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A review of the environmental Kuznets curve hypothesis for deforestation policy in Bangladesh

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Deforestation in the tropical developing countries is the critical environmental concern to ecologists and environmentalists. Environmental Kuznets Curve (EKC) hypothesis is critical to understanding the development path of a nation in relevance to its environment. The dictation of national economic growth to deforestation can be found through the study of EKC. To understand the EKC phenomena for deforestation, the study was undertaken through reviewing the literature. With the understanding of the different EKC trajectories for deforestation, an attempt was made to implicate the economic development of Bangladesh with the EKC. The proven EKC trajectories for deforestation in some regions/countries show a higher income per *capita* requirement for the turning point. The study suggests that tunneling in the EKC trajectory for Bangladesh would be favorable. The type of economic and forest policy that Bangladesh should follow to retard deforestation is also revealed. Clean Development Mechanism (CDM) and Reducing Emissions from Deforestation and forest Degradation (REDD) have been suggested for tunneling the EKC in Bangladesh. The findings of the study are expected to contribute to the environmental development of Bangladesh.

Keywords: CDM, Climate change, Economic growth, EKC, REDD+, Slowing deforestation

Introduction

Deforestation in the developing countries is one of the most serious environmental concerns because of the resulting biodiversity loss, soil degradation and significant contribution to global climate change, etc. (Ehrhardt-Martinez et al. 2002). The economic activities of a nation including its livelihood and cultural integrity are also affected by the degradation (Culas 2007). The quick deforestation in the tropical zone has come into the limelight as a major source of global greenhouse gases (GHG). Fearnside & Laurance (2004) report that tropical deforestation contributes from 0.8 Gt to 2.4 Gt (Gigatons: 1 Gt = 1 x 10^9 metric tons = 10^{15} grams) to the total global annual GHG emissions, varying due to the uncertainty of the estimates and debates by different studies. Forests in the tropical zone, especially Asia and including Bangladesh, have become the most threatened region on the earth and have also been a significant source of GHGs (Laurance 2007). An increased amount of GHGs is considered the main cause of global warming, causing climate change. The most important GHGs are CO_2, CH_4, N_2O, SOx, NOx and F-gases (gases that contain Fluorine).

Growth in Gross Domestic Product (GDP) or income per capita in a nation seems to be interlinked with environmental ups and downs. Where an economy develops by taking resources from the environment, after a certain point, an economy must help the environment to keep up both of their sustainability. The abatement activity starts after a substantial amount of capital stock is achieved (Selden & Song 1995). An Environmental Kuznets Curve (EKC) is a hypothesized relationship between economic growth (income per *capita*) and environmental quality. This curve indicates that economic growth initially contributes to the degradation of environmental quality, but with further growth, the relationship is reversed and environmental degradation starts to decrease. This relationship provides an inverted U-shape curve, where environmental degradation first rises and then falls with increasing income per *capita*. The idea of EKC came into the limelight in 1991 with the study of NAFTA (North American Free Trade Agreement - Grossman & Krueger 1991), though the idea of Kuznets curve (relationship of economic growth and income inequality) existed from 1955 (Kuznets 1955). However, the Environmental Kuznets curve (EKC) hypothesis became very important after 1991 for its potentiality and promise of finding a final solution to environmental degradation. Deforestation, an important phenomenon of environmental degradation, has already been shown to be subject to national economic growth in many countries. Koop & Tole (2001) analyzed the economic distributional profile of a developing country on the forest loss. They found that an economy with greater inequality had more deforestation than that of an egalitarian economy. Rather, the egalitarian economy could ameliorate the negative impact of the economic growth on the forest. Mather (2007) also studied the forest transition in some Asian countries, which proved the effect of economic growth on forests.

Bangladesh, a south Asian least developed country, has been experiencing severe deforestation over the last 3 to 4 decades. Still, Bangladesh has not found any effective way to halt the deforestation. It hypothesizes that Bangladesh is presently at the initial up-facing stage of EKC considering deforestation. Many studies were found to judge the EKC for deforestation in different developing countries (Koop & Tole 1999, Bhattarai & Hammig 2001, Ewers 2006). While studying the economic impacts on deforestation at a global level, Scrieciu (2007) concluded that case-specific factors might influence deforestation in different countries and socio-geographic zones. Therefore, he focused his research on a more disaggregate, local level. However, there is no validly published study of EKC on deforestation in Bangladesh. This study aimed at relating the results of EKC for other developing countries with Bangladesh. What will be the fate of the deforestation of Bangladesh in regards to ongoing economic development? Will Bangladesh follow the inverted U-shape of the EKC? If yes, what should be the economic and environmental policy to retard deforestation within a shorter period? We expect this paper will contribute significantly to this environmental issue. The findings of the study would be of immense importance for the forestry development in Bangladesh.

