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AN ANALYTICAL STUDY OF ECOLOGICAL FOOTPRINT DYNAMICS AND SUSTAINABLE ENVIRONMENT IN ASIAN REGION

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Abstract: The Ecological Footprint (EF) developed by William Rees and M. Wackernagel (1992) is an accounting tool that is used to address the underlying issue of sustainable consumption. It provides a means for measuring and communicating human induced environmental impacts upon the planet. A high level of ecological footprint index is linked to high consumption of natural resources, which causes a negative impact on the environment. Today, Indo-Pacific countries which makes up more than one-third of all global economic activity. Research shows that Ecological footprint in those countries has a biocapacity deficit. This paper aims to study the ecological footprint of the selected countries in recent years and also analyzed systematically the contribution of different land types. This study makes a comparative analysis on bio deficit and bio reserve. The results demonstrate that the ecological footprint has increased slightly and continuously during the 50 years of timespan. These effects have been caused mainly due to conversion of primary forest to agricultural land, extensive exploitation of marine resources, freshwater ecosystems. The results also indicate much information about the socioeconomic dynamics of these countries and measures for reducing the ecological footprint.

Keywords: ecological footprint, biocapacity, sustainability, carbon footprint.

INTRODUCTION:

The term Ecological Footprint (EF) was conceptualized and developed by a Canadian ecologist named William Rees and was further developed in a dissertation by Swiss urban planner Mathis Wackernagel, under Rees' supervision [14]. The EF measures human consumption on earth. Globally, ecological footprint and bio generative capacity are facing a biocapacity deficit and this 'ecological overshoot' has been increasing every year explaining us that the current level of consumption is not sustainable. Footprint can be divided into six major categories on the basis of demand: cropland, grazing land, fishing grounds, forest land, carbon sequestration land and built-up land. Emission of carbon dioxide from burning fossil fuels has been the dominant component of humanity's Ecological Footprint for more than half a century and its share continues to grow.[16]

The levels of ecological footprint, biocapacity deficit/reserve vary greatly between countries. The ecological footprint of an entire nation is calculated by multiplying the per-capita footprint by population size. Biocapacity is measured by calculating the amount of biologically productive land and sea area available to provide the resources a population consumes and to absorb its wastes, given current technology and management practices [3]. The values of EF/BC are converted in a common unit called global hectares (gha). The world-average ecological footprint was 2.58 global hectares per person (20 billion total) in 2022, with an average biocapacity of 1.51 global hectares. This computes to a global deficit of 1.17 global hectares per person, or a biocapacity reserve of -1.17, meaning humanity's consumption of natural resources is currently outpacing the Earth's ability to replenish those resources [5].

The Ecological Footprint of Indo-Pacific region varies widely depending on factors such as resource consumption patterns, increase in population size and economic development. The total footprint of these countries is 1.6 gha per person, which is 60% below the global average of 2.7 gha per person [5]. The contribution of carbon towards the Ecological Footprint is 60%. The national footprint of Japan, PRC, Malaysia, Thailand, Philippines, India ranges from, <4.1 gha person. Most countries in Indo-Pacific have total footprints of production higher than their biocapacity, indicating either that domestic natural capital is been degraded. Indonesia, while rich in biodiversity, faces challenges related to widespread habitat loss, overharvesting of renewable resources, and worsening climate change.

It is important to track the environmental performance of nations in order to determine the sustainability of the present human's lifestyle and the Earth's biocapacity. Through EF we can assess the current situation and can limit the impact of people's activities and care for the environment.

OBJECTIVES:

1. To discuss the meaning and concept of ecological footprint, biocapacity, ecological overshoot.
2. To determine the EF status of various countries of the Indo-Pacific region.
3. To suggest measures to reduce the ecological footprint.

LITERATURE REVIEW:

Numerous studies on related to ecological footprint and the deterioration of the biocapacity reserve are in the literature. For instance, EF is a meaningful, tangible and relatable concept.

EFA shows that rich countries use two-to five-times their per capita equitable Earth shares; that the eco footprints of high-income countries generally exceed their domestic biocapacities; and that the human enterprise as a whole as in a state of overshoot.[12]

Another study on EF by M.Wackernagel, J. Kitzes shows that energy land and crop land are the land types that make the largest contribution to the average Australian's Ecological Footprint [11].

