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D4.1 – Development of a multi-scale system dynamics assessment framework for nature-based solutions in cities

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Glossary

Acronym	Full name
CICES	Common International Classification of Ecosystem Services
D2.1	Deliverable 2.1 (Nature4Cities) "System of integrated multi-scale and multi-thematic performance indicators for the assessment of urban challenges and NBS"
EC	European Commission
EbA	Ecosystem-based Adaptation
EEA	European Environment Agency
ES	Ecosystem Service(s)
GI	Green Infrastructure
HAVC	Heat, Air Ventilation, and Cooling
IUCN	International Union for Conservation of Nature
LULC	Land Use Land Cover
MAES	Mapping and Assessment of Ecosystems and their Services
MEA	Millennium Ecosystem Assessment
MIMES	Multiscale Integrated Modelling of Ecosystem Services
NBS	Nature-based Solutions
NUTS	Classification of Territorial Units for Statistics
PET	Physiological Equivalent Temperature
SEEA	System of Integrated Environmental-Economic Accounting
SDM	System Dynamics Model
SME	Small and Medium Enterprise
SPE	Service Providing Elements
SPU	Service Providing Unit
SUDS	Sustainable Urban Drainage Systems
TEEB	The Economics of Ecosystems and Biodiversity
UC	Urban Challenge
UES	Urban Ecosystem Service(s)
USC	Urban Sub-Challenge
UE	Urban Ecology
UK NEA	United Kingdom National Ecosystem Assessment
UM	Urban Metabolism
UN	United Nations
UPE	Urban Political Ecology
USLE	Universal Soil Loss Equation
WFD	Water Framework Directive
WP	Work Package

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Executive Summary

The mainstreaming of urban Nature Based Solutions (NBS) requires a better understanding of their economic benefits and co-benefits, contributing to the assessment of their sustainability, feasibility and advantages against traditional solutions. The most suitable and effective approaches to assess the sustainability of NBS are the ones that explicitly consider the technosphere and eco-sphere nexuses and quantify benefits and co-benefits through the valuation of urban ecosystem services.

In this context, the aim of Deliverable 4.1 is to define a system dynamics modelling framework at different spatial and temporal scales for assessing ecosystem services (ES) supplied by NBS designed to address specific challenges of urban environments. The modelling framework of any process-based model has to provide an adequate representation of the real system and generate accurate output behaviours. In this sense, the development and validation of system dynamics models requires the fulfilment of the following stages: (i) problem description and definition; (ii) system conceptualization; (iii) model formulation; (iv) validation and evaluation of structure and behaviour; and (v) implementation. The first three stages and initial works for the fourth stage were developed as part of this deliverable.

For the description and definition of the problem, an extended literature review was done to identify a large group of existing urban challenges, ES, and NBS and establish the links between these components. From that large group, a smaller set of urban challenges, ES, and NBS was selected for inclusion in the modelling framework. This selection was then followed by a revision of conceptual NBS frameworks, land management and ecological restoration techniques, which together with the work conducted in the Task 1.1 informed the development of an urban NBS typology for modelling purposes.

The system conceptualization and an initial model formulation was supported by the identification of the biophysical structures and socio-ecological processes related to the provision of the selected ES, following the ES cascade framework. This identification was based on the initial literature review, complemented by the review of studies investigating relations between structures and processes as well as studies describing existing ES process-based models. The review of these sources permitted the identification of main variables (input, intermediate variables and outputs) and processes to be considered in the system dynamics model and, together with the outputs from the Task 2.1, facilitated the identification of suitable proxy-parameters to use as ES indicators.

