Carrying capacity of present & the upcoming Megacities of India: A case for geo-spatial data application

Aishwarya Narain
Remote Sensing Applications and Image Processing Area
Space Applications Centre, ISRO, Ahmedabad 380 015
e-mail: aishwarya19@yahoo.com
Voice: 91 79 26862789

1. INTRODUCTION

Ecologists have defined the **"carrying capacity"** as the population of a given species that can be supported appropriately in a defined habitat without damaging the ecosystem. In practice, this does not happen and that is why there is a disparity in economic levels of different countries. In the simplest form, the carrying capacity (cc) is the point where the rate of birth equals the death – a kind of equilibrium (no change situation). In a dynamic environment, the underline factors are controlled by various regulators. Any undue utilization can lead to mass fatalities and serious shortage of basic needs like food and water. In general, these regulators not only affect a given population but also de-stabilize others, as they are interdependent. The imposition of any regulatory mechanism is easily done on animal and plant population whereas it is most difficult in human. It is because of the fact that these entities are residing in a fixed territory. The humans on the contrary can migrate depending on the demand and supply of the resources. The economic criterion of a region/space is the only constraint. This has resulted in large disparity in exploitation of resources by rich developed nation viz. a viz. poor who can ill afford it. To rise above the disparity among the various countries, the ecologists have been considering the concept of an average carrying capacity across various components of the ecosystem with humans as the prime. This was modified and normalized with respect to the area and is called as the "ecological footprint". At a functional level, the sustainability becomes the single most important in the present as well as future projection of ecological footprint. However, the resultant from this decides the fate of mankind, as one knows that the environment and resources on the earth are limited. The factor that becomes important is not the population alone but the resources available and its judicious utilisation. In recent times the population and its environment have led to a unique situation of causing health hazard like the outbreak of bird flu in the Asian region. If this is not checked, it may lead to catastrophy. Both man-made as well as natural factors are impending the growth and sustainability.

1.1 Parameters of Carrying Capacity

Technology although always appearing as improving the quality of life through better utilization of resources has on the contrary led to over exploitation. This condition is best explained by the second Law of Thermodynamics. In a highly ordered technology intensive world, we created disorder at higher level in the system (Schneider and Kay 1992.). One finds that a natural system has the following three assets/capitals namely:

a) Renewable resource (species and ecosystem).

b) Replenishable Resource (Ground Water and the Ozone layer in the atmosphere)

3. Non-Renewable resource (Fossil fuel and minerals).

It is generally found that the technologies have been responsible for proper utilization of resources in different regions of the world. However, it is known that over a period of time the economic levels of various countries have gone up including India but at a substantial cost of natural capital (reduced

biodiversity, pollution air/ water besides land degradation). The over-exploitation of water resources (inland and groundwater) has resulted in serious shortages apart from pollution in many countries. This is more serious for ones who have limited resources and large population. This essentially means that starting with low entropy (highly ordered) has resulted in high entropy. The global climate change can be very well felt today. The high entropy has already altered the changes in natural ecosystem besides triggering various unfavorable weather events at much larger and frequent scales than in the past. In the last two decades, the global weather has seen large scale changes and this can be taken as direct expression of increased entropy. The following are some of the observations to show that the technology has been found harmful.

- Technology provided short-term benefits at the cost of permanent erosion or disappearance of the resources/stock.
- One such example is the use of fish finding devices resulting in over fishing and lowering of fish stocks all over the world.
- Improved farming practices and inputs and have resulted in short term gain but have already started showing loss of carrying capacity by increase in waste/ degraded
- The trade is seen as another deterrent to carrying capacity although it has improved efficiency in availability of goods and services. The economically rich states have put demand to meet these from natural resource surplus states. An example of this is Netherlands, which needs 14 to 15 times of its area to meet its own demand of resources of various kinds. Moreover, is currently facing serious problem of waste disposal.

