000 of which are postgraduates. Teaching and research are carried out by 2,500 members of staff.

The University of Alicante is always keen to develop strong links with other institutions and to add new international projects to the many already underway.

Professor Antonio Galiano, Head of the School of Architecture, then welcomed the delegates and spoke of his commitment as Director of International Relations to foster strong links with other schools.

KEYNOTE PRESENTATIONS

The Conference programme was enhanced by a series of keynote addresses by well-known speakers:

- "Urban metabolism and regenerative economics", **Brian Fath**, Towson University, USA.
- "Relative vulnerabilities of urban residential development to oil depletion: pilot case studies of a representative building typology in the Australian context", **Roger Brewster**, Bond University, Australia.
- "Reforging spatial identity for social sustainability", **Robert Barełkowski**, West-Pomeranian University of Technology, Poland.
- "Public participation in the process of improving quality of the urban frame", **Antonio Galiano**, University of Alicante, Spain.
- "Urban growth and urban infrastructure relations in Turkey", **Sirma Turgut**, Yildiz Technical University, Turkey.
- "Exploring affordances of the street", **Andrew Furman**, Ryerson University, Canada.
- "Social conflicts in coastal touristic cities. Holistic renovation of buildings in Benidorm", **Victor Echarri,** University of Alicante, Spain.

- "The role of public spaces to achieve urban happiness", **Marichela Sepe**, University of Naples, Italy.
- "Planning and management challenges of tourism in natural protected areas in Baja California, Mexico", **Rosa Rojas-Caldelas**, Autonomous University of Baja California, Mexico.
- "Illegal pedestrian crossing at traffic signals: a study on tourist behaviour", **Antonio Pratelli**, University of Pisa, Italy.
- "Urban management foundation in Risk Reduction", **Cristina Olga Gociman**, University of Architecture and Urban Planning, Romania.
- "Water quality of the beach in an urban and not urban environment", **Yolanda Villacampa**, University of Alicante, Spain.

SPECIAL SESSIONS

There were also three special sessions organised by members of the International Scientific Advisory Committee, as follows:

Special Session on Sustainable urban regeneration and public spaces, organised by **Marichela Sepe**, University of Naples, Italy, consisting of papers on the following topics:

- The role of public spaces
- Place identity and sustainable urban regeneration
- Quality of public spaces and sustainable urban development
- Place making and its implications for social value
- Interdisciplinary transformation of Warsaw University of Technology buildings
- Sustainable living methods
- Concepts and methods to evaluate uses of a noise polluted site
- Urban regeneration of public spaces in down town Cairo
- Solid waste management strategies
- Social dimension of urban renewal, the case of Yildirim districts
- An approach to identify Naples real driving cycle regarding WLTC framework

Special Session on Pedestrian behaviour in different traffic situations, organised by **Antonio Pratelli**, University of Pisa, Italy, consisting of papers on the following topics:

- Pedestrian crossing at traffic signals
- Modern and ancient pedestrian mobility
- Pedestrian level of service

Special Session on City and beach, organised by **Yolanda Villacampa**, University of Alicante, Spain, consisting of papers on the following topics:

- Water quality on the beach
- Urban development in Denia and its influence on the beach
- Alicante beach, city sustainable development
- Alicante coastal management
- Sustainable development in the city-beach of Alicante

CONFERENCE TOPICS

The numerous papers presented at the conference were classified under a series of topics, as follows:

- Urban conservation and regeneration
- Urban strategies
- Urban metabolism
- Urban planning and design
- Urban development and management
- Landscape planning and design
- Urban regeneration and public spaces
- Quality of life
- Waterfront developments
- Architectural issues
- City and beach
- Socio-economic issues
- Transportation
- Pedestrian behaviour
- Case studies – sustainable practices

PRIGOGINE MEDAL 2016

The conference was the occasion of awarding the Prigogine Medal to the 2016 candidate, Professor Brian Fath. The ceremony was presided by the Vice Rector, Professor Rafael Muñoz Guillena. The academic process included twenty or so doctors from many different countries, as well as from the University of Alicante.

