J. ENVIRONMENTAL SYSTEMS, Vol. 30(3) 207-231, 2003-2004

ENVIRONMENTAL IMPACT ASSESSMENT OF WATER RESOURCE PROJECTS WITH MATRIX AND MULTI-CRITERIA DECISION-MAKING METHODS: A CASE STUDY

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ABSTRACT

The importance of environmental evaluation of water resources projects has been realized world over in view of their long-term consequences and large investment requirements. Environmental Impact Assessment (EIA) can be defined as the systematic identification and evaluation of the potential impacts of proposed projects, plans, programs, or legislative actions relative to the physical, chemical, biological, cultural, and socioeconomic components of the total environment. The primary purpose of the EIA process is to encourage the consideration of the environment in planning and decision-making and to ultimately arrive at actions which are more environmentally compatible. The objective of the present study was to assess the environmental impacts of the Kalni-Kushiyara River Management Project (KKRMP) in Bangladesh. The KKRMP covers a gross area of 335,600 ha between latitude 24° 56′ and 24° 15′ N and longitude 92° 05′ and 90° 55′E. It extends over the districts of Sylhet, Sumanganj, Moulvibazar, Habiganj, and Kishoreganj. The project is bounded by Kushiyara-Bijna-Ratna River system on the south, the old Surma-Dahuka River system and Jagannathpur-Sylhet road on the north, the old Surma-Baulai River system on the west, and the Sylhet-Kaktai village road on the east. Some of the major problems faced in the project area are river erosion, damage to boro crops by flash floods in pre-monsoon season and to aman crops during the monsoon, and the silting of beels, ponds, and channels. The overall goal of the project is to enhance economic activity and the quality of life on the Kalni-Kushiyara flood plain.

Among various methods available for conducting EIA of water resources projects, matrix, indices and computer-based approaches have been used more frequently in recent times. Two methods—a conventional matrix method and a more sophisticated Multi Criteria Decision Making (MCDM) method—have been employed in this study. Whereas the main utility of the matrix method lies in communicating complex information in a simplified and easily assimilated form, the MCDM techniques present an interaction of network indices, and matrix approaches within a computation framework suitable for consideration of a diverse range of options and criteria characterizing the environmental impacts and subsequent integration of the same. The impact identification matrix developed for this project exhibits generally positive impacts that reflect the adaptability of the project. Further, the composite programming-based MCDM method yields a more holistic evaluation of the system, and a ranking in decreasing order of environmental soundness of various future options.

INTRODUCTION

Environmental Impact Assessment (EIA) of water resources projects is considered highly significant around the world [1]. It provides for a quantified assessment of the biophysical, economical, and social impacts of a proposed project, and of the likelihood of such impacts occurring. A thorough analysis of the environmental components worthy of consideration in this regard is given by the International Hydrologic program of the United Nations Educational Scientific and Cultural Organisation (UNESCO) [2, 3]. The primary purpose of the EIA process is to encourage the consideration of the environment in planning and decision making and ultimately to arrive at actions which are more environmentally compatible. EIA accomplishes its purpose by providing decision makers with the best quantitative information available regarding intended and unintended consequences of particular investments and alternatives, the means and costs to manage undesirable effects, and the consequences of taking no action [4].

The chief sources of the environmental policy of the Government of Bangladesh are the Environmental Policy 1992 and implementation program, published by the Ministry of Environment and Forest, Government of Bangladesh, May 9, 1992 (in Bangla); and the fourth five-year plan, 1990-95; particularly Chapter IX on Environment and sustainable development. The general aims of the Environmental Policy 1992 include conservation and environmentally sound development in all sectors, protection of the country from natural and anthropogenic hazards, and environmentally sustainable long-term harnessing of resources. In Bangladesh, a set of 10 steps has been recommended in standard EIA guidelines as presented in Figure 1.

