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FOOTPRINT OF URBAN LIVING: AN ECOLOGICAL AND ENVIRONMENTAL PERSPECTIVE OF COIMBATORE CITY

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ABSTRACT

Humanity faces an escalating environmental crisis, marked by rapid resource depletion and widespread ecosystem degradation, pushing the planet towards profound unsustainability. Urban centres, as major consumption hubs and waste generators, critically impact natural capital. This study employs the Ecological footprint (EF) framework, a globally recognized sustainability metric, to comprehensively assess the environmental demand of the Coimbatore city residential area in India. Utilizing a blend of component-based and direct methodologies, and gathering primary household consumption data via extensive questionnaires, alongside local biocapacity measurements, the research quantifies the area's ecological impact. Preliminary findings indicate that the Coimbatore city residential area operates in a significant ecological overshoot, with an estimated per capita EF of 2.0 - 2.5 global hectares. This notably surpasses India's national average (0.8-0.91 gha/person) and the earth's available biocapacity (1.6 gha/person), highlighting unsustainable consumption patterns. The analysis identifies energy consumption as the predominant driver of this high footprint, followed by food and transportation, a trend consistent with other rapidly urbanizing Indian cities. Conversely, the local biocapacity is exceedingly limited, underscoring the area's profound reliance on external natural resources. Despite inherent limitations in highly granular data availability, this research provides a robust foundation for understanding urban ecological burdens. It offers critical insights into the long-term sustainability implications for Coimbatore and proposes strategic recommendations. These include promoting energy efficiency, fostering sustainable food consumption, enhancing green transportation options, and strengthening integrated waste management practices. By advocating for these targeted interventions, this study aims to guide urban policymakers toward cultivating a more ecologically sustainable and resilient urban future in Coimbatore.

1. INTRODUCTION

As we navigate the twenty-first century, the intensifying deterioration of our environment, driven by both inherent natural forces and human endeavours, emerges as one of humankind's foremost difficult issues (Costanza & Patten, 1995; Parris & Kates, 2003). We are observing swift clearing of forests, the ruination of natural habitats, the exhaustion of crucial natural assets, and extensive harm to ecological systems, collectively leading to a significant worsening of our planet's well-being (Ayres, 1996; Templet, 1995). The unregulated removal of finite resources, the imprudent utilization of replenishable ones, and persistent expansion without regard for environmental ramifications are propelling the world towards a profoundly untenable tomorrow (Bossel, 2000; Rennings & Wiggering, 1997). This predicament highlights the critical necessity to transcend mere growth and embrace a more enduring methodology, one that places paramount importance on a comprehensive grasp of the complex connection between human conduct and the earth's provisions within the planetary context (Fischer-Kowalski, 1998; Rees, 1996).

Urban centers, functioning as intricate and continually expanding frameworks, are immense devourers of natural capital and substantial generators of refuse, all in service of sustaining their inhabitants (Chrysoulakis, 2008). Consequently, it becomes paramount for city residents to assess their interaction with the biological systems that underpin their existence, guaranteeing these systems are not stretched past their capacities (Rees, 2008). As our collective understanding deepens regarding the scope of human resource use and waste output, diverse approaches for quantifying societal influence have materialized (Csutora et al., 2009; Geyer et al., 2010). Among these, the Ecological footprint emerges as a highly regarded and globally acknowledged metric for assessing sustainability (Collins & Flynn, 2007; Galli et al., 2012; Moran et al., 2008; Wiedmann & Barrett, 2010). Conceived in 1990 by Mathis Wackernagel and William Rees, this instrument assists in elucidating our environmental limitations and facilitates the development of more efficacious and viable sustainability blueprints (Wackernagel & Rees, 1997). It gauges humanity's demands on the natural world by calculating the terrestrial and aquatic areas necessary to yield

the provisions we consume and assimilate our carbon dioxide discharges, based on prevailing technological advancements (Borucke et al., 2013; Lenzen & Murray, 2001; Wackernagel et al., 2002; Wackernagel et al., 2004). Disturbingly, present human consumption habits necessitate the equivalent of one and a half Earths annually, implying our planet requires eighteen months to rejuvenate what we exhaust in merely twelve. Conservative United Nations projections suggest that if present demographic and consumption trajectories persist, by the 2030s, we will require the wherewithal of two planets. This concerning trajectory – where resources are utilized and converted into waste more rapidly than they can be reconstituted – propels us into a condition of global ecological overshoot, exhausting the fundamental resources upon which human existence and biological diversity rely (Wackernagel et al., 2002).

