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Natural Resources Depletion in Hill Areas of Bangladesh: A Review

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Abstract: Hilly or mountainous terrain occupies around 12% of the area of Bangladesh. Natural resources associated with Bangladesh's hill are forest resources, biodiversity, minerals, and agricultural crops. Natural resources have been exploited in the recent four decades due to excessive clearing of hill forest cover, resulting in loss of species richness, impacts related to increased water flow variability, increased hill slope erosion and flooding intensity, and a gradual decrease in the extent of hill area in Bangladesh. This review explores the major causes and effects of depletion of natural resources by linking drivers, pressures and the related impacts. A review has been conducted to structure the effects on the hilly areas and describe the responses to minimize them in the associated DPSIR framework. Population growth has been identified as a major driver contributing to high deforestation rates. This may negatively effect agricultural productivity and increase the frequency of serious flooding. Slash and burn cultivation also impacts the regeneration of evergreen forests, which may accelerate soil erosion. Due to this and other factors, local people are facing a deficits of natural resources (food, fodder, fuel wood and water), which exacerbates the effects of poverty. Future research should try to facilitate decision making for sustainable utilization of natural resources management in the hilly areas of Bangladesh. Additional conservation measures should be developed to increase the resilience of ecosystems at national and regional levels.

Keywords: Hill environment; Deforestation; Land degradation; Hill restoration and conservation; DPSIR

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Introduction

Mountains are unique landscapes that harbor much of the world's biological and cultural heritage. Mountain issues have been highlighted as important factors in sustainable development planning. Mountains and hills are differentiated on the basis of the mean sea level elevation of the highest landforms (> 500 m for mountains, 200-500 m for hills; Messerli 1983; Meybeck et al. 2001; Viviroli et al. 2007). Mountain areas occupy about one fifth of the world's land surface area (Viviroli et al. 2007; Anon 2002), while hills occupy 24 percent of the earth's land surface (Kapos et al. 2000). Certain attributes characterize hilly or montane areas, from the negative (inaccessibility, isolation of inhabitants from social services, severe climatic influences) to the positive (cultural diversity, specialty crops, interception of rainfall or snow). Such features are often referred to as hill specificities (Jodha 1990; Jodha 2007).

Population growth, changes in living pattern and expectations, and increasing usage of mountain resources have led to more attention to conservation and restoration in mountain environments (United Nation Conference on Environment and Developments (UNCED) in Rio Conference 1992). As a consequence of the ongoing dialogue, it has become evident that mountains are critical for human societies, including lowland communities. The United Nations General Assembly, at its 53rd session, adopted Resolution 53/24 to celebrate 2002 as the "International Year of Mountains" to focus on the livelihood of marginalized mountain people, their limitations and expectations on mountain resources (Price 2003; Viviroli et al. 2007).

Mountains and hills are a source of fresh water, power (hydro-electric), alluvial enrichment of lowland soils, tourism-related revenue, and other benefits, and also function as reservoirs of biodiversity, indigenous knowledge, and cultural heritage (Viviroli et al. 2007; Lama and Sattar 2002; Jodha 1990). Since much of the remaining forest cover in most regions of the world is relegated to mountains (Price 2003), mountains are the source of many forest-related values, including timber, non-wood forest products and ecosystem services (Appanah and Ratnam 1992). About 26 percent of the world's population lives in mountain areas (Meybeck et al. 2001; Thapa and Rasul 2005), and more than half of humanity may depend on hilly resources such as drinking water, irrigation, industry and security (Messerli 2001; FAO 2002). Steep slopes, variation of precipitation with altitude, shorter growing seasons, and rugged topography render mountain ecosystems vulnerable to natural perturbations (climate change, exceptional meteorological events, seismicity, slope instability) and the effects of human activities (including deforestation and agricultural/grazing uses) (Messerli 1983). In Bangladesh, degradation of these environments has increased markedly in the last four decades (Miah et al. 2011b). Deforestation and land degradation are the most frequent pressures related to environmental change (Miah et al. 2011a; IPCC 2007; Helmut and Eric 2002). The natural resource base in the hill regions of Bangladesh has declined due to land cover and land use change (Biswas et al. 2011; Biswas and Chowdhury 2007; Iftekhar and Hoque 2005). Consequently, phenomena such as downstream watershed management, water quality and supplies, agricultural productivity, and wildlife migration are affected (Ives 1985; Douglas 1999; Thapa and Rasul 2005). In Bangladesh, hill resources are threatened by increasing deforestation and land degradation (via agriculture and other activities). As a result, montane cultures are losing their cultural heritage, are increasingly marginalized by decision-making mechanisms in government, and are subject to disproportionate poverty and inequity. They face various physical and socio-economic risks that are directly related to the fragility of their hills landscapes. Consequently, attention has shifted to curbing and reversing unsustainable impacts on the natural resources of the hill ecosystems of Bangladesh. Major causes (deforestation and land degradation) and locations of specific types of resource depletion were highlighted by Ali (2004), Upadhyay et al. (2005), Wasson et al. (2008), Dewan and Yamaguchi (2009), Biswas et al. (2011).

This review on natural resources depletion in hilly areas of Bangladesh will explore the main reasons behind the increasing risks and locate future research areas. Management and conservation strategies should be developed for protection and rehabilitation of degraded hilly areas. This contribution will analyze the environmental problems associated with the rate of deforestation and cumulative loss, rate of additional siltation downstream and attendant negative effects, impacts of increased water flow variability (flooding), and amounts of downstream pollution from mining. The compilation will help not only relevant stakeholders (specially related to hilly areas of Bangladesh) to prioritize their activities but also policy makers of the country in decision making for a sustainable development.

