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研究解説

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Impacts of Disasters on Environment and Development ——A Case Study of Bangladesh——

環境と開発に災害が及ぼすインパクトについて ——バングラディッシュの事例より——

M. A. H. PRAMANIK*
M. A. H. プラマニック

The impacts of disasters on environment and development have been highlighted focusing Bangladesh as a case study. Major aspects of various disasters, environmental issues and development strategies have been discussed citing examples from Asian countries in general and Bangladesh in particular. The strategies of attaining environmentally sound and sustainable development have been pointed out. The applications of space sciences, remote sensing and geographic information system in conjunction with conventional information / data have been also mentioned.

1. INTRODUCTION

The interactions between disasters, environment and development work in a complicated way affecting people, ecosystem and bio-diversity. As such an optimum balance is needed between these factors so that all actions of human interventions should be taken in such a way that could be ultimately led to the welfare of human being with maximum benefit, less environmental degradation and sustainable conservation of ecosystem and bio-diversity. It is very difficult to attain environmentally sound and sustainable development (ESSD) without making a compromize optimization of the requirements of ESSD, adequate disasters preparedness and mitigation techniques development, tackling of environmental issues, application of country-specific development strategy and other related parameters.

The Asia-Pacific region occupies about 27 percent of the solid earth and accounts for 58 percent of the global population. About eighty to eighty-five percent of the global disasters occur in this region with heavy casualities and severe damages. These disasters create tremendous problems on environment and socio-economic development efforts of the countries with a high density of population. This calls for concerted national efforts and international cooperation.

The present paper deals with the interactions between disasters, environment and development focusing Bangladesh as a case study. As such it is felt that certain special characteristics of Bangladesh should be elaborated. Bangladesh is a disaster-prone country with a high density of population (about 800 persons per square kilometer) having an area of 144,000 sq km and a population of about 110 million. The physiography, morphology and other conditions have made her vulnerable to disasters like floods, droughts, windstorms (cyclones / storm surges / tornadoes) and others which occur regularly and frequently. Major factors responsible for disasters are:

- Flat topography more than 50 percent of the area having less than 10m elevation and the highest flat-plain area is of the order of 100m (highest peak about 1004m—Mowdok Mual); 12 percent hilly region, 8 percent old Pleistocene region and 80 percent recent alluvium region (1).
- Rapid run-off and drainage congestion the relief of the flood plains is extremely low between 1 and 2 m and low-rivers gradient (3 cm / km for the Meghna, 4-5 cm / km for the Ganges and 6-10 cm / km for the Brahmaputra (2).
- Effects of the confluences of the major rivers-system (The Ganges-Brahmaputra-Meghna-GBM-delta) with a vast network of rivers. The tributaries and distributories of the GBM delta that are criss-crossing the country with a large number of islands in between the channels.
- Enormous discharge of river-water heavily laden with sediments—both suspended and bed load (order of 2.4 billion tons per year).

*International Center for Disaster-Mitigation Engineering (INCEDE)

- Funnel-shaped and shallow northern Bay of Bengal causing strong tidal and wind actions and amplifying the effects of cyclones and storm surges.

These factors act in complicated ways to bring about geomorphological changes in the Bangladesh coastal areas. Based on the available information of the morphological conditions and hydrological features, the coast of Bangladesh covering about 710 km could be divided into three broad regions: Eastern Region, Central Region and Western Region-which have special characteristics-made them more vulnerable to disasters particularly to cyclones and associated storm surges causing huge loss of human lives, physical properties and infrastructural facilities.

In the present paper an attempt has been made to highlight various issues, and interactions related to disasters, enviornment and development in the Asian countries focusing on Bangladesh experiences and the role of space science, remote sensing technology and GIS in the management of natural resources and monitoring of environment and disasters. Possible international collaboration through information exchange, education, training, research, joint research projects of mutual interest is also highlighted.

