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Towards the Development of an Integrated Sustainability and Resilience Benefits Assessment Framework of Urban Green Growth Interventions

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Academic Editors: Francesca Montevecchi, Martin Hirschnitz-Garbers, Tomas Ekvall, Martha Bicket and Patrick ten Brink
Received: 18 February 2016; Accepted: 28 April 2016; Published: 10 May 2016

Abstract: Considering the current emerging demographic, urbanization and climatic trends, integrating sustainability and resilience principles into urban development becomes a key priority for decision-makers worldwide. Local and national governments, project developers and other urban stakeholders dealing with the complexities of urban development need projects with clear structure and outcomes in order to inform decision-making and ensure sources of financing. The need for developing an integrated assessment methodology that would capture and quantify multiple urban sustainability and resilience benefits of projects in one common framework and eventually lead to verifiable sustainability and resilience outcomes is immense and challenging at the same time. The main objective of this paper is to present the development of a methodological approach that aims to integrate sustainability and resilience benefits, derived from the implementation of green growth urban projects, into a unified framework of criteria addressing environmental, social, economic and institutional perspectives. The proposed sustainability and resilience benefits assessment (SRBA) methodology is a combination of top down and bottom up approaches, including GIS-based scenario building. The different types of sustainability and resilience benefits of urban green growth projects are also identified at different levels (*i.e.*, individual, neighborhood, city and global). Moreover, the proposed methodology creates scenarios that can be illustrated by a map-based approach to enable a better illustration and visualization of benefits. It demonstrates how a map-based approach can assess not only the extent of sustainability and resilience benefits accrued (how much is benefitted), but also their spatial distribution (who is benefitted). The main methodological challenges and issues on developing an integrated sustainability and resilience benefits assessment are identified and discussed.

Keywords: integrated framework; sustainability and resilience benefits assessment; urban interventions; green growth; SDGs

1. Introduction

Rapid urbanization puts pressure on natural resources and increases demand for energy, water and sanitation, as well as for other public services. Since 2007, more than half of the world's population has been living in urban centers, and it is estimated that the proportion will exceed 70 percent by 2050. In the future, large cities will be primarily located in low- and middle-income countries. It is in such countries, who often struggle with competing development and sustainability agendas, where additional resources and the capacity development of local governments are ever more so a pressing issue [1].

Activities in cities and urban areas affect the environment locally, regionally and globally (see Figure 1), in both negative and positive ways. Local issues of public health, sanitation and waste management are very visible in low-income cities. In many cities of low- and middle-income countries, access to public services (e.g., water, sanitation, electricity) remains inadequate. Furthermore, there is great pressure on the institutional capacities of local governments to improve access to adequate infrastructure, creating decent employment, reducing pollution and vulnerability to natural disasters [2].

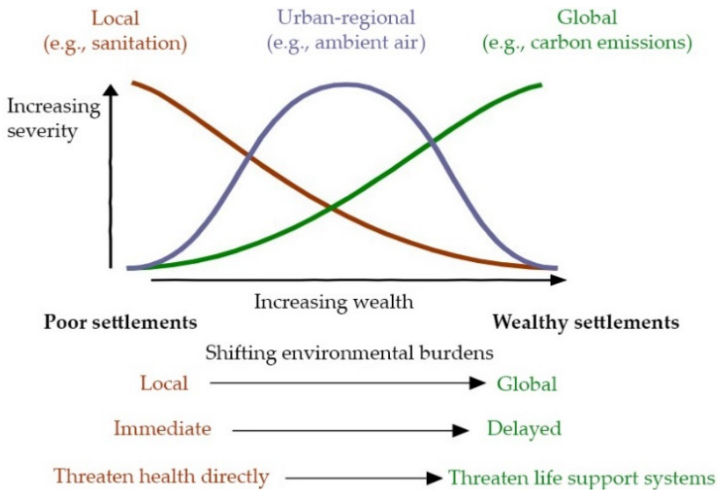

Figure 1. A stylized environmental transition (source: McGranahan *et al.*, 2001 [3]).

On the other hand, the expansion of cities together with high consumption-driven lifestyles and carbon-intensive urban economic activities of middle-income countries contributes to the rapid increase of global GHG emissions. High levels of consumption in middle- and high-income cities can generate a wide range of environmental consequences (e.g., increased pollution locally and an increase in carbon emissions globally) through the use and flows of raw materials and energy from distant locations for the production of goods and services locally [3].

In turn, the increase of GHG emissions contributes to the intensity of the problem of global warming, thereby exacerbating and intensifying subsequent climate-induced disasters. It is now evident how climate change induced risk and impacts increase cities' vulnerabilities, hinder local development and place additional stress on the adaptive capacities of urban areas, particularly that of the urban poor and other vulnerable groups.

In the previously-described complex global system of cities, integrating and making sense of different urban agendas can be a daunting and complex task; however, sustainable and resilient development of urban areas requires precisely the integration of different agendas and of different objectives if cities are to prosper as the main way of living for humanity [4] (Figure 2). Co-benefits and synergies between different urban policies, plans and actions should be explored, and potential conflicts and trade-offs should be identified.

In 2015, UN members agreed (for the first time) on a specific global goal for urban areas, as part of the 17 Sustainable Development Goals (SDGs) for 2030. The urban SDG (Goal 11) brings sustainability and resilience to the foreground: "Make cities and human settlements inclusive, safe, resilient and sustainable". The goal is divided into seven specific thematic targets (regarding: housing and basic services, transport systems, planning and management, cultural and natural heritage, human and economic losses from disasters, environmental impact of cities, safe and inclusive public spaces) and also three suggested "means of implementation", which have attracted attention because of their importance for the potential impact of the SDGs. Emphasis is given to "cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters". The "integrative nature" of the urban SDG, apparent throughout the targets and suggested means of implementation, makes it imperative to facilitate and manage urban issues with holistic approaches and tools.

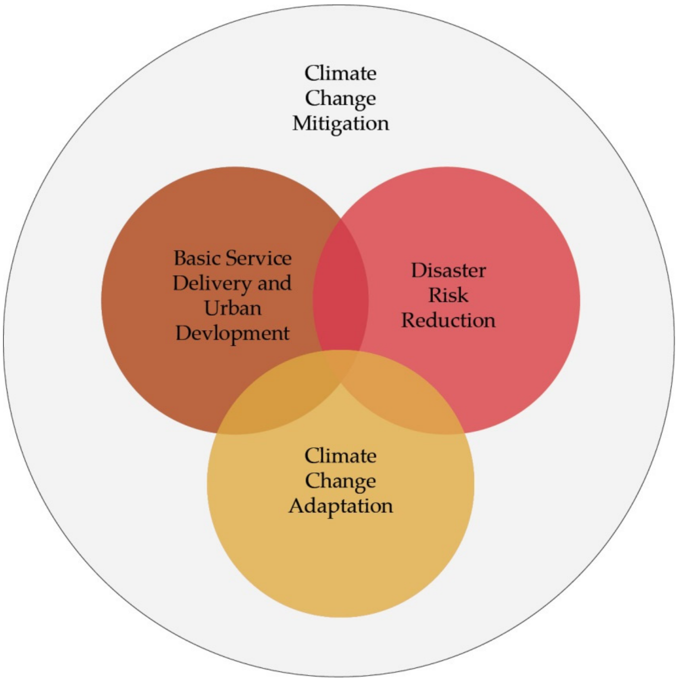

Figure 2. Integration of different urban agendas (source: adapted from Satterthwaite, 2016 [4]).

Moreover, the urban SDG and its targets stress the need for a framework of indicators for urban sustainability and resilience. A first set of universally-accepted SDG indicators, to be used at the national, regional and city level, according to the data availability, was suggested at the Second Urban Sustainable Development Goal Campaign Consultation on Targets and Indicators [5]. Although the indicators are still under development, there is global awareness for the collection and distribution of data that will support SDG implementation and monitoring. The World Council on City Data and the Global Partnership for Sustainable Development Data are two platforms promoting the use of open data for decision-making.

Against the background of emerging demographic, urbanization and climatic trends, policy and assessment frameworks need to promote a common integrated approach that will simultaneously address local sustainability, resilience and climate change objectives. As cities depend on the effective and reliable operation of infrastructure systems to deliver energy, mobility, water, sanitation, shelter, information, emergency response and other critical services [6,7], they must adopt appropriate development policies as soon as possible, because today's infrastructure investments will be locked in over the medium to long term.

Sustainability and resilience are two intertwined concepts, and both highlight the ability of a system (urban, social, ecological) to evolve into "desirable development pathways" [8]. The variety of relationships and equilibria between sustainability and resilience have been studied in the literature [9,10], where sustainability is seen as a normative concept promoting justice between generations, while resilience as a descriptive, desirable or sometimes even undesirable (in persisting, negative situations, such as environmentally-degraded water bodies) concept [11]. However, the right combination of sustainability and resilience aspects could provide strategies that allow them to be implemented in their full potential: a city cannot be sustainable without being resilient, and *vice versa* [12].

Even though sustainable development is a fluid concept and various definitions have been put forward, the definition by the Brundtland World Commission on Environment and Development in 1987 remains valid and timely. One of its key principles is that sustainability should promote understanding and foster the integration of the complex interconnections that exist between the environment, economy and society. On the other hand, the concept of resilience has its origin in engineering, expressing strength and resistance [13]. Recently, the term has gained popularity in many science fields and especially in urban studies, indicating the abilities of adjustability, adaptive capacity and transition. Although resilience can have different connotations in different contexts, when related to disaster risk management, it indicates the ability of a system, community or society that is exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner [14]. Building resilience is a demonstration of the ability to change in order to protect and preserve the characteristics of the urban system [8].

Except from the benefits that sustainability and resilience entail for the urban context when pursued separately, building both sustainability and resilience into urban development would entail multiple benefits for the urban socio-economic system [10,15,16]. There are strong reasons to integrate the two concepts in urban management and planning processes and agendas and also to explore how they can be assessed and applied together in practice through tools and guidelines [17,18]. In the urban environment and in the context of sustainable development, this integration would provide the essential ability to capitalize on the development and sustainability benefits that the urban system has achieved so far. A non-resilient (but "sustainable") urban system could be found in the position of losing benefits achieved during the development process, and even returning to points that are years back on the development track, due to the lack of ability to be resilient against a hazard [19].

Working across sectors to achieve the aforementioned deliverables would assist in building urban sustainability and long-term resilience in cities, along with achieving development goals [19]. However, one of the main challenges for sustainable and resilient interventions seems to be political understanding and commitment [17]. Consequently, interventions that aim to contribute to the progress in sustainable development need to be tailored to the particular challenges and opportunities identified and prioritized by cities' stakeholders in concert with their expected multiple benefits and impacts. The combination of the two concepts relies on investment decisions that prioritize spending on activities that offer alternatives that perform well in different scenarios [20]. Leapfrogging investment in a green urban transformation can generate employment, drive innovation and foster green local economic development [21].

The notion of green growth is high on the global policy agenda and offers relevant insights into how appropriate interventions should be carried out. According to the World Bank [22], green growth means growth that is efficient in its use of natural resources, clean in that it minimizes pollution and environmental impacts and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. Cities are central to green growth strategies, as they are both key areas of economic activity and the drivers of energy consumption and greenhouse gas emissions. Although only a limited number of cities have explicitly adopted and are in the process of implementing green growth strategies (e.g., Stockholm in Sweden, Copenhagen in Denmark, Da Nang in Vietnam), cities across the globe are already pursuing greener futures by incorporating environmental objectives into their economic strategies [23]. In practice, this often means identifying urban activities to reduce environmental impacts that are most likely to contribute to job creation, urban attractiveness, supply of green products and services and increased urban land values. These activities can be implemented in different sectors, such as water, solid waste, transport, energy and urban greening (see Figure 3 and Appendix C). The urban green growth process can also generate a wide range of co-benefits (both economic and social), including poverty reduction, in particular locations. The adoption and implementation of green growth strategies at the urban level calls for the development of methodologies to assess the extent to which green growth projects and initiatives in different urban sectors (Figure 3) contribute to the wider green growth agenda, including the measurement of the sustainability benefits that they generate in view of attracting funding sources.

