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Original Research Paper

Achieving Sustainable Development Goals Through Urban Biodiversity Conservation and Animal-Centered Policies

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Abstract

Habitat fragmentation and the loss of biodiversity and environmental degradation has accelerated as a result of the rapid urbanization process, creating great difficulties in achieving the United Nations Sustainable Development Goals (SDGs). Animal-centred Policies have helped build the effectiveness of Urban Biodiversity Conservation as a way to build ecosystem resiliences, environmental quality and sustainable city development. The paper delves into the contributions of urban biodiversity to the Sustainable Development Gaps of SDG 3 (Good Health and Well-Being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land). Existing methods of biodiversity conservation, biodiversity assessment and intelligent monitoring technologies are comprehensively reviewed to determine gaps and challenges in existing research. The results point to an integrated framework for SDG-oriented framework, integrating urban environmental data acquisition, biodiversity and wildlife monitoring, AI enabled spatial analysis, animal based governance and sustainability performance evaluation. The proposed framework is found to be significantly better than the conventional frameworks in terms of the biodiversity monitoring accuracy, which has been increased from 74% to 95%, habitat assessment, which has been increased from 70% to 93%, ecosystem service evaluation, which has been increased from 68% to 92%, wildlife detection, which has been increased from 72% to 96%, real-time monitoring capability, which has been increased from 60% to 97% and overall sustainability score, which has been increased from 72% to 95%. The framework is a scalable, evidence-based decision-support tool that can foster cities that are biodiversity-rich, climate resilient and animal inclusive, and that can help to speed up the global transition towards sustainable development.

Keywords— Urban biodiversity conservation, Sustainable Development Goals (SDGs), animal-centered policies, artificial intelligence, GIS, remote sensing, ecosystem services, smart cities, sustainability assessment, urban planning.

I. Introduction

More than half of the world's population is now living in cities and urbanization has become one of the most prominent features of the 21st Century. Urban areas are known to be the site of economic development, technological advancement and social development, but the processes of rapid urbanization have significantly changed the natural ecosystems by habitat fragmentation, land use change, pollution and climate change. These changes have led to the degradation of biodiversity and a decrease in ecological resilience of the city, which represent great challenges for sustainable development. Therefore, urban conservation has become a very important part of urban planning for achieving sustainable development in the city and is a balance between environmental preservation and socio-economic development [1, 2]. Recent research also shows that urban green spaces that support biodiversity greatly enhance their ecosystem functioning and ecological stability at different levels of space [6]. Urban biodiversity is

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the diversity of plants, animals, microorganisms and relationships that are found in the metropolitan environment. Birds, pollinators, bats, amphibians, insects, and small mammals are vital to an ecosystem's balance, helping to pollinate, disperse seeds, control pests, cycle nutrients and stabilize foodwebs in the city. Providing habitats for these species, green spaces, wetlands, urban forests, parks and water bodies also offer valuable ecosystem services like climate regulation, air purifying, stormwater management, and recreation. For example, well managed and clean urban water bodies are known to enhance urban ecological networks, by supporting nocturnal flying insects and insectivorous bats, and improve biodiversity conservation [5]. Likewise, management approaches that promote a greater diversity of species have been shown to improve the ecological interactions and connectivity of urban landscapes [6].

The United Nations Sustainable Development Goals (SDGs) have laid the groundwork for an integrated global framework to tackle environmental sustainability, economic prosperity and social well-being. Urban biodiversity helps achieve multiple SDGs, such as SDG 3 (Good Health and Wellbeing), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land). Within the context of urban areas, the conservation of biodiversity contributes to better ecosystem resilience [1], mitigation of the urban heat island [1], improvement of public health [2, 3, 4, 5], climate adaptation [2, 6, 7] and wildlife conservation [1]. This means that animal-related urban policies are gradually being identified as crucial tools in the process of sustainable urban development, which have to focus on habitat conservation, infrastructure design to favour animals, ecological corridors, and ethical coexistence with animals [2].Although there is an increasing awareness of urban biodiversity conservation, there are still many research gaps that need to be addressed to ensure that it is effectively included in urban planning and policy-making. Current urban planning frameworks are mostly about transportation, housing, infrastructure development expansion and economic development and biodiversity conservation is rarely seen as a main priority of a city plan but more of an environmental target [1]. Furthermore, most biodiversity assessment research focuses on extent of vegetation cover or landscape features, while neglecting the ecological value of the animal component of urban ecosystems and their ecosystem services. Existing policy documents also do not have a standard approach to assessing the contribution of biodiversity conservation to achieving several SDGs. Consequently, urban biodiversity management is still disjointed, with lack of coordination in terms of ecological monitoring, implementation of policies and sustainability assessment.

There are several technical and operational limitations of the existing methods for urban biodiversity assessment. Traditional ecological surveys rely on time-consuming, expensive, geographically constrained, manual, field observations and cannot be used to continuously track the rapidly changing urban environment. Most GIS-based assessments are static, and offer only a limited understanding of wildlife movements or habitat quality, species interactions, or ecosystem dynamics. Biodiversity is often assessed in its own right as part of environmental impact assessment, which may lead to environmental and urban planning decisions being made without connection to each other. In addition, current monitoring infrastructure does not often combine artificial intelligence, machine learning, remote sensing, wireless sensor networks and automated ecological monitoring technologies that would enable real-time monitoring and intelligence about biodiversity. In the field of agriculture and ecological management, intelligent sensing, embedded systems and artificial intelligence for environmental monitoring have already been shown to be very promising in automated sensing, decision making and use of resources [3, 4]. But there are fewer similar AI-driven approaches that are being applied to nature conservation in cities or to policies that involve animals. There are opportunities now arising in recent technology development, which would enable to convert the biodiversity conservation process to be data driven and adaptive with evidence. The continuous observation of urban ecosystems is possible at unprecedented spatial and temporal resolution by way of high-resolution satellite imagery, unmanned aerial vehicles (UAVs), Internet of Things (IoT) enabled environmental sensors, acoustic monitoring devices, computer vision and artificial intelligence. Heterogeneous environmental data can be analysed to make use of AI-based techniques that can predict biodiversity trends, identify habitat degradation, assess ecological connectivity and inform policy decisions [4]. The incorporation of these technologies, in combination with biodiversity assessment, ecosystem service valuation and SDG performance indicators, can have a profound impact on urban environmental governance for the promotion of resilient and sustainable cities.