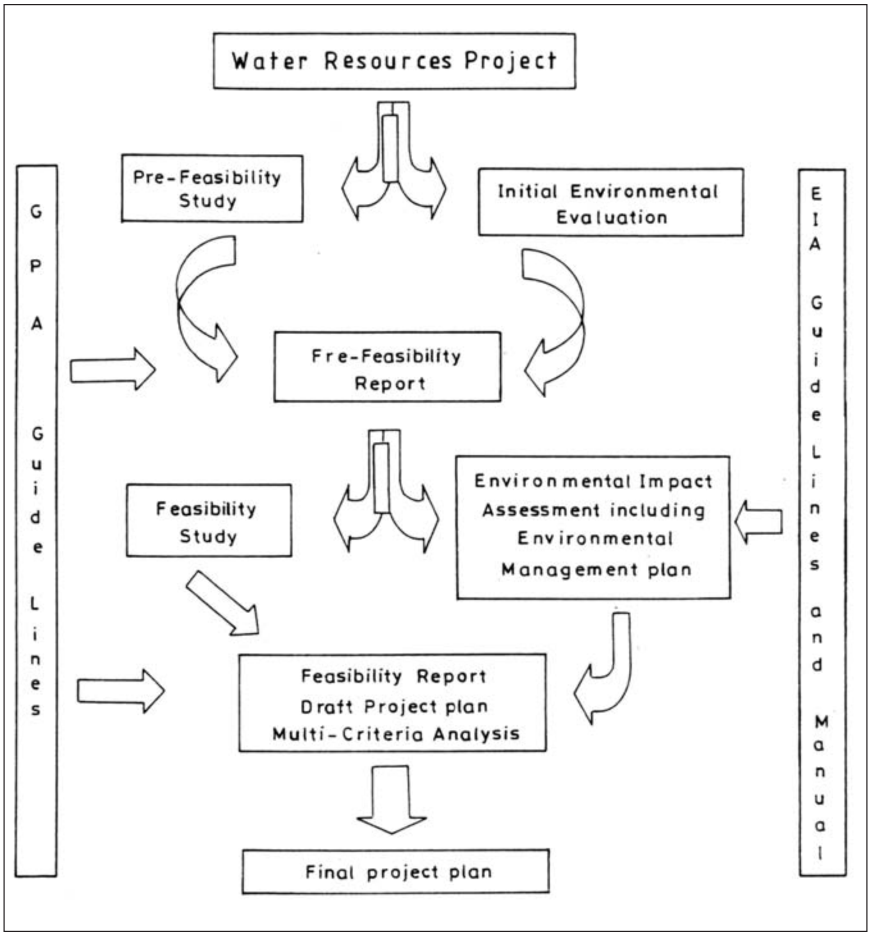

Figure 1. EIA Guidelines.
Source: FPCO, 1992.

METHODS ADOPTED FOR EIA

A variety of methods, including checklist, matrix, network, overlay, and computer-assisted optimization, have been employed for EIA internationally [2, 3, 5-10]. The conventional "matrix method" and the more sophisticated "multi-criteria decision making (MCDM) optimization method" have been used most in practice. Whereas matrix and checklist methods remain popular because of their simplicity of comprehension and lesser time requirement, MCDM methods are preferred mainly due to their capability of providing a hierarchical quantitative framework and a process of holistic integration of diverse components. Matrix and MCDM methods were used in this case study.

Matrix Method

Matrices are useful two-dimensional models for relating two set of items represented by rows and columns in a matrix. The main utility of matrix lies in its use in communicating complex information in a simplified and easily assimilated form. Its common use in EIA is to relate project activities to important environmental components (IECs) through some form of quantification or ranking.

EIA guidelines require scoring of the impacts [4]. The methodology described in an EIA manual [9] for project impact assessment and scoring has been used in this study. The impact assessment of the IECs is generally a task of a multidisciplinary team. A uniform, well-defined, and stepwise-structured format and criteria is to be used for assessment and scoring. When an impact cannot be quantified, qualitative judgment has to be used based on experience. The scoring in this study has been done within a 21 point score ranging from –1 to –10 for negative impacts and +1 to +10 for positive impacts, 0 denotes no impact or neutral impact, as shown in the scoring charts presented in Tables 1, 2, and 3.

Table 1. Scoring Chart A: Magnitude of the Change

Intensity of the modification	Probability of the change		
	Unlikely	Likely	Unavoidable
No modification	No impact	No impact	No impact
Little modification	Low	Low	Medium
Medium modification	Low	Medium	High
Large modification	Medium	High	High

Source: [4].

Table 2. Scoring Chart B: Importance of the Change

Magnitude of the change as per Chart A	Scale of the change		
	Site-specific	Local	Regional
Low	Very little importance	Little importance	Much importance
Medium	Little importance	Much importance	Great importance
High	Much importance	Great importance	Very great importance

Source: [4].

Table 3. Global Scoring Chart

Duration	Value of the IEC	Importance of the change as per Chart B				
		Very little importance	Little importance	Much importance	Great importance	Very great importance
Short-term	Low	1	2	2	3	3
	Medium	2	3	3	4	4
	High	2	3	3	4	5
Mid-term	Low	2	3	3	4	5
	Medium	3	4	4	5	6
	High	3	4	5	6	7
Long-termn	Low	3	4	5	6	8
	Medium	4	5	6	7	9
	High	5	6	7	8	10

Source: [4].

The impact scoring charts have been developed considering such factors as the value of the IECs in terms of rarity; economic value; importance for humans; magnitude of the change (low or high); scale of the change (site-specific, local, regional, national); frequency (occurs a few times or repetitively); duration (short-, mid-, or long-term); reversibility (through mitigation or natural processes); probability (unlikely, likely, unavoidable); and lastly, significance summarizing the magnitude, frequency, duration, and reversibility of the predicted impacts.

Multi-Criteria Decision Making (MCDM) Methods

The three principal types of MCDM techniques internationally employed are outranking types as ELECTRE, multiattribute utility functions (MAUT), and distance-based techniques like compromise or composite programming.

Outranking Types: ELECTRE

This methodology, developed by Benayoun et al. [11] was first used for water resources development by David and Duckstein [12]. The main idea in ELECTRE is to choose those systems which are preferred for most of the indicators and yet do not cause an unacceptable level of disturbance for any one indicator. There are two versions of ELECTRE, ELECTRE I, and ELECTRE II.

The concordance of any two actions is a weighted measure of the number of criteria (criterion always means indicator here) for which one action (here action is synonymous with option) is preferred or indifferent to another action. Concordance can be thought of as the weighted percentage of criteria for which one action is preferred to another, where the decision-maker (DM) provides the weights.

To compute the discordance matrix, an interval scale common to each criterion is first defined. The scale is used to compare the discomfort caused between the "worst" and the "best" of each criterion.

Both the concordance and discordance matrices are synthesized after employing additional threshold values as defined by the DM. The result of ELECTRE I is a preference graph which presents a partial ordering of the alternative systems. ELECTRE II [13, 14] may then be used to obtain a complete ordering.

Multi-Attribute Utility Functions (MAUT)

Utility (or disutility) is defined as the subjective benefit(s) (or losses) derived by the DM from the achievement of the stated objectives. The motivation for using MAUT is that the DM's utility function can be specified numerically. This is accomplished by eliciting the DM's utility for each indicator and then combining these single utilities into one overall utility function. The system, which provides the highest degree of utility with respect to all the indicators, is defined as the preferred alternative [2].