1 Methodology

This literature review draws on peer-reviewed literature, media reports, government or agency reports, policy documents, and the authors' research experience. Hill or mountain areas of Bangladesh in which significant degradation has occurred are identified, and suggestions for hill

restoration and conservation are made. The DPSIR framework has been used as an effective way to organize complex environmental information to facilitate sustainability assessment of socio-economic, political and environmental processes (EEA 1999; Agyemang et al. 2007; Crabtree and Bayfield 1998). Causes, consequences and responses of natural resources depletion in the hilly region are analyzed using the DPSIR framework for integrated natural resources management (Kristensen 2004; Wolfslehner and Vacik 2011).

2 Hill and Mountain Ecosystems of Bangladesh

Bangladesh is located between latitudes 20°34" and 26°38" N and longitudes 88°01" and 92°41" E. The area of the country is about 147,570 km2 of which 116,727 km2 (79.1%) is floodplain, 12,248 km² (8.3%) is terraced land and 18,593 km² (12.6%) is hilly area. The terraced lands occur in the center and northwest of Bangladesh, and the hills occur in the north and east. Physically, Bangladesh may be classified into four district regions, each having distinguishing characteristics of its own: (1) the eastern hilly region, (2) the great table land, (3) flood plains of the Ganges, the Brahmaputra and the Meghna river systems, and (4) the Delta. The eastern and northern frontier hilly region consists of Chittagong Hill Tracts, Lalmai Hills, and the hill ranges of Sylhet and Mymensingh districts. The elevations of some notable peaks in this hill ranges are Mowdok Mual(1003.3 m), Ramiu Taung (920 m), Rang Talang (95-7.3 m), Keokradang(884 m) etc. These hill ranges are a continuation of the hill ranges of Chittagong and the Chittagong Hill Tracts northwards through Tripura state of India. The Chittagong Hill Tracts (CHTs), covering 13,295 km² (10% of Bangladesh), are an extension of a larger range that runs from the eastern Himalayas in China to the western edge of Myanmar (Burma) (Figure 1). Bangladesh administers a narrow strip of this range, roughly 280 km by 60 km of the hill range (Hassan 1999).

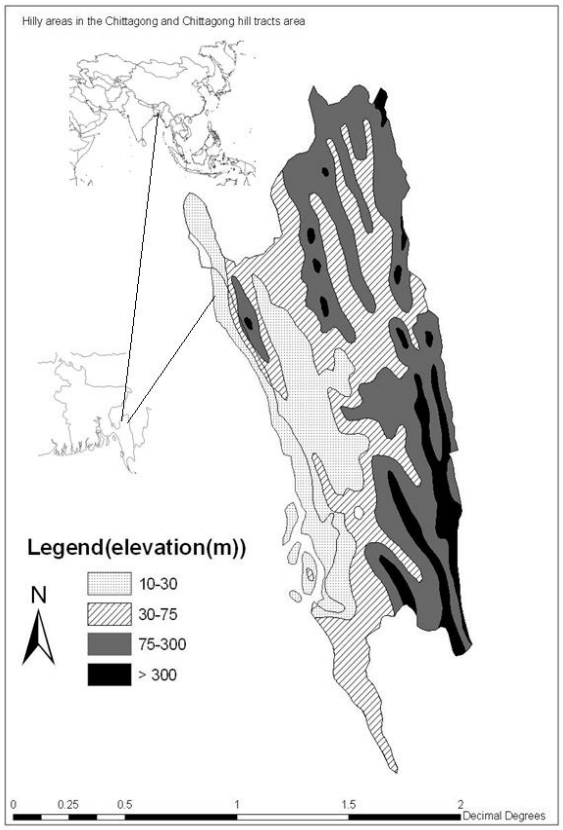

Figure 1 Different elevation of hills (10 to >300m) in Chittagong and Chittagong hill tracts of Bangladesh

3 Analysis of Hill Resource Depletion

The Driving forces, Pressure, State, Impact and Responses (DPSIR) approach is a conceptual framework for reporting environmental change in relation to sustainability in complex systems (Browne and McPhail 2011; Lozoya et al. 2011; Atkins et al. 2011). *Driving forces* refer to human activities responsible for pressure on the environment, *Pressure* refers to which variables cause environmental problems, the *State* component represents the current state of the environment (within the scope of analysis), *Impact* indicates specific damages, and *Responses* designate which measures should be taken to improve the state of environment (EEA 1999; Dietrich et al. 2007). It is a valuable tool for parallel assessment of socio-economic and environmental issues (Karageorgis et al. 2005). Using DPSIR in this research allows for communicating the relations between anthropogenic activities and loss of ecosystem resources. We have incorporated the DPSIR approach for natural resources management in the

hilly areas of Bangladesh as a framework for structuring problems (Figure 2) inholistic decision making.

3.1 Drivers

Overpopulation, unsustainable agriculture, lack of policy and institutional environment (Ali and Hoque 2009; Rasul and Thapa 2007; Biswas et al. 2010), industrial and residential development, scarcity of land resources, and sand mining are the main drivers of deforestation and land degradation in the hilly areas of Bangladesh (Ali 1995; Turner and Ali 1996; Ali 2004; Saha and Azam 2004; Islam et al. 2006; Dewan and Yamaguchi 2009; Alam et al. 2010). Implementation of environmental management and conservation activities have largely failed due to a host of challenges (poverty, insufficient flood mitigation, lack of basic public health management, and political issues). A number of crucial response elements are lacking, including coherent and consistent forest policy, motivation and education on the part of local people, infrastructure, marketing facilities and financial incentives (Salam et al. 1999; Muzaffar et al. 2011).

