Environmental Issues of North East India

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PREFACE

Our planet earth is unique. Its physical and biological components are parts of an interacting system known as ecosystem. Human activities depend mostly on the exploitation and consumption of resources (mostly biotic) and cause a wide range of environmental degradation.

The most important natural resource is land comprising soil, water and associated plant and animal life involving the total ecosystem. Our future depends on the preservation and improvement of the natural resources. But there has been extraction of bio-mass over large areas at the cost of land's natural capability of regeneration and re-enrichment, resulting in an irreversible land degradation causing socio-economic and environmental problems. In the field of mindless mining of coal and other natural resources the miners and the metallurgists to an extent are responsible for polluting the rivers, streams and atmosphere. They function as an agent to disturb the ecological balance by their unscientific works. The making of roads in the hill regions without proper slope stabilisation may induce landslides, excessive cutting of forest may increase soil erosion, depletion of wild life, worms and insects which sustain the ecosystem. In a planned development process all the issues of eco-balance have to be considered and then decision has to be taken scientifically on any development activity.

It is imperative that an awareness of this situation be created at all levels with decision makers, land use planners, farmers and the people. A sound technical basis for the preservation and improvement of the mother earth in the context of North East India has to be found. We need to improve our soil capital as well. With this end in view the North-East India Council for Social Science Research held a seminar on 'the Mother Earth' in the context of North East India on 5 June 2002. The present volume has included 21 papers presented to it.

We take this opportunity to thank Mr. K.L. Tariang, Director, Dept. of Soil and Water Conservation, Govt. of Meghalaya for his initiative and support to hold this important seminar. We would like to thank Mr. Arun Kumar Verma of Regency Publications, New Delhi for undertaking expeditious publication of this volume.

5 February, 2003

B. Datta Ray
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EDITOR'S NOTE

Every year on the 5th June the North-East India Council for Social Science Research (NEICSSR), Shillong organises a seminar or a panel discussion or a lecture to mark the occasion of the *World Environment Day.* This is because of two main reasons. First and the foremost being that the NEICSSR is an affiliated body of the United Nations Environment Programme (UNEP), hence it is obligatory on the Council to join the efforts of the UNEP in propagating the cause of the world environment. Secondly, the Council is itself dedicated to facilitate research, discussion and publication on environment. This is evident from its various academic activities and number of publications related to the environment and management of natural resources, particularly of the Northeast India. Therefore, on the 5th June 2002 a Seminar was held on 'The Mother Earth' to celebrate the *World Environment Day* by focussing attention on the land and its resources in Northeast India. The theme was purposely selected to focus attention on the deteriorating state of the earth/land and the land based/ governed environment, nowadays called *'geoenvironment'*. In fact, the rapid rate of depletion and degradation of the land and its resources has jeopardised the existence of the various life forms on the surface of the earth. It has not only disrupted the functioning of the global ecosystem/ geoecosystem/geosystem/ecosphere but also reduced the carrying capacity of the earth. This is the most burning topic in any discussions on environment of the earth today. Hence, the present book is entitled as *'Environmental*

Issues of Northeast India' to actually understand and solve the environmental problems of the region.

The book is primarily an outcome of the papers presented in the Seminar. However, there are some invited papers as well to have a comprehensive picture of the state of the environment as far as possible. The environmental issues raised in this book are, in fact, a sequel to the topics discussed a few years back in the previous edited book-*'Environmental Degradation and Conservation in Northeast India'* (Husain, 1996). The only difference is that the present volume concentrates more on the geoenvironment or land based environment.

The degradation and conservation of environment are two complementary issues which are the most important ones also from the point of view of having a healthy environment capable to give sustainable supply of energy and matter for the better functioning of all types of ecosystem with their abiotic and biotic components (including man). Today, on one side, we are very much concerned about the nature, type, rate, intensity, magnitude and causes of the degradation taking place in land, water, air and organic components of environment and their impact on the living and non-living components of the global ecosystem. On the other side, we are very much worried and thus making every possible efforts to check further deterioration of the environment and restore the lost glory of the environment by conserving it on ecologically sound principles. That's why environmental conservation tops the agenda in any meetings on man and environment of the earth, right from the entire globe to a farmer's field levels. This is because to save the environment with all its potentialities we have to think globally but act locally. Otherwise, the environmental problems cannot be solved because they are not only complex but they transcend all boundaries, including the political ones. Moreover, in this age of globalisation the environment has also been globalised where people and environment of any part of the earth are subjected to the happenings the world over, and the

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The present book has three broad sections, each emphasising a particular issue of the environment, which is worth paying attention by the environmentalists. The First Part deals with the *state of the geoenvironment*, especially different aspects of the land and water—the two most vital components of the environment. It helps us not only to manage these resources properly but also to efficiently manage the hazards and disasters related with land and water. While the Second Part covers the most common environmental problem experienced the world over—the *environmental degradation*, particularly of the land, water and the organisms. *Environmental management* is the theme of the Third Part, for this is the basic approach and method which can help us to reduce the rate, intensity and extent of environmental degradation on one hand, and maintain the ecological balance on the other so that sustainable supply of environmental resources is maintained for the present and future generations.

The five papers included in the First Part deal with very critical issues of the land and water. Of course, here land is considered in its all-comprehensive sense, which includes geological and geomorphological points of view related with the geodynamics, structure, lithology, seismisity, and mass movement in the form of landslides, subsidence etc. It also focuses on the productivity of land for agriculture purpose, which actually determines fate of the people living in any part of the earth. Landslide is the most frequent and devastating geohazard in the hills affecting life and property of the hill dwellers and disrupting the communication system, particularly along the roads, railways and in and around human habitations. The entire hilly part of the Northeastern region suffers from this problem with varying magnitude, frequency and extent. Day by day the problem is getting more and more severe and it has become chronic; and crores of rupees are spent every year for the management of this geohazard.

The first two papers by the geologists are related with the geodynamics and the landslides. R.K. Avasthy as a pioneering worker on the landslides has given a brief account of the researches carried out on occurrence and causes of landslides in different parts of Northeast India. He has attributed both natural (earthquakes, faults, discontinuities, etc.) and human (road cutting, wrong location of the settlements, etc.) causes for the occurrence of landslides. He has identified six types of landslides in the region. Keeping the seriousness of the problem in mind appropriate suggestions have been put forward to check the incidence of landslides and reduce the risk involved in it, particularly how to save and develop the hill towns (mostly the state capitals like Aizawl and Kohima). Landslide hazard zonation map of Northeast India has also been prepared to help in locating the vulnerable areas and for disaster management. In the similar paper Trilochan Singh describes the occurrence of the landslides as a geoenvironmental hazard in context of the restless Arunachal Himalaya. According to him the geodynamics plays an important role in making this part of India more prone to the landslides and earthquakes. The juxtaposition of the three litho-tectonic systems in Arunachal, the slow northward movement of the Indian shield and the presence of various faults and thrusts in the region are main causes of the geodynamic activities in the Northeast India. Landslide is an outward expression of these activities, which itself create dangerous geohazard.

Very crucial property of the land is its productivity on which depends the food production in a region; hence its assessment is essential for food security on one hand and to take stock of the land degradation on the other. Undoubtedly, land productivity is unevenly distributed over time and space, due to both natural and human factors. The paper by Bimal Sharma and Zahid Husain explains the districtwise spatial variation in land productivity in the state of Assam. The state has two basic land units—the *valleys* of the Brahmaputra and Barak, and the *hills* of Karbi Anglong and North Cachar Hills, mainly responsible for variation in land productivity, but within each land unit there are some variations also. Land productivity of each district has been evaluated with the help of simple statistical formula. Then districts have been grouped into three categories of high, medium and low land productivity by giving suitable reasons for the difference in the land productivity in Assam. This vital property of land is under serious threat from the pollution, degradation and soil erosion, and over exploitation of the land to produce more food to feed the rapidly increasing population. Actually, for the better survival of man and environment not only the land productivity has to be maintained but it has to be enhanced/improved also with appropriate methods, technology and strategy, especially in agrarian country like ours.

After the land, water is the most vital natural resource on the surface of the earth. Therefore, its proper appraisal, assessment, utilisation, conservation and management are as essential as water itself is for the all life forms. Within the Northeast India the valleys of the rivers like the Brahmaputra, Barak, Imphal etc. have an excess of water by virtue of having a good number of water bodies and wetlands in their fold. In contrast to it, the Himalaya Mountains, Meghalaya Plateau and some parts of the Indo—Burma Ranges though receive a substantial amount of annual precipitation but surprisingly suffer from scarcity of water resources, *e.g.*, the Cherrapunjee area which shares the record of receiving the highest orographic rainfall in the world with Mawsynram. In reality, the mountains are the sources/storehouses of water for the plains, for whatever is the rainfall in the hills it flows down the slope towards the plains, more rapidly in case the rainfall intercepting vegetation cover has been removed and water-absorbing/holding soil has also been eroded, mainly due to the human activities. Hence, the rainfall has to be properly harvested in the hills itself to have water round the year, and here the forest and soil cover plays a vital role in naturally storing the rainfall. Recently, the Union Government has launched a rupees 1000 crore project—*Hariyali* (greenery) for rainwater harvesting in India with the dual objective of tackling water scarcity problems and augmenting the resources of the panchayats/village councils.

K.L. Tariang while taking stock of the rich water resources of Meghalaya has pointed out that these resources are at risk due to degradation of land and forest in the catchments/watersheds. Because of it the sources of water have depleted from a happy state of plenty to a miserable state of scarcity. Moreover, one has to pay a heavy price now for small quantity of water that too not available at right time and in good quality. Therefore, he has suggested innovations and strategies for harvesting rainwater in the area where it falls to solve water scarcity problem and change the paradoxical situation occurring in the place of 'the abode of clouds', *i.e.*, Meghalaya in general and the rainiest area of the Cherra-Mawsynram particularly.

The pattern and trend of rainfall over an area greatly control the availability of water in time and space. Its yearly variation, rise and fall affect the sources of water. It is a common belief that rainfall has been decreasing in many parts of the earth, including the Northeast India. However, the paper by Prasenjit Das and H.J. Syiemlieh tells a different story. While analysing the trend of annual rainfall in the Brahmaputra valley they have clearly negated the common belief. Their study shows that over the last 25 years the annual rainfall has increased, instead of decrease, in the seven stations out of the nine stations in the Brahmaputra valley. Coupled with deforestation in the surrounding hills and resultant increased surface flow and shorter concentration time of rainwater in the rivers could the increasing annual rainfall be attributed to occurrence of more frequent and severe floods in the recent years in the valleys.

Papers in the Second Part discuss the most serious issue of environment—the degradation that is responsible for reducing the value of environment both qualitatively and quantitatively. Degradation of environment has been going on from centuries in many types, rates, ways and extent due to a number of factors and processes. Even people of the early civilisations experienced and contributed to this problem. The ultimate result is decline in the suitability and comfortability of environment for different living beings, including man whose survival has definitely been threatened. Because of it, environmental degradation has gained attention of the scientists from various disciplines. A.K. Bhagawati has presented a very gloomy picture of the riverine tracts of the Brahmaputra. He has given an account of the environmental degradation in this very sensitive landscape due to pressure of over population even on the marginal lands like the *chars* (sand bars) and islands lying in the course of the mighty Brahmaputra River. Utilisation of the marginal land units for various purposes has led to their degradation. Floods and bank erosion are severe hazards in these tracts, especially after the occurrence of the great earthquakes of 1897 and 1950. Faulty construction of the houses, roads, embankments etc. are equally responsible for the environmental degradation of the area.

