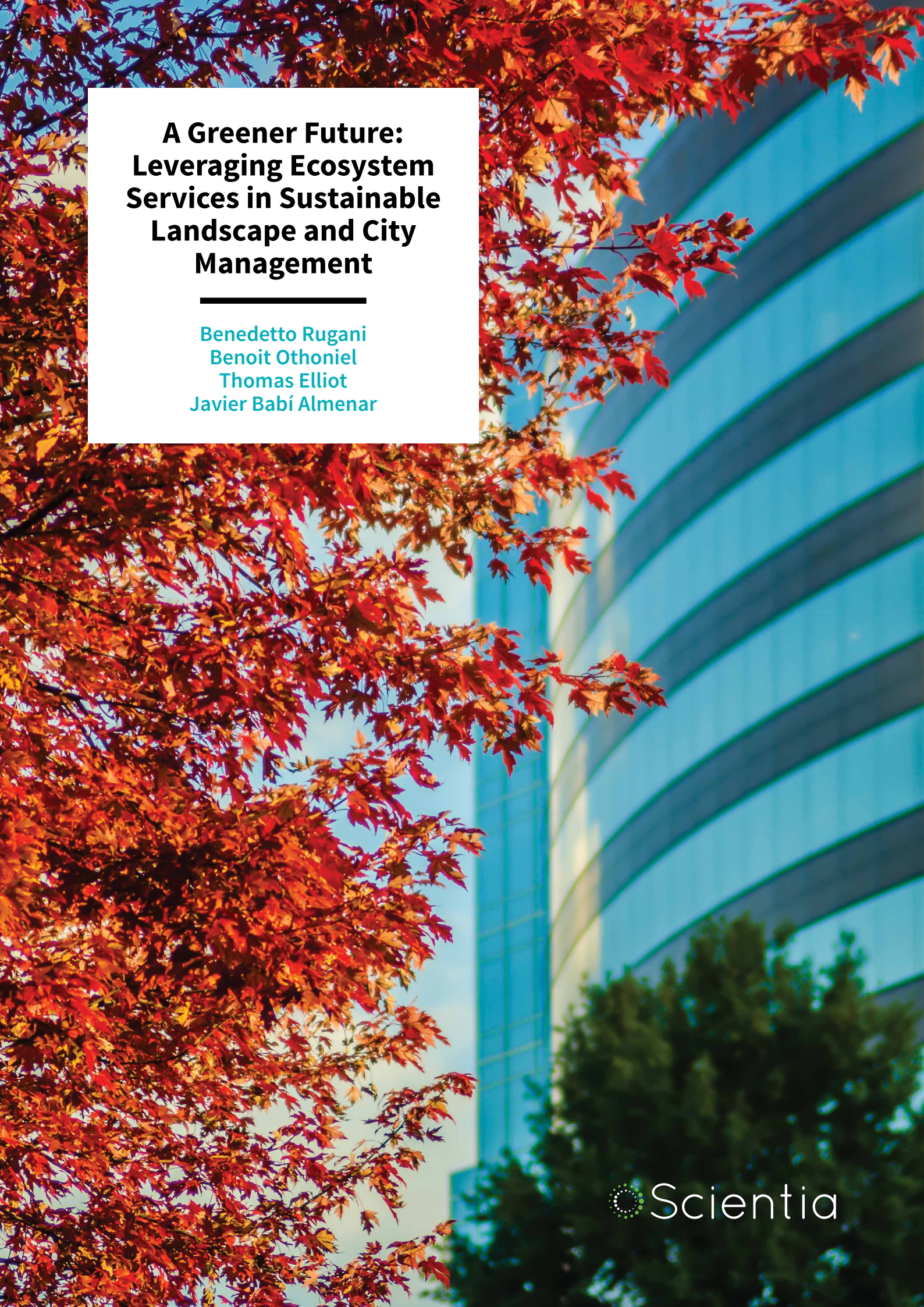

A Greener Future: Leveraging Ecosystem Services in Sustainable Landscape and City Management

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Scientia

A GREENER FUTURE: LEVERAGING ECOSYSTEM SERVICES IN SUSTAINABLE LANDSCAPE AND CITY MANAGEMENT

As global climate change and other major environmental threats advance, scientists are looking for ways to evaluate sustainable solutions for energy, agriculture and city management. Ecosystem services are benefits provided to humans by nature, and over the past two decades researchers have begun refining ways to assess the value of these services compared to human-made options. **Dr Benedetto Rugani** and his team are developing novel ways to assess ecosystem services and advance the use of nature-based solutions in urban areas.

