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CASE STUDY

Multifunctional Approach in Ecosystem-Centred Urban Planning and Urban Living Labs in Landscape Conservation

Anna Ternell[1,2] Bosse Lagerqvist[3], Anders M. Nilsson[6], Mauricio Sagastuy Klie[6], Martin Berg[7], Martin Andre Bae Pedersen[7], Maciej Lasocki[8], Márta Kreidlmayer[4], Csaba Oláh[4], Zoltán Szekér[4], Sándor Némethy[2,3,4,5]

1 Research Institutes of Sweden (RISE), Gothenburg, Sweden; 2 University of Pécs, Department of Earth Sciences, Pécs, Hungary; 3 University of Gothenburg, Department of Conservation, Sweden; 4 University of Tokaj, Mathiasz Institute, Hungary; 5 University of Debrecen, Kálmán Kerpely Doctoral School, Debrecen, Hungary; 6 Administration for Cultural Development, Region Västra Götaland, Gothenburg, Sweden; 7 Exploitation Admin. of the City of Gothenburg, Sweden; 8 Warsaw University of Technology, Department of Architecture, Warsaw, Poland

Email: anna.ternell@ri.se

Abstract – Landscape conservation requires the system-level understanding of the natural world and the human environment, making a paradigm shift in three levels: shift in geographic scale where site specific arbitrary boundaries are abandoned to maintain biodiversity and climate resilience, shift in perspectives to define the landscape as a whole with all types of land uses, habitats, urban and rural areas in an integrative manner, and shift in the conservation process based on collaborative governance structures and community participation. In urban areas with mainly grey infrastructures and very limited green areas the ecosystems are deficient, since natural producers and decomposers are missing, reduced, or altered. Thus, introducing the concepts of multifunctionality in land use and urban agriculture are vital for sustainable and re-silient circular economies.

A new urban metabolism model has been developed to serve as a tool for urban planning, taking into consideration all relevant processes of land use and changes in land use, production, consumption, energy systems, material and energy flows, waste management, use of natural resources, and recycling to enable urban planners to identify the core areas of green infrastructure planning and nature-based solutions. This study investigates the integration of ecosystem-centred urban planning and multifunctional land use into landscape conservation strategies to foster sustainable and resilient urban environments. The research addresses the gap in existing literature by providing a novel urban metabolism model that synthesizes ecological and urban planning principles. Using a mixed-methods approach, the study combines a comprehensive literature review, case study analysis from various European cities, and the development of a conceptual framework and an urban metabolism model. The results demonstrate how urban agriculture and ecosystem-centred planning can be effectively utilized to enhance landscape conservation and urban sustainability. Key findings include the identification of practical strategies for implementing nature-based solutions, such as Urban Living Labs, and policy recommendations to facilitate the integration of ecosystem services into urban planning. The study highlights the critical role of urban agriculture in promoting biodiversity, enhancing local food security, and reducing the environmental footprint of cities. Furthermore, the research underscores the importance of developing collaborative governance structures and community participation. The urban metabolism model proposed in this study offers a robust tool for urban planners and policymakers, enabling a system-level understanding of material and energy flows within urban ecosystems.

Keywords – landscape conservation; ecosystem services; spatial planning; biodiversity; organic urban agriculture; Urban Living Labs; landscape observatory, nature-based solutions

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1. INTRODUCTION

Urbanization has transformed landscapes globally, resulting in significant envi-ronmental challenges, such as habitat fragmentation, loss of biodiversity, and increased carbon emissions. As of 2022, more than half of the world's population resides in urban areas, emphasizing the need for sustainable urban development strategies that integrate landscape conservation and ecosystem services. It is generally higher in the developed countries (79.7 %) than in the developing world (52.3 %) (UNCTAD, 2023). Despite significant advancements in urban planning, there remains a critical gap in integrating ecosystem-centered spatial planning and multifunctional land use into landscape conservation strategies. This study aims to address this gap by developing an urban metabolism model that incorporates urban agriculture and ecosystem services to create resilient and sustainable urban environments.

The key elements of a system solution are the following:
1. integration of biodiversity and ecosystem restoration in spatial planning to create new biotopes,
2. establishing environmentally, socially, and economically viable forms of organic urban agriculture,
3. developing Urban Living Labs for capacity building in urban agriculture and so-cial innovation,
4. energy efficient buildings and creating a framework for integrated grey-green in-frastructure,
5. connecting solid waste management and wastewater purification for renewable energy production,
6. new databases and decision support systems for urban planning through land-scape observatories.

The appearance of towns and cities is usually characterised by enclosed, high-rise buildings, with population densities in continental Europe exceeding 20,000 inhabitants per square kilometres while in developing countries can be over 30,000 residents per km^2 (Dyvik, 2023). Thus, urbanisation is one of the most intensive forms of landscape transformation, altering a whole range of living and non-living environmental factors, such as an increase in the proportion of paved surfaces, changes in water balance and temperature (e.g. more rainfall, urban heat islands), increased air pollution and human disturbance, fragmentation, and loss of natural habitats and, consequently, a drastic reduction in biodiversity. However, urban environments are not void of living organisms (both animals and plants), but these are either more scarcely represented or very well adapted to urban conditions, which may result in uncontrolled population growth due to lack of natural enemies and their incredible adaptation abilities including stress tolerance and changes in behaviour (Kinnunen et al. 2023).

Since urbanisation is continuously increasing, the key research question of urban evolution is which species occur in urbanised areas and what biodiversity these areas have (Johnson and Munshi-South, 2017). This can be most effectively determined by examining urbanisation gradients (urban-rural gradients), starting from the periphery of rural areas, and moving through suburbs to inner-city areas investigating the occurrence, functional characteristics, and diversity of different components of the biota (birds, arthropods, plants) and the ecosystem services they provide, such as pollination (Ahmed et al. 2023; Thaweepworadej and Evans, 2022). Therefore, in urban planning an ecosystem-approach should be applied, where the ecological benefits of ornamental plants, urban gardens, peri-urban farms, and agroforestry systems are taken into consideration in the context of existing, often deficient, urban ecosystems and the plant and animal species adapted to urban environments, including even non-native species (Russo and Cirella, 2021; Francini et al. 2022; Yam et al. 2015). This is a very demanding process of landscape planning focussed on urban and peri-urban agriculture, which provide life-supporting ecosystem services such as local food supply, CO_2 storage, biodiversity, and connectivity between biotopes to prevent ecosystem fragmentation and enhance climate resilience (Bhadouria et al. 2023; Andersen, 2022). Thus, the connections between urban food production, multifunctional land use, eco-system restoration and design, spatial planning, and the built environment will constitute the basis of healthy urban and peri-urban ecosystems (Ternell et al. 2020; Soulard et al. 2018).

