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Ecological Footprint Analysis – An Overview

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Abstract :- *In the past, natural resources were plentiful and people were scarce. But the situation is rapidly reversing. According to the Living Planet Report 2006, during the last thirty years, consumption of natural resources has increased 40%, while Earth's natural wealth in biodiversity has decreased 30%. Our challenge is to find a way to balance human consumption and nature's limited productivity in order to ensure that our communities are sustainable locally, regionally and globally. Ecological Footprint Analysis (EFA) is physical accounting method, developed by William Rees and M. Wackernagel (1992), focusing on land appropriation using land as its "currency". It provides a means for measuring and communicating human induced environmental impacts upon the planet. In this paper, an attempt is made to explore the tool Ecological Footprint Analysis. The paper also analyses the methods for calculating ecological footprint, scope of the tool as an impact assessment tool for India and measure for reducing the ecological footprint.*

Keywords:-*Biocapacity, biodiversity, ecological footprint analysis, environment impact, sustainable living*

I. INTRODUCTION

Everybody (even if a single human individual to a whole city or a country) makes an impact on the earth, because they are consuming the products and services of nature. As per the environmental studies, at sometime in the 1970's humanity as a whole passed the point at which it lived within the global regenerative capacity of the mother earth, causing depletion of the earth's natural capital as a consequence. Each generation is demanding more from our stocks of natural capital than the last generation did.

There are more than six billion people, but there is still only one planet earth. Five years later we will be living in a riskier world with more people, more consumption, more waste and more poverty, but with less forest area, less available fresh water, less soil and less stratospheric ozone layer. Many individuals, groups and communities now regularly consider the issue of sustainable development in their everyday lives.

The impact assessment tools so far developed do not provide strong protection for the environment. But considering our present situation, each and every impact, including individual human impacts should be studied to have a sustainable living as our life styles are causing serious threats to environment. We all know that we are farther away from sustainability. But how far? If we cannot measure, we cannot manage. To have a better living condition for us and our future generations, we must know where we are now and how far we need to go. We (including a single human being) must calculate how much nature we use and compare it to how much nature we have available.

Ecological Footprint Analysis (EFA) is a tool, having been developed less than 30 years ago by William Rees and M. Wackernagel. The Ecological Footprint (EF) is an accounting method which focuses on land appropriation. It provides a means for measuring and communicating human induced environmental impacts on the planet earth.

II. DEFINITION

Ecological footprint analysis is a quantitative tool that represents the ecological load imposed on the earth by humans in spatial terms. The ecological footprint of a defined population is the total area of land and water ecosystems required to produce the resources that the population consumes, and to assimilate the wastes that the population generates, wherever on earth the relevant land/ water are located [1]. Fig. 1 shows the representation of ecological footprint.

Fig. 1 Representation of Ecological footprint
Source: [2]

The footprint is the area, expressed in global hectares, needed to keep producing the food and fibre we use, absorb our wastes, generate the amount of energy we consume and provide the space for the roads, buildings and other infrastructure we rely on [3].

Our ecological footprint is the sum of those areas (ecologically productive space) we need to sustain the lifestyle of each person. This would be the area of cropland necessary to produce the food we eat, the area of grazing land for producing animal products; the area of forest to produce wood and paper; the area of sea to produce the fish and seafood we consume; the area of land to accommodate housing and infrastructure; and the area of forest necessary to absorb the CO_2 from our energy consumption. Fig. 2 shows the land use categories for calculating the ecological footprint.

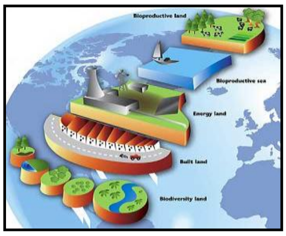

Fig. 2 Land use categories for ecological footprint
Source: [4]

III. METHOD FOR THE ANALYSIS

The ecological footprints were calculated first using a component based approach [5]. Later this was evolved into a more comprehensive and robust approach which is now used for national footprint calculations. This method is called compound foot printing method.

