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Ecological Footprint of South Asian Countries: A Comparative Study

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Abstract

Ecological footprint is being widely used as an indicator of global sustainability. The purpose of this paper is to make a comparative analysis of South Asian countries' ecological footprint. Literature review which forms the basis of this study, reveals that India grasps the largest ecological footprint of 1063.37 million gha; whereas Sri Lanka holds the smallest footprint of 24.14 million gha. Furthermore, India holds the largest footprint and Sri Lanka grabs the smallest footprint of all the components except fishing ground which is the smallest in Nepal. The footprints of grazing land in South Asian countries are relatively marginal. Specific country based analysis of footprint components and estimation of ecological deficit or overshoot are also incorporated in this paper. Bangladesh has the lowest per person biocapacity of 0.38 gha; while the highest per person biocapacity found in Nepal (0.55 gha). It is observed that ecological footprints of South Asian countries have exceeded their biocapacity extensively. Ecological overshoot is the highest in India (- 469.04 million gha) and the lowest in Sri Lanka (-15.24 million gha). A comparison has been made in this paper among population growth, change of ecological footprint and biocapacity, GDP growth rate and HDI ratings of the South Asian countries.

Introduction

Over the last century, the world has experienced rapid urbanization. Among the greatest challenges of the twenty-first century, the rapid growth of cities is most notable (UN-Habitat, 2013). More than 50 percent of the world's populations live in urban area (UNDP, 2009). Cities are nodes of consumption that depend utterly on a constant flow of materials and energy from around the world in order to function (Rees, 2012, Girardet, 1999, Downton, 2009). As the world urbanizes, the role of cities in determining sustainability outcomes grows in importance. Sustainable city analysis and management requires understanding the demands of city on a wider geographical area and its ecological resource base (Moore, 2013).

The rapid growth of cities raises a number of challenges, such as water pollution, air quality degradation, biodiversity loss, lack of solid waste management and noise pollution (Newman, 2006; Geng, 2012). Urban sustainability analysis requires understanding the city's ecological resource base and the demands the city makes on an increasingly global hinterland as cities are the dominant form of human habitat, and most of the world's resources are either directly or indirectly consumed in cities (Moore, 2013). It is critical to conduct a scientific assessment so that appropriate solutions can be

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found by considering the local realities. Many evaluation methods, such as energy analysis, material flow analysis, data envelopment analysis and ecological footprint analysis, have been proposed. Among them, ecological footprint analysis has been applied as a useful policy and planning tool for evaluating urban sustainability (Geng et al, 2014). The Ecological Footprint has proven one of the most successful indicators for communicating the concept of environmental sustainability and the physical limits of the planet. In the past decade the Ecological Footprint has developed into one of the most important measures for resource use in production and consumption at the international level and it is used by a large number of institutions for evaluating impacts of human activities on the environment (Giljum et al, 2007).

While Africa and Asia are among the least urbanized continents, they also have the fastest rates of urbanization in the world (UN-Habitat, 2013). South Asia is in the midst of rapid transformation from a predominantly rural to urban society. The region has seen an upward trend in terms of the urban population, with an annual growth rate of 2.52 percent. Population growth and demographic transitions are directly related to the key issues of the region like land degradation, resource depletion, food security, deteriorating air quality and loss of biodiversity (UNEP, 2014). In South Asia, as in many other parts of the world, environmental degradation is becoming so severe that it is undermining growth itself (UNEP, 2014). The challenge for these countries is to manage their natural capital sustainably, so that they maintain these services in the interests of long-term development. In countries of South Asia, the gap between the Ecological Footprint, or the demand for natural resources, and the environment's ability to replenish those resources, or its biocapacity, is widening (WWFa, 2012). Moreover, the Ecological Footprint is used by companies, municipal and local planning institutions as well as environmental and development NGOs all around the world. However, examples of the application of the Ecological Footprint at the national level are rare (Giljum, Hammer, Stocker and Lackner, 2007). Therefore, it is critical to assess ecological footprint of the South Asian countries in order to adopt their sustainable development policies. This paper is an endeavor that analyzes major components of ecological footprint, biocapacity and ecological overshoot of South Asian countries.

