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POPULATION CARRYING CAPACITY AND SUSTAINABLE DEVELOPMENT IN BANGLADESH

Abstract

Rapid increase in population puts immense pressure on an economy and eats up a country's finite resources at a pace faster than they can be regenerated. Lack of balance between such high growth of population and limited resources tends to hinder the sustainable development efforts of a country. Considering the principal resource endowments, in this study an attempt has been made to estimate the population carrying capacity (maximum number of population that can be sustained from a given endowment of resources) of Bangladesh in order to assess the limits to population growth. Examining the case of major resources i.e. agricultural output, fishery, and fuelwood, the study revealed dominant constraints as the country already reached the carrying capacity level. Positive result has been obtained for water resources, meaning only this particular resource is not currently indicating any constraint. However, when a single constraint binds all other carrying capacity measures become insignificant. The study further advocates for an integrated and comprehensive approach for tackling the constraints in question.

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SECTION 1 : INTRODUCTION

Current economic system does not inherently incorporate any concern about the sustainability of our natural life support system and the economies which depend on it. Sustainability is basically justice with respect to future generations. It has been variously constructed but a useful definition is the amount of consumption that can be continued indefinitely without degrading the capital stocks – including 'natural capital' stocks. A nation seeking sustainable development needs the idea of carrying capacity in order to operationalize the concept of sustainability. Carrying capacity measure as a principle of sustainable development is both an operational starting point and a sufficient challenge to the present order. It offers the idea about the level of population consistent with the sustainable use per capita of a resource.

In Bangladesh population is growing fast, and the struggle to raise living standards in the face of a growing population often resulted in enormous pressure on finite resources. A slight per capita shift easily multiplies total product requirement. It inhibits sustained economic growth, resource management and intensifies competition of the very limited land and other resources for different uses. If uncontrolled, it will cause further poverty and environmental degradation.

The principal objective of the study is to ascertain potential population supporting capacities of land and other resource endowments (such as, fuelwood, water and fishery). Besides, the study will enhance awareness about the quantification of land and other resources and their potential as an essential prerequisite to the development of sound policies in agriculture, energy, water, fishery and population planning. The paper consists of six sections. Section 1 provides the introduction about the topic in question. Section 2 gives an overview of the existing theories in this particular area of research. Section 3 discusses in detail about the status and trend in population in Bangladesh. Aspects of major resources in Bangladesh are depicted in Section 4, while Section 5 illustrates the methodology used in detail, estimates the carrying capacity of major resources and analyses the findings of the result obtained. Finally, some concluding remarks have been offered in the last section.

SECTION 2 : CARRYING CAPACITY: A CONCEPTUAL FRAMEWORK

2.1 Population Growth, Carrying Capacity and Sustainable Development : The Interrelationship

The simple type of analysis usually depicts population as primarily an aggregate of consuming units requiring a whole range of goods and services whose production puts pressure on the natural resource base in an environment. Eventually the pressure can increase to such an extent that the regenerative capacity of these resources cannot cope with the rate of extraction and waste. A dire consequence of rapid population growth is the surpassing of carrying capacity of natural resources by the size of human population. Although no universal consensus has been reached regarding the relationship between per capita well-being and population, but the general view is that the population growth harms per capita well-being at least when the population base is relatively high

(Kelly, 1988). Therefore, the urge for developing a sustainable economy (in terms of non-declining human well-being per capita over time, given the resources provided by the earth and technological capabilities) and the notion of sustainable carrying capacity, deserves wider recognition.

2.2 Carrying Capacity : An Overview

The concept of carrying capacity has been proposed as one way of understanding the relationships between population, technology, consumption and resource base (Mahar, 1985). The concept permits us to understand the mechanisms that liquidate our natural capital assets and offers insights on the ecological constraints any economy will have to cope with in the long run. It gives us the scope to assess limits of the population growth and acts as a fundamental basis for demographic accounting. Simply stated, the carrying capacity of a given area is the maximum number of population that can be sustained indefinitely by a given habitat without progressively impairing the functional integrity and productivity of relevant ecosystems. At low levels of population, rapid increases in population occur as food and space are relatively abundant. At higher levels of population, the rate of growth begins to taper off and population asymptotically approaches the carrying capacity (Wilen, 1985). At the carrying capacity, the population will reach its maximum sustainable level. Of course, the carrying capacity of a nation is categorically not the desirable level of population unless the level of well-being at which that population is sustained is itself desirable. The term essentially relates to the maximum number of population that can be sustained at the minimum standard of living that ensures minimum intake of calories (Pearce and Warford, 1993)

Despite all the concern it is interesting to note that economists are by and large reluctant to apply the idea of carrying capacity to human populations. The arguments advanced by economists stand in part on the twin pillars of technological development and enormous scope of trade subsequently criticized by the ecologists. In particular, ecologists argued that the process of adaptation and diffusion of the new technology to achieve the degree of market penetration arising out of population pressure usually takes place over a long time span that can influence negative ecological trends. Besides, the absence of new ecologically benign technologies also dramatically shrinks the population carrying capacity. Optimistic speculations would, therefore, not change the impasse posed by rapid increase in population and strong likelihood of overshooting the carrying capacity (Daly, 1991).

