Discussion Paper

Landscape Carrying Capacity Assessment Framework for Sustainable Development

Indira Gandhi National Forest Academy

Dehradun, Uttarakhand

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EXECUTIVE SUMMARY

The Carrying Capacity assessment-based approach is essential for steering contemporary economic development without overstepping of planetary boundaries, such as those posed by global warming and environmental pollution. However, the assessment of the carrying capacity of a landscape for this purpose presents several challenges, including gaps in the understanding of intra and inter-landscape interactions, the difficulty in verifying carrying capacity in advance and a lack of knowledge about tipping thresholds of environmental attributes. Despite the inherent challenges, carrying capacity assessment offers a rational and collaborative pathway to align developmental goals with environmental preservation. To address these challenges, reliance on proxy indicators and expert judgment becomes necessary. Furthermore, the associated uncertainties with knowledge gaps and subjectivity in expert judgment prompt the adoption of environmental precautionary principles as a practical and reliable option for considering the developmental carrying capacity of a landscape.

At its core, carrying capacity assessment involves determining the maximum impact a landscape can sustainably endure from human activities without causing degradation. Given the escalating pressure on the natural environment from economic activities and environmental crises, the carrying capacity assessment approach is arguably the most potent tool for aligning economies for sustainable development.

Recognizing the significance of operationalizing the carrying capacity concept for guiding sustainable development in a landscape, this discussion paper proposes a framework for its assessment. A systematic approach to balance developmental aspirations with environmental sustainability by considering landscape dynamics and the performance of landscape environmental attributes is presented. The proposed framework encompasses delineating landscape boundaries, characterizing landscape components, identifying significant values in the landscape, engaging stakeholders, locating identified activities in specified area zones, and fostering consensus on permissible developmental activities and their scale.

The discussion paper explores different methodologies for carrying capacity assessment and underscores the importance of technological advancements, management capabilities, and understanding of system dynamics. Through the adoption of this comprehensive approach, policymakers can make well-informed decisions to foster sustainable development while safeguarding the integrity of landscapes and their ecosystems.

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ABBREVIATIONS

CC	Carrying Capacity
CPCB	Central Pollution Control Board
EOD	Earth Overshoot Day
IPCC	Intergovernmental Panel on Climate Change
PM2.5	Particulate matter 2.5
WHO	World Health Organization
GDP	Gross domestic product
NGT	National Green Tribunal

Discussion Paper

Landscape Carrying Capacity Assessment Framework for Sustainable Development

1.0 Context for the Discussion

The present discussion is embedded in the intensifying debate on the pursuit of economic development and its sustainability. The contemporary economic model has been successful in creating wealth and promoting technological advancements. During the past 110 years, the global human population, global average per capita incomes, and global GDP have increased 5, 7 and 35 times, respectively. The scale of economic activity, and thereby, the flow of mass and energy from economic activity, has been growing and reached the proportion that the regenerative and waste assimilative capacity of natural environmental resources is falling short. This has resulted in increasingly aggravating environmental crises e.g., climate change, ocean acidification and plastic pollution. Planetary boundaries of environmental attributes, such as stable ambient land and ocean temperatures, atmospheric composition, and patterns of rainfall, are breached. This has implications for human development and welfare. The extreme weather events causing widespread damage and loss are ready evidence of it. Seized with the situation, national governments, citizen organisations, international agencies, and other stakeholders are looking for avenues and mechanisms to mitigate the circumstances and realign developmental approaches.

Overall, while the underlying issue in this discourse pertains to the regeneration and waste assimilation capacity of the natural ecosystems, the approach to development respects ecological limits. Enough literature is now available to suggest that an ecologically limiting (carrying capacity) approach is neither about not aspiring for a higher GDP target nor about *degrowth*. Potentially, assessing the carrying capacity of a landscape for economic activities and using it as a guiding tool can help to attain this purpose.

Further, the Ministry of Environment, Forest and Climate Change, Government of India has issued ***Guidelines for assessing the carrying capacity of hill stations, including cities and eco-sensitive zones,*** in the year 2020. The guidelines state the following regarding the assessment methodologies in para 5.