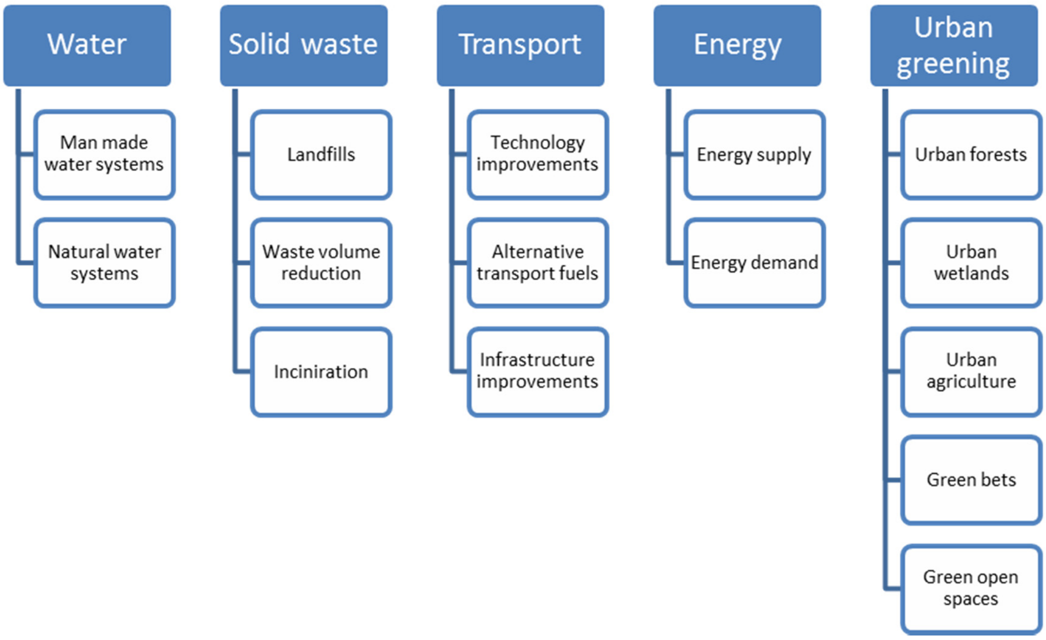

Figure 3. Sectoral urban green growth interventions (source: authors).

There is a large diversity of sustainability assessment methods at different levels, such as city (e.g., the Green City Index developed by Siemens and the Urban Sustainability Index developed by Columbia University, Tsinghua University and McKinsey), neighborhood [24,25] and building [26], and in relation to different sectors, such as energy [27], transport [28], waste management [29] and water [30]. However, there is a lack of a project-based sustainability benefits assessment methodology that could integrate different urban agendas, be relevant to multiple sectors and provide the flexibility of modification and application to different local contexts. Moreover, there is a strong need for developing approaches and methodologies for measuring and eventually verifying sustainability benefits as an essential element of decision-making processes aiming to efficiently and effectively allocate scarce resources.

Against this background, the article aims at addressing the following research question: "How can the multiple sustainability benefits of urban green growth projects be assessed by incorporating resilience aspects in the assessment framework?" A pertinent sub-question is: "Which are the main issues that a sustainability benefits assessment methodology of urban projects should address?" The objective of the article is to present the development of a project-based assessment methodology that can capture both sustainability and resilience aspects and incorporate different urban agendas in one flexible assessment framework. The developed sustainability and resilience benefits assessment (SRBA) framework could be applied in cities in low- and middle-income countries and fast growing economies. The focus of the developed approach addresses, on the one hand, issues related to poverty alleviation, basic services provision and health and risk and, on the other hand, issues that cities in fast growing economies face, such as air pollution and GHG emissions (see also Figure 1). The SRBA framework follows an integrated and holistic approach to sustainability assessment in cities and aims to support local and national governments to implement green growth projects in various urban sectors while accounting for sustainability- and resilience-related benefits.

The structure of this article is as follows: Section 2 presents the methods employed in the desk study. Section 3 presents the outcomes of the extensive literature review that was conducted on different sustainability assessment methods and approaches that have been applied and are relevant to cities. Section 4 discusses the main issues to be considered when developing an SRBA methodology according to the literature review. Section 5 introduces the systems approach and explains how the conceptual framework of the developed methodology has been built. Consequently, Section 6 presents the step by step development of the SRBA methodology. Section 7 demonstrates an illustrative example of the application of SRBA in Colombia, including GIS maps and matrices with the identified benefits. Lastly, Section 8 discusses future research directions and provides concluding remarks.

2. Methods

A systematic literature review (SLR) was conducted by looking into databases of scientific journals, specifically: (1) Scopus; (2) the Web of Science; (3) Science direct; and (4) sEURch, the online library of Erasmus University Rotterdam. The inclusion criteria were the following:

- Keywords: sustainability benefits, urban, sustainability assessment, impact assessment, resilience assessment;
- Research areas: sustainability studies, engineering, environmental assessment, decision science, economics, urban studies, geography, architecture, climate change mitigation, climate change adaptation, energy, buildings, water, transportation, solid waste management, ecosystem services;
- Date of publication: between 2005 and 2015;
- Publication language: English.

Furthermore, we also looked into the available sectoral reviews as these provided an overview of the extent of sustainability assessment methodologies. The papers found through database search and from sectoral reviews were further classified according to the following categories:

- City-wide sustainability assessments,
- Integrated sectoral sustainability assessments,
- Rating sustainability benefits assessment approaches,
- Climate project-based sustainability assessment methods and
- Sustainability assessments with resilience components.

The inclusion criteria generated more than 500 research results for sustainability assessment papers in various sectors (including integrated assessment frameworks). While we attempted to provide an exhaustive review of the literature, we consider the final classification as indicative of the extent of sustainability assessment methodologies that have been developed and applied.

3. Existing Sustainability Assessment Methodologies

Based on the literature, we categorize five main approaches of sustainability assessment methodologies that are relevant for cities:

3.1. City-Level Sustainability Assessment Methodologies

Measuring urban sustainability is an ongoing challenge for cities. A range of indicator and index systems has been developed over the past two decades, to measure a wide variety of issues ranging from carbon emissions to ecological footprint and material flows [6,31,32]. A key differentiation should be made between indicators and indexes developed by international organizations and those developed at the city level. Often, the latter are simply derived and adapted from the former. The indicators and indexes in use across the different cities and regions worldwide vary according to their particular needs and goals of the local context. It is possible to further categorize city level sustainability assessment methodologies into sustainability indicators (e.g., carbon, water and energy footprint), sustainability assessments (e.g., life cycle assessment, strategic environmental assessment, environmental impact assessment) and integrated sustainability indexes (e.g., Green City Index, Urban Sustainability Index). It should be emphasized that most currently available methods still fail to demonstrate sufficient understanding of the interrelations and interdependencies of environmental, social and economic considerations [33]. A comprehensive list of the indicator-based sustainability assessment frameworks at the city level can be found at the in-depth report of the Science for Environment Policy [34].

3.2. Integrated Sectoral Sustainability Benefit Assessment Approaches

Different approaches have been developed to measure the sustainability benefits deriving from the implementation of sectoral interventions in water, solid waste, transport, energy and urban greening. Most of these approaches, such as life cycle assessment, material flow analysis, cost benefit analysis, cost effectiveness analysis and multi-criteria analysis, are commonly applied to all sectors. A life cycle assessment (LCA) aims to describe the environmental impact of a product or service, from "cradle to grave". The objective is to use this information to improve efficiency and reduce environmental impacts in the entire life cycle chain and thereby avoid sub-optimization. There are international standards for how to perform an LCA, and this methodology is frequently used in research and industry. An LCA, however, focuses primarily on describing environmental aspects (sometimes including human-health aspects) and does not address other aspects of sustainability and sustainable development [35]. Material flow analysis (MFA) is the study of physical flows of materials into, through and out of a given system (usually the economy). It is generally based on methodically-organized accounts in physical units. It uses the principle of mass balancing to analyze the relationships between material flows (including energy), human activities (including economic and trade developments) and environmental changes. An MFA does not consider the costs and seldom the environmental or social effects of the material flows studied, even though it is very useful for identifying substances that may cause acute problems in the future [36]. As mentioned above, other commonly-used approaches include cost benefit analysis (CBA) in which all costs, as well as benefits of a sectoral intervention are monetized, as well as cost effectiveness analysis (CEA), where only the costs, but not the benefits, are expressed in monetary terms. Recently, more integrated approaches have been applied to include all diverse dimensions of sustainable development and the multiple impacts and aspects of sectoral interventions. Multiple criteria analysis (MCA) evaluation approaches have been applied increasingly in the last two decades in various decision-making contexts in different sectors [37–39].

3.3. Rating Sustainability Benefit Assessment Approaches

There is a large diversity of rating sustainability assessment tools that have been developed in the last decade and that have been applied in different regions and countries at different levels, such as green buildings, infrastructure projects and neighborhoods. The main objective of this type of sustainability rating tool is to assess the overall sustainability performance of the project under consideration (e.g., building), reconciling multiple sustainability criteria (energy, environmental, water, *etc.*), to rate and to compare it with other similar projects (*i.e.*, buildings). A detailed review of sustainability rating tools for buildings can be found in Nguyen and Atlan [40] who reviewed and compared five prominent rating tools, namely Building Research Establishment Environmental Assessment Methodology (BREEAM), Leadership in Energy and Environmental Design (LEED), Comprehensive Assessment System for Building Environmental Efficiency (CASBEE), GREEN STAR (a sustainability rating system for buildings in Australia) and the Hong Kong Building Environmental Assessment Method (HK-BEAM). Furthermore, Sharifi and Murayama [24] and Komeily and Srinivasan [25] conducted critical and extensive reviews comparing different neighborhood sustainability assessment (NSA) tools. They concluded that NSA methodologies should be improved and enhanced with regard to: (a) a more balanced approach towards inclusion of a wider array of stakeholders, particularly citizens' participation; (b) balanced consideration towards all four aspects of sustainability, including institutional aspects; (c) adaptability to the local context and characteristics of the project; (d) a focus on cross- and multi sectoral aspects; and (e) a project's life time considerations. On the other hand, Charoenkit and Kumar [26] investigated to what extent selected rating tools have incorporated aspects of disaster resilience and carbon emissions reductions in their evaluation criteria. Envision [41], one of the most advanced rating tool to assess the sustainability of different infrastructure projects, incorporates aspects of quality of life, leadership, resource allocation, the natural world and climate change (including resilience and emissions) in its assessment framework.

3.4. Climate Project-Based Sustainability Assessment Methods

Climate project-based sustainability assessment methods aim to assess the sustainability benefits of projects that have a primary climate objective (e.g., reduction of carbon emissions). The first climate project-based approach to sustainability benefits assessment is the widely-applied Clean Development Mechanism Sustainable Development (CDM SD) benefits assessment [42–45]. This type of approach aims at measuring qualitatively the contribution of CDM projects to different sustainability benefit categories, such as environmental, social and economic. This type of assessment, unlike rating tools, does not allow the aggregation of scores of different criteria in one final composite index. Furthermore, the contribution of the CDM project to sustainable development benefits is measured in comparison to the baseline situation, without the project. Another climate project-based sustainability benefits assessment method is the Climate Community Biodiversity (CCB) standards that aim at measuring the benefits of a project with specific objectives, such as carbon emission reductions (sequestration), biodiversity, community and climate adaptation [46]. This approach also compares the project situation with the baseline situation (without the project).