Research Methodology

This study is limited to identifying South Asian countries' ecological footprint, biocapacity, determining ecological deficit or overshoot, and comparing their changes over a time period. The research is mainly based on literature review. Initially literature concerned with ecological footprint, biocapacity, ecological deficit or overshoot, use of land in hectare and bioproductive land have been reviewed to develop conceptual framework. Country wise data on ecological footprint and biocapacity (as per land use category and gha per person) have been extracted from Ecological Footprint Atlas, 2010 by Global Footprint Network. Based on these data, country wise ecological footprint component and ecological deficit or overshoot have been calculated. Finally, a comparison has been made among population growth, ecological footprint, biocapacity, ecological overshoot, Gross Domestic Product (GDP) growth rate, Human Development Index (HDI) ratings. Five South Asian countries i.e. India, Pakistan, Bangladesh, Sri Lanka and Nepal have been selected for this study.

Conceptual Framework

Ecological Footprint

The ecological footprint was introduced by Wackernagel and Rees (1996) as a simple measure of the sustainability of a population's consumption (Fiala, 2008). This is promoted as a policy guide and planning tool for sustainability (Wackernagel et al., 1997; Wackernagel and Silverstein, 2000). The Ecological Footprint is a measure of the demand human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network, 2010). Ecological footprint analysis uniquely enables comparisons of demand with supply, i.e., between current urban metabolic load and available biophysical carrying capacity, both regional and global (Wackernagel and Rees, 1996; Chambers et al., 2000). For example, while world average biocapacity demand is 2.7 gha per capita and global supply is only 1.8 gha per capita (WWF, 2010), the average per capita biocapacity demand in high-income cities is often much higher (Moore, 2013).

Biological Capacity or Biocapacity

The measurement of ecological asset that human being relies on for basic needs, such as food, clothing and shelter, as well as the absorption of carbon is termed as biocapacity (WWFb, 2012). Biological capacity represents the ecologically productive area that is locally available, and it indicates the local ecosystems potential capacity to provide natural resources and services. Biological capacity is the total annual biological production capacity of a given biologically productive area (Bala and Hossain, 2009). Biocapacity is dependent not only on natural conditions but also on prevailing land use practices e.g. farming, forestry (Schaefer, et al, 2006).

Ecological Deficit or Overshoot

A comparison of the Footprint and Biocapacity reveals whether existing natural capital is sufficient to support consumption and production patterns. A country whose footprint exceeds its biocapacity runs is termed as an ecological deficit or overshoot. Ecological overshoot has been derived by following equation (Wackernagel, *et al*, 2005).

Ecological Overshoot (gha) = Footprint (gha) - Biocapacity (gha)

Global Hectare: The Common Unit

Ecological Footprint accounts express the use of built-up areas, and the consumption of energy and renewable resources—crops, animal products, timber, and fish—in standardized units of biologically productive area, termed global hectares (gha). Each global hectare represents an equal amount of biological productivity (Wackernagel, *et al*, 2005).

Biologically Productive Land

Measurement and assessment of ecological footprint and biocapacity is based on biologically productive land and water area. Six major land use types such as cropland, grazing land, forest land, carbon Footprint, fishing grounds, and built-up land have been categorized for this purpose (Global Footprint Network, 2010). Table 1 shows the bioproductive land use types.

Table 1: Bioproductive land use type

Land Type	Description
Cropland	Areas used to produce food and fiber for human consumption, feed for livestock, oil crops, and rubber.
Grazing land	Areas used to raise livestock for meat, dairy, hide, and wool products
Forest Land	The forest Footprint is calculated based on the amount of lumber, pulp, timber products, and fuel wood consumed by a country on a yearly basis.
Fishing Grounds	The fishing grounds Footprint is calculated using estimates of the maximum sustainable catch for a variety of fish species. Represents fisheries' demands on aquatic ecosystems as the equivalent surface area required to sustainably support a country's catch.
Carbon Footprint	Carbon Footprint is calculated as the amount of forest land required to absorb given carbon emissions.
Built-up Land	Land covered by human infrastructure — transportation, housing, industrial structures, and reservoirs for hydropower.