The imperative to comprehend the impact of metropolitan existence is especially clear in swiftly progressing territories where uncontrolled demands and haphazard consumption models generate profoundly untenable circumstances (Dewan & Yamaguchi, 2009; Holden, 2004; McManus & Haughton, 2006; Xu et al., 2010). This current investigation specifically endeavours to commence an evaluation by computing the ecological footprint of the Coimbatore city residential area. This specific urban locality, acting as a prominent nexus of consumption, functions as a vital gauge of sustainability within a wider metropolitan framework. The appraisal merges component-based (Barrett, 2001) and direct methodologies (Miglietta & Pastore, 2010) to ascertain the ecological footprint. Information regarding household usage trends for diverse elements was gathered via an extensive questionnaire poll (Dell et al., 2002) conducted within the Coimbatore city residential area. Furthermore, the biological capacity of the Coimbatore city residential area is also quantified, derived from the biologically productive terrains accessible in its proximity (Haberl et al., 2001; Krausmann, 2001). Subsequent to obtaining these outcomes, a thorough assessment of sustainability has been performed (Graymore et al., 2008; Graymore et al., 2010; Vačkář, 2012). Preliminary discoveries indicate a considerable disparity between the requisite natural resources and their availability within the examined urban milieu (Van den Bergh & Verbruggen, 1999; Yue et al., 2006). This inquiry further pinpoints the use of natural gas for domestic needs as the paramount element contributing to the imprint of the Coimbatore city residential area, with electrical power, provisions, and transit ranking next (Facanha & Horvath, 2007; Muñiz & Galindo, 2005; Shakil et al., 2014; Wiedmann & Minx, 2008; Wiedmann et al., 2006). Drawing from these observations, this study puts forward a range of strategic recommendations intended to diminish the ecological footprint and bolster overall durability in urban settings (Barrett et al., 2005; Rabbani et al., 2011; Rees, 2009). This investigation advances a more profound comprehension of metropolitan ecological and environmental consequences, presenting practical guidance for cultivating a more enduring urban lifestyle (Superczynski & Christopher, 2011; Wilson & Grant, 2009).

2. OBJECTIVE OF THE STUDY

This research aims to calculate the ecological footprint of the Coimbatore city residential area. By quantifying the resource consumption and waste assimilation demands of its urban populace, this study seeks to:

- Assess the current ecological impact of the residential sector within Coimbatore city.
- Determine if the consumption patterns of the residents are exceeding the Earth's available biocapacity.
- Identify the primary consumption categories (e.g., energy, food, transportation) that contribute most significantly to the area's ecological footprint.
- Propose actionable policy recommendations aimed at reducing the ecological footprint and enhancing sustainability within urban living environments.

3. LIMITATIONS OF THE STUDY

This study, while offering valuable insights into the ecological footprint of the Coimbatore city residential area, is subject to several limitations. The accuracy of our calculations depends heavily on the availability and granularity of local consumption data, which can be challenging to acquire in detail, sometimes necessitating the use of regional averages. Furthermore, while we measure biocapacity within the study area, the true ecological support for an urban population typically extends far beyond its immediate administrative borders, meaning our localized assessment might not fully reflect the broader environmental debt. Inherent methodological simplifications within the Ecological footprint framework, along with the difficulty in comprehensively capturing indirect impacts from global supply chains and the full heterogeneity of diverse household consumption patterns, mean our findings represent a focused snapshot rather than a dynamic, exhaustive account of all ecological pressures.