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Bangladesh forestry sector: general overview

Bangladesh is a south Asian least developed country located between 20° 34' to 26° 38' N latitude and 88° 01' to 92° 42' E longitude with a geographical coverage of 14.76 M ha with three broad categories of land-hills, uplifted land blocks and alluvial plains (BBS 2009). The country is characterized by low per capita gross national product; low natural resource base; high population density, and high incidence of natural disasters. The climate is subtropical, characterized by high temperature, heavy rainfall, often-excessive humidity, and marked seasonal variations. There are three main seasons: (1) a hot summer season, with high temperatures (5-10 days of more than 40 °C maximum in the west), highest rate of evaporation, and erratic but heavy rainfall from March through June; (2) a hot and humid monsoon season (temperatures ranging from 20 to 36 °C), with heavy rainfall from June through October (about two-thirds of the mean annual rainfall); and (3) a relatively cooler and drier winter from November through March (temperatures ranging from 8 to 15 °C), when minimum temperature can fall below 5 °C in the north, though frost is extremely rare (MoEF 2005). The mean annual rainfall varies widely within the country, according to geographical location, ranging from 1200 mm in the extreme west to 5800 mm in the east and northeast (MoEF 2008).

Forestry is an important sector in Bangladesh's economy. Forestlands make up almost 18%, agricultural lands 64% and urban areas 8% of the total lands in Bangladesh (FAO 1998). Other land uses account for the remainder. Total forestland area is 2.56 M ha, including officially classified and unclassified state lands, village forests and tea/rubber gardens. Most of the state forestland is degraded (Chowdhury et al. 2009, Iftekhar 2006, Muhammed et al. 2008). Classified and unclassified forestland signifies an administrative or legal category, not necessarily areas with tree cover. Natural forest accounts for about 31% and forest plantations 13% of total forest areas. Shifting cultivation, illegal occupation and unproductive areas account for the remaining forestland (FAO 1998). Presently, protected areas represent just over 5% of forestland. Bangladesh Forest Department is responsible for administering 65% of state forestland. Local District Commissioners (DC) administers the other government forestlands. The better quality natural forests and plantations in the government forestlands, excluding parks and sanctuaries (medium to good density), make up around 0.8 M ha, which is 5.8% of Bangladesh's total area. The area included in the present protected area network is 0.12 M ha, equal to 5.2% of state forestland or less than 1% of Bangladesh's total area (FAO 1998). The hilly areas of Chittagong, the Chittagong Hill Tracts, Cox's Bazar and the Sylhet Forest divisions consist of hill forests, which are subject to severe degradation due to overpopulation, shifting cultivation and extension of agriculture (Salam et al. 1999). There are two main types of forests in the hilly areas, *i.e.*, evergreen and deciduous. These forests may be subdivided into several subtypes based on altitude, soil, rainfall, and other factors. The evergreen forest is made up of tropical wet evergreen and tropical mixed evergreen. The deciduous forest consists of tropical moist deciduous and tropical open deciduous. Tropical mixed evergreen forest is the most important type, with the dominant trees, Dipterocarps, being highly valued due to their high-priced timber. In the forests of the hilly areas, more than 100 evergreen and deciduous tree species have been identified as growing naturally (Salam et al. 1999).

During the period 2000-2005, the annual rate of deforestation in Bangladesh was 0.3% (2000 ha) as stated by FAO (2007). Due to the deforestation, many plants and animals have become extinct or endangered in Bangladesh (Chowdhury et al. 2009). A total of 40 inland mammals, 41 birds, 58 reptiles, 8 amphibians and 106 vascular plant species have reached at-risk status in varying magnitudes (IUCN 2000, Khan et al. 2001). Salam et al. (1999) indicate that deforestation and degradation in the forests of Bangladesh are influenced by infra-structural problems related to the country's underlying socioeconomic features. Salam et al. (1999) divided the underlying factors into four sets of actors: (1) the indigenous forest dwellers, having their own problems (*e.g.*, high population growth); (2) migrants, who move to the forests; (3) the timber industries cutting down too many trees; and (4) the government through its Forest Department which is not able or willing to implement suitable policies to regulate the cutting of trees and to prevent illegal cutting. Mitigating the first and second factors is a time-consuming task. The country is facing a high rate of population as a severe problem (Niroula & Thapa 2005, Lush et al. 2000). The constantly increasing population and its growing consumption are expected to cause further loss of forest cover due to these first and second factors. In contrast, the third and fourth actors can be seen as a relative indulgence. The nature of the causes of forest loss in Bangladesh is such that any attempt to revert these trends will be ineffective without changes in the attitudes and practices of Forest Department officials and politicians with forest interests. The Forest Department has been losing its management capacity for many reasons, mostly related to the third and fourth actors.

Method of the Study

To explore the EKC trajectories for deforestation in relevance to Bangladesh, the study was conducted from August 2008 to August 2009. The data on global warming and its causes and consequences; EKC and behavior of deforestation in the EKC trajectory; and the socio-economic status of Bangladesh were collected mostly from the authoritative sources available on the Internet. Some facts were crosschecked directly in the offices of Bangladesh, mostly located at Dhaka and Chittagong. For researching the most recent facts, Scirus (http://www.scirus.com), Scopus (http://www.scopus.com) and ISI web of knowledge (http://apps.isiknowledge.com) were used for reviewing the most relevant scientific articles. For that, some common keywords like economic growth, environmental degradation, deforestation, EKC and Kuznets curve were used to search out the specific articles. After selecting all the required articles, these were downloaded from the online sources. The downloaded articles were then printed out for the study. To establish a concrete understanding of the EKC regarding deforestation, many cross-references were also used.