Distance-Based Technique: Composite Programming

In this technique [15], the "best solution" is that point which minimizes the distance from an "ideal" point to the set of non-dominated solutions. The "best solution" in the case of discrete alternative options is that point which minimizes the distance from the "ideal point" to an "alternative solution." The composite distances are calculated as function of the various options and plotted. An option is considered best when it results in the closest state to the ideal state high-lighting maximum benefit and no negative impact (Figure 2). Since the system composite index L measures the distances from the ideal state, the best options should correspond to minimum L (X) with respect to 0 or maximum L (X) with respect to origin (0, 0).

The system to be studied is discretized in two major interacting components, an ecological (natural resources) sub-system and a socioeconomic (consumptive) sub-system [2]. These are present as "third level" indicators. Each third level indicator is determined by a set of "second level" indicators (e.g., water quality,

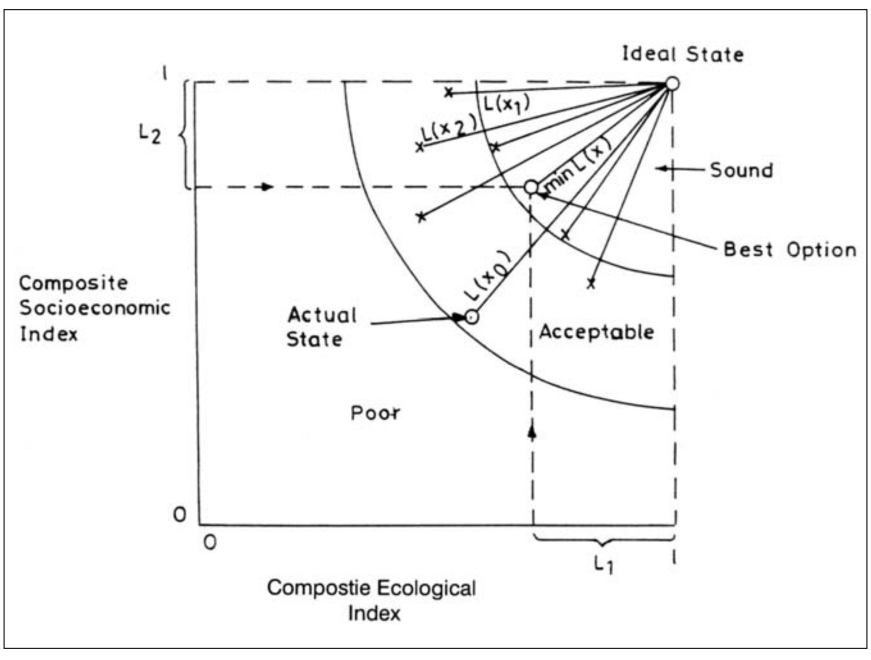

Figure 2. Comparison of options (Composite Programming Method).

health, and nutrition) which, in turn, depend on "basic indicators." Basic indicators are important environmental parameters or components (IECs) that can be directly observed, measured, or computed, such as dissolved-P load, sediment yield, diversity, GNP, energy production, and infant mortality. After identifying the system structure, "ideal and worst values" for each basic indicator are defined. These limits, together with a scheme for assigning weights reflecting judgments of relative importance, are meant to accommodate changes in priorities. In principal, the values of all basic indicators with respect to the "zero option" (present state) and other proposed management options may be observed, measured, or computed with the help of available information, precise field monitoring, or reliable models.

In this method, composite distances are calculated as functions of various options x. First of all, to transform the different basic indicators (Z_i) to a common scale, all are normalized in order to produce index functions $S_i(x)$.

$$S_i(x) = \frac{\max Z_i - Z_i(x)}{\max Z_i - \min Z_i} \quad \text{or} \quad \frac{Z_i(x) - \min Z_i}{\max Z_i - \min Z_i} \tag{1}$$

Next, they are aggregated into second level indicators (composite distance functions) and lastly into overall composite system indicators as per equations (2), (3), and (4).

$$L_j(x) = \left[\sum_{j=1}^{n_j} \alpha_{ij} S_{ij}(x)^{P_j} \right]^{1/P_j} \tag{2}$$

$$L_k(x) = \left[\sum_{j=1}^{m_k} \alpha_{jk} L_{jk}(x)^{P_k} \right]^{1/P_k} \tag{3}$$

$$L(x) = \left[\alpha_1 L_1(x)^2 + \alpha_2 L_2(x)^2 \right]^{1/2} \tag{4}$$

where,

L_j, L_k, L = composite distance functions for second level ground j of basic indicators, third level group k, and final over all systems respectively.

α_{ij}, α_{jk} = Weights Expressing the relative importance of basic indicators in second level group j and third level group k.

$$\sum_{i=1}^{n_j} \alpha_{ij} \quad \text{and} \quad \sum_{j=1}^{m_k} \alpha_{jk} = 1$$

S_{ij} = actual value of basic index i in second level group j and third level group k.
L_{jk} = second level composite distance for ecology (k=1) and socioeconomic (k=2).
α_1 and α_2 = weight indicating the relative between conservation and development.
L_1 and L_2 = composite distance for ecology and socioeconomics respectively.
n_j = number of basic indicators in group j.
m_k = number of elements in group k.
P_j and P_k = Balancing factor among indicators for group j and k.

The option (among various options x), which results in the closest state to the ideal state, is considered the best. Since the systems composite index L measures the distance from the ideal state, the best option corresponds to Min L (x) with respect to (1, 1) or maximum with respect to the origin (0, 0). Minimization of equation is needed which, however, incorporates both equations (2) and (3).

Comparison of MCDM Techniques

Table 4 presents a comparison of various MCDM Techniques. In view of this table, distance-based "Composite Programming" technique is adjudged more suitable and applied in this case study.