1.2 Sustainable Development

A concerted effort and debate at Earth summit held in Rio de Janeiro (1992) led to historical goal of achieving sustainable development. The well known outcome was the adoption of Agenda 21. The following key issues were projected:

a) Pattern of sustainable production

b) Alternative sources of energy to replace non-renewable fossil fuel due to its almost irreversible affect on global climate change

c) Reliance on Public transportation to reduce vehicle emission

d) Growing Scarcity and concerned for the availability of safe clean water

Recommendations of the summit whether followed or not the fact remains that the present population of plus 6 billion is 'sustaining' with a deficit of 30 per cent in resources. "It is too late to achieve sustainable developments, now let us strive for 'survivable development', is said by Dennis L Meadows at the Eighth Toyota Conference held in Mikkabi, Japan (Meadows 1995). Based on this observation and the wisdom acquired and knowing the ecosystem response, it is clear that only two kinds of scenarios are possible (Murai 1995):

a) Uncontrolled development:

A fast development/exploitation of resources with a short-term increase in carrying capacity will finally resulting in deficit and collapse resulting mass mortality shortages of everything, which is required.

b) Sustainable development:

The development, which aims at optimal resource utilization and keeping, pace with the population allows a scope of sustainable carrying capacity conditions of all the components of the ecosystem.

2. ANALYSIS AND CASE STUDIES

In order to strike an appropriate solution in the light of parameters affecting the carrying capacity with humans as the key element vis-à-vis the global disparity and the countries, there is a need for optimal/ sustainable resource harvesting and least waste generation. At the same time, this has to be done without affecting the productivity and

functional properties of the ecosystem. A sustainable approach essentially needs such a criteria. In recent times, a concept based on the '**ecological footprint'** has proved to be a good measure of sustainability (Rees 1996). It is defined as the use of a given resource whether terrestrial, aquatic or oceanic to produce certain output for sustenance of a given population and keeping provision for assimilation of the waste produced in such an activity. One such example in particular is of the CO2 emissions vis-à-vis provision of green cover to act as sink. An estimate normalized over the population at a certain time is considered the ecological productive land available on the earth. This is approx. 1.5ha and is called as 'fair earth share' and similarly the 'fair sea-share' is little over 0.5 ha (includes productive ocean, coastal, upwelling area and estuaries). An estimate of this finally leads to the estimation of "Ecological Deficit" i.e. the ratio of resource consumption and waste discharge for an unit area in excess of sustainable level. This essentially means that the alternatives have to be evolved to absorb the ecological deficit. The last term in all these analysis is the 'sustainability gap" i.e. the residual or deficit. Rees (1996) has recently defined the concept of "ecological footprint" for various countries and the ecological deficit. In a sustainable development, it is always essential that an appropriate development and utilization of resources treated as equivalent to that in commercial a term that is the capital or reserve available. Rees (1996) has defined the various steps involved in the calculation of the ecological footprint. The first step in calculating this is the estimation of per capita land area appropriated (aa_i) for the production of each consumption item ('i'). This is arrived by dividing the average annual consumption of an item c in kg/ capital) for each item 'i' by its average annual productivity or yield. ('p' in kg/ha) per ha:

$$aa_{i} = c_{i} / pi$$

Wackernagel and Rees (1995) have made calculations for a variety of items vis-à-vis the productive land available. The calculations were found to be difficult due to constraints like as to how best it is possible to account for the borrowed capacity of items, which in many cases was found difficult and very complex. The per capita ecological footprint (**ef**) was summed up for various items was as follows:

$$\mathbf{ef} = \sum_{I=1}^{i=n} \mathbf{aa}_{i} \ldots \mathbf{aa}_{2} \ldots \mathbf{aa}_{3} \ldots\ldots \mathbf{etc}$$

The ecological footprint (Ef_p) of an area is calculated by multiplying the per capita footprint by the population (N)

$$Ef_p = N\ (ef)$$

The ecological productive land per capita land area **c**, is given as follows

$$\mathbf{c = a / b}$$

where a, is productive agricultural area and b is the population. An assumption on the global basis for various countries/region has been made for an average ecological footprint size. An assumption of the ecological per capita footprint was based on the geographical area and population. This is used in estimation of ecological deficit per capita (d), which is as follows:

$$\mathbf{d = footprint - c}$$

The total ecological deficit (e) in per cent is as follows:

$$\mathbf{e = d / c}$$

Where, d is the deficit and c is the ecological productive land per capita on the basis of the above computation the ecological deficit was calculated for the national level as well as two of the upcoming mega cities in the countries viz. Ahmedabad (Ahmedabad Urban Development Authority) and Hyderabad (Hyderabad Urban Development Authority). It is observed that there is a large deficit at National and at the level of upcoming megacities (Table). The deficit can be seen in other countries like Netherlands and even in an advanced like United States (Rees 1996). A comparison of two time frame data of 1967 (Source: US Photo Reconnaissance Satellite Data, EROS Data Centre)