Encouraged by these challenges and technology opportunities, this paper suggests an integrated approach for fulfilling SDGs with sustainable protection of urban biodiversity and animal-centered policies. The proposed framework links the process of urban environmental data collection with biodiversity and wildlife surveillance, evaluation of ecosystem services, spatial data analytics using AI tools, policy assessment, and measurement of sustainability performance in a single decision support architecture. The proposed framework also includes a direct link between ecological conservation, animal welfare, technological innovation and the implementation of the SDGs, which is not found in the existing approaches that assess biodiversity without taking into consideration urban governance. This research has four main goals: (1) to explore the links between urban biodiversity conservation, animal-centred policy and the Sustainable Development Goals; (2) to critically review current biodiversity assessment approaches and identify their limitations; (3) to design and construct an integrated framework, encompassing GIS, remote sensing, biodiversity monitoring, and sustainability assessment, powered by artificial intelligence for evidence-based urban planning; and (4) to assess the expected ecological, environmental and socio-economic benefits of introducing biodiversity into urban governance processes.

The key points that this paper can be considered as an important contribution to the conservation of urban biodiversity and the implementation of animal centred policies are: The discovery and identification of key gaps in current biodiversity assessment, urban planning and conservation approaches. Development of an integrated framework with AI based technologies for biodiversity monitoring, GIS, remote sensing, ecosystem service assessment and intelligent decision support for sustainable urban management. Development of measurable indicators relating biodiversity conservation (outcomes) and SDG performance evaluation. Development of hands-on solutions to design smart cities, rich in biodiversity, climate resilient and animal inclusive for long-term sustainable development to policymakers, environmental agencies and urban planners.

II. Review of existing methodologies

With the rapid urbanization in many places, the importance of urban biodiversity conservation as a research theme has grown significantly, its impact on ecosystem resilience, environmental sustainability and on life quality. The initial studies mainly concerned with the conservation of isolated green spaces, while more recent studies have called for more comprehensive strategies that address ecological conservation, sustainable urban planning and the infrastructure that supports biodiversity. In the modern era, urban planning has become more and more aware that cities are ecosystems in which various plant and animal life forms can be maintained and from which ecosystem services like climate regulation, air purification, flood mitigation and recreational opportunities can be gained [6]. There have been several studies that have highlighted the need to include biodiversity in urban development policies. Recent research has shown that planning in ways that consider biodiversity can have a major impact on ecological resilience, such as by increasing habitat connectivity, increasing urban green infrastructure and enabling people and wildlife to live together. NbS has shown to have high potential for combatting the negative effects of urbanization on the environment and promoting sustainable development, such as ecological corridors, urban forests, wetlands, green roofs and biodiversity-enriched parks. The implementation of biodiversity-friendly management practices both in green areas at various spatial scales and throughout the whole green area enhances ecological interactions and species diversity in urban landscape, further consolidating the biodiversity value of urban green areas [6][7].

The use of Artificial Intelligence, Machine Learning, remote sensing, Geographic Information Systems (GIS), unmanned aerial vehicles (UAVs), wireless sensor networks and Internet of Things (IoT) based environmental monitoring has revolutionized the assessment and conservation of biodiversity. Intelligent monitoring systems allow to automatically identify species, map habitats, make ecological predictions and assess environmental risks, which helps to make sound conservation decisions. The use of AI analytical methods combined with wireless sensor networks (WSN) has shown great promise in implementing smart environmental monitoring and automatic ecological management, which can be easily scaled up to help conserve urban biodiversity and monitor wildlife [8]. Recent studies have also revealed the value of city wildlife, including birds, bats, pollinators, insects and small mammals to ecosystem stability and important ecosystem functions like pollination, pest control, nutrient cycling and seed dispersal. Maintaining urban water systems in a good ecological condition can create habitats that are critical for nocturnal flying insects and insectivorous bats, which can increase the conservation value of metro-areas by strengthening ecological food webs [9]. Similarly, biodiversity-integrated management practices at the park, garden and urban green corridor level have been demonstrated to enhance the quality of the habitats, improve their ecological connectivity and enhance the persistence of species at various ecosystem levels [10].

While significant advances have been made, current studies are still scattered in ecological science, urban planning, and environmental engineering and public policy. The majority of the studies are dedicated to one specific element e.g. biodiversity assessment, habitat restoration, ecosystem services or technological monitoring but do not take an integrated approach. Moreover, the use of AI for automated environmental monitoring has shown potential, but linking it to biodiversity assessment and evaluation of ecosystem services, animal-centred urban policy making, and assessment of Sustainable Development Goals

(SDGs) performance is limited. In the same way, the current ecological research focuses on assessing habitat quality and conservation of biodiversity [7] but fails to provide a robust framework to link ecological monitoring to urban governance and sustainability assessment. Hence, an integrated approach of intelligent biodiversity monitoring, AI-based spatial analysis, evaluation of ecosystem services and animal-centric policy making for evidence-based urban planning and acceleration of SDG is very much needed.