As deforestation is the most important factor in global warming and major biodiversity loss in Bangladesh, it has been considered for understanding the EKC behavior. The most important findings on those parameters were synthesized, their specific research paradigms were compared and deviations among the results were discussed. The calculation of GDP and/or income per capita were considered for US$ at the specific period. The synthesis of the original scientific articles on EKC and different environmental degradations was used to implicate those for Bangladesh considering the national income and other drivers of EKC in Bangladesh.

The EKC hypothesis and its general review

The EKC curve shows that environmental degradation first increases with increasing income per *capita*, but that after a certain point in increasing income per *capita*, environmental degradation tends to diminish (Fig. 1). Though environmental degradation rises quickly with a steep slope in the curve, its reduction gives a moderate slope. However, it gives a hill shaped curve by taking income per *capita* in X-axis as an independent variable and environmental degradation in Y-axis as a dependent variable. When there is no turning point in income per *capita* for any pollutant, the curve simply represents a straight line (Fig. 1).

In some cases, an N-shaped EKC has also been found, *i.e.*, Bhattarai & Hammig (2001) for deforestation, Torras & Boyce (1998) for SOx emissions, etc. This happens when en-

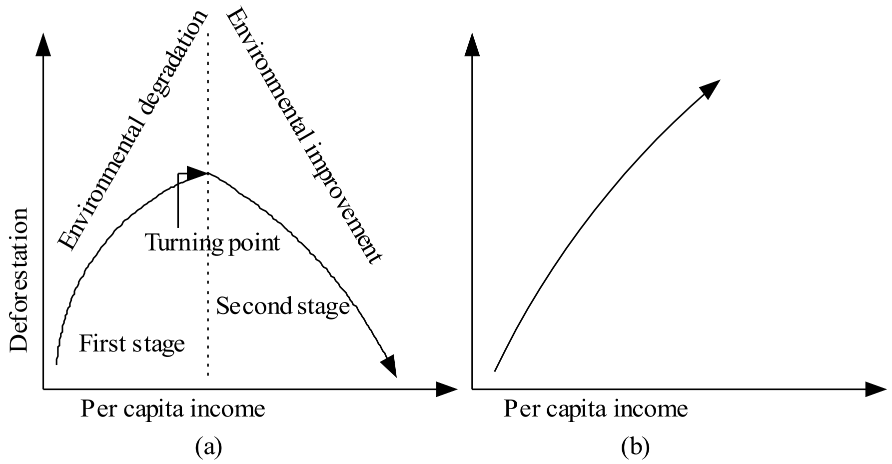

Fig. 1 - General environmental Kuznets Curve, (a) A full trajectory of inverted U-shape EKC; (b) Straight line of EKC, where no turning point is found.

vironmental degradation shows a positive, negative and positive relationship, respectively with income per *capita*. It means environmental degradation first increases with income per *capita*, but decreases after a certain level. This is how a peak is formed. Along with further increase in income per *capita*, degradation tends to rise again, which provides a trough in EKC (Fig. 2).

In EKC relationship, the environment is like a luxury good (Gangadharan & Valenzuela 2001). At the early stage of development, the environment is not really taken care of, but when income reaches a certain level, people want to act smart for the environment. However, this relationship is not as automated as it seems. Grossman & Krueger (1995) stated that it is "an induced policy response" and that it has some variables working on it.

Generally, the EKC measures economic effect on environmental degradation by two models, *i.e.*, Fixed Effect (FE) and Random Effect (RE). In the first model, all the variables remain constant except income per *capita*, where it only measures the changes in environmental degradation with the changing income per *capita*. In the second model, it measures other additional variables as a changing factor. It is certain that the result will be different, depending on the model used. For example, RE model has given a higher value for the turning point than FE model for NOx emissions (Selden & Song 1994). In addition to this, Grossman & Krueger (1991) have found that FE model has shown a higher value for the turning point. Not only has the turning point differed with the chosen model, but the presence of the hill-shaped EKC depends on them as well. Similarly, Koop & Tole (1999) have found a turning point for deforestation using FE model, but no statistically significant turning point is found using RE model.

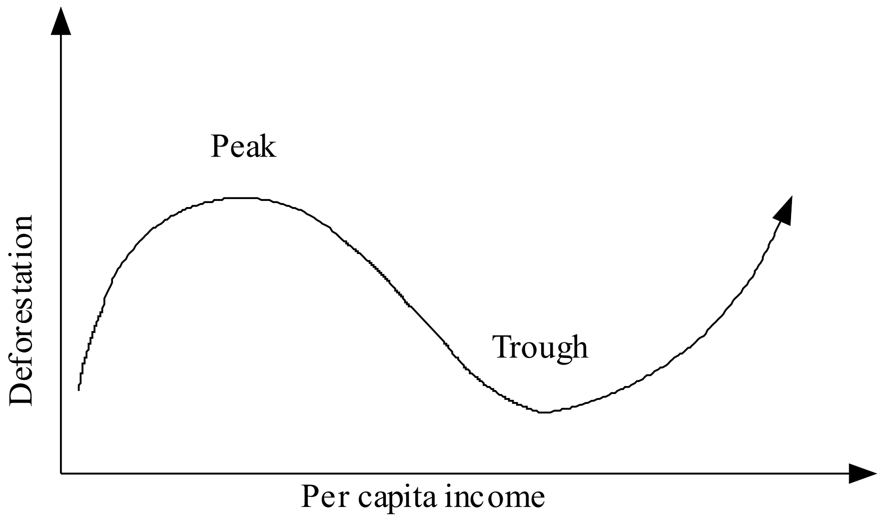

Fig. 2 - Peaks and troughs of EKC.

