Chapter 13
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Surface Water Nitrogen Load Due to Food Production-Supply System in South Asian Megacities: A Model-based Estimation

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ABSTRACT

Food production and supply system contributed more than 90% of the nitrogen originated in south Asian megacities that pollute the surface water. Five megacities of three South Asian countries were considered in this study. These countries are developing and their population is increasing tremendously. All the five megacities are very densely urbanized. A numerical model has been used to calculate the anthropogenic nitrogen load on the environment. FAO statistics on fertilizer consumption and food balance data sheet has been used to calculate the nitrogen load. Human waste plays the vital role in nitrogen production of south Asian megacities. So, in these contexts the nitrogen load for all the study areas extremely harmful for environment and ever increasing population also increased the load of nitrogen on surface water produced from human waste which also very awful for the environment. So, a proper sewage treatment facility is compulsory for all the study areas. Four findings has been identified are; (1) for all three countries, rice and wheat production-supply produce the maximum amount of nitrogen. (2) Though the amount of nitrogen due to fertilizer input more or less same among the countries but amount of produced nitrogen due to human waste is huge in Bangladesh. (3) Moreover, in city scale, the amount of nitrogen due to fertilizer input is maximum in Delhi city and negligible in Kolkata due to an insignificant amount of farmland. (4) Interestingly, the maximum amount of nitrogen load in surface water is in Kolkata city due to human waste but Mumbai and Dhaka shows a medium amount of nitrogen load. This can give the estimation for city wise untreated nitrate content and this is necessary for the capacity development of existing sewerage treatment plant as well as the establishment of new plants.

Keywords: Nitrogen load; South Asia; megacities; numerical model; water pollution.

1. INTRODUCTION

South Asian countries are the densest areas over the world [1]. Population growth rate also increased over the years [2]. Increased population requires high agricultural production. For the world as a whole, per-hectare output of cereals, which account for more than half the food people eat if the grain fed to livestock is factored in, had risen by the late 1990s to 3.0 metric tons, which was double the average yield in the early 1960 [3]. High yielding variety with excessive use of pesticides and fertilizer enhance the agricultural production and meet the excessive demands. Overuse of fertilizer and pesticides affect the environment. Sometimes alter the ecological balance and chemical cycles. In many developing countries there are many fertilizer management technologies suited to regional agricultural and socio-cultural structures, such as crop management knowledge models [4], N fertilizer models [5], leaf color charts (LCC) [6], and soil–plant analysis development (SPAD) [7], but adoption rates are very low. Fertilizer contains nitrogen which also affects the nitrogen cycle in both micro and macro level. Eutrophication followed with excessive nitrogen use. This nitrogen pollution transmitted to the surface water and finally seepage to groundwater. To quantify the effects of anthropogenic

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nitrogen load, this research has been modeled at country and city scales. In South Asia, currently the main origin of anthropogenic nitrogen is Food production and supply [8, 9, 10, 11, 12]. Future scenarios based on past trends coincide with assumptions on increased animal protein consumption, while population increase alone cannot explain the projected demand. If this scenario happens, it will imply massive losses of reactive N to the environment, with eutrophication, loss of biodiversity, air pollution via higher NO_x and NH_3 emissions, water pollution, soil acidification, and emission of N_2O [13].

The Rapid urban growth of the megacities deteriorates water quality simultaneously [14, 15, 16]. Pollutants increase over the years due to urbanization which affects the pollution load to the surface and groundwater [17]. Discharge of domestic and industrial effluent wastes, leakage from water tanks, marine dumping, radioactive waste and atmospheric deposition are major causes of water pollution. Heavy metals that disposed off and industrial waste can accumulate in lakes and river, proving harmful to humans and animals [18]. Toxins in industrial waste are the major cause of immune suppression, reproductive failure and acute poisoning. According to United Nations, the probable economic cost of environmental deterioration due to water contamination is very rigorous in the South Asian region in terms of restoring the quality of life and installing controls [19]. In the context of the South Asian region, specifically in Bangladesh, India and Pakistan, nitrogen pollution has turn into more severe and critical near the urban areas due to high pollution loads discharged from urban activities. In this study, the authors try to evaluate the nitrogen load to surface water caused by farming and livestock production, food trade and human waste to clarify nitrogen flow and its effects on water quality for the year 2005 in 3 countries and their five megacities in South Asia.