SECTION 3: A DEMOGRAPHIC PROFILE OF BANGLADESH

3.1 Population Levels and Density

The carrying capacity of a nation is determined and often constrained by its demographic profile. At the beginning of this century, Bangladesh had a population of about 29 million people. The 1981 Census reveals a population growth rate of 2.35% per annum. The increase in population size continued, and rose up to 114.3 million in 1991. The size of the population in 1996 is estimated as 122.9 million and the population is still growing at a pace of 1.72% per year. Land-man ratio is extremely low (1:18 decimal), and landlessness has been continuously rising.

3.2 A Brief Overview of the Fertility and Mortality Status

In the past centuries rate of population growth was checked by high levels of death rates; slow mortality decline began early in the present century due to control and eradication of various infectious diseases. However, infant and child mortality continues to remain still high today. The life expectancy at birth appears to be around 60.3 years for both sexes as of 1997, and the infant mortality rate is found to be 67 per 1,000 live births.

Although the family planning programme has been in existence in the country for a long time, a notable success in fertility reduction has not been achieved so far. The average number of children borne by a woman has been documented at 3.4 in 1996. However, the urban-rural difference in total fertility rate appears to be 1.28 for the year 1996. The situation can be attributed to relatively higher concentration of population and family planning activities in the urban area compared rural area, prevailing social custom and uncertainty associated to child survival[1].

Although the current population policy is to attain the replacement level fertility by the year 2005, the absolute size of population in Bangladesh is destined to grow for another forty or fifty years until the age-sex composition of the population is

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1 Since children play an important role in providing old-age support, as long as uncertainty related to child survival remains high, parents will be motivated to desire enough children to ensure the survival of at least one son to adulthood.

stabilized (Islam, 1996). Still population below the age of 15 years is around 46% of the total population and females within the reproduction age (15-49 years) represent 48.4% of the total population. Even in 1996, the proportion of population in 0-4 years age group to the total population has not changed much compared to 1981 level. Recent studies indicate that if population continues to grow at the present rate, it will be doubled in the next 41 years and will frustrate the development efforts of the economy. Such a high rate of population growth along with the 5.7% GDP growth rate, 2.9% of agricultural sector growth rate and 1.8% of industry sector growth rate recorded in 1998, will further accentuate the problem for a country like Bangladesh.

3.3 Population Projection of Bangladesh

The future projections can be based on alternative assumptions regarding the trends in fertility, mortality and other relevant parameters. In order to reveal the magnitude of the problems, we consider here some of the available projections. The most recent estimate by the Planning Commission (PDEU) of Bangladesh (Government of Bangladesh - GOB, 1998) also confirmed that due to the large base of young age population, future growth potential is indeed very high. In the short run, even under the optimistic assumption of NRR-1 (i.e. total fertility rate [TFR] of 2.2 or 2.3) by the year 2005, there will be a net increase of 8.8 million people by the end of Fifth Plan period (1997-2002) over the 1997 level of 123.8 million; while in the long run, say, by the year 2020, there will be a net increase of 46.74 million people. Current population density is 850 persons per sq. km. Due to population growth momentum, number of working age population (15-59 years) is projected to increase from 66.6 million in 1997 to 80.2 million in 2002; 98.0 million in 2010; and 109.1 million in 2020. Given the current status of the economy, such an increase in population will have several adverse implications.

Some other alternative projections for the period 1995-2050 made by the United Nations (United Nations, 1999) are shown in Table 1, based on three fertility variants and constant-fertility scenario. Assumptions are made as to future trends in fertility (three variants plus the constant fertility scenario), mortality (one variant) and international migration (usually one variant). The high-, medium- and low-fertility variants are all thought to provide reasonable and plausible future trends in fertility. Projection 1 (high-variant) assumes moderate decline in fertility, Projection 2 (medium-variant) assumes substantial decline in fertility and Projection 3 (low-variant) assumes drastic decline in fertility. In all these projections migration is assumed to be zero and assumption of mortality decline remains as moderate and common. We have Projection 4 based on the assumption of constant fertility where future fertility will remain unchanged at the level calculated for 1995.

However, among the projections presented in Table 1, we found Projection 2 is similar to the PDEU projection and more relevant for the analysis of our present study. According to Projection 2 (medium growth), there would be the population of 171.42 and 218.19 million respectively by the years 2020 and 2050. Bangladesh is likely to have 33.56 million school age population (5-15 years) by mid-2020. Between now and the year 2020 about 18 million persons will be added to the labour force aggravating further the existing unfavourable situation in labour market with other pressing needs.

SECTION 4 : REVIEW OF MAJOR RESOURCES IN BANGLADESH

The large population base and its accelerating growth in recent decades have heightened the burden on the country's limited resources and this requires a careful and comprehensive assessment of the country's natural resources. It is evident that extremely high population density of Bangladesh has contributed to the intense use of land, energy, forests, fisheries and water resources. However, we will first address the issue of agricultural output and would review other resources considered in this study subsequently.

