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CONTENTS

PARAGLACIAL ADJUSTMENT OF ROCK SLOPES : CAUSES AND CONSEQUENCES

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Abstract

Paraglacial stress-release acting on glacially-steepened rockwaills during and after deglaciation produces three types of geomorphological response: immediate or delayed catastrophic failure, deep-seated rock-mass deformation, and progressive slope adjustment by frequent rockfall activity, leading to the accumulation of talus on lower slopes. The nature of response is primarily governed by lithology and inclination of structural discontinuities. All three effects diminish through time as the residual strain energy of rock masses declines, but relaxation times are prolonged (10^3-10^4 years). In permafrost environments, paraglacial rockslope failure and paraglacial rockfall have probably been critical in the development of some protalus rock glaciers. Paraglacial rock-slope adjustment may also play a significant role in providing debris for subsequent glacial transport, particularly during the initial stages of glacial advance, and represents an important component of the evolution of major alpine erosional landforms such as cirques and glacial troughs.

Introduction

The withdrawal of glacier ice exposes landscapes that are in an unstable or metastable condition, and consequently liable to rapid and extensive modification. Such accelerated geomorphological activity is termed '*paraglacial*', a termed defined by Church and Ryder (1972, p. 3059) as referring to 'nonglacial processes that are directly conditioned by glaciation'. The concept of paraglacial processes and paraglacial landscape modification has been extensively applied to the reworking of glacigenic sediments, notably on hillslopes (e.g. *Owen, 1991;* Ballantyne and Benn, 1994; Ballantyne, 1995; Watanabe et al., 1998; Curry, 1999), on glacier forelands (e.g. Matthews *et al.*,1998; Etzelmüller, 2000), within river and lake catchments (e.g. Ryder, 1971; Church and Ryder, 1972; Jackson *et al.*,1982; Church and Slaymaker, 1989; Owen and Sharma, 1998; Müller, 1999) and in the coastal zone (e.g. Forbes and Syvitski, 1994; Forbes *et al.*,1995; FitzGerald and van Heteren, 1999). In many mountainous environments, however, one of the most important geomorphological consequences of deglaciation occurs independently of sediment reworking, namely the exposure and subsequent paraglacial adjustment of steep rockwalls. This paper first

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explores the theoretical consequences of glacial loading and deglacial unloading on steep rock slopes and outlines evidence for three forms of paraglacial response, namely catastrophic rock slope failure, rock-mass deformation and enhanced rockfall activity. The paper then considers some consequences of paraglacial adjustment of rock slopes, with particular reference to glacial reworking of paraglacial rock-slope debris and the long-term development of large-scale glacial erosional landforms in mountain environments.

Paraglacial rock-slope modification: theory

Glaciation and deglaciation affect rock slope stability in two related ways. First, glacial erosion may steepen and lengthen rock slopes, thereby increasing the self-weight (overburden) shear stresses acting within the rock face. Secondly, during glacial periods the weight of overlying or adjacent glacier ice increases stress levels within rock masses. Part of the resulting ice-load deformation is elastic and stored within the rock as strain energy. During deglaciation and consequent unloading of glacially-stressed rock, release of strain energy causes 'rebound' or stress-release within the rock (Fig. 1). Stress release causes extension of the internal joint network, together with reduced cohesion along joint planes and a reduction of internal locking stresses (Wyrwoll, 1977). These

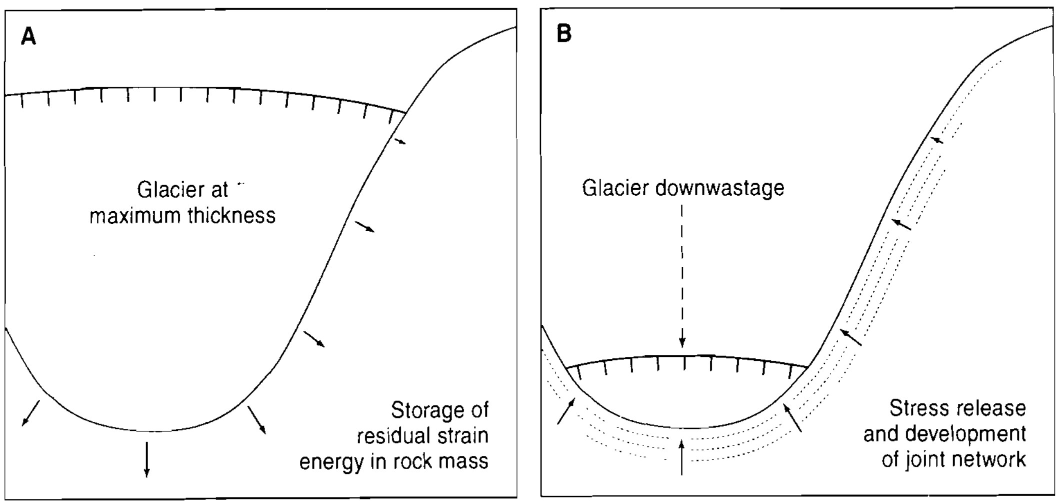

Fig. 1: (A) During the glacial maximum the weight of glacier ice imposes compressional stresses on the valley sides and valley floor. Part of the resulting ice-load deformation is elastic and is stored as residual strain energy. (B) During glacier downwastage and resulting unloading (debuttressing) of glacially-stressed rock, stain energy is released. Such stress release causes tensional fracturing and joint development, weakening the valley-side slope. Self-weight (overburden) stresses are not shown.

changes may initiate rockslope failure during or after deglaciation, rock-slope readjustment through slow rock-mass deformation, or progressive adjustment through numerous small-scale rockfalls.

Several additional effects may also play subsidiary role in reducing rock-mass stability following deglaciation. Where glacial valleys cross a compressive tectonic system (for example in orogenic belts) there may be further redistribution of stresses within the rock mass that promote zones of tensile failure parallel to the rock face (Augustinus, 1995a). Development of an internal joint network due to stress release may lead to enhanced cleftwater pressures that ultimately facilitate failure, especially if outlets are subject to seasonal freezing. Finally, seismic shocks may trigger the failure of rockwalls that have been reduced to a state of critical conditional stability by the processes identified above.

The nature of the response of glacially-steeped rock slopes to deglaciation is determined by lithology and structure, and particularly by joint density and the orientation and inclination of discontinuities and planes of weakness relative to that of the newly-exposed rock face. Augustinus (1995b) has shown that glaciated valley-side slopes of variable lithology and structure in New Zealand have exhibited very different forms of paraglacial response. Massive gabbro and diorite, for example, support very steep slopes, and paraglacial modification has been limited to small planar slides along slope-parallel sheeting (stress-release) joints. Conversely, planar rockslides and rockfalls are widespread on schists, with failure typically seated on foliation planes on dip or overdip slopes. On densely-jointed greywackes and argillites, glacially-steepened slopes rapidly degrade by a combination of sliding and toppling failure and rockfall, so that even slopes deglaciated within the last century are often support extensive talus accumulations.

Paraglacial modification of rock slopes therefore reflects the interaction of changing stress conditions (due to both glacial steepening and unloading/debuttressing as overlying or adjacent ice downmelts), and rock mass strength controlled by lithology and jointing. This interaction produces a complex, time-dependent morphological response. Three general types of response can be identified, namely: (1) large-scale catastrophic failure, (2) slow rock-mass deformation, and (3) progressive slope adjustment by small-scale topples, slides and rockfalls. These categories are not mutually exclusive. Slow rock-mass deformation may lead to catastrophic failure, and the distinction between small-and large-scale failure is blurred. The three categories of response nevertheless provide a framework for considering the processes and geomorphological consequences of paraglacial rock-slope modification.

Catastrophic rock-slope failure

Numerous recent major rock-slope failures have accompanied glacier retreat and downwastage in mountainous environments. Example include a major rockslide on to the Lyell Glacier in South Georgia (Gordon *et al.*,1979), the Brenva Glacier rockfall in 1920 (Porter and Orombelli, 1981), the Sioux Glacier rock avalanche in Alaska (Reid, 1969), the Sherman Glacier rock avalanche of 1964 (Shreve, 1966), the rockslides that triggered a surge of Bualtar Glacier in the Karakoram Mountains (Gardner and Hewitt, 1990) and the Pandemonium Creek rock avalanche in British Columbia in 1959 (Evans *et al.*,1989). Such catastrophic failures appear to result directly from glacier downwasting and consequent debuttressing of valley-side slopes. Recent thinning of the Maud Glacier in New

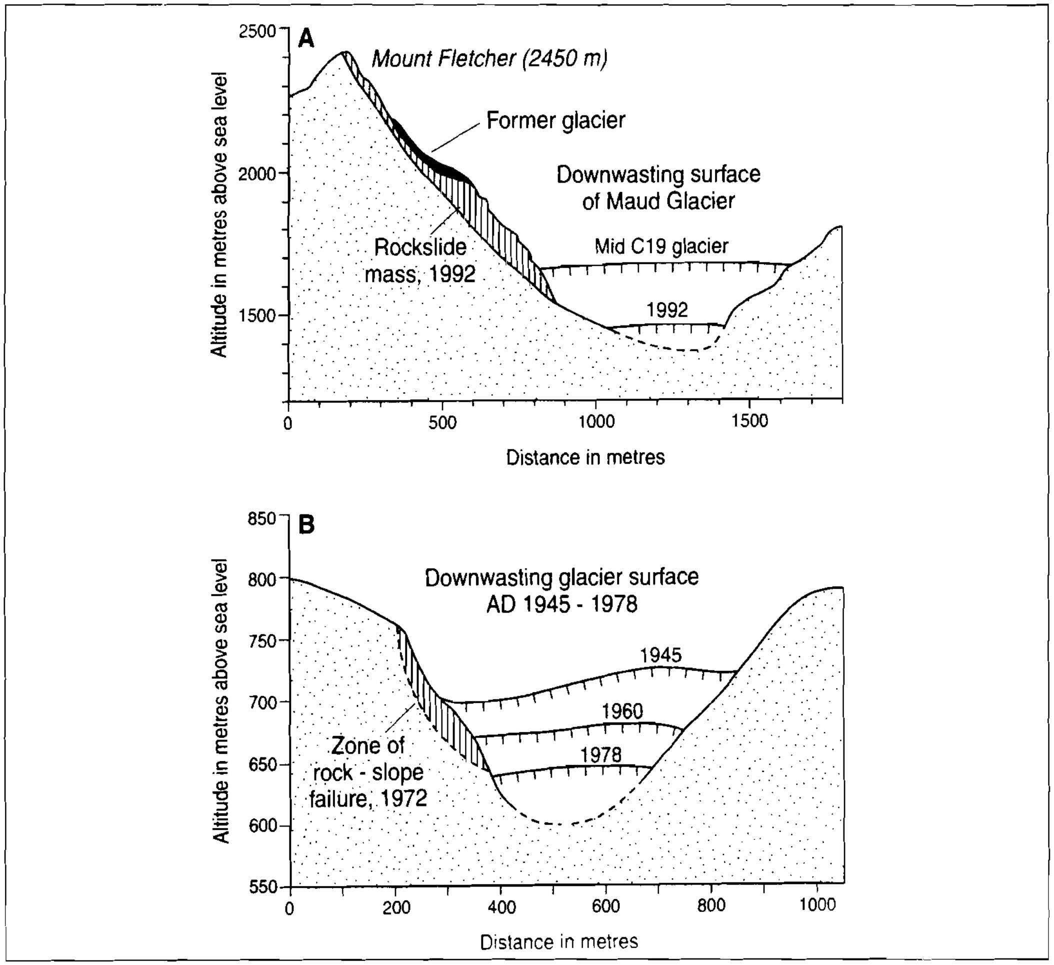

Fig. 2: (A) Zone of rock slope failure initiated by downwasting of the Maud Glacier in New Zealand (McSaveney, 1993). (B) Zone of rock slope failure initiated by downwasting of an outlet glacier, Myrdalsjökull, Southern Iceland (Sigurdsson and Williams, 1991).