Rozana Zakari et.al; presented a study on EF of different nations where it discussed about the EF status of 13 countries in terms of the area and the population. The results show that develop countries has high EF value as compared to developing countries have lower EF value.[2]

Kongbuamai Nattapan et.al; studied the impact of tourism on the EF of the ASEAN countries spanning from 1996-2016. It is found out by cross sectional test that U-shaped inverted curve which shows negative natural resources with the EF [9].

Thus, the EF analysis calculates the amount of the biophysical output of the earth that is essential for the resource consumption and waste absorption for a given population. [4]

Methodology and Database

The Ecological Footprint is derived by tracking how much biologically productive area it takes to provide for all the competing demands of people.

For any land use type, the EF of a country, in global hectares, is calculated by: [3]

$$EF = P/YN \times YF \times EQF$$

P: Amount of Product Harvested or Waste Emitted, YN: National Average Yield for P, YF: Yield Factor, EQF: Equivalence Factor [3] i.e., is the ratio of a given land type's average global productivity divided by the average global productivity of the entire planet's productive surfaces.

Biocapacity is measured by calculating the amount of biologically productive land and sea area available to provide the resources a population consumes and to absorb its wastes, given current technology and management practices. To make biocapacity comparable across space and time, areas are adjusted proportionally to their biological productivity. To calculate the number of hectares available per capita, one adds up the biologically productive land per capita world-wide of arable land, pasture, forest, built up land. The following formula entails the calculation for biocapacity:

$$\textbf{Biocapacity} = A_n \times Y_n / Y_w \times EQF$$ [8]

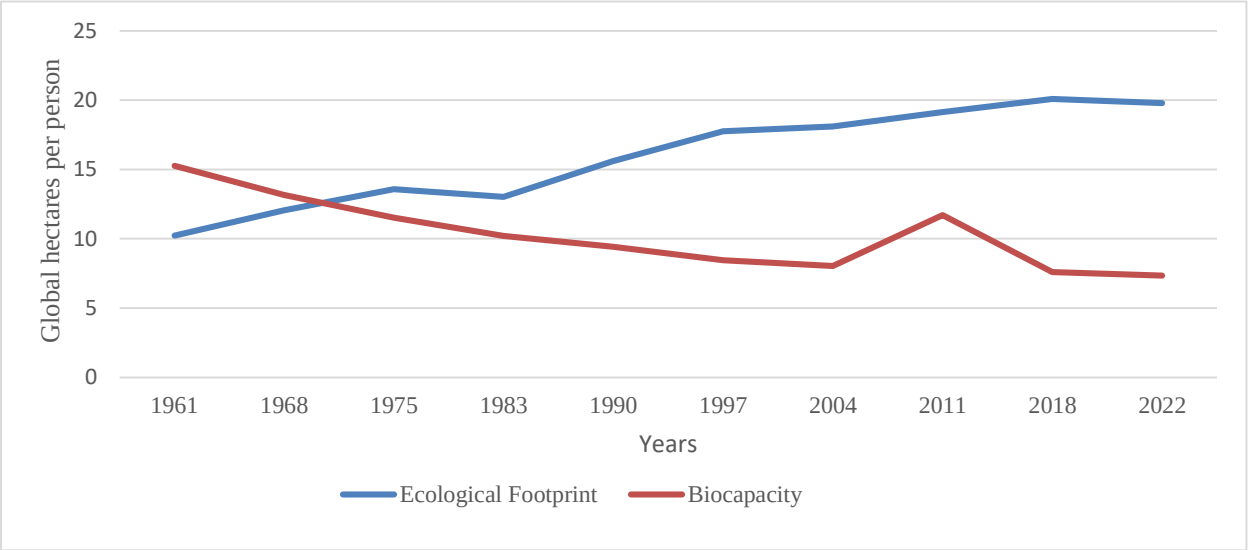
Where: A_n *is the area in country "n" for this land-use category in hectares, and*
Yn is the national average yield for this land use category in tons per hectare and year.
Y_w is the world average yield. [10]
The values of EF/BC are converted in a common unit called global hectares (gha).

The research is mainly based on literature review. Initially concepts concerned with ecological footprint, biocapacity, determining ecological overshoot, biologically productive land have been reviewed in order to develop a basic understanding of the concepts. Country wise data on ecological footprint and biocapacity have been extracted from Global Footprint Network's National Footprint Accounts, and have been calculated carefully. The results determine the EF and also the required planet Earth for supplying enough resources for this assumed person. Based on these data, a comparison has been made on the basis of its ecological footprint, biocapacity, human development index (HDI) ratings between the ten countries of Indo-Pacific region that have been selected for the study.