Moreover, it was also necessary to characterize the urban systems in which the NBS are developed. For this purpose, the urban system boundaries (primary and secondary) and urban typologies at different spatial levels (urban region, city/metropolis, and neighbourhood) were

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identified via descriptive indicators, based on an integrated urban metabolism and urban ecology perspective. The metropolis/city level was identified as the primary system boundary, whilst the urban region level as the secondary one. The advantage of using a double system boundary perspective is related to the possibility to consider the dependency of the urban systems on their surrounding environment and the potential burden shifting. This characterization was supported by key references of urban sustainability, urban ecology and urban metabolism as well as a review of the grey and scientific literature on urban systems. The sets of descriptive indicators identified for urban system boundaries and urban typologies were narrowed down making use of two criteria: *easiness* (i.e. calculated from available data and without requiring specific tools or models), and *replicability* for different urban areas in Europe. Moreover, the selection of indicators for urban typologies favoured those indicators adequate for all or several of the spatial levels against others, ensuring consistency among different levels and ultimately obtaining a reduced core set of indicators.

Based on the previous stages, an initial representation of NBS and urban systems in modelling framework was developed by extending and adapting the Multiscale Integrated Model of Ecosystem Services (MIMES) to urban systems, providing the model conceptualization and an initial model formulation. MIMES is built using a system dynamics approach and was originally developed for regional studies. This modelling framework is capable of representing complex systems, such as coupled human and natural systems including their exchanges and feedbacks. Designing a modelling framework of NBS and urban systems via the MIMES approach therefore allowed to acknowledge the behaviour of these complex systems and better informing on the cost-effectiveness of urban NBS in a more realistic form.

A first evaluation of the model structure was done making use of data gathered from pilot cities and small and medium enterprises, which assessed the availability of input variables considered for the model, including their adequate temporal and spatial resolution, and helped to understand if substantial modifications to the initial modelling framework were required. A second evaluation of the structure of the model was supported on expert knowledge gathered through a workshop with external advisors. This double evaluation permitted to understand that there is a lack of data available for the urban systems across the pilot cities and their sites of intervention, which may jeopardise the development of the model, their testing, and calibration. Nevertheless, it assisted in the refinement of the urban system boundaries, served to test the interest of the definition of urban typologies at different spatial levels, and allowed the definition of a modelling temporal scope for the models.

The main output of Deliverable 4.1 is the definition of a system dynamics modelling framework for assessing ES supply by urban NBS that can inform their effectiveness for addressing main challenges of urban systems. In order to do so, two main modules were defined following the MIMES approach: NBS module and urban system module. The NBS module focuses on the calculation of ES as final outputs, also considering changes in the consumption of materials and

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energy to inform the impact of certain ES (e.g. the impact of the regulation of temperature and humidity in the consumption of energy). In contrast, the urban system module aims to understand how the supply of ES by NBS could affect the urban metabolism by modifying the demand of materials and energy.

For the development of this modelling framework, an extended literature review was further performed, which constitutes a second valuable output of the present Deliverable. This work of review allowed to identify urban challenges directly related to NBS based on the works of D2.1, and supported the selection of an ES classification system (i.e. CICES) with ES classes that can be linked to specific urban challenges. Moreover, the study of the literature could suggest how to adapt the NBS typology of the Task 1.1 for modelling purposes, and assisted the selection of NBS types able to provide the ES, which are relevant for the future integrated assessment of the case studies proposed by the pilot cities (WP7).

A third output worth mentioning is the identification of the main processes and biophysical and social factors influencing the supply of ES. These helped to define parameter proxies for the selected ES classes (outputs of the model), and the main compartments, submodels, relations, and assumptions underpinning the system dynamics NBS module based on MIMES.

Additionally, the modelling framework, the selected ES classes and their parameter proxies provide a basis for the current development of an economic assessment scale (Task 4.2) to monetarise the values of ES provided by NBS, which can be compared with the NBS life cycle costs.

Finally, this report shows that a knowledge gap still exists regarding the explicit relationship among biophysical structures, processes and supply of ES. It also highlights that there is a lack of environmental, economic and social data for urban systems which could hamper the development of system dynamics models for assessing cost-effectiveness of NBS, but also for those assessing urban sustainability at high temporal and spatial resolution. This implies that further efforts are required to develop methods for easy data collection, which would minimise the impact that data scarcity could have in the implementation of future system dynamics models.

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