Source: Global Footprint Network, 2010

Results and Discussion

Ecological Footprint of South Asia

Asia has 0.8 gha of biocapacity per person, less than half the global average, and the lowest biocapacity relative to population of any of the world's regions. Asia's average per-person Ecological Footprint of consumption is 1.8 gha, well below the global average of 2.7 gha per person. However, the difference between the countries with the highest and the lowest per-person Footprint of consumption in Asia is greater than in any other region of the world. Residents of the United Arab Emirates have the world's highest average Ecological Footprint, at 10.7 gha per person, while the average Footprint of consumption in Pakistan is just 0.77 gha per person. Most countries in Asia have total Footprints of production higher than their biocapacity, indicating either that domestic natural capital is being degraded, or that they are imposing a demand for external biocapacity through carbon dioxide emissions in excess of what their own ecosystems could potentially sequester (Global Footprint Network, 2010).

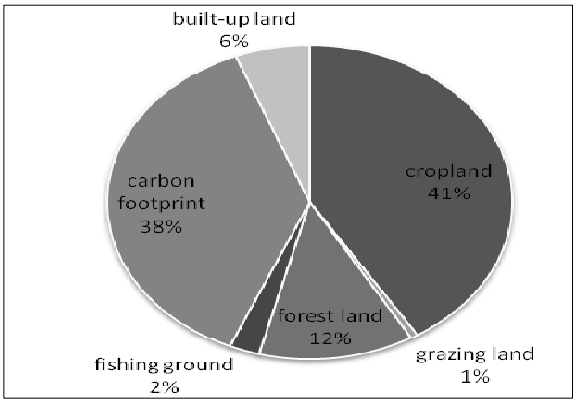
Table 2 summarizes ecological footprint of South Asian countries by land use type. Five countries of South Asia comprises of total 1418.96 million gha of footprint. Among the five countries India holds the largest footprint of 1063.37 million gha; while Sri Lanka embraces with the smallest footprint of 24.14 million gha.

Table 2: South Asia total Footprint by land use type

Country	Total Ecological Footprint [million gha]	Cropland [million gha]	Grazing Land [million gha]	Forest Land [million gha]	Fishing Grounds [million gha]	Carbon Footprint [million gha]	Built-up Land [million gha]
Bangladesh	98.01(4)	51.68(3)	0.72(4)	11.48(3)	3.14(3)	20.44(4)	10.56(2)
India	1063.37 (1)	454.70(1)	4.21(1)	139.85(1)	22.87(1)	381.28(1)	60.45(1)
Nepal	100.67(3)	10.46(4)	1.28(3)	5.69(4)	0.04(5)	80.63(2)	2.57(4)
Pakistan	132.77(2)	59.58(2)	1.46(2)	15.05(2)	2.45(4)	44.75(3)	9.47(3)
Sri lanka	24.14(5)	6.82(5)	0.54(5)	3.12(5)	5.90(2)	6.52(5)	1.24(5)
Total	1418.96	583.24	8.21	175.19	34.4	533.62	84.29

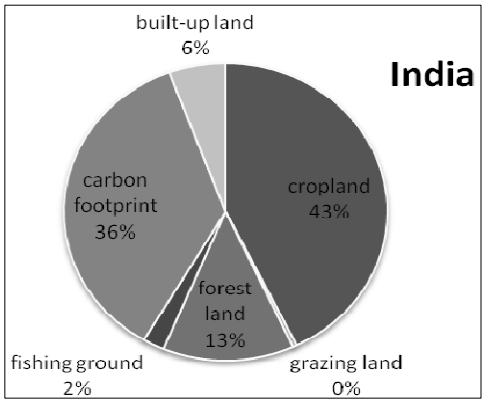
Source: Global Footprint Network, 2010, Ranks are shown in parentheses