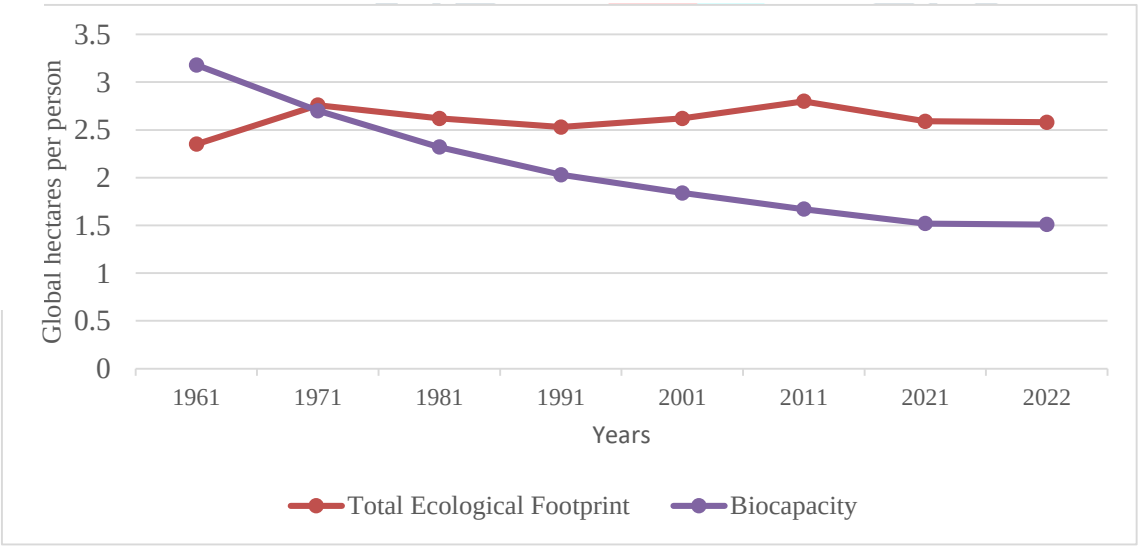
DISCUSSION AND RESULTS:

Global Trends:

Humanity is exhausting nature's renewable resources in just over half a year, leaving us in an ecological deficit for the rest. Human consumption now requires the natural capital 715 faster than Earth can renew it, which they describe as meaning humanity's ecological footprint corresponds to 1.71 planet Earths [15]. Overshoot if continued for a long time, can lead to the degradation and liquidation of ecological capital, the productive foundation on which the natural environment and human society depend [9]. Globally, the ecological footprint has been increasing steadily at an average rate of 2.3 global hectares to 2.6 global hectares.
Since 1965, world GDP, per capita has increased, going from $2508 per person to $ 13004 in 2022 over that same period, Biocapacity has actually gone down by 0.7 to (-1.1) global hectares.



This is a clear indication that a higher footprint is required for an increase in GDP. The carbon footprint is currently 60% of humanity's overall EF. Based on the annual report from NOAA's Global Monitoring Lab, The global average carbon dioxide set a new record high in 2023: 419.3 parts per million. Since the middle of the 20th century, annual emissions from burning fossil fuels have increased every decade, from close to 11 billion tons of carbon dioxide per year in the 1960s to an estimated 36.6 billion tons in 2023 according to the *Global Carbon Budget 2023*.[13]. The figure 1, shows that there is a significant increase from the carbon Footprint in 1961, which contributed to 44 percent of the world's Ecological Footprint of what it is today 60 percent. [17]



Source: Global Footprint Network,2022

Figure 1. Trend line showing the relationship between total ecological footprint and biocapacity in gha / person in world.