3.5. Sustainability Assessments with Resilience Components

The importance of incorporating resilience aspects in sustainability assessments has been discussed in the literature, and the extent to which resilience factors are in included in existing methodologies has been explored. Matthews *et al.* [18] calculated the ratio between sustainability and resilience factors in 11 of the most widely-used sustainability assessment frameworks. The findings indicate that resilience represents 3.3% to 17.9% of the total factors examined in the analyzed frameworks. On average, one the 11 frameworks focuses on resilience, while nine on sustainability [19]. Based on these results, the authors highlight the reasons why resilience (in the wider concept of hazard risk reduction) should be systematically incorporated in sustainability frameworks. Apart from the educational dimensions of mainstreaming resilience, the mutual benefits and also mutual threats of combining sustainability and resilience need to be understood (both in theory and practice) by communities, experts and governments [18].

4. Main Issues to Consider When Developing an SRBA Methodology

This section discusses the main issues to be considered when developing a project-based sustainability and resilience assessment methodology in urban areas based on the literature review.

4.1. Sustainability Dimensions and Resilience Coverage

The first issue to consider when developing a sustainability benefits assessment is the thematic coverage. Which dimensions of sustainability will be considered? Which themes and sectors will be included in the assessment framework? Will the assessment framework address resilience aspects? Those are additional critical questions that should be carefully considered when incorporating resilience aspects in a sustainability benefits assessment framework. The different sustainability and resilience dimensions and themes to be included will determine the specific aspects that will be measured by using relevant indicators. It is imperative to define well what needs to be assessed and what would be included in the assessment. In most cases sustainability and resilience have been approached in isolation, and only a few studies the last few years have looked at their synergies, overlaps and complementarities [17,18,47]. As discussed also in the section of the literature review, there are sectoral approaches to urban sustainability covering only specific urban sectors, but also holistic approaches that aim to integrate the sustainability aspects of multiple sectors.

4.2. Reference for Measuring Sustainability Benefits

A second important methodological consideration is to decide the point of reference that will be used for measuring the sustainability benefits that would be generated by different urban green growth projects. Based on academic literature and international experience in sustainability impact assessments [47–51] there are two main options to use as points of reference for measuring sustainability benefits:

- Baseline as a reference:

Using the baseline as a reference for measuring sustainability benefits would require first to measure the baseline scenario, which actually means measuring the current situation of all parameters (potential sustainability impacts) without considering the proposed intervention (project). Secondly, we need to measure the potential sustainability benefits by implementing the intervention. Then, having the measurements of both the baseline and project scenarios, we can compare them and estimate the actual sustainability impacts, which will be the difference between the two scenarios. This approach focuses on the improvement towards sustainability in comparison to the current situation than on the actual sustainability performance of the project. This type of approach has been applied widely in Clean Development Mechanism (CDM) and climate, community and biodiversity projects [46,51].

- Benchmark as a reference:

Using the benchmark as a point of reference for measuring sustainability benefits would require first to set benchmarks for each type of sustainability benefit. The benchmark will have the form of a standard or target that reflects the sustainable performance of an urban project. Secondly, the actual sustainability impact (performance) of the intervention under investigation should be measured for each sustainability benefit that would be generated. Thirdly, the actual sustainability impacts of the intervention will be compared against the multiple benchmarks that have been established for each type of sustainability benefit. Therefore, this approach focuses more on the project's actual performance towards certain sustainability targets and not on the improvement in relation to the baseline. The main challenge of this approach is the selection of benchmarks, as in many cases, it is not clear and straightforward who should decide for the selecting or setting of them. Another challenge is the actual establishment of a benchmark and estimation of sustainable performance. In the case of a large number of sustainability impacts, the establishment of benchmarks for all possible sustainability impacts becomes even more challenging. Rating systems in buildings and infrastructure projects apply this type of approach, as their main objective is to compare the performance of different projects and to rate them accordingly [41,48].

It should be noted though that the two aforementioned options to measure the level of sustainability benefits are not necessarily mutually exclusive, but rather complementary, since they serve slightly different purposes. They can be combined depending on the type of sustainability benefits they aim to measure. For instance, the baseline can be used as a point of reference (*i.e.*, 1990 levels for carbon) and still set benchmarks (*i.e.*, 80% reduction in CO_2 emissions by 2050); the progress in this case is measured against both the former and latter.

4.3. Multiple Levels of Sustainability and Resilience Benefits

Another important issue when approaching the assessment of sustainability and resilience benefits in cities is to identify the different levels of the benefits/impacts. It is important to understand who will be benefited or affected by the intervention at different levels and possibly within different scales, such as spatial, temporal and institutional [52]. Projects in different sectors in urban areas could have different levels of impact and affect just a number of individual consumers or enterprises (a reduction of energy bills due to energy savings measures), neighborhoods (e.g., flood risk reduction), the city as a whole (e.g., improved air quality) or even resulting in global benefits (e.g., GHG emissions reductions) [53]. Therefore, it is important to be able to identify the level of the benefit/impact realization and to include this information in the analysis. Often, this type of information could indicate possible funding options of the intervention depending on the level that the benefit is accrued.

4.4. Weighting

Another crucial methodological consideration when developing a sustainability and resilience assessment methodology is the decision on whether to include factors of relative importance of different benefits or not. Some benefits might be more important than others depending on the local context; therefore, considerations of relative importance between them can be incorporated in the assessment process. This has been technically applied and incorporated widely in rating systems, both for buildings and infrastructure projects, where different sustainability criteria get different weights according to their predefined relative importance. For instance, in the LEED rating system, energy efficiency criteria get higher factors of importance in relation to water efficiency criteria [48]. An important issue when assigning factors of relative importance is who is going to define these factors. Would the selection be based on a participatory process, such as stakeholder consultation, or would it be a top down selection by the assessment tool developer? Therefore, the incorporation of weighting factors implies a high degree of subjectivity in the overall assessment process. This subjectivity, however, also reflects the reality, since sustainability benefits have different importance in different cities and for different stakeholders [54].

4.5. Trade-Offs between Categories of Benefits

As important it is to identify synergies between multiple sustainability objectives, similarly and probably more important is to identify trade-offs between different sustainability categories [16,47]. Consideration of the trade-offs between different benefits is an aspect to address also when we attempt the assessment of both sustainability and resilience benefits.

Often, there are cases where projects, while improving the sustainability condition of one aspect, might affect negatively the sustainability condition of another aspect, e.g., the improvement of transport infrastructure might increase the noise pollution at a certain area. When planning for compact urban development in order to reduce the need for mobility and, therefore, reduce transport GHG emissions, we should also consider the negative impact that this action might have on reducing urban green areas or on increasing natural hazard risk. Understanding and evaluating trade-offs in sustainability assessment requires making judgments and taking into account the perspectives of different stakeholders. We recognize that the consideration of trade-offs in a sustainability and resilience assessment is highly context specific, both with respect to the type of projects, as well as the values of stakeholders. For example, whether people uphold weak or strong conceptualizations of sustainability will directly determine the kinds of trade-offs they are prepared to accept [47].

4.6. Applicability and Adaptation Ability

Very often, sustainability assessment methodologies, tools and models tend to follow a top down and supply-driven approach, which means the methodology developers would have minimum interaction with potential users [55]. This type of top down standardized approaches to sustainability assessment can lead to limited applicability of these methodologies, since most of the times they fail to relate to the local context and meet the needs of the users or local communities [24]. The flexibility and adaptability of sustainability assessment tools and methodologies are considered essential not only from an adaptive management perspective (adaptation to new information), but also from a demand-driven and local community perspective, providing the opportunity for local users and stakeholders to adapt the main elements of the methodology (e.g., criteria categories, priorities) in order to maximize local relevance and applicability [24].

4.7. Participation and Learning

Different authors who work on the development of new sustainability assessment methods suggest the inclusion and actual engagement of stakeholders in the assessment process [47,55], not only as users, but as co-developers, as well. Sustainability and resilience refer to long-term time horizons and intergenerational equity, bringing the issue of long time frames at the heart of sustainability assessment. The actual impacts of the development of a project and the expectations about these impacts could change over different time periods, implying the need to adapt to the new information, values and priorities. This adaptive approach suggests continuous redesigning of projects and plans and, therefore, regular reiteration and interaction with different stakeholders [55]. In that respect, testing and learning are also becoming important elements of the assessment process leading to a continuous evolution and co-development of the sustainability assessment [56]. Stakeholders can be involved in different phases of sustainability assessment by: (1) defining and redefining the sustainability objectives and targets; (2) providing and periodically re-constructing their preferences and values with regard to the importance (weights) of sustainability criteria; and (3) providing feedback either as users or co-developers of the sustainability assessment process. Moreover, different authors have emphasized how the participation of different stakeholders in the decision-making can by itself lead to the enhancement of resilience [17,18].

4.8. Illustration and Communication of Results

The results of the sustainability benefits assessment can potentially be used by different stakeholders, including project developers, urban planners, local authorities, potential investors, donor agencies, residents, *etc.* Therefore, the way the assessment results are presented and illustrated will determine the level of the assessment's support in decision-making and planning [24] to a large extent. Geographical Information Systems (GIS) and other visualization techniques can support decision-making processes by conveying spatial information in an easily accessible way. They can be used as a basis for communication with stakeholders, as well as for simple visual analyses of the spatial relationship between different relevant parameters [57,58]. GIS maps can be also customized according to the requirements of the project developers and/or local governments in order to give to decision-makers and planners a spatial illustration of where projects are likely to contribute to sustainable development of a city. If combined with further data layers (e.g., important areas for biodiversity or areas where real estate values would be increased), the maps can be used even to assess certain benefits or to illustrate the generation of specific environmental, social and economic benefits.

5. Conceptual Framework

5.1. A Systems Thinking Approach

According to Pisano [8], "resilience thinking is inevitably systems thinking, as much as sustainable development is", while Redman [10] also presents the "system dynamics" as the main domain that requires attention in order to study the two concepts of sustainability and resilience combined. It is therefore essential to follow a systems thinking approach for understanding the interrelationships between the natural environment and human society, before introducing any sustainability and resilience benefits assessment methodology.

Certain functions of environmental assets and resources benefit human beings. Moreover, human activities often cause changes to the quantity or quality of environmental assets and resources, closing the cycle of the socio-ecological system. Figure 4 is an oversimplification of the interrelationships of ecological and socio-economic systems and the way they form a complex socio-ecological system, describing it in a conceptual manner.

The urban socio-economic system is directly interlinked with the ecological system, which provides multiple services to human societies, economies and cities through its three main functions: the resource, sink and service functions (Figure 4 and Table 1). The ecological system is continuously being transformed, as much as the socio-ecological system itself is. The trajectories of these transformations are unpredictable and responsive to a wide range of internal and external influences. An integrative way to understand and deal with these multidimensional changes is by considering the ecological and socio-economic systems as one, a system that is cutting through different, multiple spatial scales and timeframes [8]. This unified system, the urban socio-economic system, in order to persist and withstand internal and external changes, has to be both resilient and sustainable.

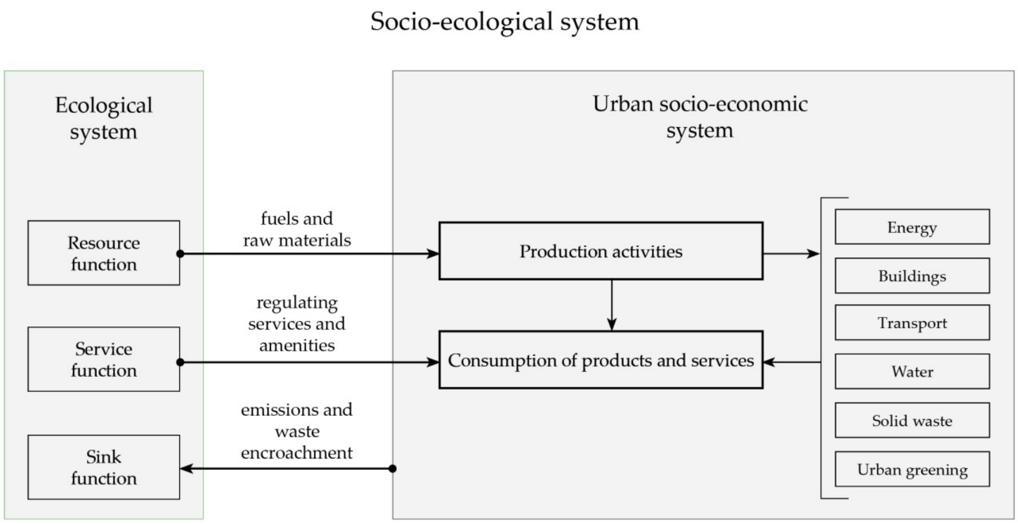

Figure 4. Conceptual diagram of the urban socio-ecological system (source: adjusted from OECD, [59]).

