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Assessing the Potential of Ecosystem Services in Sustainable Regional Planning of Peri-Urban Area in the Southern Context

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Abstract

Rapid urbanization alters links between the urban and rural areas and uses resources carelessly, destroying peri-urban areas. This situation is made worse in India especially due to lack of a legal structure to plan and manage the transformation of PUAs. In the context of peri-urban planning, the ecosystem services model's assessment of the environment's carrying capacity tend to have a major impact on maintaining the ecology as well as the economy of rural and urban areas thereby enhancing human well-being. To support the sustainability of Indian cities, this study provides an ecosystems-based integrated strategy to environmental conservation-management and peri-urban development. The "Expert matrix technique" is used in a situation where there is a lack of data to generate a general, qualitative assessment of the potential for multiple ecosystem services. By utilizing the data acquired from the Expert matrix technique over different time periods, the potential for numerous ecosystem services in the research area was mapped. The findings offer insightful information for land developers and urban planners on the trade-offs between spatial design and ecological preservation to achieve sustainability.

Keywords: Potential of Ecosystem Services in Sustainable Regional Planning of Peri-Urban

Introduction

India has experienced a recent surge in urbanization, and future predictions indicate that this trend will continue. Rapid urbanization has had disastrous effects, especially in terms of how quickly resources are being used up, ecosystems are being destroyed, and pollution is rising (Tripathi YC & Tripathi G 2003, Chandra M 2015). Rapid urbanization causes actual physical changes to land use patterns, habitat fragmentation and biodiversity loss, disruption of natural hydrology, energy flow, and nutrient recycling processes, as well as habitat fragmentation and loss. The main cause of this is the adoption of an unsustainable form of urban expansion that ignores the existing environment, exploits it, and reduces its capacity to provide essential services like flood protection, water resource management, and air quality regulation, among others (Heymans A et al 2019). To achieve sustainability, it is crucial to prioritize environment-inclusive planning that encourages the empowerment of the landscape and natural capital, such as the forests, ridges, lakes, rivers, deltas, and

lagoons that offer priceless eco-system goods and services to humans.

In India, peri-urban landscapes are places where natural resources, including water, are used to meet urban requirements. Recent studies highlight that, India's main metropolitan cities' peri-urban areas will experience a significant amount of urbanization in the future, and these PUAs will grow more quickly than the traditional urban centers (Ismail Haque & Priyank Pravin Patel, 2017). The urban-rural divide that is so ingrained in India's current planning system is insufficient to deal with problems and manage growth and development in "in-between" peri-urban areas (Raparthi, K 2021c). Furthermore, the lack of an efficient legal framework to organize and control the transformation of PUAs makes the issue worse because arbitrary changes in land use and cover have an impact on numerous scales of biodiversity, climate, water, nutrient cycles, etc. Therefore, it is critical to create a spatial planning technique that incorporates ecological knowledge at the local level in order to assess the feasibility of land use for development in India's peri-urban regions. A landscape-ecology based urban planning paradigm that understands and utilizes the dynamics of cities & their systems can prove to be a powerful tool for achieving sustainable urban development with minimal environmental impacts and better quality of life for the society in the wake of rapid urbanization. In order to support the sustainable expansion of Indian cities, this study offers an integrated strategy to environmental conservation-management and urban development (Raparthi, K 2021b).

Ecosystem Services Approach

Urban planners are progressively examining various Landscape Ecology theories & models to promote sustainable development in terms of integrating nature/ecology with the socio-economic-cultural demands of people (Silva EA et al, 2008). In the peri-urban setting, the environment can be crucial to fostering growth but can also suffer from its effects. Environmental carrying capacity, or a region's threshold or boundaries to support human activities, supply sustenance (natural resources), and serve as a waste sink without seriously harming the environment, is directly tied to sustainability (Raparthi, K 2021a). The anticipated development would be unsustainable and lower the environmental quality if it exceeded the region's environmental carrying capacity. As a result, it becomes important to determine the peri-urban area's environmental carrying capacity under the pressure of urbanization. The ecological footprint method and the ecosystem services method are the two main ways to assess the environmental carrying capacity (Subekti RM & Suroso DSA, 2018). The ecological footprint method's advantage is that it establishes the upper limit for resource consumption. The method's flaw, however, is that it requires trade data on the production, imports, and exports of goods related to agriculture, forestry, fishing, etc., which may be available at the state or national level but not at the regional or city level (Subekti RM & Suroso DSA, 2018), making it impossible to use in regional planning exercises, particularly in developing nations like India. The ecosystem services model has the