Very rarely man has been able to practice the principle of *'development without destruction'*. Thus, many a times there have been deleterious impacts of the development projects on the benign environment. This is happening even today despite implementation of the rule of submitting an *'Environmental Impact Assessment'* (EIA) report with every developmental plan as a part of the planning process. Now the report about the probable impact of a development project on environment submitted with the plan is called *'Environmental Impact Statement'* (EIS). Whereas EIA is now actually applicable to the study of the impact(s) of a development project after its completion, and A.K. Bora's paper is an attempt in that direction. He has made an empirical assessment of the adverse effects of an irrigation project on the environment and economy. No doubt the irrigation facilities have improved the agriculture performance in the command area, but the benefits compared to the losses are very less. The irrigation system has degraded the forest, land and water due to its improper maintenance and operation. Moreover, high sediment yield from the catchment has even threatened the life span of the barrage itself. Is it a real development/sustainable development?

Land is the most degraded component of the environment, only next to the forest. Though all types of land/landscape are subjected to degradation (*e.g.*, hills, plateaux, plains, coasts, etc.) but the highly degraded seems to be the wetlands, especially those that are located in and around urban and industrial centres. Of course, there are examples in the world where the wetlands of countryside have also been degraded due to draining off the water to prepare agricultural fields. That's why great concern is being shown nowadays to the wetlands through out the world, and in the Northeast India as well which can boost of having a great variety and number of fresh water wetlands. Serious efforts are afoot the world over to save and conserve the wetlands as they are very valuable ecosystems formed at the interface of the land and water. Wetlands are indeed a typical geoecosystem characterised by water saturated or submerged piece of land having unique geomorphology, hydrology, soil, flora and fauna. These are an essential (vital as well) segment of the landscape ecology, for they play a crucial geomorphological, hydrological and biological role in the complex of the geoecosystem. Therefore, degradation and depletion of such a valuable unit of land is definitely a matter of great concern for the scientists of different disciplines in general and the geoenvironmentalists in particular. That's why there is a paper by N. Memma Singha and Zahid Husain to show concern about the dying wetlands of Assam, particularly of Guwahati City. Decline in total wetland area and total water spread area of the Silsako and Numalijalah wetlands has been calculated by them from the sequential toposheets and satellite imagery. This pitiful situation has arose due to encroachment of the wetlands for construction of houses (colonies), roads, railways, industries etc. as the City requires space for horizontal expansion with the increase of population and development. Blockage of incoming streams has also caused decline in the total water spread area. Almost 80 per cent of the original area of the wetlands is lost to the encroachment—a wasteful use of the wetlands indeed. Pollution of the wetlands is another reason of their degradation.

Environmental pollution as a result of the contamination of the land, water, air and biome by toxic substances and gases has not only reduced the quality and quantity of environment but the biodiversity too. Biodiversity is certainly lost the world over, but the rate and intenstiy varies in time and space. O.P. Singh has tried to explain the lethal effects of the contamination of environment on various life forms and also on the inorganic elements. Such papers remind us of our erroneous acts which are costing too much to the plants and animals, and even man himself is not free from its detrimental effects.

The land is so much so important resource that it could easily be called the mother of all resources, that's why we address it as *'mother earth'*. Every society has its own perception about the earth/land and its usefulness for various purposes and P.R. Mawthoh has presented the perception of the Khasi people. He has also described abuse of the land in Northeast India through soil erosion and land degradation. Shifting cultivation has been considered responsible for the land degradation. The Second Part on environmental degradation ends with another paper on abuse of land/environment by Bibhash Dhar. He has not only tried to create public awareness about it but also suggested measures to check it and maintain our surroundings in much better and beautiful manner.

The Third Part of the book is devoted to the management of environment (land, water and forest). It is because the proper management of environmental resources can only save man and environment both. Therefore, appropriate technology and strategy has to be developed and employed to achieve efficient management of environment and its resources. This would not only ensure optimum utilisation of resources but also the ecological balance and sustainable development, all of which are equally important. The starting paper on this theme is by K.K. Satapathy, which deals with the methods and techniques of management of land in the mountains where shifting cultivation (now detrimental) is still practised by thousands of hill dwellers. In place of it he has suggested agri-horti-silvipastoral system for the hilly region in which toposequence based crop cultivation has to be developed. He has also suggested methods of soil and water conservation in the hills. It is worth mentioning here that no developmental plan can afford to ignore the indigenous knowledge about the husbandry of land and animal. Hence, the indigenous methods, techniques and strategies have to be incorporated in the developmental plan for the future.

N.N. Sarmah has discussed land and water management problems in the region. Being two vital resources of the environment the management of land and water has to be integrated by adopting the watershed management approach. In fact, watershed management is a practical answer to the eco-friendly development and environmental conservation where all the resources of a river basin are managed in such a manner that development of one does not harm the development of the other, and in this way an over all development of man and environment both takes place. On the other hand, Sujit Deka and A.K. Bora advocate that environmental conservation is also possible through the wasteland management. If wastelands could be developed properly it will certainly help in enhancing the potential of an area and thus in saving the environment as well. This is because increasing population pressure on land and demand for food has led to subsequent expansion of agriculture and that is not possible now without utilisation of the wastelands. They have suggested ways and means for the wasteland management. The only point that has been bothering the mind for a long time is a correct definition of the wastelands. Of course, for the wastelands in terms of agriculture Dudley Stamps' definition of the wastelands can be taken as authentic one. This is because a piece of land considered waste for a particular use (here for example for agriculture) might not be waste for any other use (say industry or settlement). Therefore, wasteland concept is land use specific. Moreover, a land lying unused now but has the potential for the development of agriculture can also be considered a wasteland. Dealing with the land management the last paper is by Niranjan Das, where he has suggested application of the organic manure to replenish the soil on one hand and check the land degradation on the other, because the chemicals used in the agricultural fields are harmful to the land and water resources.

After careful and sustainable management of land, it is time now to turn to the management of the forests, and in this regard U.K. De's paper is a welcome contribution, first exhaustively covering different aspects/issues of forest management theoretically, and then giving an example of Joint Forest Management (JFM) in Tripura. He is of the opinion that economic incentive should be given to the people to make JFM more attractive and fruitful. Actually, JFM has emerged as a practical approach towards management of forests, especially the degraded forests or regenerated forests where the community or communities living in and around the forest area participate actively in its management to get benefits from the forest. Sometimes, such efforts are not as successful as desired due to lack of interest shown by the people. Hence, De has proposed economic incentive for JFM programme in Tripura whose case study has been cited. Effectiveness and success of the policies and campaigns of environmental conservation depend on the nature and ownership pattern of resources (commonness, exclusion and non-exclusion possibility), socio-economic conditions of the people and the possibility of enforcement of different policies. He has pointed out drawbacks of common property resources (CPRs), thus the principle of anticommons could be an effective way of preserving the critical environmental resources. In fact, the greed, selfishness, lack of responsibility towards the community and the environment, and declining role of the traditional institutions in the management of environment and resources are some of the main causes for the over exploitation of the CPRs. Otherwise, CRPs have been bank of resources for the society in the past, and it can still play the same role, provided peoples' attitude towards it changes.

Over all environmental management is in focus even if a single resource is being developed. That's why D.C. Goswami has suggested social forestry for the environmental management in the Himalayan region. While R.P. Bhattacharya has discussed forest conservation in Arunachal Pradesh as forests are declining rapidly. One of the primary reasons of the depletion of forest is collection of fuel wood from it. Hence, to save the forests alternate sources of energy have to be discovered. In this regard D.R. Das has suggested bioenergy as a renewable source of energy not only to save the forests but also to meet the growing energy needs. Technological know how and financial support are required by the people to develop such schemes. Therefore, for the establishment of a bioenergy plant the Ministry of Non-Conventional Energy Sources gives 90 per cent subsidy in the Northeast India.

For an efficient and successful management of environment it is necessary to understand the processes of resource formation, recognition, utilisation and conservation. S. Aravamudhan has theoretically tried to explain it through various definitions, concepts and diagrams, along with examples from the Northeast India. According to him it is important to know what is available as resources in the region, and how far they are being utilised for the benefit of the people of the region. A. Henia in her paper has discussed that how environmental awareness could be raised in the region through the literacy campaigns to successfully manage the environment.

Some points emerge from the book. First is about having fundamental knowledge of the state of environment that helps in understanding the factors and processes involved in the occurrence and solution of the environmental problems on one hand and in finding appropriate technology and strategy for environmental management and solution of the problems. This also helps in disaster management. In this case the nature and characteristics of land have been touched upon in the book, mainly those related with the geoenvironment. Second point tells about the application of the 'systems approach' in the environmental studies. It is because the various components (land, water, forest, animals, etc.) of environment are interrelated, interdependent and interconnected, hence should be taken as parts of a system. Though studied separately, but as a part of the larger system they play crucial role in the functioning and maintenance of the system, which is called as *ecosystem* by the ecologists, *geosystem* by the earth scientists and *geoecosystem* by the geoenvironmentalists. The integrated approach of watershed management comes nearer to the systems approach; of course, a watershed can be a part of a larger river basin. Therefore, a comprehensive understanding of the entire environment as a system is necessary to deal effectively and efficiently with its management and problems, and this is possible only through multi/inter-disciplinary works. That's why this book comprises of contributions on various aspects of environment from the scientists of different disciplines. It has been tried to integrate their contributions, conclusions and results for understanding the environment from holistic point of view, manage the environment without destroying its potentials and attack the environmental problems from all directions to get the best results.

Thirdly, it emphasises on adoption of appropriate technology and strategy of environmental management, and to have the right attitude towards the environment. The days of plundering attitude have gone. Man will be benefited if he harmonises and tunes his activities with the nature and functioning of the environment. Utilisation of environment has to be in such a way that sustainable supply of its resources could be maintained. In fact, man does need both—the environment and development for the sustenance and progress of not only the present generation but of future generations as well. That's why man cannot afford to destroy the very base of his survival.

In the end it can be said that the environmental issues discussed in the book are only tip of the iceberg. Still much more has to be done to really understand the intricacies and complexities of the environment and its management. It is because every day the environmental problems are increasing in number, extent, frequency, intensity and complexity, which further complicate the situation. Even then sincere efforts have to be made in this direction to have a better environment on which the present and future generations can flourish. Though the time is passing out of our hands, but still we can make a fresh beginning where utilisation of environment goes on without damaging and degrading its potentiality. With the fast growing concern about the environment the task seems not to be very difficult one. Moreover, man has got now better picture of the problems and the science and technology to solve them too. We only need little efforts at our own level that can become part of the global efforts. Destiny of man is dependent on a healthy, resourceful, unpolluted and equally distributed environment.

6.2.2003

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CONTENTS

PART I: LAND AND WATER ENVIRONMENT

PART II. ENVIRONMENTAL DEGRADATION

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A BRIEF REVIEW OF THE INVESTIGATIONS ON LANDSLIDES IN NORTH-EAST INDIA

R.K. Avasthy

Introduction

The North Eastern India with its vast potential of natural resources is poised for all round accelerated development. The important developmental activities in the region are the establishment of road/rail communications joining the remote and difficult places to the main communication network, construction of urban agglomerations and construction of a number of hydroelectric projects in the area.