4.1 Agricultural Output

Bangladesh, the eighth most populous country in the world, provides a classic illustration of the precarious balance between food and population. The population of the country is estimated to be 122 million during 1995-96 with a growth rate of 1.75%, while the annual per capita food production for the period 1995-96 is found 0.15 percent (Bangladesh Bureau of Statistics - BBS, 1998). At the time of partition of India (1947), the region now constituting Bangladesh was nearly self sufficient in food. But a virtually stagnant agriculture in the 1950s, and a rate of growth of food grain production below that of population in the sixties and afterwards has turned it into a region of growing food deficit.

More than three fourths (81.01%) of the gross temporary cropped area (35.49 million acres) is covered by cereals of which rice is grown on about 25.4 million acres, that is, nearly four-fifths of the total cropped area. In terms of production, it claims a dominant share of 54% of total production in the crop sub-sector. The area under wheat is 5.5% (1.98 million acres) of total area under cereals (BBS, 1998).

First half of the last decade witnessed an upward growth in food grain output as a result of expansion of area under irrigated winter season cropping. It can be seen from Table 2 that in 1993/94, 1994/95, and 1997/98, food grain production declined and it is due to depressed prices and natural disasters, particularly floods and droughts. An exception has been the year 1996/97 which witnessed an all time high food grain production of about 20.43 million metric tons. However, food grain production continues to depend on the vagaries of nature; its dependence on weather continues resulting in fluctuation in production.

Inspite of some improvements, the scale of production problem we face can be seen from the fact that we consume, on average, about 1.5 to 2.0 million tons more food grain than we produce. The average yearly imports of rice and wheat was only 23 thousand tons in 1948-50 period, 1.3 million tons in 1976-78, 1.5 million tons in 1990 (about 9% of domestic demand). During 1996, amount of cereal import was 1.76 million tons. At present, government's annual import bill for foodstuff is Tk.5,600 million. Considering the case of food requirements based on nutritional need, demand for food, based on 5% GDP growth with achievable production of different food items as estimated, exceeds the potential achievable production[2] in the year 2010 (GOB, 1998). It seems quite certain that Bangladesh will not be able to eliminate imports of food grain even in next 20 years, unless annual growth in domestic production accelerates to 3.5 to 4.0%.

4.2 Land Resources

The total surface area of the country amounts to about 14.3 million hectares of which 15% is under forest and 20% is occupied by water bodies and homestead. Arable land is about 21.66 million acres, of which 19.41 million acres is currently cultivated (BBS, 1998). About 71% of the total cultivable area is in the highlands (flood depth 0-30 cm) and medium highlands (flood depth 30-90 cm). Due to rapidly growing population in 1997 arable land[3] per person decreased to .16 acre (BBS, 1998).

4.3 Energy

Of all issues associated with resource development and exploitation, energy has attracted the most attention in recent years. Bangladesh currently faces two energy crises, one in the modern, and the other in the traditional, energy sectors. Combined, the two sources are unable to meet the country's present energy needs. Among its energy resources, Bangladesh

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2 The term 'achievable production' is used here to mean the maximum production that can be achieved at the farmer's level using full potential of existing natural resources and modern technology.

3 Arable land means aggregation of net cropped area, cultivable wasteland and current fallow land.

has a vast deposit of natural gas, some hydroelectricity and coal and a large amount of fuelwood[4], crop residue, cowdung etc. Exploration activities carried out so far could not discover any significant oil deposit.

Energy consumption in Bangladesh is overwhelmingly domestic, rural and supplied from traditional sources. Annual per capita energy consumption which is however, lowest in the world is approximately 100 kgoe (kilograms of oil equivalent). Fifty five percent of the total energy consumed in Bangladesh is collected from the traditional organic fuels. Natural gas meets 24% of the country's total fuel need while hydroelectricity provides 2% of the need. The total estimated natural gas reserve is around 22.90 trillion cubic feet (TCF) of which about 13.60 TCF is considered as recoverable. The per capita consumption of commercial fuel is 45 kgoe which is increasing gradually. Nineteen percent of the fuel needed in the country comes from imported coal and mineral oil (World Bank, 1995).

4.4 Water Resource

Bangladesh has been called a land of rivers. The river system that flows through Bangladesh comprises the third largest source of fresh-water discharge of the world's oceans (The New Encyclopedia Britannica, 1988). There are about 250 rivers of varying sizes forming a network along with the three major rivers viz. the Ganges, the Brahmaputra, and the Meghna. The river system together drains a catchment area of about 1.7 million sq. km. of which about 7% lies in Bangladesh (GOB, 1998).

4 The term fuelwood means firewood derived from tree stems and large branches and it excludes small branches, twigs and leaves.

Bangladesh water resource consists of three general components: rainfall, surface water and ground water storage. The mean annual rainfall over Bangladesh is 2320 mm. Main components of surface water are stream flow, static water and in-stream storage. Stream flow is the most dominant component of water resource in Bangladesh. On an average, approximately 2.98 billion cubic metres of stream flow are discharged into the Bay of Bengal every day (BBS, 1998).

