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A POLICY MEASURE FOR OPTIMAL WATER RESOURCE UTILIZATION AND ALLEVIATION OF SOCIO-ENVIRONMENTAL PROBLEMS IN THE TEESTA RIVER BASIN

M. Fakrul Islam and Yoshiro Higano

ABSTRACT

The water of many international rivers are not shared following formal intergovernmental agreement, ensuring highest benefit for the region as a whole because bilateral agreements often do not provide equitable and optimum economic benefit for both parties. This paper focuses on a bilateral optimum water-sharing model of international river water, citing the Teesta River which runs through India and Bangladesh, as a specific case. This input-output model, which determines the optimal share and its optimal use for economic activity, maximizes the welfare function, which is subject to bilateral trade and business, fixed water allocation agreement, etc., under a cooperative scenario. If the agreement can satisfy the condition for maximum joint benefit, the parties would work together to maintain the the functional integrity of river's eco-system and environmental balance of the Teesta basin area. Moreover, this policy prescription would help to endure treaties of bilateral water sharing and trade between the two countries.

Introduction

Throughout the world, with the expansion of human needs and economic activities, multifaceted use of freshwater resources has increased and the adoption of different types of strategies and competition in these regards has begun. Man-made barriers on natural water flow have made the global environment very vulnerable; stronger parties violate the rules and regulations of international law creating complicated situations. In many cases, conflicts arise from unequal competition. Some of these conflicts become complex and linger for a long time, creating barriers in the implementation of the principles of equitable and optimal water allocation (Wolf 1998). Sometimes treaties are signed, but due to lack of appropriate guidelines for bilateral socio-economic benefit, those treaties do not work well. As a result, people increasingly manipulate the natural environment, threatening the quality and quantity of natural resources. Freshwater, especially, is a non-replaceable, scarce commodity, the need for which strains relationships between countries and nations (Smith 1931). As an example of sharing international river resources, both up and downstream, this paper focuses on the case of the Teesta River, which runs through both India and Bangladesh.

Foreigners, who see video pictures of Bangladesh, taken during June-September, may consider the Bangladeshis as a people who have an abundance of water (Chowdhury 1999). However, land and surface water sources begin to dry up in November. In March and April, the land becomes cracked and the ground water level drops significantly (Alam 1988) and the condition in the villages becomes quite opposite to the scene observed during the flood season.

Bangladesh is a riverine country with an agricultural economy. Since the 1950s, attempts have been made to modernize agriculture and to reduce dependence on nature. In the northern region of the country, in order to save a vast area of plain and fertile agricultural land from flood and drought, the Dalia Irrigation Project on the Teesta River was implemented and started operating in 1993, (providing irrigation water for only about 30% of the project area) (BWDB 1993). During the first five years of operation, agriculture production increased substantially. However, as a result of later problems, the operation of the project was stopped during the dry season. Thus, the largest irrigation project of the country, in which millions of dollars have been invested, has caused considerable economic loss and environmental concerns for the inhabitants of the Teesta basin area, not to mention its impact on alleviation of poverty through agricultural development.

Even with limited and unused natural resources, natural and man-made disasters and related problems, Bangladesh is continuing her efforts toward economic development by increasing agricultural production. As a part of this effort, the government of Bangladesh undertook and completed the Teesta Barrage Project which provides irrigation to boost agricultural production by bringing more land under cultivation during the dry season. However, the Gazoldoba Barrage built by India at 60 km (Teesta Barrage 1987), (The Daily Ittefaq 1998, 1999, 2000), upstream of the Teesta River (in Indian Territory) has

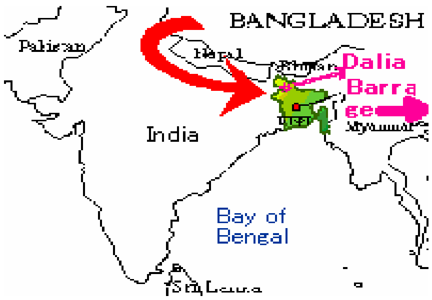

Figure 1 Map of India + Bangladesh and a view of the Dalia Barrage, Bangladesh.

made the Dalia Barrage project useless. In this regard, a brief history on the use of the Teesta water for economic purposes (for example, irrigation, navigation, productioin of electricity, etc.) needs to be discussed. Figure 1 shows a map of India and Bangladesh and a picture of the Dalia Barrage on the Teesta River, Bangladesh.

Thoughts regarding the utilization of Teesta water for irrigation purposes began during the British rule, before the partition of India. Later, India and Bangladesh implemented separate plans separately to use the Teesta water for irrigation and built two barrages on the river in their own territories (Islam & Higano 2000). However, the project implemented by Bangladesh, with a view to increase agricultural production, to a great extent, has now come to a point of closure, because of its downstream location and the scarcity of water in the dry season. Many bilateral meetings took place between the authorities of the two countries, but only in vain.

In this paper, therefore, an input-output model and a simulation model are discussed to examine the possibilities of water sharing. The paper also discusses the results of computer simulation for measuring the loss incurred by the withdrawal of water at the upstream of the Dalia Barrage and the bilateral water trade and business, and country-level transfer of water rights as alternative water allocation policies.