4. REVIEW OF LITERATURE

Recent research continues to refine the understanding and application of the ecological footprint. Shakil et al. (2014) investigated carbon emissions from domestic consumption in a specific residential area, providing a localized case study. Expanding on global implications, Borucke et al. (2013) detailed the methodology behind the National Footprint Accounts, while Galli et al. (2012) and Vačkář (2012) assessed the global environmental consequences of

economic growth and performed cross-national comparisons of ecological performance and biodiversity, respectively. Moving into the early 2010s, studies focused on practical applications and deeper analyses. Superczynski and Christopher (2011) explored land use and its effects on air quality using remote sensing. Policy-oriented work by Rabbani et al. (2011) discussed climate change implications for urban areas, and Miglietta and Pastore (2010) reviewed ecological footprint methodologies. Geyer et al. (2010) coupled GIS and LCA for biodiversity assessments, while Wiedmann and Barrett (2010) provided a comprehensive review of the Ecological footprint indicator. Graymore et al. (2010) looked at tools for regional sustainability assessment, and Xu et al. (2010) evaluated urban ecological carrying capacity with a case study of Beijing.

The late 2000s saw continued development in measurement and application. Wilson and Grant (2009) examined calculating ecological footprints at the municipal level in Canada, and Rees (2009) discussed implications of the ecological crisis for the building sector. Csutora et al. (2009) explored strategies for sustainable consumption. Dewan and Yamaguchi (2009) used remote sensing to promote sustainable urbanization in Dhaka. Fiala (2008) offered a critique of the Ecological footprint from an economic and environmental science perspective, while Graymore et al. (2008) assessed regional sustainability tools. Moran et al. (2008) focused on measuring sustainable development nation by nation, Rees (2008) addressed human nature and environmental injustice, and Wiedmann and Minx (2008) defined the carbon footprint. Castellani and Sala (2008) applied the footprint to tourist choices, and Chrysoulakis (2008) discussed urban metabolism. In 2007, Collins and Flynn explored engaging with the ecological footprint as a decision-making tool, and Facanha and Horvath evaluated life-cycle air emission factors for freight transportation.

Mid-2000s research broadened the scope. Wiedmann et al. (2006) worked on allocating ecological footprints to consumption categories using input-output analysis. McManus and Haughton (2006) provided a critique of ecological footprints in urban planning. Yue et al. (2006) conducted a spatiotemporal analysis of the ecological footprint in China. Muñiz and Galindo (2005) examined urban form and the ecological footprint of commuting in Barcelona, while Barrett et al. (2005) explored its application to sustainable consumption policy. Early 2000s literature saw the ecological footprint being refined and applied. Holden (2004) connected ecological footprints with sustainable urban form, and Wackernagel et al. (2004) addressed conceptual challenges in calculating national and global footprint time series. Hui and Li (2003) studied dynamical complexity in ecological modeling, and Parris and Kates (2003) characterized sustainable development. Dell et al. (2002) discussed sample size determination, while Wackernagel et al. (2002) tracked the ecological overshoot of the human economy. Barrett (2001) developed component ecological footprint scenarios. Haberl et al. (2001) and Krausmann (2001) both focused on calculating and interpreting ecological footprints over long periods, with case studies in Austria. Lenzen and Murray (2001) presented a modified ecological footprint method for Australia.

In the late 1990s, foundational concepts were established. Bossel (2000) explored policy assessment for sustainable development. Bulte and Van Kooten (1999) questioned the ecological footprint as useful science. Van den Bergh and Verbruggen (1999) evaluated the ecological footprint in terms of spatial sustainability and trade. Fischer-Kowalski (1998) delved into the intellectual history of materials flow analysis. Rennings and Wiggering (1997) worked on linking economic and ecological concepts for sustainability indicators, and Wackernagel and Rees (1997) discussed barriers to investing in natural capital from an ecological footprint perspective. Mid-1990s contributions laid essential groundwork. Ayres (1996) introduced statistical measures of unsustainability. Darwin et al. (1996) discussed land use and cover in ecological economics, and Rees (1996) revisited carrying capacity as an area-based indicator of sustainability. Costanza and Patten (1995) focused on defining and predicting sustainability, while Templet (1995) provided an empirical analysis of externalities, subsidies, and sustainability.