In 2005, after four years of rigorous research, the United Nations published the Millennium Ecosystem Assessment – an extensive review of the state of our planet's ecosystems. A popular term that emerged from the assessment is 'ecosystem services' – benefits that humanity gleans from nature around the world.

Ecosystem services are natural processes that support human economy and quality of life, such as harvesting fish from the sea or enjoying a hike in a national park. Generally, ecosystem services are divided into four categories: support services, such as nutrient recycling in the soil and production of carbohydrates by plants; provisioning services, which allow us to obtain food, clean water, raw materials, and energy from our environment; regulating services, which purify our air and water, sequester carbon, and break down waste; and cultural services, the functioning of ecosystems that we enjoy for recreation, science, and education.

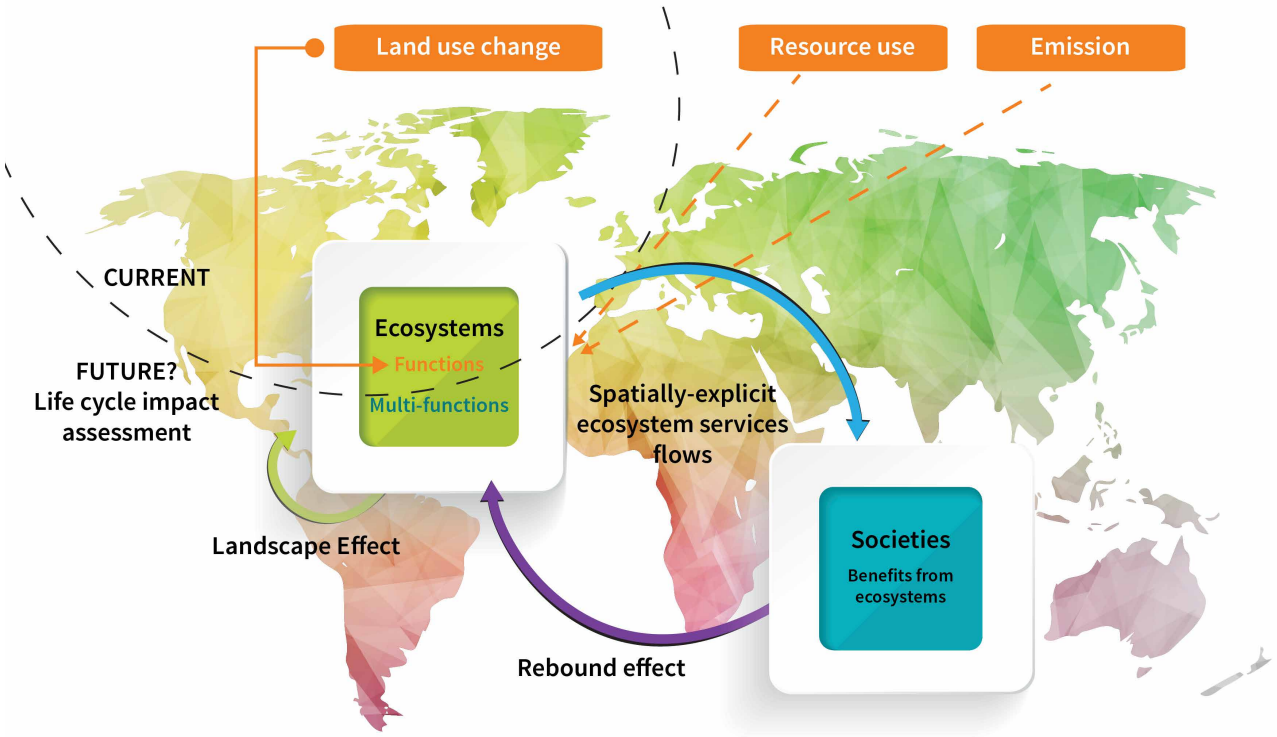
Valuation of ecosystem services, notably their monetisation, is becoming increasingly popular, as climate change and ecosystem loss threaten habitats worldwide. For example, some estimates put the agricultural value of honeybees and other insects pollinating crops in the US at $29 billion a year, underscoring the critical importance of protecting hive health. In a seminal paper from 1997, ecological economists estimated that the environment provides on average $33 trillion USD in ecosystem services worldwide every year (over $50 trillion in today's money), many of which would be nearly impossible for humans to replicate or replace even with modern technology.