2. DATA AND METHODS

2.1 Nitrogen Flow Model

This model calculates the flow of nitrogen due to food production and supply system (Fig 1). By following Shindo et al. (2003) [12] the nitrogen flow model has been used for the calculation of this research. In this model, magnitude of nitrogen flow estimated from the published statistics on fertilizer consumption and crop production and from food balance sheets for three South Asian countries and also for five megacities. The data were collected from the FAO (2005) [20]. Table 1 show the food list which is considered in the calculation. In the table, the protein contents and conversion factors from protein to nitrogen follows the “Standard Tables of Food Composition in Japan” [21].

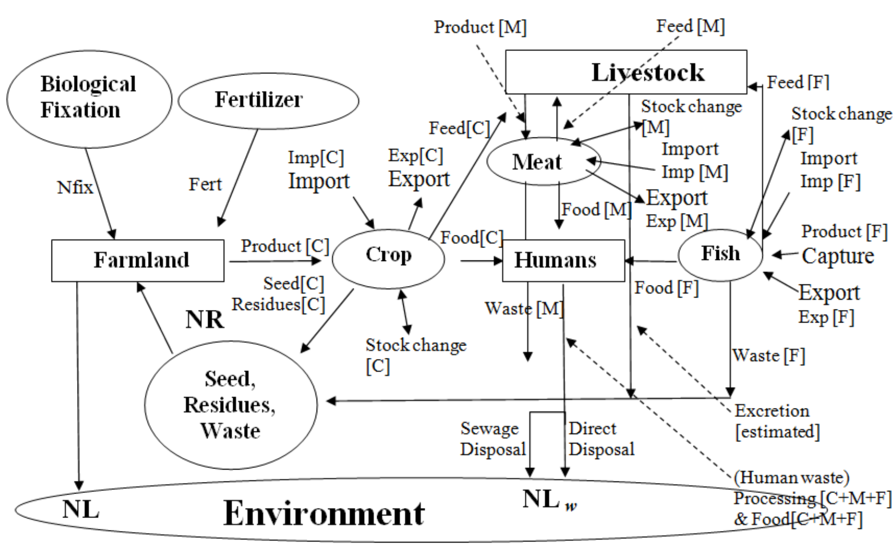

Fig. 1. Nitrogen flow in food production- supply system and environmental load
Source: [12]

In FAO food balance data [20], utilization and food supply are classified in to different items like, “production”, “imports”, “stock changes”, “exports”, “feed”, “seed”, “processing”, “domestic supply quantity”, “other uses”, and “food”. Shindo et al. (2003) described that the net food supply was calculated as “production”+ “imports”+ “stock changes”- “exports”. The authors assumed that “seed” and “other uses” were applied to farmland, “feed” was eaten by livestock and “processing” and “food” were used by humans. They also assumed that all crop residues, meat and fish are unused for food and feed were returned to farmlands. Nitrogen is taken out of farmlands by crop harvesting, and remaining nitrogen was considered to discharge from farmland to the environment (NLf). All nitrogen was considered to discharge from humans to the environment in human waste, food waste and food processing industrial waste (NLw). Some of These wastes can be treated through the sewerage system or septic tank. In Asia, only 35% of urban wastewater is properly treated by sewerage system and a large part of the waste directly discharged into the water without any treatment [22]. So, that value has been assumed for five megacities water treatment rate. Land use data with a spatial resolution of 1km*1km [23] was used to classify the farmland, forest and also calculate the total country and city area. The calculated values have been displayed by graph and map.