Zealand exposed toe slopes that failed catastrophically in 1992, releasing an avalanche of up to 10^7 m^3 of rock (McSaveney, 1993). Similarly, in southern Iceland a major rockslide on to an outlet glacier of the Myrdalsjökull ice cap in 1972 was attributed by Sigurdsson and Williams (1991) to '...the decrease of the buttressing mass at the base of the valley wall resulting from the recession of the glacier' (Fig. 2). Further examples of catastrophic rock-slope failures associated with retreating glaciers have been described by Evans and Clague (1994), who noted that of 30 large (> 10^6 m^3) rock avalanches known to have occurred in the Canadian Cordillera in historic times, 16 were located on slopes debuttressed by recent glacier retreat. They concluded (1994, p. 109) that 'slopes adjacent to glaciers that have significantly thinned are particularly prone to landslides'. Such paraglacial slope failure may constitute a major hazard. Catastrophic landslides from Nevados Huascaràn in Peru in 1962 and 1970 were probably caused, at least in part, by glacier thinning and retreat (Plafker and Ericksen, 1978). In 1962, 4000 inhabitants of the neighbouring Rio Shacsa valley died when *c.* 13,000,000 m^3 of rock and ice travelled 16 km down the valley. In 1970 a further 50-100,000,000 m^3 of rock and ice failed and travelled 65 km downvalley, leaving an estimated 18,000 dead.

Widespread paraglacial rock slope failure following Late Pleistocene or Early

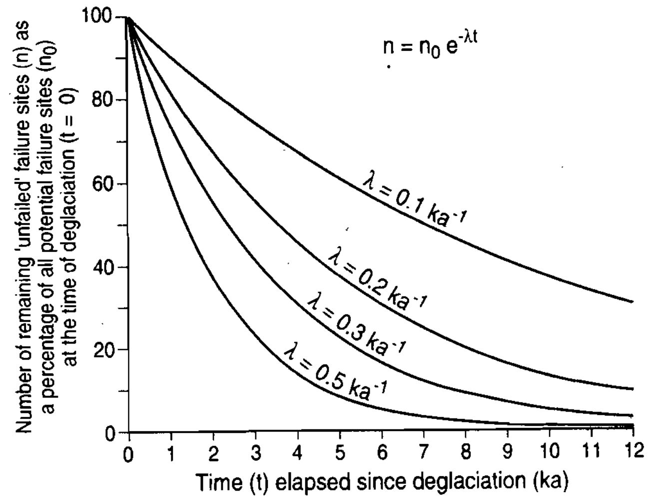

Fig. 3: Graphical representation of the exhaustion model of the timing of rock slope failure following deglaciation for $\lambda = 0.1$ ka^{-1}, $\lambda = 0.2$ ka^{-1}, $\lambda = 0.3$ ka^{-1}, and $\lambda = 0.5$ ka^{-1}. The model predicts that 99.7% of all potential failure sites fail within 12 ka when $\lambda = 0.5$ ka^{-1}, but only 69.9% of potential failure sites fail within 12 ka if $\lambda = 0.1$ ka^{-1}. For explanation, see text.

Holocene deglaciation has also been inferred by a number of authors. Gardner (1980) and Luckman (1981) have suggested that most major rock-slope failures in the Canadian Rocky Mountains occurred soon after deglaciation, and Rapp (1960; Rapp and Åkerman, 1993) reached a similar conclusion for the Karkevagge Mountains in northern Sweden. Caine (1982) has shown that scarp-edge toppling in Tasmania represents a paraglacial response to Late Pleistocene deglaciation, as such failures do not occur on simular slopes outside the former glacial limit. In the Alps, most large-scale rock-slope failures reflect glacial steepening and debuttressing, though in some cases failure did not occur until several millennia after deglaciation (Abele, 1997). In Great Britain, paraglacial rock-slope failure was widespread in mountain areas in Lateglacial and Early Holocene times (Ballantyne, 1986, 1997; Shakesby and Matthews, 1996), though dating of landslides on the Isle of Skye has shown that failure did not occur until at least 7000 years after deglaciation in this area (Ballantyne *et al.*,1998).

Cruden and Hu (1993) have proposed that the temporal pattern of paraglacial rock-slope failure in response to Late Pleistocene deglaciation can be described by an exhaustion model. This model assumes that there are a finite number of potential failure sites following deglaciation, that each site fails only once, and that the probability of occurrence of individual rockslides remains constant. Under these assumptions the overall probability of failure occuring within a given area diminishes exponentially with time elapsed since deglaciation as the number of potential (i.e. 'unfailed') failure sites is progressively reduced (Fig. 3). The model is expressed as:

$$n = n_0 \, e^{-\lambda t}$$

Where n_0 is the initial number of potential failure sites, n is the number of remaining ('unfailed') failure sites, t is time elapsed since deglaciation and λ is rate of failure, expressed as the probability of failure of individual sites within a given time interval. For glacially-steepened overdip slopes in the Canadian Rockies, Cruden and Hu (1993) calculated that the average pre-failure endurance of individual sites is *c.* 5,700 years. The exhaustion model (Fig. 3) provides a useful tool for conceptualising the progressive decline in the frequency of paraglacial rock slope failures since deglaciation, but cannot at present be validated or calibrated in view of the difficulties inherent in dating the occurrence of individual rock slope failures. Recent work has shown that these can be overcome using cosmogenic isotope dating techniques, which are ideally suited to establishing the age of catastrophic rock-slope failures (Ballantyne et al., 1998). At present, though, no suitable date set exists to test the exponential form of the decay curve proposed by the exhaustion model, or to estimate the average rate of failure (λ). Some support for the validity of the exhaustion model comes from a study of rates of rock slope debris accumulation in Yosemite Valley, California, where the volume of rock slope debris deposited at the foot of granite rockwalls during the period AD 1851-1992 implies an average accumulation rate that is less than half the postglacial average (Wieczorek and Jäger, 1996), consistent with a progressive slowing in the rate of rock-slope failure as predicted by the exhaustion model.

Rock-slope deformation

Stress release due to deglacial unloading and debuttressing may also result in slow paraglacial rock-slope deformation, often referred to as rock-mass creep. Such rock-slope deformation represents wholesale failure of large rock masses, but occurs (at least initially) without catastrophic runout of debris. The occurrence of rock-mass creep is evident through the formation of a wide range of distinctive landforms, including ridge-top trenches or graben (Fig. 4), crevasse-like tension cracks, upslope-facing scarps (antiscarps or obsequent scarps) and convex 'bulging' slopes (Fig. 5). Rock-mass creep may reduce glacially-steepened rock slopes to a state of critical conditional stability, and thus sometimes precedes catastrophic failure (Chigira, 1992).

Fig. 4: Ridge-top graben formed by paraglacial rock-slope deformation, Ladhar Bheinn, NW Scotland.

Fig. 5: Slope bulging and antiscarp formation due to paraglacial rock-mass deformation following Late Pleistocene deglaciation, Bheinn Fhada, NW Scotland. The slope is now stable.

A close relationship between debuttressing of rock slopes during deglaciation and initiation of rock-mass creep has been observed by several authors. In the Olympic Mountains of Washington State, Tabor (1971) noted that recent glacier retreat had been accompanied by the formation of tensional fractures and trenches adjacent to glacially-steepened rockwalls. Radbruch-Hall (1978) described tensional fracturing and antiscarp formation on a mountain in Alaska, and concluded that debuttressing during glacier downwastage had contributed to surface fracturing. Evans and Clague (1993) have described slope deformation at Melburn Glacier in British Columbia triggered by glacial downwasting over the past century. Deepseated rock-mass deformation is also evident along the margins of the rapidly downwasting Tasman Glacier in New Zealand. Here the bedrock ridge separating the Tasman Glacier from the adjacent Ball Glacier has deformed slowly along shear planes, with tension cracks, flexural topples and antiscarps developing on both sides of the ridge (Blair, 1994).

The most thorough research on paraglacial rock slope deformation has been carried out by Bovis (1982, 1990) on slopes overlooking Affliction Glacier in British Columbia. These slopes support numerous features characteristic of rock slope deformation, including wide fractures, antiscarps, elongated graben and collapse pits, all indicative of tension and movement in the near-surface zone. A survey of rock slope movement indicates that an estimated 3 x 10^7 m^3 of rock is presently subject to slow gravitational movement at this site, with surface velocities of a few millimetres to a few centimetres per year.

Though the above accounts provide convincing evidence for a causal relationship between glacier downwastage and the initiation of rock-slope deformation, the process is by no means ubiquitous. Bovis (1982) noted that though all valley-side slopes within the limits of glaciation have experienced changes in stress conditions, the evidence for gravitational deformation is localised, implying that the occurrence of significant rock-mass deformation following deglaciation is controlled by factors such as lithology, structure, gradient, rate and depth of glacial downwastage and possibly seismicity. Numerous authors have nonetheless associated widespread rock mass creep in formerly-glaciated mountains with changes in stress patterns during and following Late Pleistocene deglaciation (e.g. Tabor, 1971; Brükl and Scheidegger, 1972; De Freitas and Watters, 1973; Radbruch-Hall et al., 1976; Mahr, 1977; Radbruch-Hall, 1978; Holmes and Jarvis, 1985; Savage and Varnes, 1987). As Bovis (1990) observed, however, many of the associated landforms such as graben, tension cracks and antiscarps now appear inactive, implying that slope deformation initiated by Late Pleistocene glacier downwastage and debuttressing is more or less complete.

Paraglacial rockfall and talus slope accumulation

A third possible response of glacially-steepened rock slopes to deglaciation is through initially rapid rockfall activity that results in the development of paraglacial talus accumulations below cliffs (Augustinus, 1995b). Several authors have observed that the large volumes of talus present at the foot of rockwalls deglaciated in the Late Pleistocene are inconsistent with the present rates of rockfall activity, and have concluded that the rate of rockfall was very much greater immediately after deglaciation (e.g. Luckman, 1981; Gardner, 1982; Johnson, 1984a, 1995; Marion *et al.*,1995) Luckman and Fiske (1995), for example, found that the rate of talus accumulation over the past 300 years at a site in the Canadian Rocky Mountains has been roughly an order of magnitude too small to have produced the volume of talus at the site. Similarly, Hinchliffe and Ballantyne (1999) found that roughly 80% of talus accumulation on the Isle of Skye in the Scottish Highlands took place within six millennia of deglaciation (17.5-11.5 cal ka BP), with only about 20% of talus debris accumulating after 11.5 cal ka BP, implying a marked reduction in rockfall rate through time.