It is obvious that when income per *capita* crosses a certain point, the nation attempts to invest in mitigation measures for the betterment of the environment (if society is fully aware of the environment and the new technology). In general, the idea of EKC assumes that environmental degradation has no effect on economic growth (Stern 2004). Koop & Tole (2001) and Mather (2007) confirm the effect of national economic growth on tropical deforestation. Scrieciu (2007) and Barbier & Burgess (2001) conclude that national income's effect on deforestation varies from region to region.

Several experts often argue the fate of developing and poor countries through the viewpoint of EKC. As EKC shows that economic growth is the only possible way to retard deforestation when will they achieve enough income per *capita* to reach turning point? However, Munasinghe (Munasinghe 1995, Munasinghe 1999) has hypothesized a tunnel through the EKC which will help developing countries to attain a lower turning point by adopting measures from the developed ones (Fig. 3). He has shown three possible paths of economic development aligned with the environmental damages. Among them, an economy should look for an optimal path through which it will avoid severe or moderate distortions of its environment (Fig. 4).

EKC for deforestation

People use forest products at the early stage of development, but after a certain rise in income per *capita*, forest products are replaced with some other alternative products that do not exert any harm to the forest (Culas 2007). Higher population growth and the consequent agricultural expansion significantly cause deforestation and this trend can be halted through vertical development of agriculture and constructing socio-political institutions (Laurance 2007, Rudel et al. 2005, Rudel et al. 2010, Culas 2007). This development of agriculture can go forward at some point of increased national income. These are the basics of EKC consideration in deforestation. The idea depends on several factors. Forest biomass fuels, especially firewood collected from forests, have been found to be universally dominant, especially in rural areas of the developing countries (Balat & Ayar 2005). In many countries, household income has been found to be the major driving force for determining the type of preferred energy carrier. (*e.g.*, Gupta & Köhlin 2006, Heltberg 2004, Joon et al. 2009). In addition to this, "Energy Ladder Hypothesis" shows how the households shifts from using apparently dirty fuels to efficient clean fuels with the improvement of socio-economic conditions, especially income (Alam et al. 1998, Davis 1998, Leach 1992, DeFries & Pandey 2010). Thus, fuel-wood use is assumed to be reduced with increasing income per *capita* by replacing it with modern energies, *e.g.*, gas, electricity, etc. Amount of timber used in furniture, house building or other chores will be reduced with the substitution of wood composite materials, alternative reinforced building materials and the like (Barbier et al. 2010, Lambin & Meyfroidt 2010). Another fact is that both the government and private sectors can induce several afforestation programs and make them successful if GDP/income per *capita* is above a certain level. The successful reforestation program in the Republic of Korea and the recent afforestation/reforestation success in Vietnam corroborate this statement (Brown 2006, Chun 2002, KFS 2006, Meyfroidt & Lambin 2008). Furthermore, with increasing income per *capita*, education and awareness about the environment will also increase, which will in turn help reduce the rate of deforestation. However, all of these factors should be considered to contain uncertainties.

Shafik & Bandyopadhyay (1992) first did an empirical study on deforestation in 1992. In 1976, Samuelson had hypothesized an EKC relationship with respect to forestry and conservation in a seminal paper on the economics of deforestation (Bhattarai & Hammig 2001). However, Shafik & Bandyopadhyay (1992) yielded no statistically significant evidence for EKC, which means there was a positive relationship between income per *capita* and deforestation. Tab. 1 shows the different EKC studies for deforestation mostly cited by Winslow (2005). They studied data for 66 countries using a log linear model. Their study considered data produced between 1962 and 1986. Shafik (1994) yielded the same result as Shafik & Bandyopadhyay (1992) for deforestation using Quadratic, FE model. Bhattarai & Hammig (2001) conducted a vast study of EKC for deforestation in 66 tropical countries. A quadratic RE model to estimate those aggregated data provided no statistically significant support for an inverted U-shape EKC. When they studied data (using cubic, FE and RE model) of 31 countries in Africa, they found a turning point from which deforestation decreases. This peak was at an income per *capita* of US$ 1300. However, there was another turning point from which deforestation began to increase again. This trough point was at an income per *capita* of US$ 5000. One experiment, however, was particularly revealing for EKC in relation to deforestation. A cubic FE and RE model for the data of 20 countries in Latin America has shown a turning point in deforestation at US$ 6600. Koop & Tole (1999) studied the facts for Latin America in a Quadratic, FE model and found a turning point at an income per *capita* of US$ 8660.