Table 1. Foods used in the nitrogen cycle model, their protein contents, and conversion factors from protein to nitrogen

Foods	Protein content (g/100g)	Factor for converting protein to N
Cereals		
Wheat	10.6	5.77
Rice	6.8	5.95
Barley	8.0	5.83
Maize	8.6	6.25
Rye	12.7	5.83
Oats	13.7	5.83
Millet	10.6	6.25
Sorghum	10.3	6.25
Other cereals	12.0	6.25
Starchy roots		
Cassava	1.6	6.25
Potatoes	1.6	6.25
Sweet potatoes	1.2	6.25
Yams	2.0	6.25
Other roots	3.0	6.25
Legumes		
Pulses general	22.0	6.25
Soyabeans	34.2	5.71
Oil crops excluding soyabeans	18.5	5.31
Vegetables	1.5	6.25
Fruits	0.7	6.25
Meat	18.1	6.25
Milk	3.0	6.38
Eggs	12.3	6.25
Fish and seafood	18.7	6.25

Source: [12]

3. RESULTS AND DISCUSSION

3.1 Country wise Nitrogen Budget

Fig. 2, 3 and 4 show the calculated nitrogen from the FAO Stat food supply data sheet in three South Asian countries. In Bangladesh the highest amount of nitrogen provided by rice production. Wheat, and fish, seafood also provided some nitrogen (Fig 2).

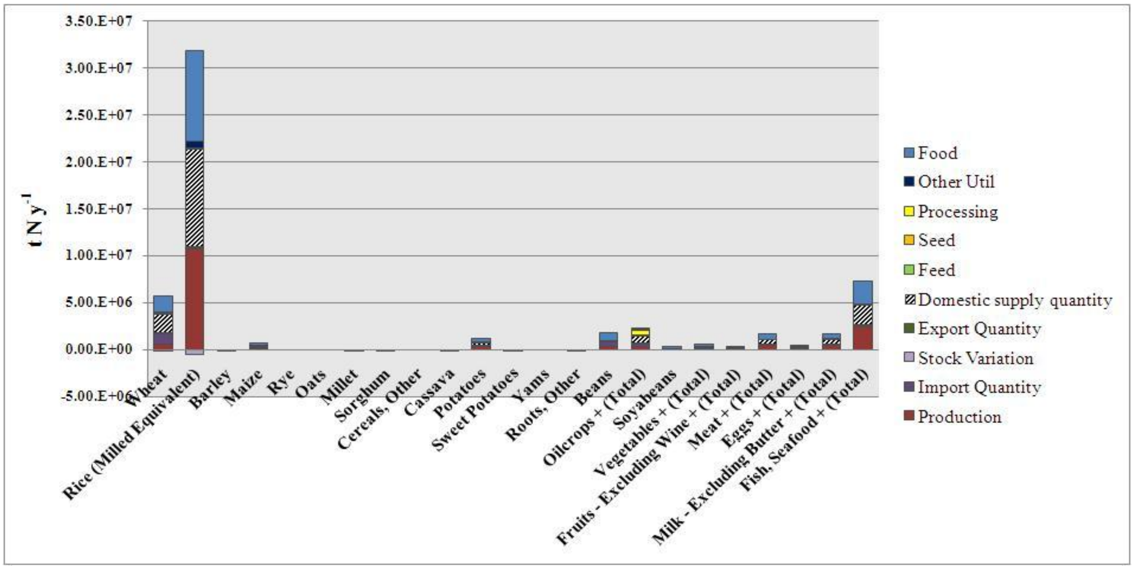

Fig. 2. Amount of nitrogen content due to food supply in Bangladesh (calculated from FAO data)

In India wheat, rice and oil crops provided a large amount of nitrogen. Other food like beans, soya beans, milk-excluding butter and fish, seafood also generate a large amount of nitrogen (Fig. 3).