Majority of the people in rural Bangladesh are dependent on ground water as a source of water for their general household use including drinking, washing and irrigation. Major hydro-geological regional investigation shows that total ground water potential is 25750 Mm^3 out of which 7810 Mm^3 has been developed upto 1985(Khan, 1990). Ground water availability varies depending on location and is constrained due to hazard of salt water intrusion (Islam, Q. I., 1998).

4.5 Fisheries Resources

Fishery sub-sector contributes about 60% of the nation's animal protein intake, 10% of agricultural GDP, 3% to total GDP and income for about 12 to 13 million people (GOB, 1998). In Bangladesh, fishery sub-sector is broadly divided into inland and marine fisheries. The total area of inland open waters is estimated to be 40,47,316 hectare of which about 25 percent are rivers (BBS, 1998). The marine water bodies (200 nautical miles along the coast) covers an area of 166,000 sq. km (SEHD, 1998).

The production of fish has been estimated to be 1,373 thousand metric tons (mt) during 1996/97 as against the production of 847 thousand mt in 1989/90. In 1996/97 production of inland fish was 1,079 thousand mt and that of marine fish about 294 thousand mt, which is about 27% of the total fish harvest of the country. The growth rate of fish production during the last seven years averaged at 6.5% which fell short of increase in demand. The stagnation in fish production over the years is attributed mainly to gradual reduction in production of inland capture fisheries due to over fishing, flood control and irrigation projects and indiscriminate use of agro-chemicals and pesticides. Besides, Bangladesh's wetlands are reported to have reduced to half its size and the fisheries' catch has dropped by an average of 9% every year over the past decade (Ali, Y. M.,1997).

SECTION 5: CARRYING CAPACITY MEASUREMENT OF MAJOR RESOURCES

5.1 Agricultural Output

5.1.1 Methodology

We seek to develop an expression for carrying capacity measure that can sufficiently signify a sustainable system of food production not only in the present but also in the indefinite future. The carrying capacity measure, given food requirement, essentially draws upon the amount of agricultural output produced within the national boundaries that is compatible with the goal of achieving self-sufficiency in food. The scope of modern agricultural practices that is necessitated from the increased pressure of human population is also considered here in addition to traditional agricultural practices. The objective is to assess the per capita increase in yield that can capture the possibility of outweighing the gains to be made from the increased production due to rapid population growth. Thus, defining carrying capacity as the maximum sustainable population at the present standard of living or the minimum standard necessary for survival (Atkinson, 1992), the population carrying capacity given food output at any point in time can be expressed as,

$$CC_{POP,t,q} = \frac{Q_{MAX}}{C_{MIN}} \tag{1}$$

C_{MIN} is the per capita food consumption sufficient to meet individual's calorie requirements related to the minimum availability requirement. This is the ratio of current output (Q_0) to current population (POP) indicating the underlying principle that the current production is sufficient to sustain current demands. The term Q_{MAX} includes the possibility of maximum output to be obtainable from inputs and from the varying quantity and quality of lands that are potentially or actually bring under cultivation. This might not be analogous to Q_0 which is the maximum output available in the current period 0. This Q_0 is constrained by the amount of land under cultivation and technology currently used. A movement from Q_0 to $Q_{MAX}(t)$ is then characterized by the change in either of these two factors,

$$Q_{MAX}(t) = Q_0(1+u)^t(1+k)^t \tag{2}$$

where u denotes the net rate of change in land use and k denotes the physical growth of output yields. u in turn, implies the process of extensification (positive u) that involves the process of bringing more land in production[5]. Positive k, however, indicates the role of intensification for the possibility of cropping intensity and yield.

Q_{MAX} and Q_0 will be identical if k and u are both zero. Replacing the expression for $Q_{MAX}(t)$ in equation (1) we end up with the following,

$$CC_{POP,t} = \frac{Q_0(1+u)^t \cdot (1+k)^t}{Q_0/POP_0} \quad (3)$$

$$\text{or,} \quad CC_{POP,t} = (1+u+k)^t \cdot POP_0 \quad (4)$$

The final measure states that any non-zero positive rate of change in agricultural output or change in the use of land will be consistent with some population growth and this will not necessarily be consistent with actual population growth between period 0 and period t.

5.1.2 Estimation and Analysis of Findings

In order to apply the formula developed in equation (4) what we essentially need is to get an estimate of u and k, and the knowledge about current population POP_0, t stands for the time period for which we are interested to measure the population carrying capacity. Since a rationale estimate of u and k is expected to be based on the actual experience, an annual data of 48 years (1951-1998) on growth in yield and the rate of change in agricultural land is used to show the absolute

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[5] Ruttan (1991) emphasizes that the expansion of agricultural production through extensification ultimately implies expansion into ecologically fragile areas. This encroachment also implies increasing appropriation of a finite natural world by human populations.

scope for such increases in the future where past trends are being extrapolated into the future.