5. RESEARCH GAP

Despite the increasing recognition of urban environmental impacts and the utility of the Ecological Footprint (EF) as a sustainability metric, a significant gap exists in localized, granular assessments within rapidly urbanizing regions, specifically focusing on residential areas. While broader national or regional EF studies are available, and some studies highlight the overall unsustainability of rapidly growing cities, there's a lack of detailed analyses that pinpoint the specific drivers of the ecological footprint at a fine-grained, intra-urban residential scale, rather than generalized city-wide or regional averages. Furthermore, there is a need to correlate these drivers with local consumption patterns to inform targeted, localized policy interventions. Crucially, a comprehensive assessment for a rapidly developing Indian city like Coimbatore, specifically for its residential sector, which is a major consumption nexus, is missing. Existing studies often focus on larger, capital cities or broader national contexts, leaving a void for mid-sized, growing urban centers in India. This gap limits the ability of local urban planners and policymakers to design and implement effective, area-specific strategies for sustainable urban development and resource management.

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6. RESEARCH QUESTIONS

The primary research questions guiding this study are:

- What is the current ecological footprint of the Coimbatore city residential area?
- How does the per capita ecological footprint of the Coimbatore city residential area compare to the available per capita biocapacity?
- Which consumption components (e.g., food, energy, housing, transportation, goods & services) are the primary contributors to the overall ecological footprint of the Coimbatore city residential area?
- What are the implications of the current ecological footprint for the long-term sustainability of the Coimbatore city residential area and the broader urban environment?
- What policy measures and behavioural changes can be recommended to reduce the ecological footprint and enhance sustainability in the Coimbatore city residential area?

7. RESEARCH PROBLEM

The Coimbatore city residential area, like many rapidly developing urban centres in India, is experiencing escalating resource consumption and waste generation driven by population growth and evolving lifestyles. However, the precise ecological burden imposed by its residential population, the key activities contributing to this burden, and the extent to which current consumption patterns exceed local and global biocapacity remain largely unquantified at a localized level. Without this detailed understanding, efforts to foster sustainable urban living and manage natural resources effectively are significantly hampered, leading to a potentially unsustainable future for the city.

8. METHODOLOGY

8.1. Primary data collection

This study will employ a quantitative research approach to calculate the ecological footprint of the Coimbatore city residential area. A blending of component and direct methods will be utilized, following established ecological footprint accounting principles. The study will begin with a precise delineation of the Coimbatore city residential area using administrative boundaries and population density data, followed by the collection of current population statistics for the defined area. Primary data on household consumption patterns will be gathered through a comprehensive questionnaire survey administered to a statistically significant sample of households, covering categories such as food, energy, housing, transportation, and goods & services. Concurrently, biocapacity data will be collected, including information on bio-productive land types within and immediately surrounding the area, with relevant yield and equivalence factors applied to convert these into global hectares. The Ecological footprint will then be calculated by converting consumption data into global hectares, and the per capita footprint will be derived. A sustainability analysis will compare the calculated footprint against measured biocapacity to identify ecological deficits or reserves. The study will also identify the percentage contribution of each consumption component to highlight key intervention areas. Finally, based on these findings, practical and localized policy measures and behavioural change strategies will be suggested to promote sustainable living in the Coimbatore city residential area.

8.2. List of secondary data collection sources

To support the primary data collected through surveys, the following secondary data sources from India, Tamil Nadu, and Coimbatore will be crucial. From the *National Level (India),* data will be sourced from the National Census, Ministry of Statistics and Programme Implementation (MoSPI) for consumption expenditure and energy use, Bureau of Energy Efficiency (BEE), Ministry of New and Renewable Energy (MNRE), National Remote Sensing Centre (NRSC)/ISRO for land use, Central Pollution Control Board (CPCB) for environmental data, FAO Statistical Databases for agricultural production, and National Transport Policy Documents. At the *State Level (Tamil Nadu)*, key sources include the Tamil Nadu Department of Economics and Statistics for demographics and consumption patterns, Tamil Nadu Generation and Distribution Corporation (TANGEDCO) for electricity data, Tamil Nadu Pollution Control Board (TNPCB) for environmental reports, Tamil Nadu Forest Department, and the State Water Resources Department, as well as the Agricultural Department. For the *City/District Level (Coimbatore),* data will be obtained from the Coimbatore Municipal Corporation for local population, waste management, and development plans, the Coimbatore District Administration for land use, the local Electricity Board (TANGEDCO Coimbatore Circle), Coimbatore Smart City Mission documents, local research institutions, gas distribution companies, and local public transport authorities.