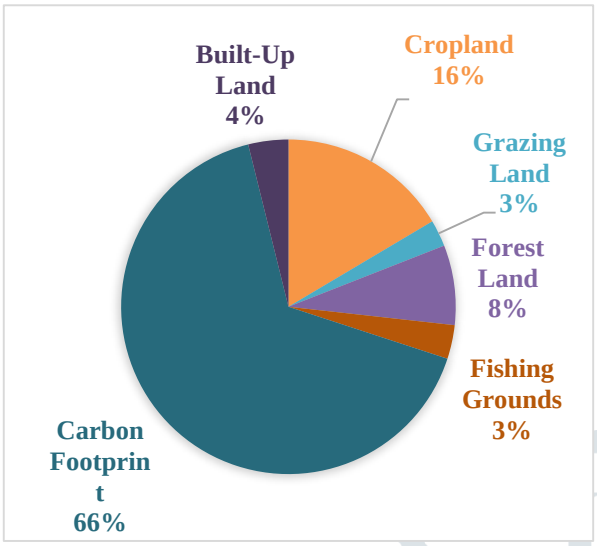
Japan has a higher EF per person (4.04 gha) with a least biocapacity per person (0.63 gha) as compared to other countries of the Indo-Pacific region. China the second most populous country globally has an EF of 3.62 gha per person and biocapacity of 0.8gha per person. Malaysia is ranked 3rd in terms of reserve/deficit with EF (4.24 gha per person) and biocapacity (2.06 gha per person) followed by Thailand with an EF (2.35 gha per person) and biocapacity (1.14 gha per person). Philippines and India's EF (1.18 & 1.04 gha per person) and biocapacity (0.4 & 0.34 gha per person). This is due to increasing per capita consumption of non-renewable energy resources. Other countries show a minor difference in EF and biocapacity i.e., Nepal, Bangladesh & Indonesia has an almost similar gap between them, EF (0.9, 0.67 & 1.68) gha per person and biocapacity (0.39, 0.25 & 1.23) gha per person. Pakistan shows minimum EF and biocapacity as compared to the rest with an EF of 0.73 gha per person and biocapacity of 0.36 gha per person. Pakistan shows a similar trend of EF (2.35 & 0.73 gha per person) and biocapacity (1.14 & 0.36 gha per person).

Source: Global Footprint Network,2022

Figure 2. Trend line showing the relationship between total ecological footprint (blue) and biocapacity (red) in gha / person in the Asian region from 1961 to 2022.

Regional Trends:

Asian countries by land use type



Source: Global Footprint Network

Source: Global Footprint Network

Figure 3: Total Ecological Footprint of 10 Asian Countries by Land Use Type

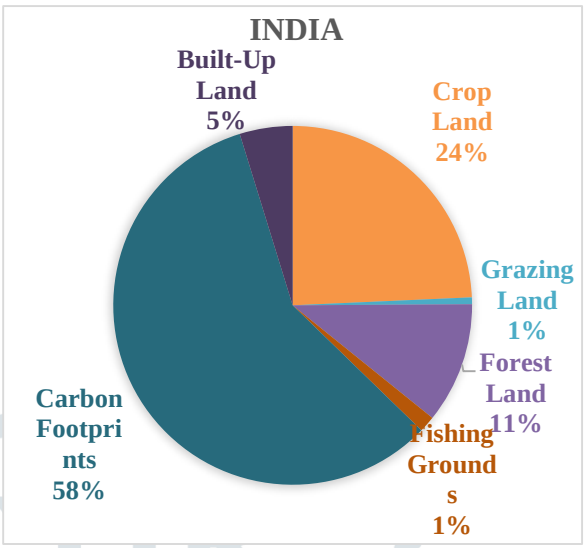
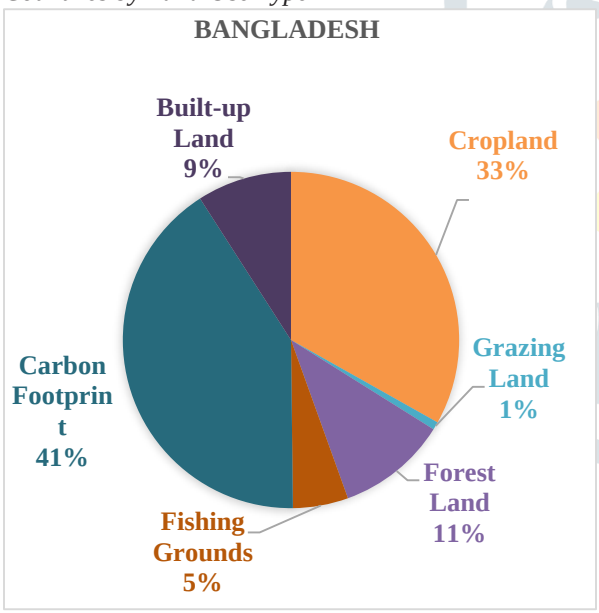
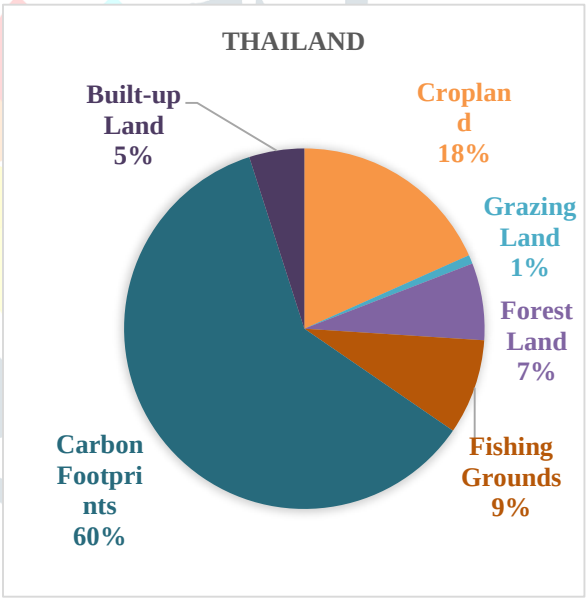