The most important factor to be taken care of is the incidence of large scale landslides (Figure 1) occurring frequently in this region (Avasthy, 1998 and Verma and Avasthy, 1990). Many of the slides may have contributions apart from the natural factors also from the intense human activities through road construction and urbanisation.

The high rainfall and extensive surface drainage system of the major rivers like the Brahmaputra and Barak not only weaken the rock mass but they are also responsible for large scale erosion and toe cutting of the valley slopes. Thus, triggering landslides, which, are a part of the ongoing geodynamic processes (Eckel, 1958). Therefore, the mitigation of the adverse effects of the processes of landslide and mass wastage by geotechnical studies has

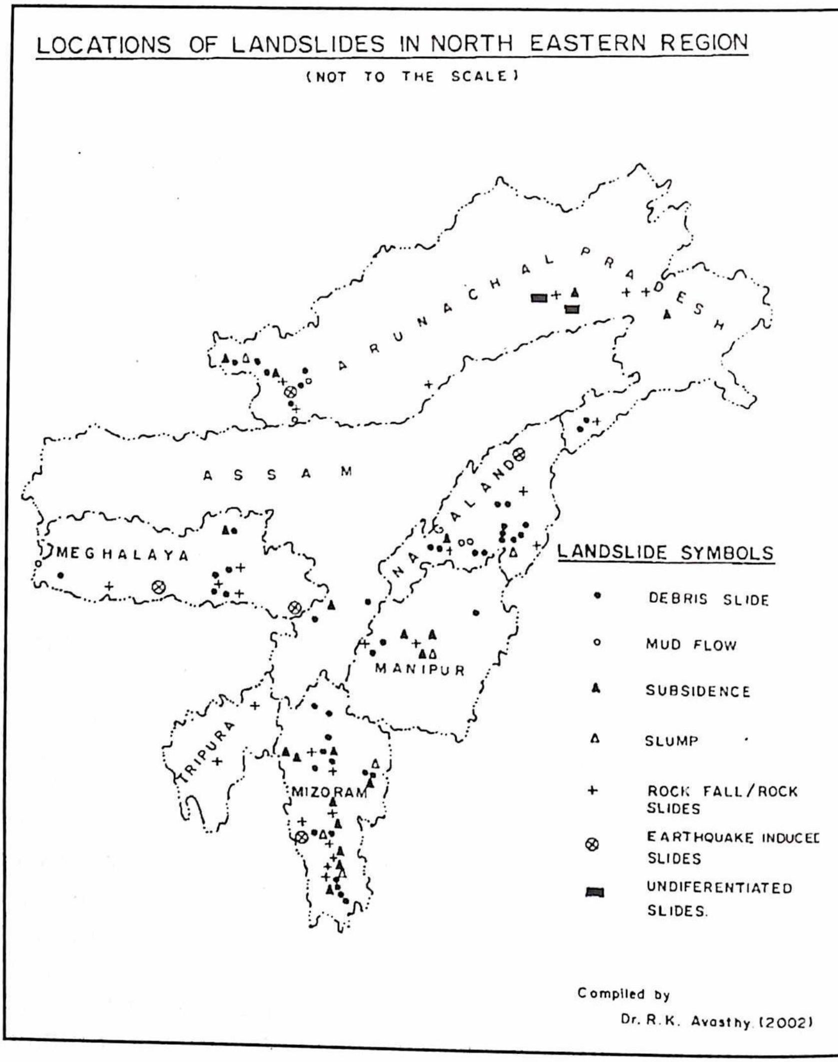

Figure 1

remained high on the Geological Survey of India's agenda in this region for the past one century.

Landslide Incidences in North Eastern India

The landslide events studied in the region are mostly located along the road cuts, besides some in rural and urban areas because the construction of roads has followed the major drainage lines (Avasthy, 2001). Large number of landslides have been studied over the years and have been categorised in six types viz., (i) Mud flow, (ii) Debris slides, (iii) Subsidence, (iv) Slump slides, (v) Rock fall/Rock slides, and (vi) Earthquake induced slides.

The landslides in Assam, Mizoram, Nagaland and Tripura are located on relatively soft sediments, whereas landslides in Arunachal Pradesh and Meghalaya are located in Metamorphic and Igneous Rocks. However, in all the cases the prevalent excessive rainfall infiltrating into the ground leads to increase in the pore pressure and decrease in shear resistance which in turn promote slippage and landslides.

In the sub-Himalayan and Greater Himalayan Region of Arunachal Pradesh the mass wastage along the strategic road section between Baisakhi and Tsela in West Kameng District is attributed to the bare relief and periglacial solifluction resulting in huge sheetwash erosion. The removal of toe material of the slopes by Bharoli river (Ranga Nadi) in the Subansiri District is the main cause for landslides in Kimin-Zero road section.

The old landslides at places form the flat ground and have, more often than not, been utilised for developmental activities. Hundung Cement Plant in Manipur and Mawrykhong village in Meghalaya are good illustrations where after the construction works developed extensive creep, resulting in ground distress. The studies carried out have brought to light the causative factors for which remedial measures were suggested.

Kohima in Nagaland and Aizawl township of Mizoram are good examples of how demographic pressure under heavy rainfall mobilised the critical slopes in soft formations. The soft sediments, immature topography and complex structural disposition are responsible for the landslides in Mizoram and in the foothills of the Arunachal Pradesh.

In view of the critical slope all along the water conductor system an insitu Reinforced Cement Concrete (RCC), cut and cover section was provided to protect the appurtenant structures of Gumti Hydel Project in Tripura. Subsequently, different reaches of the water conductor system were affected by the slope failure demanding suitable remedial measures.

Communication Projects in Fragile Environment

The slope stability problems are associated with the road alignments. A number of spots along NH-40 were examined where landslides have occurred in the past consequent to widening up of the road, a couple of them have caused road blockage for over a month. The road traverses along different type of rocks which are affected by differently oriented adverse joint sets.

The occurrence of landslides is also reported from the different road sections in Mon district of Nagaland. Seven samples of these slides have been analysed and are found to belong to 'CL' ML, and MI group of geoengineering classification. Their clayey silt and silty clay variations exhibit liquid limits between 23.19 and 48.17. Plastic limit ranges from 16.60 to 38.05. Plasticity index varies from 6.59 to 10.40. Shrinkage limits range from 20.71 to 26.578, accordingly shrinkage ratio lies between 1.60 and 1.84.

The Prestigious rail link between Kumar Ghat and Agartala in Tripura traversing through fragile terrain is demarcated on the basis of geotechnical inputs. The section between Dharmanagar and Kumar Ghat is already under operation whereas survey work between Kumar Ghat and Nalkata for geotechnical appraisal is already complete. The foundation grade material is tested for dynamic loading which belongs to 'CL' group of low plasticity having medium dry strength. The foundation grade material is classified from good to poor depending upon the amount of the moisture and degree of compaction. The unconfined compressive strength of the naturally dried undisturbed samples ranges from 2.14 to 5.19 kg/cm^2

which is found to decrease maximum by 50 per cent under drained conditions.

The problem of unstable slope between Lala Bazaar (Assam) and Bairabi (Mizoram) section of metre gauge railway line, especially that of the slope cut section east of Ramnathpur railway station and removal of toe support at Ch. 77 km are noteworthy. The geotechnical recommendations in the form of retaining structures, bamboo staggering to utilise local produce, effective drainage, provision of boulder sausages, and shot creting of the highly jointed rock mass are of practical utility.

Urban Development: A Future Prospective

The demographic pressure is on the rise in North Eastern Region which is exercising excessive stress on land in the form of concrete jungle. Aizawl, the capital of Mizoram, is an illustration to this point. Such unsystematic overgrowth imparts imbalances in the fragile ecosystem translating into slope failures causing heavy loss to the lives and material.

The township of Kohima, Capital of Nagaland, is also reeling under the heavy demographic pressure culminating in major construction activities in and around Kohima warranting systematic development and planned growth in accordance to the geotechnical considerations.

The field studies undertaken at Hundung Cement Plant, Manipur, was aimed at the assessment of foundation stability problem of the plant site and to arrive at possible corrective/remedial measures to protect the same. The determination of geotechnical characteristics of the foundation grade and slope forming material brought out the presence of plastic clays, clayey silt and silty clay. These materials qualitatively range from very poor to fair under optimum compaction. The remedial measures suggested include construction of drains, catch water sites, inverted filters, boulder sausages, slope moderation through benching, carpeting after achieving optimum compaction of the slope forming and foundation grade material.

Two landslides are located at the northern and north-western slope of the main plant area of the Tuli Paper Mill in Nagaland (Avasthy, 1990). These slides have occurred due to failure along the multiple slip circles. The material affected is slope wash and back fill which was generated due to major bulldozing work of the main plant site and was dumped on the slopes without achieving optimum level of compaction. The high saturation of the slope forming material with water through surface and subsurface induction and the shaking of the ground triggered by the 6th August, 1988 earthquake have been attributed as the major causative factors. The remedial measures suggested for the clayey silt to silty material include construction of inverted filters across the slides and boulder sausages at the toes, making of proper surface and subsurface drainage system and utilisation of the ash and cinders generated by the mill boilers as the back fill material wherever required. The monitoring of the slopes for lateral movement is considered as an essential component of the protective measures.

Signs of ground distress are recorded at several places in the Mawrynkhong village, East Khasi Hills, Meghalaya. The development of these signs of ground distress is attributed to the slope profile, poorly cohesive foundation grade material, lack of proper drainage leading to piping action, natural drainage congestion and blocking due to unsystematic constructions of poor quality and constant toe erosion.

The constructional suitability of urban agglomeration as carried out in Nagaland and proposed for Tripura is based upon the firm geotechnical basis having the ingredients of quantified data generated through insitu standard penetration tests, determination of unconfirmed compressive strengths and shear parameters of the foundation grade material together with the comprehensive inputs of geotechnical characteristics as evaluated in the geotechnical laboratory of Geological Survey of India, North Eastern

Region, Shillong. This wide spectrum approach is supplemented by detailed slope analysis due to their metastable nature which implies that the over loading of the slope may result into a disastrous slope failure (Avasthy and Singh, 1992) imparting damages to human lives, livestock and properties. Such studies help in mitigating the hazards.

Conclusion

The foregoing description is an illustration of the constraints for the developmental activities as prompted by the landslide hazards in context of the North Eastern Region. In this regard Mazumdar (1980) attempted a Regional Hazard Zonation Map on the basis of susceptibility to landslide in terms of complex physico-mechanical properties of rocks underlying the slope and intensity of rainfall. Avasthy (1998) provided a Regional Hazard Zonation Map on the basis of incidence of the landslides as an easy tool for planning and programming developmental activities in North Eastern Region.

In recent years a time bound Landslide Hazard Zonation mapping programme has been initiated by GSI with Mizoram state as targeted priority level one due to the disastrous landslides of 1995 devastating the town of Saiha and Lawgtalai leaving 34 dead and 24 sustaining various levels of injuries.

Such landslides hazard zonations map would help the planners to make an assessment of the ground conditions for taking up the site specific geotechnical investigation as an essential basic premise to the ground friendly developmental activities. It is recommended that based on such exercises regional zoning laws may be formulated and enforced in the critical landslide prone areas in all North East States, which will go a long way for ensuing the softening and longevity of the people and constructions in the area.