Review of Literature

Research conducted specifically regarding the optimal sharing and use of the Teesta River water in its basin area has not been found by the authors. However, the results of the studies found to be related to the present study are summarized below.

Dimitrios and Lekakis (1997) analyzed various aspects of policy models and suggested that in the case of surface water resources, which are gradually becoming more scarce, sustainable utilization implies the need for policies aiming to provide adequate water supplies for everyone in both national and international contexts.

They argued that many international river basis are shared without any formal intergovernmental agreement, while bilateral agreeements guaranteeing amicable cooperation are few in number. They presented a simple economic-ecological model within which they examined input-output controls., social input prices, bilateral water trade, a water market for all water users, and a fixed water allocation agreement as possible water policies for cross border water sharing. They also strongly argued that all of these policies could satisfy the conditions for maximum joint economic benefits while working toward maintaining the functional integrity of a river ecosystem. Their analyses indicate that bilateral water trade can prove a workable, efficient, and sustainable water policy for the transboundary water allocation of an international river.

Shaikh (1995), in his thesis, states that the Teesta river and its adjoining catchment areas are marked by variegated geomorphic process and forms. The flow of unstable nature, bank erosion and historical course shifting pattern, and siltation create land forms which appear to be the ideal field for his kind of study. He explains the hydro-geomorphic characteristics of the Teesta flood plain, such as water discharge, course shifting pattern, water level, duration of floods, sediment characteristics, and ground water conditions. His thesis was completed before the operation of the Gazoldoba barrage. Therefore, issues relating to water sharing were not discussed.

Schachter (1977) discusses "Equitable Apportionment of Freshwater Resources" to some extent. He emphasizes the concept of the "drainage basin," which implies integral development, giving a high priority to maximization of the benefits for the basin as a whole, by reducing wasteful uses and developing a comprehensive and unified scheme to be followed by all concerned. He also cited several points on the equitable use of the world's water resources from the report of the Fifty-Second Conference (1966) of the International Law Association held in Helsinki. These are quite important for the issues raised in this paper..

A very old book on international law, *The Economic Uses of International Rivers,* written by Smith (1931) is relevant to the current discussion. Smith presented cases of controversies related to using rivers (for economic purposes), which run through more than one state. The cases he discussed include the Meuse and its canals, the Zwillikon dam case, the, Rio Grande irrigation problem, apportionament of the Nile and 10 others. His conclusion was that "in the law of rivers there is no place for any purely legal doctrine derived from any single abstract principle, whether that principle be the absolute supremacy of the territorial sovereign or the old private law doctrine of riparian rights", (p.144). The author called upon all involved parties to realize that every river system forms an indivisible physical unit; they should do whatever needs to be done (e.g., agreements) to determine and ensure the maximum possible development of its resources and their equitable distribution among all concerned.

Wolf (1998), has shown, after analyzing relevant datasets, that, during the 20th century, no war, but " only seven minor skirmishes" had taken place, while 145 water-related treaties had been signed, signifying that shared interests outweigh conflicts over water. War over water, he concludes, seems, not to be economically viable, hydrographically effective, or strategically rational. International water induces cooperation rather than conflict that has been observed only in exceptional cases.

The Model

Skeleton of the Model

A framework must be drawn in order to conduct an analysis on the optimal policy to ensure the sharing of water, with the highest possibility of benefiting both the parties. The model is shown in Figure 2.