"There are no clear-cut methods for assessment. The use of methods depends upon analytical acumen and knowledge of analytical tools of investigators (ideally a multidisciplinary team). It may vary from complicated modelling tools software to simple thresholds/acceptable benchmark/standards-based comparisons. The setting of such standards/thresholds which are very important for assessment of breach of carrying capacity (CC overshoots/limits) needs to be done in Indian context. The carrying capacity limit setting and standardization requires experts' weightings/consultations."

Furthermore, the honourable NGT in O.A. number 462/2018 and 76/2015 (SZ) dated 17 March 2021 have directed as follows.

"we reiterate our direction for this course of action *[…undertaking carrying capacity of eco-sensitive areas in all the states/UTs directed earlier vide order dated 19.03.2020]* ***being adopted in a time bound manner to enforce the 'sustainable development' and 'precautionary principles' which the tribunal is expected to apply in giving directions under section 15 of the NGT Act 2010".***

The present discussion paper is initiated in the above context with the objective of evolving a carrying capacity assessment tool for guiding sustainable development.

2.0 The Question

Given the contemporary environmental crises, the need for the environmental compatibility of development is universal. It is particularly so in the case of high biocapacity landscapes such as biodiversity-rich protected areas and their immediate surroundings, as maintaining them offers sustainability to economic development over wider landscapes. However, in a developing country like India, sustenance, as well as commerce-oriented human activities, continue to ingress even into such areas set aside on ecological-balance priorities. In this context, the pursuit of human development has brought the focus on the concept of carrying capacity as a guiding approach. Courts and regulatory authorities are adopting it as a basis for optimizing human development with nature conservation. Carrying capacity assessments can potentially provide a rationalized and widely accepted basis for regulating and better aligning the environmental compatibility of human activities in a landscape.

The term 'carrying capacity' is believed to have originated in the early 19th century, with its first suggested usage in the context of shipping in the 1840s (Sayre 2012). Thereafter, this concept has been applied inter alia in the context of livestock grazing, wildlife management, biological limits of natural systems, limits to growth of populations, agriculture, and fisheries sectors, and as a tool to manage the 'human-nature interface' for ensuring the sustainability of our natural environment (Boa et al. 2020, Sayre 2008). Despite its criticism as a flawed concept in other than directly measurable engineering sector, it continues to find favour with practitioners, regulators, and policymakers for apparently the easy and intuitive sense the term conveys (Sayre 2012). With its long history of application, carrying capacity has emerged as an acceptable concept that can guide human development compatible with the long-term sustainability of natural ecosystems. The concept finds deep synergy, particularly with the Agenda 2030 Sustainable Development Goal number 12 - *ensure sustainable consumption and production patterns* – that prompts to undertake development, in extent and of nature, that does not cause unsustainable demand and is within the carrying capacity of natural (or human) resources. Thus, the carrying capacity concept is essentially about the sustainability of a system over the long term (Fig 1).

In the context of this article, a landscape is understood as a land parcel under consideration for developmental planning. The size of such a landscape could vary from about a village size to a much larger area. If left undisturbed, the landscape, with its assemblage of biotic and abiotic elements, would be autonomously maintained through the flow of mass and energy within and from outside of it. The carrying capacity of a landscape stems from its adaptive capacity, which is the autonomous capability to adjust to a change, duly maintaining its structure and functionality. Such capacity is primarily rooted in bioproduction and ecological and biogeochemical processes that are undergoing in a landscape. The present discussion seeks to answer the following question in the context of current environmental crises and the human desire for ever-increasing economic growth: ***How can the concept of carrying capacity be operationalized in the pursuit of sustainable development?***

The discussion seeking answer to the above question is presented in five Sections. Section 2 discusses the concept in the context of the present study. Section 3 discusses the assessment of carrying capacity and the challenges in assessment. Section 4 builds on the understanding of the concept, presents the framework for assessment, and lists the methodological steps. Conclusions are presented in Section 5.