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GEOENVIRONMENTAL HAZARDS VIS-A-VIS RESTLESS ARUNACHAL HIMALAYA

Trilochan Singh

Introduction

The picturesque Arunachal Pradesh—a land of enchanting beauty—also known as 'the land of rising sun', is located in the strategic Northeastern Region of the Indian Union. It is the largest state amongst the 'seven sisters' of the Northeastern India, covering an area of 83,743 sq. km. Its geographical position is unique and strategic as it shares sensitive and long international boundaries with three countries viz., Bhutan in the west, Tibet/China in the north and northeast, and Myanmar in the east and south-east (Figure 1).

The land of Arunachal Pradesh is endowed with rich forests harbouring a phenomenal range of biological diversity, both in flora and fauna. It has a peculiar characteristic of transitional environmental conditions and socio-economic parameters due to its typical situation in the region. Arunachal Pradesh is a land of social, cultural and ecological diversity. This mountainous extension of the Eastern Himalaya is geologically very young and its landscape has been reshaped time and again, thus, its ecosystem is in a most fragile state. Geological structures, relief features and climatic conditions are some of the

Geologically, the Himalayan Ranges in Arunachal Pradesh are divisible into three domains: Outer Himalaya, Lesser Himalaya and Higher Himalaya. The Tethyan domain of the Himalayan Ranges is absent here. As in other parts of the Eastern Himalaya, the Arunachal Himalaya also contains distinctive litho-tectonic units. The Siwalik Group represents the Outer Himalaya. The Gondwana Group, Miri-Buxa Group and Bomdila Group represent the Lesser Himalaya. Significantly, a tectonic window exists in the Lesser Himalayan domain in Siang region, known as Siang Window, where the Lower Tertiary (Eocene) sediments and the Abor volcanics in association with Gondwana and Miri-Buxa sequences are exposed. The rocks of Tse La Group cover the Higher Himalaya domain. These three domains are marked by the boundary thrusts, viz., Himalayan Frontal Thrust (HFT), Main Boundary Thrust (MBT) and Main Central Thrust (MCT). All the litho-tectonic units and thrusts run in a general E-W direction and turn to ENE-NE direction to the east and terminate against the Bame Fault. Further, rocks of the northeastern part of the Himalaya in the Mishmi Hills trend in a general NW-SE direction represented by low to high-grade metamorphics of Bomdila and Tse La groups. The Bomdila group in this part abuts against the alluviums along the Mishmi Thrust. To the northeast, the Tse La group abuts against the Tidding Suture Zone (?).

The Mishmi Hill Ranges, on the other hand, are represented by the Mishmi Massif that abuts against the Himalayan Ranges along a suture zone, named as the Tuting-Tidding Suture Zone (?). This suture zone, also named as Tuting-Tidding Belt, is composed predominantly of crystalline limestone, serpentinite, actinolite-tremolite-chlorite schist and some percentage of vesicular to amygdaloidal basalt and metavolcanic rocks. The rock association of this belt has been considered to represent ophiolitic assemblage. The Tuting-Tidding Belt is sandwiched between the Tse La Group in the SW and the Mishmi Massif in the NE. This belt extends in NW-SE direction and in the NW this belt does not appear beyond Tuting where it is truncated by a major Bame Fault (Sinha Roy and Singh, 2002). In the SE, this belt enters into the fold belt of Myanmar.

The Tuting-Tidding Belt/Tidding Suture Zone is thrusted over by the Mishmi Massif along the NW-SE trending Lohit Thrust. This Mishmi Massif, occurring over a large part of the Dibang and Lohit districts in eastern Arunachal Pradesh, also referred to as the diorite-granodiorite complex comprises predominantly of medium diorite, diorite-gneiss (metadolerite), granodiorite with hornblende schist, marble, granite plutons, and xenoliths of high-grade schists. The rocks of the Mishmi Massif have overridden the Neogene sediments, thrust and thrust sheets of Naga Hill area in Tirap District.

The Naga-Patkai-Arakan Yoma Ranges in the Changlang and Tirap districts of Arunachal Pradesh are represented by the Schuppen Belt of Upper Tertiary sequence. This Tertiary sequence is divisible into three/four groups, viz., Disang, Barail, Tipam and Dihing. The palaeogene sediments form the outer arc ridge of the Indo-Myanmar Range, which is the backbone of the Patkai-Naga-Chin-Arakan Yoma mobile belt (Nandy, 1980). To the east this tectogene is delimited by the east dipping arcuate thrust against the upthrust Palaeogene-Eocene sediments of the Central Myanmar Basin.

Geoenvironmental Hazards

The geological, structural, seismic and gravity anomaly data indicate that the above-mentioned three mountain systems are geodynamically active, which is causing geoenvironmental hazards. The Arunachal Himalaya is being pressed by the northward moving Indian Shield. The Naga-Patkai-Arakan Yoma ranges, on the other hand, link up with the Andaman-Nicobar Islands Arc, which is an active zone where Indian Ocean floor is descending under the Malaysian Plate.

In fact, the Indian Shield is moving in northeastern direction approximately @ 5.6±4 cm per year persistently, which is pressing the Himalaya Mountain very hard. In the northeastern region, it is the Meghalaya-Mikir block that is pushing and consequently the land of Assam is sliding northwards under the Arunachal Himalaya and eastwards beneath the Indo-Myanmar Ranges. It is evident from uplift of the Shillong Plateau (Meghalaya-Mikir Massif), sudden narrowing of the Brahmaputra River near Guwahati, severe deformation and recurrent seismicity in the geological province of Arunachal Pradesh. It is significant that the width of the Brahmaputra flood plain is just less than 100 km in comparison to the flood plains of the Indus and Ganga, which is nearly 350 km and 300 km, respectively (Valdiya, 1999), especially when comparing the catchment area of these rivers. Underthrusting of the Assam terrane northwards under the Arunachal Himalaya further explains attenuation of the Brahmaputra basin. Rajal and Madhwal (1996) have shown that blocks in Guwahati-Deragaon profile have been consistently rising and the vertical velocity increasing progressively from 0.4 mm/yr to 1.4 mm/yr, 2.3 mm to 3 mm/yr and 4.5mm to 31 mm/yr in three different blocks, respectively. On the other hand, the Meghalaya block has been rising @ 0.3 to 0.4 mm/yr (Valdiya, 1999). Thus, strain is building up within the framework of the Arunachal geological province, which is being released periodically in the form of earthquakes. Various records show that the earthquakes of different magnitude have been occurring in Arunachal Himalaya/Pradesh those shake the earth mildly or violently. These movements trigger landslides, especially in the areas of active fault zone. As there are a number of faults along which earth movements have been taking place repeatedly and strongly, quite a large part of Arunachal is being affected by the frequent landslides.

As seismicity in the Northeast Region is very common various teams have been working to study and record it. The teams are from the National Geophysical Research

Institute (NGRI) and Regional Research Laboratory (RRL) who worked between 1979–1990; University of Roorkee (UOR) and Geological Survey of India (GSI) between 1980–86; Wadia Institute of Himalayan Geology (WIHG) in 1993; and RRL between 1997–1998. The seismic studies indicate that ArakanYoma/Tripura folded belt region is most active, followed by the Shillong Plateau, NE Himalaya and Bengal Basin (Verma *et al.*, 1993). It has also been shown that the process of plate subduction is very active in Arakan-Yoma region. The seismic studies in Indo-Myanmar area indicate eastward under thrusting of the Indian Plate under the Burma Plate at an angle of 40° to 60° (Das and Filson, 1975). Micro seismicity studies carried out by the Geological Survey of India show that the western margin of Shillong Plateau is relatively more active (Kayal, 1987), while Mishmi-Lohit thrust region has the seismicity higher than that of the Shillong Plateau. The data show that the seismic activity in NE region is associated with the tectonic lineaments/faults/thrusts, as epicentres of the earthquake align with them.

The seismicity network in NE Region has recorded earthquake events of magnitude ≥ 4.5, which have been well recorded with some records of magnitude < 4.0. Though events of magnitude >3.0 have also been recorded, a complete list of these events is not available for the entire time period, *i.e.*, 1979–90 (Verma *et al.*, 1993). On the other hand, the UOR and GSI team recorded a total of 7,000 earthquakes in various parts of the region, of which about 500 were of the magnitude 1.0 and above occurring within the radius of 50 km of the network (Kayal, 1996). This data is just for a period of five months per year (1980–86) that too in selected areas, which means that the number of earthquakes occurring in the region must be much more than the recorded number of 7,000.

In Arunachal Pradesh, micro-earthquake survey near Yazuli in Subansiri conducted by Geological Survey of India during February to December 1990, shows a moderately high activity. Nearly 1000 earthquakes were recorded in 10 months time (Kayal *et al.*, 1992; Kayal, 1996). They have shown that on an average, about 20 events per month were recorded within 150 km radius, and that maximum number of earthquakes was recorded in the depth range of 15–25 km and a good number in the depth range of 50–80 km. A large number of earthquakes of magnitude 4.0 were recorded around the network. A few of these follow typical foreshock—mainshock—aftershock sequence. Most of the earthquakes have occurred within a depth range of 15 to 40 km.

Further, in 1993 a team of the Wadia Institute of Himalayan Geology operated 10 seismic stations in different parts of Arunachal Pradesh for a period of 4 to 5 months. The study showed micro-seismic activity with a cluster of earthquakes with magnitudes 2 to 5, in West Kameng and Tawang districts, and another cluster with magnitudes ranging from 1 to 5 in the upper reaches of the Lohit Valley. A linear zone of seismicity between magnitudes 2 to 4 occurs approximately along the MBT zone in foothills area.

It is, thus, clear that strain/stress is building up and accumulating progressively within the framework of the Arunachal geological province, particularly in active fault zones, *i.e.*, HFT, MBT, MCT and other transverse faults, which is being released periodically in the form of earthquakes. Various records show that earthquakes of different magnitude have been frequently occurring in Arunachal. These earthquakes shake the earth mildly or violently, and consequently these movements trigger landslides, especially in the areas of active fault zones. As there are a number of faults along which movements have been taking place repeatedly and strongly, quite a large part of Arunachal is being affected by frequent landslides.

It is because of the above-mentioned reasons Arunachal Himalaya has remained restless. Under the active geodynamic condition of the region, geoenvironmental threat will remain hanging as a sword on head. Thus, there is a need to take extraordinary care while undertaking the developmental activities to minimise the adverse impact on the geo-environment. It is unfortunate that the existing seismic stations are inadequate for vast coverage of the region. The seismic data given above is just tip of the ice-berg, as most of the stations were operated only over a limited area and for a short period. The need of the time is to have permanent stations in a close network covering different areas in the region. Similarly, trained manpower and support from media for public awareness is also required to meet out the natural hazard assessment and mitigation, so as to ensure sustainable development in the region.

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SPATIAL VARIATION OF LAND PRODUCTIVITY IN ASSAM

Bimal Sharma and Zahid Husain

Introduction

Owing to different environmental and human factors the land productivity in the world has great areal and temporal variations. There are numerous studies on the spatial variations of land productivity in the world. Land productivity or soil productivity is the capacity of land or soil, in its natural environment, to produce crop under a specified system of management, and is expressed in terms of yield (Sehgal, 1996: 6). A group of agricultural scientists explains the variations of land productivity in relation to the physiographic factors, especially soil and meteorological conditions, which generate land potential for cultivation and determine the agricultural yield (Stamp, 1958, 1960; Vink, 1975; Prasad *et al.*, 1987; Smit *et al.*, 1991, and others),

The agricultural production per hectare of land in India is low relative to the world average because of several reasons. However, the shift from traditional means of agricultural production to modern ones may be seen especially after green revolution effects. An un-impressed change in land productivity in India is due to unequal diffusion of the new agricultural technology from one area and crop to the others (Singh, 1994). Though Assam is endowed with ideal conditions of agricultural prosperity but there are many impediments in the way of its achievement.