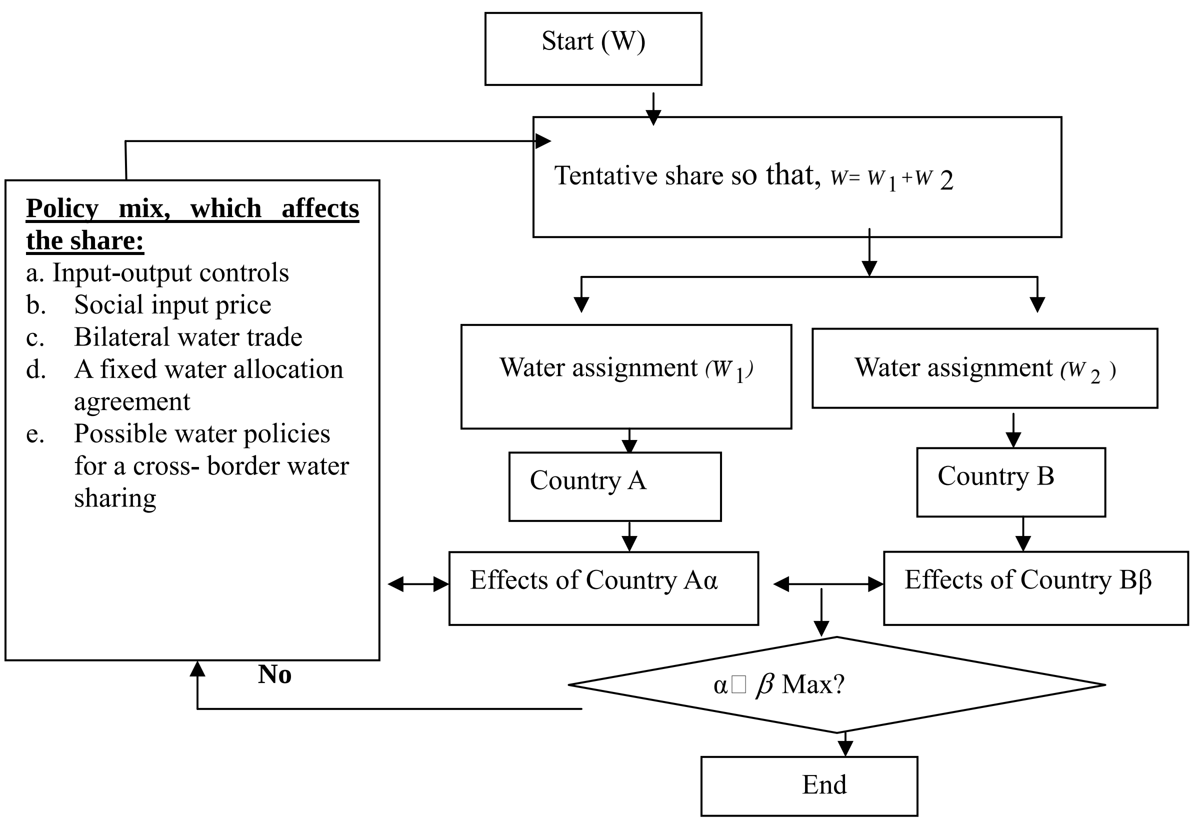

Figure 2 Skeleton of the Model

Basic Equations

Under consideration is an international river with a constant total water volume, W, shared by two countries, j = 1,2. In our example w = Teesta water resource and index (j) = India and Bangladesh.

The Teesta River originated in country 1 (India), flows through country 2 (Bangladesh), and falls to the Bay of Bengal. Teesta water supports various economic activities along the watercourses in both the countries.

The level of economic activity in India and Bangladesh depends on the level of the production inputs (such as capital, labour, machine) used, '*given*' the availability of water and its quantity. This can be shown as:

$$Y_{ij} = Y_{ij}\,(X_{ij};\, W_{ij}\,,\, Q_j\,), \tag{1}$$

where

Y_{ij} = the level of economic activity i in country j;

X_{ij} = the set of production inputs other than water used by activity i in country j;

W_{ij} = the flow of water in economic activity i in country j;

Q_j = quality of water in country j.

The semicolon represents the word *'given'* above.

As regards the economic activities, i assume two different sets of values

$i_1 = 1,\ldots m$ for country 1 and $i_2 = 1,\ldots.. n$ for country 2.

Although the primary interest is in the sharing of water between India and Bangladesh, sharing within each country is assumed to be exogenous (i.e., not immediately determined by this model) and generally given by the function;

$$W_{ij} = W_{ij}\ (W_j\,), \tag{2}$$

where, W_{ij} = the flow of water in economic activity i in country j.

In addition, the volume of water flowing to country 1, W_1, and the quality, Q_1 are also assumed to be exogenous.

$$Q_2 = Q_2\,(Y_{11},\ Y_{21}\ldots Y_{n,1};Q_1), \tag{3}$$

The next focus is inter-country water-quality issues. The economic activities of India have the privilege of accessing the stream first (W_1) and thus affect the water volume available to Bangladesh (W_2). From a given amount of water that may be diverted to a particular activity, some will be consumed by the activity, while some will be released back into the stream.

The part of the total amount of water diverted to activity i in India but not consumed by it is given by $\omega_{i1} = \omega_{i1}\ (W_{i1}, Y_{i1})$. As a result, the volume of water made available to Bangladesh (W_2), depends on how much water is used in India (W_1) and the amount of water used for the economic activities in that country which determines the level of output Y_1. This can be shown in the functional form,

$$W + \sum_{i=1}^{n_1} \omega_{i1}(W_{11,}Y_{i1}) = W_1 + W_2 \tag{4}$$

Where, ω_{i1} = released back water to the Teesta, after use other purposes like producing electricity.

Solution of the Model - Under a Cooperative Condition

If the countries under consideration cooperate with each other, the river water will be used in a way which would enhance joint benefits, and a solution to the model could be found, which also takes ecological issues into account. The solution can be derived from the optimizing problem shown below:

Equations for a Cooperative Solution

The objective function is to increase the sum of Gross Regional Production in India and Bangladesh:

$$\Phi = \sum_{j=1}^{2}\sum_{i=1}^{n_j}(P_{ij}Y_{ij} - r_{ij}X_{ij}), \tag{5}$$

where P_{ij} and r_{ij} are the prices of outputs Y_{ij} and inputs X_{ij} respectively.