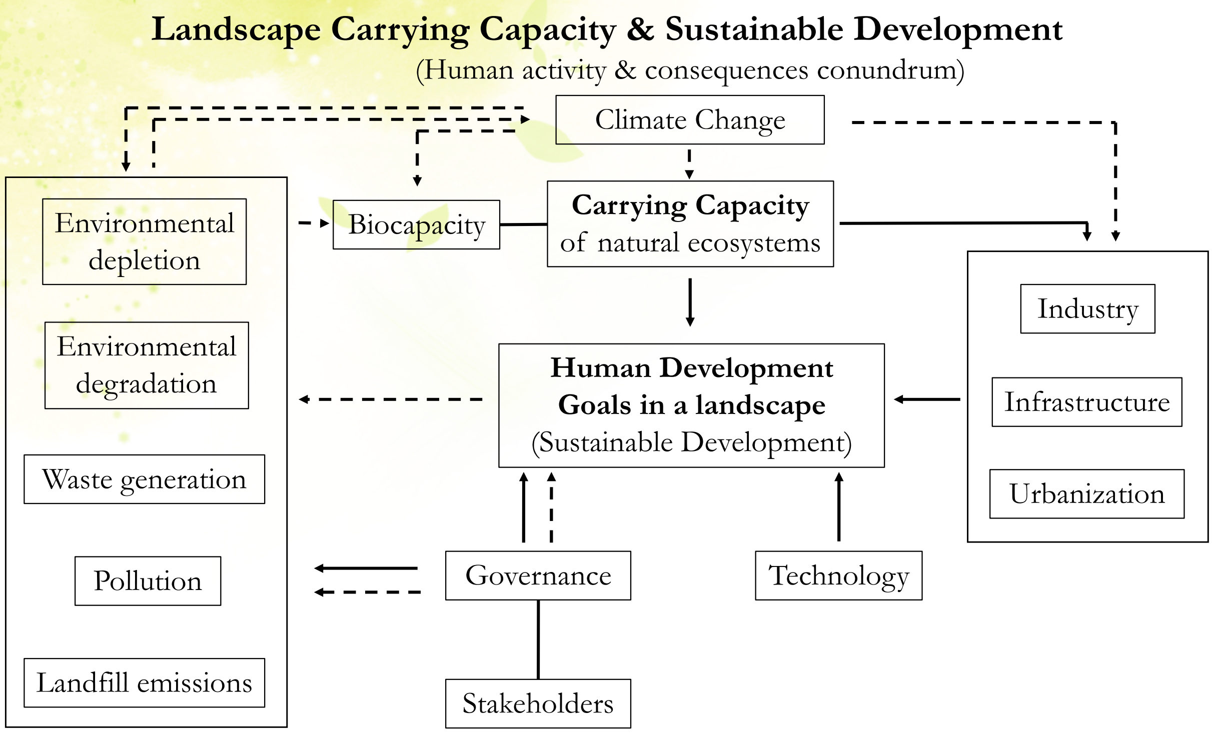

Fig 1. The concept of carrying capacity helps in operationalizing the sustainable development approach. It informs about the scope for undertaking developmental activities without impairing the biocapacity (biological productivity) of a landscape. Solid arrows indicate positive provisioning and broken arrows indicate adverse implications. Solid lines indicate integrated elements.

3.0 The Concept underlying the Question

3.1 Carrying Capacity Concept

The notion of carrying capacity (CC) is embedded in the manifestation of the 'impact' of a disturbance. In the context of this study, it is primarily about the quantum of impact of a disturbance caused by a human activity that can be autonomously absorbed by its natural environment. For example, the maximum quantity of sewage water that can be discharged into a river without impacting the quality of water for its intended usages, say bathing or agriculture or domestic or industrial consumption. If the capacity of a river to disperse and dilute the pollution to acceptable standards is exceeded, river water cannot be used for the target purpose(s). Continued overloading of river can result in a reduction in its inherent capacity to maintain the quality of water, potentially causing permanent changes in the (river) ecosystem. Thus, in the present illustration, the carrying capacity of the river is determined by its potential to disperse and dilute pollution. Similarly, the carrying capacity of forests for wood-harvesting activity is determined in terms of the quantity of wood that can be harvested from a forest without impacting its capacity to maintain the same yield perpetually. Such annually harvestable quantity is equal to the annual growth a forest puts on and is called sustainable harvest.