3.1 Component Based Approach

As per [5] the component-based approach sums the Ecological Footprint of all relevant components of a population's resource consumption and waste production. This is done by, first identifying all of the individual items–goods and services–and amounts thereof, that a given population consumes, and second, assessing the Ecological Footprint of each component using life-cycle data that track the resource requirements of a given product from resource extraction to waste disposal, or 'cradle to grave'. Fig. 3 will give a quick idea of how we can calculate our ecological footprint.

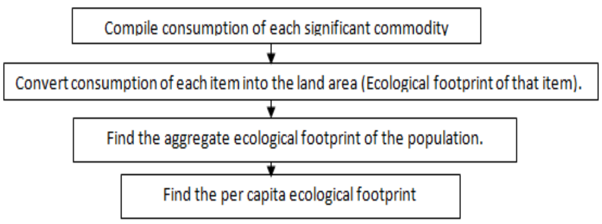

Fig. 3 Calculation of ecological footprint by component approach
Source: [6]

The first step in calculating the ecological footprint of a study population is to compile, item by item, the total annualized consumption of each significant commodity or consumer good used by that population.

For example the population's consumption of wheat can be represented as the sum of production of wheat and imports of wheat minus the exports of wheat.

The second step is to convert consumption of each item into the land area required to produce that item by dividing total consumption by land productivity or yield. This actually gives us the ecological footprint of the individual item. In general as per equation (1),

$$a_i = c_i / y_i \qquad (1)$$

a_i is the eco-footprint of item 'i' in hectares

c_i is total consumption of item 'i' in kilograms

y_i is the yield of item 'i' in kilograms per hectare.

Thus, for wheat: $a_{wheat} = c_{wheat} / y_{wheat}$ = kg wheat / (kg wheat × ha $wheat^{-1}$)

In the third step the aggregate ecological footprint of the population, (Fp), is determined by summing the footprints for the 'n' individual items as shown in equation (2).

$$F_p = \sum_{i=1}^{n} a_i \qquad (2)$$

In the fourth step, the per capita ecological footprint, 'Fc', is obtained by dividing the total population footprint by population size, 'N' which is given in equation (3).

$$F_c = F_p / N \qquad (3)$$

The overall accuracy of the final result depends on the completeness of the component list as well as on the reliability of the life-cycle assessment (LCA) of each identified component [6]. This approach produces erratic results, given LCAs' boundary problems, lack of accurate and completes information about products' life-cycles, problems of double-counting in the case of complex chains of production with many primary products and by-products, and the large amount of detailed knowledge necessary for each analyzed process [6]. In addition, there may be significant differences in the resource requirements of similar products, depending on how they are being produced.

3.2 Compound foot printing

Using a component method that is calibrated against a compound Ecological Footprints assessment can overcome the weaknesses of the component method [5]. Compound Foot printing calculates the Ecological Footprint using aggregate national data. Such aggregate data captures the resource demand without having to know every single end use, and is therefore more complete than data used in the component approach. For instance, to calculate the footprint of a country associated with paper products, information about the total amount consumed is typically available and sufficient for the task. In contrast to the component method, there is no need to know which portions of the overall paper consumption were used for which purposes, such as office use, commercial printing, etc [5].

IV. ECOLOGICAL FOOTPRINT AND SUSTAINABILITY

The ecological footprint value can be used as a sustainability measure. Ecological bottom lines or ecological quotient denoted by EQ, which is the ratio of total ecological footprint and the own share of supply limits of Natural Capital is an indicator of sustainability as shown in (4).

Ecological bottom lines = EQ = Total ecological footprint/ own share of supply limits of natural capital…..(4)

The lower, the better [6]

EQ <1 is sustainable

EQ >1 is unsustainable

If EQ is less than one, we can say the system is sustainable. On the other hand the value of EQ greater than one which indicates that the total ecological footprint exceeds the share of supply limits of nature, the unsustainability issue occurs [6].