2. DISASTERS IN ASIAN COUNTRIES

Disasters have global impact. Most of the Asian countris are disaster-prone. The physiography, morphology and other natural conditions have made them vulnerable to disasters and environmental hazards (3). The major universal disasters are:

- Floods.
- Windstorms (typhoons / cyclones) and storm surges.
- Droughts.
- Abnormal rainfall, hailstorm and lightning.
- Erosion and landslides.
- Earthquakes, tsunamis and volcanic eruptions.
- Saline intrusion.
- Industrial and other pollution.
- Deforestation and depletion of forests.
- Environmental degradation and hazards connected with disturbances in ecobalance i.e. ecological imbalance.
- Causes and effects of greenhouse gases—global warming, sea level rise, depletion of ozone layer, etc.
- Effects of El-Nino-Southern Oscillation (ENSO) and other climatic changes / variabilities / anomalies.

It may be mentioned that almost all of the above disasters occur in Bangladesh except tsunamis, volcanic eruptions, landslides, etc. but floods and cyclones are regular and frequent due to peculiar geographic location of Bangladesh and certain special characteristics as mentioned earliar. The high density of population (about 800 persons per square kilometer) has made her more vulnerable to the disasters causing huge loss of human lives and extensive damages of property during any disaster.

The above disasters have disastrous effects on life and property and offset development efforts particularly of the developing countries. The space science, remote sensing and GIS could play a vital role in the early warning, pre and post disasters events, damage assessment, rehabilitation, reconstruction and other related activities.

3. ASIAN COUNTRIES AND ENVIRONMENTAL ISSUES

The Asia-Pacific region countries are at different stages of socio-economic development and are facing varied environmental problems but except few countries almost all the countries have common issues which could be summarized as follows:

- Rapidly expanding and heavy population pressure.
- Poverty, unempolyment, lack in purchasing power and shortage of adequate facilities.
- Frequent and regular occurrences of natural disasters like floods, droughts, windstoms, earthquakes, tsunamis, volcanic eruptions, etc.
- Industrial, domestic and other pollution.
- Irrational use of chemical fertilizers / pesticides.
- Massive deforestation, depletion of biomass and energy shortage.
- Excessive abstraction of ground water.
- Human induced acivities—dams / embankments, etc.
- Shortage of safe drinking water and sanitation, safe disposal systems for urban debris / garbages.
- Rapid, unplanned and uncontrolled industrialization and urbanization.
- Emission of black smokes from factories and vehicles including loud horns / noise.
- Possible inundation of coastal areas due to climatic change / global warming / sea level rise.
- Dearth of knowledge regarding preservation of balanced and sustainable enviornment, lack of mass awareness and public education / sense of responsibility.

Environmental degradation threatens humans and

other faunal and floral species. In the Asia-Pacific region it is expected that population will increase by about 40 percent over the next 15 years (in cities by some 90 percent) and the economic activities will double the demand on natural resources (4). For optimal uses of natural resources, minimization of environmental impacts and attaining ESSD, the following actions are needed:

- To use energy more efficiently and search for alternate source of energy.
- To shift from fossil fuels to renewable sources such as wind, geothermal and solar.
- To halt deforestation and to limit emission of carbon dioxide and other greenhouse gases.
- To slow down population growth and to stabilize in the future.
- To use pollution-free technology and to create pollution-free environment.
- To strengthen global partnership and international cooperation to attain a pollution-free environment and a balanced and sustainable society.

The basic principles of a sustainable society have been elaborately described in an UNEP Report (5) as follows:

- Respect and care for the community of life.
- Improve the quality of human life.
- Conserve the Earth's vitality and diversity.
- Minimize the depletion of non-renewable resources.
- Keep within the Earth's carrying capacity.
- Change personal attitudes and practices.
- Enable communities to care for their own environments.
- Provide a national framework for integrating development and conservation.
- Create a global alliance.

It may be mentioned that the space science (SS), remote sensing (RS) and geographic information system (GIS) have been used for economic planning in attaining Environmentally Sound and Sustainable Development (ESSD), Global Climate Change (GCC) and Disasters Monitoring and Mitigation (DMM) (6, 7, 8 and 9).