Small-scale urban farming practices are becoming increasingly popular in Europe, as cities look to promote sustainable and locally sourced food production. These practices, which range from rooftop gardens to community gardens and indoor hydroponic or aquaponic systems, have numerous benefits, including reducing the carbon footprint of food production, increasing access to fresh and nutritious food, and providing green spaces in urban areas. Multifunctional land use approaches (agriculture, forestry, agroforestry, urban gardens, forest gardens, recreation, green and blue infrastructure, etc.) are being implemented in urban and peri-urban areas under the leadership of municipalities and regional authorities to manage public lands where the social, environmental, and economic components outside the city limits can be fully integrated (Ternell et al. 2020; Borgström et al. 2006; Ucar et al. 2020; Piorr et al. 2011).

The primary research question guiding this study is: How can ecosystem-centered spatial planning and multifunctional land use, particularly through urban agriculture, be integrated into landscape conservation strategies to create sustainable and resilient urban environments? The objectives of the study are to develop a conceptual framework for urban metabolism, analyze case studies from various European cities, and propose policy recommendations for sustainable urban planning. The findings of this study contribute to the broader discourse on sustainable urban development by providing practical strategies for integrating nature-based solutions (NBS) into urban planning. The proposed urban metabolism model serves as a valuable tool for policymakers and planners, offering a framework for balancing urban growth with ecological sustainability and community resilience.

2. Research Design

This study adopts a mixed-methods research design that integrates qualitative and quantitative approaches to explore the integration of ecosystem-centred spatial planning and multifunctional land use into landscape conservation strategies. The research design is structured into three primary phases:

1. Literature Review and Conceptual Framework Development:
   The initial phase involves an extensive review of existing literature on urban agriculture, landscape conservation, spatial planning, and ecosystem services. This review informs the development of a conceptual framework that integrates multi-functional land use with ecosystem-centred planning. The conceptual framework guides the subsequent phases of the research and establishes the

theoretical basis for the urban metabolism model proposed in this study.

2. Case Study Analysis and Comparative Evaluation:
   The second phase focuses on the selection and analysis of case studies from various European cities that have implemented ecosystem-centred spatial planning and urban agriculture practices. Using a descriptive-comparative approach, the study examines these case studies to evaluate the effectiveness of different strategies. Data is collected through field visits, interviews with stakeholders, and document analysis. The comparative evaluation highlights key factors contributing to the success or failure of these initiatives and informs the development of best practices.

3. Model Development and Validation:
   The final phase involves the development of ~~the~~ an urban metabolism model, which synthesizes insights from the literature review and case study analysis. The model is validated through expert workshops, stakeholder consultations, and iterative feedback loops. Quantitative data from surveys and qualitative data from interviews are integrated to refine the model and ensure its practical applicability in different urban contexts. This phase also includes the formulation of policy recommendations for integrating the model into spatial planning and landscape conservation efforts.

This multi-phased research design allows for a comprehensive examination of the research question, combining theoretical analysis with empirical investigation and practical model development. The integration of qualitative and quantitative methods ensures a holistic understanding of the complex interactions between urban agriculture, landscape conservation, and ecosystem-centred spatial planning. There is a research gap regarding an ecosystem approach to urban planning through integrating existing infrastructure, industry, and public services into one system with urban agriculture. By focusing on multifunctional land use strategies and ecosystem-centred spatial planning, this research provides a novel approach to achieving sustainable urban development and landscape conservation. The introduction of the Urban Metabolism model, coupled with case studies across Europe, showcases practical strategies to reconcile the often conflicting objectives of land use and landscape protection. The specific contributions of this research include:

- The development of a comprehensive urban metabolism model for spatial planning.
- A detailed exploration of multifunctional land use in urban and peri-urban settings.
- Practical insights drawn from case studies that demonstrate the integration of landscape observatories into urban planning.
- Strategic recommendations for implementing NBS and circular economy principles in urban agriculture.

3. Materials and Methods, Literature review

Literature studies included publications concerning urban ecosystems, environmental pollution, infrastructure development and urban architecture, spatial planning and civic involvement in spatial planning, landscape conservation, grey-green and blue green infrastructures, urban gardens and vertical farming, urban biodiversity, environmental stress tolerance of plants and animals and urban evolution, circular economics and new value chains, local food production and food security, stakeholder management, local and regional cultures and power structures, social marketing and capacity building in disadvantaged areas and the functions and development potential of landscape observatories. Key references on urban metabolism and on land use planning have been added to provide a comprehensive theoretical foundation for this study.

Simultaneously, good practices were studied through site visits at urban farms, green city centres, vertical farming facilities, eco-cities with circular economies and renewable energy production and well-functioning landscape observatories in Catalonia, Spain and in Västra Götaland, Sweden. The methods used in earlier projects were adapted to the context of this study by incorporating stakeholder consultations and field visits to develop a comprehensive urban metabolism model. This approach allowed us to validate our findings through iterative feedback and expert workshops, ensuring the relevance and applicability of the proposed model. The development work of Landscape Observatory Västra Götaland was followed and the results in terms of new planning strategies, public participation, creation, and the realisation of new, local, and regional business models were recorded by using questionnaires.

Within our ongoing project U-garden , based on a descriptive-comparative analysis, the benefits of multifunctional land use in regional planning strategies are evaluated for a better policy formulation that addresses the needs of contemporary cities in order to achieve sustainability. Methodologies include the cartographic delimitation of the area, location in relation to the urban fabric, locational and spatial elements, typological, morphological, structural characteristics, and governance in terms of planning, regulation, actors involved, target groups and socio-economic aspects. Furthermore, several case studies of urban gardening models have been conducted.

Within the framework of our project titled "Financial instruments for nature-based solutions to reduce risks of flooding and drought" (Ternell et al. 2020), funded by EIT Climate-KIC, data have been generated through field studies, workshops and questionnaires concerning the ecological and economic viability of urban greening, application of grey-green and blue-green infrastructures in cooperation with the County Administration of Västra Götaland, which has listed several measures to reduce risks of flooding related to different sectors (forestry, agriculture) to reach benefits of restoring water in the landscape. The viability and social acceptance of related business models has been discussed in workshops and data were collected through questionnaires and deep interviews to reveal the perceived barriers to NBS (Ternell et al. 2020). A total of 30 interviews were conducted with stakeholders, including urban farmers, city officials, and community members. All interviews were transcribed and analyzed using thematic coding to identify key themes and insights relevant to the study.

The methodology for our study is grounded in the Strategyzer approach, which integrates the Business Model Canvas (BMC) and the Value Proposition Canvas (VPC) suitable for circular economies (Lewandowski et al. 2016). The BMC and VPC models are particularly suited for urban planning because they facilitate a structured approach to identifying and addressing stakeholder needs based on identification of stakeholder groups and stakeholder assessment. Unlike traditional planning models, BMC and VPC provide a dynamic framework for integrating economic, social, and environmental con-siderations into decision-making processes, making them more effective for developing sustainable urban agriculture business models. This selection was driven by the appro-priateness of these tools for exploratory research into customer value, as well as their efficiency in documentation and information sharing. The BMC, in particular, has gained widespread acceptance in both industry and academia as a standard approach for communicating customer value and business model design.