One of the most recently proposed approaches to estimate changes in ecosystem services provision is by using the Life Cycle Impact Assessment (LCIA) – a cause-effect modelling framework that allows us to evaluate the impacts of human behaviour on a given ecosystem service. The problem with most LCIAs is that they focus narrowly and statically on single interaction pathways, while in reality, ecosystems are affected by a variety of dynamic relations and interacting factors. Habitats fluctuate in a multitude of ways that can mediate or amplify the effects of human activity, thus most LCIA models are limited in their ability to predict how a given change will impact an ecosystem service.

At the Luxembourg Institute of Science and Technology, Dr Benedetto Rugani and his close-knit team of graduate students, Benoit Othoniel, Thomas Elliot and Javier Babi Almenar, are engaged in developing multi-faceted measures of ecosystem services, improving LCIA methods and transforming land use planning, with a special focus on urban environments. Through their important work, the team hopes to contribute to a more sustainable future for humankind.

Placing Ecosystems in Context

The foundation of the team's work began in 2014, when the Luxembourg National Research Fund provided a grant for Dr Rugani to develop more rigorous LCIA frameworks. The VALUing Ecosystem Services for environmental assessment (VALUES) project employs novel methodologies to calculate the physical or monetary value of ecosystem services, in order to identify ways in which land managers and urban planners can most effectively utilise ecosystem services, while simultaneously protecting and preserving the ecosystem itself. The endpoint of VALUES is to create new scientific knowledge to advance the current LCIA practice for ecosystem services assessment.



Inspired by Othoniel et al., https://pubs.acs.org/doi/abs/10.1021/acs.est.5b03706

To meet these aims, the team predicted that they could take a page from the Multi-Scale Integrated Model for Ecosystem Services (MIMES), a framework that integrates the effects of multiple ecological and human activities on an outcome. This builds a more realistic picture of how complex environments operate and provides more robust predictions about how a particular activity is likely to impact an ecosystem in context.

Further, the team wanted to incorporate time-series data from both geographic information systems and statistical surveys to increase the resolution and representativeness of the model outputs. Accordingly, researchers can track changes in biodiversity, population dynamics, use of goods and services and land cover changes over time and create maps of ecosystem services over a region to identify areas that should be protected.

Utilising MIMES principles, the VALUES framework incorporates this data with features and knowledge from other modelling tools, to predict the impact of land use changes on pollinator activity and carbon sequestration in Luxembourg, and extending this approach to other ecosystem services in the European and global economies.

The integrated models developed through VALUES also allow researchers to predict changes in ecosystem service supply across different regions according to a multi-scale approach, thus supporting the development of more sustainable land management policies. For example, using the VALUES version of MIMES, one can assess whether land use changes in one country, including the demand for new productive land areas, can affect the delivery of ecosystem services locally and in other countries.

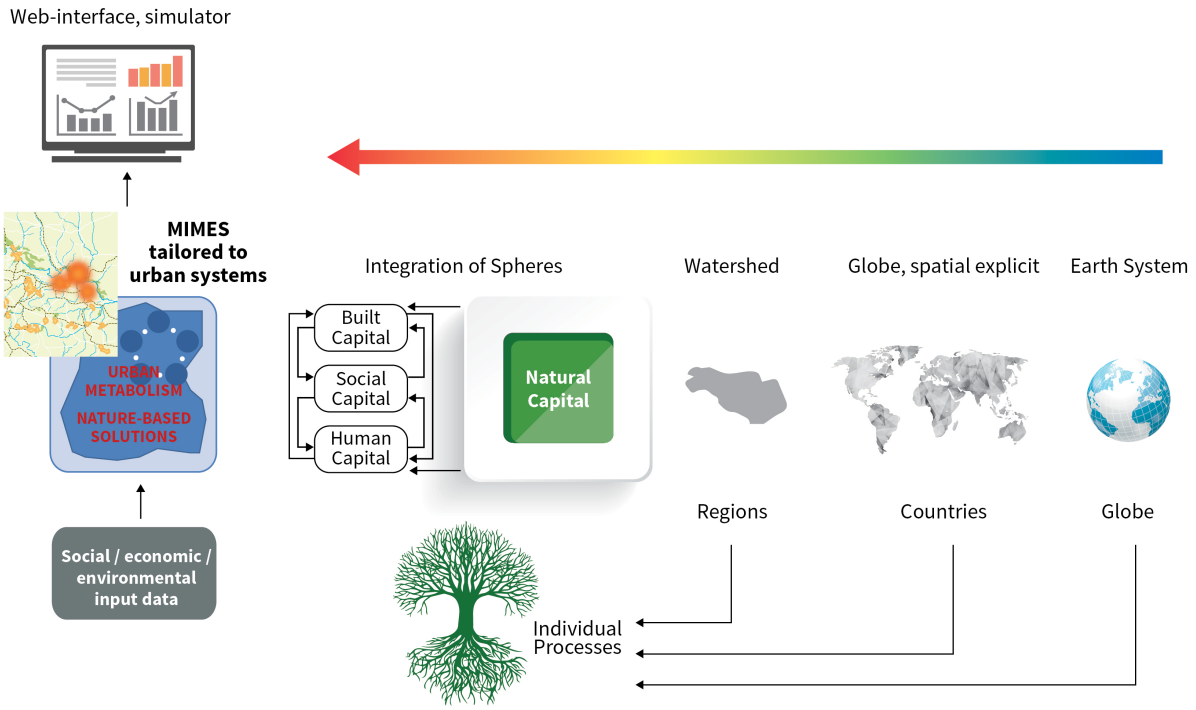
Estimating Ecosystem Impacts in Urban Areas