CASE STUDY: KALNI-KUSHIYARA RIVER SYSTEM MANAGEMENT PROJECT, BANGLADESH

Study Area: KKR System

The Kalni-Kushiyara river management project covers a gross area of 335,600 ha between latitude 24° 56′ and 24° 15′ N and longitude 92° 05′ and 90° 55′ E. It extends over the districts of Sylhet, Sumanganj, Moulvibazar, Habiganj, and Kishoreganj. The project area is bounded by the Kushiyara Bijna–Ratna River system on the south, the old Surma-Dahuka River system and Jagannethpur–Sylhet Road on the north, the old Surma-Baulai River system on the west, and the Sylhet Kaktai village road on the east (Figure 3). The sub-tropical monsoon climate typical of Bangladesh, with variations due to its location and topography, has mean annual rainfall running from an average of 2,539 mm/year in the south (at Habiganj) to 4,209 mm/year in the north (at Sylhet). The temperature varies from about 27° to 35°C with the highest temperature recorded during the period April to June. Land elevation typically ranges between 3 to 7 m P.W.D. Much of the land is traversed by distributary spill channels and other old partially infilled channels, which at one time connected the Surma River System to the Kushiyara River.

Table 4. Comparison of MCDM Techniques

SI No.	Parameters	Outranking "ELECTRE"	Utility "MAUT"	Distance-Based "Composite Programming"
1	Types of indicator present	Both quantitative and qualitative data can be handled without any bias.	A function defining quantified utilities is specified. May introduce bias.	Heuristic scaling procedure is used to convert (quantity) qualitative data. May introduce bias.
2	Nature of alternative options	Only discrete sets of options can be handled.	Interpolation between values of the independent variables needed.	Either case can be dealt with effectively
3	Robustness of results to change in parameter values	In general, all the methodologies considered are fairly robust with respect to change in parameter values.		
4	Ease of learning and computation	Tedious in learning but easy in computation.	Most cumbersome in ________	Easiest
5	Amount of interaction between DM and analyst	Little interaction is needed for specification of weights and scales.	Extensive interaction needed. Impractical for real world problems.	Little interaction is needed for specification of weights and scales.
6	Types of decision maker	Does better with respect to the group DM.	Not good with respect to the group DM.	Does better with respect to the group DM.

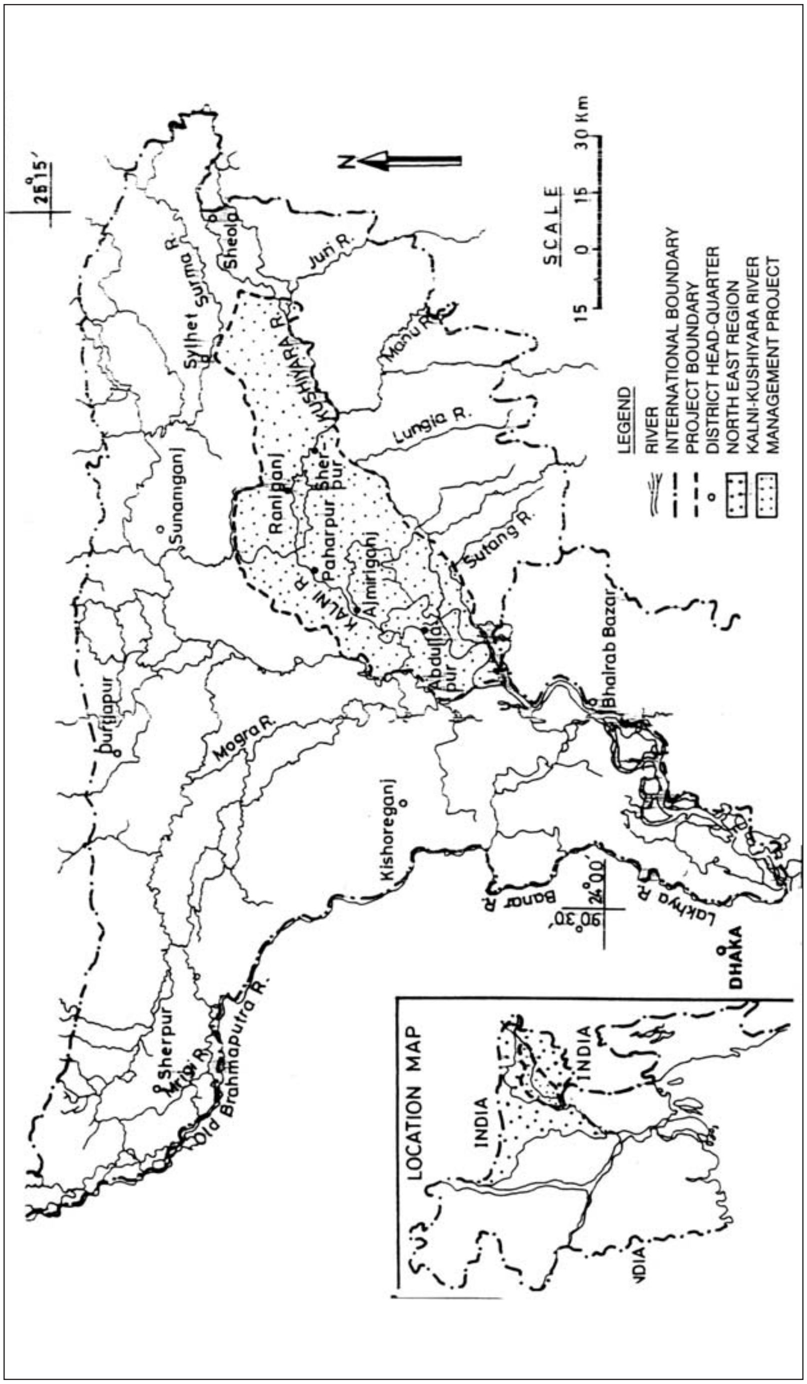

Figure 3. Study area.