The reduced form of the objective function without constraints can be derived as follows using equations (1), (2), (3) and (4);

$$\sum_{i=1}^{n_1}\{P_{i1}Y_{i1}(X_{i1};W_{i1}(W_1),Q_1)-r_{i1}X_{i1}\}+\sum_{i=1}^{n_2}\ \{P_{i2}Y_{i2}(X_{i2};W_{i2}(W+\sum_{\mathrm{i}=1}^{\mathrm{n}_1}\omega_{\mathrm{i}1}(W_{i1},Y_{i1})-W_1),$$

$$Q_2(Y_{11}Y_{21}....,Y_{n,1};Q_1))-r_{i2}X_{i2}\}.. \tag{6}$$

$$\to MAX$$

$$\{X_{i1},X_{i2},W_1\}$$

The first order condition for the maximum joint benefits with reference to the water sharing in India is given by:

$$\sum_{i=1}^{n_1}P_{i1}\frac{\partial Y_{i1}}{\partial W_{i1}}.\frac{\partial W_{i1}}{\partial W_1}-\sum_{i=1}^{n_2}P_{i2}\frac{\partial Y_{i2}}{\partial W_{i2}}.\frac{\partial W_{i2}}{\partial W_1}+\sum_{i=1}^{n_2}P_{i2}\frac{\partial Y_{i2}}{\partial Q_2}\left\{\sum_{k=1}^{n_1}\frac{\partial Q_2}{\partial Y_{k1}}.\frac{\partial Y_{k1}}{\partial W_{k1}}\frac{\partial W_{k1}}{\partial W_1}\right\}=0, \tag{7}$$

in which

$$\frac{\partial W_{i2}}{\partial W_1}=\frac{\partial W_{i2}}{\partial W_2}\left\{\sum_{i=1}^{n_1}\frac{\partial \omega_{i1}}{\partial W_{i1}}.\frac{\partial W_{i1}}{\partial W_1}-1\right\}. \tag{8}$$

With reference to the production inputs used in India:

$$P_{i1}.\frac{\partial Y_{i1}}{\partial X_{i1}}-r_{i1}+\sum_{k=1}^{n_2}P_{k2}\frac{\partial Y_{k2}}{\partial Q_2}.\frac{\partial Q_2}{\partial Y_{i1}}.\frac{\partial Y_{i1}}{\partial X_{i1}}=0(i=1,..n_1). \tag{9}$$

$$P_{i1}\frac{\partial Y_{i1}}{\partial X_{i1}}-r_{i1}=0\ (i=1,....,\ n_1). \tag{9'}$$

Here, the value of marginal product of input in India must be equated with the sum of the price of input with the same country and the social cost of the water deterioration in Bangladesh due to the production or control upstream since $\frac{\partial Q_2}{\partial Y_{i1}}$ has a negative sign.

With the advantage of being situated upstream, India has the opportunity of using the Teesta water for hydraulic power generation, irrigation, etc. However, although India has a very big project regarding the use of Teesta water, she has not been able to utilize the resource properly. The project involves complex procedures of diverting the Teesta water into another river (Mahananda), which may cause environmental problems. Since 1996, India has been withdrawing dry season water from the Teesta River and releasing excessive water during rainy season, making the Bangladesh side "worst off" rather than "worse off." However, India has not been using the withdrawn water to increase production at all, as observed in our survey.

Bangladesh received almost no benefit regarding usage of water resources of the Teesta River since she has no water when she needs it and too much water when she does not need. So, even if Bangladesh must give up most of the additional benefit given by the proposed economically efficient usage of the water resources, she would never be made worse off than the situation she had been experiencing during the last 5-7 years.

In contrast to the Indian situation, Bangladesh, provided that she receives sufficient water, would be able to implement the whole irrigation project which she has undertaken, and as the productivity of the land in Bangladesh is much higher (focused by a comparative survey on target areas of the both barrages) than that of the land in India, the net benefit to be achieved from implementing the total project area in the Bangladesh region. The maximum possible benefit is dependent on how successfully Bangladesh can bargain regarding the benefits to be paid back to India to get a higher share of the water resources, using political instruments of Bangladesh. As mentioned in the above, the welfare status, which could be realized by the maximized benefit through such a political and economic bargaining process, would be never worse off than the current status.

With reference to the production inputs used in Bangladesh:

$$P_{i2}\frac{\partial Y_{i2}}{\partial X_{i2}} - r_{i2} = 0(i = 1,\ldots n) \qquad (10)$$

Here, the value of marginal product of input in Bangladesh must be equated with the price of the input. Namely, W_1, W_2 and X_{ij} must satisfy equation (6), (7), (8), (10) and (4).

A Simulation Model

At present Bangladesh gets only 15% of the dry season water from the Teesta River for irrigation purpose. India monopolizes the share by consuming 85% of the total flow. From the survey report it can be observed that the water of the Teesta River in the dry season is not being used in an economically efficient way. Using simulation results derived from the following model, the increase in employment and total production when water resource is optimally distributed. The main purpose of this simulation is to maximize welfare of the Teesta basin area through utilizing Teesta water efficiently (from an economic point of view), the result of which can be used for convincing the authorities of India and Bangladesh to use the water optimally.