In our case, arable land is used to designate u and production of cereal is used to designate k as well. To get an accurate assessment of trends in k and scope for positive net u, Ordinary Least Square (OLS) is used. In determining the most appropriate measure of k and u various functional forms are tested to find the statistically significant association between production of cereal with time[6] and arable land with

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6 To get an estimate on growth in yield, semi-log model is used where dependent variable, cereal production, is expressed in the log form and the time trend is taken as an explanatory variable. The essence of using this model in this case is that the estimated slope coefficient (after multiplying by 100) will act as measure of the rate of growth in dependent variable we are looking for.

Squared term of the explanatory variable (time square) is also tried along with other variables to capture any change in the growth rate. However, this does not make any difference in our estimated k between the two alternatives and therefore, we concentrate on the earlier formulation (dependent variable log of cereal production and explanatory variable time).

The coefficient of multiple determination or R^2 (i.e. measuring the proportion of the total sum of squares explained by the regression) tests the goodness of fit of the regression explaining the variation in the dependent variable. For a time series study using production of cereal data at the national level, $R^2 = .94$ indicates a good fit of the estimated model in explaining the variation in cereal production. In other words it tells that the explanatory variable time explains about 94% of the variation in cereal production over the period 1951-98.

The statistical significance of the individual parameter estimates shown by the t ratio against each estimated coefficient. Using a two tailed test, a 99% confidence and 38 degrees of freedom we found the variable to be significant. The model also qualifies the Durbin-Watson (D.W) tests indicating no possibility of autocorrelation.

The sign of the coefficient of time is positive which is consistent with our *apriori* assumption of the tendency to increase in output primarily by the adoption of new and modern techniques in addition to traditional one due to increased population pressure on land.

time[7]. The results of the estimated regression equations are summarized in Table 3 of appendix.

Applying the carrying capacity constraint in agriculture, the actual estimate of carrying capacity in terms of sustainable population is shown in Table 4. The year that the population is predicted to reach the carrying capacity is shown in Table 5.

Table 4 reveals that with respect to the levels of population of 1995, the population of Bangladesh appears to be unsustainable. This computation entails the use of population projection by the United Nations mentioned in Section 3. Findings of our study indicate that given the country's high population density and decrease in arable land use over time at the rate of 6%, poor performance of food output at the rate of

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7 As in the case of k, semi log model is applied to get an estimate of net rate of change in land use. Log of arable land is used here as a dependent variable and the time and time square is used as an explanatory variable. To get an improved fit square term of the explanatory variable time is being considered in the model in order to capture any change in the rate of land use over time. The estimated slope coefficient of time will then act as a measure of the rate of growth in arable land use over time.

Table 3 shown in appendix also summarized the results of the estimated regression equation after applying OLS to the original model. Needless to say, the results of the regression of log arable with time and time square exhibits low R^2, problem of serial correlation. The regression results reported in the 4th row of Table 3 is however, an application of first order auto-regressive scheme [AR(1)] (Cochrane-Orcutt method) to remove the problem of serial correlation of the original model apart from getting an improved R^2 of .79 indicating 79% variation in arable land over the period 1951-98. The statistical significance of the individual parameter estimates shown by the t statistics shows that both coefficients of time and time square are significant at 10% level, and therefore, coefficient of time can be regarded as the appropriate estimate of u.

The sign of the coefficient of time, however, gives an indication that the pattern of land use over time is negative.

2% growth casts a shadow over the question of country's sustainability. Against this backdrop, population remains unsustainable over time even when application of HYV has been evident. Rapid growth in population is, therefore, causing a hindrance, responsible for the actual fall in per capita production although total food production seemed to increase.

Low growth in the predicted sustainable population shown in Table 4 also confirms the tendency of the population growth to outweigh the benefits of this insufficient growth in food production. The low increment in the population carrying capacity, therefore, reflects more and more conflict with the projected and actual population the country can sustain given its limited resources.

5.2 Water Resources

5.2.1 Methodology

For sustainable water use the interaction between water demand and water supply is to be considered while developing an expression for carrying capacity measure. As outlined in Atkinson (1992), the appropriate formula would be the following :

$$CC_{POP,W} = \frac{W_{MAX}}{W_0 / POP_0} \qquad (5)$$

where, W_{MAX} is the maximum renewable water flow indicating maximum sustainable supply. This maximum sustainable supply is defined as precipitation minus evaporation and transpiration (Dubourg, 1992). Alternatively, World Resource

Institute (WRI) defines W_{MAX} as annual internal renewable water resource, net of river flows between countries which coincides with the interpretation of W_{MAX} given above. This definition is, however, based on average conditions, and does not indicate seasonal, inter-annual and long-term variations (Angrew and Andersion, 1992). As opposed to the 100% capture of W_{MAX} under a highly sophisticated water management regime, Falkenmark (1982) proposed it to be 20% which may still be generous[8]. Therefore, we should weigh W_{MAX} by 0.2. W_0 is the total present withdrawal from the flow as the availability of water supplies also depends on the pressure of demand exerted by human population. Therefore, W_0 / POP_0 corresponds to the per capita water use that we intend to sustain.