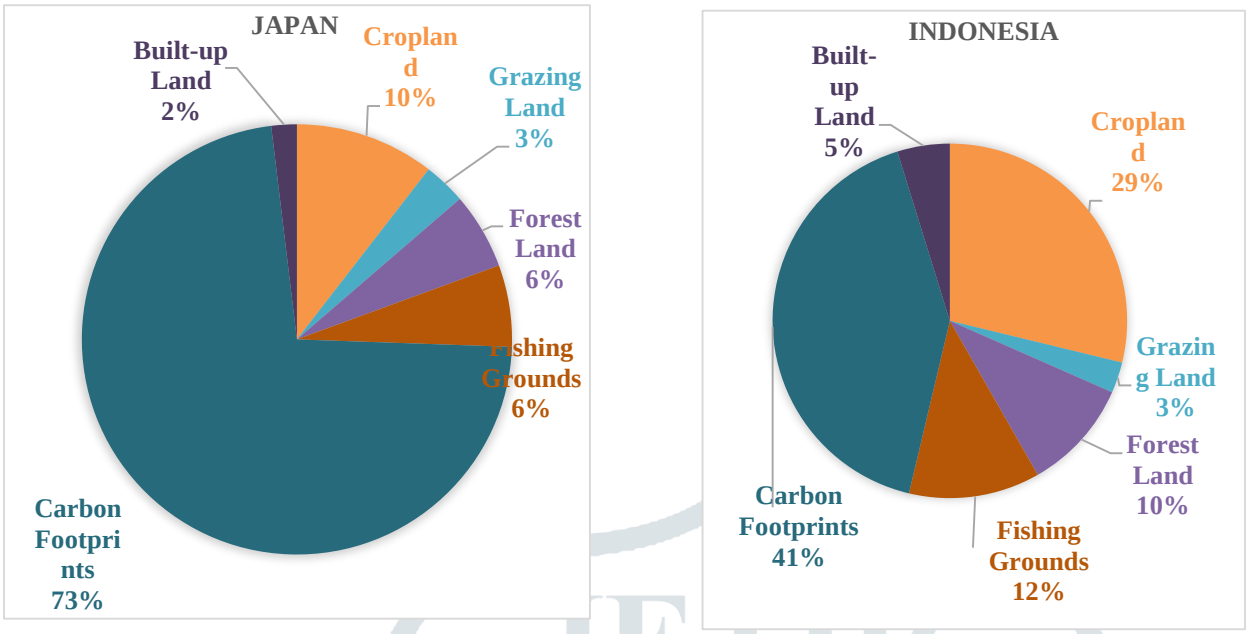
Figure 4: Ecological Footprint of India





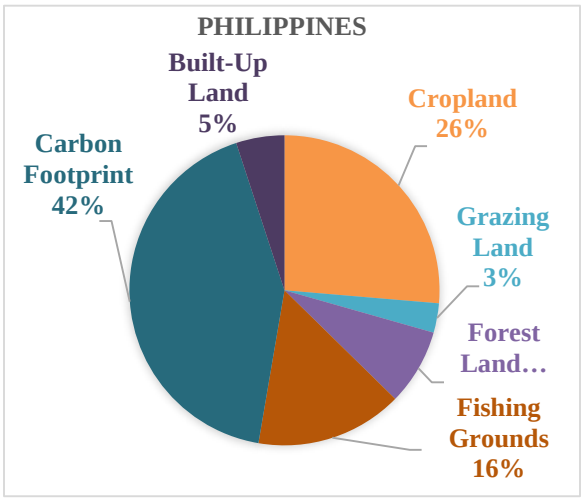
Source: Global Footprint Network

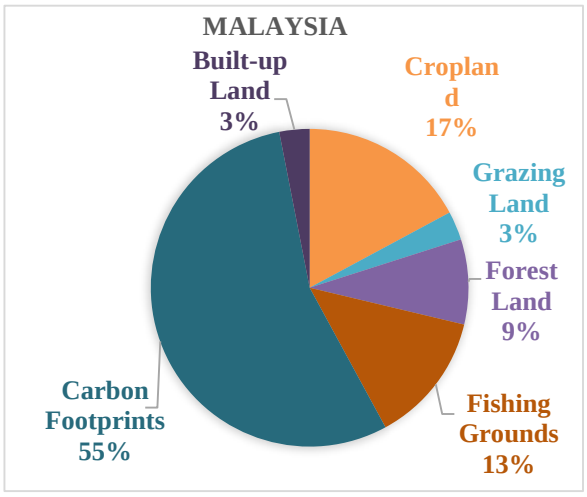
Figure 5: Ecological footprint of Bangladesh and Thailand



Source: Global Footprint Network