The Vice Rector opened the act, inviting Professor Carlos A. Brebbia to say a few words about the history and the person and personality of Professor Brian Fath. Carlos proceeded as follows:

"Ilya Prigogine was born in Moscow in 1917, and obtained his undergraduate and graduate education in chemistry at the Free University in Brussels. He was awarded the Nobel Prize for his contribution to non-equilibrium thermodynamics, particularly the theory of dissipative structures. The main theme of his scientific work was the role of time in the physical sciences and biology. He contributed significantly to the understanding of irreversible processes, particularly in systems far from equilibrium. The results of his work have had profound consequences for understanding biological and ecological systems.

"The Prigogine Medal was established in 2004 by the University of Siena and the Wessex Institute to honour the memory of Professor Ilya Prigogine, Nobel Prize Winner for Chemistry. This medal is awarded annually to a leading scientist in the field of ecological systems. All recipients have been deeply influenced by the work of Prigogine.

Professor Carlos A. Brebbia and Professor Brian Fath at the awards ceremony

Previous Prigogine Laureates are:

2004 Sven Jorgensen, Denmark

2005 Enzo Tiezzi, Italy

2006 Bernard Patten, USA

2007 Robert Ulanowicz, USA

2008 Ioannis Antoniou, Greece

2009 Emilio del Giudice, Italy

2010 Felix Müller, Germany

2011 Larissa Brizhik, Ukraine

2012 Gerald Pollack, USA

2013 Vladimir Voeikov, Russia

2014 Mae-wan Ho, UK

2015 Bai-lian Larry Li, USA

Brian D. Fath is Professor in the Department of Biological Sciences at Towson University (Maryland, USA) and Research Scholar within the Advanced Systems Analysis Program at the International Institute for Applied Systems Analysis (Laxenburg, Austria). His research is in the area of systems ecology and network analysis applied to the sustainability and resilience of socio-ecological systems. His interests range from network analysis to ecosystem theory to urban metabolism to systems thinking and environmental philosophy. Dr Fath has taught courses on ecological networks and modelling in many different locations around the world. He holds visiting faculty appointments at the School of Environment, Beijing Normal University and at the State Key Laboratory of Urban and Regional Ecology, Chinese Academy of Sciences both in Beijing, China. He was also Fulbright Distinguished Chair at Parthenope University of Naples, Italy.

He has published numerous research papers, reports, and book chapters. He co-authored three books; he is Editor-in-Chief for the journal Ecological Modelling; President of the North American Chapter of International Society for Ecological Modelling and, among other appointments, he is a member and present Chair of Baltimore County Commission in Environmental Quality.

The Vice Rector then proceeded to award the medal to Professor Brian Fath and invited him to deliver his inaugural address, which was entitled “Systems Ecology, Energy Networks and a Path to Sustainability”.

Prigogine Award Ceremony

ABSTRACT OF THE PRIGOGINE ADDRESS

One of the great advances of the 20th century was the rise of a formal systems science and systems thinking. This progress influenced ecology in ways that provided new insight to the structure and function of ecosystems using tools from thermodynamics, networks, information theory, and more. This led to a better understanding of how ecosystems function in terms of using available energy to create complex structures to move away from thermodynamic equilibrium and how these self-organizing structures adapt to changing situations. Ecological goal functions can measure this orientation of ecosystem growth and development. This presentation will address how these metrics attuned for ecosystems have relevant application in socio-economic systems. In particular, Energy network science (ENS) is a new paradigm that draws from thermodynamics, information theory, and network analysis to assess the organization, patterns, and dynamics of diverse systems such as ecosystems, financial systems, and urban metabolism. ENS will be demonstrated for community resilience in terms of 10 measures of regenerative vitality. These measures can help urban and community planners improve the overall 'metabolic' performance of the relevant ecological, economic, or social systems.