3.2 Pressures

3.2.1 Deforestation

Primary contributors to environmental degradation in the forest of Bangladesh include sand mining, soil erosion and slope failures due to deforestation and intensive agriculture, all of which decrease functional watershed area, sustainable levels of commercial extraction of raw materials and successful establishment of commercial and industrial forest plantations (Rasul and Thapa 2003; Dewan and Vacik 2010; Iftekhar and Hoque 2005; Biswas et al. 2011; Rahaman et al. 2011). The development of industrial processing capacity without concurrent development of successful forest regeneration can lead to issues regarding sustainability of forest resources. For example, deforestation accelerated with the construction of the Karnaphuli Paper Mill at Chandraghona in

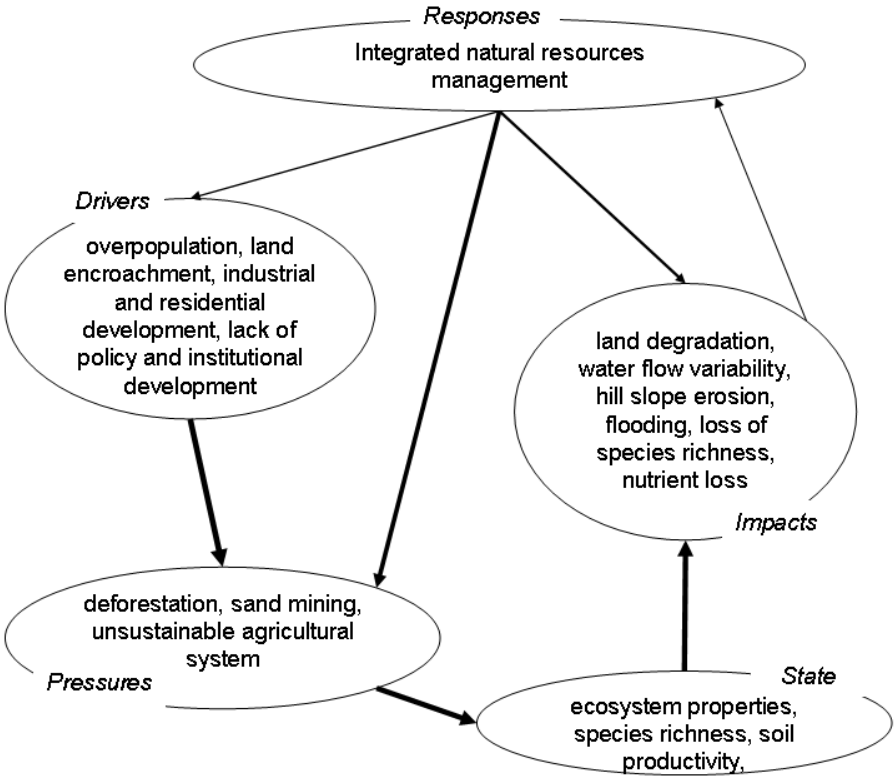

Figure 2 The DPSIR assessment framework for integrated natural resources management in the hilly areas of Bangladesh

1953. Other developments, such as dam construction, also impact the natural resource base. The construction of the Kaptai Dam in 1962 had multiple effects on forest and environment, such as inundation of forest, crop lands, villages, and habitat for wildlife (e.g., sambar and barking deer, leopard, Bengal tiger, panther, etc). This resulted in local extinction of the tiger, and major decreases in the elephant population (Rahaman 1995; Salam et al. 1999; Parveen and Faisal 2002; Karmakar et al. 2011; Barua and Haque 2011). Furthermore, the displacement of hill people from the backwater area resulted in environmental impact elsewhere. Trend of change in natural forest cover (Table 1) in the hill forest of Bangladesh for 15 years(1990-2005) are estimated for different hilly areas(Kassalong, Rankhiang, Sita Pahar, Chittagong, Cox's Bazar, Sylhet) (FAO 2006). The extent of forest cover in Bangladesh has been reduced, in spite of the existence of many governmental and non-governmental agencies dedicated to forest protection, conservation and restoration. In many places, natural stands have disappeared altogether (BFD/MOEF 2000; Saha and Azam 2004; Muzaffar et al. 2011) and been replaced with non-native plantations of commercial tree species (Barua et al. 2001; Jose 2011).

Table 1 Natural forest status from 1990 to 2005 in the hill forest of Bangladesh (thousands of ha)(FAO 2006). Note general trend of substantial declines in forest cover.

Location	1990	2000	2005
Kassalong	55.01	46.07	41.6
Rankhiang	6.23	0.35	0.35
Sita Pahar	0.65	0.65	0.65
Chittagong	26.114	19.631	16.39
Cox's Bazar	29.081	25.391	23.547
Sylhet	3.06	2.597	2.366

3.2.2 Land degradation

Removal of earth materials from the smaller hills in different parts of Bangladesh has appeared as one of the most alarming environmental problems (Mahmood and Khan 2008). This degradation has clear effects on the environment (Ali 2007). Sand mining has gradually caused other environmental damage in addition to excessive soil erosion, such as gully and rill formation and wetland siltation. Development such as road construction and unplanned expansion of residential areas has been expanding in these areas as well. These impacts have contributed to the severity of flood events (Ali 1995; Ali 2007). Accordingly, environment of the hilly areas of Bangladesh has been facing a floods, water- logging, change of weather, increase in temperature and storms, landslides etc (Turner and Ali 1996). Destruction of hills due to soil erosion and instability of hill slopes has had a negative impact on the diversity of flora and fauna of the area. Some of the immediate effects on the environment are deforestation (a precursor to surface mining), reduction in the fertility of the soil, and risk to local people and property due to landslides (Irfanullah and Motaleb 2011). It is currently difficult to assess the quantity of the degraded hill resources due to lack of a comprehensive inventory (Mahmood and Khan 2008); future efforts should be conducted with the aid of remote sensing technologies and other methods.