Barbier & Burgess (2001) conducted a vast study on the tropical deforestation of Africa, Asia and Latin America. They studied deforestation by tropical agricultural land expansion. The study encompassed data from 1961 to 1994. They studied both FE and RE models and then added three additional institutional variables: corruption index, property rights index, and political stability index. For all tropical countries, they found income per *capita* US$ 5445 as a turning point, while for Asia in particular, it was US$ 1815 and for Latin America, US$ 4946.

Cubic models have given optimistic results for EKC in some cases, while most Quadratic models have not. In many observations, deforestation has not shown any supporting evidence for the full trajectory of the EKC (Shafik & Bandyopadhyay 1992, Shafik 1994, Koop & Tole 1999). The reason for this may be that the per *capita* income of the observed countries is at the first stage of EKC, when degradation increases with increasing income per *capita*. According to Koop & Tole (1999), empirical results indicate that a significant EKC exists in the simple regression, but is gradually lost when the conditions are freed up. Tests also strongly indicate that less restrictive specifications are favored by the data. However, Bhattarai & Hammig (2001) conducted another study in Africa with less than optimistic results. They found a peak at income per *capita* of US$ 5000. However, the cases which were not found proven to have the statistically significant full trajectory of EKC, might be due to presence of income

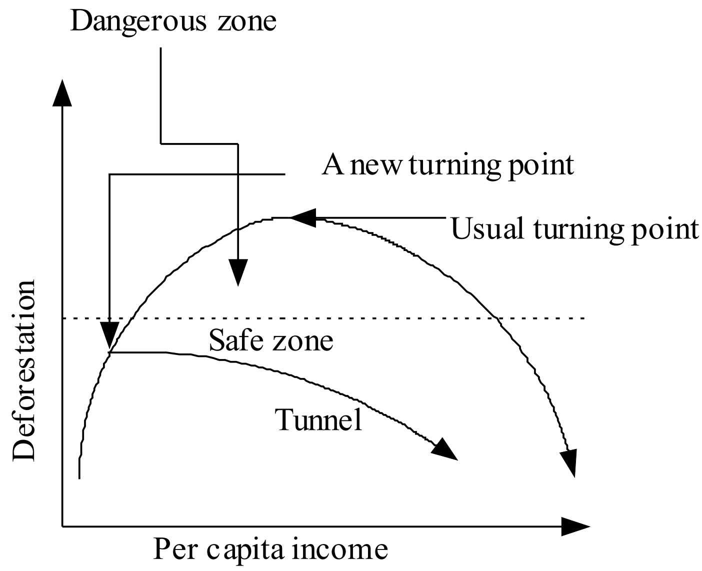

Fig. 3 - Tunneling through the Environmental Kuznets Curve.

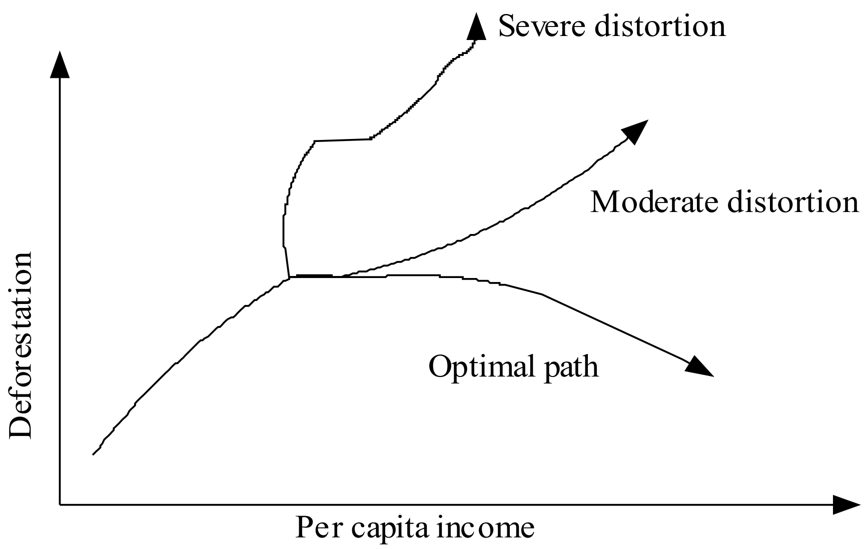

Fig. 4 - Alternative path of development to reduce environmental damage.

Tab. 1 - EKC studies for deforestation. FE and RE means Fixed effect and Random Effect model, respectively.

References	Countries/ cities	Time period	Model	EKC Result	Turning point(s)
Shafik & Bandyopadhyay 1992	66 countries	1962-1986	Log linear	Various	No statistically significant result
Shafik 1994	47 cities in 31 countries	1972-1988	Quadratic, FE	Various	No statistically significant result
Bhattarai & Hammig 2001	20 countries from Latin America	1972-1991	Cubic, FE and RE	Inverted U-shape	US$ 6600
Bhattarai & Hammig 2001	31 countries from Africa	1972-1991	Cubic, FE and RE	N-shape	Peak at US$ 1300 and Trough at US$ 5000
Bhattarai & Hammig 2001	66 tropical countries	1972-1991	Quadratic, Random coefficients model	Various	No statistically significant result
Koop & Tole 1999	Latin America	1961-1992	Quadratic, FE	Inverted U-shape	US$ 8660
Koop & Tole 1999	Latin America	1961-1992	Quadratic, RE	Various	No statistically significant result

per *capita* in the first-stage of EKC. In the RE model, lack of incorporating some important determinants might cause the deviation.