Because the city is where most of the population aggregates and consumes, and is where most environmental impacts are generated or solicited, the next logical step for Dr Rugani's team's work is to translate the findings of the VALUES project into practical tools that can aid urban planners and other built environment professionals in developing more sustainable cities.

Over half of the world's population live in major metropolitan areas, where large numbers of people and motor vehicles coupled with limited green areas often make for high levels of resource consumption and pollution, with potentially drastic effects on the health of city inhabitants and world climate as a whole. This is particularly true in developing countries, where less environmental regulation and older vehicles often converge to reduce air quality or increase noise pollution. A tool that could help urban planners and policy makers confidently plan high-impact nature-based solutions in urban areas could have a transformative effect on both the health of city residents and the global climate.

To understand city health on a grand scale, Dr Rugani and his team focus on what the scientific community calls 'urban metabolism', which describes the flow of materials and energy in a city, most often carbon. If city planners are able to accurately predict the effects of various ecological projects on the environmental and socioeconomic improvement of urban metabolism, they can make more informed decisions towards building healthier, more sustainable cities.

To this end, the team is developing ESTIMUM – the Ecosystem Services Toolbox – developed from multi-scale Integrated Modelling of Urban Metabolism. Building on the successes of VALUES, ESTIMUM utilises a system dynamics approach to simulate complex city environments under various conditions and situations, to determine which sustainability solutions will have the most positive impact across the widest breadth of climatic, environmental, and



Inspired by Boumans et al., https://www.sciencedirect.com/science/article/pii/S2212041615000054

technological scenarios. The tool will help city stakeholders simulate, monitor, and manage environmentally friendly ventures.

The team is currently testing a beta version of ESTIMUM with city planners in Esch-sur-Alzette in Luxembourg, Siena in Italy, and Lisbon in Portugal, to evaluate the performance of the tool across multiple climates and city sizes. So far, their results are promising.

For instance, the test model for Lisbon considers the synergistic effects of different transport modes, fuel types, population dynamics, and carbon and water cycles. This model simulates, under different scenarios, how in Lisbon urban trees provide both local and non-local ecosystem service co-benefits relating to carbon sequestration, heat island effect and water regulation. These preliminary findings allow for the quantification of net energy savings as a result of increasing urban trees, for example.

Bringing Nature to the City

Dr Rugani and his team recognise the powerful impact that natural solutions can have on cities and communities, not only in practical terms of ecosystem services, but also the psychological benefits that nature provides to city residents. One of their major goals is to help 're-nature' urban areas, but in order for cities to implement large-scale nature projects, there is a need for stakeholders to understand the potential costs and benefits of such a project, as well as a need for access to information and resources to facilitate sustainable urban planning.

The team's newest venture is framed within the European Union's Horizon 2020 programme, and is dedicated to evaluating and advancing nature-based solutions for city management in Europe, while creating a database of solutions that can benefit cities globally. To accomplish this, the team is partnering with numerous universities, research organisations, industry leaders, and policy makers to pilot the 'Nature4Cities' project in four cities across the EU: Milan in Italy, Çankaya in Turkey, Szeged in Hungary, and Alcala de Henares in Spain.