V. ASSUMPTIONS

In order to provide a quantitative answer to the question of how much regenerative capacity is required to maintain a given resource flow, Ecological Footprint accounts use a methodology grounded on six assumptions [5] .They are:

1. The annual amounts of resources consumed and wastes generated by countries are tracked by national and international organizations [5]. These annual amounts can be measured in physical terms such as tonnes, joules or cubic meters. Most countries have extensive annual statistics documenting their resource use, particularly in

the areas of energy, forest products and agricultural products. United Nations agencies, like the Food and Agriculture Organization (FAO), compile many of these national statistics in a consistent format. Annual aggregation of consumption and production data makes them compatible with most other national statistics that are updated on a yearly basis and accommodate seasonal variations between countries. Consumption (or final demand) occurring within a specific country can be calculated by adjusting domestic production with international trade [5].

2. The quantity of biological resources appropriated for human use is directly related to the amount of bio productive land area necessary for regeneration and the assimilation of waste. Bio productive processes are associated with surfaces that capture sunlight for photosynthesis. Even three-dimensional processes that represent layers of such surfaces, as in aquatic ecosystems or rainforests, can be mapped on the two-dimensional area represented by the 'ideal spherical surface of the planet [5].

3. By weighting each area in proportion to its usable biomass productivity (that is, its potential annual production of usable biomass), the different areas can be expressed in terms of a standardized average productive hectare[5]. These standardized hectares, called 'global hectares', represent hectares with the potential to produce usable biomass equal to the world's potential average of that year. Usable refers to the portion of biomass that can be renewably harvested and is valuable to people, reflecting the anthropocentric perspective of the Ecological Footprint accounts. This standardization is applied both to people's ecological demand (Ecological Footprint) as well as to the supply of biological capacity (Bio-capacity).

4. The overall demand in global hectares can be aggregated by adding all mutually exclusive resource-providing and waste-assimilating areas required to support the demand [5]. This means that none of the services or resource flows included in the Ecological Footprint accounts are provided on the same piece of land or sea space, ensuring that all areas are added only once to the Ecological Footprint. Otherwise double-counting would inflate the estimation of overall demand.

5. Aggregate human demand (Ecological Footprint) and nature's supply (Biocapacity) can be directly compared to each other. Both use standardized hectares to measure aspects of natural capital—the demand on natural capital versus the ability of natural capital to meet the demand. Hence, the component and aggregate areas are commensurable [5].

6. Area demand can exceed area supply. A Footprint greater than total Biocapacity indicates that demands exceed the regenerative capacity of existing natural capital. For example, the products from a forest harvested at twice its regeneration rate have a Footprint twice the size of the forest. We call the amount of overuse "ecological deficit"[5]. Ecological deficits are compensated in two ways: either the deficit is balanced through imports, resulting in "ecological trade deficit" or, as in this forest product example; the deficit is met through the overuse of domestic resources, leading to natural capital depletion ("ecological overshoot") [5].

VI. LIMITATIONS OF EFA

The eco-footprints do not account for [7]:

- Any economic, political or cultural factors such as well-being;
- 78% of the surface of the earth, which is deemed to lack any bio-capacity (deep oceans, deserts, mountains);
- Water and waste, except insofar as they affect the bio-capacity of a region and so show up by those proxies;
- Non-renewable resources and their depletion, only renewable resources in the biosphere. The exceptions are where they affect the biosphere, for example pollution from mineral mining reducing the bio-capacity of a fishery;
- Biodiversity, toxicity, pollution and other traditional environmental concerns;
- Unsustainable management of the biosphere, for example clear-cutting a rainforest for agriculture would seem to increase bio-capacity because the yield factor of cropland is higher than that of forestry;
- Related to the above point, destruction of bio-capacity by long-term processes such as climate change;
- The true use and exchange value of different land types, for example forestry doesn't include the pharmaceutical potential of the species that live there;
- Methane and other greenhouse gases, only carbon dioxide.
- The accuracy of any given footprint analysis is also constrained by the quality of the data. The granularity of most data is very low, and the error margins quite high, so in general footprints are deemed to have an error margin of around 20-30%.