Economic growth and deforestation in Bangladesh

In June 2009, the population of the country was about 156 M, with a growth rate of 1.3%. Seventy-seven percent of the total population lives in rural areas (USCB 2009). Bangladesh is a country with a developing economy. Economic growth influences urbanization of rural areas in the developing countries (Cohen 2001). In Bangladesh, total urban population in 2009 was 27.6% and it has been projected to reach at 56.4% in 2050 (DESA 2010). It shows a decrease in rural population in 2050. Average annual rate of change of urban population in the period 1975-2009 was 5.15%, which has been projected to reduce at 2.52% in the period 2009-2050. Whereas, average annual rate of change of the rural population has been projected to -0.47% in the period 2009-2050. The rate of urbanization in 1975-2009 was 3.03%, which has been projected to reduce at 1.75% in the period 2009-2050 (DESA 2010). With the increase of urban population and the reduction of rural population along with the reduction of urbanization rate in the period 2009-2050, show a long run effect of retarding deforestation. DeFries et al. (2010) also support this phenomenon. It has been recently observed in the neighboring country, India (DeFries & Pandey 2010). However, environmentalists are concerned about the present increasing environmental degradation in Bangladesh. The country is under severe threat of climate change and forest biodiversity loss. According to the IPCC and Bangladesh Climate Change Strategy and Action Plan 2008 (IPCC 2007, MoEF 2008), Bangladesh will be among the worst-affected countries of climate change in the world. The macro-economy in Bangladesh can show the movement of environmental degradation through the EKC. The following sections aim at discussing this.

Macro-economy in Bangladesh

Bangladesh is one of the thirteen countries that have the potential to grow faster in their economy (ADB 2009). It has more than tripled its GDP in real terms and food production has increased three-fold (MoEF 2008). Observing the trend of last twenty years, it is assumed that the country will become a middle-income country by 2020. In three out of the last five years, the economy has grown at 6% and over (Fig. 5 - CIA 2008). The economic survey of Bangladesh (GOB 2000a) states that though a decrease in growth rate has been observed in some years, growth is continuing nonetheless (Tab. 2). For a developing country with this GDP growth rate, Bangladesh is defying the impact of the global economic fallout (ADB 2009) and ranked 68th in World ranking in the CIA World Fact Book (CIA 2008). ADB (ADB 2009) reported that the global center for economic activity is already being shifted to India, China and other large emerging economies, and that Bangladesh must make all efforts to capitalize on its comparative advantages to benefit from this global paradigm shift (GOB 2000b).

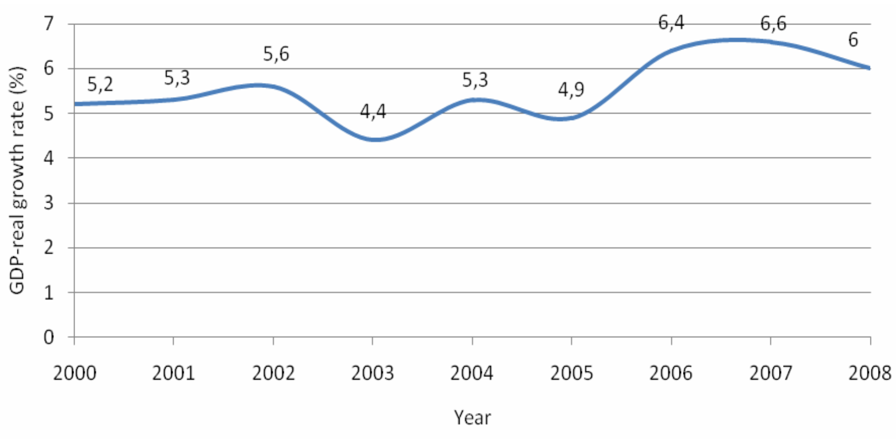

Fig. 5 - GDP real growth rate of Bangladesh from 2000 to 2008.

Considering the hypothesis along with the global observation of EKC and the growth trend of the national income of Bangladesh, it is now clear that Bangladesh is going to face a severe threat of environmental degradation in the upcoming years or decades. From the studies of EKC in the developing countries, it is assured that environmental complications will be relentless, until the peak point is achieved. However, economic growth and development are also important. The prime task will be to curb the upcoming environmental threats. The urbanization trend of Bangladesh suggests that retarding deforestation cannot be expected immediately. The literature review of the observations of the EKC hypothesis for deforestation in many regions and countries shows that to reach the turning point, Bangladesh needs to go far at its required income per *capita*. Some cases in which an N-shape EKC existed were also observed. In these

Tab. 2 - Growth trend of real Gross Domestic Product (GDP) in Bangladesh during 1975-2000 (at 1984/85 prices).