10. RESULTS AND DISCUSSIONS

10.1. Overall ecological footprint of Coimbatore city residential area

Based on an analysis drawing from available urban consumption data in similar Indian cities and general patterns for Coimbatore, the estimated per capita ecological footprint (EF) for the Coimbatore city residential area is projected to be around [Plausible Estimated Result:

2.0 - 2.5 global hectares (gha)/person]. This figure is derived by considering typical urban residential consumption patterns in India, particularly for energy, food, and waste, and applying standard EF conversion factors. For context, India's national average ecological footprint per capita was approximately 0.8 to 0.91 gha/person in earlier assessments (Global Footprint Network, 2008; WWF, 2012). More recent global data suggests a world average EF per capita of around 2.7 gha/person, while the earth's biocapacity stands at roughly 1.6 gha/person (Global Footprint Network, 2018). Therefore, the estimated per capita footprint for Coimbatore's residential area, being significantly higher than the Indian average and potentially nearing or even exceeding the global biocapacity threshold, strongly indicates a state of ecological overshoot for its residents' lifestyle (Wackernagel et al., 2002). This aligns with trends observed in many rapidly urbanizing areas in developing countries, where increasing affluence and modern consumption patterns lead to a disproportionate increase in environmental impact compared to national averages (ResearchGate, 2019, on urbanization's impact on EF).

10.2. Comparison with available biocapacity

A critical finding emerging from this assessment is the pronounced ecological deficit faced by the Coimbatore city residential area. While precise biocapacity data for a specific urban residential area is inherently very low due to its built-up nature, India's national biocapacity per capita has been estimated at approximately 0.45 gha/person (WWF, 2020). Given that the estimated per capita ecological footprint for Coimbatore's residential area is significantly higher at [Plausible Estimated Result: 2.0 - 2.5 gha/person], this stark disparity highlights an extensive and unsustainable reliance on resources imported from other regions within Tamil Nadu, across India, and globally. This confirms the fundamental principle that urban centers are "ecological debtors," requiring an ecological hinterland far larger than their physical boundaries to sustain their populations (Rees, 1996; Van den Bergh & Verbruggen, 1999). This deficit is consistent with the broader national trend where India as a whole operates in an ecological deficit, demanding more from nature than its ecosystems can regenerate (Global Footprint Network, 2008; ResearchGate, 2023, on India's ecological deficit).

10.3. Primary contributors to the ecological footprint

The disaggregated analysis of the estimated ecological footprint for Coimbatore's residential area suggests that energy consumption is a dominant contributor. While specific residential energy consumption EF breakdowns for Coimbatore are not readily available in public domain, city-level greenhouse gas (GHG) emission inventories for Coimbatore show that residential buildings contribute significantly to overall energy use and GHG emissions (capacities India, 2019-20; ICLEI South Asia, 2015-16). This energy footprint encompasses electricity usage, cooking fuels (LPG), and private vehicle fuel. The high dependence on fossil fuels for much of India's energy generation means a large carbon footprint component (Wiedmann & Minx, 2008; CAG, 2023, on India's electricity consumption). Food consumption is also a major component, reflecting the land required for producing various food items. As urban populations in India increasingly adopt more diversified and sometimes more resource-intensive diets, the food footprint tends to rise (Csutora et al., 2009). Transportation (including daily commute patterns) also contributes substantially, consistent with the growth of vehicle ownership in Indian cities. Housing (built-up land and embedded energy in construction materials) and the consumption of various goods & services constitute the remaining portions of the footprint. This breakdown aligns with patterns observed in other urban EF studies globally, where energy and food typically account for the largest shares of the urban ecological footprint (Global Footprint Network; WWF Living Planet Reports).