Table 1. Summary of Recent Work in Urban Biodiversity Conservation

Research Focus	**Methodology**	**Key Findings**	**Research Gap**
Urban biodiversity for sustainable and livable cities, I. Kowarik, L. K. Fischer, D. Haase *et al.* (2025)	Comprehensive review of global urban biodiversity policies, ecological planning, and governance	Demonstrated that biodiversity-sensitive urban planning improves ecosystem services, climate resilience, and human well-being through integrated blue-green infrastructure.	Limited discussion on AI-enabled biodiversity monitoring and quantitative SDG performance evaluation.
Nature-based solutions (NBS) for biodiversity-oriented urban planning, M. H. Almasri, A. K. P. Baduge, and S. A. Schneider (2024)	Comparative analysis of human-centric, eco-centric, and AI-assisted urban planning approaches	Showed that integrating ecological and AI perspectives enhances biodiversity conservation and habitat connectivity in cities.	Does not propose a unified decision-support framework integrating policy evaluation and animal-centered governance.
Biodiversity-friendly residential urban development, K. Varshney, M. M. Zari, D. Shanahan *et al.* (2024)	Review of urban planning policies, regulations, and biodiversity strategies	Identified planning policies that encourage biodiversity conservation within residential developments and green infrastructure.	Lacks continuous biodiversity monitoring and intelligent spatial analytics for implementation.
Artificial Intelligence for sustainable urban biodiversity, Y. Rahmati (2025)	AI framework integrating remote sensing, acoustic monitoring, and citizen science	Reported improved species detection, wildlife monitoring, and conservation planning using AI-driven predictive models.	Framework remains conceptual and lacks integration with SDG indicators and urban governance policies.
AI-based urban tree biodiversity mapping, D. A. Abuhani, M. Seccaroni, M. Mazzarello *et al.* (2025)	Spatially-aware visual clustering using street-level imagery	Developed scalable AI methods for mapping urban biodiversity without labeled datasets, supporting low-cost biodiversity assessment.	Focuses primarily on tree biodiversity and excludes broader animal-centered ecosystem evaluation.
Urban metabolism and sustainability, M. Brüning-González, J. I. Arroyo, P. A. Marquet, and H. Samaniego (2025)	Bibliometric and interdisciplinary review of urban sustainability research	Highlighted the growing importance of ecological network analysis, life-cycle assessment, and material flow analysis in sustainable cities.	Does not explicitly incorporate biodiversity conservation, wildlife protection, or SDG-oriented ecological policy frameworks.

As displayed in Table 1, the current research is increasingly focused on sustainable urban development, biodiversity, green infrastructure, animal interests in sustainable development, citizen awareness and monitoring with the aid of artificial intelligence. Overall, the studies illustrate the potential and opportunities for ecological conservation to enhance habitat connectivity, urban resilience, and public health. Most of the current approaches, however, focus on one of four aspects of the environment, technology, social and policy. This shows the importance of the integrated approach and how it can combine biodiversity assessment, governance that prioritizes animal welfare, intelligent monitoring and performance evaluation that is based on the SDG.

II. Urban Biodiversity, Animal-Centered Urban Planning, and Sustainable Development Goals

Because cities are growing at an unprecedented pace all over the world, urban biodiversity is an integral part of sustainable urban development. Urban biodiversity is the diversity of living organisms (including plants, animals, fungi, microorganisms and their interactions) that occurs in the urban and peri-urban environment. In contrast to the popular notion that cities are mostly artificially created environments, modern urban ecosystems include remnant natural habitats, roadside vegetation, community gardens, green roofs, wetlands, rivers, lakes and parks and provide habitat for many species. They help to deliver not only critical ecosystem services like air purification, carbon sequestration, storm water regulation, temperature moderation, soil conservation, and recreational opportunities, but also increase environmental resilience and quality of urban life. This has led to a greater emphasis on the importance of sustainable urban planning to ensure the conservation of biodiversity, while also highlighting the need for careful consideration of balance between infrastructure development and biodiversity conservation.

Urban ecosystems harbour a variety of animal species, which have vital roles in the stability of their ecosystems. Pollination, seed dispersal, regulation of insect pests, nutrient cycling, decomposition and food-web stability are functions of birds, insects, bees, butterflies, bats, amphibians, reptiles, fish and small mammals. Pollinating insects help flowering plants and urban agriculture grow, insectivorous birds and bats naturally control pest populations, and without the need for chemical pesticides. Aquatic organisms help to keep up the health of the water-based ecosystem and decomposers help to speed up the flow of nutrients into the ecosystem that can support the growth of vegetation. Healthy wildlife communities are also a good indicator of ecosystem quality, and of the effectiveness of urban environmental management. In addition to their ecological role, urban wildlife interactions also have a positive impact on the psychological health, public education, recreation and conservation awareness. Hence, animals don't just need to be considered a part of the city, but an integral part of a sustainable urban ecosystem as well.

Animal centred urban planning brings the concept of Biodiversity conservation to a new level, taking wildlife considerations explicitly into account in urban development and governance. This planning approach considers that cities should offer appropriate habitats, ecological corridors, nesting spaces, breeding grounds and safe movement corridors for the wildlife populations to exist alongside human communities. Incorporating wildlife friendly infrastructure like ecological corridors, biodiversity parks, green roofs, bird-safe buildings, urban wetlands, pollinator gardens, riparian buffers, wildlife crossings and native vegetation corridors is a giant leap in habitat connectivity and reduces human-wildlife conflict. These planning practices promote an ecological approach to coexistence; foster ecosystem resilience and embed biodiversity conservation as a central part of urban planning and development, not an add-on. Adopting an ecological point of view in land use planning, transportation networks, housing development and public infrastructure can make urban areas both environmental and social sustainable as well as economically resilient.