3.3 State

Changes in biodiversity due to the increasing disturbance by human population have generated national and international interest in understanding the potential consequences of such loss (Naeem 2002). The effect of biodiversity on ecosystem functioning are predicted by well-known ecological processes. Greater biodiversity leads to greater resource use and greater total community biomass (Tillman 1997). Losing a single species from the ecosystem may have great influence on community function and ecosystem properties (Symstad et al. 1998), especially if the species involved has keystone functionality. Changes in agricultural biodiversity in the Himalaya have been producing local pressure on forests elsewhere (Saxena et al. 2005). Bangladesh is rich in biodiversity. The replacement of primary forest by secondary forest and impacts on reserve forests in Bangladesh are occurring due to unplanned human disturbance and land use practices (Zaman et al. 2011). A high intensity of shifting cultivation has proved unsustainable, and shifting cultivators are increasingly facing food shortages throughout the year (Nath and Inoue 2009). Soil erosion has been

increasing at an alarming rate (Biswas et al. 2010; Chowdhury et al. 2007a; Chowdhury et al. 2007b; Islam et al. 2006).Soil erosion and agronomic productivity decline has been considered as major constraints for sustainable hill farming system (Biswas et al. 2010) in the hill areas of Bangladesh. And finally, as discussed, extraction of non-renewable materials (e.g., sand mining) has further reduced total productivity at landscape scales.

3.4 Impacts

The transformations in resources user practices in mountainous regions of Asia have significant effects on agricultural land, forests, pastures and rangelands due to the population growth, random deforestation, degradation of land resources and disruption of hydrological cycle. These impacts on natural resources reduce biodiversity, rural economy, society, livelihood and life quality of people (Tiwari 2008). Disturbances in the upland watershed in hilly areas have serious impacts on the lowland environment through water quality degradation and flooding impacts, including rapid siltation and deposition of gravels in delta areas (Biswas et al. 2011).). Slash and burn (shifting) cultivation is not always followed by successful regeneration of evergreen forest, leading to increases in soil erosion (Sitaula et al. 2004) and declining forest and agricultural productivity at stand and regional scales (Rahman et al. 2011). Consequently, people are facing a deficit of critical natural resources (food, fodder, fuel wood and water) which leads to greater poverty to local people (Saxena et al. 2005; Tiwari 2008; Karmakar et al. 2011). Nutrient loss (decreased availability of phosphorous, nitrogen, potassium and trace elements) due to soil erosion has been found in the hilly areas (Biswas et al 2010; Rasul and Thapa 2007; Gafur et al. 2003). High levels of river-borne sediment from these hills diminish the fertility of cultivable land (Islam et al. 2006). The effect of species richness loss varies depending on the productivity of individual species and their responses to environmental fluctuations (Yachi and Loreau 1999).Highly disturbed forest at the Kassalong reserve forest of Chittagong hill tracts has lower species richness than under historic forest conditions (Dewan and Vacik 2010).

4 Responses to Degradation and Integrated Natural Resources Management

In the hilly areas of Bangladesh, the poor socio-economic conditions of mountain people, combined with external economic forces, act as a catalyst to natural resource degradation. Systematic planning and application of the best available science are necessary. This research paper identifies conditions in threatened hill areas of Bangladesh. We here propose some solutions to conserve and develop hill natural resources through assessing, mitigating and preventing risks.

(1) Biodiversity loss has ultimate effects on human health (Myers and Patz 2009) due to pollution, biotic changes (introduction of exotic species), and loss of mechanisms controlling or limiting disease agents. Human health should be monitored, especially in parallel with the monitoring of ecological integrity in the hill landscapes of Bangladesh. This would facilitate correlations between landscape condition and human health factors (Burger and Gochfeld 2001).

(2) Participatory methods of governance and planning (also known as Participatory or Community based forest management, integrated resource management, joint forest management, adaptive co-management) have been recognized as effective and acceptable in many cases in recent decades (Mendoza and Prabhu 2005). Experiences from forest-based settlement projects (e.g., Karnafully rehabilitation scheme (1957-66), Supplementary rehabilitation scheme (1966-75), collective farming scheme (1968-1979), and rehabilitation of Jhumias (1981-2003)) should be utilized to ensure active participation of community (Nath and Inoue 2009). The idea of a framework for participatory decision support with local communities might be suggested for collaborative learning and social conflict reduction (Sheppard 2005; Biswas et al. 2011).

(3) Lack of skilled manpower in sustainable hill forest management is a major constraint in the development and conservation of hilly areas. Therefore, we suggest extension and teaching activities that link education and training to the specific needs of hilly areas. In addition, local awareness (Saxena et al. 2001) about the existing problems and risk in the hilly areas must be the

primary concern to fulfill the goal of sustainable natural resources management.

(4) Threatened hilly areas of Bangladesh (through sand mining) should be considered as the priority restoration and conservation areas so that conserving forests and preventing land degradation have multifunctional contribution in terms of the overall biodiversity of benefits to environment(Biswas et al. 2011). Late-seral forests (ancient woodland) are important landscape elements in the tropics (Wright 2005), conserving high species diversity (including tree species). In addition, naturally occurring early- successional forest ecosystems (ESFEs) have potential importance to meet the requirements of environmental conditions (structural complexity, spatial heterogeneity), biological diversity and food web diversity (Swanson et al. 2011). In the case of hilly areas of Bangladesh, for example, post-windstorm forest systems should be at least partially exempt from salvage practices.