Further, a natural landscape can experience a large-scale impact from human activity or an event of nature in terms of landslide(s), whereupon, opportunistic invasive plant species can gain ground and proliferate at the cost of native species, thereby significantly changing its biophysical attributes (reduction in tree canopy cover; change in tree composition) and ecosystem service benefits it can yield. The impact of such human activity or natural events would be considered beyond the carrying capacity of the landscape. However, an activity or event having a smaller impact can be overcome by the spontaneous adjustment response by the system, and no change in its structure or functionality may occur. Such an extent of activity or event would be within the carrying capacity of the system. Carrying capacity can thus be understood as the ability of a system to put up with disturbances without experiencing depletion of its ability to produce benefits.

3.2 Carrying Capacity as Threshold Capacity

Carrying capacity, understood and assessed as the threshold capacity for absorbing disturbance by the natural environment, can inform about regulating developmental activities in a landscape. On the other hand, exceeding such thresholds can diminish the carrying capacity of the natural environment and jeopardise the attainment of sustainable development goals. For example, exceeding the global warming threshold of 2 degrees centigrade is assessed as a potential trigger for large-scale irreversible changes in the earth's systems, negating all the benefits of development (IPCC 2022). Practically, in the contemporary world, threshold capacities of natural systems are articulated through two major approaches. One is the *planetary boundaries approach,* and the other is the *biocapacity overshoot approach*. These approaches are applicable at the global level, and the *biocapacity overshoot approach* is valuable at the landscape level.

The *planetary boundaries approach* is applied in the context of environmental crises such as global warming, land degradation, pollution, water stress, and biodiversity loss, as their impacts are an outcome of the overshoot of planetary boundary thresholds (Rockström et al. 2009). Planetary boundaries indicate global biophysical and geochemical threshold levels of the different attributes of our planet, breaching of which can result in uncertain and unknown changes in the earth system, potentially triggering planetary-scale transitions of unknown implications (Barnosky et al. 2012). The nine planetary boundaries (factors) identified pertain to the following: 1) climate change; 2) change in biosphere integrity; 3) nitrogen and phosphorus biogeochemical cycle; 4) ocean acidification; 5) land use; 6) freshwater; 7) ozone depletion; 8) atmospheric aerosols; and 9) chemical pollution (Rockström et al. 2009). Planetary boundary thresholds provision the ‘safe operating space’ for humanity and thus provide guidance on the limits to economic development. These planetary boundaries define the thresholds for the carrying capacity of the planet with respect to the boundary factors, individually (and in combination!).

The *biocapacity overshoot approach* is embedded in the concept of *Earth Overshoot Day* (EOD), which is a sustainability metric about the demand humans put on the earth systems by consuming the total annual productivity of the natural systems within a few months every year. It provides an empirical measure to understand carrying capacity as threshold capacity. During the year 2023, the EOD was on 12 August, i.e., by this date, humanity had already consumed the total ‘annual’ productivity of the earth systems, and beyond it, the capital stock of the natural resource was depleted. At the current consumption levels for Qatar and Kyrgyzstan, the Earth Overshoot Day during 2024 is calculated as 11 February and 30 December, respectively. Such depletion of resources reduces its potential for productivity during the subsequent years. Consuming more than the productivity of the natural ecosystems year after year sets in an aggravating spiral of reducing productivity and resource degradation, as the rate of utilization of resources is higher than the regeneration rate. Thus, knowledge about such threshold carrying capacity (consumption and production levels) is necessary for developmental planning.

3.3 Nature of Carrying Capacity

The carrying capacity of a landscape depends upon its biotic (e.g., forests, rivers, lakes) and abiotic (e.g., size, terrain, climate) resources and the manner and to the extent such resources are maintained (Storch 2019). It is further subject to imports from (e.g., freshwater availability from snowmelt flowing into the landscape) and exports to (e.g., such snowmelt water is allowed to flow out of the landscape) the neighbouring systems. It is thus dynamic in nature, and at a point in time, determined by the status of resources and its internal state processes of flow of mass and energy within and through the landscape.

Further, the dynamic nature of carrying capacity prompts the idea that it is possible to enhance carrying capacity or restore lost carrying capacity (Boa et al. 2020). For example, maintenance of grassland habitats in a wildlife-protected area can add to the capacity of such area to sustain more herbivores and, by implication, higher carnivore populations. Or, by employing technology, say by using large-size air purifiers, the capacity of the urban landscape to maintain the air quality can be supplemented, and the setting up of sewage treatment plants can supplement the capacity to handle the higher discharge of sewage.