advantage of being consistent with strategic environmental assessments employing spatial analysis based on LULC, but its biggest disadvantage is that it does not specify a resource consumption threshold. Maps showing the LULC at a scale of 1:50000 are required by the ecosystem services model for assessment at the regional/district level. This model presents the spatial distribution of ecosystem service types within a region as an output that can be traded off with planning ideas to produce scenarios that can be assessed for sustainability (Raparthi, K.2022; Subekti RM & Suroso DSA, 2018).

Research Objective

In order to attain sustainability, the goal of this research is to understand the relationship between urban growth and nature by implementing landscape ecology in peri-urban areas of Indian cities. The Ecosystem Services Approach/Model is developed as a result to combine peri-urban planning with environmental conservation-management.

Methodology

By allowing growth in the right places, the ecosystem services model aims to safeguard special and scarce resources, manage the use of finite resources, maximize sustenance, minimize risks, and secure all of these goals. The ecosystem services model was developed using a framework that integrates environmental protection with peri-urban development. The general list of actions conducted in the method is provided below. Any peri-urban area in India can use the first step because it is generic. The second through sixth steps are specific to the study area in question.

Step 1. Evaluation of the potential for ecosystem services based on LULC data using the Expert Matrix Method for a region with limited data

Step 2. Tracing the LULC transition for a prospectively evolving peri-urban study area across time

Step 3. Utilizing GIS to map the transition and assess the study area's potential for Ecosystem Services (ESS) and combining data from processes 1, 2, and 3 to gain insightful information on land-use suitability.

Step 4. Planning requirements for future growth profiling

Step 5. Analyzing land use adaptability in order to balance the potential of ESS with sustainable planning principles

Step 6. Creating scenarios and assessing their viability

In affluent countries, the supply of ecosystem services is valued using quantitative methodologies, which call for sizable, high-quality data sets gathered over time. India has used the "Expert matrix evaluation approach," a qualitative method developed by Burkhard B et al (2012), Maes et al (2012), and Jacobs et al (2015), to assess the potential for ecosystem services due to the lack of data, particularly in peri-urban areas.

With this approach, the assessment is carried out by multidisciplinary professionals connected to planning who have experience

and knowledge of India's ecosystems (Raparthi, K 2016a). A group of 30 experts from a variety of fields, including geography, agronomy, ecology & environment, forest engineering, economics, sociology, and urban planning are involved in the assessment. The majority of these experts are Ph.D. holders with publications on the topic. For planning, management, and predictive research purposes, it is important to evaluate ESS potential rather than ESS supply because these topics are conceptualized theoretically and over a long period of time (Syrbe R et al 2017). While "ESS supply" is defined as the "actual measure" of a given ESS ((Raparthi, K 2020b; Burkhard et al. 2012), which is local to the area and the result of a combination of natural conditions and socio-economic land-use decisions, ESS potential refers to the "hypothetically maximum yield in a given time and area" of an ESS.

A matrix is created, with the various ecosystem services to be evaluated on the "X" axis and the various LULC types that are available in the study area on the "Y" axis. On a scale of "0" to "5", with "0" denoting "no potential," the experts were guided by the LULC description for India (as stated on the NRSC-ISRO Bhuvan website) to evaluate the potential for multiple ecosystem services, which were categorized under providing, regulatory, and cultural services (Raparthi, K 2016b). Supporting services, which serve as the foundation for the provisioning, regulating, and cultural ecosystem services, were excluded from the assessment since they are not directly related to the factors that contribute to human well-being. Moreover, Groot & Hein (2007) claim that incorporating supporting services in the evaluation could lead to "double counting" because the advantages they offer are already apparent in the other categories of services.