(5) Agroforestry might be an alternative land use option for sustainable forest management (Alam et al. 2010) as demonstrated by two projects, the Upland Settlement Project (USP) and Betagi and the Pomora Social Forestry (SF) project (Khan and Khisa 2000; ADB 2001;Rahaman et al 2011; Rasul and Thapa 2007). Specific benefits include socioeconomic benefits, enhanced afforestation rates, and biodiversity conservation. Recommendations have been made on the basis of objectives achieved in the upland Settlement Project (USP) (Nath and Inoue 2008a; Nath and Inoue 2008b). Most people in hill regions are very traditional in their way of life (economy, livelihood and culture), and are very intimately connected with the land base and its resources (Motaleb and Irfanullah 2011). Unfortunately, traditional practices like shifting cultivation have in some situations proved unsustainable at modern rates of utilization. Thick forest areas were converted in the 1950 to early 1970s to unproductive and bushy areas (Rahaman et al. 2011; Biswas et al. 2010; Nath and Inoue 2009). Traditional knowledge must be blended with modern conservation methods (Irfanullah and Motaleb 2011) so that natural resources user groups might be convinced to adapt to new conservation and restoration principles (Mohiuddin and Alam 2011). Solutions might range from extensive forest practice based on mimicry of natural disturbance regimes (Lindenmayer and Franklin 2000) to short-term practices designed to restore soil stability and physiochemical properties (Islam and Weil 2000). Both approaches will require the commitment of public and private resources.

(6) Advanced policy and institutional reorganization with necessary support services will play an important role in resolving social, institutional and scientific issues for the people in hilly areas. One component of such a strategy might be the establishment of a national center on research, management, and restoration of hill regions, with the objective of establishing economically viable, socially acceptable, and environmentally sound strategies. However, a nation-level program must recognize the unique geophysical setting and socio-economic parameters of individual regions within Bangladesh, necessitating an adaptable policy framework. Flexibility must be built in to address the strategies, programs and projects specific to local circumstances and culture in hill regions. An appropriate and alternative policy might surmount current legal and institutional barriers, thus enabling an environmentally adaptable land use system (Rasul and Thapa 2007) so that local people will have a degree of self-determination in management of their own lands.

(7) Environmentally sound approaches to land use planning and development must be adopted. Strategies might include protection of unstable slopes and areas of high biodiversity, the application of vegetation management technology such as fast-growing trees and shrubs, utilization of local labor, and incorporation of indigenous land management practices of the mountain communities. These and other actions in a coordinated conservation and planning program would increase the chances of successful conservation and restoration, even if the effects of rapidly growing population, widespread deforestation and biotic pressure were not totally mitigated (Biswas et al. 2011). Urbanization projects, especially, must be assessed before further settlement or development activities in hilly areas.

(8) Carbon sequestration in the degraded hill might be one of the potential ways to motivate conservation efforts (Barua and Haque 2011),

employing the tools of horticulture, tree plantations and grassland (where appropriate). Modeling the effects of alternative management strategies on forest carbon (e.g,, Swanson 2009) would help to clarify the relative impacts on hill landscape carbon balance.

(9) Research facilities and technology development regarding an adequate management of mountainous or hilly forest would help generate viable policy solutions from environmental, social, political and economical perspectives (Hurni 1999; Biswas et al 2011).

(10) Hill tourism should be managed in a sustainable manner through three basic components: conservation of natural resources on which tourism depends; improvement in the quality of life of the local population and enhancement of visitor's satisfaction. Moreover, carrying capacity evaluation is mandatory for scientific planning of tourist and infrastructure in hilly areas (Hurni 1999).

References

Alam M, Furukawa Y, Harada K (2010) Agroforestry as a sustainable landuse option in degraded tropical forests: a study from Bangladesh. Environment, Development and Sustainability 12:147-158. DOI 10.1007/s10668-009-9186-3.

Ali M, Hoque ATMR (2009) Shifting regime shifted policy—interplay of interests in sustainability discourses of forest land use. Mitigation and Adaptation Strategies for Global Change 14(2): 121-134. DOI: 10.1007/s11027-008 -9154-5.

Ali AMS (2007) Population pressure, agricultural intensification and changes in rural systems in Bangladesh. Geoforum 38, 720-738.

Ali AMS (2004) Technological change in agriculture and land degradation in Bangladesh: a case study. Land Degradation & Development 15: 283-298.

Ali AMS (1995) Population pressure, environmental constraints and agricultural change in Bangladesh: examples from three agroecosystems. Agriculture, Ecosystems and Environment 55: 95-109.

Agyemang I, McDonald A, Carver S (2007) Application of the DPSIR framework to environmental degradation assessment in northern Ghana. Natural Resources Forum 31: 212-225.

Appanah S, Ratnam L (1992) The importance of forest biodiversity to developing countries in Asia. Journal of Tropical Forest Science 5(2): 201-215.

Asian Development Bank (ADB) (2001) Chittagong Hill Tracts Region Development Plan. Final report, ADB TA no. 3328, Rangamati, Bangladesh.

Atkins JP, Burdon D, Elliott M, Gregory AJ (2011) Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin 62: 215-226.

Barua SK, Haque SMS (2011) Soil characteristics and carbon sequestration potentials of vegetation in degraded hills oh Chittagong, Bangladesh. Land Degradation & Development DOI: 10.1002/ldr.1107.

Barua SP, Khan MMH, Reza AHMA (2001) The status of alien invasive species in Bangladesh and their impact on the ecosystems. In: Balakrishna, P. (ed). Report of the Workshop on Alien Invasive Species, GBF-SSEA, Colombo, Sri Lanka. IUCN Biodiversity Programme. pp 1-8.

BFD/MoEF (2000). *First five-year management plan for Lawachara National Park, Forestry Sector Project (1997/8-2003/4), volume 2: Background material and support material*, Forest Department, Ministry of Environment and Forests, Dhaka, ADB Project BAN No. 1486.