Baseline Information

Information from the project area has been collected on a variety of factors (e.g., socioeconomic, hydrology, meteorology, water quality, flora and fauna) from various agencies (Directorate of Surface Water and Ground Water Hydrology; Directorate of Economic Planning; Bangladesh, Board of Statistics etc.), and reports [15-21]. The details are briefly presented in the following sections.

Physical Environment

The land generally slopes down from the northeast to the southwest, but also slopes away from the river banks to the south and north flood plain of the Kalni-Kushiyara River (KKR). Elevations typically range from 1 to 16 m PWD. Approximately 50% of the land lies below 5 m PWD and 80% of the land lies below 7 m PWD. Terraces occupy about 1,162 ha and their elevation varies from 13 to 16 m PWD. Flood plain is the dominant landform occupying most of the project area. The low land flood plains have been created as a result of deposition and erosion from the Surma and Kushiyara Rivers. The upland landform occurs in the northeastern part of the project area and covers more than one-third of the project area.

The Kalni River bifurcates at an angle of 180° into two parts just beyond the north side of the project and the Kushiyara River originates at the international boundary near Amalshid where the Barak River bifurcates into the Surma and Kushiyara Rivers. The Kushiyara River flows south over a length of about 240 km from Amalshid to Astagram where it joins the Upper Meghna River. The river reach from Amalshid to Markuli is called the Kushiyara River. This river has eight tributaries, all originating in Tripura State, India, and entering the Kushiyara from the south. Four of these tributaries enter the Kushiyara River upstream of Sharpur gauging station and flow throughout the year.

Discharge of KKR system is governed by inflows from the Barak River at Amalshid, tributary inflows (Juri, Manu, Khowai, and Sonali Bardal), inflows or losses that occur through distributaries and spill channels and local rainfall drainage from the project area. The estimated usable groundwater recharge within the project area is 406 million m^3 based on MPO data [22]. The majority of the ground water resource potential is located in Baniachang, Nabiganj, Biswanath, and Jagannathpur Thanas. About 269 million m^3 of recharge is available within the depth range that is accessible from force mode deep tube wells (DTW). Due to aquifer constraints, suction mode shallow tube wells (STW) can withdraw only about 7 million m^3. However, about 70 million m^3 could be withdrawn by deep-set suction mode technology (DSSTW). The seasonal distribution of discharges and annual runoff are given in Table 5.

The Kushiyara River has reportedly undergone considerable channel instability over the last 40 years. The amount of sediment eroded from the 30 km reach below Sherpur during the shift of course was approximately 25 million m^3. Soils

Table 5. Seasonal Distribution of Discharge

Season	At Sheola Discharge m^3/s	At Sheola % of annual runoff	At Sherpur Discharge m^3/s	At Sherpur % of annual runoff
Pre-monsoon	472	11.5	1,152	17.4
Monsoon	1,415	69.5	1,952	59.0
Post-monsoon	555	13.6	1,175	17.8
Dry season	111	5.5	197	5.8
Year	682	100	1,101	100

Source: [15].

in the project area are relatively uniform, grey, and heavy. Silty clay loams predominate the ridges with clay in the basins. Small areas of soils along with mixed sandy and silty alluvium occur alongside rivers. The soil reaction is mainly acidic. Organic matter content in the cultivated layer ranges from 0.5–2.5% in most ridge soils and from 2.0–5.0% in basin soil. The soils occupying haor centers stay wet for most or all of the dry season; they generally have 2.0–5.0% organic matter in the cultivated layer. Fertility level is medium to high.

Biological Environment

Agriculture is the main land use in the Northeast region with perennial wetlands constituting the major remaining natural habitat of the project area. The Kalni-Kushiyara project area supports two types of wetlands: permanent and seasonal. The permanent wetlands include rivers, canals, perennial water bodies, and fish-ponds. Most of the project area supports seasonal wetlands. While permanent wetlands provide refuge and shelter for most of the aquatic flora and fauna, the seasonal wetlands serve as the grazing ground for fish and other aquatic animals like freshwater turtles. The change in the physical characteristics of wetlands has had a direct impact on its dependent flora and fauna. The fluctuation or changes in the population dynamics of the biological diversity defines the biomass productivity of the wetland.

The total area of permanent wetlands is 27,836 ha (8% of the project area) including rivers, channels, beels, and ponds. The area covered by major and minor rivers are 10,780 ha and 1,250 ha, respectively. The area of seasonal wetlands varies as a function of flooding intensity. The average monsoon flood causes about 77%, or 260,200 ha, of the net project area to be inundated. Ongoing siltation due to over bank spills and breaches in the riverbanks make the area unsuitable for both wild flora and fauna. This is further exacerbated by human interference through the encroachment of paddy fields. Incidentally, a wetland of international importance, Hakaluki Hawa, is located next to the project area.

Wetland habitat is characterized by anaerobic conditions. Continuous submergence inhibits normal plant growth. However, a group of plants known as hydrophyte are able to withstand these extreme conditions. The types of aquatic flora in the Kalni-Kushiyara area are submerged plants, free-floating plants, rooted floating plants, sedges and meadows, reed swamp, and freshwater swamp forest. Some types may be absent from a particular wetland due to disruption by human activities. Submerged plants are prevalent in the project area both in permanent and seasonal wetlands.

The hydrological cycle and the presence of perennial and seasonal wetlands provide a diversified habitat for all biota, especially for fish. The life cycle of the aquatic or wetland related fauna is dependent on the riverine ecosystem's natural fluctuations. During the pre-monsoon season, fish leave their dry season habitats and migrate upstream for spawning and breeding. Their spawning migrations start when early flash floods or rain water inundate areas rich in nutrients and the environment is favorable. Migration is generally counter-current.