5.2.2 Estimation and Analysis of Findings

Due to the lack of sufficient data, sustainable use of resource is calculated for the year 1998 only. As mentioned earlier, W_{MAX} is calculated by weighing maximum renewable water with 0.2. Substituting these numerical figures for W_{MAX}, W0 and POP_0 in the carrying capacity constraint expressed in the equation (5), we found that the sustainable population for the year 1998 is greatly in excess of actual population (shown in Table 4). This is actually ten times the actual population in 1998, suggesting that with the present water supply we can support ten times the present population.

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8 A country that uses under 5% of total W_{MAX} is unlikely to counter problems. The possibility of fairly major problems increases as 10% to 20% is used, while countries exceeding 20% may face a constraint on economic development (Falkenmark, 1982).

Again using the concept of 'water competition intervals'[9] that consists of generalization concerning maximum water availability per capita and associated possible water shortage problem (Falkenmark, 1989), it can be recommended that Bangladesh has no problem of water scarcity since the country's per capita maximum renewable water (W_{MAX}) of 10940m^3 for the year 1998 exceeds the critical level 10000m^3. Therefore, this additional check to examine whether the human population surpasses the carrying capacity constraint also indicates the fact of sustainable water flows in the country. This large figure, however, does not reveal regional and seasonal[10] variation and pattern of distribution of W_{MAX} within the country. Besides, it is important to note that this carrying capacity estimate reported in Table 4 does not correspond to the optimum or desirable level of population[11] and it excludes the possibility that some other carrying capacity limit (i.e. agricultural output, fuelwood, fisheries) might be reached at far lower levels of populations.

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9 The intervals described in Falkenmark (1989) refer to W_{MAX} where: (a) countries with over 10000m^3 of water per capita are likely to experience little or no problem of water scarcity; (b) Water resources below 10000m^3 but above 1000m^3 may experience general problems; (c) countries with 1000m^3 to 1670 m^3 per capita are described as 'water stressed; (d) chronic scarcity is predicted at 500m^3 to 1000m^3, while (e) countries whose water resources lie below 500m^3 per capita are described as beyond the 'water barrier' – severe water shortage problem which might inhibit economic development.

10 In this regard it is interesting to note that the National Water Plan in 1991 had projected a water demand in the critical dry month of March, by the year 2018, of about 24,370 million cubic meters, while the supply from both surface and ground water sources will be about 23,490 million cubic meters – showing a shortfall of 880 million cubic meters (Chowdhury, Q. I, 1998).

5.3 Fuelwood

5.3.1 Methodology

To examine how population growth is pressing against a country's carrying capacity of fuel technology, we will consider the case of fuelwood here. In developing a measure of population carrying capacity for fuelwood, we assume a scenario where the shortage of fuelwood creates a potential threat of sustaining present standard of living and energy consumption. As before we begin with our basic equation (1) and (5) of carrying capacity :

$$CC_{POP,f} = \frac{F_{MAX}}{F_0 / POP_0} \qquad (6)$$

where F_{MAX} corresponds to the maximum sustainable supply of fuelwood. Per capita fuelwood use (F_0 / POP_0) is expressed as the ratio of current fuelwood demand and current population.

The population would be sustainable if F_{MAX} is greater or equal to F_0. On the contrary, if F_{MAX} is strictly lesser than F_0, then the population would be considered to be unsustainable. Under the circumstances, unsustainability in any period will imply that the F_{MAX} as a stock of potential fuelwood in the subsequent period will run down. As an indicator of the growth rate, F_{MAX} in the subsequent period will also refer to the natural regeneration rate of biomass. If regeneration is positive then it will represent the yield on the existing stock. From the existing stock, maximum sustainable level of harvest is possible without diminishing the stock (Klassen and Opschoor, 1991). This maximum level of harvest is known as maximum sustainable yield (MSY). In a situation where MSY exceeds the harvest, the stock will grow up to a point where regeneration equals harvest. Therefore, the F_{MAX} as a measure of yield includes some regeneration and depletion over time. This is indicated in the following expression :

$$F_{MAX}(t) = F_{MAX}(0)\ (1+g)^t\ (1-d)^t \qquad (7)$$

Where g is the rate of regeneration of the biomass and d is the rate of depletion through harvest of fuelwood, both calculated as a percentage of the volume of FMAX.

Substituting this expression in equation (6), the carrying capacity for fuelwood would be,

$$CC_{POP,f,t} = \frac{F_{MAX}(0)\ \ (1+g-d)^t}{F_0\,/\,POP_0} \qquad (8)$$

5.3.2 Estimation and Analysis of Findings

To apply the measure of carrying capacity for fuelwood, what we need is the data on fuelwood supply per annum, current fuelwood demand and idea about the future supply of fuelwood if current demand per capita is projected into the future. Carrying capacity is, therefore, calculated under the two scenarios: *status quo*[12] and likelihood[13] situation.

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12 *Status quo* situation assumes a scenario which does not allow the possibility of substitutes (i.e. no further expansion in the natural gas), stagnancy in technological innovation, poor forest management, proportionate level of industrial consumption and continuing relative transport cost.