Biswas SR, Choudhury JK (2007) Forests and forest management practices in Bangladesh: the question of sustainability. International Forestry Review 9(2): 627-640. DOI: 10.1505/ifor.9.2.627.

Biswas S, Swanson ME, Shoaib JU, Haque SM (2010) Changes in soil chemical properties under Modern and Traditional farming system at Khagrachari, Chittagong Hill Tracts, Bangladesh. Journal of forestry research 21(4): 451-456.

Biswas S, Vacik H, Swanson ME and Haque SM (2011) Evaluating integrated water resource management using multiple criteria analysis—a case study at Chittagong hill tracts in Bangladesh. Environmental Monitoring and Assessment. DOI: 10.1007/s10661-011-2148-x.

Browne G, McPhail I (2011) Transition principles: Experiences from the Victorian State of the environment reporting process and relevance to sustainability in complex systems. Australasian Journal of Environmental Management 18(1): 6-20.

Burger J, and Gochfeld M 2001. On developing bioindicators for human and ecological health. Environmental Monitoring and Assessment 66:23-46.

Chowdhury MSH, Biswas S, Haque SMS, Muhammed N, Koike M (2007a) Comparative analysis of some selected macronutrients of soil orange orchard and degraded forests in Chittagong Hill Tracts, Bangladesh. Journal of Forest Research, 18(1):27-30.

Chowdhury MSH, Halim MA, Biswas S (2007b) Comparative evaluation of physical properties in soils of orange orchard and bushy forest in Chittagong hill tracts, Bangladesh. Journal of Forestry Research 18(3): 245-248.

Crabtree B, Bayfield N (1998) Developing sustainability indicators for mountain ecosystems: A study of the Cairngorms, Scotland. Journal of Environmental Management 52: 1-14.

De Groot RS, Wilson M, Boumans R (2002) A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41: 393–408.

Dewan S, Vacik H (2010) Analysis of regeneration and species diversity along human induced disturbances in the Kassalong Reserve Forest at Chittagong Hill Tracts, Bangladesh. Ekologia Bratislava 29: 307-325.

Dewan AM, Yamaguchi Y (2009) Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. Applied Geography 29:390-401.

Dietrich J, Schumann AH, Lotov AV (2007) Workflow orient. Participatory decision support for integrated river Basin planning. In: Castelletti A, Soncini-Sessa R (eds.) Topics on