Although enhanced rockfall activity immediately after deglaciation may to some extent reflect more effective freeze-thaw action under the periglacial conditions that accompanied and/or succeeded deglaciation, there is evidence that paraglacial rock-slope instability has been the dominant factor governing rates of rockfall and thus talus accumulation on deglaciated terrain. Closely-jointed rockwalls in New Zealand undergo extensive rockfall immediately after deglaciation, forming thick talus accumulations near the snouts of retreating glaciers (Augustinus, 1995b). Similarly, recent retreat of glaciers on Mexican stratovolcanoes has been accompanied by rapid rockwall degradation and talus accumulation (palacios and de Marcos, 1998). The rapidity of rockwall response in these contrasting environments, neither of which is subject to severe periglacial conditions, suggests that paraglacial rock-slope instability rather than freeze-thaw cycling is the dominant influence. On Spitsbergen, André (1997) has demonstrated that rates of rockwall retreat due to recent paraglacial stress-release average 0.72 m ka^{-1}, compared with only 0.008-0.22 m ka^{-1} for rockwalls in areas not affected by recent glacier retreat, thus demonstrating the dominance of paraglacial stress release over freeze-thaw activity as an agent of rockfall initiation. If these findings are of general applicability, they suggest that intrinsic paraglacial effects have been of much greater importance than freeze-thaw cycling in promoting rockfall and talus accumulation in formerly-glaciated areas, and thus that many supposed 'periglacial' talus accumulations reflect a strong element of paraglacial inheritance.

Indirect consequences of paraglacial rock-slope adjustment

It has been shown above that paraglacial stress-release acting on glacially-steepened slopes exercises a profound influence on the subsequent development of such slopes. The consequences of paraglacial slope adjustment, however, are not limited to its direct morphological effects (slope failure, slope deformation and talus accumulation), but also have three indirect implications for long-term landscape development. The first of these concerns the evolution of large-scale features of alpine glacial erosion, particularly glacial troughs and cirques; the second relates to glacial reworking of paraglacial rock-slope debris; and the third to the formation of protalus rock glaciers. These are considered in turn below.

Paraglacial rock-slope modification and the development of cirques and glacial troughs

Alpine glacial landforms such as cirques and glacial troughs are commonly perceived as consequences of long-term glacial erosion. However, mountainous areas that contain such 'classic' glacial landforms have generally not been subject to continuous glacier cover during the Pleistocene, but have experienced episodes of glacial erosion interrupted by nonglacial (interglacial) periods when rock slopes experienced paraglacial slope adjustment. Such adjustment may have been critical in determining the evolution of landforms traditionally attributed to glacial erosion alone.

As noted above, paraglacial stress-release results in the propagation of internal jointing and, on some slopes, rock mass creep and associated near-surface tensional fracture. Even where stress release does not lead to slope failure, it may contribute to the long-term development of glacial erosional landforms. Tabor (1971, p. 1821) noted that 'the presence of shattered rock on valley walls due to large-scale creep ... may be a significant aid to glacial scour during a subsequent ice advance'. Similarly, Benn and Evans (1998, p. 262) suggested that during interglacial periods '... the retreat of valley walls and provision of debris to valley floors are critical to the erosion of glacial troughs over repeated periods of glaciation', and noted the importance of paraglacial stress release in the formation of glacial valleys with a parabolic profile. Gordon et al. (1978) suggested that major paraglacial rockslides and glacial erosion represent

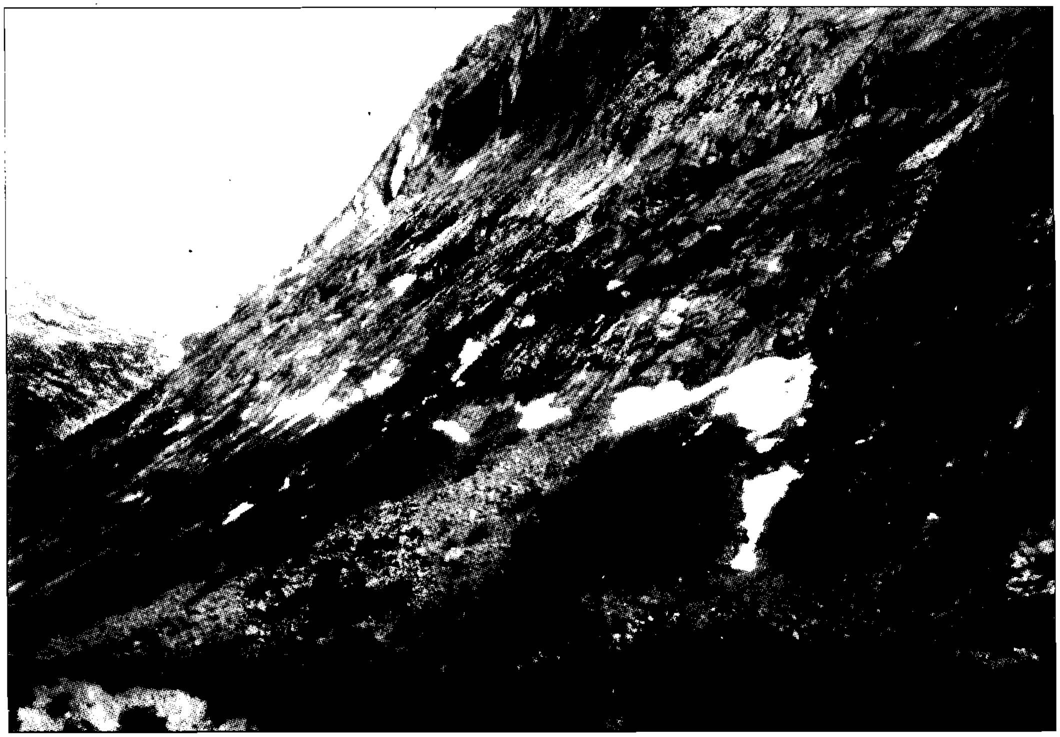

Fig. 6: Sidewall of glacial trough, Jostedalen, Norway. The high rock-mass strength of the underlying gneiss allows the survival of steep valley walls; paraglacial slope adjustment is restricted to shallow planar rockslides along slope-parallel stress-release joints.

complementary processes for cirque initiation and enlargement; many catastrophic rock-slope failures leave deep, sheltered scars that may favour later glacial occupance and ultimately cirque development, and existing cirques may be substantially enlarged by paraglacial rock-slope failure and rockfall during interglacial periods. Paraglacial rock-slope adjustment may therefore be viewed as contributing to the formation of alpine glacial landforms in two ways : directly, through modification of slope form by slope failure and rockfall during nonglacial periods, and indirectly, by creating zones of weakness that are subsequently exploited by subglacial erosion during later ice advances.

These two influences have been assessed by Augustinus (1995a), who modelled the evolution of glacial troughs in both plutonic rocks with high rock mass strength, and in sedimentary rocks with low mass strength. He found that, for plutonic rocks, lower slopes are placed under tensile stress as a result of glacial loading and incision. The resulting break-up of rock along joints on lower slopes as a result of paraglacial stress release promotes trough deepening during subsequent glaciation. The high rock mass strength of valley walls, however, allows steep gradients to be maintained, with only localised shallow slope-parallel (translational) failure during and after periods of glacier downwastage (Fig. 6). The resulting valley form is that of the classical U-shaped profile, with deepened valley floors but steep, high valley-side slopes. Similar modelling of the evolution of glacial valleys in weak sedimentary rocks suggested that paraglacial failure of the valley walls under relatively low stresses is likely to favour trough widening rather than deepening, with rapid restabilization of slopes by failure and rockfall following deglaciation. Augustinus (1995a) thus demonstrated that the long-term development of glacial troughs reflects the alternation of periods of glacial erosion and paraglacial rock-slope adjustment (Fig. 7). His research shows that explanation of the landscapes of alpine glacial erosion involves not only an understanding of glacial processes, but also an appreciation of how these processes interact with the effects of paraglacial rock-slope adjustment under nonglacial conditions.

Glacial reworking of paraglacial rock-slope debris

Another consequence of alternating periods of glacial erosion and paraglacial rock slope adjustment is that the latter provides an abundant source of readily-entrainable debris for glacier transport during subsequent ice advance. Such sources of debris include not only that produced by catastrophic rock-slope failure and paraglacial talus accumulation, but also bedrock on valley-side slopes and valley floors that has fractured along joints due to stress release. During a period of renewed glacial advance, therefore, glacier ice advances over terrain modified and weakened by the preceding episode of paraglacial rock-slope adjustment.