13 The assumption of likely scenario entails an alternative estimation that considers expansion of natural gas, effective banning of fuelwood for brickmaking and domestic coal substitutes for commercial fuelwood.

In our study, the year 1998 is used as the reference point and the per capita fuelwood use is calculated by using the data on fuelwood demand and population data for the year 1998. The expression for the numerator of the basic equation (6) is measured with the data on current fuelwood supply and the projected supply of fuelwood. This essentially reflects both the rate of regeneration of the biomass and the rate of depletion through harvest of fuelwood.

The results from application of carrying capacity constraint on fuelwood is presented in Tables 4 and 5. Columns 4 and 5 of Table 4 show an actual estimate of the carrying capacity in terms of the sustainable population under *status quo* and likely scenario respectively. Rows 3 and 4 of Table 5 represent the year when the population is predicted to reach the carrying capacity under both the scenario. This table is, however, constructed with the aid of population projection (Projection 2) of Table 1.

Under a *status quo* situation Column 4 of Table 4 shows a low growth in the predicted sustainable population due to the over use of fuelwood. The increment of carrying capacity of 27 million by the year 2020 is, however, likely to fail to cope with the projected population of that year and therefore, the country remains unsustainable over time.

Under a likely scenario (shown in column 5 of Table 4) carrying capacity estimate (152.87 million population by the year 2020) looks better but the finding is similar and by and large, corresponds (the country remains unsustainable over time) to what we have obtained under a *status quo* situation. Therefore, it is evident that the fuelwood availability situation poses a potentially serious threat to the fulfillment of energy requirements in Bangladesh[14].

5.4 Fisheries Resources

5.4.1 Methodology

For the purpose of estimating the population carrying capacity with regard to the country's fishery resource, we will entirely rely on our basic equation (1) and (5) discussed earlier. This can be interpreted as follows:

$$C_{POP,fish,t} = \frac{FISH_{MAX}}{FISH_0 / POP_0} \qquad (9)$$

As in the earlier case, $FISH_{MAX}$ corresponds to the maximum sustainable supply of fish production. The ratio of current fish demand and current population i.e. $FISH_0$ / POP_0 denoted here as the per capita fish availability. It, therefore, signifies that for any given level of population, if $FISH_{MAX}$ is greater or equal to $FISH_0$, then the population would be sustainable. This clearly implies the decrease in the stock of potential fish production i.e. $FISH_{MAX}$ in the subsequent periods. As referred in the earlier cases, $FISH_{MAX}$ as a measure of yield also exhibits regeneration and depletion rate of the fishery stock. Likewise expression can be developed as follows:

$$FISH_{MAX}(t) = FISH_{MAX}(0)\ (1+g)^t\ (1-d)^t \qquad (10)$$

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[14] In 1993 Ketabi and Ahmed noted that the current per capita fuelwood consumption of 2.7 cubic feet represents a 50% decline from that of 1954 (Ketabi and Ahmad, 1993)

g and d are the regeneration rate and the depletion rate of fishery resources computed as a percentage amounts of $FISH_{MAX}$.

Rewriting the equation (9) the carrying capacity measure for fish would be,

$$CC_{POP,fish,t} = \frac{FISH_{MAX}(0)\,(1+g+d)^t}{FISH_0 \,/\, POP_0} \qquad (11)$$

5.4.2 Estimation and Analysis of Findings

Analogous to the requirements of the carrying capacity estimate for the fuelwood, carrying capacity measure for fishery resources needs data on fish supply per annum, current fish demand and the impression about the future fish supply if current demand per capita is projected into the future.

Projected data used on fish supplies are based on historical performance and future plan and analysed under the reasonable scenario of 2.3% growth rate per annum. The supply of fish production is projected to grow from 795,000 mt. in 1987 to 1.6 million mt. in the year 2010. In our study, the year 1987 has been taken as the reference point and the per capita fish use is then calculated by using data on fish demand and actual population data for the year 1987. Calculation of the numerator of the basic equation (9) with the aid of current and projected supply includes regeneration and depletion rate relating to maximum sustainable supply of fish.

Carrying capacity measures are, therefore, presented in Table 4 and Table 5. As before, projected population calculated under the scenario of average condition is used here.

Our finding of the study suggests that Bangladesh with a population of 118 million in the year 1995 is found to be already unable to feed its population at the minimum standards. The estimates of sustainable population shown in Table 4 found a gap between actual population carrying capacity and the projected population presented in Section 3 under average condition. The threat deserves attention since carrying capacity level has already been reached. Even the projected fish productivity considered for computation might not be realized without improved inputs, technology, investment and adequate credit availability.

5.5 Indicators of Interrelationships

Although in our study we have dealt with the four carrying capacity indicators separately but when we take into account what Rees and Wackenagel (1992) has pointed out as 'Liebig's Law', it can be readily argued that once a single constraint binds, all other carrying capacity constraints become irrelevant. In other words, it can be said that a country is constrained by any of the carrying capacity components which is reached first, i.e.

$$CC = min.\ CCi \quad \text{------} \qquad (12)$$

This is expressed in Table 5. The outcome of this study examining the case of Bangladesh indicates a dominant constraint with regard to food output, fuelwood and fishery resources. Only the water availability does not seem to constrain current per capita rate of usage.