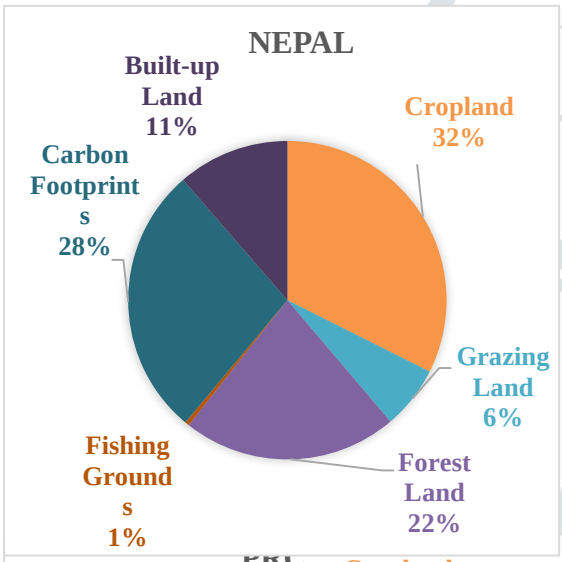
Figure 6: Ecological footprint of Japan and Indonesia

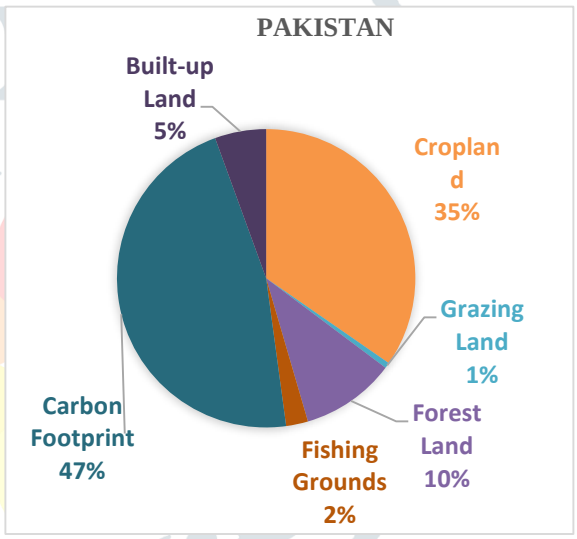




Source: Global Footprint Network

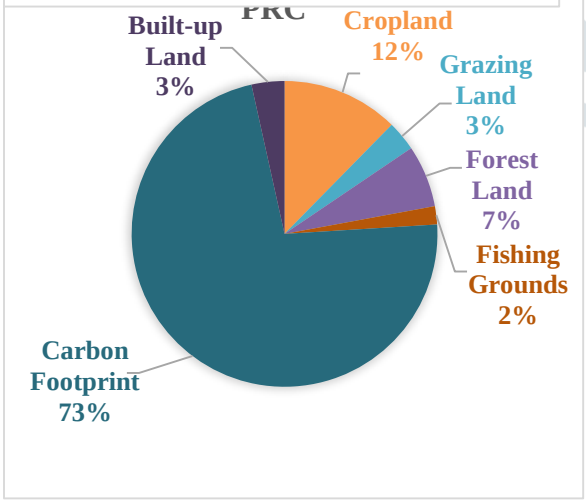
Figure 7: Ecological Footprint of Philippines and Malaysia