Equations: Case—1, for Separate Simulation

In case 1, the GRP of both the target areas of Dalia (Bangladesh) and Gazoldoba (India) is maximized and simulations are run using same type of model separately. The present share of Bangladesh is 15% of the total water; $\overline{W}_B = \overline{W}_B^{15\%}$, and India 85% water; $\overline{W}_I = \overline{W}_I^{85\%}$;

$$\max_{\{X_j\}}$$

$$GRP \equiv \sum_{j=1}^{23} \upsilon_j X_j\,, \qquad (1)$$

in which

ν_j : value added ratio of industry ($i = 1,\ldots,n$);

X_j : production sectors;

s.t. $AX + C + \overline{I} + E - M \leqq X$, (2)

in which

X : $n \times 1$ production vector whose i th element is production in i th industry,

A: $n \times n$ matrix of input coefficients of industries;

C: $n \times 1$ consumption vector whose $i-$th element is consumption of $i-$th commodity, $C_i (i = 1,2,\ldots,n)$;

$\overline{I}$: $n \times 1$ investment vector whose $i-$th element is investment in industry i, $\overline{I}(i = 1,2,\ldots,n)$;

E: $n \times 1$ export vector whose $i-$th element is export of $i-$th industry to other regions or the countries, $E_i (i = 1,2,\ldots,n)$;

M : import vector whose $i-$th element is import of $i-$th industry to other regions or other countries, $M_i (i = 1,2,\ldots,n)$;

(Due to space constraints, all equations of the model are not included in this paper)

Case—2, Simulation for the Teesta Region as a Whole

Specify the same type of model from eq. (1) through eq. (20). Simulation for optimal share of water between India and Bangladesh; we maximize the utility function:

$$\max_{\{X^I, X^B\}} \quad GRP^I + GRP^B, \qquad (21)$$

in which

s.t. system eqs. (2)-(20) for Bangladesh, and
system eqs. (2)-(20) for India;

$$\sum_{k=1}^{2} \beta_k^B L_k^B + \sum_{k=1}^{2} \beta_k^I L_k^I \le \overline{W} \qquad (22)$$

in which

β^B : coefficient of demand for irrigation water by $i-$th industry (i=1,2) in Bangladesh;

β^I : coefficient of demand for irrigation water by $i-$th industry (i=1,2) in India;

L^B : land use for production in industry $i = (i = 1,2);$ in Bangladesh;

L^I : land use for production in industry $i = (i = 1,2);$ in India;

$\overline{W}$: the total water of the Teesta River available for irrigation purposes in either India or Bangladesh in dry season.

$$\sum_{k=1}^{2} \beta_k L_k \le W^{IB} + \overline{W}_{B}^{15\%}, \qquad (23)$$

in which

$\overline{W}^{IB}$: water shifted from India to Bangladesh compared to the current situation;

$$\sum_{j=1}^{23} \overline{I}_j^B + \sum_{j=1}^{23} E_j^B = S^B + \sum_{j=1}^{23} M_j^B + P^{BI}, \qquad (24)$$

in which

$+P^{BI}$: payment that is made by Bangladesh for India as a compensation for the shifted amount of water in terms of export of food crops or other crops to India at a fairly lower price than the international one;

$$\sum_{j=1}^{23} \overline{I}_j^I + \sum_{j=1}^{23} E_j^I = S^I + \sum_{j=1}^{23} M_j^I - P^{BI}, \qquad (25)$$

in which

$-P^{BI}$: payment that is made by India to Bangladesh as a compensation for macroeconomic equilibrium between the two countries or in the region;

(Due to space constraints, all equations of the model are not included in this paper)

Cases for Simulation

In the simulation, two types of cases have been tested. The cases are as follows:

(1) In case 1 under two maximization procedures, simulation have been carried out. Under a fixed amount of water, each area tries to maximize its share. At present, Dalia's share is 15% (4,900 cusecs of water) and Gazoldoba's share is 85% (27,767 cusecs). Under this circumstance, Dalia maximizes its share. The sum of the GRP of both India and Bangladesh are maximized without constraints of water between these two countries GRP*(I) + (B).

(2) The case 2 simulation is for the Teesta region only. In the present situation, India monopolizes the share and it is not shared according to economic efficiency. So the purpose of the case 2 is to maximize the sum of GRPs and optimize the share of water according to economic efficiency.

This simulation was run using 'LINGO', which is the computer software for operational research released by LINDO SYSTEM. For the simulation data please see (Islam 2002).

Results of Simulation

With an objective to maximize GRP of both Dalia and the Gazoldoba regions, the results of the computer simulation on the increase in Gross Regional Production (GRP), increase in agricultural production, increase in employment of labour in agricultural fields and possible trade and businesses between the regions have been shown through the following figures:

Optimal Share of Water in Dry Season

Figure 3 shows the present share of the Teesta River between the Dalia barrage (15%=4,900 cusecs of water) and the Gazoldoba barrage (85%=27,767 cusecs of water) in the dry season. Case 2 shows an optimal share of water and its amount. In Case 2 the share of Dalia has increased by 6% (total 21% = 6, 794 cusecs) of water to make it an optimal share. The share of Gazoldoba, India is 79% = 25,873 cusecs of water in the dry season.