Table 1. The three functions of the ecological system (sources: OECD, 2005 [60]; Millennium Ecosystem Assessment, 2005 [61]).

Resource Function	Through the resource function, the ecological system provides renewable and non-renewable resources, raw materials, fuels, minerals and fibers, which are used as inputs for production activities. Production activities through industrial processes transform these inputs into products and services to human societies. However, production processes and consumption of products lead ultimately to emissions and waste flows back to the environment.
Sink Function	The sink function of the ecological systems is the capacity of the environment to absorb the unwanted by-products of production and consumption, emissions from combustion or chemical processing, *etc.* (OECD, 2005 [60]). However, air pollutants and waste in large amounts often challenge nature's capacity to absorb and process them, leading to contamination of natural resources (air, soil and water). Consequently, environmental contamination and pollution often lead to impacts to human welfare, such as polluted air and water, affecting human health and welfare directly
Service Function	The service function of the ecological system refers to the (i) regulating and (ii) socio-cultural (amenity) services that nature provides to human beings. According to the Millennium Ecosystem Assessment (2005) [61], regulating services (or life-supporting services) are services that provide benefits to human societies from the control of natural processes by ecosystems, such as flood control, micro-climate regulation, carbon sequestration, water purification, *etc.*, and are intensely linked with the main constituents of human well-being (e.g., security, health). Furthermore, socio-cultural (amenity) services are the non-material benefits ecosystems provide to humans for socio-cultural and recreational activities.

5.2. Different Types of Sustainability and Resilience Benefits

Stemming from the material and urban metabolism framework [62,63], we classify the sustainability benefits as *primary, secondary* and *tertiary*. The resource function inputs are *primary* benefits (or impacts), which in the literature have been also identified as input stocks and flows [64]. The primary benefits are the first ones to be observed due to an urban green growth project. For instance, the level of energy resources (resource function input) that would be consumed by a new "green" building would be the first impact that can be relatively easily quantified. Through the multiple activities, processes and projects in different urban sectors, output flows are generated in the form of emissions and wastes, causing pressures on the environment and its sink function (Figure 5 and Table 1). At the same time, these urban sectoral activities and projects provide essential services (e.g., sustainable housing) to urban inhabitants. Their emissions and waste (output flows) or their reduction can be considered as *secondary* impacts/benefits. Moreover, any changes that urban sectoral interventions cause to the regulating and socio-cultural services provided by the ecological system (Table 1) would be also considered as secondary benefits. Changes that secondary environmental benefits (e.g., reduction of air pollution) will cause to human welfare, health and their economic implications can be considered as *tertiary* benefits. It should be emphasized at this point that as we move towards the identification and assessment of secondary and tertiary benefits, their quantification becomes more complex and uncertain (Figure 5).

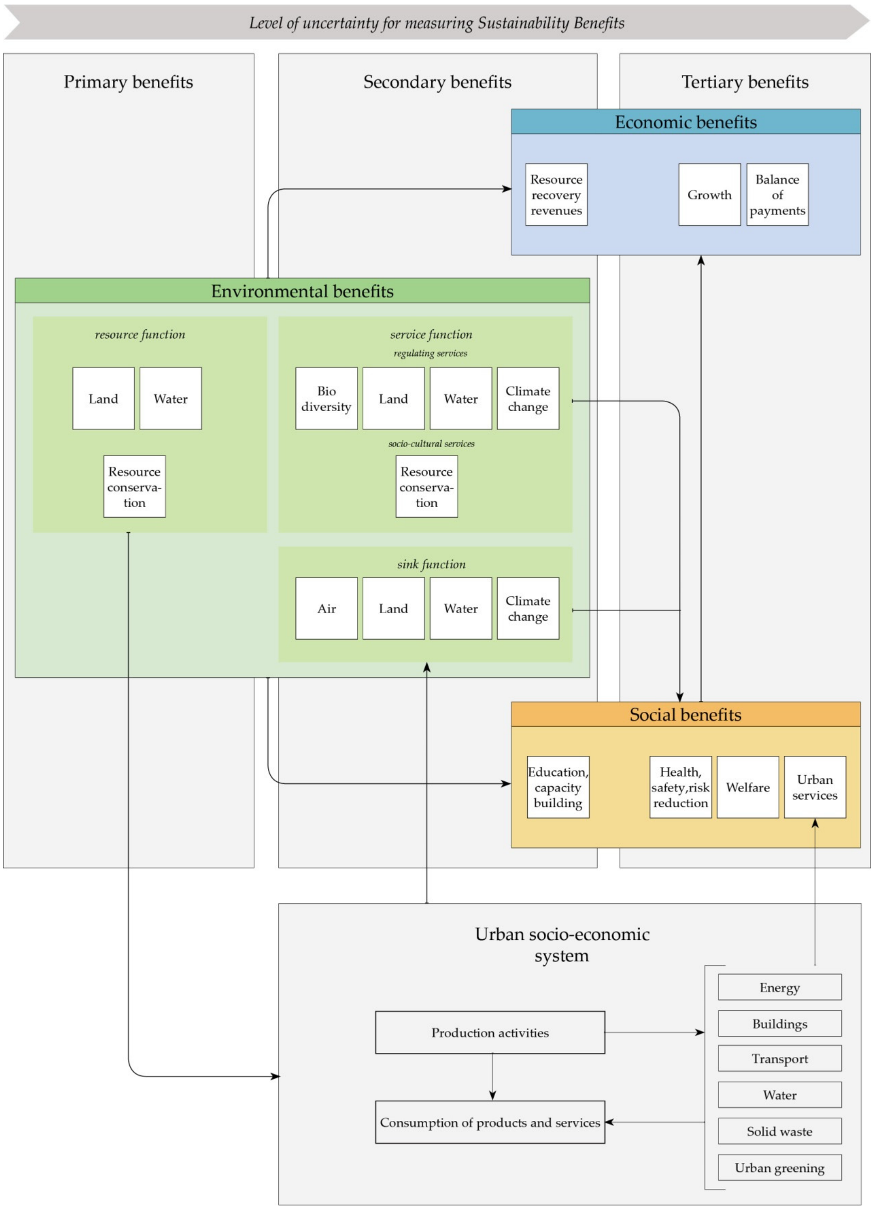

Figure 5. Economic, environmental and social sustainability benefits and their connection to the urban socio-economic system (source: authors).

As mentioned in the literature review, there are numerous approaches attempting to standardize sustainability assessment indicators at the city level for comparative purposes, while resilience aspects are also incorporated in some of these frameworks. However, considering the large diversity of urban socio-ecological sub-systems and green growth projects, standardized approaches are not easy to universally develop; and are also not desirable. The subjectivity of sustainability and resilience assessments is such that the same project would generate different outcomes and benefits, when implemented in different geographical locations or even at the same location, but at different points in time.

Considering that the sustainability and resilience benefits of green growth interventions are contextual, it is important to provide a flexible framework for their identification in different situations. On the basis of the sustainability definition by the Brundtland commission and frameworks for resilience [13,14,65], it can be argued that sustainable and resilient projects should be assessed in terms of the impacts they cause/benefits they bring in four different *dimensions (types of benefits)* (environmental, social, economic and institutional). Overall, urban green growth interventions can lead to a wide range of sustainability benefits in these categories, while many of these benefits include resilience aspects (Figure 6).

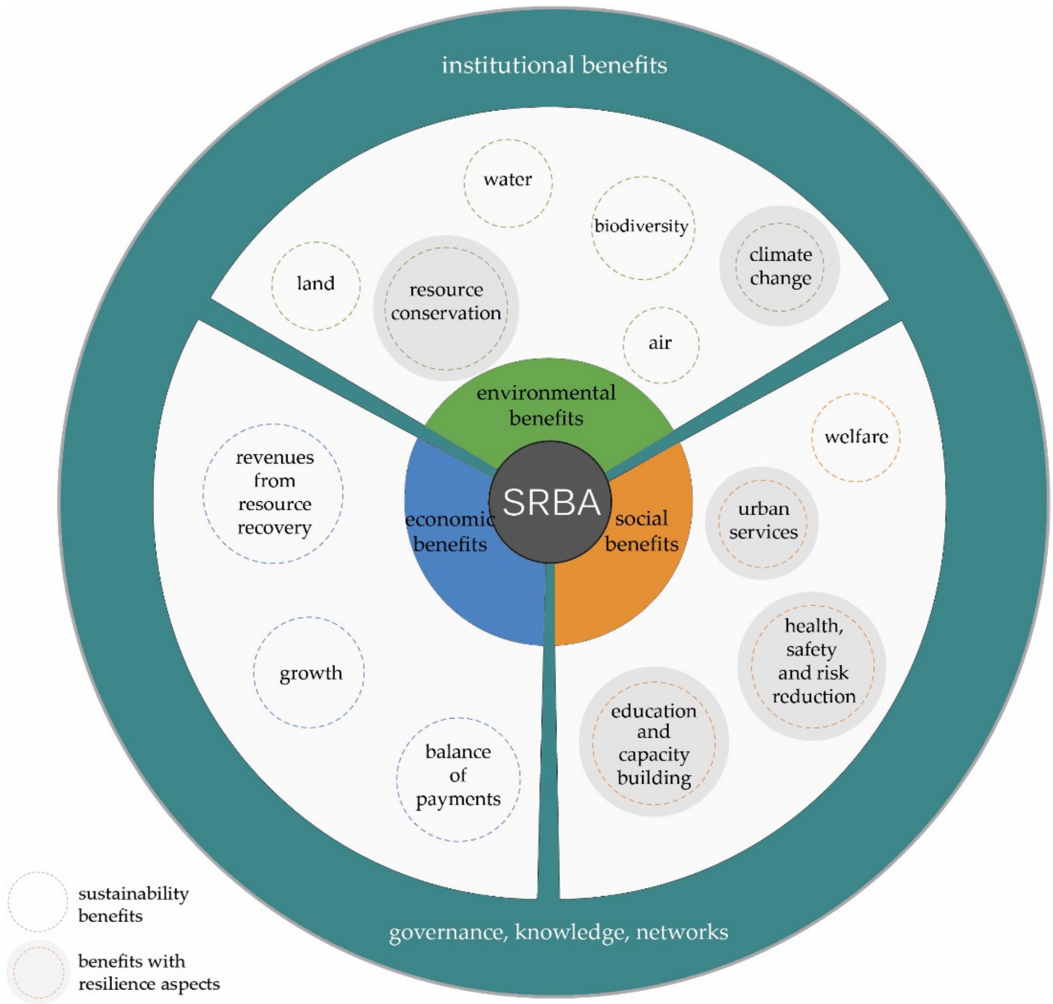

Figure 6. Overall sustainability and resilience benefits assessment (SRBA) sustainability and resilience benefits framework (source: authors).

5.3. Sustainability and Resilience Benefits Categories

Considering the need for flexibility, an overall (but not exhaustive) framework for evaluating urban green growth projects against sustainability and resilience criteria is presented in Appendix A. The framework is based on an extensive review of existing categorizations [41,66–69] and aims to analyze the performance of projects from an environmental, social, economic and institutional point of view.