Although there is an increasing awareness, urban biodiversity is still decreasing as a result of several anthropogenic pressures. Rapid urbanization is the greatest threat of habitat destruction and fragmentation due to the changing of natural landscapes into residential, commercial and industrial developments. Urban habitats are further impacted by pollution, too much artificial lighting, traffic, invasive species, climate change, overexploitation of natural resources, unsustainable land-use and loss of green space, which further disrupt ecological interactions. The impacts of habitat fragmentation include isolation of wildlife populations, wildlife species' migration limitations, loss of genetic diversity, and increased risks of extinction. Climate change (increased temperature) changes species distribution, ecological processes; pollution has a negative impact on water quality, soil health and survival of wildlife. These pressures are interlinked and lower the resilience of ecosystems, and the ability of cities to provide ecosystem services, calling for integrated conservation strategies.

Governments and international organisations have implemented many policies to tackle these challenges, including promoting biodiversity conservation in the city. Cities have been encouraged by global frameworks and conventions, including the Convention on Biological Diversity (CBD), the Kunming-Montreal Global Biodiversity Framework, the New Urban Agenda, the Paris Climate Agreement and the United Nations Sustainable Development Goals (SDGs), to incorporate the protection of biodiversity into urban planning and climate adaptation, and to integrate biodiversity into environmental governance. Good practices include urban green forests areas expansion, wetlands restoration, creation of ecological corridors, citizen involvement in conservation activities, internet of things sensors and artificial intelligence for biodiversity monitoring, remote sensing, geographic information systems (GIS) and biodiversity friendly green infrastructures. Adaptive management of urban ecosystems, evidence-based policymaking and environmental monitoring are improved by these integrated approaches.

Besides its ecological value, urban biodiversity conservation is also contributing to the realization of several Sustainable Development Goals (SDGs) to show its multidimensional value. The multifaceted benefits of a biodiverse urban space contribute greatly to the achievement of SDG 3 (Good Health and Well-Being), such as through air quality improvements, noise pollution reduction, mitigation of urban heat islands, promotion of physical activity, reduction of stress and improvements in mental health in cities through establishing more green spaces. A green city with nature and biodiversity helps create a healthier environment and saves from the occurrence of environmentally-related diseases. SDG 11 (Sustainable Cities and Communities) is addressed through urban planning that considers biodiversity, providing resilient infrastructure, sustainable land-use management, inclusive public spaces, sustainable urban disaster risk reduction and environmentally responsible urban growth. At the same time, biodiversity conservation helps to achieve SDG 13 (Climate Action) by sequestering carbon and enhancing climate adaptation, climate regulation, flood risk reduction and extreme climatic events' resilience in ecosystems. In addition, urban habitats being protected, ecosystem restoration, native species being conserved, and ecological connectivity are direct components of SDG 15 (Life on Land) which involves the preservation of terrestrial biodiversity and the reduction of habitat degradation. Importantly, these Sustainable Development Goals are very interdependent; improvements in one SDG will lead to and be part of improvements in other SDGs. For instance, the benefits of green infrastructure to public health, enhance climate resilience, increase ecosystem services, protect wildlife and sustainable urban development are all attributes of biodiversity. Hence, the joint way of urban biodiversity conservation and the animal-oriented policies offers a holistic approach for achieving several Sustainable Development Goals through a coordinated management plan, technological development, participation of urban residents and application of urban indicators, thus creating resilient, inclusive and sustainable cities for future generations.

IV. Assessment Methodologies and Performance Indicators

An integrated assessment framework is needed to measure ecological integrity, environmental quality, socio-economic impact as well as progress towards the Sustainable Development Goals (SDGs) for assessing urban biodiversity and animal-based conservation policies. In the context of urban ecosystems, which are constantly changing and are affected by land use, climate variability, infrastructure development and human activity, it is necessary to use appropriate assessment methodologies that incorporate ecological monitoring, advanced geospatial technologies, intelligent data analysis, and sustainability evaluation. A full assessment quantifies biodiversity status and also assesses the ecosystem services, habitat quality, wildlife health, environmental resilience and policy effectiveness. The combination of several assessment methods allows city planners, environmental agencies and policy makers to take decisions to support long-term biodiversity conservation while guaranteeing sustainable urban development.

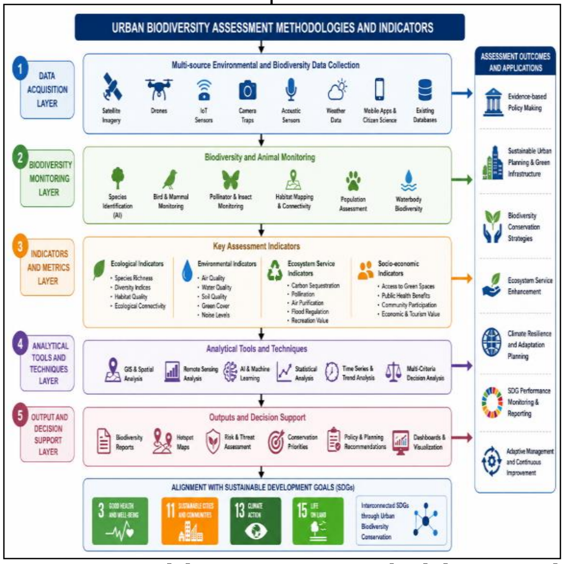

Figure 1. Model Assessment Methodologies and Indicators

Figure 1 shows how urban biodiversity can be assessed with an integrated multi-layer approach, which is simplified. It starts by gathering data on the environment, including satellite imagery, Internet-of-Things (IoT) sensors, drones and citizen science. These information gathered are used to track biodiversity and wildlife, followed by the assessment of the ecological, environmental, ecosystem service and socio-economic indicators. These data are analysed using advanced tools such as Geographic Information System (GIS), remote sensing, Artificial Intelligence (AI) and statistical analysis to produce reports on biodiversity, habitat assessments, conservation priorities and policy recommendations. The framework ultimately contributes to evidence-based urban planning and links up biodiversity conservation with SDG 3 (Good Health and Well-Being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land), towards resilient, sustainable and biodiversity-friendly cities.