Changes in Gross Regional Production (GRP) in All

the Areas

Figure 4 shows almost no significant changes in the GRP of the Dalia, Gazoldoba and the Teesta regions in Case 1 and Case 2 separately. But the Teesta regional GRP, as a whole, is comparatively quite high

Changes in Agriculture Labour in All the Areas

Figure 5 shows that the changes in agricultural labour in the Dalia region is related to the increase in amount of available water share. It depicts that if water amount increases, land use increases and, for that reason, labour input increases. The figure points out that changes in number of optimal labour input for Dalia and the Teesta region is high, but for the Gazoldoba cases, there is no significant change.

Changes in Total Labour (in All the Areas)

Figure 6 shows that the changes in the total labour at Dalia target area is high (Dalia labour increases by 6,58,163 persons) in the optimal Case 2. In the Gazoldoba target area it is not high (Gazoldoba labour decreases by 86,676 persons). For the Teesta region it can be more than 9,000,000 persons (Teesta regional labour increases by 5,71,487 persons) for Case 2 as a whole.

In a nutshell, the simulation results point out that food grain production at Dalia increases, but at Gazoldoba, food grain production decreases while other crop production at Dalia is almost equal to food grain, but, at Gazoldoba, other crop production increases. Gazoldoba area is efficient for other crop production, but other crops don't need a lot of water like food grain production. The Dalia area is suitable for food grain production.

The Input-Output (I-O) data of both India and Bangladesh have been squeezed into 23 sectors from 79 total sectors of Bangladesh I-O Table (1993-94) and 115 sectors from Indian I-O Table (1993-94). I-O King Software has been used to prepare regional I-O tables for both Bangladesh and India. The GRP of both regions is estimated from the national I-O tables of the respective regions. The GRP of Dalia region in its I-O table was 84176.5 million Taka and the GRP of the Gazoldoba region was 115,617.7 million Taka. The reality, suitability and fitness of construction of this simulation model have been compared with the simulation results of basic cases. The I-O data is comparable to the simulation result of case 1, and it means there is a good fit between the model and the real economy.

If optimal share is fixed at 6% increased level from the present share 15% for Dalia it would be 21% of the total share and this increased amount of water can increase food grain production significantly. It can raise the GRP by 5,340 million Taka (per dry season) for Bangladesh. However, decreasing the share of water for the Gazoldoba area to 79% (from 85%) will cause a decrease in GRP up to 2,333 million Taka. Nevertheless, the GRP of the Teesta region as a whole would increase by 3,010 million Taka (optimal GRP of 241,257 million Taka – current GRP of 238, 247 million Taka. The total increase in the Teesta region is to be equitably distributed through various means, such as bilateral trade, business etc., and, thus, the decrease in GRP in the Gazoldoba area can be compensated to some extent.

The current number of labourers in the Dalia region is 4,318,045 persons. If Dalia's share is increased to 21% in dry season (which was found as optimal) it would be possible to employ up to 4,976,200 persons as labourers in this area, which would increase the total number by 658,155 persons. The current number of labourers in the Gazoldoba region is 4,294,949 persons. If Dalia's share increases to 21%, a decrease of 86,676 labourers would occur in the Gazoldoba target area, as in this case, the number of labourers in the area will go down to 4,208,273 persons. However, the total number of labourers for the Teesta region will go up to 5,71,487 persons, as the total number of labourers currently employed in the Teesta region as a whole is 8,612,994 persons, and the number will increase up to 9,184,481 persons if Dalia gets 21% of the total flow in the dry season. It points out that labor exchange program can balance the total labour increase in the Teesta region. If labour transfer is accepted by both the governments, new jobs can be created, there will be less unemployment in the region and program for the alleviation of poverty can be successful, if proper policy, in this regard, can be implemented.