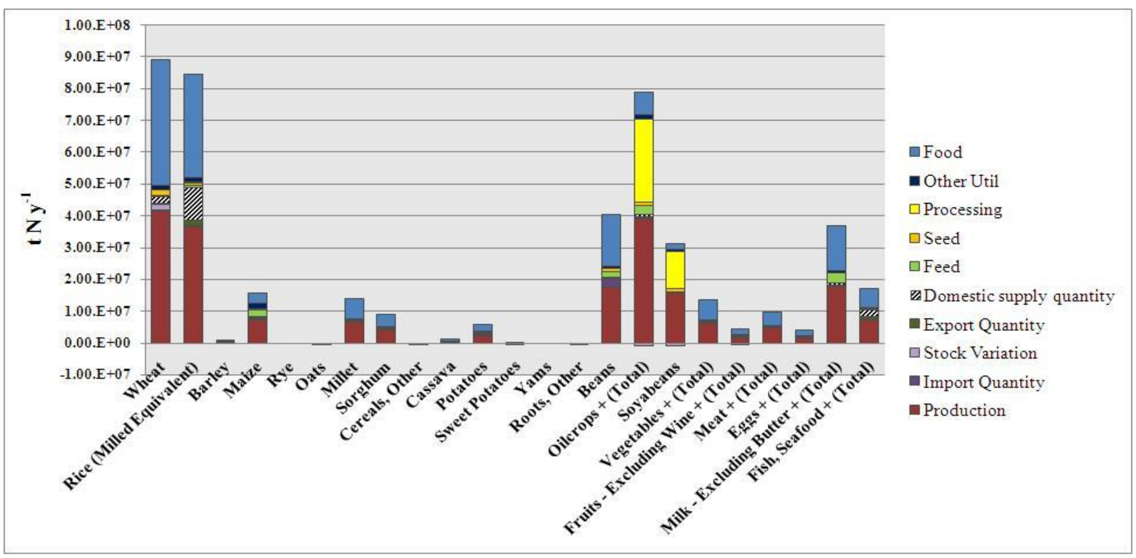

Fig. 3. Amount of nitrogen content due to food supply in India (calculated from FAO data)

In Pakistan, wheat, rice and beans, oil crops, soya beans, milk-excluding butter are the main contributor to nitrogen production (Fig. 4). For all country, food production sector contributes very high nitrogen compared to other sectors. The stock variation shows some negative value for some foods for every country.

Fig. 5 displays the calculated nitrogen budget due to the food supply, fertilizer input and human waste of three South Asian countries. Among the three countries, Bangladesh shows very high nitrogen load per square km compared to other two countries. These may be due to the small country area and large population burden since fertilizer input shows more or less similar in each country but a large amount of human waste in Bangladesh. These wastes discharged into the surface water and pollute the surface as well as groundwater. Calculated residues input for all the country shows negative result so we assume the result is zero.