Social Environment

From 1901 to 1991, with an average annual growth rate of 1.3%, the population more than tripled. During this period, the national growth rate was 1.5%. During the inter-census period 1981-1991, population increased at an annual rate of 1.8%. According to projections, population in the project area is 1.89 million. The average number of household members is 5.7, which is slightly higher than the country average of 5.5. The demographic dependency ratio (DDR) is the ratio of the dependent population (below 15 years and above 65 years) to the population of working age (15 to 65 years), expressed in percentage. In the project area, the DDR has been estimated to be 85%.

In the study region, there are less than six primary schools and one secondary school per 10,000 people. The level of schooling is presented in Table 6.

Public health infrastructure in the project area includes on health center-cum-hospital in each Thana headquarters with limited laboratory facilities and a few beds for indoor patients. At the union level, one family welfare center provides limited mother and child health services and immunization to children and pregnant women. People mainly suffer from water-borne diseases, particularly diarrhea. The incidence of all diseases, including diarrhea, is highest in the post-monsoon season. Immunization of children against six killer diseases is a major thrust of the government.

Hand tubewells are the main source of safe drinking water in the project area. These are located on homestead land and therefore access to safe water is related to homestead land-holding. Of landless households, 74% drink tubewell water, while the remainder use water from river and haor for drinking. Each functioning

Table 6. Level of Schooling

Schooling	Birth series	Male %	Female %
No schooling	72.3	67.4	77.5
Primary secondary	19.4	21.3	17.5
Above, secondary	1.4	2.2	0.5
Total	100.0	100	100

Source: [15].

tubewell serves an average of 20 households [15]. The national standard for potable water coverage is one tubewell for 16 households [20].

Sanitation facilities in the project area are well below the national standard. In villages of the project area, only 5% of households have a sanitary latrine, composed of 4% earthen pit latrines and 1% concrete water seal latrines. The remaining 95% of households have an unacceptable standard of sanitation. Comparatively, national sanitation coverage indicates that only 52% of households use an unacceptable sanitation facility (hanging latrine and open space), while 48% of national households use a sanitary water seal or earthen pit latrine [20].

Household income is not sufficient to maintain a decent life for most of the households. The absolute and hard-core poverty rates are much higher than that of the national rates. As much as 65% of households are below the absolute poverty line in terms of calorie intake. The extent of hard-core poor is 50%. By WHO/UNICEF Bangladesh standards, the absolute poverty line is the required level of calorie intake of 2,122 calorie per capita per day. Hard core poverty level is 85% of the required level, i.e., 1,805 calorie per capita per day.

Economic Development

According to the NERP landuse survey carried out in 1995-96 [23], the net cultivated area accounts for 83% of project area. Net cultivated area within the project is 279,850 ha. Of this, over 94% is single-cropped, 3% is double-cropped, and 3% is fallow. The distribution of cropped area is given in Table 7.

The land use survey has confirmed that rice dominates crop farming. The four main rice crops are: rained upland (B. Aus), deep water (B. Aman), rainfed low land (T. Aman), and irrigated (Boro). Spices and vegetables are the major non-rice crops. There are three crop seasons in the project area, Kharif-I (premonsoon), Kharif-II (late monsoon), and Rabi (dry winter season).

The project area is characterized by high quality fisheries habitats. The most important habitats constituting 95.8% of the total occur on the extensive flood plain, beels, and ponds as given in Table 8.

Table 7. Distribution of Cropped Area

Crop	Percent of total cropped area
Rice	98.3
Oils, seeds	0.4
Vegetable/spices	0.7
Other	0.6
Total	100
Total cropped area	2,81,787 ha

Source: [16].

Table 8. Fisheries Habitats

Habitat group	Habitat type	Area (ha)	Area (%)	Standing crop kg/ha/yr	Production (tones)	% of total
Riverine	Kalni-Kushiyara River	3,955	1.40	201.8	798	1.5
	Other flowing rivers	3,104	1.10	273.2	848	1.5
	Closed and rivers	3,721	1.30	121.7	453	0.8
	Distributaries	1,250	0.40	121.7	152	0.3
	Sub total	12,030	4.20	187.1	2,251	4.1
Flood plain	Flood plain	260,200	90.30	159.7	41,554	76.2
	Beels	13,340	4.60	503.1	6,711	12.3
	Ponds	2,466	0.90	1,636.5	4,036	7.4
	Sub total	276,006	95.80	189.5	52,301	95.9
	Total	288,036	100	189.5	54,552	100

Source: [24].

The NERP household survey (1995-96) [23] provides data on per capita income from all sources in 568 households (HHs) from six villages selected from the upper, middle, and lower reaches of the Kalni-Kushiyara River. Absolute poverty levels are experienced by 65% of HHs; 50% of the HHs suffers from hard-core poverty. In the Kalni-Kushiyara area 42% of all HHs do not own cultivable land. Further, the bottom 20% of HHs earn 6% of total income, while the top 10% of HHs earn 40% of income.

The region has a surplus of rice and fish. These commodities are exported outside the region. Rice is mainly transported to Bhairab, while Bhairab and

Kuliarchar are the most important fish outlets of the region. The region has a poor industrial base. Although it accounts for more than 2% of the total area of Bangladesh, only about 1% of the manufacturing enterprises of the country (employing 10 or more persons) are located in the region. The highest proportions of enterprises are in food processing followed by timber processing, wood products, and brick manufacturing.