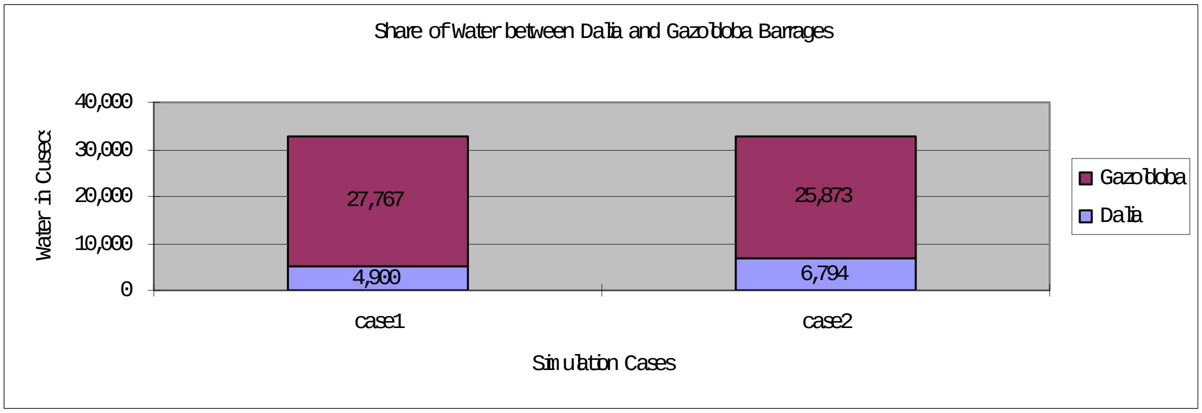

Figure 3 Optimal Share of Water in Dry Season

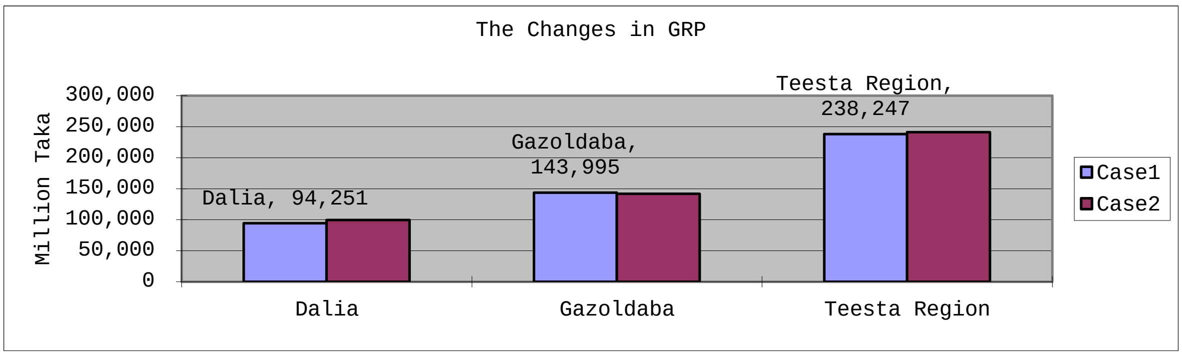

Figure 4 Changes in Gross Regional Production (GRP) in All the Areas

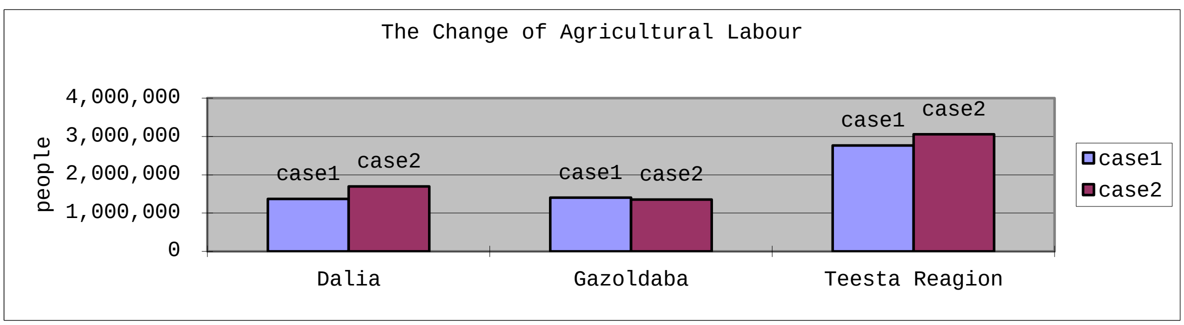

Figure 5 Changes in Agriculture Labour in All the Areas

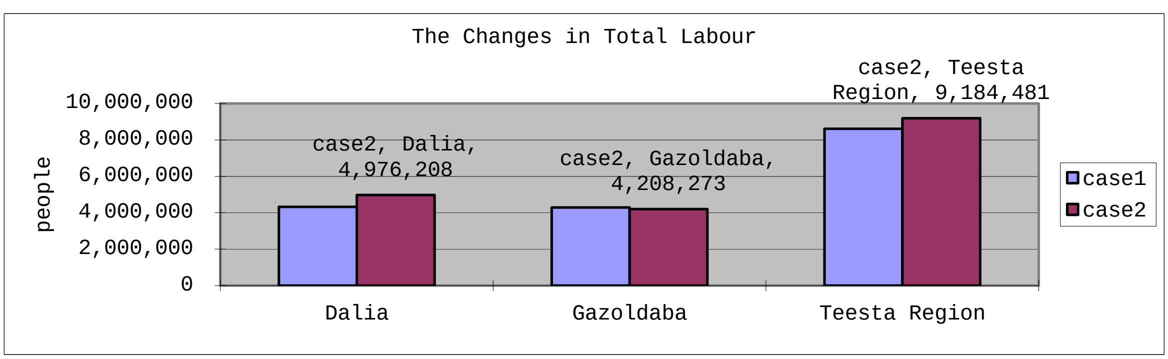

Figure 6 Changes in Total Labour (in All the Areas)

Policy Proposals

The following is proposed:

An Optimal Approach of Sharing Dry-season Water

Through the following estimation, a possible optimal sharing of the Teesta water has been shown, considering the number of affected people and the land productivity of both India and Bangladesh. The barrage at Dalia point requires at least 8,000 cusecs of water, (assuming 40% of the total water flow) in the dry season to remain active. A maximum amount of land (30% of the total target area) was cultivated in the year 1996. This cultivation produced crops worth US$ 48.86 million. The sum of the total crop production during the last four years was valued at US$ 136 million. The total production has drastically decreased in the last two years (1998-1999). Assuming the ratio of the Teesta River water in the dry season in India and Bangladesh as 85% (27,667) and 15% (4,900 cusecs) (Daily Ittefaq, March 23, 1998) respectively, the share is optimized.