The ecosystem services assessment in this study involved over 30 specialists from different fields across India, including academics, researchers, policymakers, NGOs, and forest authorities. Purposive sampling with no regard to probability was the sampling method employed. To address scoring variability, it was determined to employ 25–30 samples (experts), and to statistically analyze the data, simple mean was used (Campagne CS et al, 2017). Meeting with experts via email with other experts in India were used to evaluate ecosystems' capacity to provide a variety of services. To obtain the final values of the potential for different ecosystem services for the various land uses and land covers in India, a simple statistical average of the expert scoring on the matrix was used (Raparthi, K 2020a; Raparthi, K 2015).

The ESS potential values provided by experts for the total Provisioning, Regulating, and Cultural services were applied to the LULC types for the time periods 2005, 2011, and 2015 using QGIS in order to assess the broad transition in the ES potential in the study area from 2005 to 2015 in relation to the LULC change. The total ESS was mapped using overlay analysis for the years 2005, 2011, and 2015. By tabulating the locations with varying degrees of ESS potential (from high potential to very low potential) for providing, regulating, and cultural

ecosystem services as well as the overall ESS potential for the years 2005, 2011, and 2015.

Analysis & Observations

Transition in Total Provisioning Services - Between 2005 and 2015, there was an increase in the region with very low Provisioning ESS potential, which is consistent with the growth of the LULC type "Built up land- Towns & cities". The trend in the Provisioning ESS potential has been clearly improving from 2005 to 2011, but it has been declining from 2011 to 2015. Overall, the research area has a moderate potential for Provisioning ESS.

Transition in Total Regulating Services – Approximately 14% of the research region has a relatively high Regulating ESS potential spatially correlating to two LULC kinds that have been well-maintained with no encroachments between 2005 and 2015: "Water bodies - Reservoir, lakes & ponds" and "Forest lands." Built-up lands and scrubby land are LULC categories that have a poor potential to offer regulating ESS. Between 2005 and 2011, there was an improvement in the Regulating ESS potential, and between 2011 and 2015, there was a significant fall. Approximately 68% of the study region has a moderate potential for providing regulatory ESS, and 21.5% of the study area has a poor potential for doing so.

Transition in Total Cultural Services – In terms of spatial alignment with LULC types "Agricultural Croplands," "Forest Lands," and "Water Bodies - Reservoirs, Lakes, and Tanks," the research area has extremely strong potential for cultural ESS. Around 12% of the study region has moderately high cultural ESS potential, compared to 77% of the area with moderate cultural ESS potential. Overall, the trend in the Cultural ESS potential between the years of 2005 and 2011 and between the years of 2011 and 2015 is positive, which can be attributed to the decline in the amount of Agricultural Fallow land.

Transition in Overall ESS (2005 to 2015) - The most important finding is that, over the course of the study area's 10-year lifespan from 2005 to 2015, its ESS potential has increased. About 74% of the research area, which falls under the LULC types "Agricultural land - Cropland & Plantation" and "Built-up land - Rural villages," has a "Moderate potential" to deliver ecosystem services. Spatially, "Built-up land - Towns and cities," "Waste lands - Salt affected & Land with scrub," and "Agricultural Fallow land" are the places with low & very poor potential. "Water bodies - Reservoirs, Lakes & Tanks" & "Forest land" are the LULC types that have "Moderately high ES potential."

Potential of Ecosystem Services Potential in Development of Sustainable Peri-Urban Area

The idea of ecosystem services in human-dominated urban and peri-urban landscapes has not yet been investigated in India (Raparthi, K 2014a). The environment is getting worse since post-independent planning initiatives embraced the economic model with little regard for the ecology of the region. It is fundamental and essential for urban planners to use a scientifically supported strategy to determine whether a

piece of land is suitable for development in terms of ecological and economy if they want to accomplish sustainable planning. This study illustrates how to prioritize environmental considerations in spatial decision-making by integrating the ESS approach into land-suitability assessments for development (Raparthi, K 2018; Raparthi, K 2014b).