Year	Real GDP (millions of taka)	Growth Rate (%)
1975-76	293820	5.7
1976-77	301670	2.7
1977-78	323010	7.1
1978-79	338520	4.8
1979-80	341300	0.8
1980-81	352880	3.4
1981-82	357220	1.2
1982-83	374700	4.9
1983-84	395030	5.4
1984-85	406930	3.0
1985-86	424590	4.3
1986-87	442340	4.2
1987-88	455130	2.9
1988-89	466610	2.5
1989-90	497530	6.6
1990-91	514440	3.4
1991-92	536190	4.2
1992-93	560230	4.5
1993-94	583840	4.2
1994-95	609790	4.4
1995-96	642440	5.3
1996-97	680210	5.9
1997-98	718670	5.7
1998-99	756120	5.2
1999-2000 (provisional)	801710	6.0

cases, halting deforestation occurs for the time being and a subsequent increase in income per *capita* again degrades the forests. However, if we are to wait for that standard turning point, the forest ecosystem in Bangladesh may be irreversibly degraded. It would be best to follow the alternative routes (Fig. 3 and Fig. 4). Oestreicher et al. (2009) conclude that several surveillance measures with greater funding and proper governance are critical to slowing deforestation. Santilli et al. (2005) and Culas (2007) confirm that adequate funding of programs for enforcing environmental legislation, finding alternative livelihoods for the forest-dependent people, and alternatives to massive forest clearing and capacity building for dealing with the remote forest regions are critical to reducing deforestation. Over-population indirectly results in deforestation and forest degradation due to poverty (Salam et al. 1999). Some economic mechanisms can transform this poverty and peoples' attitude, which can in turn reduce deforestation. To this end, this paper suggests that Clean Development Mechanism (CDM) and Reducing Emissions from Deforestation and forest Degradation (REDD+) can work towards forest transition. However, this paper assumes that CDM and REDD+ are only parts of a whole forest transition process in Bangladesh, which this paper focuses on. These two mechanisms can be useful to construct an alternative path in the EKC in Bangladesh. The following sections brief on these mechanisms.

CDM as a flexible mechanism

Article 12 of the Kyoto Protocol introduces the CDM, originally a part of AIJ (Activities Implemented Jointly). CDM projects typically involve Annex I Parties as investors and Non-Annex I Parties as hosts, and are essentially joint ventures between developed and developing countries. Emission reductions resulting from these projects, beginning in the year 2000, count towards satisfying an Annex-I Party's obligations to reduce aggregate emissions during the years 2008 to 2012 (first commitment period).

Silveira (2005) discusses the role of CDM in respect to sustainable development, formation of carbon markets, and promotion of bioenergy options. His study concludes that bioenergy projects are attractive and CDM provides a complementary bridge for international cooperation towards sustainable development. Sustainable forest production is at the core of the afforestation/reforestation CDM projects (Khatun et al. 2010). In this respect, plantation with CDM projects can work better as the source of bioenergy production, which will ultimately reduce the rate of deforestation. Ravindranath et al. (2006) and Reddy & Balachandra (2006) conclude that a woodfuel stove project with the improvement of traditional stoves can be put on the international "carbon market" at competitive cost for GHG emission reduction. They also confirmed that improved cooking stoves would release pressure on the forests. Teixeira et al. (2006), for three A/R CDM projects developed in Brazil, demonstrate that CDM projects have a significant potential impact on local and rural development in Brazil. They have the potential to promote the sustainable use of forestry and soil resources. Klooster & Masera (2000) argue for Mexico that adequately designed and implemented community forestry management projects (proposed as CDM project) can avoid deforestation and restore forest cover and forest density. They comprise promising options for providing both carbon mitigation and sustainable rural development. However, forest management and conservation (slowing deforestation) as well as carbon sequestration in agriculture are not allowed in the first commitment period of the CDM. CDM projects are expected to usher in sustainable development in the Non-Annex I Parties. The development must be in the social, environmental and economic arena of a country. The possible carbon sequestration, biomass combustion efficiency and carbon substitution projects are expected to impact the overall well-being of the host country in many ways.

REDD+ to slow down deforestation

Receiving GHG benefits from the slowing deforestation, the 2007 COP (Conference of the Parties) 13 in Bali made reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) a central topic of discussion. The same was true of the 2008 COP 14 in Poznan. The mechanism has not come into force yet, as negotiations are ongoing. However, it is expected that REDD+ will be the central forestry activities (slowing deforestation) in the tropical developing countries after 2012 (Skutsch & Trines 2008). The financial incentives for REDD+ in the pilot projects established in tropical and sub-tropical areas of Asia, Africa and South America have been found to alter the drivers of land use changes by reducing opportunity costs of retaining forest cover, and are often promoted as multifaceted solutions that not only generate profits and reduce carbon emissions, but also provide benefits for human development and biodiversity (Carlson & Curran 2009). India and Costa Rica have already had success with programs to restore their forests and they feel they should receive compensation for these early conservation efforts (Trivedi et al. 2009). The Democratic Republic of the Congo has large areas assigned to logging concession and is keen for REDD+ to support sustainable forest management (UNFCCC 2007). Stickler et al. (2009) found that nations in the Amazon region can potentially participate in REDD+ by slowing clear-cutting of mature tropical forests, slowing or decreasing the impact of selective logging, promoting forest regeneration and restoration, and expanding afforestation/reforestation. Possible REDD+ program interventions in a large-scale Amazon landscape indicate that even modest flows of forest carbon funding can provide substantial co-benefits for aquatic ecosystems, but that the functional integrity of the landscape's myriad small watersheds would be best protected under a more even spatial distribution of forests. As ecosystem services derived from REDD+ projects will have a global interest, it could access a large pool of global stakeholders willing to pay to maintain carbon in forests. Calling for low-biomass Indian forests, Singh (Singh 2008) confirms that appropriately designed community-based forest management under REDD+ can provide a means to sustain and strengthen community livelihoods and at the same time avoid deforestation, restore forest cover and density, provide carbon mitigation and create rural assets.