System Analysis and Integrated Water Resource Management. Elsevier, Amsterdam, NL. pp 207-221.
Douglas M (1999) IFAD proposed programme for Asia: A Strategy for alleviation of poverty through sustainable development in the uplands of Asia. Paper presented at the Workshop on Special Programs for Sustainable Upland
Development in Asia—Reality Check Consultation, 19–21 April 1999. Klong Luang, Thailand, organized by IFAD/IUCN.
EEA—European Environment Agency (1999) Environment in the European Union at the Turn of the Century. Environmental Assessment Report No 2. European Environment Agency, Copenhagen, Denmark.
FAO (Food and Agriculture Organization of the United Nations) (2006) Global forest resources assessment 2005: Progress towards sustainable forest management. FAO, Rome.
FAO (2002) Mountain people suffer more malnutrition and disease. http://www.fao.org/english/newsroom/news/2002/6763-en.html. Acessed at 02-17-2012.
Gafur A, Jensen JR, Borggaard OK, Petersen L (2003) Runoff and losses of soil and nutrients from small watersheds under shifting cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh. Journal of Hydrology, 279(1-4): 293-309. DOI: 10.1016/S0022-1694 (02)00351-7.
Gurung H (1999) Mountains of Asia: A Regional Inventory. ICIMOD (International Centre for Integrated Mountain Development), Kathmandu, Nepal.
Haque SMS (1997) Afforestation Effects on Former Agricultural Soils. Ph. D. thesis, University of Aberdeen, Scotland, UK.
Hassan M (1999) Soils of Bangladesh: Their genesis, classification and use potentials. The March Printers, Narinda, Dhaka.
Helmut JG, Eric FL (2002) Proximate causes and underlying driving forces of tropical deforestation. BioScience 52(2): 143-150.
Hurni H (1999) Sustainable management of natural resources in African and Asian Mountains. Ambio 28(5):382-389.
Irfanullah HM, Motaleb MA (2011) Reading nature's mind: Disaster management by indigenous peoples of Bangladesh.Indian Journal of Traditional Knowledge 10(1): 80-90.
Iftekhar MS, Hoque AKF (2005) Causes of forest encroachment: An analysis of Bangladesh. GeoJournal 62: 95-106.
IPCC (2007) Climate Change: Synthesis Report. Cambridge University Press, Cambridge, UK and New York, USA.
IRIN (2008) Bangladesh: 70,000 People Vulnerable to Landslides. http://www.irinnews.org/Report.aspx?ReportId=79406. Accessed at 02-17-2012.
Islam KR, and Weil RR 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agriculture, Ecosystems, & Environment 79(1): 9-16.
Islam MS, Hasan GMJ, Chowdhury MAI (2006) Destroying hills in the north-eastern part of Bangladesh: A qualitative assessment of extent of the problem and its probable impact. International journal of Environmental Science and Technology 2(4):301-308.
Ives JD (1985) The mountain malaise: Quest for an integrated development. In: Sing TV, Kaur J (eds.) Himalayan Books. New Delhi, India.
Jodha NS (2007) Mountain commons: Changing space and status at community levels in the Himalayas. Journal of Mountain Science 4(2):124-135. DOI: 10.1007/s11629-007-0124-2.
Jodha NS (1990) A Framework for Integrated Mountain Development. MFS Discussion Paper No.1. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.
Jose S (2011) Managing native and non-native plants in agroforestry systems. Agroforestry Systems 83:101-105. DOI: 10.1007/s10457-011-9440-1.
Kapos V, Rhind J, Edwards M, Price MF, Ravilious C (2000) Developing a map of the world's mountain forests. In: Price MF, Butt N (eds.) Forests in Sustainable Mountain Development: A State-of-Knowledge Report for 2000 p 4-9.IUFRO Series No. 5. Wallingford, UK, CAB International.
Karageorgis AP, Skourtos MS, Kapsim V, Kontogianni AD, Skoulikidis NTh, Pag K, Nikolaidis NP, Drakopoulou P, Zanou B, Karamanos H, Levkov Z, Anagnostou Ch (2005) An integrated approach to watershed management within the DPSIR framework: Axios River catchment and Thermaikos Gulf. Regional Environmental Change 5:138-160. DOI: 10.1007/s10113-004-0078-7.
Karmakar S, Haque SM, Hossain MM, Shafiq M (2011) Water quality of Kaptai reservoir in Chittagong Hill Tracts of Bangladesh. Journal of Forestry Research 22(1):87-92.
Khan FH (2000) Geology of Bangladesh. The University Press Limited Dhaka, Bangladesh.
Khan NA, Khisa SK (2000) Sustainable land management with rubber-based agroforestry: A Bangladeshi example of upland community development. Sustainable Development 8:1-10.
Khisa SK, Shoaib JU, Khan NA (2006) Selected Natural Resource Conservation Approaches and Technologies in the Chittagong Hill Tracts. Bangladesh, BANCAT, CHTDB, Khagrachari.
Kristensen P (2004) The DPSIR framework. European Topic Centre on Water, European Environment Agency. Paper presented at the 27-29 September 2004 workshop on a comprehensive / detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach. UNEP Headquarters, Nairobi, Kenya.
Lama, W. B. and Sattar N., 2002. Mountain Tourism and the Conservation of Biological and Cultural Diversity. Thematic Paper B3, Bishkek 2002 Global Mountain Summit.
Lindenmayer, D.B., and J.F. Franklin. 2002. Conserving forest biodiversity: a comprehensive multiscaled approach. Island Press, Washington, DC. p 351 .
Lozoya PJ, Rafael S, Jimenz JA (2011) A methodological framework for multi-hazard risk assessment in beaches. Environmental Science and Policy 14: 685-696.
Mahmood AB, Khan MH (2008) Landslide vulnerability of Bangladesh hills and sustainable management options: A case study of 2007 landslide in Chittagong city. International Seminar on "Management and Mitigation of Water Induced Disaster" to be held on 21-22 April 2008 in Kathmundu, Nepal.
Mendoza GA, Prabhu R (2005) Combining participatory modeling and multi-criteria analysis for community-based forest management. Forest Ecology and Management 207: 145-156.
Messerli B (2001) From the Earth Summit 1992 to the International Year of Mountains 2002. In Mountains and People. Swiss Agency for Development and Cooperation. Burne, Switzerland. pp. 12-13.
Messerli B (1983) Stability and Instability of Mountain Ecosystems: Introduction to a Workshop Sponsored by the United Nations University. Mountain Research and Development 3(2): 81-94.
Meybeck M, Green P, Vorosmarty CJ (2001) A new typology for mountains and other relief classes, an application to global continental water resources and population distribution. Mountain Research and Development 21(1):34-45.
Miah MD, Masum MFH, Koike M (2011a) Global observation of EKC hypothesis for CO_2, SOx and NOx emission: A policy understanding for climate change mitigation in Bangladesh. Energy Policy 38:4643–4651.
Miah MD, Masum MFH, Koike M, Akther S, Muhammed N (2011b) Environmental Kuznets Curve: The case of Bangladesh for waste emission and suspended particulate matter. Environmentalist 31(1):59-66. DOI 10.1007/s10669-010-9303-8.
Mohiuddin M, Alam MK (2011) Opportunities of traditional knowledge in natural resource management experiences from the Chittagong Hill Tracts, Bangladesh. Indian Journal of Traditional Knowledge 10(3):474-480.
Motaleb MA, Irfanullah HM (2011) Tobacco cultivation in