Agricultural production has not been able to keep pace with the growing demand in the state. Even until the early years of planning, Assam was a food surplus state, but due to excessive growth of population, the usual slow growth rate in production turned it gradually into a deficit state (Lekhi and Choudhury, 1993). Oschwald (1996) interpreted the process of change in landuse scientifically considering the productive capacity of soil according to its natural potentials and imposed limitations for different types of landuses. Though Assam has good physiographic conditions but it does not show a good response in the productivity level. These facts should be studied for the under developed agricultural economy prevailing in the Assam plains where the agricultural landuse pattern seems to be stagnant in nature and unchangeable over time inspite of fertile soil and favourable meteorological conditions with significantly increasing population pressure as well as the urban growth (Taher, 1975; Das, 1984; and Bhagabati, 1993). Therefore, the spatial variations in land productivity may be result of both human and physiographic conditions in the state. The present research examines the districtwise spatial variation of land productivity in Assam. A simple cartographic technique of showing the areal variation of land productivity in Assam has been adopted by collecting districtwise agricultural statistics for the year 2000–2001, simple statistical formula is used to derive land productivity of each district.

A number of studies have been done and models developed by economists and geographers on land productivity. There are several reasons behind the changes in productivity patterns over time and space. They may systematically be described in order to understand the major attributes of land productivity. Of course, land productivity (that is defined as $Y=O/A$) is directly proportional to the total quantity of agricultural output and inversely proportional to total cultivated land (Rahman and Singh, 1995). The spatial patterns of agricultural growth and productivity relationship are infact the result of the intensification of output augmenting practices (especially the increasing use of modern technology and irrigation). The application of these input factors increases level of land productivity and the rate of agricultural output (Binswanger and Ryan, 1977; Binswanger, 1978).

Generation of Indices

In order to test the validity of the facts as described above, the districtwise quantitative strength of land productivity is indexed in the following manner:

Land productivity refers to the agricultural output per unit of cultivated land as:

$$Y = (O/A)$$

where, Y = Yield production per unit of land

O = Production
A = Area

The Agricultural output (o), which can be measured as:

$$O = AiYi$$

where, I = 1, 2...n as number of crops

Ai and Yi are the Area and Yield of a particular crop of a region.

Results and Discussion

Land Productivity Variations

After compiling data on the land productivity of each and every district of Assam with the help of above mentioned equations for the year 2000–2001 (Table 1), the districts are arranged in four major categories of land productivity (Table 2 and Figure 1) namely, areas of Very High

Productivity (>18 quintals/hectare), High Productivity (15–18 quintals/hectare), Low Productivity (12–15 quintals/hectare) and Very Low Productivity (<12 quintals/hectare). It is found from Table 2 that 17.17 percentage of total area falls under Very High category where as 16.85 percentage falls under High category, 44.44 percentage falls under Low category and 21.54 percentage falls under Very Low category. It means maximum area is under Low category, followed by the Very Low category, together covering about 60 per cent land of Assam.

From the Table 1 and Figure 1 it is quite evident that land productivity in Assam has great spatial variations. Of course the temporal variation is also there but it is out of the purview of the present paper. The highly uneven areal differentiation in the land productivity of Assam is due to various agro-climatic factors.

Table 1: Districtwise Land Productivity in Assam (2000–2001)

Sl.No.	Name of Districts	Land Productivity (quintals/hectare)
1.	Dhubri	14.08
2.	Goalpara	16.49
3.	Kokrajhar	10.58
4.	Bongaigaon	10.28
5.	Kamrup	13.85
6.	Nalbari	10.94
7.	Barpeta	11.77
8.	Darrang	11.83
9.	Sonitpur	12.76
10.	Nagaon	16.51
11.	Morigaon	18.95
12.	Jorhat	15.54
13.	Golaghat	18.91
14.	Sibsagar	19.36
15.	N. Lakhimpur	9.81
16.	Dhemaji	13.26
17.	Dibrugarh	16.12
18.	Tinsukia	13.38
19.	Karbianglong	13.40
20.	N.C. Hills	12.88
21.	Cachar	21.13
22.	Hailakandi	17.38
23.	Karimganj	21.28

Source: Directorate of Statistics and Economics, Govt. of Assam, Guwahati.

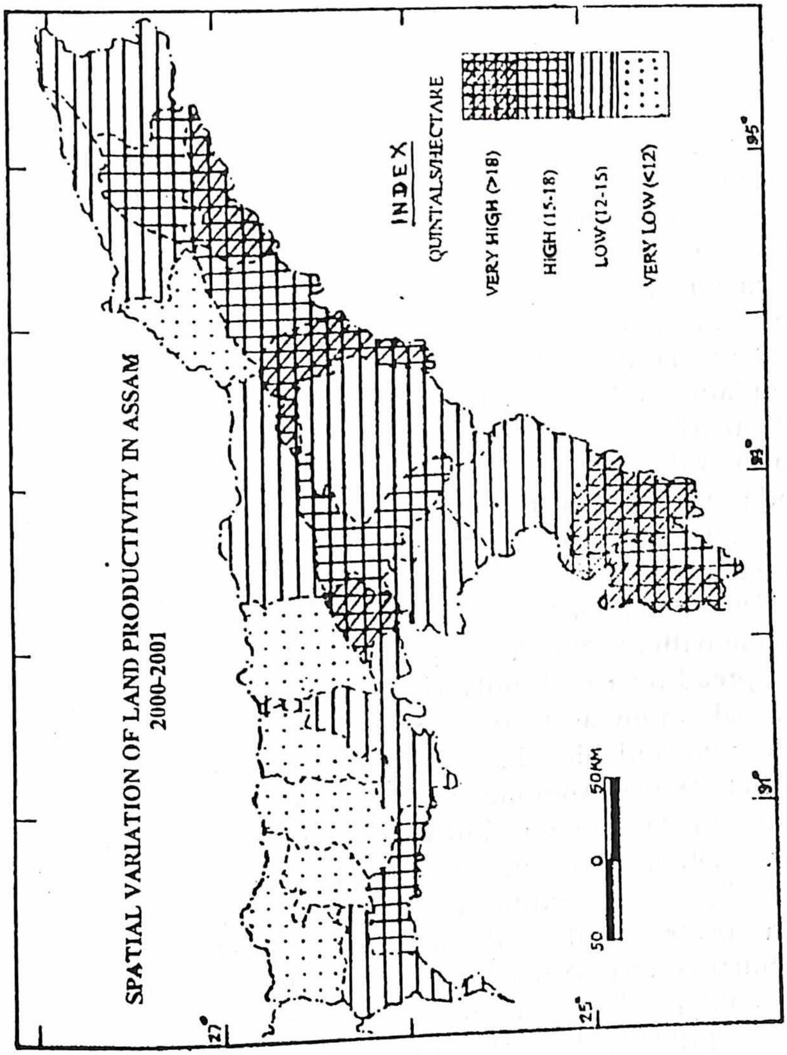
SPATIAL VARIATION OF LAND PRODUCTIVITY IN ASSAM
2000-2001
INDEX
QUINTALS/HECTARE
VERY HIGH (>18)
HIGH (15-18)
LOW (12-15)
VERY LOW (<12)
50 0 50KM
27°
25°
91°
93°
95°

Figure 1

Table 2: Areas under different land productivity classes

Categories (quintals/hectare)	No. of District	% of District Area	% of the Area of the State Total (ha)	Percentage
Very High (above 18)	5	21.74	1346900	17.17
High (15–18)	5	21.74	1321400	16.85
Low (12–15)	7	30.43	3485600	44.44
Very Low (below 12)	6	26.09	1689900	21.54

The pattern of spatial variation of land productivity in Assam shows that very high productivity is found in the districts scattered in the Brahmaputra and Barak valleys of Assam viz., Karimganj, Cachar, Sibsagar, Golaghat, and Morigaon. It is not concentrated in one zone and moreover hill districts are not included in this category.

High land productivity districts are spread all over the plains in Assam. These are Goalpara, Nagaon, Jorhat, Dibrugarh (all in Brahmaputra Valley) and Hailakandi (Barak Valley). Another characteristic pattern of the high land productivity districts of Brahmaputra valley is that they are distributed from west to east on the southern bank of the valley from lower to upper part of the valley.

The spatial distribution of low land productivity has unique pattern. The districts having low land productivity are spread over both hills and plains of Assam but absent in Barak Valley as all three districts of Barak Valley show very high and high land productivity. Not only the hill districts (Karbi Anglong, and North Cachar Hills) are included in this category but plain districts of Brahmaputra Valley (Dhubri, Kamrup, Sonitpur, Dhemaji, Tinsukia) right from the lower, middle and upper and as well as from both northern and southern banks are included in it.

Surprisingly to note that all the districts having very low land productivity are confined to northern bank of Brahmaputra valley (Kokrajhar, Bongaigaon, Nalbari, Barpeta, Darrang, North Lakhimpur) right from west to east. It is also interesting to note that very high cropping intensity is found in the very low land productivity zone. This appears to be quite contrasting keeping the very low land productivity in mind but this is basically due to increasing human pressure on cultivated land.

Conclusion

Great spatial variation in land productivity is found in Assam. Districtwise variation is found in both plains and hills. It is evident that high land productivity is concentrated in the Barak Valley region. Both the Hill districts show low land productivity. But amorphous pattern of land productivity is found in the districts of Brahmaputra Valley. It is also interesting to note that most of the districts of lower Brahmaputra Valley show very low land productivity. As Assam is an agro-economic based region, its economy depends on the land productivity. Thus, a proper landuse management is necessary for the development of agro-economic conditions. Farmers should keep their mind on increasing land productivity by using organic manures, irrigation, etc. Intensive cultivation has to be practiced instead of extensive one, but in that case also every possible care should be taken to prevent land degradation, due either to over taxing of the soil fertility or to soil erosion. It should also be kept in mind that the land or soil fertility is not infinite, it has its own limit and that could not be crossed to save the productivity of land and make it sustainable. In this way a healthy land environment can be maintained.

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MEGHALAYA'S WATER RESOURCES AT RISK

K.L. Tariang

The world's thirst for water is likely to become one of the most pressing issues of the 21st century. Global water consumption rose six folds between 1900 and 1995—more than double the rate of population growth—and continues to grow rapidly as agricultural, industrial and domestic demand increases. The United Nations assessment makes clear that the global water situation will get considerably worse over the next 30 years without major improvement in the way water is allocated and used. A United Nations Conference in Beijing warned that we are silently but surely leading to 'water shock'. Some 80 countries and 40 per cent of the world's population are already experiencing "water stress."

While water is a renewable resource, it is at the same time a finite resource and vulnerable to loss and depletion. It is neither always available perennially nor it is available everywhere. There is a growing realisation that there are limits to finding more water. It is important to appreciate the fact that only 3 per cent of the world water is fresh—roughly one third of which is inaccessible—the rest is unevenly distributed. On one hand, water is used abundantly; on the other, available supply of water has become increasingly contaminated with wastes and pollution from industry, agriculture and households.