4.0 Assessment of Carrying Capacity

Throughout history, humans have sustained themselves on provisioning by nature. Prior to industrialization, 'consumption' by humans completely relied on the productivity of nature from the area that could be physically accessed, and hence, the size of the pie available for consumption was fixed (fixed-pie situation). However, the advent of new technologies has constantly enlarged the size of the pie available for consumption. For example, technological advancement has enabled a manifold increase in agricultural production per unit area of land, sustaining an ever-growing human population. Today, enough food is being produced to support an 8 billion human population. Estimates suggest that without agriculture, the carrying capacity of the earth would be only between 1 and 15 million humans (Biology Dictionary 2016). Thus, while it has been possible to enhance the human carrying capacity of the Earth in terms of food production, it has not been without negative implications for the natural resources and ecosystems. The impact of advances in agriculture technology on biodiversity and freshwater resources has been immense. This is besides other equally or more pernicious impacts like penetration of pesticide residues in the food chain and depletion and degradation of soil fertility and structure. Is such food production capability desirable and sustainable? Does it exceed the environmental carrying capacity of agricultural landscapes?

Similarly, establishing a network of roads in a hilly landscape without considering its implications for the stability of slopes can potentially result in an increase in number of landslides with wider impacts on forests and water resources, degradation of landscape due to soil erosion, loss of biodiversity from proliferating invasive species, and even damage to human habitations and loss of human life. The obvious question is: how dense a road network can be established without triggering negative impacts?

Alongside the abovementioned case scenarios, it is worthwhile to consider certain natural processes in a landscape that can autonomously deal with the impact of developmental activities. For example, while the self-purification mechanism of rivers enables water purifica tion through dilution of pollution load, and oxygenation and microbial action, maintaining adequate forest cover in the landscape limits the damage from landslides. However, such opportunity is available only up to a certain threshold level of pollution beyond which river self-purification processes cannot restore water quality or landslides due to road cutting cannot be avoided. Such threshold level of pollution or disturbance defines the carrying capacity of a river for purification of pollution load or the carrying capacity of the landscape for landslide-causing developmental activities.

Moreover, avoidance or limiting damage and loss appear to work only within the tolerance threshold of a system, beyond which the response of the system is uncertain and difficult to predict. Breaching such thresholds may introduce fundamental and widespread changes in the landscape that are beyond autonomous or may even be beyond assisted restoration. Thus, deciding the type and density of developmental activities in a landscape is challenging and demands careful consideration and a precautions-based approach. In this scenario, assessment of carrying capacity can help by informing the developmental planning process, as the likely impacts are identified and carefully studied, and consensual precautions are applied through stakeholder consultation.

Further, with the increasing spread and density of development works and aggravating environmental crises, it has become necessary to guide the process of development with inputs on the carrying capacity of natural ecosystems and landscapes. Without the assessment of environmental carrying capacity, and thereby ensuring environmental protection, losses and damages due to natural hazards may only increase the suffering of humans and deprive them of the benefits of social and economic development. Environmental instability has implications for the vulnerability of the people, particularly those at the bottom of the pyramid, and the resilience of natural ecosystems. This scenario prompts for adopting precautionary principles while assessing the carrying capacity of natural ecosystems and landscapes for optimizing the benefits of development in promoting human well-being.

4.1 Landscape Carrying Capacity Assessment

Assessing Landscape Carrying Capacity is challenging. Empirically, the carrying capacity of a landscape for human development is a measure of its ability to meet the current needs of the dependent human population and other species that use the landscape to sustain themselves and flourish, while the landscape's capability to meet such needs in future is maintained. However, undertaking the assessment of such maximum ability of a landscape (i.e., its carrying capacity) requires knowledge about the maximum level of disturbance (threshold level) it can put up with without undergoing degradation. For the purpose of the present discussion, at this stage, the imports into and exports from the landscape are ignored.