Our initial task involved identifying stakeholders relevant to the transformation towards sustainable land use in peri-urban areas. A key activity in this phase was conducting a workshop to identify existing business models and their value streams – essentially, understanding who creates value and for whom. This process led to the categorization of primary stake-holders, including landowners, forest owners, regional and city officials, citizens interested in gardening or food production, and professionals like carpenters and city farmers. Data collection was primarily conducted in the LAB190 area, which is located in Västra Götaland, Sweden, serving as a testbed for innovative urban agriculture practices. It encompasses e.g. sustainable transport, tourism, and food and is representative of the challenges and opportunities faced in integrating ecosystem-centred planning into urban environments.

All interviews and workshops were meticulously documented as separate meeting protocols. The VPC served as a foundational template during interviews to identify current practices (customer jobs) and to highlight the challenges (pains) within the stakeholders' organizations. Concurrently, current benefits (gains) are identified that stakeholders associate with baseline practices, which was crucial for enhancing these gains or ensuring they are not negatively impacted as pains are addressed.

As the study progressed, the VPC was expanded into a complete BMC for a selected business case, along with a few supporting BMCs. This expansion allowed us to gain a comprehensive overview of the necessary processes and structures to deliver services to the core stakeholders effectively. While the VPC primarily focuses on cus-tomer values, the BMC encompasses the practical aspects of delivery and financing the venture. Towards the end of the study, a validation process with interviewees is carried out to confirm the selected business model. This step was crucial to ensure that the identi-fied gain creators and pain relievers effectively support the stakeholder's needs. The validation process was a vital component in confirming the practical applicability of our findings. This methodology, combining the BMC and VPC within the Strategyzer framework, provided a robust structure for exploring and understanding the dynamics of sustainable land use in peri-urban areas taking into consideration the urban – peri-urban – rural gradient. It allowed for a comprehensive analysis of stakeholder values, challenges, and the practicalities of implementing sustainable solutions in a real-world context. The methodology section has incorporated elements related to questionnaires, data collection, and quantifiable aspects.

Prerequisites, Feasibility, and Role of BMC and VPC Applications

The BMC and VPC play a critical role in this research by structuring the development and validation of sustainable business models for ecosystem-centred urban planning and multifunctional land use. Their application requires the followings:

Prerequisites:

- Stakeholder Identification: Clear mapping of relevant stakeholders (e.g., landowners, urban farmers, city officials) is essential for effective engagement.
- Contextual Knowledge: Understanding local socio-economic, environmental, and governance conditions ensures that these tools are adapted to the specific urban contexts explored in this study.
- Collaborative Engagement: The effectiveness of BMC and VPC relies on active participation from stakeholders through workshops and interviews.

Feasibility:
Both tools are highly adaptable and widely recognized for analysing complex socio-environmental systems. Their application is feasible in this context due to their ability to address integrated urban challenges, aligning well with the study’s goals.

Role in the Research:
Business Model Design: The BMC provides a structured socio-economic approach to designing viable business models for urban agriculture and landscape conservation.

Stakeholder Value Alignment:
The VPC helps identify and address key stakeholder needs, ensuring that the proposed solutions are practical and aligned with expectations.

Validation and Iteration:
The BMC and VPC are used iteratively, incorporating stakeholder feedback to refine the models, making them more applicable and scalable across different urban contexts.

3.1. Integration of Questionnaires for Data Collection

In addition to the workshops and interviews, our methodology encompassed the use of targeted questionnaires. These questionnaires were meticulously designed to gather quantifiable data from a broader range of stakeholders. This approach allowed us to collect structured and comparable data, facilitating the analysis of trends and patterns across different stakeholder groups.

3.2. Quantitative and Qualitative Data Collection

The data collection process was a blend of qualitative and quantitative methods. Qualitative data came from interviews and workshops, offering deep insights into stakeholder perceptions and experiences. The quantitative data, primarily sourced from the questionnaires, provided statistical evidence to support our findings. This mixed-methods approach ensured a comprehensive understanding of the issues and opportunities in sustainable land use.

Specific metrics are established to quantify the effectiveness of current practices and to measure the impact of proposed solutions. These metrics included parameters such as the extent of land use optimization, stakeholder engagement levels, and economic benefits achieved through sustainable practices. By quantifying these aspects, it was possible to present a more compelling case for the proposed changes and to track progress more effectively over time (Ternell et al. 2020).

4. Results and Discussion

From literature studies it became obvious, that urban landscapes constitute an integral part of larger landscapes with special, often damaged ecosystems, and, consequently, an ecological continuity in terms of urban-rural ecological gradients connecting well-functioning ecosystems is non-existent. These landscapes are highly fragmented often due to infrastructure development disregarding ecological cross-scale interactions (even if some spatial, temporal, and functional scales are recognized), which resulted in a gradual degradation of ecosystems and their capacity to provide ecosystem services (Borgström et al. 2006). In case of smart cities, the so called zero vision often concerns zero emission, zero waste and zero crime as a function of smart city technologies, information and communication technology (ICT), energy supply and transportation (Ucar et al. 2020; Icaza et al. 2024). Furthermore, the urban environment is often treated separately, isolated from the countryside with its own green surfaces, food production systems (mostly food processing) and recycling processes, often neglecting environmental sustainability concerns and socio–economic needs, and favouring technical innovation and industrial competitiveness (Bhadouria et al. 2023).

4.1. The Role of Urban Agriculture in Urban Metabolism

Since most cities have seriously damaged ecosystems, establishing environmentally, socially, and economically viable forms of organic urban and peri-urban agriculture requires a thorough environmental, social, and economic assessment, a detailed resource audit and land inventories to identify necessary changes in land use, reconstruct or design new ecosystems, develop appropriate infrastructure, support local businesses, and enhance community participation, local and regional sustainability agendas (Ebissa et al. 2024; Ko and Chiu, 2020; Kalfas et al. 2023). The environmental economic issues of urban agriculture concern many areas such as:

- land use and consequences of land use change,
- multifunctional land use and the multifunctionality of agriculture,
- environmental remediation strategies of polluted urban areas,
- ecosystem design, biodiversity, and creation of new habitats,
- soil conservation and remediation,
- groundwater remediation of polluted sites,
- water resources management and wastewater purification,
- urban ecology and assessment of urban ecosystems and their carrying capacity in view of urban evolution and climate change,
- urban agricultural production systems and their economic viability,
- the economic viability of low input organic agriculture in urban and peri-urban areas
- waste management based on reuse and Life Cycle Assessment (LCA)
- renewable energy production and energy mix linked to ecological cycles,
- zero-waste approach and waste-to-energy strategies,
- restoration or construction of urban-rural ecosystem-continuities and ecotones,
- urban–rural ecological networks for landscape planning,
- co-operative methos of civic involvement in spatial planning,
- innovative development of grey-green and blue-green infrastructures to mitigate the adverse impact of climate change in cities,
- development of local and regional sustainable business models,
- shortening food supply chains through urban agriculture,
- developing new ‘looped’ value chains based on circular economy in urban agriculture.