The carbon footprint is the highest in India (381.28 million gha) followed by Nepal (80.63 million gha) and the lowest in Sri Lanka (6.52 million gha). India covers largest footprint of built-up land (60.45 million gha). Emerging economy, industrialization, growing use of fossil fuels, electricity, energy-intensive commodities and demographic growth enlarge the carbon and built-up land footprint of India (Niccolucci, et al., 2012 and Galli, et al., 2015). Though Bangladesh has a small territory, its footprint of built-up land is 10.56 million gha, second largest in South Asia because of it high and rapid level of urbanization. The forest land footprint of India (139.85 million gha) is exceedingly larger than any other South Asian countries. Similar conditions are found in cases of cropland and fishing ground footprint. The grazing land footprints of the South Asian countries are relatively much smaller.



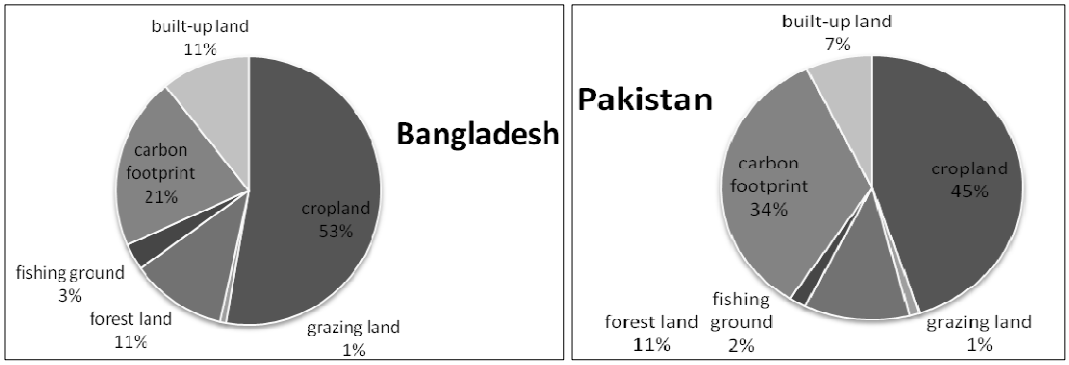
Source: Global Footprint Network, 2010

Figure 1: Total Ecological Footprint of 5 South Asian Countries by Land Use Type



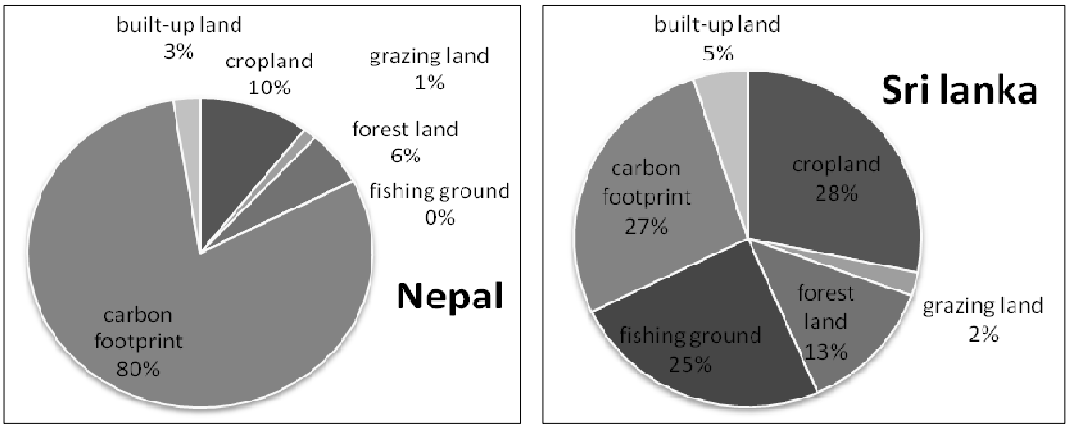
Source: Global Footprint Network, 2010

Figure 2: Ecological Footprint of India by Land Use Type



Source: Global Footprint Network, 2010

Figure 3: Ecological Footprint of Bangladesh and Pakistan by Land Use Type



Source: Global Footprint Network, 2010

Figure 4: Ecological Footprint of Nepal and Sri Lanka by Land Use Type

The specific country based analysis of footprint components portrait a different scenario. It is observed from the Figures 2, 3 and 4 that Nepal holds the highest carbon footprint (80%) followed by India (36%) and Pakistan (34%). Firewood meets 88% of the total energy demand in Nepal; which in turn decreases forest land and increases carbon dioxide emission. So, carbon footprint is the highest country wise footprint component in Nepal (Government of Nepal, 2004). The carbon footprint of Bangladesh is the lowest among these countries (21%). Bangladesh captures the largest cropland footprint (53%) followed by Pakistan (45%) and India (43%). The fishing ground footprint is the largest in Sri Lanka (25%); while India and Sri Lanka each country covers some 13% of forest land. Nepal embraces the lowest forest land footprint of 6%. The footprint of built-up land is the largest (11%) in Bangladesh and smallest in Nepal (3%). Rapid urbanization of Bangladesh cumulates its built-up land footprint.