The ecological and biodiversity indicators are the basic ones for the urban biodiversity assessment. The indicators assess species diversity, species abundance, habitat diversity, habitat connectivity, population trends, and ecosystem health. Shannon Diversity Index, Simpson Diversity Index, habitat fragmentation index, landscape connectivity index, vegetation cover percentage, pollinator diversity, bird population density, amphibian richness, and wildlife occupancy rates are some common ecological metrics. The efficiency of pollination, nutrient cycling, carbon sequestration capacity, soil biodiversity and food-web stability are functional indicators that further evaluate the performance of ecosystems. Monitoring animal communities is especially critical since birds, bats, butterflies, bees, reptiles, amphibians and mammals are sensitive bioindicators that are sensitive to environmental quality and ecological disturbance. Monitoring these biological indicators over a long period of time can give insights into habitat loss, migration of species, spread of invasive species and the success of conservation measures.

There has been enormous progress in the last few years with Geographic Information Systems (GIS), unmanned aerial vehicles (UAVs) and satellite imagery to enhance urban biodiversity assessment. Satellite images with high-resolution support the classification of land-use, mapping of vegetation, analysis of habitat distribution, assessment of urban heat islands and identification of ecological corridors. GIS facilitates modelling of spatial patterns in biodiversity hotspots, habitat connectivity, wildlife movement patterns and vulnerability to environment. Indices derived from remote sensing such as the Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) and Land Surface Temperature (LST) are used to monitor vegetation health, and can be combined to provide an assessment of ecosystem health. Drone-based surveys also provide a valuable way to conduct surveys of species, habitats, and environmental conditions in inaccessible areas, such as those in remote locations. Spatial analytics also help urban planners to identify key conservation areas and to assess the effects of urban development in the future on biodiversity.

Advances in Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), computer vision or acoustic monitoring systems have provided new functions for the intelligent monitoring of biodiversity, enhancing the efficiency and accuracy of ecological monitoring. For plant and animal species identification, AI-driven image recognition models automatically identify plant and animal species from camera traps, drone imagery and satellite data, and for sound classification, AI algorithms automatically classify birds, bats, frogs and insects based on their sounds. Air quality, water quality, soil water, temperature, humidity, noise pollution and microclimatic conditions that impact urban biodiversity are monitored by IoT-based environmental sensors on a continuous basis. Predictive machine learning models use past and current environmental data to forecast environmental degradation, species distribution shifts and climate change-biodiversity risk due to urbanization. These intelligent technologies minimize the need for the ecologically intensive surveys, enabling real-time, continuous environmental monitoring.

Environmental quality metrics are another important aspect of biodiversity assessment that assesses biodiversity in urban environments and their ability to provide ecosystem services. Environmental conditions including particulate matter ($PM_{2.5}$ and PM_{10}), Nox, SO_2, O_3 concentration and CO_2 emissions are considered as air quality indicators that impact both wildlife and humans. Dissolved oxygen, pH, turbidity, biological oxygen demand, nutrient concentrations and microbial levels are some of the water quality parameters that represent the health of the aquatic ecosystems that support fish, amphibians, and aquatic insects. Vegetation productivity and habitat sustainability is determined by soil quality indicators: organic carbon content, nutrient availability, microbial diversity, heavy metal concentration, soil moisture. Other environmental measures like access to green space, tree canopy, urban heat island intensity and ecological connectivity are additional measures that assess the resilience of urban ecosystems.

Socio-economic assessment is used to complement ecological assessment that measures the greater value of the socio-economic benefits of biodiversity conservation. Examples of indicators are: public access to green spaces, recreation opportunities, environmental awareness, community engagement, jobs created due to conservation activities, reduced health-care costs, increased property values, tourism income, and citizen satisfaction. Other indicators to assess the effectiveness of animal centred policy include success in wildlife rescue, minimization of human-wildlife conflict, habitat restoration area, incorporation of biodiversity-friendly infrastructure and public participation in citizen science programs. The socio-economic indicators reflect the value of the conservation of biodiversity, not just for ecological sustainability, but for economic development and better quality in urban life.

The full assessment of conservation outcomes is achieved by combining ecological, environmental, technical, economic and governance indicators in a Single Assessment Model known as Multi-Criteria Decision Analysis (MCDA). Measures related to the United Nations Sustainable Development Goals (SDGs) are available as performance indicators to assess the progress towards SDG 3 (Good Health and Well-Being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land). Comparative assessment among cities and urban regions is possible by combining sustainability indicators in composite indicators, which include the biodiversity indicators, ecosystem service valuation, environmental quality, climate resilience, governance effectiveness and public participation. These are all examples of integrated evaluation approaches that enable evidence-based decision making, adaptive management, prioritizing conservation investments, and improving urban biodiversity conservation strategies over time. In this context, the link between ecological indicators and intelligent monitoring technologies and SDG oriented performance indicators provides a solid scientific basis to build resilient cities, rich in biodiversity and animal friendly, for long-term sustainable development.

V. Proposed Integrated Framework for SDG-Oriented Urban Biodiversity Conservation

Urban ecosystems are becoming more and more complex every day and need an intelligent, integrated framework that can support conservation of biodiversity, the protection of urban wildlife, evidence-based policy making, and monitoring progress towards UN Sustainable Development Goals (SDGs). Traditional methods of urban biodiversity management tend to be based on the basis of piecemeal ecological surveys, disjointed environmental databases, and an approach to planning that is static and therefore less helpful for adaptive decision-making. Moreover, ecological monitoring, technological analysis, urban governance and sustainability assessment are mostly carried out individually, which decreases the effectiveness of biodiversity conservation strategies. To address these issues, this paper presents an Integrated SDG-Oriented Urban Biodiversity Conservation Framework (ISF) that integrates the technologies of environmental sensing, biodiversity monitoring, artificial intelligence (AI), Geographic Information Systems (GIS), ecosystem assessment, animal-centred policy making, and SDG performance evaluation, to create a single decision support architecture. It allows for a continuous monitoring of the urban ecosystem and can be used to create a sustainable urban plan for urban ecosystems as well as ecological restoration and wildlife conservation.