Figure 7 displays an example of optimal sharing. The horizontal axis σ_i symbolizes a share of Bangladesh. So, $1-\sigma*$ (measured to the left from the point 1) is that of India in the context of the Teesta River basin. Left and right vertical axes measure the marginal productivity of water resources in Bangladesh and India, respectively. According to an estimation of

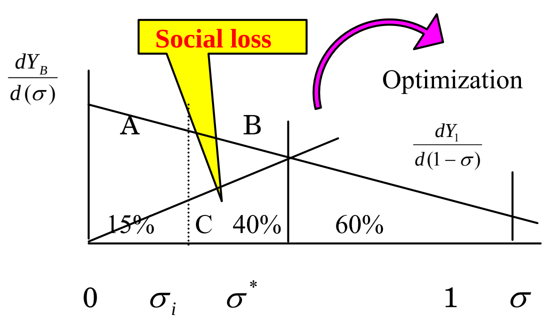

Figure 7 Optimization of Water Sharing between the two countries

the available amount of dry season water at Dalia point in the Teesta River on March 23, 1998, the 15% shows 4,900 cusecs of water, the 40% shows 13,066 cusecs of water, 85% shows 27,667 cusecs of water and 100% shows 32,667 cusecs of water.

If the share is fixed due to some reason at the level of σ_i which is far less than the optimal share $\sigma*$, there exists a social loss of triangle area ABC (the difference between the lost value of crops in Bangladesh due to the lack of water and the value of crops in India which can be produced in India by using more water than the optimal sharing) and σ_i is not optimal from cooperative point of view of both countries in a general sense. If the share increases from 15% to 40%, then an increase equivalent to the value of triangle area can be made possible. Economically, an optimal sharing of a fixed amount of resource can be shown at the crossing point of the marginal productivity curves of both parties, provided that both the curves have decreasing slopes.

Establishing a Special Economic Block

For the betterment of the people of the Teesta River basin area (both in India and Bangladesh), we recommend the following::

* While planning and policymaking, emphasis must be placed on optimal and amicable water sharing and on a suitable trade model.
* Bangladesh should make certain arrangements, for example, to take measures so that Indians, using the Teesta River water (at Dalia or northern districts), can get some opportunities for business and trade in Bangladesh territory;
* Joint ventures (co-project or bilateral agricultural projects) should be encouraged in establishing mills and factories (e.g. rice mills, tobacco husking mills, paper mills, food processing mills) dependent on crops produced in the Teesta region.
* Every year India `pushes in' thousands of Muslims to Bangladesh over the border calling them 'illegal Bangladeshi immigrants'. Bangladesh authorities try to `push them back' into India. For this reason, many people are hurt and even killed, caught between the battles fought by the border security forces of both countries. This has become an important political issue. Instead, trade can be established between the two countries over the whole Teesta basin area through joint ventures, allowing easy movement of the citizens from one country to another. Following Europe, where people travel from one country to another very easily, bilateral problems and even regional problems within the SAARC countries can be solved.

Reducing Conflicts and Ensuring Justice

* The donors or donor countries should have some restrictions on the construction funds of such barrage or irrigation projects, when it has a

possibility to harm riparian states. The feasibility studies before granting such funds should be foresightful.

* However, we must remember that "mutual confidence and cooperation" (Smith 1931) between the leaders of India and Bangladesh is necessary for an economic policy to be implemented properly. Leaders of both sides have to be sincere in their efforts. They must also have an open mind and be ready to accept rational suggestions given by their counterparts."

Conclusion

The theme in this paper is very simple. We have discussed the issue of sharing of Teesta water briefly and put forward a simple theoretical model and a simulation model for using international river water and proposed some policies with an optimal solution to the Teesta water-sharing problem by which total and unilateral benefits for both the parties can be made greater. The simulation results point out that if optimal share is fixed at 6% increased level from the present share of 15% for Dalia it would be 21% of the total share and this increased amount of water can increase food grain production significantly. It can raise the GRP by 5,340 million Taka (US$ 97 million), (per dry season) for Bangladesh. The regional GRP also is raised by 241,257 million Taka (US$ 4386.49 million) per year and the changes in regional GRP is comparatively quite high (Tk. 238,247 million = US$ 4331.76 million), per year. This is good for each region because this benefit could be shared by the Indian people too. It also points out that labor exchange program can balance the total labour increase in the Teesta region. If labour transfer is accepted by both the governments, new jobs can be created. There will also be less unemployment in the region and a program for alleviation of poverty can be successful, if proper policy can be implemented.

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M. Fakhrul Islam, Ph.D.
Assistant Professor
Department of Social Work
University of Rajshahi
Bangladesh

Y Higano
Professor
Environmental Policy
University of Tsukuba
Japan