A considerable body of evidence, albeit indirect, suggests that debris derived

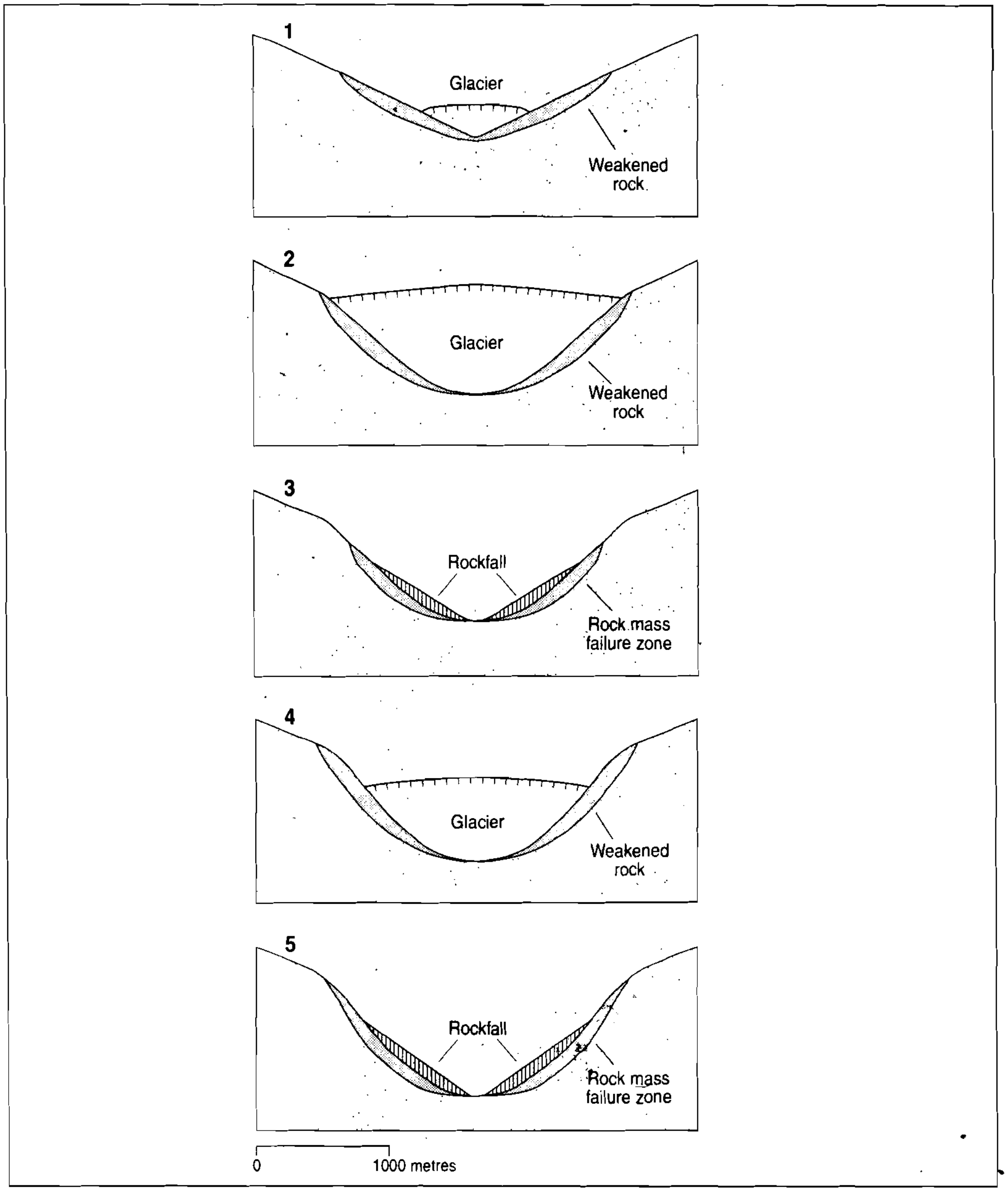

Fig. 7: Model of glacial valley cross-profile development on sedimentary bedrock with low rock mass strength during repeated episodes of glaciation. The evolving form of the valley is dependent not only on subglacial erosion but also on paraglacial rock slope adjustment during non glacial intervals. Adapted from Augustinus (1955a)

from paraglacial rock-slope failures, talus accumulations and stress-fractured slopes may significantly enhance the volume of glacially-transported sediment, at least in the initial stages of glacier advance. Bentley and Dugmore (1998) have shown that all of the debris from landslides that occurred prior to the last glacial maximum in northern Iceland has been removed by glacier ice, thereby demonstrating that paraglacial rock-slope debris is unlikely to survive renewed glacial expansion. Several authors have also observed that the outermost lateral moraines deposited by valley glaciers tend to be markedly larger on valley sides overlooked by steep rockwalls. This may to some extent result from rockfall directly on to the former glacier surface, but Matthews and Petch (1982) and Benn (1989) found that such large lateral moraines often contain a substantial component of subglacially-modified clasts. This suggests that the exceptional size of the moraines downvalley from steep rockwalls partly reflects subglacial entrainment and redeposition of rockfall debris that had accumulated in the interval between the previous glaciation and renewed glacier expansion, and thus that the moraines owe their large size, at least in part, to glacial reworking of paraglacial rock-slope deposits.

On a larger scale, valley glaciers that formed in Scotland during the Loch Lomond Stade of c. 12.9-11.5 cal ka BP deposited vast quantities of sediment in the form of hummocky recessional moraines (e.g. Benn, 1992; Hambrey et al., 1997). There is often a marked contrast between the volume of thick hummocky glacigenic drift characteristic of many areas formerly occupied by Loch Lomond Stadial glaciers and ice-abraded bedrock or thin till sheets immediately outside the limits of these glaciers. One explanation for this contrast is that the Loch Lomond Stadial glaciers advanced across abundant deposits of paraglacial rock-slope debris that accumulated in the interval between ice-sheet deglaciation (c. 17.5-15.0 cal ka BP) and the readvance of glaciers after c. 12.9 cal ka BP, and that such debris now forms a major component of the resultant hummocky recessional moraines.

A further possible piece of evidence suggesting glacial reworking of paraglacial rock-slope debris is an up-valley diminution in the size of readvance or recessional moraines in mountain areas. Recessional moraines deposited by Loch Lomond Stadial glaciers in many mountainous parts of the Scottish Highlands, for example, tend to diminish in size or disappear altogether towards former glacier source areas (Benn 1992; Bennett and Boulton, 1993). Similarly, the outermost end and lateral moraines deposited by many valley glaciers as they reached their Little Ice Age (AD 1600-1900) limits in the Alps, Scandinavia, North America and elsewhere are often much larger than readvance or recessional moraines deposited inside these limits (Grove, 1988). Though this tendency is not ubiquitous and may in part reflect glacier dynamics, it is tempting to relate the up-valley diminution in the size of readvance and recessional moraines to progressive reduction of readily-entrained paraglacial sediment sources; in other words, most paraglacial rock-slope debris is evacuated during glacier advance and redeposited in the outermost moraines, with progressively less paraglacial debris available for glacial transport and redeposition during later, less extensive readvances. When glacial recycling of paraglacial rock-slope debris is complete, glaciers transport only sediment supplied by 'normal' glacial entrainment processes such as subglacial erosion and direct sediment delivery from valley-side slopes. Thus the initial stages of valley glaciation may be characterised by unusually large rates of sediment transfer as glaciers evacuate readily-entrainable paraglacial rock-slope debris and excavate bedrock that has been fractured by paraglacial stress-release (Fig. 8).

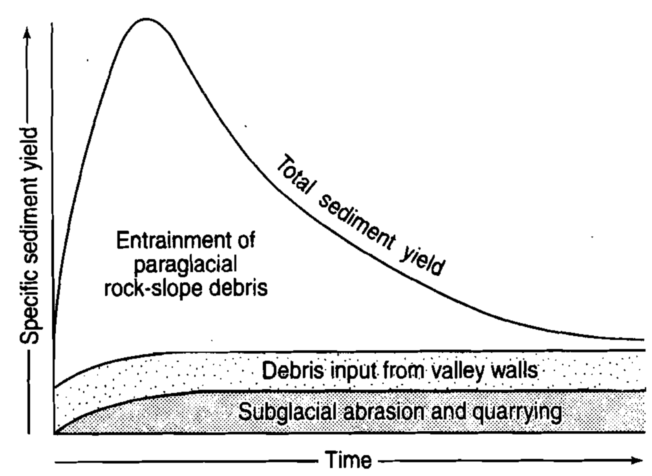

Fig. 8: Rates of glacial sediment transport during the advance of a valley glacier (schematic). In the initial stages of glacier advance, sediment transport rates are high because of the abundance of readily-entrainable paraglacial rock-slope debris. As such debris is progressively exhausted, sediment transport rates fall to 'normal' levels dictated by subglacial erosion of sound bedrock and sediment delivery to the ice surface from valley-side slopes.

Paraglacial rock-slope instability and the formation of protalus rock glaciers

Accelerated paraglacial rockfall activity in the centuries or millennia immediately following deglaciation may also have implications for the origins and age of many protalus rock glaciers. These landforms are widespread in glaciated mountain environments presently or formerly underlain by permafrost, and are thought to develop through the slow deformation of buried ice and/or ice-rich sediment within talus, forming lobate or bench-like toe slopes that extend outwards from the parent talus accumulation (e.g. Haeberli, 1985; Barsch, 1988, 1992; Fig. 9). The distribution of active protalus rock glaciers is dictated by two factors, namely climate and debris supply (Kirkbride and Brazier, 1995). The formation of

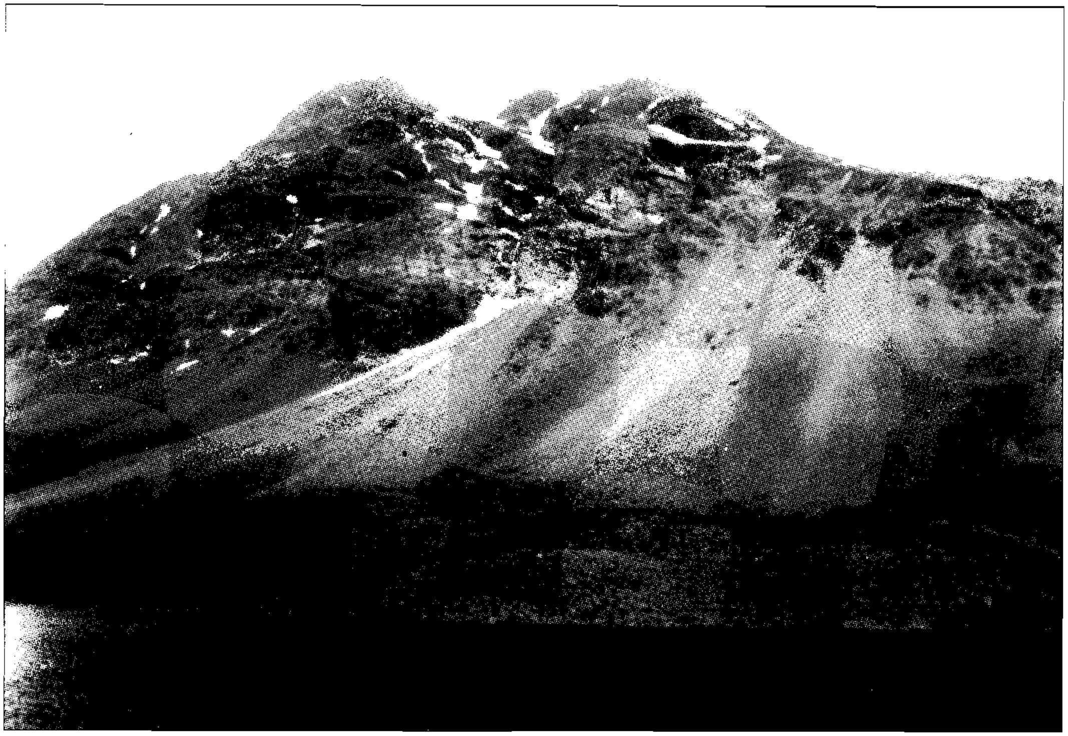

Fig. 9: Inactive protalus rock glacier, Lyngen, arctic Norway. Such rock glaciers probably developed soon after deglaciation in response to rapid paraglacial rockfall delivery and talus accumulation in a permafrost environment.

protalus rock glaciers requires the existence of permafrost, and hence such landforms are widely classified as being of periglacial origin. However, even in locations climatically suitable for protalus rock glacier development, formation and subsequent deformation of internal ice or ice-rich sediment will occur within talus only if the applied (overburden) shear stress exeeds the yield strength of the buried ice or ice-sediment mixture. If the overburden provided by rockfall on to talus in insufficient to generate shear stresses in excess of yield strength, internal ice may form without rock glacier development (Haeberli, 1985; Kirkbride and Brazier, 1995; Sandeman and Ballantyne, 1996).