The original meaning of urban metabolism, by analogy with the metabolic processes of biological systems, is the dynamic processes of resource use and waste and pollution emissions in cities, including all the technical and socio-economic processes that contribute to growth, energy production and waste disposal (Kennedy et al. 2011; Oliveira and Vaz, 2020; Assumma and Pittau, 2022). The new concept of urban metabolism is based on the Swedish Hammarby model, understanding of the city as an ecosystem with the calculation of the ecological footprint taking into consideration the ecological cycles processes (Iveroth et al. 2013; Pincetl et al. 2012; Long et al. 2014). Furthermore, the conversion of natural ecosystems, such as forests, grassland, wetlands into agricultural land is causing deforestation in many places, draining the soil, which will eventually become unsuitable for production and lead to desertification. The long-term economic consequences of such environmental deterioration are obvious. Moreover, by expropriating farmland, the study contributes to the understanding of adverse impacts of climate change. About 15 percent of the planet is specifically barren as desert, glacier, or karst land, but this does not matter for indoor production, where vertical farms can produce up to 100 times more per square metre, since they can operate all year round, and farmers can think in three or, rather, four

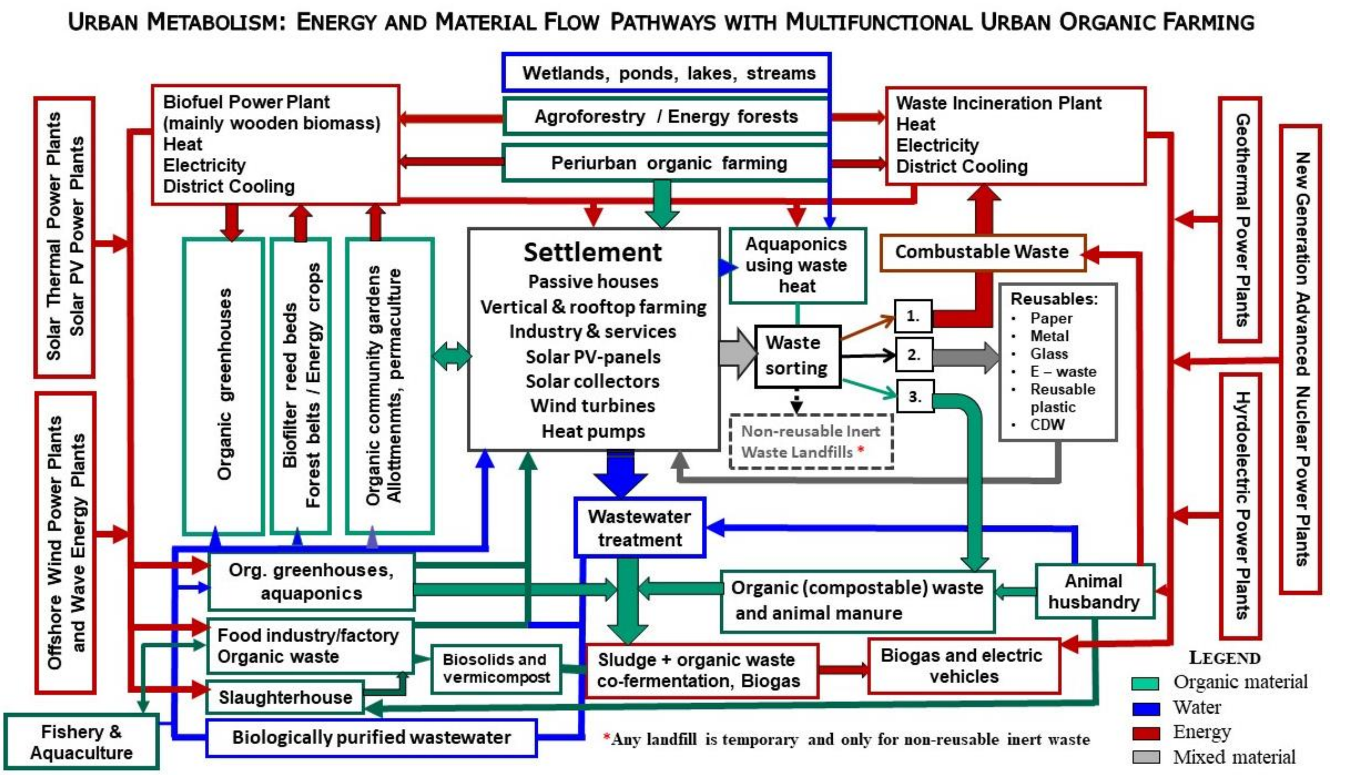

Figure 1. Urban metabolism illustrating the ecological cycle processes and the material and energy flows in green urban ecosystems, with well-developed multifunctional and organic urban and peri-urban agriculture. Important to emphasize the importance of sustainable energy mix and the ecocycle-approach based on the energy-product/service-reuse-zero waste concept. Source: own design.

dimensions taking into consideration even the longer time available for cultivation (Kennedy et al. 2011; De Mauro, 2017; Sammarco and Terracciano, 2023). Thus, by growing on rooftops, in parks, greenhouses and buildings to create economic, social, and ecological sustainability (José and Rodrigues, 2024), urban farming has multiple benefits. It can supply the city with locally produced food, which reduces the need for transport and generates economic sustainability for both society and businesses, while teaching people more about food production (Gawryszewska et al. 2019). In addition, urban farming contributes to ecological sustainability as it can close the city's cycle and create a unique urban metabolism (Fig. 1) taking into consideration land use (Sammarco, and Terracciano, 2023) energy supply, environmental impacts, ecological cycle processes (Mendes et al. 2008; Wilinska-Lisowska et al. 2021; Fanfani et al. 2022; Icaza et al. 2024) that enables the creation of a self-sufficient system. A prerequisite for urban farming to be sustainable is that it uses the nutrients that already exist in the city and does not transport artificial fertilisers and animal manure over long distances. Composting food, often by co-fermenting it with sewage sludge, that would otherwise be thrown away, makes it possible to utilise the nutrients available in the city to grow new food, contributing to closing the urban ecological cycle processes (Boonstra and Boelens,´2011; Ackerman et al. 2014; Specht et al. 2014; De Jesus, 2024).

Several challenges such as high investment costs, development of new technologies, new materials or cultivation methods and high energy consumption are perceived obstacles that could be solved with today's technology and a healthy, comprehensive system approach (Fig 1). Here an urban metabolism chart with all the relevant material and energy flows is presented, including the main urban agriculture systems:

- Community gardens
- Vertical farming
- Rooftop farming
- Aquaponics
- Indoor Hydroponic Systems
- Aeroponics
- Local seed farms
- Living Gene bank
- Marine allotments
- Testbeds
- Urban agroforestry
- Temporary rooms in the city
- Allotments
- Market gardening

4.2. Case Studies from European Cities

Farming and food production in urban and peri-urban areas have faced several obstacles, particularly with the expansion of cities, urbanization, and the massive expansion of agriculture to meet the worldwide increasing demand for food (Sertyesilisik, 2024). Although urban agriculture has been a part of society for centuries, urban expansion absorbs agricultural and natural terrains resulting in a decline of urban agriculture practices and land. To successfully address environmental degradation in urban areas and the climate crisis, however, urban agriculture must play a role in how food is grown in cities. However, several initiatives have proved successful and suggests that specific in-novative models can establish synergies between agriculture, urban farming, and the city, aiming to address food growing in urban environments. Case studies from European cities are presented that demonstrate how European cities can adapt to new land management alternatives using sustainable and innovative models that incorporate local food production, social inclusion, community identity, and ecosystem services.