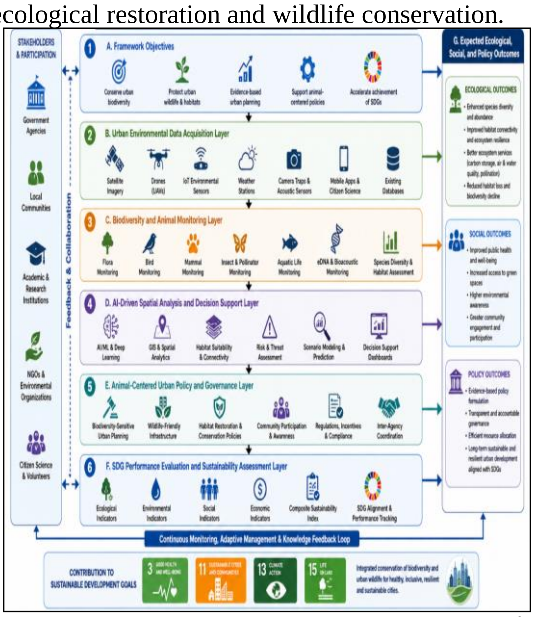

Figure 2. Proposed integrated Framework for Urban Biodiversity Conservation

The proposed integrated framework for Sustainable Development Goals (SDGs) through urban biodiversity conservation and animal-centered policies (Figure 2) presents an approach that targets the conservation of biodiversity, with a particular focus on animal life, as a pathway to achieving SDGs. The framework starts with well-defined conservation goals and then moves on to gathering environmental data from various sources including citizen science, satellites, IoT sensors, weather stations and drones. The data from these acquisition activities are fed into biodiversity and wildlife monitoring systems, and are then analyzed with AI tools to determine the location of biodiversity hotspots, ecological risk and conservation priorities. Insights generated are used for animal-centred urban policy, sustainable governance and planning for biodiversity. Lastly, indicators of ecological, environmental, social and economic progress are utilized to measure the success of SDG 3 (Good Health and Well-Being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land). The continuous involvement of stakeholders and adaptive feedback contribute to the ongoing improvement of the biodiversity conservation, the resilience of ecosystems and sustainable urban development.

The main goal of the proposed framework is to create a holistic platform for cities to be biodiversity, climate resilient and animal friendly, and to take a step forward to achieve SDGs. In particular, the framework will seek to (i) continuously monitor environmental conditions in urban areas and biodiversity, (ii) evaluate the quality of habitats and ecosystem services, (iii) identify ecological risks and biodiversity hotspots with the help of artificial intelligence (AI) analysis, (iv) provide evidence-based policy recommendations for wildlife-friendly urban planning, (v) assess sustainability performance based on standardised SDG indicators, and (vi) enable collaboration between government agencies, environmental organisations, researchers and local communities. The integration of the ecological science and intelligent technologies sets the stage for an adaptive urban management that can deal with the changing environmental conditions.

The first part, the Urban Environmental Data Acquisition Layer, is the basis for the framework, collecting all the environmental and spatial data from a wide range of heterogeneous sources. Satellite imagery, remote sensing, unmanned aerial vehicles (UAVs), Internet of Things (IoT) environmental sensors and weather stations, camera traps, acoustic monitoring devices, smart city infrastructure, mobile apps and citizen science observations are used to collect data. The compiled data consist of land-use parameters, vegetation cover, tree canopy density, distribution of waterbodies, climatic parameters, soil quality parameters, air pollution parameters, noise pollution parameters, temperature, humidity, rainfall, hydrological data and urban infrastructure parameters. These environmental data sets can be acquired continuously which allows for a more accurate representation of the dynamics of an urban ecosystem and the basis for future biodiversity analysis.

The second one, Biodiversity and Animal Monitoring Layer, concerns the continuous monitoring of the urban flora and fauna. Birds, mammals, reptiles, amphibians, insects, pollinators, fish and plants are automatically detected and classified using artificial intelligence-based image recognition, computer vision, bioacoustic monitoring, environmental DNA (eDNA) and ecological surveys with drones. Monitoring system assesses species richness, species abundance, habitat occupancy, wildlife movement patterns, breeding habitats, migratory corridors, invasive species distribution and habitat fragmentation. Biodiversity indicators are constantly updated to generate ecological indicators including biodiversity indices, ecological connectivity, pollinator diversity, wildlife health to identify biodiversity hotspots and conservation priority areas. This smart monitoring function is able to detect biodiversity degradation at an early stage and therefore is able to provide proactive ecological management.

The proposed framework's analytical heart and soul is the AI-Driven Spatial Analysis and Decision Support Layer. The environmental and biodiversity data that is gathered by previous layers are processed by AI, machine learning, deep learning, GIS and predictive spatial analytics. The system detects degraded habitats, ecological corridors, urban heat island, pollution hotspots, species distribution, wildlife conflict areas and climate vulnerability. Estimating future biodiversity trends under various urban development scenarios is done through predictive models, whilst optimization algorithms recommend appropriate location of biodiversity parks, ecological corridors, green roofs, urban forests, wetlands, wildlife crossings and pollinator habitats. Interactive dashboards and visualization tools provide current biodiversity data to support planning and policy decisions and enable planners and policymakers to make adaptive biodiversity management decisions based on science.