SECTION 6: CONCLUSION

It is increasingly recognized that the idea of sustainable carrying capacity and development must be explicitly developed in economic policies and programmes of a country. Effective incorporation of the carrying capacity concept into national as well as local development planning will invariably assist government in meeting their goals, and promote the development techniques which can be used for regional and national planning. Findings of our study reassert that for successful, sustainable development consistent with the issue of long-term contingency planning, the notion of carrying capacity should be given due considerations. The study, in particular, reveals that the economy of Bangladesh has already reached the population carrying capacity limit in resources like agricultural output, fuelwood and fishery. Only with regard to water the country is in a better position, although continued and unchecked high population growth by intensifying the over use of the said resource might affect this position. We should be aware of the fact that irrespective of abundance of other resources a country might eventually become unsustainable even if a single constraint binds.

However, no simple one-dimensional policy conclusion could be drawn from this capacity measurement exercise. Shortage of food, energy and fishery when placed in juxtaposition with rapidly expanding population, indeed creates some of the most serious issues confronting economic development. But it would be a mis-specification of Bangladesh's population/resource problems if carrying capacity limits are thought to be so inherently constraining that the full burden of the development problem is ascribed to population growth only. Therefore, policies to slow population growth will not be an immediate panacea for problems of low productivity and resource depletion in Bangladesh. Rather this will contribute only in part to solve the problem. Many other factors generate resource depletion and degradation, especially misdirected policies concerning land tenure and prices. While undertaking integrated multidimensional and comprehensive approach, we should be careful about combining population policies with others – changing the property rights that reassert local control over natural resources, land-use zoning, land reforms, agronomic research coupled with increasing the incentives for resource conservation – directed to ensure that the country's resource base is developed in an equitable and sustainable manner.

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APPENDIX

Table 1: Population Projections of Bangladesh 1995-2050 (million)

Year	Projection 1 (High-variant	Projection 2 (Medium-variant)	Projection 3 (Low-variant)	Projection 4 (Constant-variant)
1995	118.23	118.23	118.23	118.23
2000	128.82	128.31	127.81	129.63
2005	141.61	139.91	138.22	144.35
2010	155.45	151.89	148.32	161.15
2015	168.81	162.68	156.49	178.57
2020	181.09	171.42	161.75	196.88
2025	193.78	179.98	166.54	216.94
2030	207.70	189.06	171.32	239.85
2040	236.56	205.81	177.82	292.63
2050	264.68	218.88	178.19	355.02

Source: World Population Prospects, United Nations, 1999.

Table 2 : Growth Rates of Agricultural Contribution to GDP at Constant Market Price (Base : 1984-85 = 100)

Year	Growth rate (%)
1990-91	1.61
1991-92	1.95
1992-93	1.81
1993-94	0.34
1994-95	-1.04
1995-96	3.66
1996-97	6.44
1997-98	2.94

Source: BBS, 1998.

Table 3 : Estimated Land and Output Trend

	Constant	Time	Time square	R^2	D.W
Cereal Production	8.8 (369)	.024 (24)	------	.94	1.66
	8.8 (236)	.022 (5)	.000048 (.48)	.94	1.67
Arable Land	10.1 (902)	-.010	.00021	.67	.60
	10.1 (261)	-.006 (-2)	-.00014 (2)	.79	1.61

Table 4 : Population Carrying Capacities (million)

Year	Agricultural[15] Output	Water[16] Resources	Fuelwood[17]		Fishery[20] Resources
			Status-quo[18] Situation	Likely[19] Scenario	
1995	114.00				117.78
1998	------	1375	83.66	94.61	---
2000	122.29	--	85.07	97.25	127.11
2003	------	--	87.93	100.13	---
2005	133.52	--	89.68	108.09	138.07
2008	------	--	92.46	113.26	----
2010	145.79	--	95.74	121.37	150.34
2013	------	--	97.65	130.06	----
2015	154.18	--	106.25	141.61	----
2020	------	--	111.14	152.87	----

Note : Calculated for the data of the resources available.

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15 Data is collected from various issues of Statistical Year book of Bangladesh published by BBS, GOB.

16 Data is collected from WRI, 1998-99.

17 Data source is Forestry Master Plan: Statistical Data and Yearbook of forestry resources, Government of Bangladesh.

18 This assumes no substitutes and stagnancy in technology and innovation.

19 The scenario assumes no substitutes alternative state, like expansion of natural gas, effective use of fuelwood for brickmaking.

20 Data obtained from a report on department of fisheries Bangladesh, Department of Fisheries, Government of Bangladesh, 1999 and various issues of Statistical Year book of Bangladesh published by BBS, GOB.

Table 5 : Population Carrying Capacities : Year When Sustainable Population is Reached

RESOURCES	YEAR
Agriculture	1995
Water resource	No Constraint
Fuelwood: Status quo situation	1995
Likely Scenario	1995
Fishery	1995

Note : Footnotes and notes of table 4 are also applicable here.