Under these four dimensions, benefits are organized into two tiers: categories and subcategories. In more detail, environmental benefits are comprised of six main categories (*i.e.*, air, land, water, resource conservation, biodiversity and climate change); social benefits are comprised of four categories (*i.e.*, health, safety and risk, welfare, urban services and education); economic benefits are comprised of three categories (*i.e.*, growth, revenues from resource recovery and balance of payments); and institutional benefits are comprised of three categories (*i.e.*, governance, knowledge, networks). Each of the main categories is further divided into subcategories to specify the types of benefits related to urban projects. It should be pointed out that as sustainability and resilience are nuanced and complex, there may be overlaps between categories and subcategories, and these are best dealt with at the level of the single project being assessed. The graphical representation of the SRBA framework is illustrated in Figure 6. Resilience aspects are incorporated in the highlighted (gray) sustainability benefits categories. The institutional aspects (governance, knowledge, networks) are important for building resilience in the overall urban system. Furthermore, considering the current discourse on and need for developing methodologies for capturing and measuring the achievement of the SDGs, we provide an overall list of all of the linkages between the proposed SRBA framework and different SDGs (Appendix B).

5.4. Different Levels of Sustainability and Resilience Benefits

As it was discussed in Section 4, it is important to identify the stakeholders who actually benefit from a particular urban intervention. Often, cost benefit analysis approaches to sustainability assessment tend to aggregate all benefits in a monetary unit from an investor's perspective. This reductionist approach to sustainability has been widely criticized, opting for new approaches that are able to identify the diversity of benefits and their multiple beneficiaries. Furthermore, identifying the different levels at which sustainability and resilience benefits are generated determines also the interests of the various stakeholders and could potentially indicate funding opportunities for the project. When the various benefits of a project are being assessed, their identification will be dependent on the stakeholders at different levels. For example, local stakeholders may particularly value a benefit, such as local air pollution reduction, which may be irrelevant at the national or international level, whereas international institutions would appreciate a global benefit, such as GHG emissions reduction, which might have less importance for local stakeholders. Hence, an SRBA methodology should aim at identifying the full range of potential stakeholders who will benefit by the project at different levels. This methodology recommends that stakeholders should be identified at four different levels. Benefits from a project may accrue at *individual, neighborhood, city and global* levels.

6. Steps of the Proposed SRBA Methodology

6.1. Identification of the Project and Its Main Characteristics

During the first step of the assessment, the project developer would describe the project and provide information about its main attributes. It is important to highlight here that by project developer, we mean any agent who is proposing a project development and implementation that aims to achieve sustainability and resilience benefits. It could be an individual or a local government or a local community who is developing a project. While the project developer is providing the background project information, he/she would also identify the relevant urban sectors (*i.e.*, energy and buildings, transport, water, waste management, urban greening). More specifically, information should be provided on the location of the project, its main activities, physical features and parameters and the boundaries of the project area.

6.2. Identification of Expected Benefits

The second step provides an overview of the project's main objectives, activities and expected impacts in relation to the sustainability and resilience benefits. In this step, the project developer identifies the type (environmental, social, economic, institutional), direction (positive, negative) and magnitude (low, medium, high) of the expected project impacts by using a screening template, which is identical to the proposed framework of sustainability and resilience benefits (Appendix A). The screening template provides a pre-determined, but still flexible list of environmental, social, economic and institutional impacts. The list of categories and possible impacts is just indicative and subject to modification by local stakeholders and communities to reflect the local context and priorities. The positive impacts are considered as benefits and are included in the SRBA during the *ex ante* assessment stage, whereas, where identified, the negative impacts should be mitigated or minimized to an acceptable level by relevant and affected stakeholders through a participatory consultation process. This preliminary identification of the expected impacts can be derived by the project developer and can be based on background project documents and project objectives.

6.3. Identification of Indicators for Expected Sustainability Benefits

The quantification of benefits requires the creation of specific indicators that best reflect the change between the with project scenario compared to the baseline (without project). The indicators can be decided upon by the project developer, adopted from other valid sources or be selected in a participatory manner by involving local experts and stakeholders. It is important to note that the indicators should be defined in such a way that their value can be measured using the same units for both the without and with project scenarios. The indicators should meet certain attributes, such as measurability, simplicity, availability, cost-effectiveness, acceptability and relevance [37].

6.4. Development of the Baseline Scenario

This step of the methodology consists of the specification of the existing situation scenario (or baseline). The existing situation scenario describes the original conditions of the project area before the project is implemented and is a precondition for measuring the impact of the project following its implementation.

In order to illustrate the situation prior to an intervention, the creation of a Geographical Information System (GIS) database containing all of the relevant information, which will be used in subsequent steps of the SRBA, can be used.

GIS can be used to create and manage a multi-dimensional, multi-purpose and multi-temporal database in a common frame of reference. This is essential in scenario analysis methods when there is a requirement of comparing two different scenarios related to the same geographical area. The geo-spatial database will have spatial information, as well as aspatial information:

- Spatial information refers to the features that have a spatial significance and can be geographically mapped, such as open spaces, surface water bodies, buildings, roads, topography, *etc.*
- Aspatial information refers to the datasets that are not spatial in nature, but are connected with the area of interest, such as household size, average household income, use of buildings (residential, commercial, institutional), property prices, *etc.*

6.5. Development of the Project Scenario

The with project scenario attempts to measure the incremental changes brought about by the implementation of the project, including both the direct and indirect, intended and unintended effects. The outcome of this step should be a list of primary physical impacts of the project. For example, in the case of the enhancement of a wetland project, canopy cover change and water retention area change are the primary physical impacts of the project. The identification of primary physical impacts is a necessary condition in order to be able to identify the secondary (and tertiary) sustainability benefits of the project.

In the case of GIS application, the project features should be mapped using the same geo-referencing system as the one in the baseline (pre-project scenario), including both spatial and aspatial information for the project scenario. This can be mapped in one GIS layer or multiple layers depending on the project design and specifications. All of the project layers should be added to the SRBA geo-spatial database.

6.6. Estimation of the Difference between Baseline and Project Scenarios

This step aims at measuring the net benefits deriving from the implementation of the project by estimating the change between the situation without the project and the situation with the project. The change in net sustainability benefits will be measured for all relevant benefits, and the change will be expressed also as a percentage that is the percentage change of the with project scenario compared to the without project scenario. Each sustainability benefit of the project would be expressed in terms of absolute and relative change to the baseline. The combination of changes in the types and levels of sustainability benefits constitute the overall change in the state of sustainability derived from the implementation of the project in a non-aggregated manner.

It shall be noted that change in the state of sustainability (ΔS) for each indicator is measured as:

$$\Delta S = PS_{(\text{value of indicator in the “with project” scenario})} - BS_{(\text{value of indicator in the “without the project” scenario})}$$

where FS stands for “project state” and BS stands for “baseline state”.

In cases where there is information on project benchmarks, standards or an ideal project situation (scenario), an additional measurement of the level of benefits achieved by the project could also be assessed against an “ideal scenario” represented by selected or established benchmarks. As mentioned above, the benchmarks will be in the form of standards or targets that reflect the sustainable performance of an urban project. The sustainability impacts of the intervention should therefore be compared against the multiple benchmarks that have been established for each type of sustainability benefit; whereas the level of achievement of sustainability (AS) in comparison to the sustainability benchmark set would be measured as:

$$\text{AS} = \text{IS}_{(\text{value of indicator in the “ideal” scenario})} - \text{PS}_{(\text{value of indicator in the “with project” scenario})}$$

where IS stands for “ideal state” and PS stands for “project state”.

The measurement of different types of sustainability benefits would rely on different techniques. By way of illustration, for measuring environmental benefits, it is possible to use specific quantification methodologies, such as environmental impact assessment, air quality impact assessment, dispersion modelling, *etc.* For measuring social impacts, it is possible to use other approaches, such as social impact assessment, quality of life assessment, health impact assessment, *etc.* For measuring economic benefits, economic assessment methodologies can be used, such as hedonic pricing, contingent valuation, cost benefit analysis and econometric modelling [70].

6.7. Development of the Sustainability and Resilience Benefits Assessment Matrix

In the last step, the net sustainability and resilience benefits deriving from the project are presented in a matrix called the sustainability and resilience benefits assessment (SRBA) matrix. The SRBA matrix summarizes different types and different levels of net benefits and is structured in two axes. On the vertical axis, it shows four levels where benefits accrue (individual, neighborhood, city and global), and on the horizontal axis, it shows the different types of sustainability benefits (environmental, social, economic and institutional) (Figure 7).

Levels of Benefits	**Types of Benefits**			
	Environmental	**Social**	**Economic**	**Institutional**
Individual				
Neighborhood				
City				
Global				

Figure 7. The SRBA matrix depicting four different types and levels of sustainability benefits (source: authors).

This matrix will help in illustrating which type of sustainability and resilience benefits will be accrued as a result of a project. The benefits, as explained in Step 4, are measured in terms of absolute and percentage changes in comparison to the baseline (and to a benchmark whenever relevant). Here, the sustainability and resilience benefits are presented in an overall matrix according to the type (*i.e.*, environmental, social, economic, institutional) and level (*i.e.*, individual, neighborhood, city, global) of the benefit. All of these ranges of benefits do not have the same importance for the city. The city could decide which type of sustainability and resilience benefits are the most important ones according to its priorities. One way to consider the relative importance issues would be to investigate to what extent the benefits accrued by the project contribute to the Sustainable Development Goals, particularly those the city has prioritized. Therefore, the local stakeholders could see these ranges of multiple benefits in comparison to the actual city performance against the relevant SDG indicators.

7. An Illustrative Example: Urban Forest in the City of Cali, Colombia

For illustration purposes, we present an example of the SRBA pilot application on an urban forestry project in the city of Cali, Colombia. Cali is the third largest city of Colombia, with two million inhabitants, located on the Cauca River valley. A stakeholders' workshop was organized, where the involved stakeholders identified the expected benefits of the urban forest and selected the indicators to be used to quantify and measure two of the sustainability benefits, using the SRBA methodology. The quantification of the identified benefits and their illustration on GIS maps was done with the support of the Universidad del Valle in Cali.

7.1. Identification of the Project and Its Main Characteristics

As one of the greening projects, Cali is planning to enhance an urban forest in the east of the city and to reduce the deficit of trees in the area. The project involves the establishment and maintenance of the forest area as part of the renovation of urban public areas and as an action for mitigation and adaptation to the effects of climate change. The project is located in Commune 14 (Figure 8), one of the 22 administrative subdivisions of the city of Cali, which itself consists of 10 neighborhoods. Currently, Commune 14 has 151,544 inhabitants, 7.4% of the total population of the city, making it the third most populous area of Cali. The density in the area is almost double that in the rest of the city (70 compared to 41 dwellings per hectare).