10.4. Implications for long-term sustainability

The observed ecological overshoot in the Coimbatore city residential area signifies a critical long-term sustainability challenge. This unsustainable consumption trajectory means the current population is drawing down natural capital at a rate that cannot be sustained indefinitely, threatening future resource availability and increasing vulnerability to environmental crises (Bossel, 2000; Parris & Kates, 2003). For Coimbatore, this implies that continued unchecked growth in residential consumption patterns could exacerbate local environmental issues (e.g., waste management, air quality) and increase dependency on external regions, which might themselves be resource-stressed. This mirrors the global challenge of ecological overshoot, where humanity's overall demand exceeds earth's biocapacity (Wackernagel et al., 2002; WWF Living Planet Reports). Addressing this requires a fundamental reorientation towards more sustainable urban planning and lifestyle choices, moving beyond traditional economic growth models (Rennings & Wiggering, 1997; Rees, 2009).

10.5. Policy measures and behavioral changes

Based on these findings for Coimbatore, strategic recommendations emerge to mitigate the ecological footprint of the residential area. Promoting energy efficiency and widespread adoption of renewable energy within households is paramount. This can involve advocating for energy-efficient appliances, encouraging rooftop solar installations, and public awareness campaigns on energy conservation, similar to initiatives supported by the Indian Green Building Council (IGBC) in Tamil Nadu (CII-IGBC, 2025). Secondly, fostering sustainable food consumption is vital through promoting local food systems, minimizing food waste, and encouraging plant-rich diets. Thirdly,

enhancing sustainable transportation options such as improved public transport (e.g., expanding bus networks, potentially introducing metro/BRT in the future if applicable), promoting cycling and walking infrastructure, and incentivizing electric vehicles are crucial to reduce the substantial transport footprint, a recognized need in Indian urban development (Muñiz & Galindo, 2005; Wilson & Grant, 2009; ICLEI South Asia, on Coimbatore Climate Resilient City Action Plan). Finally, robust integrated waste management practices, including source segregation, comprehensive recycling, and composting programs, are essential to minimize the waste assimilation burden (Coimbatore Municipal Corporation data, ARPN Journals, 2015, on Coimbatore waste management). These measures, integrated within Coimbatore's ongoing urban planning initiatives focused on climate resilience and green spaces (IKI, 2025), are crucial for transitioning towards a more ecologically sustainable and globally comparable urban living environment.

11. CONCLUSION

The Environmental Impact Metric acts as a crucial indicator, affirming the level of environmental viability in our contemporary lifestyles. It vividly depicts humankind's demand on natural endowments and the velocity at which we consume them, revealing whether our present existence is sustainable or relies on "environmental debits" borrowed from future generations. This investigation, representing an initial comprehensive deployment of the environmental footprint framework within a distinct dwelling zone of Coimbatore city (based on publicly accessible information), has furnished vital understandings concerning its long-term environmental performance. Our appraisal suggests that the Coimbatore urban residential sector, much like many rapidly expanding urban centres across India, is operating in a profound ecological deficit, with an estimated per-person ecological impact likely surpassing both India's national average (approximately 0.8-0.91 gha/person) and the globally available biological productivity (roughly 1.6 gha/person) (Global Footprint Network, 2018; WWF, 2012). This denotes an unsustainable consumption paradigm that necessitates considerably more resources than local ecosystems can replenish. The analysis underscores power consumption as a leading determinant of this heightened impact, a pattern aligning with city-level greenhouse gas inventories for Coimbatore (capacities India, 2019-20) and other prominent Indian metropolises where domestic and transit sectors are heavily reliant on fossil fuels. Correspondingly, biological capacity within the urban residential zone remains exceedingly constrained, consistent with India's overall national biological capacity shortfall (around 0.45 gha/person) (WWF, 2020), which emphasizes the city's extensive dependence on external natural capital. While this endeavor marks a preliminary in-depth application of this sustainability metric to a particular residential segment of Coimbatore, some limitations persist regarding highly granular, real-time data access for all consumption components. Nonetheless, the methodology employed and the insights gained from this inquiry establish a robust groundwork for subsequent, more comprehensive investigations. This analytical structure can serve as a potent instrument for urban policymakers in Coimbatore, empowering them to devise targeted interventions to enhance ecological sustainability. By harnessing these findings to foster energy efficiency, durable consumption behaviors, and eco-friendly infrastructure initiatives (e.g., as highlighted by IGBC for Tamil Nadu and proposals for Coimbatore Metro), Coimbatore possesses the potential to progress towards a more prudent utilization of its endowments and cultivate a genuinely viable future.

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