Meghalaya has been endowed with high intensity rainfall and plenty of natural water sources. The State has got several perennial rivers and streams. Besides these, there are springs, lakes and ground water sources. Every district in the State is drained by rivers flowing either to the plains of Assam or to Bangladesh. But much of the water resources remain unutilised due to absence of proper water resources planning and systematic management. There is scarcity of water in most part of the year and in almost all the major towns of the State. Distribution of water is not streamlined and there is no uniform supply of water throughout the day. Because of this, water is available at a costly price in many localities of the towns. This has become a lucrative business for many water tanker owners. Bottled drinking water is now a common sight in many special occasions. Much of the irrigation water distributed through irrigation channels is wasted whereas there is a lack of such irrigation water in other areas. While the potential for installation of mini-hydel power in Meghalaya is very high, so far only a negligible amount of it is being tapped and harnessed. This indicates that there are still vast water resources to be explored and developed. Besides, because of absence of proper planning and systematic arrangements, the water resources are also adversely affected due to biotic interference. This has continued unabatedly and unless urgent steps are taken to protect and conserve this vital natural resource, there is possibility of water stress of unimaginable proportion in future. Therefore, the efficient utilisation and management of water is the core issue in the State and not so much of water availability.

Factors Affecting the Water Resources in Meghalaya

Degradation of Catchments

Catchments of many important rivers and streams have been denuded due to deforestation, *jhum* cultivation, and intensive agriculture on the hill slopes. These activities have caused destruction of tree cover thereby reducing the water retention capacity of the soil. Soil erosion, because of faulty agriculture, has caused siltation and choking of stream beds. Many rivers in the Garo Hills districts are affected because of extensive *jhum* cultivation in the catchments. The Garo Hills District (*Jhum*) Regulation of 1954 enacted by the Garo Hills Autonomous District Council forbids any person to practice *jhum* or cut any tree within a distance of 400 metres of any water sources or catchment areas. However, this act has not been strictly enforced. Important water reservoirs have been heavily silted up which in the long run could affect their life span. The Umiam reservoir, which is the main source of power supply in Meghalaya, is already being affected by siltation. In the absence of proper legislation, complex land tenure system, lack of integrated approach and planning, the issue of catchments degradation still lack focused attention and this may prove detrimental in the long run. We have the typical example of the Greater Shillong Water Supply Scheme (GSWSS) where several crores of rupees have been invested in construction of dam on the Umiew river, filtration plants, distribution works, there is almost a negligible concentration of programmes in protection of the catchment of the Umiew river which is affected by intensive unscientific agriculture and deforestation. This may severely affect the supply of sufficient quantity and quality of water to the reservoirs meant for impounding water for subsequent distribution. In many parts of the United States, attention is now focused on the upkeep and protection of natural watersheds to assure safe and plentiful drinking water supplies, rather than on building expensive filtration plants to purify water from degraded watersheds. New York city recently found that it could avoid spending US six billion dollars to eight billion dollars in constructing new treatment plants by protecting the upstate watersheds that have traditionally accomplished these purification services for free. Based on this economic assessment, the city invested US 1.5 billion dollars in buying land around its reservoirs and in instituting other protective measures, action that will not only assure bountiful supply of pure water at a bargain price but also enhance recreation, wildlife and other ecological benefits.

Location of Settlements

Some rivers in the State are affected by settlements which are extended upto their banks. Some of these rivers are the sources of drinking water supply to the settlements downstream. The water of these rivers is also used for different domestic purposes. Due to inadequate sewerage and waste treatment facilities, pollutants from the settlements find their way into these rivers which are also used as dumping grounds. Throughout most part of the year these rivers are choked with filth and rubbish with stinking smell which pose serious health hazards to the residents of the settlement. These rivers, which are supposed to be lifelines, are now deadweights. Many people have lately realised the detrimental effects that come out of such settlements and have been inclined to take pro-active role in lessening the adverse effects such settlements have on the rivers and other water bodies. Yet the issue is too complicated to be tackled. Heavy investments and social rethinking are required. Lessons are only to be learnt and future steps need to be taken to ensure that such settlements do not appear in many of the unaffected rivers without a proper perspective plan for lessening the adverse effects.

Coal Mining

Coal mining started in Cherrapunjee during the British period and is one of the factors responsible for land degradation in areas around Cherrapunjee. Its adverse impacts on water sources can be seen when many streams within the area are dried up during winter. The adverse impact on water is greatly felt in the coal mining areas which opened up during the last two decades in some parts of the Jaintia Hills District, West Khasi Hills District and Garo Hills Districts. Mining is unscientific and careless resulting therefore in contamination of drinking water sources which renders the water unfit for human consumption. Great hardship is felt by the people residing in these areas because of this. The highly toxic water runoff from the mining areas (acid mine drainage) and coal storage dumps finds its way into the rivers and streams thereby destroying all forms of aquatic life. These rivers which were once abundant in fishes of different species are now lifeless. The local fishes from these rivers are now replaced in the market by fishes imported from outside. Livelihood of many people is affected. These rivers are no longer the anglers' paradise like they used to be. The Kupli reservoir, which is considered to be the fishing ground of the State, is severely affected because of coal mining around its banks.

Stone Quarrying

Stone quarrying in the catchments of rivers is very common in Meghalaya. In some, quarrying takes place on the river banks itself where detached or extracted stone or sediment causes siltation of the river beds, thereby reducing the carrying capacity of the river. Stone quarrying along and in the upstream of the Myntdu river near Jowai has affected the natural course of the river and has considerably reduced the volume of water in the river, thus causing shortage of supply of water to the drinking water reservoir of the P.H.E. The river Myntdu, which is one of the sources of recreation of the inhabitants of Jowai, has lost its charm and attraction. Closer home, one can observe the adverse impact of stone quarrying on the Umtynagar stream, the tributaries of the river Umiew, the drinking water source of the GSWSS. The stream is almost choked all the year round because of heavy silt accumulation, which subsequently goes to the river Umiew and ultimately into the Mawphalang reservoir.

The above are a few indicators showing that there is a growing threat to our water resources. The magnitude of the problem is not gigantic as compared to the problems faced by some of the major river systems of the country. The major consolation is that ground water sources are yet to be heavily exploited and there is also an absence of medium and heavy industries in the State thereby reducing the risk. Nevertheless, one cannot afford to be complacent and certain steps are required to be taken up to check the existing threat to the water resources of Meghalaya—'The abode of clouds.'

Direction, Innovation and Strategies for Harnessing Water Resources

Inventory

Till date no comprehensive survey of water resources in the State has been undertaken. This is a must for identification, quantitative measurement, and assessment of the availability and potential of water resources in the State. Unfortunately, this has been overlooked because of the absence of any appropriate authority on the matter. The P.H.E. is only responsible for supplying drinking water to urban and rural areas, the Irrigation Wing of the Agriculture Department is responsible to provide water to the agricultural fields, the Shillong Municipal Board is involved only in distribution and usage of water. The Soil and Water Conservation Department is responsible for conservation of water in a small scale. Therefore, an authority or agency must to be created to look after the whole gamut of water availability, assessment, storage, distribution and conservation.

Catchments' Protection

A holistic approach of catchments' protection should be adopted. It may not be always possible to have an integrated approach, planning and implementation of different activities in many catchments due to the complex land tenure system. However, it may be necessary to declare certain areas around important reservoirs as "Critical Areas" and Government may take steps to acquire such areas and bring them under proper permanent forest cover with suitable plantations. In less important areas, community involvement in protection through general joint forest management is advocated.

Water Harvesting

Though Meghalaya is endowed with a place receiving the highest rainfall in the world, yet there are many areas, including Cherrapunjee, facing acute shortage of water during the dry season. Micro level storage structures for water harvesting need to be developed fully on participatory basis. It is necessary to encourage water harvesting preferably on a community basis or on individual basis if need be. Water harvesting can be undertaken through a variety of ways by:

- Capturing runoff from rooftops
- Capturing runoff from local catchments
- Capturing seasonal floodwaters from local streams
- Conserving water through watershed management

Water is a social platform that brings about significant social change and betterment of the people. Community-based water harvesting in rural areas is a solution to various ills that plague resource-degraded regions. Community action brings about cohesiveness in the society which is then capable of addressing issues that go far beyond water.

Restoration of Coal Mining Areas

In coal mining areas, it will be necessary to construct suitable ponds/silt detention dams for arresting the silt, control of seepage and leaching of water from the mines within the mining sites thus avoiding the possibility of flowing of toxic substance to surrounding streams and water sources. Degraded areas due to mining may be brought under afforestation and other environmental regenerative measures.

Planned Settlements

Domestic and commercial activities in settlements along the banks of rivers and streams should be regulated. Certain steps primarily aimed at controlling and checking dumping of residuals and effluents including sewage in water bodies are to be taken up. Focus is to be given to the filtration, treatment and disposal of solid and liquid wastes to safeguard the water systems from heavy deposition of foreign materials thus rendering them susceptible to clogging, pollution and general degradation.

Stone Quarrying Regulation

Quarrying in catchments of important rivers and along the stream banks should be regulated with maximum emphasis on diversion of run-off water from the quarries to the main stream or river. Existing legislations, if available, may be enforced and in case of absence of such legislations, new ones are to be enacted. This will, to a large extent, control rampant and indiscriminate quarrying which causes siltation of the water systems.

Make Water Everybody's Business

This implies that conventional attitude where water is regarded as a free commodity to be used and squandered at will should be changed. It will be necessary to motivate people and make endeavour to effect a mind-shift towards proper utilisation and conservation of water. It is impossible for the state to meet the water requirements of the growing population, hence people themselves must play a more active role. For this, there is a need for social mobilisation and community empowerment so that communities have rights over the resources that they regenerate and manage. An enabling environment for water management would mean decentralisation and community empowerment and laws that promote both. Local institutions could offer a platform to bring this about.

Water wealth of Meghalaya deserves attention. Hydrological advantage on one hand and deficiency on the other for lack of proper management should not be allowed to co-exist. Proper utilisation and management of this vital natural resource could radically improve the social, economical and environmental health of Meghalaya.

METHODS AND TECHNIQUES OF LAND MANAGEMENT IN NORTH-EAST INDIA

K.K. Satapathy

The hills, mountains and undulating plateaus account for 72 per cent of the total geographic area of the North Eastern Region. The hilly terrain is highly exposed to environmental degradation causing much concern amongst developmental agencies engaged in the economic upliftment of the area. This worrying situation has been ascribed to the erroneous utilisation of natural resources namely, soil and water, unscrupulous deforestation, shifting cultivation, rapid urbanisation, floods in the valleys and so on. A long term developmental approach of these areas in the direction of restoration of ecological balance is therefore to be envisaged through measures aimed not only at optimum utilisation but also at development of the natural resources such as land, water, and forest, and man power itself.

The multi-disciplinary research programme of ICAR aimed at developing alternative land management practices has identified several viable farming systems for the region following their evaluation in terms of their long term runoff production, soil and nutrient losses, yield behaviour, biotic and abiotic changes and so on. Watershed based farming system, appropriate soil conservation measures, mixed landuse of Agri-horti-silvipastoral system, subsidiary source of income through livestock rearing, creation of water harvesting and silt retention structures at lower reaches—these are the important distinguishing features of the suggested agricultural strategy on the hill slopes.