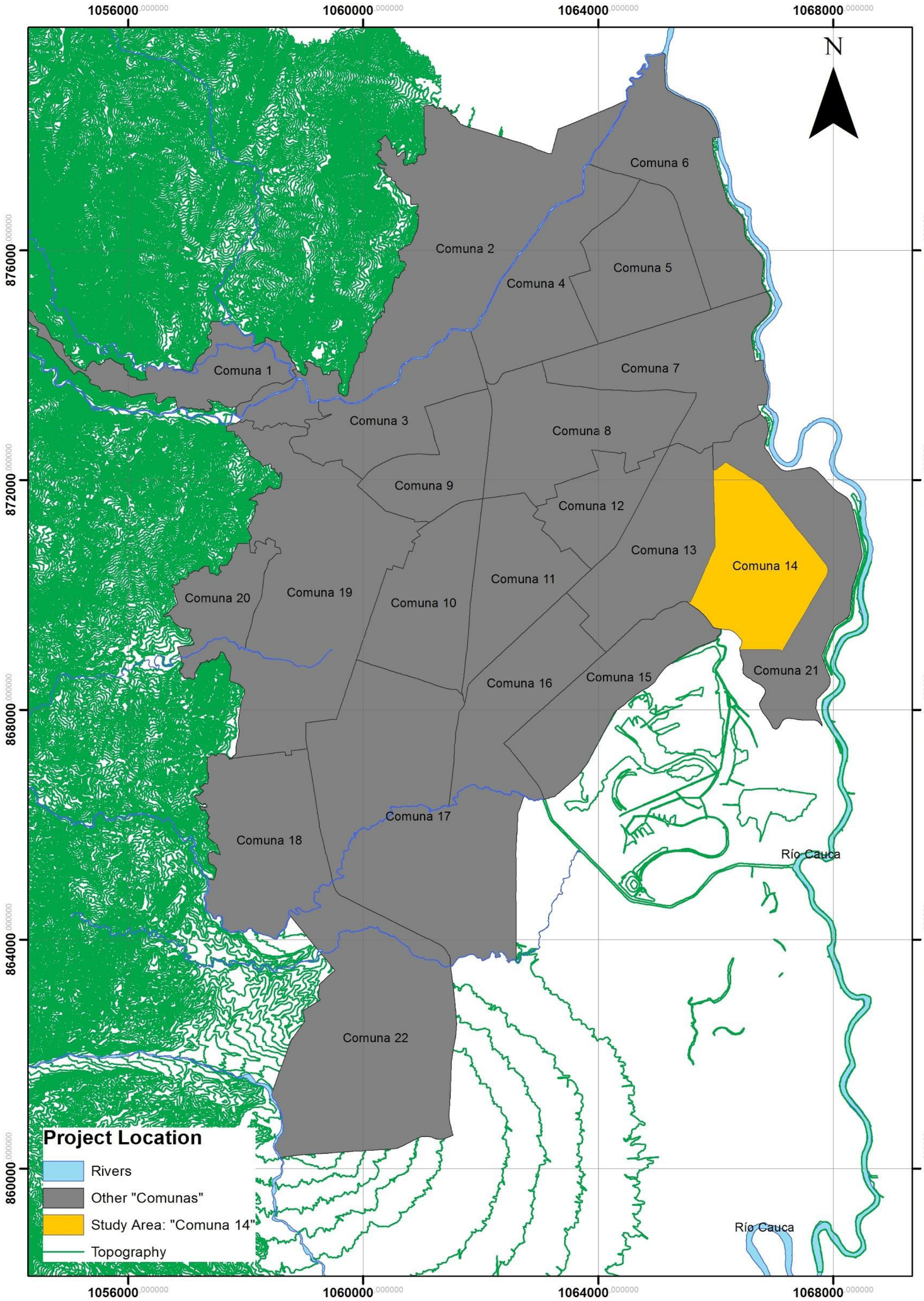

Figure 8. The location of Commune 14 in Cali.

7.2. *Identification of the Expected Impacts/Benefits*

Within the framework of the local workshop, local stakeholders identified the main expected sustainability impacts/benefits. The workshop was organized by the Municipality of

Cali—Administrative Department of Environmental Management, called DAGMA, involving 18 local experts and stakeholders representing different agencies of the municipality that are involved in the development of urban projects. The stakeholders used the overall SRBA framework template and identified the expected sustainability benefits presented in Figure 9. The identified (by the workshop stakeholders) expected benefits are of three types (environmental, social, institutional) on three different levels (neighborhood, city, global).

Levels of Benefits	Types of Benefits			
	Environmental	Social	Economic	Institutional
Individual				
Neighborhood	-Improvement of air quality	-Aesthetic improvement		
City	-Conservation of natural resources -Biodiversity	-Quality of open public green space -Quantity of open public green space -Quality of life -Recreation facilities		-Coordination between governmental institutions/departments
Global	-Carbon sequestration			

Figure 9. Expected sustainability and resilience benefits of the urban forest project in Cali, Colombia.

7.3. Identification of Indicators for Expected Sustainability Impacts/Benefits

As was explained in Section 6, the quantification of benefits requires the development of measurable indicators that could reflect the change between the situation of the "with project" scenario compared to the baseline "without project" scenario. For the sake of illustration of the overall methodology, we limit this example to two sustainability benefits, which was also the focus of the local stakeholders' workshop. The stakeholders selected measurable indicators for the sustainability benefits of carbon sequestration and the quantity of open public green space. Carbon sequestration was measured by the "percentage of area of CO_2 capture", and the quantity of open public green space was measured by the "number of inhabitants per tree".

7.4. Development of the Baseline Scenario

The two aforementioned indicators were measured (Appendix D) for the current situation (baseline scenario). In addition, the indicators were geo-referenced in GIS, by creating a database that helps to observe the impacts and benefits of the project spatially, on the project area (Figure 10).

7.5. Development of the Project Scenario

The same process described in Section 7.4 for calculating and illustrating the baseline scenario was followed also for the project scenario, in order to estimate the impact of the project with regard to the two selected benefit indicators. The GIS maps in Figure 11 illustrate the project area, including the new trees added through the urban greening project.

7.6. Estimation of the Difference between Baseline and Project Scenarios

In order to estimate the sustainability improvement, each of the two selected sustainability benefits of the project are expressed as the difference between the baseline and the project scenario (Figure 12). In this example, there is no use of a specific target or benchmark to compare to these two sustainability benefits.

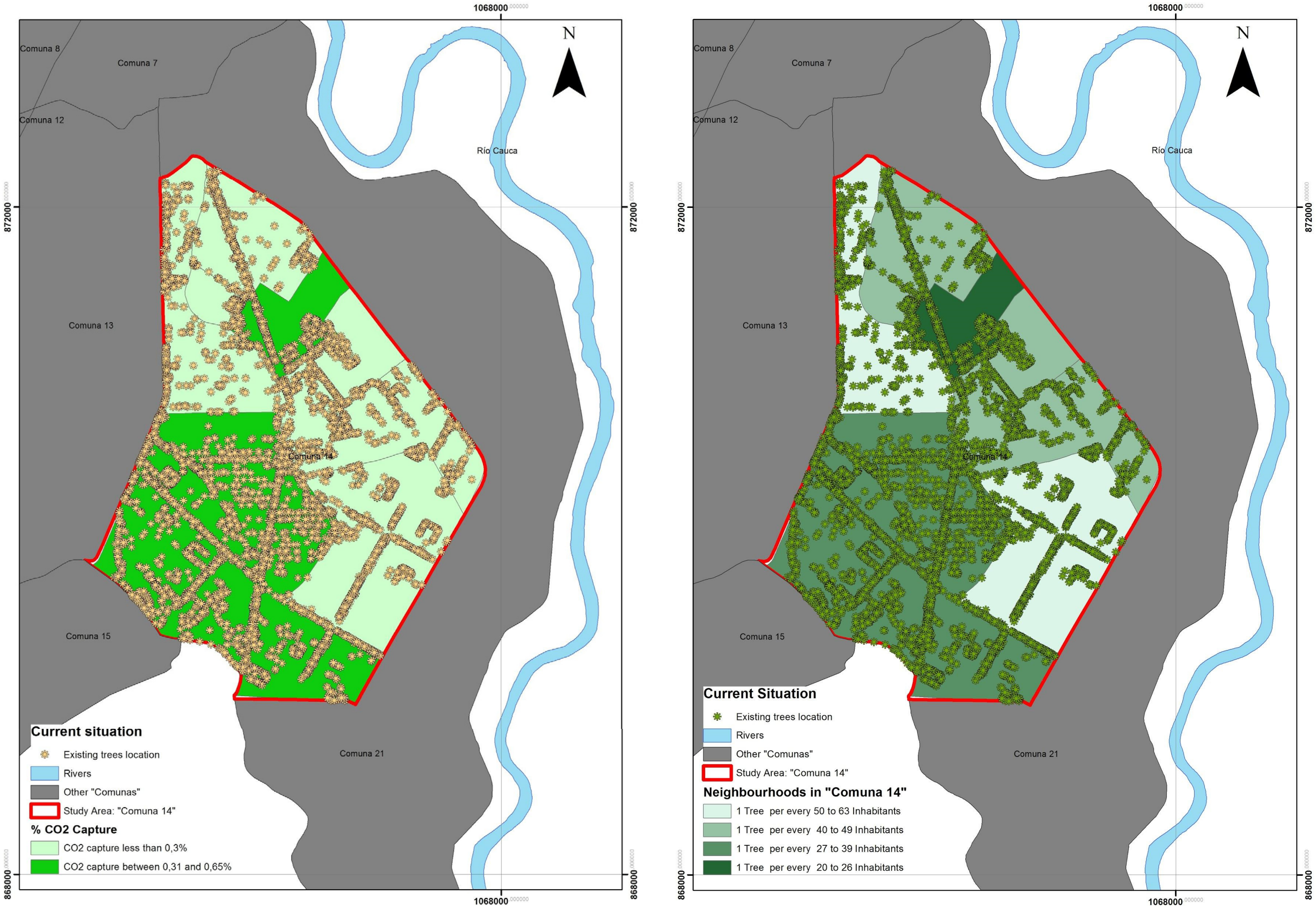

Figure 10. GIS maps of the baseline scenario.

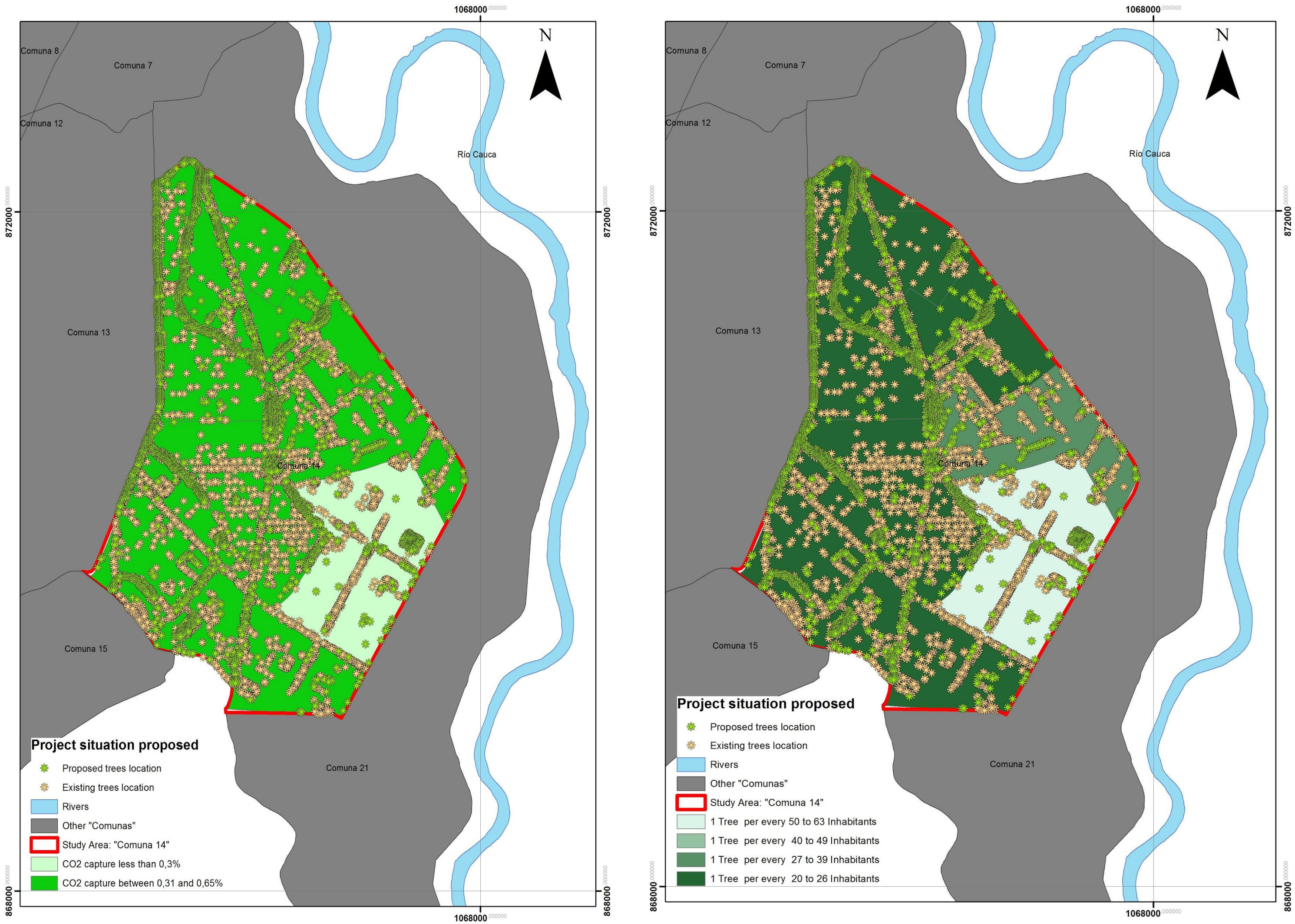

Figure 11. GIS maps of the project scenario.