In light of the data presented above, which indicate greatly enhanced paraglacial rockfall activity following glacial debuttressing of rockwalls, it is pertinent to consider whether many protalus rock glaciers are essentially paraglacial landforms produced by rapid loading of ice-rich sediments in permafrost environments (Johnson, 1984a; Thorn and Loewenherz, 1987). Luckman (1981) has noted that in the Canadian Rocky Mountains most protalus rock glacier development predated the deposition of a tephra layer at c. 7.5 cal ka BP, and inferred that this reflected greater rates of debris provision following Late Pleistocene deglaciation. More recently, Hétu and Gray (2000) have shown that following deglaciation of the Gaspé Peninsula in Québec, protalus rock glaciers fed by enhanced paraglacial rockfall extended on to emergent marine terraces. Perhaps the most telling argument for regarding at least a subset of protalus rock glaciers as 'paraglacial periglacial' landforms is that many such features are apparently dormant, even in present-day permafrost environments, suggesting that they developed during a paraglacial period of enhanced rockfall activity, and that current rates of debris delivery are no longer adequate to sustain movement. In some cases, protalus rock glaciers appear to have developed as a result of large-scale paraglacial slope failure in permafrost environments (e.g. Vick, 1987; Barsch, 1987; Johnson, 1984b; Sandeman and Ballantyne, 1996), though this mode of formation appears atypical.

Conclusions

Many glaciated mountain environments exhibit widespread evidence of rock-slope instability in the form of catastrophic landslides and rock avalanches, large-scale rock-mass deformation and accumulation of rockfall talus deposits. A growing body of evidence suggests that such rock-slope instability represents a paraglacial response to slope steepening and especially loading by glacier ice. Stress release during and after deglaciation promotes the development of joint networks within rockwalls, and the interaction of stress release with rockwalls underlain by different lithologies and variable structural configurations determines the nature of paraglacial response: catastrophic failure, internal deformation (sometimes leading to catastrophic failure) or progressive adjustment by numerous rockfall events. All three effects probably diminish with time elapsed since deglaciation as the residual strain energy within rock masses is dissipated and slopes regain stability, though the duration of rock-slope relaxation is prolonged (10^3-10^4 years). In permafrost environments, paraglacial rock-slope failure and rockfall may have been critical for the development of some protalus rock glaciers. Paraglacial rock-slope adjustment may also play a significant role in providing debris for subsequent glacial transport, particularly during the early stages of glacial advance, and is an important component in the long-term evolution of major alpine erosional landforms such as cirques and glacial troughs.

Paraglacial rock-slope adjustment is, however, by no means the only factor affecting the stability and evolution of rock slopes in glaciated mountain environments. In tectonically active mountain belts, for example, uplift, tectonic stress and seismic activity play an important role in conditioning slope stability, and in some periglacial environments freeze-thawcycling promotes high rates of rockfall activity. Paraglacial rock-slope adjustment has nevetheless dominated the trajectory of postglacial rock-slope evolution in many glaciated mountain areas, and played a major (if hitherto largely unappreciated) role in the long-term evolution of alpine landscapes.

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GLOBAL CLIMATIC CHANGE AND ITS AFTERMATH

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Abstract

Concern over the increasingly warmer global climate in recent decades has been discussed in the light of climatological records and other evidences made available from a wide range of sources. Unprecedennted rate of global warming, particularly in the northern hemisphere since the 19th Century, identified from the ice-core data, has been referred to and it has been projected that in this century the globe will be warmer of the order of 1.5°C to 4°C due to increase in Green House gases like CO_2, CH_4, N_2O, CFC-12, HCFC-22 and CF_4. Mainly variation in the solar input, Milankovitch effect, volcanic pollution, Green House effect and *El Nino-La Nina* phenomena have been attributed to this global climatic change. Measurements of surface temperature at hundreds of locations for more than one hundred years point to the fact that the earth's temperature has increased by 0. 6°C and over the last 20 years, this temperature increase has been particularly predominant. Data suggests that CO_2 alone accounts for three fourths of the predicted increase in the Green House gases causing global warming. Carbon dioxide concentration in the atmosphere has become twenty two percent higher than at the beginning of the 20th Century and is now increasing by four percent every ten years. The world wide consumption of fossil fuel releases carbon dioxide at the rate of 5.5Gt/yr. Socio-economic, chemical-physical-biological and ocean-atmsphere interaction models have been suggested to understand and predict the global climatic change. The major impacts of global warming predicted by the scientists have also been compared with the actual happennings. It is also apprehended from the trend that this climatic change would severely affect the world's poor countries, including India, causing loss of land productivity.

Introduction

The general circulation of the atmosphere and the oceans, the winds and currents that move heat and moisture around the planet earth shape the character of the climate system. The climate system consists mainly of the following components:

- The atmosphere
- The ocean
- The continent
- The ice masses
- The biological masses

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The World Meteorological Organisation (WMO) has a leading role in stressing the importance of Global Climatic Change (GCC) through its World Climate Programme (WCP). The Tropical Oceans and Global Atmosphere (TOGA) programme as well as the programme on Climate Variability (CLIVAR) are making important contributions in the field of GCC.

The climatic variability is mainly caused by the change in the amount of energy emitted by the Sun. The geological history of the earth indicates that the trend of the solar output has played a major role in shaping the earth's climate. In fact, energy from the Sun drives the earth's weather and climate and heats the surface of the earth. In turn, the earth radiates energy back into the space. Some of the outgoing energy is trapped by atmospheric Green House Gases (GHGs) retaining heat somewhat like glass panels of a Green House.

Svante Arhenieus predicted GCC in 1986. He realised the amount of CO_2 to have released during industrial revolution. In 1986 his proposition of the role of CO_2 in heating the earth prompted him to predict that if atmospheric CO_2 doubled, the earth would be several degrees warmer. About 100 years after the prediction of Arrhenius's it has been confirmed that CO_2 concentrations in the atmosphere will double by the middle of this century in comparison to the level of concentration prevailing in 1896.

Global climate change, its cause and evidences

GCC occurs due to (a) variation in the Sun's output, (b) Milankovitch effect, (c) Volcanic pollution, (c) Green House Effect (GHE) and (e) *El Nino* and *La Nina* phenomenon. The observational studies of GCC are too short to give clues to an appropriate answer because the time scales of climate change are considerably long. Past climate variations have put forward circumstantial evidences about the phenomena of GCC. Research is being conducted under International Geosphere and Biosphere Programme (IGBP). Particularly the research programme on Global Change and Terrestrial Ecosystem (GCTE) is worth mentioning so far as GCC is concerned. In recent decades the northern hemisphere appears to be warmest since about 1000 AD. Also since the 19th Century warming has been unprecedented over the last 1000 years. The 20th Century has been warm in various parts of the globe as is evident from the ice core data. Considering the trend of warming, the projected change over the next century would be to the scale of 1.5° to 4°C.

The severity of climate change through temperature rise was cited by Planet Watch (1998) as "Hot Spells in 1998" affecting several parts of the world as stated below:

1. ***India:*** Warming up to 51°C causing death of 3000 people is regarded as the worst "Hot Spell" in the last 50 years.
2. ***Bahrain:*** Warming up to 50°C causing heat exhaustion to 56 workers.
3. ***Texas:*** Warming up to 47°C. More than 120 died and one third of cotton crop

destroyed in a single month.

4. ***California:*** Warming up to 45°C. Early August heat waves brought blackouts to the San Francisco Bay area.
5. ***Cyprus:*** Warming up to 43° C. The worsts hot spells in last 40 years killed people and at least 3200 suffered heat stroke.
6. ***Germany:*** Warming up to 41°C. Record Hot Spell produced severe smog.
7. **France:** Warming up to 38°C. 20% of grape vines in some areas of Bordeaux withered away due to severe heat.
8. ***Switzerland:*** Warming up to 35°C. Schools were closed. Several instances of heat stroke were recorded.

The change of global weather takes place with increase of the earth's surface temperature. As a result, frequent occurrences of storms, hurricanes and melting of polar ice takes place, accentuating thermal expansion of sea-water. The global average surface temperature increased by 0.6°C over the 20th century; 1990s was the warmest decade and 1998 the warmest year. GCC is now a stark reality threatening everyone. The total climate forcing can be explained by inducing both natural forcing and human induced changes and this has been shown in Fig.1 (source – Report of IPCC working group 1, 2001).

Today, most of the scientists agree that the rate of heating of the earth is accelerating and the consequent temperature change would be increasingly disruptive. Thus, the question is not whether the climate will change in response to human activities but rather how much, at what rate and where. It is also being agreed by experts that GCC will adversely affect the socio-economic sector including water resources, agriculture, forestry and human settlements, ecological systems and health with developing countries being most vulnerable.

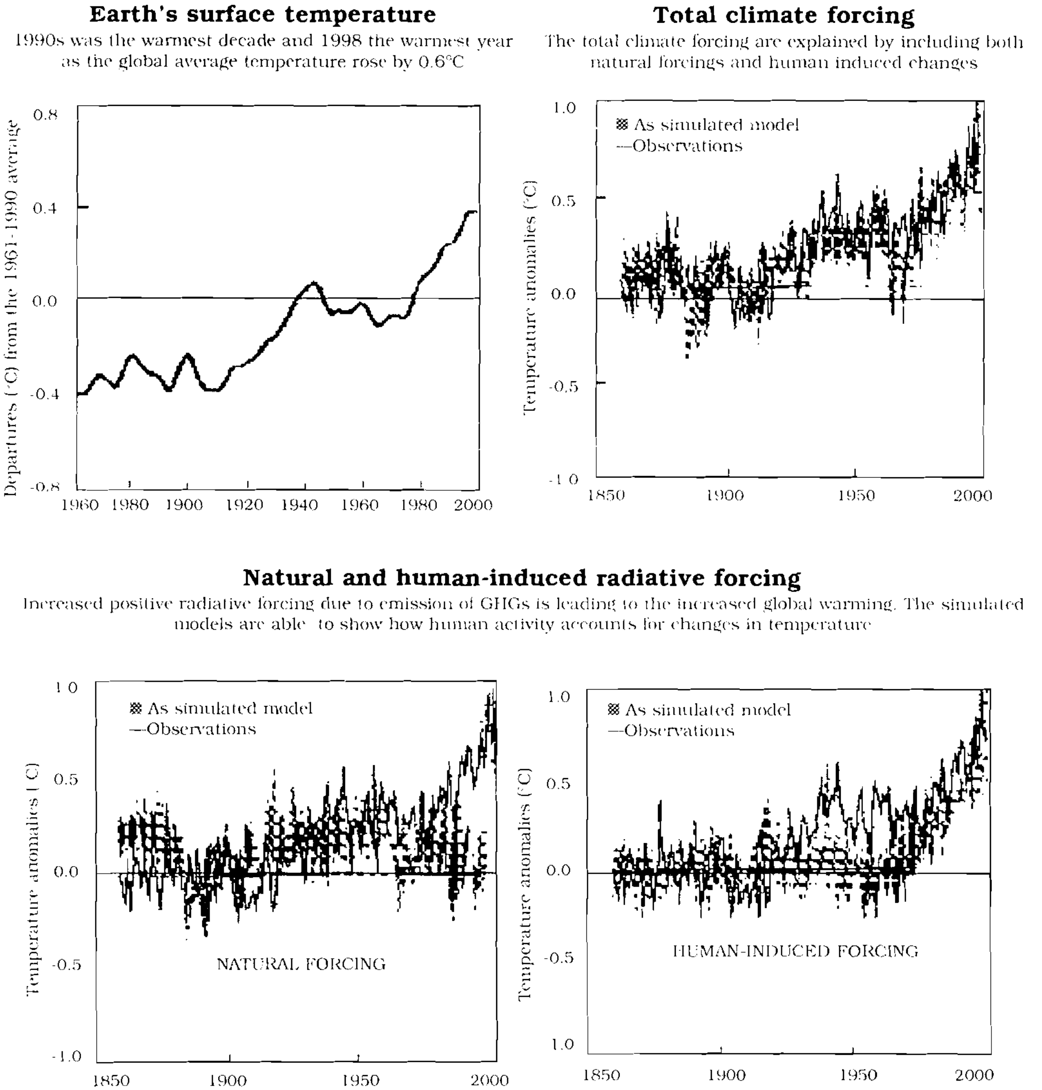
Global climate change and the models for its prediction