The project Peri-urban Land Use Relationships - Strategies and Sustainability Assessment Tools for Urban-Rural Linkages (PLUREL) studied by 36 partners (2007-2011) addressed peri-urban land use relationships showing that urban development is by far the most rapidly expanding land use change in Europe (European Commission 2012). They highlighted the need to reach sustainable development required for more policy attention at the regional level and on the urban-rural interface. They concluded that the European Union must promote an integrated rural-urban development by concentrating its policies and funding on peri-urban regions.

UN Habitat's (2017) study the "Implementing the new Urban Agenda by strengthening Urban-Rural Linkages" highlights the importance of urban-rural linkages for achieving the Sustainable Development Goals, as it identifies the need to bridge the development gap between urban and rural zones for the benefit of both urban and rural populations. Strong interdependence exists between rural and urban ar-eas, and there is an immediate need to reconsider and recognize the urban-rural con-tinuum of space and its planning.

Peri Urban Regions Platform Europe (PURPLE) , a third example, was founded in 2004 and has brought together diverse regions from across Europe to maximize the benefits and increase awareness of the specific peri-urban agenda at the European, national, and regional levels. In addition to promoting new trans-European initiatives in the field of peri-urban regions, the platform disseminates examples of best practices in designing and developing partnerships for EU projects. According to PURPLE, peri-urban agricultural areas are ideal for multifunctional activities related to the re-quirements of nearby cities. They promote an extensive variety of agricultural produc-tion innovations that necessitate new standards and regulations.

Specifically, examples of sustainable food systems are becoming more prevalent. For example, the pan-European project EIT Climate-KIC SATURN (SATURN), (2019-2021 involving three cities Gothenburg, Trento, and Birmingham), investigated how resilience at a city scale could be achieved and how landscape fragmentation issues could be addressed. The objective of the SATURN project was to develop frame-works and design tools to assist cities and regions in addressing the landscape fragmentation they experience, while exploring innovative ideas to future-proof cities. The Gothenburg model demonstrates the viability of urban farming in densely populated areas through four distinct actions, resulting in numerous benefits for the municipality, the farmers, and the general public. The green space will revitalize the area and make the city healthier and greener, while the local food production and consumption will mitigate the carbon emissions caused by shipping and transportation.

In the case of the Nutrire Trento #Fase2 project, the emergence of synergies between farmers led to the creation of a local Community Supported Agriculture (CSA) project. The CSA is a model for the production and distribution of food based on a partnership between consumers and farmers. In fact, it is a more sophisticated alternative to food networks in Italy (such as Solidarity Purchasing Groups) because consumers are asked to make a moral and financial commitment to a group of farmers.

The Birmingham model entails establishing a growing network in an urban setting, which includes gardening and urban farming. Even though the two preceding models are focused on agriculture and entrepreneurship, the "Growing in the Community" initiative aims to increase community awareness and engagement through farming. The team behind this model asserts that the creation of physical space fosters and affords opportunities for the emergence of social space within the urban fabric.

Another example is the C40 Food Systems Network, the Urban Food Policy Pact of Milan as well as Madrid's Food Strategy all of which investigate agriculture in urban areas with the goal of creating healthy, sustainable cities.

4.3. Value Chains in Urban Agriculture

The new value chain of urban agriculture and urban production systems is based on circular economy while Porter's value chain theory focuses on value creation and value transmission in a linear way. It describes the operation of a company as a series of successive internal activities that the organisation undertakes to create value.

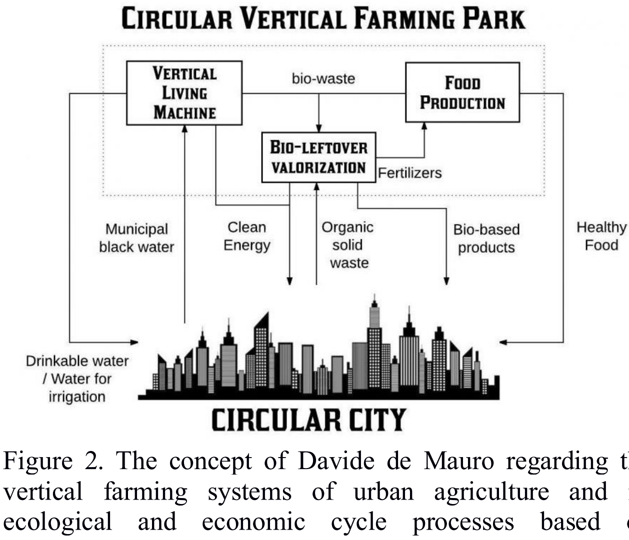

Figure 2. The concept of Davide de Mauro regarding the vertical farming systems of urban agriculture and its ecological and economic cycle processes based on valorisation of organic waste, total recycling, and green energy production (Source: de Mauro, 2018).

Each of these activities individually produces value. Porter's value chain model divides business activities into two broad categories: support (service) activities and primary (value creating) activities (Porter, 1985, 1998). Supporting activities include the firm's infrastructure processes, human resource management, technology development, procurement. Primary activities include procurement logistics, production operations, delivery logistics, marketing and sales, customer service.

Circular economy is based on the minimal use of external resources through the cascading reuse and recycling of products and materials at the end of their life linked to renewable energy systems. Thus, a circular economy is mini-mizing waste in the whole supply chain applying the energy-product/service-minimum/zero waste concept including sustainable waste-to-energy technologies. In urban agriculture, circular economy is particularly well represented in vertical farms, which are based on ecological cycle processes and intrinsic circular configuration even in economic terms (Steen and van Bueren, 2017; von Wirth et al. 2019), since they can be symbiotically linked with urban renewable energy and waste flows, as illustrated in the urban metabolism (Fig. 1) and the synergies and system connections between vertical farms and cities according to the concept of de Mauro (Fig 2).[1]

Improving existing incubator programme in Gothenburg for urban small-scale entrepreneurs into sustainable business models.