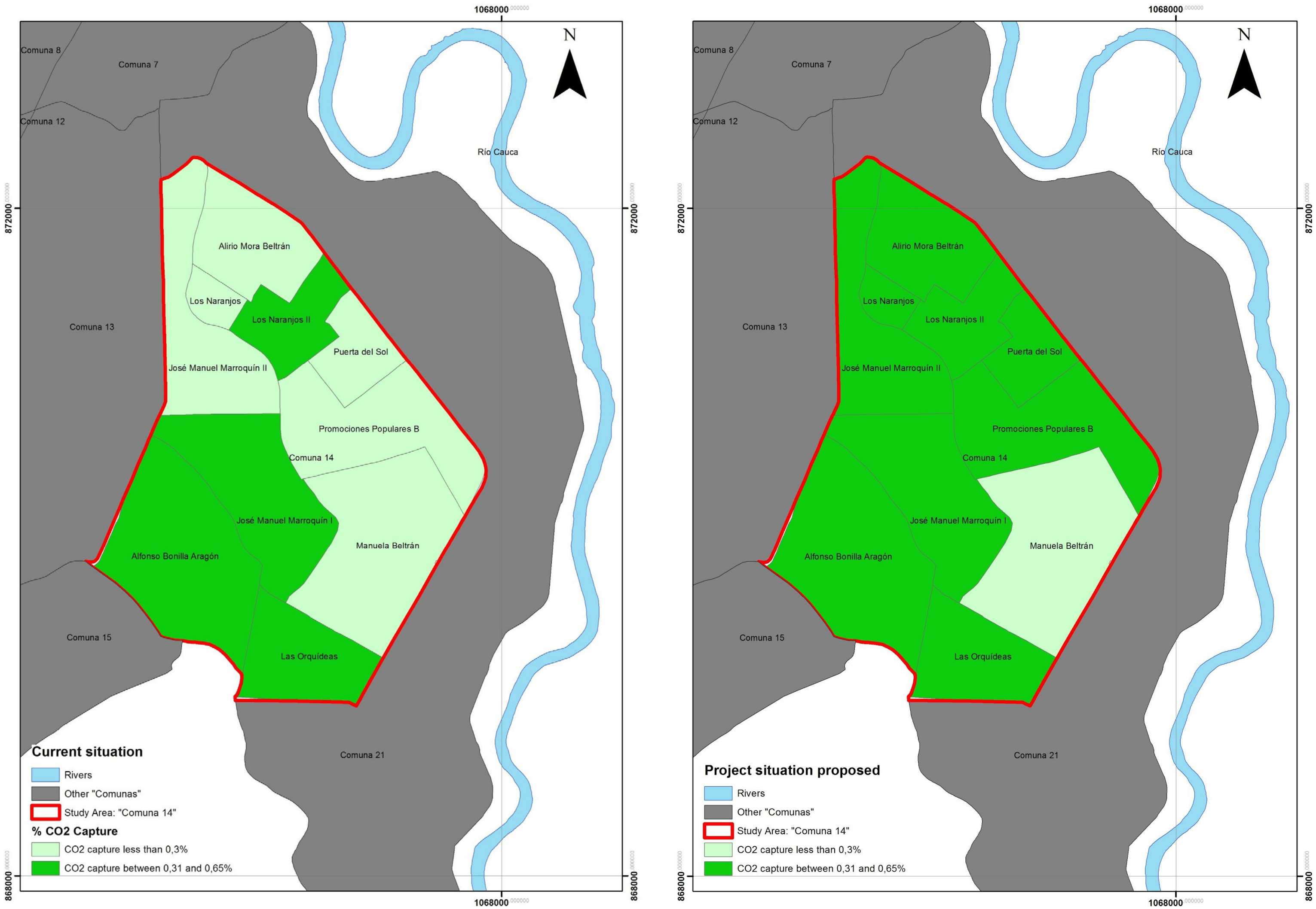

Figure 12. *Cont.*

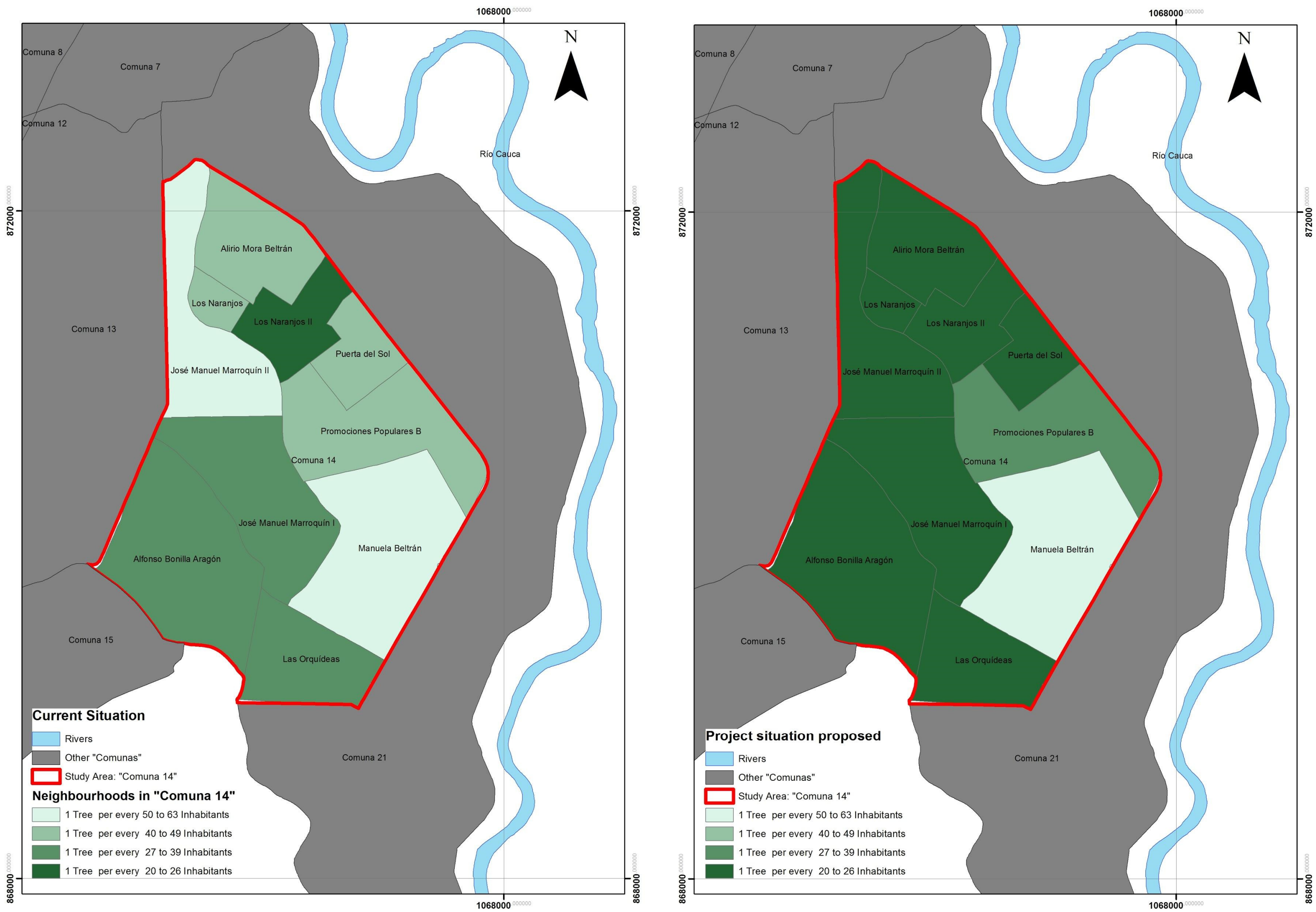

Figure 12. Maps illustrating the difference of the selected sustainability benefits between the baseline and project scenarios.

7.7. Development of the Sustainability and Resilience Benefits Assessment Matrix

In the last step, the net sustainability and resilience benefits deriving from the urban forestry project are presented in the sustainability and resilience benefits assessment (SRBA) matrix. The matrix shows the different types of benefits (environmental, social, institutional) and the different levels (neighborhood, city, global) that would be accrued (Figure 13). The city of Cali could decide which type of sustainability benefits are the most important ones according to its priorities. In this particular case, as can be evinced from the matrix, the project has brought about an increase in the percentage amount of CO_2 capture (from 0.29% to 0.51%), as well as a decrease in the ratio of the number of trees per inhabitant (from one tree/48 inhabitants to one tree/27 inhabitants).

Type of Sustainability Benefits/Impacts	Environmental				
	Benefit	**Level of Benefit**	**Baseline Scenario**	**Project Scenario**	**Difference**
	Improvement of air quality	Neighborhood			
	Conservation of natural resources	City			
	Biodiversity	Neighborhood			
	Carbon sequestration	Global	0.29% of CO_2 capture	0.51% of CO_2 capture	0.22% of CO_2 capture
	Social				
	Benefit	**Level of Benefit**	**Baseline Scenario**	**Project Scenario**	**Difference**
	Aesthetic improvement	Neighborhood			
	Quality of open public green space	City	1 tree/48 inhabitants	1 tree/27 inhabitants	1 tree/21 inhabitants
	Quality of life	City			
	Recreation facilities	City			
	Institutional				
	Benefit	**Level of Benefit**	**Baseline Scenario**	**Project Scenario**	**Difference**
	Coordination between governmental institutions/departments	City			

Figure 13. SRBA matrix for the urban forestry project.

8. Concluding Remarks

The current article presents the main methodological issues to be considered when developing a sustainability and resilience benefits assessment methodology based on an extensive literature review. In particular, the article discusses how issues of sustainability coverage, the reference point as the measurement, weighting, sustainability trade-offs, applicability and adaptability and the illustration and communication of results can be addressed and considered during the development of an urban project-based sustainability and resilience benefits assessment methodology. The current study proposes an SRBA methodology that integrates both top-down (based on literature review) and bottom-up (adaptability and validation of the framework by local stakeholders) approaches and further incorporates a map-based visualization technique for sustainability benefits' illustration and communication. The proposed methodology aims to identify and measure multiple sustainability (environmental, social, economic, institutional) benefits that can be accrued by green growth projects in different urban sectors and to support urban green growth project developers and local governments to identify and assess sustainability benefits that can be generated at different levels, namely individual, neighborhood, city and global. Furthermore, the SRBA methodology can identify and measure simultaneously in a holistic way local sustainability, urban resilience and disaster risk reduction benefits along with global climate mitigation benefits. The step by step approach to the sustainability and resilience benefits assessment provides a high degree of adaptability and flexibility for application based on different local contexts.