Table 3: Per person footprint of consumption in South Asia by land use type

Country	Total Ecological Footprint [gha per person]	Cropland [gha per person]	Grazing Land [gha per person]	Forest Land [gha per person]	Fishing Grounds [gha per person]	Carbon Footprint [gha per person]	Built-up Land [gha per person]
Bangladesh	0.62(5)	0.33(4)	0.00	0.07(5)	0.02(2)	0.13(4)	0.07(2)
India	0.91(3)	0.39(1)	0.00	0.12(3)	0.02(2)	0.33(2)	0.05(4)
Nepal	3.56(1)	0.37(2)	0.05	0.20(1)	0.00(4)	2.85(1)	0.09(1)
Pakistan	0.77(4)	0.34(3)	0.01	0.09(4)	0.01(3)	0.26(3)	0.05(4)
Sri lanka	1.21(2)	0.34(3)	0.03	0.16(2)	0.30(1)	0.33(2)	0.06(3)

Source: Global Footprint Network, 2010, Ranks are shown in parentheses

Table 3 summarizes per person footprint of consumption by land use type of South Asian countries. It is notable from this table that, the scenario of per person ecological footprint in South Asian countries is mostly different from the total footprint (Table 2). Nepal possesses the highest ecological foot print (3.56 gha per person) whereas the smallest foot print found in Bangladesh (0.62 gha per person). This is also notable that, built up land footprint of Nepal is the highest (0.09 gha per person) followed by Bangladesh (0.07 gha per person). In Nepal 80% of total population are dependent on forest and land and land resources are severely affected by fragmentation process. Hence, per person ecological footprint as well as forest, grazing and built-up land footprint of Nepal is the highest in South Asian region. Increase of per capita energy consumption and large scale burning of firewood constitute the largest per person carbon footprint of Nepal (Government of Nepal, 2004).

Biocapacity of South Asian Countries

Table 4 states total biocapacity of South Asian countries by land use type; which indicates that India possesses the largest biocapacity of 594.33 million gha followed by Pakistan (74.12 million gha) and Bangladesh (59.21 million gha).