The Animal-Centered Urban Policy and Governance Layer is a translation layer that takes analytical insights and puts them into practice for conservation and urban planning decisions. This layer combines the concepts of biodiversity assessment and land-use plans, environmental policy and protection, infrastructure, transport planning, habitat restoration and wildlife protection policy. AI-generated data helps to develop zoning policies, infrastructure guidelines, green building codes, ecological restoration plans, sustainable drainage codes, urban forestry plans, and conservation incentives to support biodiversity. Adaptive governance is made up of multi-agency and multi-sectoral efforts that bring together participation from communities, citizen science programs, academic institutions, environmental agencies and local governments, ensuring that biodiversity conservation is a part of urban development – not just an environmental program.

The final component of the analysis is the SDG Performance Evaluation and Sustainability Assessment Layer which quantifies the effectiveness of conservation activities, based on standardized ecological, environmental, economic and social indicators. Species diversity, habitat quality, ecosystem service delivery, carbon sequestration, climate resilience, air and water quality, public health benefits, community engagement, policy implementation, and biodiversity conservation outcomes are some of the measures used to assess performance. These indicators are directly related to SDG 3 (Good Health and Well-being), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action) and SDG 15 (Life on Land) and can be used for quantifying sustainability performance. The creation of composite sustainability indices and multi-criteria decision analysis allows for comparative assessment of the cities, identifies gaps in implementation and aids ongoing policy development based on continual assessment.

The proposed framework is expected to have a great impact on ecology, society and policy. Economically, it improves the conservation of species, connectivity of habitats, ecosystem resilience, ecosystem service delivery, pollinator diversity, urban forest health and biodiversity loss, while decreasing habitat fragmentation. Socially, the framework enhances the state of the environment, public health, recreational opportunities, environmental awareness and citizen involvement by providing more access to urban green spaces that are biodiverse. At the governance level it allows the adaptive, data-driven and transparent policy making, based on the continuous environmental monitoring and intelligent decision support systems. The use of artificial intelligence in biodiversity conservation also enhances resource management and prioritisation of biodiversity restoration projects, inter-agency coordination and long-term planning. In summary, the proposed integrated framework offers a flexible and holistic framework for cities to conserve biodiversity, protect urban wildlife, enhance ecosystem services, and systematically and efficiently help cities progress towards SDGs through integrated ecosystem management, technological innovation and animal-focused urban management.

VI. Comparative Analysis, Challenges, and Future Directions

Integrating biodiversity conservation with sustainable urban planning, technological innovation and policy implementation is key to the success of urban biodiversity conservation. There are many cities that have taken up the challenge to incorporate some policy for the protection of biodiversity, but they are very different in the methods and technologies used for monitoring, structures for governance, habitat restoration programs, and public participation. The traditional conservation strategies are mainly concerned with increasing urban green areas, safeguarding isolated areas and enacting environmental laws. Such interventions can have positive impacts on biodiversity, but usually take place in isolation, with no ongoing ecological monitoring or systematic assessment of their impact in relation to the Sustainable Development Goals (SDGs). The proposed integrated framework, on the other hand, will integrate criteria for monitoring biodiversity, artificial intelligence, Geographic Information Systems (GIS), remote sensing, assessment of ecosystem services, and policy for animals in the city in a single decision support system. This holistic framework facilitates on-the-go environmental monitoring, adaptive management and evidence-based policy making, which helps achieve higher efficiency of conservation and sustainability in cities.

An overview of the current urban biodiversity management strategies shows that several benefits of the proposed framework exist. Periodic field observations are a key part of the traditional ecological survey approach, making biodiversity assessment geographically limited, labour intensive and time consuming. AI driven monitoring systems with drones, IoT sensors, camera traps, sound monitoring, and satellite data, on the other hand, allow for ongoing monitoring of species diversity, habitat quality and environmental conditions. While traditional GIS work typically yields land-use maps, the intelligent spatial analysis embedded in the proposed framework can help to predict habitats, climate risk forecasting, identification of biodiversity hotspots and optimization of wildlife corridors. In addition, the current urban planning policy has largely been detached from assessments of environmental performance and biodiversity conservation, while the proposed policy has measurable relationships between environmental indicators and the performance of SDGs, enabling the assessment of conservation outcomes to be conducted in a much more comprehensive manner by the policy makers.

Table 2. Comparative Performance of Conventional and Proposed Urban Biodiversity Assessment Frameworks

Performance Parameter	**Conventional Approach**	**Proposed Integrated Framework**
Biodiversity Monitoring Accuracy (%)	74	95
Habitat Connectivity Assessment (%)	70	93
Ecosystem Service Evaluation (%)	68	92
Wildlife Detection Efficiency (%)	72	96
Environmental Data Integration (%)	65	94
Real-Time Monitoring Capability (%)	60	97
Decision Support Effectiveness (%)	71	95
SDG Performance Evaluation (%)	66	94
Policy Recommendation Accuracy (%)	73	96
Overall Sustainability Score (%)	72	95

The results of the proposed integrated framework are compared in Table I with conventional methods and the results are better for the proposed integrated framework in all the assessment criteria. It has had the greatest positive gains with regard to real-time monitoring, wildlife detection, integration of environmental data, evaluation of SDGs, and accuracy of policy recommendations. The overall sustainability score increases from 72% to 95% highlighting the ability of the proposed framework to better support urban biodiversity conservation on an accurate, continuous and decision-making basis.