The Incubator aims to increase the number of local/ecological farmers in Swedish Cities. This is done through agripreneurship (agricultural entrepreneurship) training and with a strong collaboration with the Gothenburg municipality who offer access to land. The aim is achieved by gathering, creating, testing, and sharing successful business models relevant to the farmers context: low investment, small surfaces, direct sales and high sustainable values. It consists of a winter training program where 10 new entrepreneurs per year get access to the network, training, workshops and support throughout the farming season. At the end of each season, feedback is given to the municipality to help in the selection process for land access. Through increasing number of entrepreneurs, the research indicates that by boosting the number of farmers, make a better use of empty and/or farming land in and outside of the city and contribute to reduced transport and packaging, furthermore, increase consumers knowledge about the environmental impact of the food system. Urban farming is a flexible food production solution that adapts to any situation. From indoor farming to suburbs, it allows our food systems to rely on their own environment and conditions. Local production has a significant impact on reducing transportation and packaging (Lu et al. 2024). It also means seasonal farming and it requires less energy, thus contributing to a more stable climate. Buying food from a local farmer is an efficient way to boost the local economy and participate in the recycling of goods and services. Urban compost, made from food waste, can be used by farmers to regenerate their soil, and grow new vegetables.

Our main method of increasing local food production is through entrepreneurship education, which leads to the creation of new businesses. As such, it encourages and strengthens local entrepreneurs on their way to food production. Outdoor farming and fresh food have a huge impact on health, and new innovative tools have made the farm workforce more and more "body friendly" (?). The Farmers' Incubator is linked to the long-term strategic work of the City of Gothenburg to provide opportunities for residents to create farm opportunities and enable an agricultural career within the city. The Incubator creates knowledge production in conjunction with a new (old) agricultural technique called Market Gardening, in which new businesses have to be tested and disseminated in new contexts. This creates new farm entrepreneurs who have a wider toolbox for successfully building a sustainable farming business being herewith an integral part of a new Urban Living Lab.

4.4. Urban Living Labs

Key instruments in the development of urban agriculture are Urban Living Labs (ULLs), which can be defined as the 'real life' laboratories of urban environments to experiment with innovation, develop participatory processes based on existing multi-level governance structures, and analyse the particular local conditions of social and environmental capital, which requires a high level of public-private involvement and collaboration for its implementation. Furthermore, the implementation of ULLs serve, among others, evaluative purposes to strengthen decision-making support systems and capacity building, which are intrinsic constituents of the very nature of ULLs. The ideal living lab platform integrates interests of citizens and other stakeholders with innovative experiences can be urban areas such as city centres, neighbourhoods, universities, NGOs, and companies. Within this approach, the whole city is seen as one living lab focusing on long-term scaling of co-creating innovation for a resilient urban environment and well-functioning ecosystem services, which constitute the base of the urban sustainability transition (Franz, 2015; Steen and van Bueren, 2017; von Wirth et al. 2019). Our ongoing international project U-garden has been initiated to promote the development and implementation of urban gardens and all forms of urban agriculture and agroforestry as key components of the strategic framework for sustainable urban development in European cities, from an interdisciplinary approach according to the above-described dimensions of Urban Metabolism (Fig 1) and setting the following objectives:

- to identify needs, problems and opportunities concerning urban garden and agro-forestry experiences;

[1]https://www.agritechtomorrow.com/article/2017/12/vertical-farming--the-city/10414/

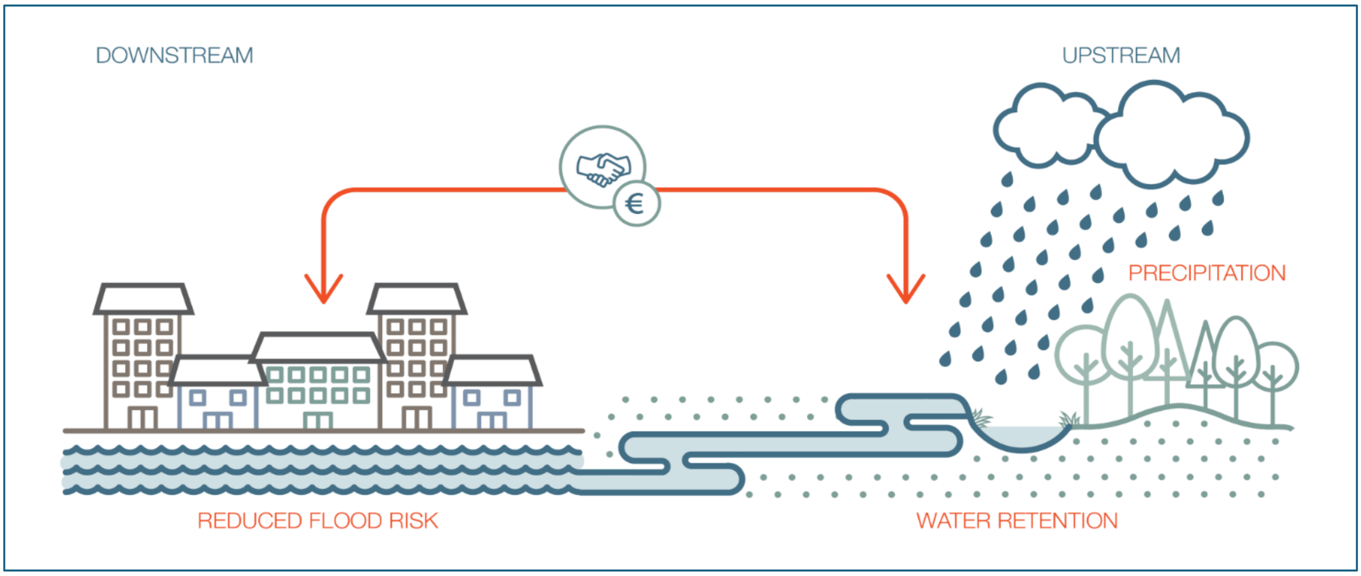

Figure 3. Business scheme – Vulnerable downstream areas benefit from upstream flood retention services. Source: own design.

- to promote, through Urban Living Labs, the stakeholders' capacity building in terms of green governance for food production and consumption in cities;
- to enhance citizens' capacity building for the involvement in sustainable, ecosystem-based urban development experiences;
- to foster innovative business models around sustainable and local food production;
- to evaluate the impact of the implementation of agroforestry/urban garden experiences in their social, cultural and environmental dimensions addressing the problems of ecosystem reconstruction and the carrying capacity of these ecosystems;
- to set up a multi-criteria framework to support decision-making in the location of urban and peri-urban gardens, and agroforestry plots.

Collaborative training to the beneficiary population is an indispensable instrument of Urban Living Labs for their capacity building functions (von Wirth et al. 2019; Jagadisan et al. 2023). The main elements of this include: (1) adapted training programmes (cultivated biodiversity, crop management, use and management of irrigation systems, organic farming, composting, etc.), (2) support and advisory services to support urban farming initiatives (mediation, intergenerational mentoring, etc.), (3) creation of urban agriculture networks to promote collaboration with research entities and foster the sharing of experiences, practices, skills, and knowledge.