Lack of knowledge about thresholds of tolerable disturbance for a landscape poses a major limitation in directly assessing the carrying capacity for such disturbance. Moreover, information about nature and the extent of the impact of a disturbance on a landscape is rarely available. The situation becomes more challenging when multiple disturbances occur simultaneously. In the absence of such knowledge, exceeding the carrying capacity threshold of a landscape with permanent adverse changes is likely. This is best avoided by adopting a precautionary approach, where under the lower-end value of the tolerance range for a parameter of interest is adopted employing expert judgment based on the experience or perception as the carrying capacity limit for a landscape. Also, it is better be so, as it helps in securing the sustainability of a landscape since the perceived or known range of tolerance may be riddled with uncertainties due to other factors that may be at play in the landscape. Experts and other stakeholders should agree on the abundance of precautions to remain within a 'safe operating space'.

Further, whenever the benchmark values for parameters of interest are available, assessing carrying capacity becomes an exercise in comparison, and the status of a system or a process is assessed against the acceptable benchmarks. For example, the carrying capacity of the ambient environment for healthy living can be assessed in terms of air quality, water quality, or opportunity for open spaces. In such a situation, determining the carrying capacity of a landscape with regard to such parameters is about assessing whether the value of a parameter is within the prescribed limit in the landscape. However, parameterization of all that may impact a landscape and prescribing values for them may not be available or feasible.

Carrying capacity depends on and is also assessed on the considerations of technological advancement, management capability, time horizon consideration, perceived safe levels of parameters of interest, and knowledge about the system and system-processes thresholds. Accounting for these factors involves subjectivity as the assessors make judgments. Moreover, assessment can often be very nuanced. For example, the PM2.5 threshold level of 5 µg/m3 notified by the WHO renders almost the whole geography of India unsafe. However, given the background level (natural abundance without human activity) of PM2.5 in four megacities in India being about 40 µg/m3, the WHO standard is contested in view of the adaptability to the higher levels of PM2.5 naturally encountered by the inhabitants (Beig et al. 2021). Finally, assessing environmental carrying capacity may become more challenging in the rapidly changing socioeconomic and or technological environments, and in such a case, assessed carrying capacity may practically be undermined as a guiding metric (McLeod 1997; Rees 1992). However, despite the challenge, the assessment of carrying capacity by employing environmental precautionary principles is considered a practically robust and reliable tool to guide human development in a landscape.

5.0 Framework for Assessment

Knowledge gaps exist about the overall impact of human activity on a landscape and about the tolerance limits of a landscape for such impact. However, communities aspire for development in their native landscapes and undertake activities to achieve it. This gives rise to two fundamental questions: what infrastructural facilities and services do they aspire for? And what quality of the natural environment are they ready to accept? Consensus on these questions is practically impossible to reach, as different stakeholders perceive development (its nature and extent) differently and consider different time horizons. Here, the tussle between the 'developmental governance' in the immediate term and the 'sustainability of development' over intergenerational periods intensifies. While the *developmental governance* arguments are rooted in meeting present needs, the sustainability logic is rooted in the consideration that a natural system should be able to meet the needs in perpetuity. Consequently, due to the lack of a common meeting ground, the question of meeting current developmental aspirations and ensuring its sustainability remains. In such a situation, the need for evolving criteria for pursuing development without compromising sustainability arises. Carrying capacity assessment approach based on the precautionary principles criterion provides the option to deal with the abovementioned scenario practically.

Nonetheless, knowledge gaps about the disturbance-tolerance thresholds for different landscape parameters often make this approach challenging to operationalize. For example, knowledge about the disturbance-tolerance thresholds of a hilly landscape for establishing a network of roads is lacking. Also, techniques for undertaking even preliminary-level ex-ante assessment of disturbance-tolerance thresholds for a landscape are lacking. Consequently, prescriptions about the density of road networks in different landscapes - flat, rolling, hilly - are unavailable. Comparatively however, as the standards for breathable air are prescribed, the levels of air pollution higher than the prescribed limits are considered unacceptable and an activity that can add to pollution is rejected as beyond the carrying capacity at a locality. Similarly, water standards are available to guide pollution levels, and an inflow of polluted water that would render the river or tank water polluted is considered beyond the carrying capacity of such river or tank. Thus, the availability of guidance on standards facilitates the assessment of carrying capacity.