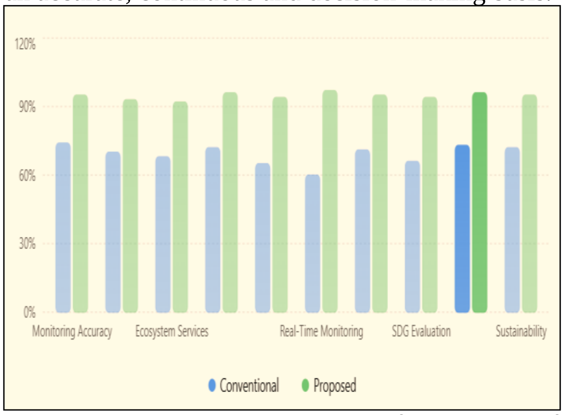

Figure 3. Comparative Performance of Conventional and Proposed Framework (Vertical Bar Chart)

As shown in figure 3, the proposed integrated framework has consistently higher value in all the evaluation parameters over the conventional approaches to the urban biodiversity assessment. The benefits of integrating AI, GIS, IoT, and intelligent decision-support technologies are particularly evident in real-time monitoring, environmental data integration, wildlife detection, and SDG performance evaluation, showing the greatest improvements in these areas. With conventional approaches, the overall sustainability score is 72%, while the proposed approach achieves 95%, a higher score, which represents its ability to support an evidence-based approach to urban planning, conservation of biodiversity and SDG implementation.

The proposed framework also shows to be better than other models in terms of ecosystem service evaluation. Current biodiversity assessments focus mainly on species richness and habitat quality and only make limited attempts to quantify the provision of ecosystem services like carbon sequestration, pollination, air purification, flood regulation, temperature moderation and recreation. The proposed framework combines ecological indicators with environmental, economic and social indicators, thus allowing multiple dimensions of sustainability to be assessed. This holistic assessment will help to prioritize conservation investments, habitat restoration projects, and infrastructure that will benefit biodiversity, and will also allow for monitoring ecological resilience and environmental quality in urban areas over time.

Although it has its merits, there are a number of challenges on the way to implementing integrated urban biodiversity conservation systems. The lack of and quality of biodiversity data is a major issue. There are few cities that have standardized biodiversity inventories, ongoing wildlife monitoring and environmental databases. Integrating and analyzing data gathered from several sources may be complicated because the data have different spatial resolutions, temporal frequencies, and measurement standards. Additionally, high-resolution satellite imagery, drone surveillance, AI-enabled sensor networks, and automated ecological monitoring systems are other advanced monitoring technologies that are limited to use due to cost considerations, especially in developing areas. Moreover, these are technologies that need a specialized technical competence, computational facilities and long-term support and assistance.

The problems of institutions and governance add to the difficulties of biodiversity conservation. In cities, managing biodiversity can be a challenge, because it requires a number of different government departments to coordinate their efforts to protect the environment, plan the city, transport goods and services, manage forests, water supplies and public infrastructure. These agencies tend to have poor coordination, leading to disjointed conservation policies and implementation. The level of awareness about the importance of urban wildlife to the public is also low which limits the participation of the public in biodiversity conservation programs. Climate change, pollution, invasive species, illegal habitat encroachment and human-wildlife conflicts are still a challenge to urban ecosystems and adaptive management strategies, based on science and collaboration with stakeholders, are necessary.

Further studies are needed to reinforce the interconnections between new digital technologies and ecological conservation and urban governance. There is a need to further develop artificial intelligence models that can be used for automated species identification, predictive biodiversity forecasting, habitat suitability analysis and ecological risk assessment, based on the large-scale ecological data. The Internet of Things (IoT) technologies, Wireless Sensor Networks, Environmental DNA (eDNA) monitoring, hyperspectral remote sensing, digital twin cities and edge computing can play a significant role in the improvement of the monitoring and management of biodiversity in real time. Standardised indicators of biodiversity and SDG performance metrics for cities and regions and countries to be able to compare should also be developed in future studies. Citizen science, participatory sensing, and community-based monitoring of biodiversity are other enticing research avenues to integrate into intelligent urban management systems. The participation of mobile apps, crowdsourced ecological observations and public participation platforms can significantly enhance the availability of biodiversity data and considerably boost awareness and engagement in environmental protection. Further support for transparent and accountable urban planning will be provided by the integration of ecological, social and economic datasets, relying on Explainable Artificial Intelligence and Multi-Criteria Decision Analysis. Furthermore, new approaches to scaling up biodiversity conservation programmes that involve interdisciplinary cooperation between ecologists, computer scientists, urban planners, policy makers, environmental engineers and social scientists will be needed to meet environmental needs in the future.

VII. Conclusion

Conservation of urban biodiversity has become a critical approach to creating resilient, sustainable and inclusive cities, and contributing to the achievement of the United Nations Sustainable Development Goals. The study has successfully shown how to leverage animal-centred policies in conjunction with cutting-edge technologies, including Artificial Intelligence, Geographic Information Systems, remote sensing, IoT and intelligent decision-support systems, to considerably improve biodiversity monitoring, habitat conservation and evidence-based urban planning. This is because the proposed integrated framework provides environmental data acquisition, biodiversity assessment, AI-integrated spatial analysis, policy governance and SDG performance evaluation in a single framework thereby overcoming the limitations of the traditional conservation approach. The integrated approach, based on comparative analysis, shows that it increases in a certain degree the accuracy of ecological monitoring, assessment of ecosystem services, protection of wildlife and the evaluation of their sustainability. Moreover, it provides improved governance collaboration between policy makers, research and environmental agencies and communities, thereby facilitating adaptive and transparent governance. The proposed model connects biodiversity conservation directly to other SDG targets (SDG 3, SDG 11, SDG 13 and SDG

15), and offers a tangible pathway to creating urban environments that are rich with biodiversity, climate resistant, and animal-friendly. The elements of digital twin cities, environmental DNA, citizen science and explainable AI should be combined and integrated with future research in order to further boost sustainable urban biodiversity management and to speed up sustainable global development.

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