Table 1. The diversity of measures classified as Natural Water Retention Measures (NWRM)

Type	Class	Examples
Direct modification in ecosystems and use of ecosystem services	Hydro-morphology (rivers, lakes, aquifers, connected wetlands)	Restoration and maintenance of rivers, lakes, aquifers, and connected wetlands; ~~R~~reconnection and restoration of floodplains and disconnected meanders, elimination of riverbank protection, etc.
Change & adaptation in land-use & water management practices	Agriculture	Restoration and maintenance of meadows, pastures, buffer strips (ecotones) and shelter belts; soil conservation practices (crop rotation, cover crops, intercropping, conservation tillage), green cover, mulching, etc.
	Forestry and pastures	Afforestation of upstream catchments; targeted planting for "catching" precipitation; ~~C~~continuous cover forestry; maintenance of riparian buffers; peri-urban and urban forests; ~~L~~land-use conversion for water quality improvements;
	Urban development and urban agriculture	Green facades, roofs and rooftop-farming; urban gardens; rainwater harvesting, permeable paving, swales, soakaways, infiltration trenches, rain gardens, detention basins, retention ponds, urban channel restoration, etc.

The idea of ULL may work well at different scales. Our case of ULL set up by U-Garden project in Warsaw proves that it brings benefits even to smallest initiatives raised on a local scale of a neighbourhood. “Muranów ULL” gathered representatives of municipal-led institutions (integration centre for seniors and youth, kindergarten, grammar school, real estate management board and municipal greenery management), academics, social activists and, first of all, citizens – inhabitants of one neighbourhood that was in the scope of ULL’s activity. In the short two-months period of intensive work the team managed to collect stakeholders, facilitate locally the idea of urban gardening, learn about local needs and capacities, work out a common vision of the new urban garden, propose a landscape design of the space in the neighbourhood dedicated to future gardening activities and apply for funding to external donator. We have proved that an ULL provides better results than regular activities led by the municipality in adjacent neighbourhoods, which were aimed at greenification of housing courtyards.

4.5. Financial Instruments for NBS to Reduce Risks of Flooding and Drought

Floods and droughts are among the most significant hazards worldwide and en-tail large ecological, economic, and social costs in terms of flood damages, loss of in-come and social health. Climate change is a predominant reason for the increase in the frequency and intensity of floods and drought. Climate adaptations include Natural Water Retention Measures (NWRM), which are multifunctional measures that aim to protect and manage water resources in the landscape using natural means and processes (European Commission, 2014). The water-related risks can be handled through two main paths: grey infrastruc-ture (e.g. concrete walls, elevated quaysides, and water dikes); or NBS (natural dams, preserved, reconstructed, or newly developed wetlands, and other blue-green structures). Most commonly, measures to prevent flooding are based on the construction of grey infrastructure. Today's expansion and densifying of cities, where more space is being impermeably surfaced by grey infrastructure, entails an increased risk of flooding while in hot summers urban spaces with less green areas are less resilient to increased urban heat. Therefore, building up green infrastructure, for example, by restoring ecosystems (e.g., wetlands) and changing land use offers economically and ecologically better, regenerative and sustainable solutions.

Our research group studied the possibilities and the effectiveness of NBS in the Gothenburg region for water resource management, disaster risk re-duction, and climate change adaptation, since these get more attention internationally as a complement to grey infrastructure. The benefits achieved by NBS can be categorized into direct and indirect benefits. Direct relates to biophysical impacts, i.e. the mechanisms of water retention which is slowing and reducing runoff. This improves the water bodies’ status, control flood risks, and reduce water scarcity and droughts. Indirect benefits are the side benefits of water retention and can provide additional services such as biodiversity enhancement, or increased recreation opportunities.

Nature based solutions as to store water in the landscape by increasing the storage capacity higher up in the landscape will contribute to reduce the risk for flooding downstream as e.g. in the City of Gothenburg as a form of climate adaptation. There is also a potential for climate mitigation as these measures reduce the use of concrete for storm drains etc and possibly fossil fuels as is necessary for grey infrastructure. Climate solutions are most effective when embedded in integrated solutions that also enhances the viability of other societal goals. This is a key objective in sustainable urban development, i.e. to provide a business case and develop a business model for measures with a clear contribution to climate adaptation as well as preservation and recreation of wetlands, and conservation or remediation of biodiversity. The idea of the business model (Fig. 3) is that downstream beneficiaries pay upstream providers for increasing water retention capacity in order to reduce risks for flooding and drought, illustrated by the arrow representing the financial transfer from downstreams to upstreams. It thus addresses climate vulnerability on a multi-scale level, strengthening its adaptational effectiveness.

3.6. Landscape Observatories for Ecosystem-Centred Development and Landscape Conservation

A landscape observatory is a complex tool that is not only a database or a meth-odological approach, but also a new model institutional system and organisation for the protection of landscape character to implement the European Landscape Convention (ELC). Landscape observatories are meeting points between and among governmental bodies, local/regional authorities, formal organizations, university research and education, education system, civil society organizations, and trade organizations. They have multiple and intimately interconnected functions:

1. Monitoring of landscape formation, landscape change and continuous refinement of the assessment processes
2. Defining landscape quality objectives and identifying and adapting the means to achieve them
3. Identifying landscape types and landscape characters and creating landscape catalogues to incorporate landscape into the formal categorization of territories
4. Long term monitoring of landscape and societal functions, evaluation of activities and societal effects
5. Organising landscape protection and development actions
6. Development of models for landscape inventories and creation of databases
7. Conducting assessments regarding landscape ecology, natural, human, and cul-tural resources, regional development, nature and heritage conservation, social and economic status
8. Preparing a landscape inventory for policymakers
9. Monitoring continuous European landscape-related legislation
10. Organising landscape-related research and promoting innovation
11. Organising campaigns, keeping landscape at the centre of attention
12. Disseminate studies, reports, research materials, methodologies, organise semi-nars, courses, exhibitions

13. Increase the knowledge in all layers of society on landscape content, landscape interpretation, and potentials for sustainable and regenerative development
14. Stimulate cooperation between different stakeholder groups
15. Development of decision support systems to enhance the formation of effective and efficient governance structures

change and the necessity for planning landscape conservation in view of climate change (Lin et al. 2019) to increase the resiliency of ecosystems. Landscape observatories are value-preserving, resilient and at the same time innovative, transdisciplinary collaboration platforms for all types of landscapes including both rural, semi-rural and urban environments, particularly well-suited to identify and maintain the important urban-rural gradient. They are multifunctional knowledge centres for landscape thinking and decision-making in a given region, enhancing nature and cultural heritage conservation and socio-economic viability. Furthermore, landscape observatories function as decision support systems enhancing coordination in regional politics.