PROJECT INTERVENTION AND IMPACT ON SELECTED ENVIRONMENTAL COMPONENTS (IECs)

The overall goal of the project is to enhance economic activity and the quality of life on the Kalni-Kushiyara flood plain. It has been formulated to meet multiple objectives including:

- Improving the river's stability and providing a more stable environment for development;
- Reducing damage to agriculture by reducing pre-monsoon flood damage and improving post-monsoon drainage;
- Improving living conditions along the river by reducing erosion damage to village and by creating new flood-free platforms; and
- Improving navigation along the river during the dry season.

The focus of the work in this project extends along the 168 km reach of the Kalni-Kushiyara River between Fenchuganj to the junction of the Dhaleswari-Baida River downstream of Kalma. Various concepts for rehabilitating the river were developed during pre-feasibility level investigations in 1993 pertaining to:

- River stabilization works—Construction of two loop cuts (7 km) channel excavation (31 km), channel re-alignment and river training at three locations.
- Flood Control Works—Construction of embankment and levees at strategic locations for a total length of 20 km to maximizing river over-bank spills and breaches.
- Navigation channel improvements—Dredging at five locations to develop class II navigation channel.
- Village homestead platforms—Construction of 247 ha of homestead platforms at 44 locations using dredged spoil and including the implementation phase, as well as construction of another 40 locations (200 ha) during the operation and maintenance phase.
- Implementation of environmental management—Designed to enhance positive impacts and mitigate negative ones.

Several IECs have been identified and the impact of the project intervention on these has been quantitatively presented in (Table 9), as evaluated and illustrated in the project report [24].

Table 9. IECs and Impact of Project Intervention

Sl No.	Important environmental components	Unit	Present	FWO	FW-Alt-1
1	Terrestrial habitat	ha	8660	3341	9060
2.	Bank erosion	ha/yr	55	44	27.50
3.	Area inundated by pre-monsoon flood	ha	195202	239385	184172
4.	Post-monsoon inundation requiring drainage	ha	23847	34279	20175
5.	Agricultural crop production	Tonnes/ha	2.97	2.86	3.21
6.	Fish production	10^4 ton	5.46	5.24	5.37
7.	Farmers income opportunity	10^6 tk/yr	307.4	355.5	1337.5
8.	Project cost	tk/hr	1100	1100	9407
9.	Nutritional status	Calories	2122	1805	2228
10.	Sanitation	% HH	5	5	48
11.	Drinking water	%	81	72.9	91.12
12.	Relocation of families/homestead	Nos	0.00	0.00	11250
13.	Education	%	27.70	50	65

EIA Employing Matrix Method

On the basis of the earlier discussions and the available charts, impact classification and scoring have been attempted. The results are presented in Table 10.

As observed, a net positive result (score) indicates the adaptability of the project. However, there are some components which highlight negative impacts (e.g., fish productivity) indicating the need for more attention to remedial or mitigation measures.

EIA Employing MCDM (Composite Programming Method)

Table 11 shows the indicator structure proposed for the project area. The weighting and balancing factors presented in Table 12 were chosen from an in-house opinion poll. Ideal and worst values corresponding to each indicator, which have been selected depending upon the apparent suitability of either the observed maximum or minimum values in the available data or available targets, along with their justification are tabulated in Table 13.

An effort has thereafter been made to evaluate the results corresponding to the data available for three management options: present condition, future

Table 10. Impact Identification Matrix of KKRMP Project

Sl No.	IECs	Intensity	Magnitude	Probability	Scale	Importance of the change	Value of IEC	Duration	Impact scoring
1.	Terrestrial habitat	Little	Low	Likely	Site	Very little important	Medium	Long	+4
2.	Bank erosion	Likely	Low	Likely	Local	Much important	Low	Long	+5
3.	Area inundated by pre-monsoon flood	Little	Low	Likely	Regional	Much important	Medium	Long	+6
4.	Post-monsoon inundation requiring drainage	Likely	Low	Likely	Local	Very little important	Low	Long	+5
5.	Agriculture crop production	Medium	Medium	Likely	Regional	Very important	Medium	Long	+7
6.	Fish production	Little	Low	Likely	Local	Little important	Medium	Short	–3
7.	Farmers income	Little	Low	Likely	Regional	Much important	Medium	Long	+6
8.	Project cost	Little	Low	Likely	Regional	Much important	Medium	Medium	+4
9.	Nutritional status	Little	Low	Likely	Local	Little important	High	Medium	+4
10.	Sanitation	Little	Low	Likely	Regional	Much important	High	Long	+7
11.	Drinking water	Large	Medium	Unlikely	Site	Little important	High	Short	+3
12.	Relocating people on homestead	Little	Low	Likely	Local	Little important	High	Long	+6
13.	Education	Little	Low	Likely	Regional	Much important	High	Long	+7

Table 11. Structure of Environmental Indicators

SI No.	Basic indicators	Target	Unit	Composite indicators		
1.	Terrestrial habitat	Conservation	Ha			
2.	Bank erosion	Reduction	Ha/yr.	Land	Ecology	
3.	Area inundated by pre-monsoon flood	Reduction	Ha			
4.	Post-monsoon inundation requiring drainage			Water		System
5.	Agricultural crop production	Increase	Tonnes/ha			
6.	Fish production	Increase	10^4 ton			
7.	Farmers income opportunity	Increase	10^6 tk/yr.			
8.	Project cost	Decrease	tk/ha	Economy		
9.	Nutritional status	Improvement	Calories		Socio-economy	
10.	Sanitation	Improvement	% HH	Sociology		
11.	Drinking water	Improvement	%			
12.	Relocation of families/homestead		Nos.			
13.	Education	Improvement	%			