4. DEVELOPMENT STRATEGY OF ASIAN COUNTRIES

The overall development strategy of the Asian countries vary considerably from country to country but the general trends are almost the same. All countries have the following critical objectives and strategy of development:

- To increase national income growth and self-reliance.
- To alleviate poverty and to generate employment.
- To develop human resources and skill manpower.
- To decentralize participatory planning and people-centered development.
- To integrate group-based with sector-based approaches.
- To identify more efficiency sectors and groups.
- To integrate poor and disadvantaged groups and bring them to the center.
- To bring women to the mainstream of the development process.
- To optimize capacity utilization in all sectors.

The different Asian countries are at different stages of development but almost all have the identical problems of overpopulation, weak infrastructural facilities, low industrial base, disasters, environmental degradation, etc. To attain the above objectives and to resolve the problems, all-out and coordinated efforts are needed at national levels and in addtion cooperation at regional and international levels are also prerequisite.

The interactions and impacts of disasters on environment and development are explained in figure 1 and this concept required to be integrated in the development process.

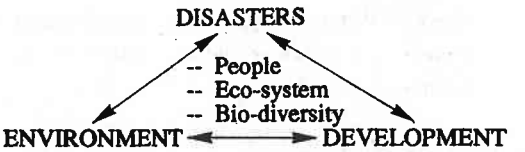

Fig. 1 Interactions between Disasters, Environment and Development

5. THE USE OF SPACE SCIENCE AND THE INTEGRATED RS-GIS (REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM)

Space Science (SS) and RS-GIS (Remote Sensing-Geographic Information System) have wide applications in the natural resources management, development planning, environment studies and disaster monitoring purposes. Major fields of applications of space science, remote sensing and GIS are (10):

- Agriculture and vegetation.
- Water resources and hydrological regime studies.
- Conservation and environmental management.
- Engineering applications.
- Science and engineering in data acquisition and analysis.

- Geology and mineral exploration.
- Hazard monitoring and disaster mitigation.
- Urban planning and industrialization.
- Oceanography, marine resources and shipping.
- The atmospheric and stratospheric studies.
- Medical applications.
- Image processing and pattern recognition.
- Topographic mapping and automated cartography.
- Geographic information system (GIS).

Based on the focus of the present paper applications of SS-RS-GIS in the following fields are elaborated (11):

○ Economic Planning
- Identify optimal sites for human settlements, schools, health facilities, hospitals, commercial enterprises, waste disposal systems.
- Indentify optimal locations and necessary specifications for communication networks, power lines, water pipes and sewer systems and plan for maintenence.
- Plan transportation routes that take factors such as population distribution, environmental vulnerability, land values, economic parameters, slope gradients and soil suitability into account.
- Identify and correlate spatial patterns in health and diseases with chemical element distribution and pollutants.

○ Environmental Protection
- Assess environmental quality.
- Assess the likely impacts of proposed land uses; evaluate land acquisition priorities for conservation.
- Model the cost of alternative environmental policy options for sustainable development.
- Develop national and regional environmental regulations.

○ Natural Disasters Reduction
- Prepare hazard maps.
- Determine optimal locations for disaster relief centres and cyclone shelters.
- Identify populations at risks from disasters; design and implement natural disaster planning and strategies.

It may be mentioned that SS-RS-GIS has been extensively used in the Asian countries particularly in the following studies:

○ Environmentally Sound and Sustainable Development (ESSD) through integrated resource management.
○ Global Climate Change (GCC).
○ Disasters Monitoring and Mitigation (DMM).

Environmentally Sound and Sustainable Development (ESSD)

The space science, remote sensing and geographic information system (SS-RS-GIS) has now become a tool for the holistic and integrated management of the land and water resources as well as other physical and infrastructural resources. The information when combined with conventional geo-political and socio-economic informatin / data and integrated use of SS-RS-GIS, will provide timely input for carrying out development planning, environmental protection and disaster mitigation activities. Many nations have already obtained immense benefit of this technology (6, 7, 8, 9, 11, 12 and 13).