However, before adopting REDD+ as an

effective deforestation-reduction mechanism, decisions on the nature of carbon buyers and sellers, financing mode, compensation scheme, and type of land use to be targeted should be made (Oestreicher et al. 2009). However, good governance and political will are also important to make this program successful (Melick 2010).

Bangladesh, a non-Annex I Party, ratified the Kyoto Protocol on 22 October 2001. Therefore, Bangladesh is eligible to be a host country for CDM and the expected REDD+ activities. Furthermore, Bangladesh signed the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1973; UNFCCC in 1992; and the Convention on Biological Diversity (CBD) in 1992. It is a signatory to the Ramsar Convention and the World Heritage Convention. The Bangladesh Wildlife (preservation) Act, 1974; the Forest Act, 1927 (amended in 1989); the Fish Act, 1950; and the Environment Protection Act, 1995, provide legal support for forest and biodiversity conservation in Bangladesh. The present "National Forest Policy 1994" also supports the mass reforestation activities throughout the country. However, it is necessary to adjust or pinpoint the objectives of the forest policy, national renewable energy policy, and national energy policy, all of which should be compliant with the biodiversity conservation of the forests and thus reduce GHGs.

Although the present national forest policy covers retarding deforestation and biodiversity conservation (Muhammed et al. 2008), it does not have any openings for accepting economic flexible mechanisms like CDM and REDD+. In the global climate-change perspective, Bangladesh forest policy should be reoriented to mitigate the climate change retarding deforestation. The present "Renewable Energy Policy 2008" of Bangladesh has an important objective of promoting clean energy for CDM (GOB 2008), but there are no strong guidelines for CDM activities. As the CDM forest can give birth to huge carbon credit (Silveira 2005), the attitudes of the rural peoples can be altered towards maintaining the sustainability of the forest biomass through the encouragement of small-scale CDM in the homestead forests. The present renewable energy policy has marked the importance of biomass for producing electricity through biomass gasification. This importance can be linked with CDM. As carbon sequestration and carbon substitution are the most important approaches for mitigating climate change (Shin et al. 2008), sustainable production of biomass and its conversion to secondary clean energy, *i.e.*, electricity, can be useful for both the economic development of rural livelihoods and environmental amelioration. The most useful form of commercial energy is electricity, which can be produced from both renewable and non-renewable resources. The present "National Energy Policy (Draft), 2008" should emphasize the use of renewable resources for producing electricity. Of these renewables, biomass has the added advantage of being able to be set up on a small scale to provide power and electricity to villages and small clusters or on a large scale for electrical power generation to be fed to the national grid. Thus, there is a need to produce woody biomass not only as fuel but also as a means to address climate change-related issues and socio-economic problems.

To retard the deforestation/degradation of the forestlands, governance is a key issue (Shin et al. 2008). The elimination of corruption in the forest department and ensuring political commitment to preserving the forests is vital in order to achieve the effective implementation of policy and strategies. Governance in the arena of bridging gaps between policy, science and practice, is also important. Various regulatory policies and measures in force in the country are often too vague to be of much use in actual practice and leave a great deal of scope for interpretation and therefore their abuse through legal loopholes. These policies, rules and regulations should therefore be examined closely for such loopholes. Sufficient explanatory clarifications should be provided and guidelines should be more clearly laid down. A case in point is the national energy policy needing to take the issue of GHG mitigation more seriously. Resolution of intersectoral conflicts among the forestry, agriculture, environment, land, wildlife and energy sectors is another important governance issue. There is a serious gap in terms of coordination between economic and environmental objectives. The gap is more serious in the case of the understanding and coordination of the linkages between GHG abatement activities and measures. Filling this gap is of immense importance for retarding deforestation through the undertaking of CDM and REDD+ activities in Bangladesh.

Conclusion

A literature review shows a significant number of cases proving the EKC trajectories for deforestation. However, this study found higher per *capita* income as the turning point. The trend of economic growth and urbanization suggests that Bangladesh has far to go before it may reach this turning point where deforestation will be retarded. Hence, the study supports its hypothesis that Bangladesh is presently at the initial up-facing stage of EKC for deforestation. However, the economy of Bangladesh is growing. In order for the turning point for halting deforestation in Bangladesh to be shortened, a tunnel in the EKC has to be made. The discussions show that CDM and REDD+ can be effective mechanisms for making this tunnel. Reorientation of the national forest policy, national renewable energy policy and national energy policy would be favorable for retarding deforestation in Bangladesh. Furthermore, good governance in the country has been emphasized as a vital component in the development of deforestation-halting activities. The findings of this study would be relevant for both forestry development in Bangladesh and global climate change mitigation.

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