The proposed SRBA framework transparently identifies and assesses the sustainability benefits accruing to a single project, either independently or as part of a broader initiative of the municipal authority. However, the effort of eventually implementing the methodology at a programmatic level could be also reasonable and relevant. Eventually the methodology could be expanded to assess the sustainability benefits of a portfolio of projects or wide green growth programs in cities. The SRBA methodology could be combined with a monitoring reporting and verification (MRV) framework and strengthen the credibility of the sustainability benefits claimed by project or program developers, increase stakeholder confidence and eventually attract investments. The SRBA methodology should be considered as work in progress to be further refined through further research, testing and application to concrete projects in various urban sectors and urban green growth programs. The authors are in the process of involving local stakeholders and experts in the city of Cali, Colombia, in order to adapt and apply the current methodology at the local context measuring all of the sustainability benefits that would be accrued from a project. The authors have already started testing the methodology in a real urban green growth project and would aim to present the results and lessons learned of the application at the next phase.

Acknowledgments: The authors would like to acknowledge that this research and the development of the SRBA methodology was funded by the World Bank Group under Contract Number 5830 0000.020. In addition, the authors would like to thank the following experts for providing valuable comments and contributions at different levels of the development of the SRBA methodology: Monali Ranade and Sara Mill-Knap (The World Bank Group), Abhishek Banzal and Vikash Talyan (Gold Standard Foundation), Sonia Sandhu (Asian Development Bank), Somesh Sharma, Taslim Alade, Luca D' Acci, Joris Tieleman and Veronica Olivotto (Institute for Housing and Urban Development Studies). Furthermore, the authors would like to express their gratitude to Adriana Lopez from the Universidad del Valle (Colombia) for providing data and GIS maps on the urban forest project example in Cali, Colombia. The authors would like also to thank three anonymous reviewers who provided fruitful comments and feedback for the improvement of the manuscript.

Author Contributions: Stelios Grafakos conducted part of the literature review, conceived and developed the overall SRBA framework regarding its conceptual framework, methodological steps and illustrative example. Alberto Gianoli conducted part of the literature review and contributed to the development of the different steps of the SRBA methodology. Alexandra Tsatsou conducted part of the literature review and contributed to the development of the SRBA conceptual framework.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A: SRBA Framework

Figure A1. SRBA framework.

Appendix B: Link of the SRBA Framework and Global SDGs

Sustainability & Resilience Benefits	Relevant SDGs & targets
Environmental Benefits	
Air	11, 12
Sink function	
Reduction of air pollution (Emissions/waste)	11.6, 12.4
Improvement of outdoor air quality (Quality of resources)	11.6
Land	2, 5, 11, 12,15
Resource function	
Land saving	15.3
Increase of soil fertility	2.4, 15.3
Sink function	
Avoidance of land contamination (Quality of resources)	12.4
Avoidance of landfill methane (Emissions/waste)	11.6, 12.4
Reduction of solid mass and volume of waste (Emissions/waste)	12.5
Water	6, 11, 15
Resource function	
Conservation of water resources	6.6, 15.1
Increase in rainwater harvesting	6a
Development of natural water bodies	15.1
Regulating Service function	
Storm water retention	11.b
Enhancement in flood control	11.b
Sink function	
Prevention/reduction of ground water contamination	6b
Prevention/reduction of surface water contamination	6b
Improvement in the ecological state of water bodies	6.6
Improvement in the quality of water resources	6.3
Resource conservation	6, 11, 12, 15
Resource function	
Conservation of natural resources	6.6, 12.2, 15.1
Fuel use reduction	7.2, 11.b
Energy use reduction	11.b
Renewable energy production	7.2, 7a
Improvement in energy efficiency	7.3, 11.b
Production of recycled materials	12.5
Biodiversity	2, 15
Regulating Service function	
Protection of biodiversity	2.5, 6b, 15.4, 15.5, 15a
Climate change	11, 12, 13
Sink function	
Reduction in GHG emissions (Emissions/waste)	11.b, 13.2
Avoidance of short lived climatic pollutants (Emissions/waste)	12.4
Social Benefits	
Health, safety and risk reduction	1, 2, 3, 5, 11, 13
Lives saving	11.5
Reduction of diseases	3.3
Reduction of accidents	3.6
Reduction in the vulnerability to extreme weather events	1.5, 2.4
Risk reduction to natural hazards	11.5, 13.1

Sustainability & Resilience Benefits	Relevant SDGs & targets
Welfare	1, 2, 8, 11, 15, 17
Support to community development	1.3, 8.9, 11a
Poverty alleviation	1.1, 1.2
Improvement in working conditions/quality of	8.8
Improvement in recreational facilities	11.4, 11.7
Aesthetic improvements	11.7
Time savings	11.2
Reduction of foul smell	3.a
Reduction in traffic congestion	11.2
Quality improvement of open public spaces	11.7
Increase in the quantity of open public spaces	11.7
Increase in food security	2.1, 2,3, 2.4
Increase in food quality	2.2, 2.5
Urban services	6, 7, 10, 11, 12
Improvement in the accessibility to water resources	6.1
Improvement in the affordability of water resources	6.1, 10.1
Improvement in the accessibility to transport	11.2
Improvement in the affordability of transport	11.2, 10.1
Improvement in coverage/accessibility of energy supply	7.1
Improvement in the affordability of energy supply	7.1, 10.1
Incineration of clinical waste	12.4, 12.5
Incineration of hazardous waste	12.4, 12.5
Education and Capacity Building	3, 4, 6, 11, 12, 13, 14, 17
Enhancement in educational services	4.1, 4.2, 4b, 4c
Increase in knowledge dissemination	3.7, 13.1, 13.3, 14.a
Enhancement in capacity	6a, 11.3, 12.5, 13.1, 13.3, 17.7, 17.8, 17.9, 12.5
Economic Benefits	
Growth	1, 7, 8, 10, 17
Promotion of local economic development	8.1
Increase of investment opportunities	7a, 10b
Techonology diffusion	1.2
Employment generation	8.3, 8.6
New sources of income generation	17.1
Revenues from Resource recovery	7, 12
Balance of payments	17
Reduction of dependency on foreign goods and services	17.1
Institutional Benefits	
Governance	16
Coordination (vertical/horizontal) between departments/government institutions	16.6
Knowledge	9, 12, 13, 17
Knowledge enhancement based on data and scientific information	9.5, 17.8
Creation of awareness	12.8, 13.3
Networks	6, 7, 16, 17
Cooperation between multiple stakeholders	6.a, 7.a, 17.6, 17.17
Participation of stakeholders	6.5, 16.7, 17.16

Figure B1. Link of the SRBA framework and global SDGS.

Appendix C: Urban Green Growth Interventions in Different Sectors

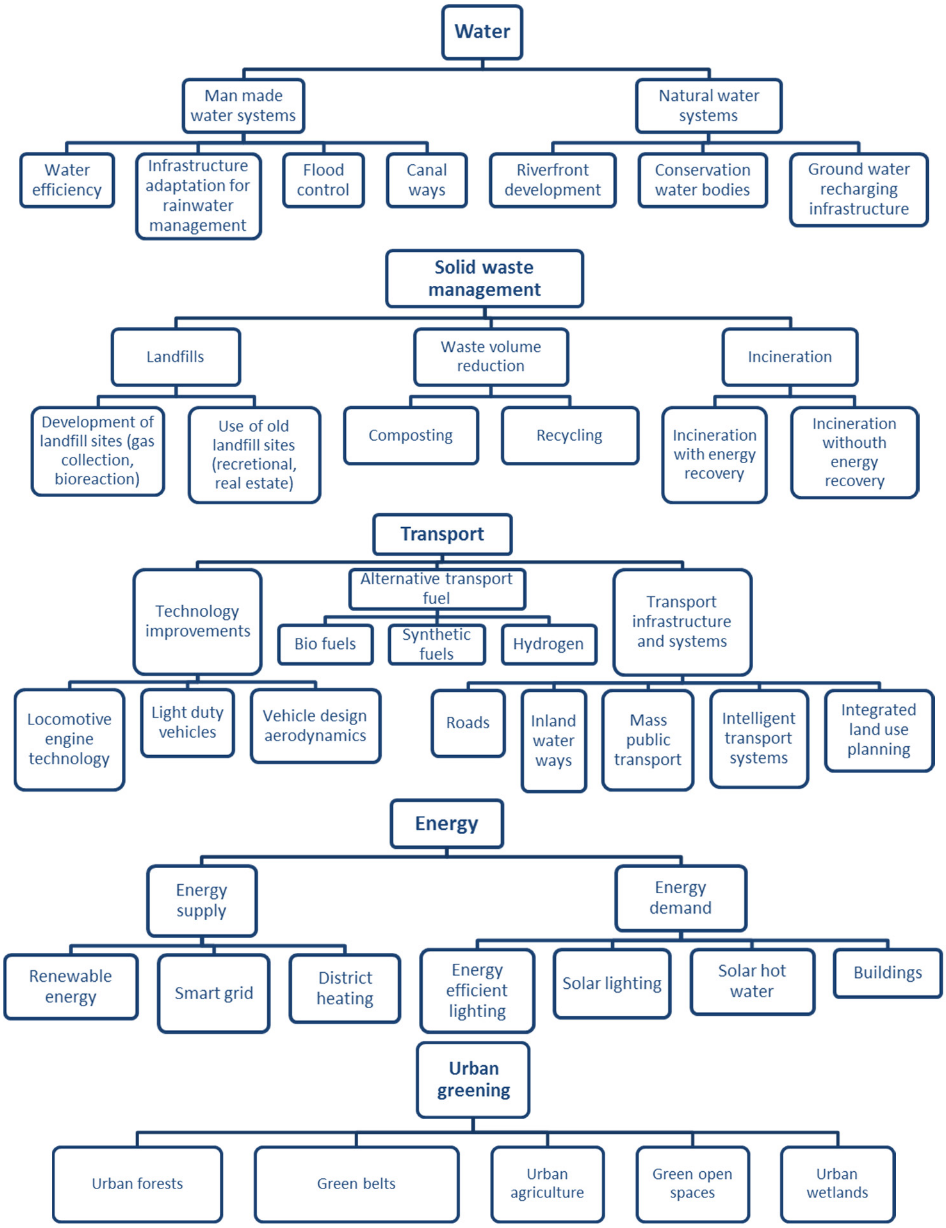

Figure C1. Urban green growth interventions in different sectors.

Appendix D: Scaling of Indicators for GIS Illustration

Table D1. Sustainability indicator: CO_2 capture.

Level of Performance	CO_2 Capture (Percentage)	Scaling for GIS Process	Qualitative Evaluation
Very low	CO_2 capture 0% to 5%	0.00	Very low level CO_2 capture per area
Low	CO_2 capture 5% to 10%	0.25	Low level CO_2 capture per area
Acceptable	CrO_2 capture 10% to 15%	0.50	Acceptable level CO_2 capture per area
High	CO_2 capture 15% to 20%	0.75	High level of CO_2 capture per area
Very High	CO_2 capture more than 20%	1.0	Very high CO_2 capture per area

Table D2. Sustainability indicator: trees per inhabitants.

Level of Performance	Tree Cover (Trees per Inhabitant)	Scaling for GIS Process	Qualitative Evaluation
Very low	1 tree per more than 12 inhabitants	0.00	Areas with very low cover in terms of trees per capita
Low	1 tree per 6.1 to 12 inhabitants	0.24	Areas with low cover in terms of trees per capita
Acceptable	1 tree per 4.1 to 6 inhabitants	0.48	Areas with medium cover in terms of trees per capita
High	1 tree per 3.1 to 4 inhabitants	0.72	Areas with high cover in terms of trees per capita
Very High	1 tree per 3 inhabitants	1.00	Areas with very high cover in terms of trees per capita

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