Table 12. Weighting and Balancing Factors

SI No.	Basic indicators	Weight	Balancing factor	Second level	Weight	Balancing factor	Overall	Weight	Balancing factor
1.	Terrestrial habitat	0.40	1	Land	0.50	1	Ecology	0.50	1
2.	Bank erosion	0.60							
3.	Area inundated by pre-monsoon flood	0.45	1	Water	0.50				
4.	Post-monsoon inundation requiring drainage	0.55							
5.	Agricultural crop production	0.35	1	Economy	0.52	1	Socio-economy	0.50	
6.	Fish production	0.15							
7.	Farmers income opportunity	0.25							
8.	Project cost	0.25							
9.	Nutritional status	0.15	1	Sociology	0.48				
10.	Sanitation	0.20							
11.	Drinking water	0.25							
12.	Relocation of families/homestead	0.15							
13.	Education	0.25							

Table 13. Justification of Ideal and Worst Values

SI No.	Basic indicator	Ideal value	Worst value
1.	Terrestrial habitat	Area under vegetation is expected to expand rapidly up to about 9,276 ha under the project condition	Area under vegetation is expected to remain about 3,341 ha without project
2.	Bank erosion	Erosion of river bank is completely controlled (0.00 ha/yr)	The present level of erosion
3.	Area inundated by pre-monsoon flood	The entire area becomes flood free (0.00 ha)	The value of project area inundated under FWO condition (34,279 ha)
4.	Post-monsoon inundated requiring drainage	Some inundation is desirable to sustain aquatic animals (especially fisheries) (10,859 ha)	Maximum water logged area under about 1 m depth distributed over the project area (239,385 ha)
5.	Agricultural production	High yield projected under FW condition (3.53)	Minimum yield achieved during 30 years (0.00)
6.	Fish production	Fish production under present condition (5.46×10^4 tonnes)	Worst condition achieved during 30 years (0.00)
7.	Farmer income	Income 40% higher than projected value under FW condition considerable achievable ($1{,}471.25 \times 10^6$ tk/yr)	Income under present condition (307.4×10^6 tk/yr)
8.	Project cost	Low investment for implementation under present FWO condition (1100 tk/ha)	Higher investment under escalated condition (10,000 tk/ha)
9.	Nutritional status	National target proposed by WHO/UNICEF/BD Standards (2267 cal/capita/day)	Hard core poverty level of 50% value available presently (1,805 cal/capita/day)
10.	Sanitation	Complete utilization availability of sanitary latrines under WHO/BD Standards (100%)	Present situation of utilization (5%)
11.	Drinking water	Hand tubewells located on homestead lands. Full provision are main source of safe drinking water (100%)	Under arsenic contamination and no homestead availability (0%)
12.	Relocating the families	Relocation of families in FW condition (11,250)	Absence of any provision for relocation (0.00)
13.	Education	Full facility (100%)	Further dropping down in attendance rate, full illiteracy (0%)

without (FWO) condition, and future with project condition (Table 9). The results obtained after evaluation are shown below in descending order of overall status of system.

Management Option	Composite Distances
1. FW condition	0.6474
2. Present condition	0.4421
3. FWO condition	0.2826

The results are graphically shown in Figure 4. From the figure, it is clearly visible that the overall environmental status under FW (project) condition emerges as the most favorable.

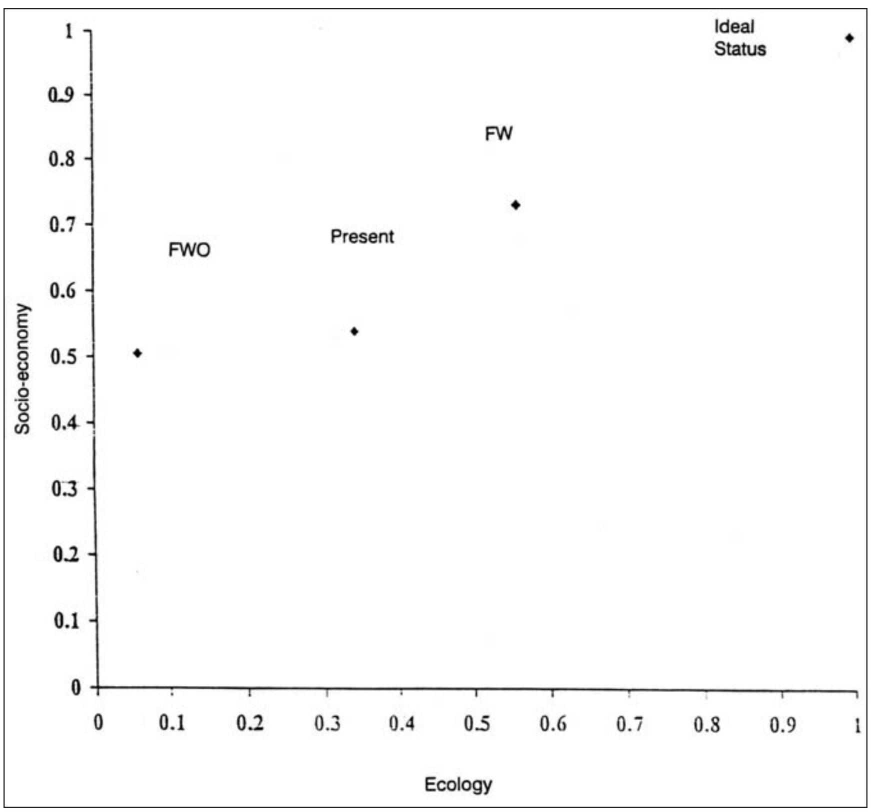

Figure 4. Graphical illustration of results.

CONCLUSION

The "MCDM Composite Programming Method" has been applied in a clear and holistic evaluation of a water resource project of Bangladesh. Its use after a rapid evaluation by "Matrix Method" is strongly suggested.

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