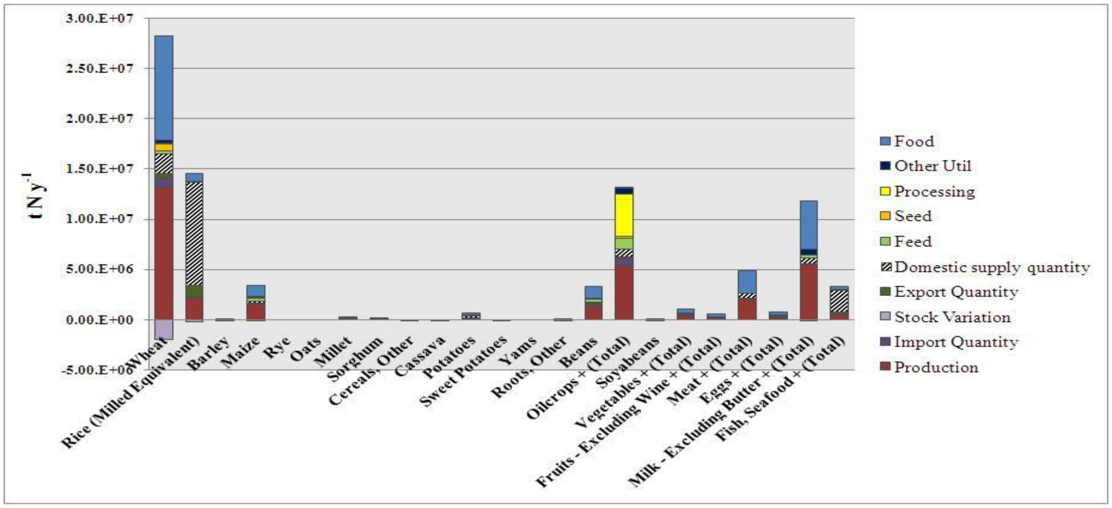

Fig. 4. Amount of nitrogen content due to food supply in Pakistan (calculated from FAO data)

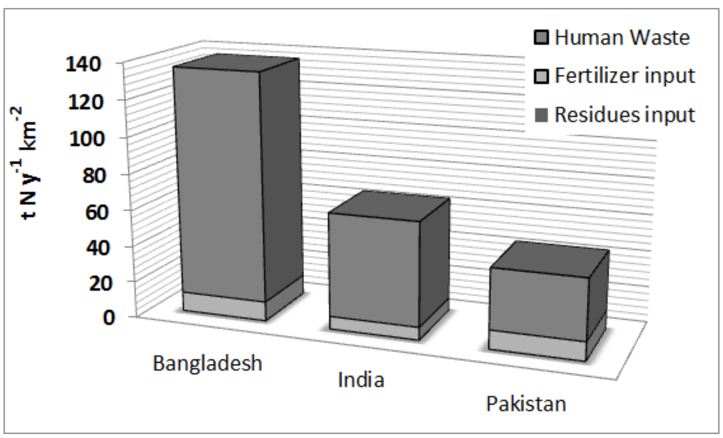

Fig. 5. Nitrogen budget due to agriculture and food supply in three south Asian countries

3.2 Spatial Distribution of Nitrogen

After calculating the country scale nitrogen load the model is used for calculating the five megacities nitrogen load. The three studied country and their five megacities are displaying in Fig 6. Circle of the Fig.6 displays the amount of nitrogen due to fertilizer input. Surface water of Delhi city receives the maximum amount of nitrogen due to fertilizer input. In Kolkata city total amount of farmland area is negligible so the amount of fertilizer input also negligible and the calculated nitrogen load displays negative value. The second large value of nitrogen load display in Karachi city, Dhaka and Mumbai city display less than one ton of nitrogen per km square area.

3.3 Nitrogen Load to Megacities and Concentrations in Surface Water

Among the five megacities, Kolkata city shows a large amount of nitrogen due to human waste. These may be due to the small area and very vast amount of population growth (Fig. 7). This nitrogen directly discharged into the surface water, so the amount of nitrogen per sq. km for all the cities excluding Karachi is excessive. In total nitrogen, all the country shows a very high amount of nitrogen due to human waste. Because all the five cities are megacity and their population also more than ten million so human wastes are increasing gradually. These excessive human wastes increase the nitrogen load in the water. These scenarios will turn in to more severe because of the increasing rate of population.