The ecological footprint is one indication of unsustainability. Because of the limitations cited above, we can say that ‘x’ is unsustainable because it's ecological footprint exceeds the fair share but you cannot say ‘x’ is sustainable because it fits within the fair share; you would then need to account for pollution, water use, toxicity, health, happiness, and so on [7]. Therefore ecological foot printing should be used as one tool amongst many. It is excellent at providing an overview of global, national and regional resource use, producing headline figures [7].

VII. ANALYSIS THROUGH NATIONS

An ecological footprint of a nation is determined by its population, the amount consumed by its average resident, and the resource intensity used in providing the goods and services consumed. The area required to meet people’s consumption from cropland; grassland and pasture (grazing of animals for meat, hides, wool, and milk); fishing grounds; and forest (wood, wood fibre, pulp, and fuelwood) are included in the calculations. It also estimates the area required to absorb the CO2 released when fossil fuels are burned, less the amount taken up by the oceans. The footprint of nuclear power, about 4 per cent of the global footprint, is included by estimating the footprint for the equivalent amount of energy from fossil fuels [8]. The area used for a country’s infrastructure, including hydropower, is included as the built-up land footprint component.

Humanity’s footprint first grew larger than global biocapacity in the 1980s; this overshoot has been increasing every year since, with demand exceeding supply by about 25 per cent in 2003 [8]. In 2008, the Earth’s total biocapacity was 12.0 billion gha, or 1.8 gha per person, while humanity’s Ecological Footprint was 18.2 billion gha, or 2.7 gha per person. This discrepancy means it would take 1.5 years for the Earth to fully regenerate the renewable resources that people used in one year [8]. Fig. 4 shows the trends in Ecological Footprint and biocapacity per person between 1961 and 2008.

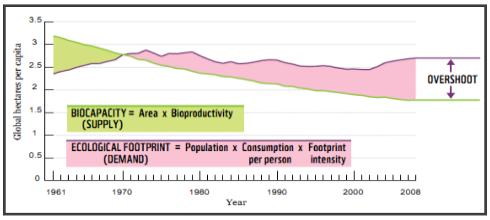

Fig. 4 Trends in ecological footprint &biocapacity per person between 1961& 2008 Source:[8]

As per the Living Planet Report 2012, the high-income countries have historically had the most rapid increase in per capita footprint. The growth in the carbon component of the per capita footprint – by 1.6 times between 1961 and 1970 is the reason behind the increase. In contrast, middle and low-income countries had demanded less than the average per capita bio-capacity available globally, until 2006 when middle-income countries exceeded this value. With increased industrialization, the population has more than doubled since 1961, while the footprint per person has increased by 65 per cent. Although population growth rate is reducing in some places like USA, Canada etc., further population increases, together with a rise of middle class consumption patterns in emerging economies, have the potential to increase humanity’s global footprint dramatically in the near future [8]. Some countries with high bio-capacity do not have a large national footprint. Bolivia, for example, has a per capita footprint of 2.6 global hectares and a per capita biocapacity of 18 global hectares.

Globally, urban residents are already responsible for more than 70 per cent of the fossil fuel related CO2 emissions. The urban population is expected to increase, as the world is rapidly urbanizing, particularly in Asia and Africa. Urbanization usually comes in tandem with increasing income, which in turn leads to growing Ecological Footprints, particularly through growth in carbon emissions [9]. For example, the average Ecological Footprint of a Beijing resident is nearly three times larger than the China average [10]. However, well planned cities can also reduce direct carbon emissions by good management of the density and availability of collective transport. For example, per capita emissions in New York City are 30 per cent less than the United States average [11].