Bangladesh: is it a threat to traditional agro-practice? Indian Journal of Traditional Knowledge 10(3): 481-485.
Muzaffar SB, Islam MA, Kabir DS, Khan MH, Ahmed FU, Chowdhury GW, Aziz MA, Chakma S, Jahan I (2011) The endangered forests of Bangladesh: Why the process of implementation of the convention on biological diversity is not working. Biodiversity and Conservation 20:1587-1601. DOI 10.1007/s10531-011-0048-6.
Myers SS,Patz JA (2009) Emerging threats to human health from global environmental change. Annual Review of Environment and Resources 34:223-252.
Naeem S (2002) Ecosystem consequences of biodiversity loss: The evolution of a paradigm. Ecology 83(6): 1537-1552.
Nath TK, Inoue M (2008a) Upland Settlement Project of Bangladesh as a means of reducing land degradation and improving rural livelihood. Small-Scale Forestry 7(2): 163-182.
Nath TK, Inoue M (2008b) How does local governance affect projects' outcomes? Experiences from a participatory forestry project of Bangladesh. International Journal of Agricultural Resources, Governance and Ecology 7: 491-506.
Nath TK, Inoue M (2009) Forest based settlement project and its impacts in Chittagong hill tracts, Bangladesh. International Forestry Review 11(3):394-407.
Parveen S, Faisal IM (2002) People versus power: The Geopolitics of Kaptai Dam in Bangladesh. Water Resources Development 18(1):197-208.
Price MF (2003) Why mountain forests are important. The Forestry Chronicle 79(2): 219-222.
Rahman S (1995) Wildlife in Bangladesh: A diminishing resources. Tigerpaper 22(3): 7-16.
Rahman MM, Csaplovics E, Pretzsch J (2000) Assessment of tropical deforestation in social dimension: a study in Chittagong, Bangladesh using remote sensing and GIS. In: Procedings 4th International Conference Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs, Banff, Alberta, Canada.
Rahaman SA, Rahaman MF, Sunderland T (2011) Causes and consequences of shifting cultivation and its alternative in the hill tracts of eastern Bangladesh. Agroforestry Systems 84(2): 141-155. DOI: 10.1007/s10457-011-9422-3.
Rasul G, Thapa GB (2003) Shifting cultivation in the mountains of south and southeast Asia: Regional patterns and factors influencing the change. Land Degradation & Development 14:495-508. DOI: 10.1002/ldr.570.
Rasul G, Thapa GB (2007) The impact of policy and institutional environment on costs and benefits of sustainable agricultural land uses: The case of the Chittagong Hill Tracts, Bangladesh. Environmental Management 40(2):272-283.
Saha N, Azam MA (2004) The indigenous hill-farming system of Khasia Tribes in Moulvibazar District of Bangladesh: Status and impacts. Small-scale Forest Economics, Management and Policy 3(2): 273-281.
Salam MA, Noguchi T, Koike M (1999) The causes of forest cover loss in the hill forests in Bangladesh. GeoJournal 47: 539-549.
Saxena KG, Maikhuri RK, Rao KS (2005) Changes in Agricultural Biodiversity: Implications for
Sustainable Livelihood in the Himalaya. Journal of Mountain Science 2(1): 23-31.
Saxena KG, Rao KS, Sen KK, Maikhuri RK, Semwal RL (2001) Integrated natural resource management: Approaches and lessons from the Himalaya. Conservation Ecology 5(2): 14.
Sheppard SRJ (2005) Participatory decision support for sustainable forest management: A framework for planning with local communities at the landscape level in Canada. Canadian Journal of Forest Research 35:(7) 1515-1526.
Sitaula BK, Bajracharya RM, Singh BR, Solberg B (2004) Factors affecting organic carbon dynamics in soils of Nepal/Himalayan region—a review and analysis. Nutrient Cycling in Agroecosystems 70: 215-229.
Soberon J, Rodriquez P, Vasquez-Domingues E (2000) Implications of the hierarchical structure of biodiversity for the development of ecological indicators of sustainable use. Ambio 29:136-142.
Swanson ME (2009) Modeling the effects of alternative management strategies on forest carbon in the Nothofagus forests of Tierra del Fuego, Chile. Forest Ecology and Management 257:1740-1750.
Swanson ME, Franklin JF, Beschta RL, Crisafulli CM, DellaSala DA, Hutto RL, Lindenmayer DB, Swanson FJ (2011) The forgotten stage of forest succession: Early-successional ecosystems on forest sites. Frontiers in Ecology and the Environment 9(2):117-125. DOI:10.1890/090157.
Symstad AJ, Tilman D, Wilson J, Knops JMH (1998) Species Loss and Ecosystem Functioning: Effects of Species Identity and Community Composition. Oikos 81(2):389-397.
Tilman D, Lehman CL, Thomson KT (1997) Plant diversity and ecosystem productivity: Theoretical considerations. Proceedings of the National Academy of Sciences of the United States of America 94:1857-1861.
Thapa GB, Rasul G (2005) Patterns and determinants of agricultural systems in the Chittagong hill tracts of Bangladesh. Agricultural system 84:255-277.
Tillman D (2000) Causes, consequences and ethics of biodiversity. Nature 405: 208-211.DOI:10.1038/35012217.
Tiwari P (2000) Land-use changes in Himalaya and their impact on the plains ecosystem: Need for sustainable land use Land Use Policy 17: 101-111.
Tiwari P (2008) Land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India. Advances in Atmospheric Sciences 25(6): 1029-1042. DOI: 10.1007 /s00376-008-1029-x.
Turner BL, Ali AMS (1996) Induced intensification: Agricultural change in Bangladesh with implications for Malthus and Boserup. Proceedings of the National Academy of Sciences of the United States of America 93:14984-14991.
Upadhyay TP, Sankhayan PL, Solberg B (2005) Review:A review of carbon sequestration dynamics in the Himalayan region as a function of land-use change and forest/soil degradation with special reference to Nepal. Agriculture, Ecosystems and Environment 105:449-465.
Viviroli D, Du¨rr HH, Messerli B, Meybeck M, Weingartner R (2007) Mountains of the world, water towers for humanity: Typology, mapping, and global significance. Water Resources Research 43: W07447. DOI:10.1029/2006WR005653.
Wasson RJ, Juyal N, Jaisal M, McCulloch, Sarin MM, Jain V, Srivastava P, Singhvi AK (2008) The mountain-lowland debate: Deforestation and sediment transport in the upper Ganga catchment. Journal of Environmental Management 88:53-61. DOI:10.1016/j.jenvman.2007.01.046.
Wolfslehner B, Vacik H (2011) Mapping indicator models: From intuitive problem structuring to quantified decision making in sustainable forest management. Ecological Indicators 11(2): 274-283. DOI:10.1016/j.ecolind.2010.05.004.
Yachi S, Loreau M (1999) Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. Proceedings of the National Academy of Sciences of the United States of America 96: 463-1468.
Wright, S.J. 2005. Tropical forests in a changing environment. TRENDS in Ecology and Evolution 20(10):553-560.
Zaman S, Siddiquee SU, Katoh M (2011) Species composition and forest structure in tropical moist deciduous forest of Bangladesh—a case study in Thakurgaon. Arabian Journal of Geosciences 4(7-8): 1315-1321. pp. 1-7., DOI 10.1007/s12517 -010-0235-x