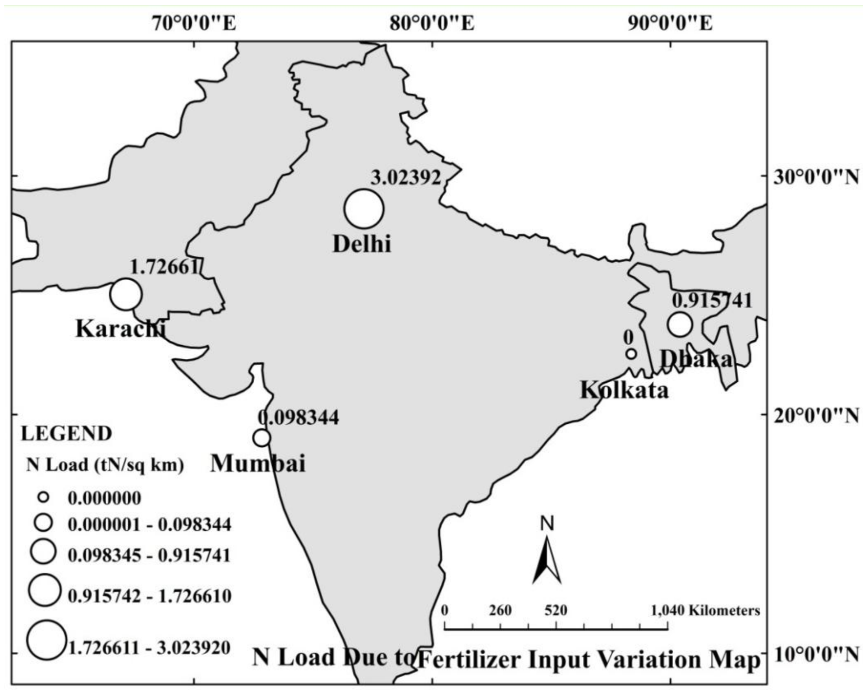

Fig. 6. Nitrogen load (tN km^{-2}) due to fertilizer input in five megacities (0 indicate negligible amount of farmland)

Sewerage treatment facilities can treat the sewerage of less than 25% of the city dwellers of Dhaka city [24]. Dhaka situated by the river Buriganga is one of the most polluted rivers in Bangladesh. Industrial untreated effluents, natural and human activities change the water quality properties. Dhaka also surrounded by three other rivers (i.e. Balu, Turag and Shitalakhya). Water quality of these surrounded rivers also deteriorated since the last couple of decades. Most of the industries have no effluent treatment plant and these industries release effluents without any treatment and a huge volume of toxic wastes released into Buriganga river day and night [25]. Dhaka city produces about 3500 to 4000 m tons of solid wastes per day now [24]. Pollutant release amount increases over the years.

The Yamuna is the major rivers of Delhi and has a social, economic and religious consequence for vast sections of the population. Domestic and industrial sewage generated within the Delhi is the main source of pollution of the river Yamuna during its course through the city. A number of fecal coliforms severely increased since last ten years. In March 2004, the estimated sewage generation was about 719 MGD but Government of Delhi provided sewage treatment capacity of only 512 MGD whereas actual sewage being treated was only 335 MGD. This amount represented only 47 percent of the total estimated sewage production [26]. The balance of 384 MGD discharges into the river without any treatment.

Hooghly river of Kolkata is used for different purposes from livelihood to industrial pollutants release and transportation. But BOD and DO found satisfactory that means the water is good for aquatic life. Besides, fecal coliform concentration found high in value (approximately 750000 MPN/100ml) which indicate that direct consumption this water without any treatment is unsafe for human [27]. All the open wells of wetlands are hydraulically connected with surface water that is biogenically polluted [27,28].

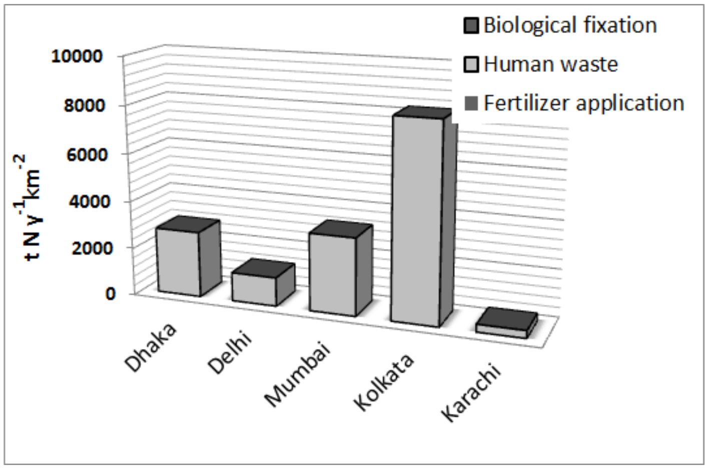

Fig. 7. Nitrogen load to the environment due to food supply, farmland and human excretion in five south Asian megacities

Drinking water of Karachi city is provided from Indus river at Kotri. Total nitrogen (Nitrate+ Nitrite) content found in the acceptable limit (3.078 mg/l) and not exceeds the standard of EPA (10mg/l) [29]. Besides, total nitrogen concentration found increasing trend in the coastal area and adjacent area and river water (Malir, Lyari river) due to urbanization. The Lyari river is the main transporter to an estimated amount of 909.218 million liters of raw sewage to the Arabian Sea [30].