Further, central to the purpose of assessing carrying capacity is the 'system' whose carrying capacity is intended to be assessed. It essentially means that the planners and decision-makers are seeking guidance about the nature and extent of anthropogenic activities that can be undertaken without impacting the capability of the system to maintain itself and that its structural and functional integrity is not compromised. Practically, therefore, while planning for development in a landscape, planners would like to know the environmental compatibility of a proposed developmental activity and avoid or redesign it if it causes high disturbance. In this regard, it is also important to consider that alongside episodic impact, some activities can trigger a change process that gradually builds up, eventually inflicting a much higher impact on the natural environment. For example, invasive weeds, once introduced, can spontaneously proliferate and degrade native biodiversity over the whole landscape over a period of time.

Furthermore, the focus of carrying capacity assessment could also be on an 'activity' that can potentially cause a high impact on a landscape. For example, an industrial unit emitting high air and water pollution load or a large-scale construction activity causing a lot of disturbance, including movement of earth and generation of waste or a linear intervention (e.g., roadway, railway, canal) cutting across and impacting the physical integrity of landscape(s). Thus, while in the case of system-centric consideration, the focus is on the tolerance of the landscape to withstand the impact, under activity-centric consideration, the focus is on the disturbance caused by the activity and then on the sensitivity of the system to such disturbance. Landscape carrying capacity assessment is essentially an exercise rooted in *system-centric considerations*, as the system is geographically locked and biologically live while undertaking activities therein is uncertain and discretionary.

From the above discussion, it is clear that the current state of knowledge does not adequately support the assessment of the environmental carrying capacity of a landscape for setting up the limits for development. However, due to the lack of other practical approaches, and despite limitations, the carrying capacity assessment approach is gaining importance as a rational and consensus-based approach to develop a prescription for developmental activities that can be undertaken in a landscape for environmentally compatible sustainable development.

5.1 Assessment Approaches

Different approaches are reported in the literature for assessing landscape carrying capacity. These approaches assess carrying capacity in terms of *bio-capacity and carbon footprint* (Swiader et al. 2020); or by considering the element-wise balance, say the availability of water versus demand for water (CPCB 2021); or assessing the present status of environmental parameters and comparing them against the prescribed standards (CPCB 2021); or those assessing the demand for energy and sustainability of such energy consumption (Campbell 1998); and, system dynamics-based carrying capacity modelling approach that seeks to optimize the limiting factors of carrying capacity. Each of these approaches suffers from its own limitations (Boa et al. 2020), for which the referenced studies can be consulted.

In practice, assessing carrying capacity involves the assessment of a variety of factors or indicators that determine carrying capacity, directly or through mutual influences (Ren et al. 2021). In a given context, a rational approach would involve developing a suite of methodological tools and techniques and employing precautionary principles of environmental conservation whenever necessary and feasible. Such an assessment approach would potentially yield practical results that are able to balance the competing demands in the landscape and are acceptable to the stakeholders. Considering the discussion in the preceding sections, the framework for assessing landscape carrying capacity for undertaking developmental activities is presented below (Fig 2).

5.2 Methodological Steps

Drawing from the framework presented in Figure 2, the following methodological steps are suggested for undertaking the assessment.

***Step 1*: ** Define the 'landscape' and 'landscape boundaries' as narrowly as possible. This involves listing its geographical spread and biotic and non-biotic components.

Step 2: Characterize the listed components in terms of their extent, location, and significance.

Step 3: Draw a 'statement of significance' of the landscape. 'Statement of significance' brings out the most important values of the landscape that must be preserved. This informs about the elements and processes with respect to which precautionary approaches and principles are to be adopted. Practically, this is operationalized by identifying activities that are prohibited or restricted. For example, prohibition on mining activity within river riparian zones, or restrictions on blasting within a certain distance from an archaeological monument as prescribed by the archaeology department.

Step 4: Recognize that a system exists in its own environment, which influences it (Campbell 1998). This makes it challenging to isolate the inherent capacity of the system to tolerate disturbance (inherent carrying capacity) from the supplemented capability that it organically gains from its immediate environment. For example, winds blowing in the larger region, where the assessment landscape is located, may help the dispersal of air pollution, which may add to the carrying capacity of the study landscape with regard to air pollution.