Table 4: South Asia total biocapacity by land use type

Country	Total Biocapacity [million gha]	Cropland [million gha]	Grazing Land [million gha]	Forest Land [million gha]	Fishing Grounds [million gha]	Built-up Land [million gha]
Bangladesh	59.21(3)	39.33(3)	0.52(4)	0.38(5)	8.42(2)	10.56(2)
India	594.33(1)	465.01(1)	4.30(1)	26.45(1)	38.12(1)	60.45(1)
Nepal	15.45(4)	9.88(4)	1.28(2)	1.57(3)	0.14(5)	2.57(4)
Pakistan	74.12(2)	55.96(2)	0.70(3)	1.92(2)	6.06(3)	9.47(3)
Sri lanka	8.90(5)	5.52(5)	0.42(5)	0.83(4)	0.89(4)	1.24(5)

Source: Global Footprint Network, 2010, Ranks are shown in parentheses

Bangladesh has the lowest biocapacity of forest land (0.38 million gha) among the South Asian countries followed by Sri Lanka (0.83 million gha). On the contrary, the fishing ground biocapacity of Bangladesh (8.42 million gha) takes second largest biocapacity after India (38.12 million gha).

Table 5: South Asia per person biocpacity by land use type

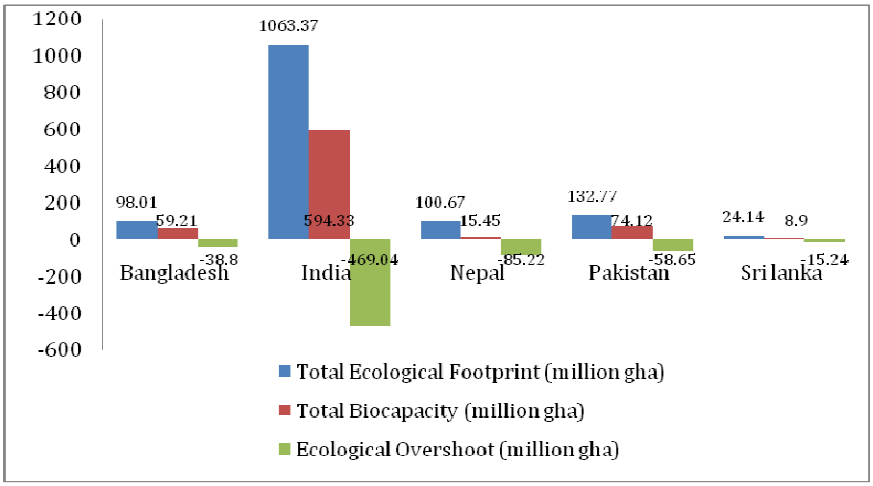
Country	Total Biocapacity [gha per person]	Cropland [gha per person]	Grazing Land [gha per person]	Forest Land [gha per person]	Fishing Grounds [gha per person]	Built-up Land [gha per person]
Bangladesh	0.38(5)	0.25(5)	0.00(3)	0.00(5)	0.05(1)	0.07(2)
India	0.51(2)	0.40(1)	0.00(3)	0.02(3)	0.03(3)	0.05(4)
Nepal	0.55(1)	0.35(2)	0.05(1)	0.06(1)	0.00(4)	0.09(1)
Pakistan	0.43(4)	0.32(3)	0.00(3)	0.01(4)	0.03(3)	0.05(4)
Sri lanka	0.45(3)	0.28(4)	0.02(2)	0.04(2)	0.04(2)	0.06(3)

Source: Global Footprint Network, 2010, Ranks are shown in parentheses

Table 5 indicates that, Bangladesh has the lowest biocapacity of 0.38 gha per person; while the highest biocapacity found in Nepal (0.55 gha per person), followed by India (0.51 gha per person). Biocapacity of South Asian countries are relatively low due to rapid population growth, deforestation or export of raw materials and agricultural products (Global Footprint Network, 2010 and FAO, 2010).