Source: Global Footprint Network

Figure 8: Ecological Footprint of Nepal and Pakistan



Source: Global Footprint *Network*

Figure 9: Ecological Footprint of People's Republic of China

Country	Total Ecological Footprint (gha)	Cropland (gha)	Grazing Land gha)	Forest Land (gha)	Fishing Grounds (gha)	Carbon Footprint (gha)	Built-Up Land (gha)
India	1.1	0.26	0.01	0.12	0.02	0.62	0.05
Bangladesh	0.7	0.23	0.01	0.08	0.04	0.29	0.06
Thailand	2.4	0.44	0.02	0.17	0.21	1.46	0.12
Japan	4.2	0.44	0.13	0.24	0.26	3.07	0.08
Indonesia	1.7	0.48	0.05	0.17	0.2	0.7	0.08
Philippines	1.3	0.34	0.04	0.1	0.2	0.54	0.06
Malaysia	4.3	0.73	0.12	0.37	0.57	2.34	0.13
Nepal	0.9	0.29	0.06	0.19	0	0.24	0.1
Pakistan	0.7	0.24	0	0.07	0.02	0.33	0.04
PRC	3.5	0.43	0.11	0.23	0.07	2.54	0.12

The figure 4 to 9, illustrate results of the EF's calculations by land use type for the above-mentioned countries. The carbon footprint is the highest in China (3700 million gha) followed by India (857.2 million gha). Japan occupies the 3rd position (386.4 million gha). Nepal has the lowest EF (7.01 million gha). China due to its economic growth and industrialization, high energy consumption, demographic growth enlarges the carbon and built-up land footprint (177.4 million gha) is highest among all. Similar conditions are found in cases of grazing land, cropland and fishing ground footprint.

Table 1. Per person footprint of consumption in Asian by land use type

Source: Global Footprint Network

Table 1 shows per person footprint of consumption by land use type. It is notable from this table that, the scenario of per person EF is mostly different from the total footprint. Here, Malaysia has the highest EF per person i.e., (4.3 gha) followed by Japan (4.2 gha). PRC is 3rd among the countries (3.5 gha). Similar trends can be seen in the case of India which has an EF (1.1 gha per person). Pakistan and Bangladesh have the lowest EF per person (0.7 gha). Malaysia's rapid economic growth, high reliance on fossil fuel, heavily reliable on resource-intensive industries which leads to habitat loss and deforestation that contributes to a larger EF as well built-up land (0.13 gha), cropland (0.73 gha per person), fishing ground (0.57 gha per person) footprint. This is also notable that, built up land footprint is lowest in Pakistan and India (0.04 & 0.6 gha per person).

Country	Total Biocapacity (gha)	Cropland (gha)	Grazing Land gha)	Forest Land (gha)	Fishing Grounds (gha)	Built-Up Land (gha
India	0.4	0.25	0	0.02	0.03	0.05
Bangladesh	0.3	0.13	0	0	0.05	0.06
Thailand	1.2	0.69	0.01	0.22	0.18	0.12
Japan	0.6	0.1	0.01	0.34	0.1	0.08
Indonesia	1.2	0.5	0.05	0.27	0.35	0.08
Philippines	0.4	0.2	0.01	0.08	0.06	0.06
Malaysia	2.1	0.69	0.02	0.55	0.76	0.13
Nepal	0.4	0.16	0.05	0.09	0	0.1
Pakistan	0.4	0.28	0	0.02	0.03	0.04
PRC	0.8	0.31	0.1	0.22	0.04	0.12