Framework for assessment of Landscape Carrying Capacity

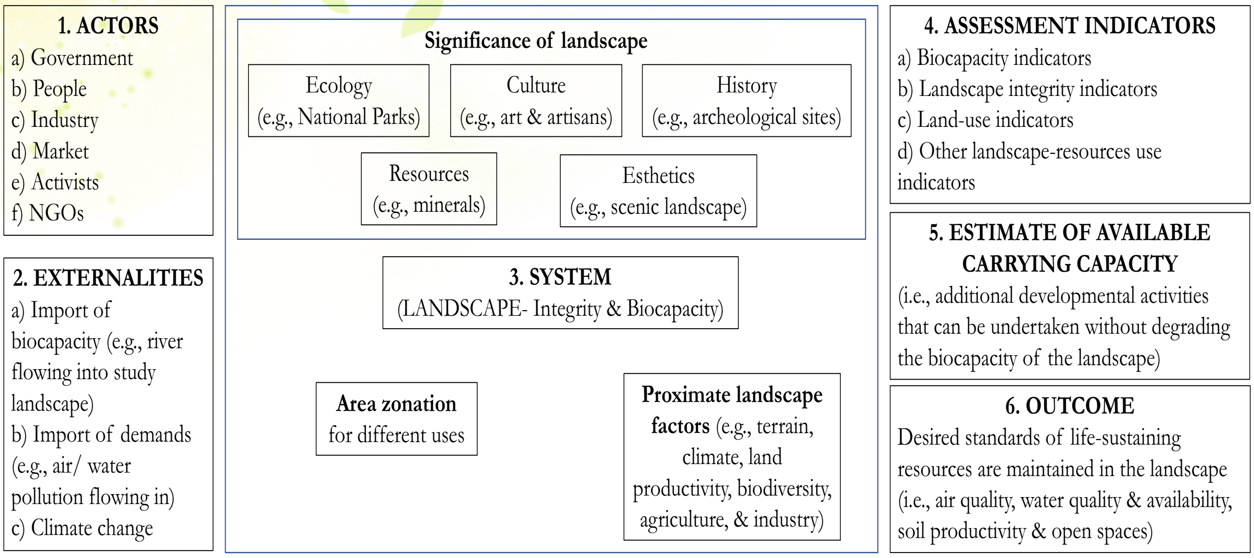

Fig 2. Framework for assessment of carrying capacity considers proximate and distant influencing factors that have implications for the integrity and biocapacity of the landscape. An indicator-based approach for the assessment of attributes of the landscape and a comparison of the present status of such attributes provides guidance on the available carrying capacity to undertake developmental activities in the landscape.

Step 5: List the proximate and distant stakeholders in the landscape and shortlist them for undertaking the consultation process. Agreeing on the boundaries of the landscape, its various elements, values to be preserved, and the possible ways to preserve them is the first stage outcome of stakeholder consultation.

Step 6: Experts arrive at the zonation of the landscape for different types of developmental activities, such as archaeological sites, residential areas, agriculture, markets, industrial areas, stone quarry areas, etc. They also provide guidance on limiting the extent of activities based on prescribed norms about pollution, waste generation and handling, soil conservation, tree cover and green areas, slopy areas, water drainage patterns, wildlife corridors, and any other factors identified in view of the significance of the landscape.

Step 7: In the final stage, stakeholder consultations are undertaken again to evolve a 'consensus on the permitted extent of developmental activities' identified by the experts. This step involves conservation-development trade-offs and balancing competing interests and thus demands skillful negotiations.

6.0 Closing Remarks

Development is a fundamental aspiration of humans and is considered the first deliverable by governments. Technological advancement has made it increasingly possible; however, in the drive for development, the cost and implications of the depletion and degradation of natural resources are ignored. Assessment of carrying capacity by employing precautionary principles can guide the process of development in a landscape and ensure sustainability. However, assessing landscape carrying capacity is challenging due to a lack of knowledge about the threshold of disturbances the landscape can accommodate, the dynamic nature of carrying capacity, the subjectivity involved in the assessment, and the competing stakeholder interests. Assessment demands a synthesis of methodology by combining an area-zonation approach, prescribed norms for air and water quality, use of expert judgment, and extensive stakeholder consultation. Carrying capacity-based landscape development planning can potentially facilitate meeting developmental aspirations with well-preserved standards of life support resources – air and water quality.

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