The following types of models are needed to understand and predict GCC:

(a) *Socio-economic models* that would predict future consumption of fossil fuels and utilisation of alternative fuels. Socio-economic models depend upon (i) industrial production methods, (ii) energy efficiency, (iii) new materials, (iv) public policy, (v) concern for the environment and economic development, (vi) standard of living and (vii) reliance on energy and chemical-based products of the Earth system.

(b) *Chemical-Physical-Biological models* that would inform us as to what happens to gases released into the atmosphere. In other words, it would tell us how much carbon dioxide has been taken up by the oceans and biosphere and how industrial and agricultural uses of chemicals and natural processes on Earth's surface affects the release of CH_4, NO_2 and other Green House Gases (GHGs) into the atmosphere.

(c) *Coupled Ocean-Atmosphere interaction models* which would inform us



Source Anon 2001

Figure 1: Pattern of the rate of global warming in recent decades

how the climate system (temperature, humidity, cloud and rainfall responds) to changes in the chemical composition of the atmosphere.

A Complete Climate Model (CCM) would necessarily contain all the physical processes that determine the various components of the climate system.

Green House Effect (GHE)

The popular belief so far as GHE is concerned is that atmosphere is transparent to sunlight, which heats the earth's surface. The surface offsets that heating by radiation in the infrared. The Infrared Radiation increases with increase in surface temperature and the temperature adjusts until balance is achieved. The atmosphere is also not transparent to the infrared. So the earth must heat up somewhat more to deliver the same flux of infrared to space. This is what is called the GHE. The fact that the earth's average temperature is 15°C rather than −18° C is attributable to GHE. Water vapour and clouds are the main absorbers of infrared. All GHGs may disappear, but we would still be left with over 98% of the current GHE. CO_2, CH_4 and NO_2 were always present in the atmosphere. Water vapour along with these gases cause GHE. They trap some of the Sun's energy and keep the earth warm enough to sustain life.

Global Warming (GW) and Green House Gases (GHG)

As discussed earlier, Arrhenius first described GW but in 1988 James Hansen of NASA and others proposed a theory of GW depending on the fact that humans are causing a dangerous change in the Earth's climate. Their theory took into consideration the data on temperature, GHG levels and climate phenomenon. Their GW theory rests on the various aspects of climate models, scientific analyses of the past and present climate data and the trends as well as the assertions that increases in GHG concentration in the atmosphere are driving up global temperatures. Measurements of surface temperature at hundreds of locations for more than 100 years point to the fact that the earth's temperature has increased by 0.6°C in the past century. Global average temperature rise during 1950-1997 is shown in Fig. 2 following Agarwal *et al.*, (1999). GW was particularly prominent during the last 20 years and has been accompanied by retreating glaciers, thinning Antarctic ice, rising sea levels, lengthening of growing seasons for some countries and earlier arrival of migratory birds. All these data support the feature of GW. There is also a debate over the phenomenon of GW because of disparities between surface temperature of the earth and upper air temperature. Inspite of this debate the warming trend in the global mean surface temperature observations during the past 20 years is absolutely real and is substantially greater than the average rate of global warming of the 20^{th} Century. More precisely, GW is an example to substantiate the fact that GCC is taking place. In other words, GW is the mother of all environmental scares. GW is also a tempting issue for many groups to exploit.

During the last five years, many parts of the world have suffered heat waves, floods, droughts, fires and extreme weather events leading to significant loss of life and property. The individual events cannot be directly linked to human induced climate change. The frequency and magnitude of these types of events are predicted to increase during GW. Moreover, GW makes the weather pattern more erratic and storms more severe. The GW is accelerating the hydrological cycle. The June 1992 Earth Summit held at Rio de Janeiro, Brazil focused on international agreements to deal with the threat of GW but nothing concrete has been achieved from that meet.

Some GHGs occur naturally in the atmosphere while others arise out of human activities. Naturally occurring GHGs are water vapour, carbon dioxide, methane, nitrous oxide and ozone. CO_2 is released to the atmosphere when solid

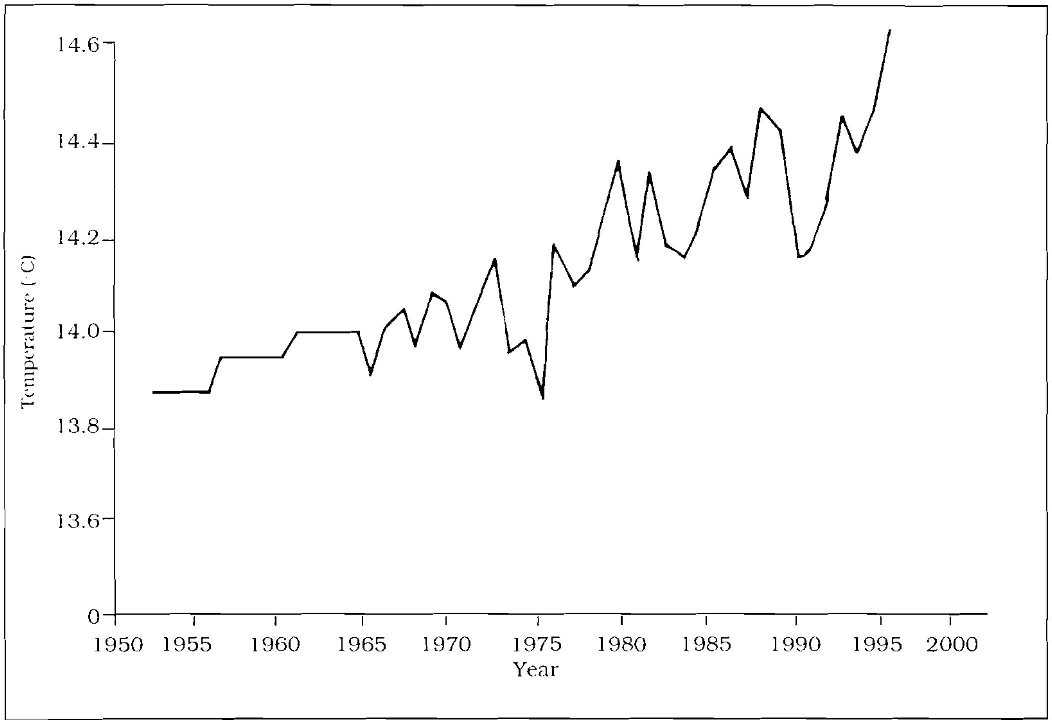


Figure 2: Global average temperature during 1950-1997

waste, fossil fuels (oil, coal and natural gas), wood and wood products are burned. Methane is emitted during the production and transportation of coal, natural gas and oil. Methane emissions also result from the decomposition of organic wastes in municipal and waste landfill. Nitrous oxide is emitted during agricultural and industrial activities as well as during combustion of solid wastes and fossil fuels. GHGs that are not naturally occurring include byproducts from foam production, refrigeration and air-conditioning and are called Chlorofluorocarbons (CFCs), Perfluorocarbons (PFCs) as well as hydrofluorocarbons (HCFs) and Perfluorocarbons (PFCs) generated by industrial processes. A summary of the key GHGs due to human activities are given in Table 1 below.

Table 1: A summary of key Green House gases affected by human activities

	CO_2	CH_4	N_2O	CFC-12	HCFC-22	CF_4
Pre-Industrial Concentration	280 ppmv	700 ppbv	275 ppbv	Zero	Zero	Zero
Concentration in 1992	355 ppmv	1714 ppbv	311 ppbv	503 pptv	105 pptv	70 pptv
Recent Rate of Concentration Change per year during 1980s).	1.5 ppmv/yr. 0.4 % per yr.	13 ppbv/yr. 0.8% per/yr.	0.75 ppbv/yr. 0.25% per yr.	18-20 pptv/yr. 4% per yr.	7-8 pptv/yr 7% per/yr.	1.1-1.3 pptv/yr. 2% per/yr.
Atmospheric Lifetime (in years)	50-200	12-17	120	102	13.3	50,000

Source: Anon 1994

Sources of main GHGs (in %) are given in Table 2(a) and Carbon dioxide emission budgets for different atmospheric concentrations are shown in Table 2(b). During the Kyoto negotiation, SF6 was also identified as one of the GHGs. As a result of increase in the amount of these gases due to human induced activities, natural GHEs are intensified and this further warms up the atmosphere. Each GHG differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbant. Methane traps over 21 times more heat than CO_2, and nitrous oxide 270 times more than CO_2. The intensity of warming caused by each of these gases are as follows :

Name of Gas	Intensity of warming (%)
CO_2	76
CH_2	13
NO	6
Fluorocarbons	5

The estimates of GHG emissions are often presented in the units of millions of metric tons of carbon equivalent (MMTCE), which weighs each gas by GWP values or Global Warming Potential.

Table 2(a): Sources of Global emissions of Green Houses gases (GHGS) percentages

Gases	Green House Effect	Source	%
Carbon Dioxide	45-55	Coal Oil Gas Deforestation Others	29 20 11 29 10
Methane	10-20	Biomass Burning Gas and Coal Fields Rice, Paddies, Natural Wetlands Enteric Fermentation (Rumination) Tundra Others	11-15 14-25 16-44 16-26 15-20 4
Chlorofluro-Carbons	10-16	Aerosols Referiegerants Cleaning agents Blowing agents Others	19 30 19 28 4
Nitrous Oxide	7-11	Fossil Fuels Biomass burning Fertilizers Others	12-34 8-20 5-15 30-75
Stratospheric Ozone	5-15	N.A.	