Table 2: Biocapacity per person of Asian Countries

Source: Global Footprint Network, 2019

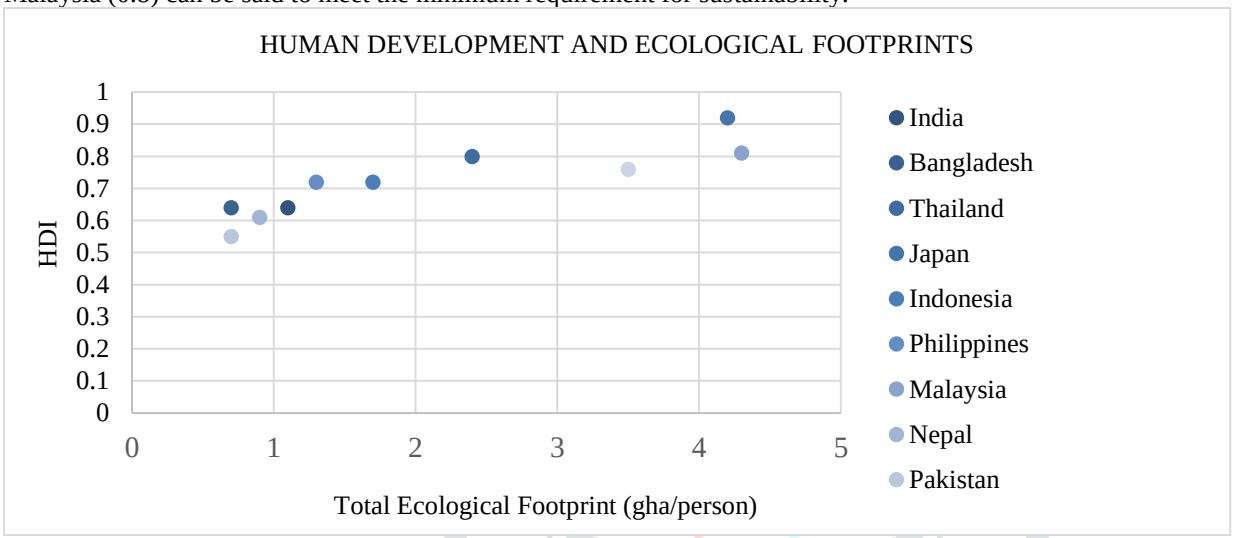
Table 2 indicates, Malaysia ranks highest in terms of biocapacity per person (2.1 million gha) which is totally different from total biocapacity. Thailand and Indonesia have a similar biocapacity per person (1.2 million gha). PRC & India, Philippines, Nepal and Pakistan have the similar biocapacity per person (0.8 & 0.4 million gha). Biocapacity of Bangladesh is lowest 0.3 million gha per person.

BC of these countries are relatively low due to rapid population growth, deforestation overuse of natural resources and agricultural products.

Sustainable Development in Indo-Pacific countries:

The Human Development Index (HDI) of the United Nations exhibits four key aspects on the basics of human quality of living: infant mortality, population growth rate, longevity, and (il)literacy. Every world citizen can be believed to strive to an HDI of close to one, implying a fulfilling of the basic needs [1]. HDI of 0.8 has been taken as the boundary between medium and highly developed nations. The figure shows the relationship between per person ecological footprint and HDI rankings of UN.

The HDI score ranges from 0.54 (Pakistan) to 0.92 (Japan). India, Bangladesh &Nepal has the same HDI ranking (0.64). Thailand, Malaysia (0.8) can be said to meet the minimum requirement for sustainability.



Source: Global Footprint Network,2022

Measures to reduce the Ecological Footprint

1. By reducing the food consumption and minimize the gap between current consumption and local production.
2. By restriction use of disposable goods. Enabling reuse and recycling centers to reuse waste materials disposed of at the sites.
3. Undertaking an awareness campaign that links climate change and household energy use.
4. Increasing use of renewable energy sources.
5. Promote public transport, fuel efficient, vehicles, etc.

Conclusion:

This paper compares the ecological footprint of 10 large Indo-Pacific regions, inhabiting 60%of the world's population. It discussed the extent of their consumption that can be supported by their local ecological capacity. In a world of increasingly diminishing resources, there is a greater dependency upon imports of natural resources, leaving countries in a vulnerable situation. The people are able to decrease the EF by reduce, reuse, recycle, such as reducing the use of home energy consumption, purchasing local food etc. Government should invest in low footprint manufacturing renewable energy and resource efficient infrastructure to maintain a robust economy while ensuring a sustainable ecological footprint. However, based on the statistics, the EF is firmly connected with per capita income of a country.

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