Extent and Causes of Land Degradation

Soil, water and forest resources—all these are under continuous state of degradation due to indiscriminate felling of trees and unscientific land use systems prevalent in the hills. A study by National Remote Sensing Agency revealed that in the course of 7 years (1972–75 to 1980–82), 0.78 million hectare of forest in the N.E. Region were lost. Nearly 22.4 per cent geographical area of the region has been classified as wasteland. The studies in the ICAR indicate that on an average under bare fallow condition, 200 mm of water per hectare or 14 per cent of annual rainfall is lost as surface runoff per annum from steep slopes having 65 per cent average slope carrying alongwith sediment of 83.8 tonnes/ha per annum. The average losses of plant nutrients per ha per annum were to the tune of 1118 kg organic carbon, 14 kg potassium, 649 kg magnesium, 407 kg zinc, 17 kg copper and 41 kg magnesium. Shifting cultivation, also locally known as *jhuming*, is currently being practised by 4.92 lakh tribal farm families of this region in an area of 3.8 m ha of land sometimes even beyond 100 per cent slopes. Biotic interference in jungle cutting, burning, clearing and dibbling of seeds accounts for a considerable amount of loss of soil material. The soil erosion from hill slopes (60–70 per cent) under first year, second year and abandoned *jhum* was estimated to be 147, 170 and 30 t ha^{-1} yr^{-1}, respectively. It is estimated that 181 million tonnes of soil are lost every year from this region due to this archaic system of farming. Due to increase in the pressure on land, the *jhum* cycle has reduced to 4–5 years in Meghalaya, 5–10 years in Mizoram and Tripura, 6–15 years in Nagaland and Manipur and 1–17 years in

Arunachal Pradesh, giving practically no chance for natural regeneration of soil fertility. In hills, development of new sites for construction of roads and buildings, and area under kitchen gardens are the major causes of soil erosion. The quantitative facts on soil erosion hazards associated with various land use systems practiced in the hills indicate that except forest land use none of the land uses are safe and lead to land degradation.

Indigenous Farming Systems

The village communities have evolved their own technologies and numerous practices based on local knowledge and materials which are cost effective, simple and easy to operate and repair, each attuned to the agro-ecological systems in which they are employed. Along with the introduction of innovative technologies, the use of indigenous knowledge and local innovations must be fostered and encouraged. Farmers have created many farming patterns including multi layer agriculture, animal husbandry farming systems and home gardens in order to maximize production. In the hill areas, several models of comprehensive land management are practiced. Planting forest trees on hill tops is a priority for controlling erosion and to improve environment. In the middle slope fruit trees are grown. In the foot of the hills, where the slope is gentle, the soil is rich and water sources are plentiful, farmlands are developed by constructing ponds and check dams; aquatic production is developed in water bodies. Such comprehensive management integrates long-term benefits with medium and short term ones. The possibilities of modification to make their improvements acceptable by the people need to be explored. Some of the prevailing potential land use systems are as follows.

Wet Rice and Terrace Cultivation

Valley agriculture is practiced through out the hilly terrain both at low and high elevations. It is a sedentary form of wet rice cultivation and is a complementary system to *Jhum*. The land utilisation for double or multiple cropping is rather poor and mono cropping is practiced in general. Mostly low yielding, long duration (>160 days) local rice varieties are grown by the farmers without using fertilisers and other chemicals. The paddy field is kept fallow for about six months after the harvest of rice crop. However, there are areas where double cropping is practiced. Bench terraces are well adopted in some areas, more particularly in Nagaland, which represent an excellent example of using steep slopes and even rocky lands where small quantity of soil is available for developing bench terraces and maintaining desirable production. One of the most interesting valley lands' rice cultivation with water management in higher hills evolved by the Apatani people with cooperative effort under the overall supervision of the village headman have optimized water use in the rice field. However, there is dearth of sufficient plain land suitable for permanent cultivation. The average size of land under valley cultivation for a family of five members consisting of two adults and three children is about 0.5 to 1 ha; larger families may have land area up to 2 ha.

Mixed Homestead Garden and Traditional Agroforestry Practices

Agroforestry is an age-old practice in the region. Pineapple, areca nut, mandarin orange, citrus, betelvine, black pepper, jack fruit etc. are the dominant plant species. Some trees are invariably grown with under storey crops such as vegetable, beans, cucurbits, ginger etc. characterised by a range of plant species with combination varying from house to house to meet a range of needs from food to shelter and the surplus sold in local market. A number of forest tree species are still being maintained or grown in shifting cultivation areas. The best examples are *Pinus kesia* and bamboos in Meghalaya and *Alnus nepalensis* in Nagaland. Bamboos are very high value potential crop for agroforestry with short gestation and recurring return.

Agriculture with Alder Trees

The ability of the *alder* trees to develop and retain fertility of the soil has been fully utilised by the farmers of the Aṅgami, Chakhesang, Chang, Yimchunger and Konyak tribes in Nagaland. The *alder* tree is also useful for providing shade to coffee plant at lower altitudes and cardamom at higher altitudes. In some areas the *alder* fields are terraced to check soil erosion. The trunks of the trees are also laid across the slopes to slow down water runoff (Prasad *et al.*, 1986).

Broom Grass—A High Value Cash Crop

Broom grass (*Thysanolaena maxima*) with soil conservation value and established market as cash crop can be grown in wastelands either by itself or as undergrowth with sparsely grown trees. The grass protects soil from erosion and prevents the landslides and has wide scope for multiplication without any care or protection. Hill slopes and the undulated hillocks are suitable for its cultivation. The fine root systems of broom grass are well ramified up to 30–40 cm soil depth and have enormous soil conservation value on hill slopes. It can be used on terrace bund/riser for stabilisation and also as vegetative contour hedge barrier for terraced land development (Singh and Singh, 1981).

Improved Agro-technology for *Jhum* Cultivation

There are two clear cut approaches: First the improvement of the existing *jhuming* and second replacement of the present form of *jhuming* by alternative programmes. Since the strategy to ban *jhum* cultivation has not been a success, efforts are needed to develop improved *jhum* cultivation practices so as to meet the challenges of soil and water conservation. Improvement of shifting cultivation will work better in the condition of farmers living in remote areas, not easily accessible to a transport network in the region. The general strategy adopted for the *jhum* fields in these areas would be to gradually change the mixture of crops in relation to the length of fallow period and promote different techniques to minimize the depletion of soil, water and forest resources in the composition of the crop mixture directed for the different levels of soil fertility which are themselves conditioned by different duration of the fallow period. Attempts should be made—(i) to decrease the relative importance of rice in the *jhum* field and increase the production of the other crops such as pulses, vegetables, tubers and rhizomes; and (ii) encourage the production of more cash crops as well as multipurpose fast growing trees in the abandoned *jhum* fields. Some of the important measures which can improve the present form of *jhuming* are: Contour bunds/contour trenches between the crops, intercropping, toposequential cropping, use of handy tools in sowing, weeding and harvesting operation, generation of subsidiary source of income through sericulture, mushroom and livestock farming. Toposequence for growing crops within contour bunds should be followed taking advantage of moisture regime and fertility of soil. Crops like cassava, maize intercropped with soybean/pigeon pea, finger millet, sesame, etc. which requires less water, can be raised in the upper portion of the hill slopes while lower portion should be used for growing rice in order to maximize production. Improved high yielding crop varieties can contribute a yield advantage of 20 to 30 per cent over the traditional ones. Use of fertilizer should yield advantage of 50–60 per cent when granular fertiliser is applied side by side in dibbling hole along with seed. When a field is under *jhuming* operation it can concurrently be planted with the fast growing tree species suitable for rebuilding soil fertility.

Cash Crop Horticulture Development in *Jhum* Land

Horticulture species including plantation crops can be cultivated in degraded and denuded areas including those areas previously under shifting cultivation, which will help in controlling the soil erosion and conserving the water. Tea, coffee, rubber and cashew are some of the important plantation crops which can be grown in these lands. Such plantations are more profitable and economical per unit area and per unit time as compared to that of trees and grasses. It has also been advocated that rubber and tea both indigenous to the region be defined as forest species and permitted to be cultivated on degraded forest land.

Alternate Land Use Model

Watershed based farming system, appropriate soil conservation measures, mixed land use of agri-horti-silvipastoral system, subsidiary source of income through livestock rearing, creation of water harvesting and silt retention structure at lower reaches are some of the important distinguishing features of the suggested agricultural strategy for the hill slopes. The model developed is based on the following distinct approaches:

- The watershed, a natural drainage unit, should form the basis for planning various land uses to optimize the use of soil and water resources for sustained production. Watershed based farming system coupled with mechanical soil conservation measures viz., contour trenches, contour bunds, bench terrace, half moon terrace, grassed waterway, etc. at appropriate locations can retain maximum rainfall within the slope, safely disposing off the excess runoff from the slopes to foot of the hills with non erosive velocity.
- Application of improved production technology and increase of cropping intensity by growing at least two high yielding crops have the possibility to increase the

productivity of rainfed bench terraces 3 to 5 times more than that of hill slopes with no detrimental effect on natural resources. The trials conducted have demonstrated that one hectare of terraced land can sustain a family of five, with 60 per cent of yield, meeting the food requirements and marketing the remaining for other needs. Introduction of remunerative horticultural crops can invite long term interest to the land for settled agriculture.

- Subsidiary income from rearing of livestock by feeding on the by-products of crops and cultivated fodders, trees raised on the terrace risers, bund surface and very steep slopes unfit for cultivation.
- Construction of small earthen dams for water storage and silt retention at lower reaches of the watershed by utilising local resources—earth, stones and human labour to utilise the stored water for fish production or to recycle back for life saving irrigation.

Soil Conservation Measures

The watershed based farming system should be coupled with mechanical soil conservation measures like contour trenches, contour bunds, bench terraces, half moon terrace, grassed water way and so on to retain maximum rain water within the slope, safely disposing off the excess runoff to the piedmont with non-erosive velocity.

Contour Trenches

These are trenches excavated along the contours to break the slope length for reducing the velocity of surface runoff, the water retained in the trenches helps in conserving the moisture. The size of trenches depends upon the soil depth available and its cross section may vary from 100 sq. cm. to 2500 sq. cm. and are designed according to the rainfall to be retained per unit area.

Contour Bunds

These are small embankments or bunds constructed across the slope to decrease the slope length, which reduces soil erosion and diverts the excess runoff to the designed outlet. The eroded soil is retained within the bund interspaces, which get levelled up in the course of 4 to 8 years to form bench terrace. These bunds on steep slopes are created by way of excavated parabolic channels (0.3 m top and 0.2 m deep) on contour and keeping the dugout soil in the form of a bund at the lower edge of the channel. The vertical interval of these bunds may vary from 0.5 to 5 m depending on the land use and soil depth.

Bench Terraces

Bench terraces are series of flat beds constructed across the hill slope separated at regular intervals in a step like formation. Manual labour as well as bulldozer can be engaged to form bench terraces. Bench terraces with inward slopes are adopted in the high rainfall areas. The alignment of bench terraces on slopes should be made to obtain convenient width making deviations wherever necessary for depressions; sharp turn field boundaries and so forth. However, the loss of surface area due to bench levelling under bund riser outlets is by far the largest loss in terracing. Such measures are normally adopted where soil depth is more than 1.0 m. Terracing of the entire hill slope is not necessary since trees and horticultural crops can be raised without terraces. Only the lower portion of the hills needs to be terraced for agricultural crops. The terrace risers, which constitute 30–40 per cent of total area, can be utilised for growing perennial fodder grasses and legumes, which not only help in conservation but also provide enough fodder.