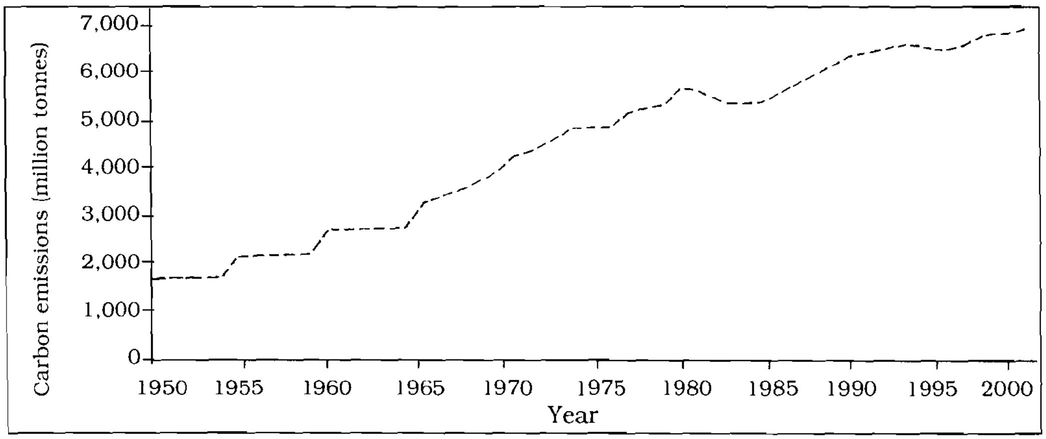
Source: Anon (1990): State of Environment in Asia and Asia Pacific

Table 2 (b): Carbon dioxide emissions budget for different atmospheric concentrations

Atmospheric Concentration of Carbon dioxide (PPMV)	Emission Budget Over the Period 1991-2100 (Billion tonnes of carbon)	Average Annual Budget Over the period 1991-2100 (Billion tonnes of carbon)
350	300-430	2.73-3.91
450	630-650	5.73-3.91
550	870-890	7.91-8.09
650	1030-1190	10.27-10.82
750	1200-1300	10.91-11.82

Source : Anon. 1995

The above data suggests that CO_2 alone accounts for three fourth of the predicted increase in the GHE causing GW. The global carbon dioxide concentration in the atmosphere is now 22% higher than at the beginning of the 20th Century and is increasing by 4% every 10 years. The worldwide consumption of fossil fuels releases carbon dioxide at the rate of 5.5 Gt/year. Brown et. al., (1998) displayed world carbon emission from fossil fuel burning during 1950-1997 (Fig.3). Human perturbations in Global the Carbon budget indicating sources and sinks of CO_2 are shown in Table 3. About half of the 20 billlion tons of carbon dioxide released by combustion of fossil fuels is retained for a long time in the atmosphere. If the present trend of fossil fuel use is continued, it will lead to substantial GCC before the end of 21st Century if not within the coming three decades of the 21st Century. The increase in carbon dioxide concentration in the atmosphere due to human activities is evident from its level of concentration in 1700 (280ppmv) and what is expected at the end of 21st Century (550 ppmv). As a result, the expected rise in mean surface temperature of the earth will be 1.5°C to 4.5°C within 50 to 100 years. NO and Chlorofluorocarbons (CFCs) are in some ways more similar to CO_2, as, once released they remain in the atmosphere for a century or more. The production of NO is indirectly dependent on human activities and mainly from a natural source i.e. by bacterial removal of NO from soils. Thus due to increase of population, the increase in amount of NO in atmosphere will be very small. The scenario of concentration of CFCs in atmosphere is not so grim. The most abundant of these man-made compounds are Freon-11 and Freon-12. These two gases under international agreements are going to be phased out because of their damaging effects on stratospheric ozone. The Freon-11 concentration was highest in 1994 but it is on the decline now. The level of concentration of Freon-12 is also to be phased out within coming years. Other gases such as CO/(Carbon monoxide), NO (Nitrogen monoxide) and VOC (Volatile organic compounds) also affect the GHG's concentration in atmosphere through chemical reactions. Ozone acts as a GHG in the troposphere.



Source: *Brown et.al., 1998*

Figure 3: World carbon emissions from fossil fuel burning (1950-1997)

Table 3: Human perturbations to the global carbon budget

CO_2 Sources and Sinks	Flux Gt C/Year
CO_2 Sources:	
Fossil fuel combustion and cement production	5.5 + 0.5
Tropical deforestation	1.6 + 1.0
Total anthropogenic emissions	7.1 + 1.1
CO_2 Sinks :	
Storage in the atmosphere	3.3 + 0.2
Uptake by the ocean	2.0 + 0.8
Northern hemisphere forest regrowth	0.5 + 0.5
Other Terrestrial Sinks :	
Carbon dioxide fertilisation, nitrogen fertilisation, Climate effects	1.3 + 1.5

The gases that are released into the atmosphere are tracked in the emission inventories. An emission inventory is an accounting of the amount of air pollutants discharged into the atmosphere. It is generally characterized by the following factors :

(i) The physical or chemical identity of the pollutants included
(ii) The geographic area covered
(iii) The institutional entities covered
(iv) The time period over which the emissions are estimated
(v) The types of activities that cause emissions

Considering the present scenario of GW, the stabilisation of the amount of carbon dioxide in the atmosphere is the prime requisite. This would necessitate a transition from carbon emitting technologies to alternative non-carbon emitting technologies which would ultimately entail the cost. In fact the cost of carbon emissions mitigation will depend mainly on the following factors:

(i) The permitted ceilings of global CO_2 concentrations
(ii) The extent of participation amongst world nations
(iii) The degree of flexibility as to where and when emissions mitigation can be undertaken
(iv) The non-carbon emitting technology alternatives that become available
(v) The availability of carbon sinks and carbon-removing technology

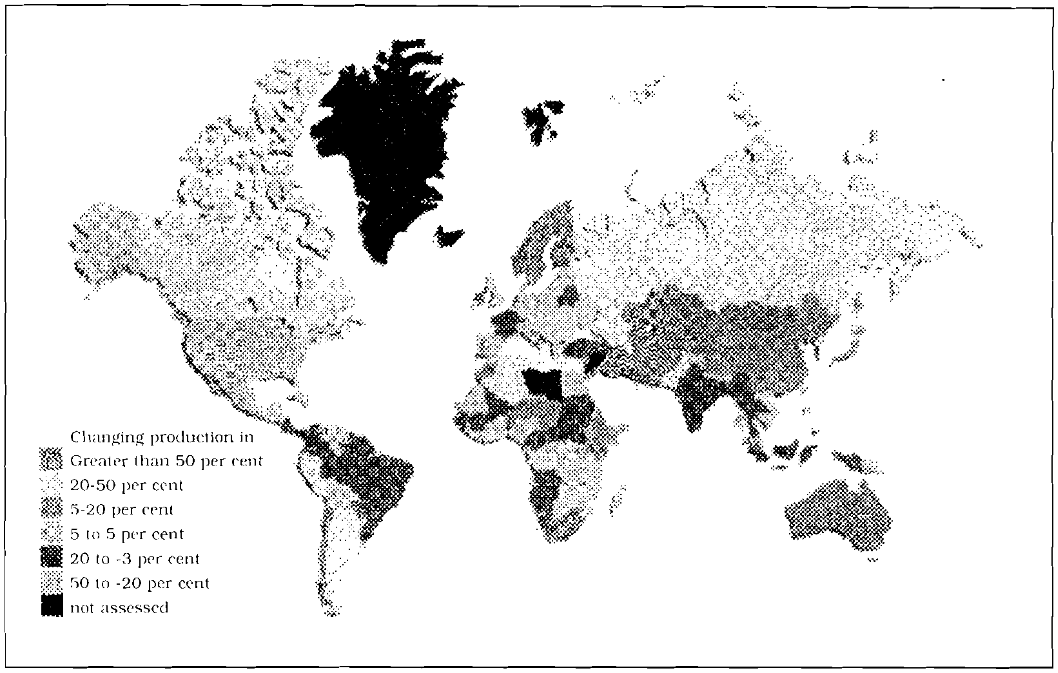
Two pre-conditions must be satisfied in order to stabilise GHGs concentrations. The first is a credible commitment to a future (in terms of energy usage) that is different from the past. The second is a strategy for controlling the costs of making so profound a change.

Global warming and its impacts

GCC could hit food production in some of the world's poor countries and this will create a gulf of difference between the industrialised countries and the rest of the world. It is forecasted that India, besides some African countries, would heavily pay with loss of land productivity. GCC would have severe impact on cereal production potential as shown in Fig.4 (*Fisher et. al, 2001*). It has been pointed out that GCC has impact on biodiversity. Barbaud and Wemerskirch (2001) reported the killing of the emperor penguin in Antartica by climate change and cautioned about complete extinction of this species due to climate change. They also demonstrated that breeding rates fall sharply with reduction of temperature (Fig. 5). Extreme events of GCC causing GW adversely affect water resources, which is directly related with monsoon rainfall. So far as Indian the subcontinent is concerned, trends from 1951-1998 show variability of monsoon rainfall (Fig.6. - *Source Lal 2001*). As revealed from various climate change models, crop production in India shows striking variation (Table. 4)

The impacts of GW can be emphasised as health risks, environmental destructions and catastrophic weather. What scientists predicted about these impacts and what are happening now, are stated below:

What scientists predicted	**What is happening**
Health Risks The rates of infectious diseases will rise, with the spread of mosquitoes and other disease-carrying organisms that thrive in warm and wet climates. More frequent and more severe heat waves will pose a threat to public health, with children and the elderly being especially vulnerable.	*Health Risks* In 1990s outbreak of malaria have occurred in different countries (including non-tropical countries). Two major heat waves in Chicago in 1995 and Dallas in 1998 (USA) -killed more than 600 people.
Environmental destruction Rising global temperatures and melting of glaciers will directly affect ocean and coastal habitats. Ecosystem will be destroyed and species will die off, as sea levels rise, seasons shift and glaciers and polar ices caps melt.	*Environmental destruction* 40% of the frog and toad species in the Costa Rican cloud forest, including the beautiful Golden Toad have gone extinct in recent years due to unusual dryness linked to GW. Polar bears are threatened with starvation as melting sea ice deprive them from their food.
Catastrophic Weather Warmer temperatures will speeds evaporation; leading to drought in some places and heavy downpours and flooding in others. Extreme weather events as well as El-Nino events may become more intense and more frequent.	*Catastrophic Weather* The El-Nino event of 1997-1998 was strongest of the century. In 1999 the USA experienced one of the most extreme droughts which were recorded in various other regions of the world (including cold regions). In 1999 the Pacific northwest experienced its second wettest year on record. Nevada, California and Iowa experienced the worst floods. Recent years have seen hurricanes—the Hurricane Mitch the deadliest in 200 years and the Hurricane Andrew, the most destructive ever.