It is very difficult to attain ESSD without making a compromise—optimization of the requirements of ESSD and the environmental problems. For this purpose SS-RS-GIS along with conventional data could play a vital role. Sustainable development of natural resources needs an understanding of the mutual interdependencies and relationships of various resources (both renewable and non-renewable resources) and the identification of the ecological problems at the microlevel. These could be achieved through phases:

○ Collection and collation of conventional data and their evaluation.
○ Preparation of set of resource maps using existing maps, satellite / space-based remote sensing data and other collateral geo-political and socio-economic data. The thematic maps could be of the types as:
  - surface water bodies.
  - ground water potential zones.
  - potential zone for ground water recharge.
  - soil map including nature and erosion status.
  - existing land use and distribution of wastelands.
  - an integrated land and water resource map giving high priority areas for development of agriculture, fuel, fodder, soil conservation and afforestation.
○ The final stage is to develop a package of appropriate strategies to address the local resources management and environmental problems.

The completion of the above stages and their proper utilization in the national development planning will

definitely help in attaining ESSD. Indian experiences for NNRMS (National Natural Resources Management System) and its applications in the development planning process could be profitably used by others (6 and 13).

Global Climate Change (GCC)

The dynamics of the global environment is changing due to human intervention and other causes and effects. The impact of greenhouse gases on the world environment has become a great concern for the mankind. The cause and effect of the greenhouse gases and other related phenomena have resulted in the global warming and subsequent sea level rise. These will have tremendous impact on the socio-economic consequences on the low-lying countries. SS-RS-GIS could be used for monitoring and measurement of various paramaters related to GCC.

Disaster Monitoring and Mitigation (DMM)

Extensive use of SS-RS-GIS has been made for disaster monitoring and mitigation purposes. Asian countries are also developing methodologies for mapping of natural resources needed for ESSD, monitoring and management of environmental changes and disasters. All the nations would greatly benefit from a regional cooperation programme which would provide a mechanism for:

- Information exchange on projects / specific disciplines of common interest.
- Sharing of training and infrastructural facilities and expertise.
- Undertaking joint research projects of mutual interest.

It may be further mentioned that there exists so many GIS's with different modes and models that it poses problem with regard to international and regional cooperation. It is felt GIS should be standardized with respect to methodology, specificity, terminology and interorganization. Moreover, use of common format or easily exchangeble mode for database be developed (7). The database may include:

- Political boundary
- Population
- DTM (Digital Terrain Model)
- Land use
- Soil
- Geology
- Land form (Geomorphology)
- Vegetation
- Planning development

Data acquisition for digital database including fundamental geographic information of political boundary, population, digital terrain model, land use, soil geology, land form, and vegetation with standardized codes should be implemented with an international aid according to the following phases:

- Global: 10 – 20km grid (1 : 3,000,000 – 1 : 5,000,000)
- Continental level: 4 – 8km grid (1 : 500,000 – 1 : 1,000,000)
- National level: 250m – 1km grid (1 : 200,000 – 1 : 250,000)
- Regional level: 50 – 100m grid (1 : 50,000 – 1 : 100,000)
- Local level: 10 – 50m grid (1 : 2,500 – 1 : 10,000)

6. BANGLADESH EXPERIENCES

It has been already mentioned that Bangladesh is a disaster-prone country with a high density of population (about 800 persons per square kilometer). The peculiar geographic location and morphological conditions have made her vulnerable to disasters. The flat topography, rapid runoff, effects of the confluence of major rivers, drainge congestions, funnel-shaped and shallow Bay of Bengal causing high windstorms and storm surges are major factors for the occurrences of disasters. Disasters-problems and environmental issues of Bangladesh are almost same as other Asian countries but high density of population, higher frequency and intensity of disasters and weaker industrial base are some of the salient characteristics of Bangladesh. Major disasters of Bangladesh are floods, droughts, windstorms (cyclones / tornadoes), storm surges, etc. which occur regularly and frequently. In the present paper effects of floods and cyclones are described briefiy.

6.1 Floods in Bangladesh

Floods frequently and regularly occur in Bangladesh. Though monsoon rains are the major causes of flooding but there are various other factors like rapid runoff, the effect of the confluences of the major rivers, the flat topography of the delta and surges in the Bay of Bengal. Types of flooding in Bangladesh are:

- o Flash floods sharp rise and drop in water levels causing high velocity damaging crops and property
- o Rain floods high intensity rainfall over Bangladesh

and surrounding area.