The current study demonstrates that the ecosystem services potential in the study area is directly impacted by changes in LULC throughout time. The increased ecosystem services potential of the studied area between 2005 and 2011 is connected to nominal changes in LULC type throughout this time. From 2011 to 2015, the research region underwent rapid peri-urbanization. A huge agglomeration of rural settlement villages can be seen, and built-up lands have grown by 7.52% during this time. The establishment of a bus terminal on the market street may have enhanced commerce and mobility, which could be one reason for this. The territory to the east of the railway line has a "moderate" to "moderately-high potential" to supply ecosystem services, according to an overlay analysis of 15 ecosystem services maps for the research area, while the area to the west of the railway line is quickly transitioning into a zone with low ecosystem services potential. Notably, between 2011 and 2015, the scrub forest, which has a moderate ability to provide regulating & cultural services, vanished from this area.

In this zone, there is a high proportion of Agricultural Land Fallow & Wasteland - Land with Scrub with poor ecosystem services potential. Agricultural fallow land is essential for enhancing soil productivity and preserving biodiversity (Fu B, 1995; Liu YL, 2012). Despite the fact that the area of agricultural land that has been left fallow has significantly decreased over the past 10 years, there is no immediate impact on the ecosystem services of the study region. However, in the long run, this may influence the soil production capacity, lowering the study area's potential for provisioning services. Different factors, such as the amount of land owned by farmers, accessible irrigation systems, the adoption of mechanized agriculture, the quality of the soil, the distance of the land from the farmer's residence, etc., may be responsible for the increase or decrease in the area of fallowing land in India.(Ranganathan T & Pandey G, 2018). It is possible to control the amount of fallow land in the study area by establishing an appropriate agricultural policy after consulting with relevant researchers. Furthermore, the presence of numerous "District roads" and a State highway in this zone may have sped up LULC modifications there.

The three LULC types in the research area that have the greatest potential for ecosystem services are water bodies, forests, and agricultural lands. To preserve and improve these places in peri-urban growth, appropriate land use planning methods and policy must be devised (Marshall and Randhawa, 2017). With more research on planning needs, closeness to existing transit, infrastructure, commerce, job prospects, etc., it may be possible to determine that the zone with low ESS potential to the west of the railway line is the most suitable for peri-urban growth.

Conclusion

In order to attain sustainability, this research suggests using the ecosystem services model to incorporate environmental considerations into land use planning. Based on its ecosystem services potential, the model suggests finding area suitable for future development. Using the official India LULC dataset and the Expert Consultation-Matrix approach, a general qualitative evaluation of the ecosystem services potential was conducted for about 17 significant ecosystem services. To include ecological, economic, and anthropological potentials in the assessment, academicians, researchers, policy makers, NGOs, and forest officers with expertise in a variety of disciplines, including geography, agronomy, ecology & environment, forest engineering, economics, sociology, & urban planning, were involved.

The suggested strategy was put into practice in an Indian peri-urban area that has the capacity to grow. To comprehend the complexities of their interaction, a map showing the study area's ecosystem services potential and LULC changes over a ten-year period was created. It was found that throughout the first five years, minimal adjustments in LULC increased the research area's overall ecosystem services potential. In the following five years, the research area underwent rapid peri-urbanization, which led to a reduction in the ESS potential. Our understanding of the spatial relationship between the LULC types and the ecosystem services in terms of supply potential is aided by a complete mapping of 15 ecosystem services potential (provisioning, regulatory & cultural) of the research area. All of the providing, regulating, and cultural ESS were subjected to an overlay analysis, with the findings tallied. The overall ecosystem services mapping demonstrates the importance of LULCs such as water bodies (reservoirs, lakes, tanks), forests (plantation & deciduous), and agricultural land (cropland and plantation) in supplying and maintaining the required ESS in the research area. In order to preserve certain LULC kinds, appropriate land use rules are necessary. Spatial analysis reveals that the western portion of the research region has low potential and can be investigated for peri-urban development with adequate consideration for other planning demands & requirements.

In order to attain environmental sustainability, this study demonstrates how the knowledge of ecosystem services potential may be utilized to assess whether land is suitable for development in a peri-urban area of India. Participating locals in the evaluation of ecosystem services potential will allow for further enhancement of this study. On a more localized, village-level scale, this would be feasible. However, at a broader regional scale, the methods presented in this study is still valid. The integration of landscape metrics assessment with the ecosystem services evaluation for improving the analysis of the appropriateness of the land based on the environment is another area that can be investigated.

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