Table: The Ecological Footprint calculation for Ahmedabad (AUDA), and Hyderabad (HUDA) and National Level as compared to that of Netherlands and United States

Region/Unit	Ecological* Productive Land (In ha)	Population Census (2001)	Ecological Productive Land per capita (in ha)	Deficit per capita	
	a	b	c = a/b	d=foot-print-c (In ha)	e= d/c (In %)
Assuming a 2 ha Footprint					
India*	169000000	1027015247	0.164	1.836	1119
Ahmedabad* (AUDA)	60223	5497962	0.011	1.989	18081
Hyderabad* (HUDA)	57238	6400000	0.009	1.991	22122
Assuming a 3 ha Footprint (source: Rees, 1996)**					
Netherlands**	2,300,000	15,500,000	0.15	2.85	1900
Assuming a 5 ha Footprint					
US**	725643000	258,000,000	2.81	2.28	80

*DES, GOI; **Rees, 1996

and IRS LISS merged product (Pan + Liss III) of 1998 shows the apparent loss of surface water storage apart from significant reduction of drainage, which can easily cause inundation in case of even a moderate rainfall (see Figure). The deficit in carrying capacity can be used through proper legislation to fix the upper growth level of a city like Hyderabad particularly as a megacity. Some more in depth study is required for parametrisation and arriving at some indices for ultimate implementation of carrying capacity.

3. CONCLUSIONS

- An estimate of the carrying capacity based on ecological footprint concept has been demonstrated in this paper. This clearly brings out the ecological deficit and an approach for making appropriate projections for the growth of the megacities.
- A comparison of two date images of a part of Hyderabad city distinctly shows the reduction in the carrying capacity in particular for the surface drainage due to large scale urbanization.

(a) **(b)**

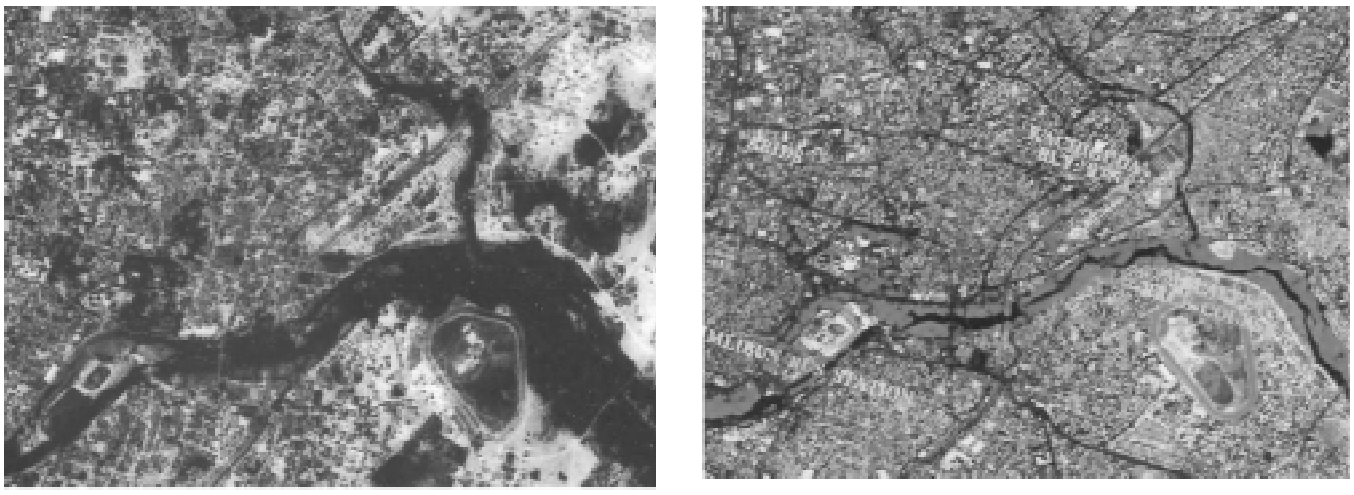

Figure a and b: A two time spaced satellite data of 1967 (a) and 1998 (b) of Hyderabad is compared to show the extent of urbanization and apparent loss of carrying capacity particularly of drainage, surface water and green cover

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