Over the next three years, Nature4Cities has four primary goals. First, the team will collaborate with other 25 partners to build a nature-based solution knowledge base that will be publicly available, and will include frameworks for analysing potential solutions. Second, they will use their integrated assessment expertise to develop a holistic assessment method that incorporates inputs from policy, business, and finance along with ecosystem services measures, to help identify the best solutions for each city's unique situation.

Third, they will adapt existing urban management processes to suit nature-based solutions, working to engage citizens and collect urban data that will drive re-naturing projects forward. Finally, the team will work with the four pilot cities to implement actual nature-based projects and assess how well their predicted scenarios align with real-life results.

Each of these goals will continue to build upon and inform the others. The knowledge base and analyses will continue to grow and be refined by contributions from partners and findings from the pilot cities. As governance models develop through the collaborative efforts of citizens, politicians, researchers, and industry stakeholders, best practices for facilitating participation will be added to the available resources.

A Sustainable Future

By understanding the dynamics and potential of ecosystem services, we can identify sustainable solutions for modern environmental problems. By developing resources to help cities understand how they can use nature-based solutions to enjoy healthier cities at lower costs, Dr Rugani's team is helping to fight climate change and build a greener future.

ESTIMUM and Nature4Cities are poised to become international resources that help cities leverage ecosystem services in novel ways that improve quality of life for residents and reduce pollution, creating a healthier, more sustainable world for everyone.




Meet the researchers

Benedetto Rugani

Dr Benedetto Rugani is a Research & Technology Associate at the Luxembourg Institute of Science and Technology, affiliated to the department of Environmental Research and Innovation, within the RDI Unit on Life Cycle Sustainability and Risk Assessment. During the last 7 years, Dr Rugani has contributed to the improvement and combination of existing methodological approaches and indicators to assess the environmental impact of life cycle activities on the supply of natural resources and ecosystems productivity. His current research and project management activity focuses on developing modelling approaches and decision support tools for assessing ecosystem services, with a focus on urban systems.

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Benoit Othoniel

Benoit Othoniel is an agronomic engineer and PhD researcher, particularly interested in the management of resources and land. After diverse experiences abroad, from working on palm populations in Madagascar, to irrigation systems in Cambodia, he started a PhD thesis on the assessment of land use and ecosystem services in life cycle assessment. By combining theoretical knowledge on ecology, economics and sociology in models, his aim is to develop tools and indicators that can support the design of sustainable development strategies at multiple scales, from local to global.

Thomas Elliot

Thomas Elliot is a PhD researcher at MIT Portugal in Lisbon, while also working with Dr Rugani at the Luxembourg Institute of Science and Technology. Originally from New Zealand, his professional background is in mathematical modelling and energy systems. His research interests include ecological economics, Life Cycle Assessment, and environmental ethics. His PhD topic incorporates ecosystem dynamics with urban metabolism in pursuit of enhancing decision support for sustainable urban planning. His work is inspired by an intrepid journey from New Zealand to Europe by bike and sailing yacht in the year following his Master's degree, during which he was exposed to some challenging negative social and ecological environments. Those experiences have shaped his philosophy towards strong sustainability.

Javier Babí Almenar

Javier Babí Almenar is a PhD researcher with BA and MA degrees in Architecture from the Polytechnic University of Valencia, a BSc in Environmental Sciences from the University of Valencia, and an MSc in Integrated Landscape Ecology from Cranfield University. He is interested in the study of socio-ecological systems, especially urban contexts, under a systems dynamics approach integrating knowledge and tools from urban metabolism, urban ecology, and life-cycle thinking. The chief purpose of his research is to better understand how to redesign urban systems in a more sustainable manner using nature-based solutions.

FURTHER READING

VALUES – VALUing Ecosystem Services for environmental assessment. More information available at: http://www.lifecycle-values.lu/; National Research Fund Luxembourg (FNR; C13/SR/5903117).

ESTIMUM – Ecosystem Service Toolbox developed from multi-scale Integrated Modelling of Urban Metabolism. More information available at: http://www.list.lu/en/project/estimum/; National Research Fund Luxembourg (FNR; C16/SR/11311935).

Nature4Cities – Nature Based Solutions for re-naturing cities: knowledge diffusion and decision support platform through new collaborative models. More information available at: https://www.nature4cities.eu/; European Commission / H2020 – Topic: SCC-03-2016: New governance, business, financing models and economic impact tools for sustainable cities with nature-based solutions (urban re-naturing); grant no. 730468.

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