- Monsoon floods overspilling of major rivers-usually rise slowly but extensive damage occurs when the three major rivers rise at a time.
- Storm surge floods arising from storm surges in the coastal area.

The peculiar geographic location and low topography of Bangladesh area has subjected her flooding from time immemorial. The severe and extensive flooding in the Bangladesh area occurred in the years 1787, 1871, 1885, 1892, 1918, 1922, 1954, 1955, 1963, 1968, 1969, 1970, 1971, 1974, 1987 and 1988.

6.2 Cyclones in Bangladesh

The term "cyclone" is derived from the Greek word "Kyklos" meaning coil of snakes. Satellite imagery showing the cyclonic formation depicts the coil of snakes like-pattern. Every year, there are some eighty tropical cyclones occurring around the globe, out of which about 4, form in the Bay of Bengal (14). The formation, intensification and structure of tropical cyclones are related to six primary climatological genesis parameters which are (15):

- Low level relative vorticity.
- Coriolis parameter.
- Weak vertical shear.
- Ocean thermal energy sea surface temperature excess of about 26 degree C.
- Vertical gradient of equivalent potential temperature.
- Middle tropospheric relative humidity.

The Bay of Bengal is the breeding place of catastrophic cyclones causing loss of life and property during pre-monsoon (April-May) and post-monsoon (September-December) periods. Cyclones in the Indo-Bangladesh sub-continent are classified according to their intensity and the following nomenclature is used:

- Depression winds upto 62 km / hr.
- Cyclonic storm winds between 63–87 km / hr.
- Severe cyclonic storm winds between 88–118 km / hr.
- Severe cyclonic storm of hurricane intensity winds above 118 km / hr.

Catastrophic cyclones occurred in the Bay of Bengal and hit Bangladesh coastal areas in the years: 1584, 1876, 1919, 1942, 1960, 1961, 1963, 1965, 1970, 1985, 1988 and 1991.

6.3 National Efforts

In spite of these government and people of Bangladesh are struggling hard for survival and improvement in the quality of life of the people by taking some appropriate steps as follows:

- Development of appropriate forecasting and monitoring system of disasters in Bangldesh.
- Establishment of Space Science, RS-GIS and other associated facilities-which are effectively used for environment and disasters monitoring and mitigation purposes.
- Formulation and promulgation of National Environment Policy (1992) and Action Programmes.
- Preparation of National Conservation Strategy (NCS) and National Environment Management Action Plan (NEMAP) and their implementation through phases.
- Mandatory Environment Impact Assessment (EIA) of development projects particular attention has been given to the Flood Action Plan (FAP) project under implementation.
- Environmental Quality Standard (EQS) and Industrial Guidelines related to Environmental paramaters are at the final stage of preparation.
- Creation of awareness and imparting of training to the concerned officials in phases are in progress.
- Regional and international collaboration for improving the environment quality.

With this background information the major themes and issues of disasters, environment and development are addressed as follows:

- Human Resources Development in the field is within the framework of short-term and long-term training programmes of the country and all-out efforts are being made in this respect. International support and cooperation is also required for the purpose.
- Status of disasters and environmental understanding / thinking / assessment in the country and its impact is encouraging. The National Planning Commission, Ministry of Environment and Forest, Department of Environment (DOE), and other concerned ministries / agencies are taking appropriate steps for the environmental components in their developments efforts. UN / ESCAP and Asian Development Bank are making studies, surveys, assessments, etc. on regional aspects of the environment.
- EIA's are mandatory for development projects and continuous monitoring are also done. Out of 26

components of FAP one component (No. 16) is for overall environment impact assessment. Similar other mandatory approaches for EIA are in implementation in the country. These are being implemented in phases through five-year and ten-year perspective plans with ultimate aim of attaining environmentally sound and sustainable development and improvement in the quality of life of the people in the country.