(Note the full version of the presentation can be found in the International Journal of Design & Nature and Ecoynamics, Volume 12 Number 1 which can be freely downloaded from the digital library of the Wessex Institute at http://www.witpress.com/elibrary.

ISAC committee meet over dinner

SOCIAL OCCASIONS

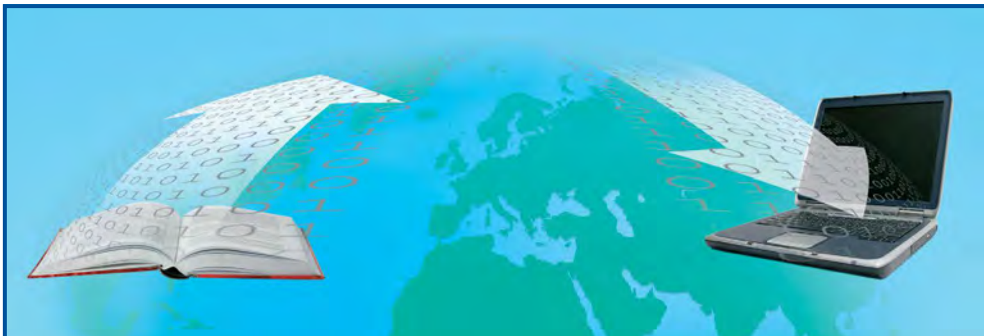
The International Scientific Advisory Committee (ISAC) met over dinner to discuss the meeting and arrange for it to be reconvened in 2017. The general impression is that the conference has been very successful and the list of topics describes well the objectives of the meeting. Nevertheless a few more themes were proposed to ensure that Sustainable City 2017 attracts the latest developments. A few more names for the ISAC were nominated by the Committee.

The Conference dinner took place in a well-known restaurant located in the Alicante marina. The excellent cuisine and good local wines provided an excellent environment to strengthen the links between the participants. The night was made more enjoyable by the performance of a music and dancing group which performed local pieces using typical Alicante musical instruments. The recital was excellent and well received by the delegates who had a unique opportunity to listen to regional music.

CLOSE OF THE CONFERENCE

The Conference was closed by Carlos who thanked all delegates for having participated in the meeting and particularly the authors who contributed to the sessions of the conference. He hoped that they will continue to be in contact with WIT and be able to visit its Campus next time they are in the region.

Conference banquet



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Sustainable Development and Planning VIII

Edited by: ***C.A. BREBBIA,*** *Wessex Institute of Technology, UK,*
S.S. ZUBIR*, Universiti Teknologi Mara, Malaysia and*
A. S. HASSAN*, Universiti Sains Malaysia, Malaysia*

The 8th International Conference on Sustainable Development and Planning is part of a series of biennial conferences on the topic of sustainable regional development which began in Greece in 2003. The papers included in these proceedings report on the latest advances from scientists specialising in the range of subjects included within sustainable development and planning.

Planners, environmentalists, architects, engineers, policy makers and economists have to work together in order to ensure that planning and development can meet our present needs without comprising the ability of future generations.

The use of modern technologies in planning gives us new potential to monitor and prevent environmental degradation. Problems related to development and planning, which affect both rural and urban areas, are present in all regions of the world and accelerated urbanisation has resulted in both the deterioration of the environment and quality of life. Urban development can also intensify problems faced by rural areas such as forests, mountain regions and coastal areas, which urgently require solutions in order to avoid irreversible damage.

The papers in the book cover the following topics: City Planning; Urban Strategies; Sustainability and the Built Environment; Regional Planning; Environmental Planning and Management; Costal Regions; Sustainable Solutions in Emerging Countries; Policies and Planning; Socio Economic Issues; Community Planning; Culture and Heritage; Energy Resources; Transportation; Mobility and Urban Space; Air Quality; Water Management; Waste Water.

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