VIII. SCOPE OF EFA AS AN IMPACT ASSESSMENT TOOL FOR INDIA

The scope of EFA as an impact assessment tool was analyzed by comparing EFA with Environmental Impact Assessment (EIA), the existing widely accepted impact assessment tool in India. EIA was developed as a consequence of increased public awareness of the harmful environment and social effects of development [6]. Since 1950's environmental awareness was on grow- it all started in USA. In 1970 EIA was mandatory for major development projects in USA. In India EIA came into existence through EIA notification of 1994. Under the notification Government clearance is required for 29 categories of projects. The project proponent is required to submit EIS & Environmental Management Plan. Expert committees evaluate the impacts and reports. Technical staff at Ministry of Environment and Forest scrutinizes the proposal before placing it to the expert committee. If site specific projects site clearance and environmental clearance is needed. Comparison of EIA with EFA is given in Table 1.

Table 1 Comparison of EIA with EFA

EFA	EIA
Impact of a single man can be measured. Considering our present situation, each and every impact including human impacts should be studied to have a sustainable living	Impact of a single man can be measured. But done mostly for large projects. EIA is mostly done for macro level projects which have regional implications resulting in the fact that the local environmental issues are often neglected.
Energy consumption is given due consideration.	Did not have an analysis on the energy consumption. This is a major drawback in the impact assessment mechanism which is very essential in the present days of energy depletion.
Quick and easy There are many software developed for the quantification of the impacts and with these technologies the analysis can be made quick and easy.	Time consuming Since the preparation of the environmental statement is done by the members of the expert committee, the difference in their views will lead to cost and delays consequent on preparation of impact statements.
Impacts are quantified and compared with the capacity. Both environmental and social impacts are quantified and compared with capacity	Impacts are quantified to an extend only. Impacts are quantified with respect to the effect on the environment only.
Can accurately measure how far we are away from sustainability.	Tries to keep a balance only in the environmental aspects.
Whoever assesses the impact, the result will be the same.	Changes will depend on the views of the expert committee
Criteria for assessment vary depending on the region and depending on the time when it is assessed. Each country can use the methodology in the assessment but the criteria can be changed with respect to their locality.	Criterion for assessment is purely developed by foreign agencies. Most of the developing countries are adopting the same criteria for impact assessment, developed by the foreign agencies, which may not be applicable to their region.

Source: [6], [12], [13]

IX. USES OF EFA

EFA is a strategic management tool; strategies that reduce the footprint can then be prioritized [6]. EFA is an awareness raising visioning tool that enables us to think about scenarios for the creation of a more sustainable future. The footprint can be used to measure any product, activity or impact, at all levels from self to planet. It is therefore possible to use the footprint in Environmental Management Systems (EMS) and as a planning tool [6].

X. MEASURES TO REDUCE THE ECOLOGICAL FOOTPRINT

10.1 Food footprint

1) Reduce the food consumption by
   a)Reducing household food waste - Reduce quantity of food purchases- encourage local stores rather than large out-of town supermarkets to reduce the over purchasing of foodstuffs [14].
   b) Conduct education campaigns to minimize the gap between current consumption and local production.
2) Change of food composition (eating lower on the food chain) [14]
   a) Promote healthy eating habits and diet awareness
   b) Education of the public -Raise awareness of the environmental impacts of different food products making people aware of the effects of their choices. Increase media awareness of positive food messages.

Undertaking a comparative study of the footprint of what an average person eats for lunch. Increase public awareness of local and regional food markets by providing information [14].

c)Encourage retailers and processors to introduce labelling schemes for fresh and processed products showing food miles, country/countries of origin and the environmental impact of production and distribution.

3) Increase the efficiency of food production

a) Production - Promote R&D into energy and space saving agriculture options

4) Improve the efficiency of food distribution and delivery: Reduce the food miles[14]

a) Buy locally produced, seasonally fresh produce; Buy nationally; Buy from the region

b) Integrate urban agriculture into policies, forthcoming community strategies etc. Encourage people to grow their own food in gardens or allotments or support local food growing initiatives [14].