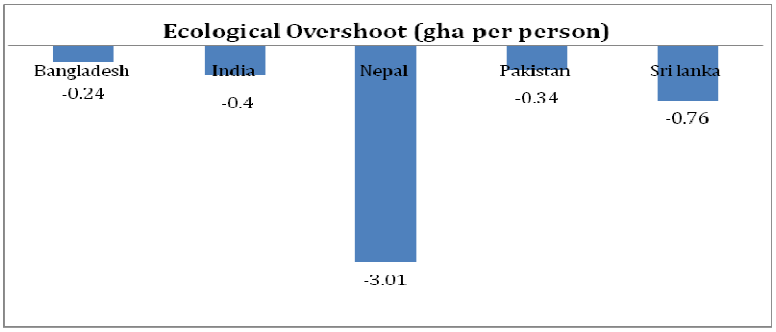
Ecological Overshoot of South Asian Countries

Figure 5 illustrates ecological overshoot of South Asian countries which have been determined in terms of difference between total biocapacity and total ecological footprint.



Source: Global Footprint Network, 2010
Figure 5: Total Ecological Overshoot of South Asian Countries

It is evident from the figure that, ecological footprints of all the countries have exceeded their respective biocapacity. India possesses the highest ecological overshoot (-469.04 million gha); followed by Nepal (-85.22 million gha) and Pakistan (-58.65 million gha). Ecological overshoot is the lowest in Sri Lanka (-15.24 million gha). Such overshoot indicates that ecosystems of South Asian countries are being exploited more rapidly than they can renew themselves and pilling-up of waste gradually (Global Footprint Network, 2010).



Source: Global Footprint Network, 2010

Figure 6: Country wise Ecological Overshoot (gha per person)

A different scenario has been found if per person ecological overshoot is taken into account (Figure 6). Nepal possesses the highest ecological overshoot of -3.01 gha per person whereas minimum overshoot is found in Bangladesh (-0.24 gha per person) among the countries. Deforestation, desertification and soil erosion reduce the biocapacity of Nepal and thereby amplify ecological overshoot (Government of Nepal, 2004).

Change of Population, Ecological Footprint and Biocapacity

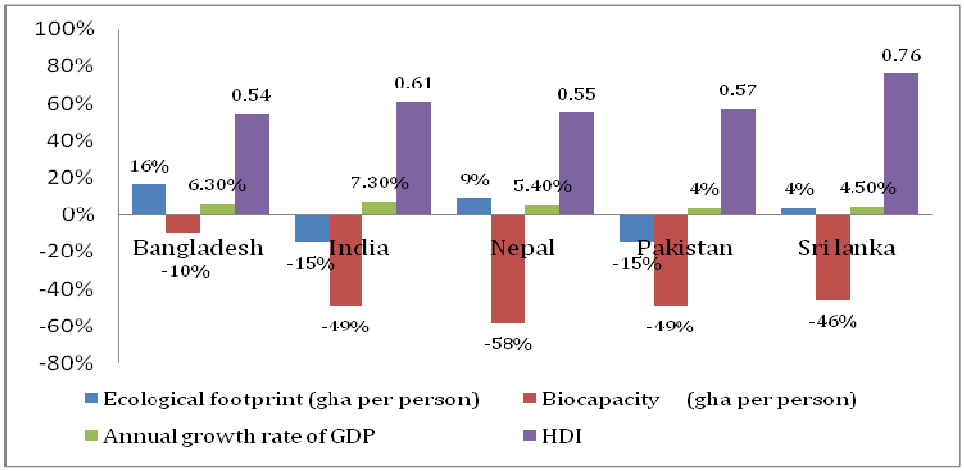
A periodical change (1961-2007) of population, ecological footprint and biocapacity along with Gross Domestic Product (GDP) growth rate and Human Development Index (HDI) rating of the South Asian countries have been presented in Table 6 and Figure 7.