6.4 Impacts of Disasters on Environment and Development in Bangladesh

Bangladesh is a developing country with numerous problems of overpopulation, poverty, complex socio-economic structure, frequent disasters, low-level industrial base, resource constraints, lack of appropriate infrastructural and institutional facilities, dearth of trained manpower, etc. These problems are complicated and compounded with the occurrences of regular and frequent disasters impeding the overall socio-economic development efforts of the country. To cite few examples, on average the Annual Development Budget of Bangladesh is of the order of 1.5 to 2.0 billion US dollar in various sectors like agriculture, water resources, health, education, industry, infrastructure (transport, utility systems and related items), social welfare, etc. In addition to the loss of valuable human lives and immense suffering of the people, the damages caused by disasters in terms of physical properties and infrastructural facilities are of the magnitude of US$ 1.0 billion (1970-cyclone), US$ 2.4 billion (1988-flood) and US$ 1.4 billion (1991-cyclone). It is estimated that the total economic loss due to disasters in Bangladesh for the period 1947–1991 is of the order of US$ 25 billion. Relief, rehabilitation and reconstruction activities after disasters require huge resources and time consuming, affecting the overall development of the country. As such disasters and development act in a vicious cycle of reconstruction and destruction—net result is the hindering of the socio-economic development of the country. It may be further mentioned that after any disasters both quantifiable and unquantifiable environmental degradation and ecological imbalance occur. Thus the efforts of improving the quality of life of the people and attaining ESSD are being frustrated. It is felt that when disasters occur, in addtion to the short-term measures by providing relief and essential items, more attention should be given to the effects of impending disasters that should be integrated in the long-term development planning and programming process in the country.

The occurrences of severe cyclones and devastating floods are inevitable and are the ferocity and vagaries of nature. These can not be stopped—but preparedness and appropriate mitigation techniques could help a lot in terms of reducing loss of life, physical property and infrastucture facility. It is felt that believing in the phylosophy of "Live with disasters", the following important disaster mitigation tools should be developed:

- Improved forecasting and monitoring techniques.
- Identification of high risks regions and dissemination of information to public.
- Awareness about disasters to policy-makers and others through mass-media.
- Preventive measures short-term and long-term basis including structural and non-structural methods.
- Integration of disasters in the development planning process.

7. SUGGESTIONS

In synchronization with the United Nation's International Decade for Natural Disaster Reduction (IDNDR) objectives and strategies (16), the following geographical levles of actions are needed: Local, National, Regional and Global.

The following functional activities are to be performed:

- Identification of hazard zones and hazards assessments.
- Vulnerability and risk assessment, cost / benefit analysis.
- Awareness at level of decision and policy makers.
- Monitoring, predicting and warning.
- Long-term preventive measures.
- Short-term protective measures and preparedness.
- Early intervention measures.

In addition, the supporting activities needed to be undertaken are as follows:

- Education and training of local and national specialists.
- Public education and information.
- Transfer of appropriate technology.
- Application of proven technology.
- Research to develop new technologies and devise new policies.

The diversity, complexity and the dynamics of the natural disasters and environmental hazards call for an elaborate system of warning-well ahead of time. This

warning system should be developed by all countries so that the above activities could be undertaken more efficiently. In addition, the following efforts should be made by all countries:

- Conception, participation and involvement of local people should be ensured at all stages of planning and implementation of disaster-mitigation activities.
- Formation of international network for exchange of information / data / expertise on disaster warning and management.
- Mass awareness, public information methodology and mass-media activities should be strengthened particularly for disaster management, survival techniques and time-spaced-based-action-oriented approaches.

8. CONCLUSIONS

The present paper has dealt with various aspects of disasters and their impacts on environment and development in Asian countries focusing Bangladesh as a case study. Appropriate steps through both structural and non-structural means without causing environmental degradation and ecological imbalance should be taken for disaster-mitigation, environmental protection and sustainable development. An all-out effort should be made at every stage of design, implementation and monitoring of projects to take care of above aspects. Space science and remote sensing-GIS technology could provide immense information / data for the purpose. A network approach and cooperation at regional and global levels are very much essential. In addition synchronization with IDNDR activities, national efforts should be taken for disaster-mitigation and for environmentally sound and sustainable development (ESSD) approach particularly in Asian countries.

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