Half Moon Terrace

Where complete terracing is not desired or feasible, productive multiple use of steep slopes is possible by planting trees on half moon terraces. These are level circular beds having 1 to 1.5 m diameters, cut into half moon shape on the hill slope. These beds are used mainly for fruit trees like guava, citrus etc. in horticultural land use.

Vegetative Bunds

Barrier hedges substantially reduce runoff and increase infiltration. Some of runoff may cross the barrier, whilst the entrained soil will be partly filtered out and deposited. Pineapple plantation has been successfully used as vegetative bunds in hills.

Grassed Waterway

There are trapezoidal or parabolic channels planted with suitable close growing grasses constructed along the slope preferably on natural drainage line to act as outlet for the terrace system. These channels along with silting basins serve the purpose of energy dissipation of flowing runoff water.

Sustainable Land Use Plan

Agriculture based Land Use

Agriculture can be adopted on hill slope up to 50 per cent where soil depth is more than 1 m. Bench terraces, and contour bunding are the major soil conservation measures; land development under the system may cost about 400 mandays/ha. Selection of the crop should be based on farmer's choice as well as market potentialities. Hill-top should be kept under forest (for fuel-cum fodder trees, bamboo, timber trees, etc.). Based on the existing farming systems, agroclimatic and soil condition, the cropping systems visualised are: rice based cropping system (rice-mustard/potato/radish); maize based cropping systems (maize-groundnut/soybean/mustard/radish/potato/tomato); oil seed based cropping system etc. Cultivation of crops in toposequence is useful on hill slopes. Normally rice is taken in the bottom and cassava, buck-wheat, etc. grown at the upper terraces and maize next to rice. Dairy farming can be effectively integrated with crop production on terraced hill slopes for sustainable agriculture under the system. By product of crops and fodder raised on bunds and terrace risers occupying about 30 per cent of land provide scope for subsidiary source of income through animal husbandry. Among perennial grasses and legumes—*Setaria sphacilata, Thin napier, Guinea* and *Stylosonthes* are found good for terrace risers. Management of forage crops on the terrace risers is important. They should not be allowed to grow more than 50 to 60 cm tall to avoid any shade to food crops on the terrace. On the wide terraces, fodder trees can be planted. The deficit green fodder during winter can be met by feeding leaves of broom grass and crop residues produced in the watershed. Such an agropastoral land use has a potential of maintaining 1.18 livestock unit (one unit equals 1.0 buffalo, 1.25 cattle, 5.0 pigs and 10.0 goat). The farm yard manure from livestock refuse, weeds and non edible crop residues can be effectively utilised under integrated nutrient management to reduce the chemical fertiliser requirements. Analysis of sustainability and livelihood potential showed that the system incorporates the classical organic recycling and non competitive land use elements, pushing the system towards sustainability by reduced dependence on external inputs, arresting nutrients in rain water flow by growing forage crops on the terrace risers, negligible soil erosion and converting in a chain all biomass produced in the watershed into economic outputs (Singh and Singh, 1981).

Management of Land with Pure Horticulture

Since citrus, pineapple and banana constitute the major fruit crops of the region, in this type of system mandarin orange can be planted at the distance of 5 m in the half moon terraces while pineapple, being well suited to semi-shady condition, may be planted on the contour bunds across the slope. Mandarin orange plants take considerable time to come into regular bearing, the space between the rows of the plant can be utilised by taking vegetable crops. The riser of the bench terraces made in the lower portion for the growing of rhizomatous or tuber crops can be used for the planting of fodder legumes. Filler crops like papaya can be grown as intercrops provided these filler plants are spaced away from the main fruit plants and removed when the based fruit crop plants reach bearing stage. The lower most portion of the land (below 40 per cent slope) can be utilised efficiently for growing of vegetables solely or combined with fruit trees. Intensive cultivation can be done in the system, which is most suitable for small and marginal farmers. At lower altitude areas (below 500 m), the crops like coconut, areca nut and rubber plantations may be adopted. In coconut and arecanut orchards high density multitier cropping systems including pepper, betel vine, ginger, turmeric, pineapple, sweet potato and colocasia can be grown to utilise vertical and horizontal space properly.

Horti-silviculture

Here various tree species can be grown as wind breaks, shelter belts or fillers in the orchard to protect it from the high velocity wind/storms. *Salix populus* sp. and *Alnus nepalensis* have been proved successful around the fruit farms without any adverse affect on the fruit production. Agricultural crops can also be grown between the rows of fruit trees to form a multitier agri-horti-silviculture system in which lemon and pineapple are found to grow very well with fodder cowpea, the latter provides 90 to 100 per cent ground coverage by the end of June which prevents soil loss during monsoons. This type of land use system can be adopted successfully in the areas having less than 50 per cent slope with moderately fertile and deep soils.

Agri-horti-silvipastoral Land Use

Land up to 100 per cent slope with soil depth greater than 1 m can be used for this mixed land-use system. The system comprises agricultural land use towards the piedmont, horticultural in the mid portion of the hill and silvipastoral crops in the upper portion of hill slopes. Contour bunds, bench terraces, half moon terraces, grassed ways are the major conservation measures. Land development may cost about 190 mandays ha^{-1}. Such land uses are expected to retain over 90 per cent of the annual rainfall with negligible soil erosion. This is the ideal system suited to steep hill slope. Choice of crops will vary according to altitudes. The fodder from terrace risers, horticultural portion and silvi-pastoral unit can sustain a unit of 10 goats with reproduction efficiency of 170 per cent and the pigs can meet part of their nutrient requirement through succulent grasses, grains and radish produced in the watershed. The diverse agro-activities would help in producing most of the produce that remote area farmers would like to grow for their self sufficiency in a highly inaccessible region of the hills (Singh and Prasad, 1987). This is an integrated system of farming and capable of providing full time and effective employment to a household.

Livestock based Farming System

Land up to 100 per cent slope with minimum of 0.5 m soil depth may be utilised for livestock farming. Cost of land development for such land use may vary between 150 and 335 mandays ha^{-1}. Such land use is expected to retain over 90 per cent of annual rainfall and restrict the soil within

2 tonnes ha^{-1} yr^{-1}. Selection of leguminous and non-leguminous annuals and perennials, shrubs, and trees will depend on the type of enterprises (such as milk, beef, mutton, wool, pork and poultry production). Carrying capacity of such high land use has been estimated to be 4 to 5 livestock/unit ha with *Setaria* and *Stylo* (1:1) mixture of fodder production. Livestock-based farming system has potential for substantial income from the farm yard manure and self-sufficiency in the matter of fuel through biogas plants. A model was developed on 0.94 ha hillock land. Out of which 0.14 ha was used for contour trenches at 1.5 m vertical interval as a conservation aid for retaining water within the area. A total number of 335 mandays were engaged for trenching and land development. Crops namely teosinate, cowpea, maize and fodder turnips were grown in the year 1984. During the first year 12.87 ton/ha green fodder was produced which was estimated to be enough to produce 228.6 kg of beef or 229.78 kg of mutton. The carrying capacity of the land as estimated on the basis of first year's performance of fodder crop, was worked out to be 1.24 cattle and 12.78 goat units per ha, respectively. In the second year yield potential of yellow maize, oat, groundnut, tapioca and perennial fodder was recorded as 0.7, 0.6, 1.5, 17.1 and 13.5 ton per ha, respectively. Out of 381 mandays per ha required for maintaining the land use, 63.7 per cent efforts were needed to produce crops. In the third year among annuals, soybean, maize, teosinate, groundnut and tapioca were grown in *kharif* season. Groundnut yield was 15 q/ha. Perennial fodder in 38 bunds yielded 44.70 kg green feed which was equivalent to 11.99 ± 3.2 ton per ha. As compared to 11.87± 4.8 ton of 1985 the yield in terms of livestock feed was considered satisfactory because this could meet 78 per cent fodder requirement of one cow (40 kg), two calves (60 kg), 6 pigs (30 kg) and 30 rabbits (Table 1).

Grasses, *Guinea*, *Setaria* and fodder crops tapioca, maize, bajara and oat were grown in the 5th year. The yield of green fodder from terraces was 34.7 q and that of grasses

Table 1: Fodder utilisation pattern for animals

Year	Beef	Heifer	Milk (old cow)	Milk (new cow)	Total
I year	3.3	3.3	18.0	–	24.6
II year	15.3	45.3	18.0	–	48.6
III year	14.2	17.3	20.0	4.5	56.4
Total	32.8	35.9	56.4	4.5	129.6

from risers was 137.4 q. Tapioca sown in trenches yielded 10.2 q on fresh basis. A total 323 saplings of *Ficus hookerii* were planted on the boundaries of watershed in 1989 (Table 2). One milch cow and one heifer were maintained in 1989. The milk yield was 1730 lit in the 1st year with concentrate consumption at the rate of 2.0 kg/day.

Table 2: The production of fodder, milk and manure in livestock based management system (1992–97)

Year	Milk production (lit)	Fodder production (t)	Manure (t)
III year	6876	38.92	27.79
IV year	5560	39.00	25.00
V year	5193	45.10	26.30
VI year	4611	38.90	20.40
VII year	4578	38.00	13.40
VIII year	5918	40.38	18.33
Average per year	5456	40.12	21.87

In the year 1990, the area under terrace (0.225 ha) was put under two kharif crops of maize (March–July) and maize + rice bean (August–October) fodder, followed by rabi fodder crops of oat. Riser area of 0.47 ha and area under bunds (0.013 ha) was under perennial fodder. In addition to fodder production, 166 kg of broom spikes was also produced annually from the watershed. The concentrate 34.14 q as an external output annually was purchased to maintain two milch cow and two heifers during the period from 1992 to 1997. The production of fodder, milk and manure from 1992–1997 are given in Table 2. The average productivity of milk was 7.47 lit/day/ cow. The dairy based farming system has potential for substantial return 1:1.78 from the farm yard manure and self sufficiency in the fuel through biogas plant. About 90 per cent of annual rainfall was retained in the watershed and the soil loss was restricted to 2 tonnes/ha/year. The carrying capacity of the land use was estimated to be 4–5 livestock unit/ha.

Multi-purpose Tree Species and Silvipastoral System

A number of species have been identified for use in afforestation and silvipasture programmes. Tailoring a number of forage plant species in the hill land use systems will provide continuous vegetative cover on the hill slopes to protect land resources from intense rains and conserve the abundant native forage plant species in the high rainfall zone. Land protective characteristics of fodder trees, shrubs, grasses and nitrogen fixing plants to develop silvipastoral systems on steep slopes, fodder tree plantations along the village roads and on the community lands, shade tolerant grass plantation in the forest, intensive forage production on commercial livestock farms under semi-organic farming, horti-pastoral systems, utilisation of terrace risers/bunds and bamboo shaded area for fodder production, are few of the many dimensions of forage resource development in the hill agro-ecosystems (Singh and Prasad, 1987).

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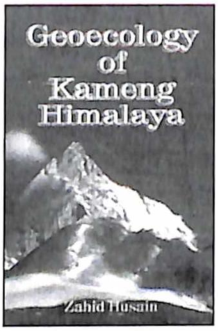

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Zahid Husain

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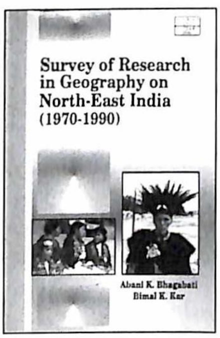

Survey of Research in Geography on North-East India (1970–1990)

Abani K. Bhagabati and Bimal K. Kar

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