Table 6: Change of Population, Ecological Footprint, Biocapacity, GDP Growth rate and HDI

Country	Population	Total Ecological Footprint	Total Biocapacity	Annual growth rate of GDP, 2014	HDI 2007
Bangladesh	+ 31% (5)	+ 51% (5)	+ 18% (4)	6.3% (2)	0.54 (5)
India	+ 155% (3)	+ 115% (3)	+ 29% (2)	7.3% (1)	0.61 (2)
Nepal	+ 187% (2)	+ 211% (1)	+ 20% (3)	5.4% (3)	0.55 (4)
Pakistan	+ 248% (1)	+ 194% (2)	+ 76% (1)	4% (5)	0.57 (3)
Sri lanka	+ 94% (4)	+ 101% (4)	+ 4% (5)	4.5% (4)	0.76 (1)

Source: Global Footprint Network, 2010, IMF, 2015, Ranks are shown in parentheses

Rampant population growth has been found in Pakistan (248%), Nepal (187%) and India (155%). Increase of total ecological footprint of Nepal is the highest (211%), followed by Pakistan (194%) and India (115%). Whereas, raise of biocapacity is the highest in Pakistan (76%), followed by India (29%) and Nepal (20%).



Source: Global Footprint Network, 2010 and IMF, 2015

Figure 7: Change of Ecological Footprint and Biocapacity; GDP Growth and HDI Rating

Figure 7 illustrates per person ecological footprint and biocapacity; GDP growth rate and HDI rating of the South Asian countries. The increase of per person ecological footprint in Bangladesh is noteworthy (16%). Higher GDP and population growth boost up per person ecological footprint of Bangladesh. It is observed that per person biocapacity of all the countries forms a decreasing trend. A substantial gap between ecological footprint and biocapacity is clearly evident among the South Asian countries. A steady growth rate of GDP has been found among the countries. The HDI score ranges from 0.54 (Bangladesh) to 0.76 (Sri Lanka). On an average 134 percent increase of South Asian countries' ecological footprint have been observed between 1961 and 2007, while average population of these countries grew by 143 percent. Thus, population growth contributes substantially in the increase of total ecological footprint of consumption. GDP and HDI are recognized as two key indicators of development of a country and recommended to study combining with ecological footprint in analyzing sustainability (Galli, et al, 2015 and Moran et al. 2008). As countries improved their citizens' well-being, their resource use grew. This is evident that, very few countries are achieving high development within a globally replicable level of biocapacity demand i.e. per capita footprint lower than 1.79 global hectares (UNDP, 2013). Therefore, overall ecological footprint, GDP growth rate and HDI score of the South Asian region is comparatively lower than other part of the globe.

Conclusion

Component wise as well as total ecological footprint analysis indicates that, India holds the largest footprint and Sri Lanka grabs the smallest footprint of all components except fishing ground. Higher carbon and built-up land footprint of India is the outcome of its

emerging economy, augmented urbanization and consumption pattern. The grazing land footprints of the South Asian countries are relatively much smaller. Nepal possesses the highest per person ecological foot print (3.56 gha) whereas smallest per person foot print found in Bangladesh (0.62 gha). Paradoxically specific country based analysis of footprint components indicates that, Nepal holds the highest carbon footprint (80%) followed by India (36%) and lowest in Bangladesh (21%). Bangladesh captures the largest cropland footprint (53%) and which is the smallest in Nepal (10%). The fishing ground footprint is largest in Sri Lanka (25%); while forest land footprint is highest in India and Sri Lanka (13%) and lowest in Nepal (6%). The footprint of built-up land is largest (11%) in Bangladesh and smallest in Nepal (3%). On the contrary, biocapacity of India is largest (594.33 million gha) and lowest in Sri Lanka (8.90 million gha). Clearly, ecological footprints of South Asian countries have exceeded their biocapacity in greater extent. India possesses the highest ecological overshoot (-469.04 million gha); followed by Nepal (-85.22 million gha) and Pakistan (-58.65 million gha). Ecological overshoot is lowest in Sri Lanka (-15.24 million gha) followed by Bangladesh (38.8 million gha). In South Asian countries, leapfrogging has been observed in growth of population and ecological footprint whereas a steady growth rate is found in total biocapacity, GDP and HDI score. Ecological footprint illustrates the state of global sustainability, and raises awareness about environmental degradation caused by excessive consumption. Scientific evaluation of ecological footprints have significance in providing valuable insights to policy makers so that sustainable development patterns can be recognized and appropriate policies can be adopted by considering the local realities.

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