5) Reduce waste associated with food

10.2 Goods and services footprint

1) Reduce Demand and shift demand for goods and services

a) Restrict use of disposable goods

b) Economic Incentives: Transfer taxes away from labour and onto the use of resources. Tax products on the basis of their embodied energy [14].

c) Increase purchaser awareness - Policies to promote recycled/low footprint goods. A reduced VAT on all products containing a high recycled content to encourage use [14].

d) Increase consumer awareness - Label for products that shows the ecological footprint value of the product.

2) Longevity of Use: Prolong the life span of products

a) Reuse materials at end-of-life- Introduce a recycling department for the state. Exchange or donate unwanted office equipment, furniture and other materials rather than disposal to land fill. Increase media awareness. Sponsor organized markets of second hand goods. Establish informal exchange centres at civic amenity sites and other suitable locations within the city [14].

b) Promote services and schemes that extend the life of goods purchased - Encourage the use of hire and lease schemes that result in more efficient use of products by consumers. Provide support for refurbishment, recycling and repair services and shops through promotion, funding and or tax incentives.

c) Provide information on longevity of products at point of purchase

d) Develop markets for used materials

3) Distribution: Purchase goods that are sourced and manufactured locally.

4) Reduction of Waste -Charge people on the basis of volume of waste and on the basis of frequency of collection of waste

5) Reuse of waste - Reuse and recycling centres - Enable reuse and recycling centres to reuse waste materials disposed of at these sites through the resale of reusable items [14]

6) Recovery: Recycling, Re engineering and composting of waste materials

a) Household waste -Introduce a kerbside collection scheme for recyclables from all homes in the city, supported by a network of recycling centres for residents to 'drop off' recyclable materials. Invest in R& D to identify new uses for waste products (for e.g. clothing from PET plastic etc.) and through market intervention to reduce the prices of recycled products. Home and community composting may be promoted through the provision of biogas plants at low cost or with subsidies [14].

b) Construction waste- Segregate and reuse/ recycle all wastes by type on construction sites

10.3 Shelter footprint

1) Reduce house area usage

a) Increase density of residential living- Require increased density of new housing developments promote apartment style developments. Apply building regulations on house area usage and house occupancy rate. Give tax reduction/incentives to joint families. Tax residents based on their shelter footprint [14].

2) Reduce energy demand of housing [14]

a) Increased energy efficiency standards for new housing

b) Awareness raising - Include energy efficiency rating in the sale of domestic properties. Undertake an awareness campaign that links climate change and household energy use, stressing the importance of action in households [14].

c) Increase use of renewable energy sources

10.4 Mobility footprint

1) Infrastructure/Urban design/ Planning - Increased mixed use, Promote high density mixed use developments, Promote and deliver through the planning system the concept of all major centers of education, retail, employment and health being located near to transport exchanges [14].

2) Facilitate a mode shift - Promote public transport, Disincentives car travel, Promote fuel efficient vehicles, Encourage use of electric cars, motorbikes etc, Promote walking and cycling, Raise the awareness of the travelling public, Promote health benefits of walking and cycling [14].

XI. CONCLUSION

Ecological foot printing can be used as both a technical concept and a figure of speech. With its instinctive meaning it says that the human footprint should not exceed the area able to support it. As per Living planet Report 2012, if everyone lived like an average resident of the USA, a total of four Earths would be required to regenerate humanity's annual demand on nature. The size of a person's Ecological Footprint depends on development level and wealth, and in part on the choices individuals make on what they eat, what products they purchase and how they travel. But decisions undertaken by governments and businesses have a substantial influence on the Ecological Footprint too. For example, individuals generally have no direct control over the size of the built-up land footprint. The same is true for the way in which a country produces its electricity or the intensity of its agricultural production. This "inherited" part of the Ecological Footprint can be influenced through mechanisms such as political engagement, green technology and innovations, and other work toward large scale social change. Governments and businesses therefore play an important role in reducing the ecological footprint of each and every person. Therefore ecological footprint studies should be encouraged through research and development programmes and a footprint calculator should be developed especially for the urban areas.

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