4. CONCLUSION

In the entire region of South Asia, about 95% of the anthropogenic nitrogen input was due to agriculture and food supply. Nitrogen content can give a clear idea of nitrate pollution in surface water. In this study, nitrogen budget are calculated on the country basis. Besides, treated sewerage is excluded to calculate nitrogen in case of the city.

Four findings has been identified are; (1) for all three countries, rice and wheat production-supply produce the maximum amount of nitrogen. (2) Though the amount of nitrogen due to fertilizer input more or less same among the countries but amount of produced nitrogen due to human waste is huge in Bangladesh. (3) Moreover, in city scale, the amount of nitrogen due to fertilizer input is maximum in Delhi city and negligible in Kolkata due to an insignificant amount of farmland. (4) Interestingly, the maximum amount of nitrogen load in surface water is in Kolkata city due to human waste but Mumbai and Dhaka shows a medium amount of nitrogen load. This can give the estimation for city wise untreated nitrate content and this is necessary for the capacity development of existing sewerage treatment plant as well as the establishment of new plants.

From this model, it can give a good idea about the current status of nitrogen of three south Asian developing countries and their important megacities. It also can realize the effect on the environment due to this nitrogen load.

5. LIMITATION OF THE MODEL

Deficiency of accurate sewage treatment data is the main bottlenecks of this study. Some industry has own sewerage treatment plant and some has absent. Besides, the government also installed some that not capable for all. So, all the treatment facilities are not inventoried properly.

Because of the total city area, farmland and forest area calculated from land use data with the spatial resolution of 1 km* 1 km [23] so it may vary with actual area.

This study considers only food supply production and agricultural data, energy production is not included. As energy production has no prominent share for nitrogen production in South Asia. Even though, the inclusion of energy production data may give the more accurate budget. Nitrogen load to catchments and concentrations in river water also not included in this calculation.

6. FUTURE SCOPE

Energy production may include in the future model with other promising sectors. Data sources and sectors might be identifying for proper calculation. Future projection and its effect on the environment also be a new arena for this kind of study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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She serves for Geological Survey of Bangladesh (GSB) as Assistant Director. After her graduation from Department of Geology, University of Dhaka, she joined this organization and till now she serves the country as a geologist. She obtained her masters degree from hydrogeology and environmental geology stream from Dhaka University too and did a unique water quality assessment and hydrogeological characterization on third aquifer of Dhaka city. She did her second masters in Engineering Geology from University Kebangsaan, Malaysia (National University of Malaysia). There also she did an exceptional research on hydrogeology and hydro-geo-chemical comparison of Dhaka and three cities of Malaysia. She successfully completed a post graduation diploma from Hiroshima University, Japan as a Visiting Researcher. At that time she did an outstanding review work on five Asian megacities water quality, urbanization effect on water quality and trend analysis. In her career she also did some distinctive palynological and paleontological research to identify the paleoenvironment of the country and climate change. She also did a distance course on Systematic Paleontology from Missouri University of Science and Technology, USA. She has published more than thirteen articles, posters and conference proceedings in peer reviewed journals. She also authored a book, titled "Hydrogeology of the lower Dupi Tila Aquifer of Dhaka City Bangladesh, The hydrogeological and hydrochemical characterization".

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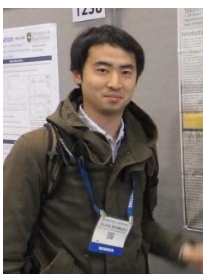

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