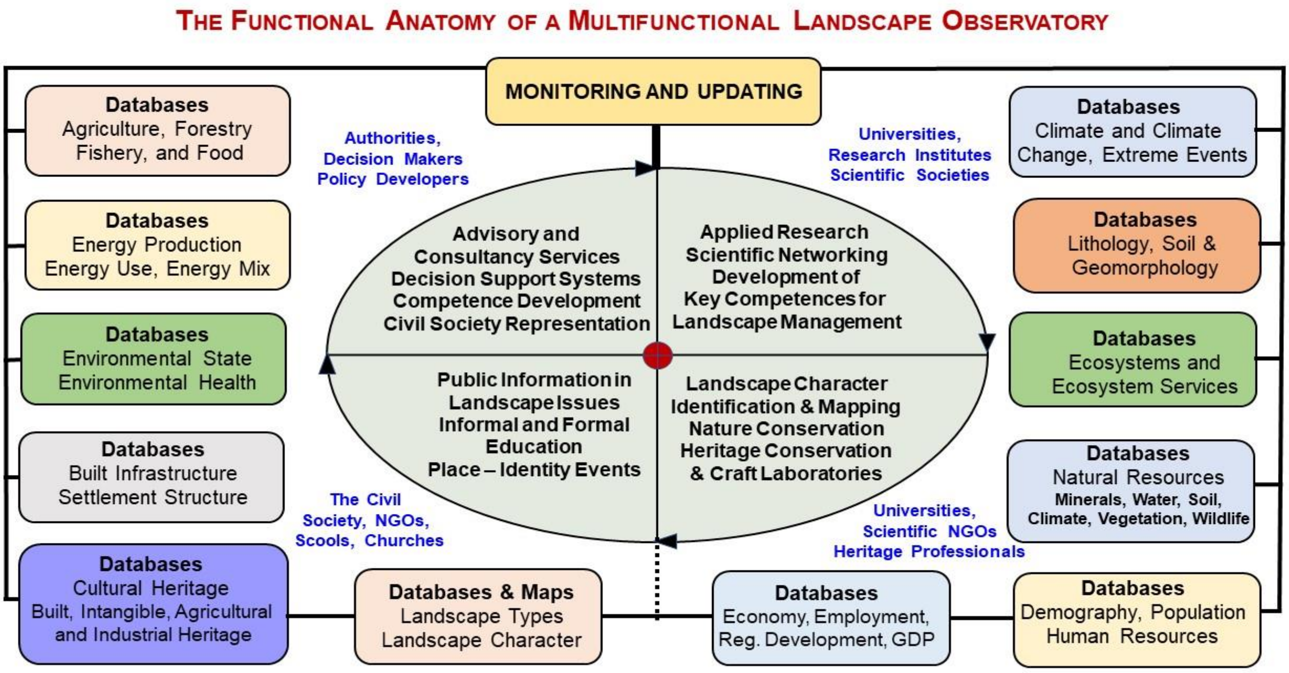

Figure 4. The new model of an effectively and efficiently working landscape observatory. (Source: Ternell et al. 2023).

The observatory's board members included representatives of the scientific community, local organisations, businesses, NGOs, and local authorities, as well as the leaders responsible for the management and planning of the territory concerned (e.g., province). The observatory's role is to promote and integrate regional planning as described in our earlier article (Ternell et al. 2023). Detailed descriptions of the landscape are to be in-corporated into local and regional educational materials and communications, thus enhancing local identity. In many countries, there are currently no interoperable sectoral geospatial databases that can be managed in a single system, and municipal-level data on public services covering the entire territory of the country in an integrated, dynamically searchable and analysable format. Thus, the most essential constituents of a multifunctional and dynamic systems of a landscape observatory are its continuously renewed and updated databases (Fig. 4). The data flow to the connected key functions in the centre is maintained from the databases, which supply all information needed for the operation. Obviously, monitoring and research together keep the databases always updated.

Although this new model has been inspired by the Landscape Observatory of Catalonia, here the concept of Earth System Science and Earth Stewardship (Chapin et al. 2011) is applied with particular emphasis on changes induced by climate

CONCLUSIONS

The realisation that the shrinking natural resources will not be sufficient for a growing population resulted in a new definition of sustainability, introducing the concepts of multifunctionality in land use and agriculture, a regenerative approach to the exploitation of ecosystem services and circular economies based on thorough LCA and total recycling. Furthermore, these circular economies will be able to establish a unique system where agricultural and industrial production and waste management linked to the production and use of renewable energy together can ensure ecosystem conservation, social welfare and enhance climate resilience.

An increasing number of initiatives using sustainable solutions to manage peri-urban lands are demonstrating that urban-rural interfaces offer new opportunities to achieve Sustainable Development Goals that favour cities, such as Goal 3: Ensure healthy lives and promote well-being;

Goal 11: Make cities inclusive, safe, resilient, and sustainable to the urban challenge;
Goal 13: Take urgent action to combat climate change and its effects; and
Goal 15: Sustainably manage the environment.

The relevance of reconsidering land use and agriculture in urban and peri-urban contexts has been highlighted by the many issues of modern urbanisation, such as the accelerating rate of population expansion, the growing demand on natural resources, and the pressing need for sustainable development. The study highlights the significance of multifunctional land use in creating resilient and sustainable urban ecosystems and offers a vision for integrating ecosystem-centred spatial planning and urban agriculture into landscape conservation initiatives.

A paradigm shift is necessary that goes beyond simply focusing on agricultural productivity or allocating green space. It promotes a comprehensive approach that acknowledges the complex relationships between urban landscapes and the natural areas that surround them. Urban places can promote biodiversity, improve ecosystem services, and create more habitable spaces for residents by using multifunctional land use principles. This method not only tackles environmental necessities but also en-hances social welfare and economic sustainability.

Urban agriculture plays a crucial role in this envisioned transition. It encompasses a regenerative approach that incorporates social, economic, and environmental factors, rather than solely focusing on food production. Urban farming initiatives, such as rooftop gardens and community-supported agriculture, provide opportunities for achieving local food security, decreasing carbon footprints, and promoting circular economies. These techniques demonstrate the capacity of cities to function as self-sufficient ecosystems that efficiently recycle their waste, preserve energy, and minimise their environmental footprint.

The urban metabolic model established in this research is a unique tool that provides a solid platform for urban planners and policymakers. It helps to fully comprehend the intricate relationships within urban ecosystems, allowing for well-informed choices that support sustainable land utilisation and resilient urban growth. The approach emphasises the need of perceiving cities as living entities that can be intentionally constructed to operate in synergy with the natural environment.

In addition, the case studies showcased from European cities demonstrate the actual implementation and advantages of incorporating multifunctional land use and urban agriculture into urban design. These examples offer valuable perspectives on how cities might effectively address the issues of urbanisation while simultaneously improving their ecological and social structure.

Cities may create environments that support human well-being and even promote resilient and flourishing ecosystems by adopting multifunctional land use and ecosystem centred co-planning concepts. This comprehensive approach to urban planning signifies a future in which cities serve not just as places for people to live but also as strongholds for sustainability, biodiversity, and community involvement. Achieving sustainable urban ecosystems is a challenging task that demands collaborative endeavours from multiple sectors. However, the ideas and plans described in this article provide clarity and guidance for achieving a balanced and enduring relationship between urban growth and the environment.

From a sustainability point of view, landscape-related tasks exist in one system, which is why only a system-level answer can be given to them. Therefore, landscape observatories are particularly well-suited as landscape management tools and decision support systems in a transdisciplinary landscape concept embracing all dimensions of regenerative sustainability.

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