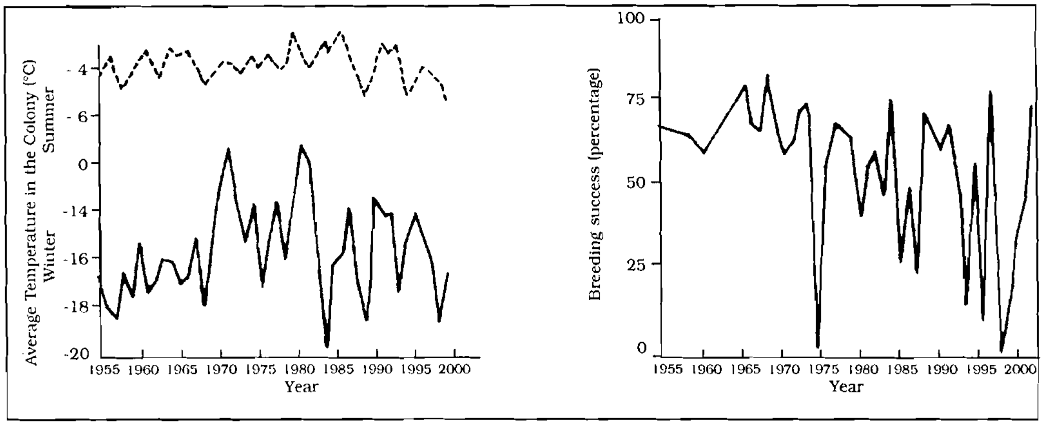


After Fisher et. al., 2001

Figure 4: Country-wise effect of climate change on rain-fed cereal production by 2080

Table 4: Decline in crop production in India, according to different climate change models (in percent)

Crop	Goddard Institute of Space Studies	United Kingdom Meteorological Office	Goefluid Dynamics Laboratory
Rice (paddy)	23.6	17.4	2.3
Rice (Upland)	19.2	20.9	7.3
Millet	0.3	9.1	14.5
Sorghum	12.2	12.00	3.3
Maize	14.5	13.4	4.5
Groundnut	16.6	15.2	3.6
Cowpea	13.2	13.9	4.2



Source: Barbaud et. al., 2001

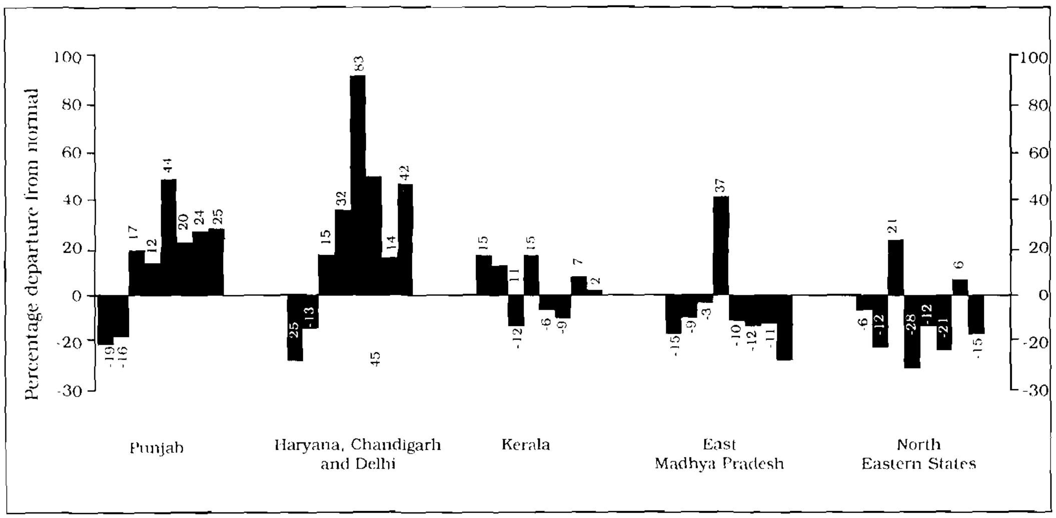
Figure 5: Climate woes - Pattern of fall of breeding rates with reduction in temperature

The effects of GW as highlighted in the second report of IPCC can be summarised as:

1. Atmospheric concentration of CO_2 and CH_4 have increased since pre-industrial time by 30% and 15% respectively as a result of fossil fuel use, land use changes and agriculture.
2. CO_2 and NO remains in the atmosphere for centuries and the reversal of their effects on the climate takes long time.
3. The level of CO_2 concentration in atmosphere will increase to 550ppmv if the emission is maintained at 1994 level.
4. Since the 19th Century the Global surface temperature increased between 0.3°C and 0.6°C. IPCC estimated that the global mean temperature will increase 2°C above pre-industrial level by 2030 and about 4°C above pre-industrial level by 2090 at the present level of emission of GHGs.
5. Change of weather pattern would take place due to which there will be droughts and floods in many areas.
6. Entire forests may disappear. Northern forests are likely to suffer irregular and large-scale losses of trees.
7. Enormous reduction of biodiversity will be experienced.
8. Loss of equilibrium in some ecological systems will be evident.
9. Problems of drinking water, lack of sanitation and drought would affect billions of people.

10. Fluctuation of crop yields will be noticed. There will be negative effects on crop yield in semi-arid and arid regions of the developing countries.
11. Over the past 100 years Sea Level Rise (SLR) took place to the tune of 10-25 cms. SLR is predicted between 9 cm and 29 cm by 2030 and between 28 cm and 96 cm by 2090. There is a possibility of the change in weather condition along coastlines. The low lying island countries will be more vulnerable.
12. Significant loss of life will take place due to heat stress and increase of diseases.
13. There will be substantial change in land use pattern.
14. Destruction of Coral Reefs particularly in tropical countries will take place.

The above predictions would have significant effects on the developing countries because of their lower adaptability to such changes due GW effects.



Source: Lal. 2001

Figure 6: Erratic rains – variability of monsoon rainfall in the Indian subcontinent (trend from 1991-98)

Global climate change and International negotiations

GCC is now being agreed upon by all policy makers scientists and consumers as a legitimate concern. The Nordwijk Declaration adopted as early as 1989, at Netherlands at a Ministerial Conference on Atmospheric Pollution and Climate Change is worth mentioning in this context.

The declaration made in the conference has :

(i) Voiced the need for initiating action to control GHGs emission.

(ii) Urged the developing countries to meet future targets of emissions.

(iii) Requested the industrial countries to transfer technology to developing countries for limiting GCC.

(iv) Stressed the need for a framework convention on climate change committing parties to address the need of developing countries in gaining access to technology, and

(v) Recommended that IPCC may initiate measures to relate the effects of other GHGs to those of CO_2 and consider the feasibility of growth of 12 million hectares of forests every year with the beginning of 21st century.

The Second World Climate Conference held in Geneva in 1990 made the following observations:

(i) The industrialized countries are responsible for 75% of GHGs emissions.

(ii) In the early process of development, the developing countries must adopt modern technologies for combating GHGs emissions.

(iii) The developing nations should be urged to commit themselves to appropriate actions.

(iv) Extra money should be provided to developing nations for restricting GHGs emissions.

The Second session of Intergovernmental Negotiation Committee (INC-2) in 1991 had witnessed the following :

(i) India submitted a full draft for negotiation and rallied for developing countries.

(ii) Industrialised countries rejected Indian contention in the draft paper.

(iii) The preparation of common text by G-77 was opposed by small island States, Brazil, India , China and Latin American countries.

(iv) India and China also opposed the designation of Global Environment Facility (GEF).

The fourth session of INC in 1991 had the following mentionable features:

(i) Though the industrialised nations reject the notion, G77 reiterated that the main responsibility of mitigating the adverse impacts of Climate Change lay with the North.

(ii) Declaration by G77 that measures be taken to guard against Climate Change should be integrated in the national development plan.

(iii) North-South differences persists over the question of technology transfer and a financial mechanism.

The salient features of Climate Change Convention in the Earth Summit in 1992 are :

(i) Tabling of a compromise text of Framework Convention on Climate Change.

(ii) Acknowledgment of provisions of Framework Convention on financial mechanisms.

(iii) Signing by 154 countries of the provisions of UN Framework Convention Climate Change (FCCC).

The highlights of First Conference of Parties (CoP-1) held in Berlin 1995 and known as Berlin Mandate are:

(i) The Alliance of Small Island States (AOSIS) urged industrialised nations for reducing their CO emissions by 20 per cent by 2000.

(ii) 5-10 % reduction of GHGs emissions by 2010 was advocated by UK Minister for Environment.

The mentionable events of the Second Conference of Parties (CoP-2) held in Geneva in 1996 are:

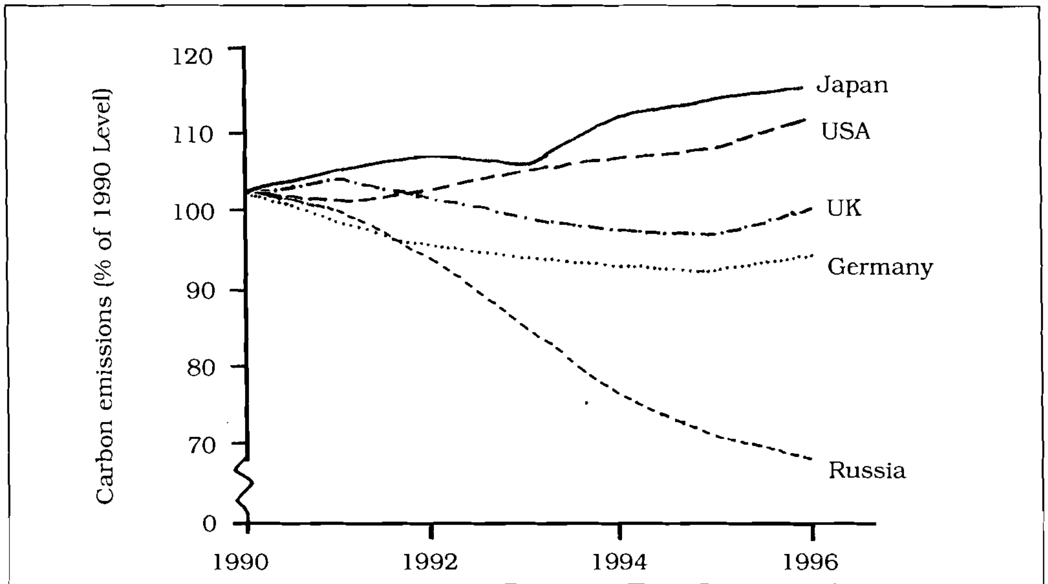
(i) US declaring a realistic and achievable target of emissions without specifying any number of years.

(ii) Assertion by EU for formulation of legal instrument for overall emission reduction below 1990 levels.

(iii) AOSIS supported EU proposal.

(iv) Acceptance of the concept of initiating action for reduction of GHGs emissions at global, regional and local levels and strengthening the action particularly by industrialised nations.

The next mentionable event with reference to GHGs emissions *vis-a-vis* GCC is the Kyoto Protocol. This Protocol adopted by160 negotiating nations in a meeting at Kyoto in 1997 point to the culmination of UN's campaign to persuade the nations of the world for significant reduction of GHGs emissions. This treaty was to commit the developed countries including the USA to reduce GHGs emissions on an average 5% below 1990 levels during a five-year period beginning from 2008. The US share would be 7 % below 1990 levels, which would mean 30 % below the currently projected emissions for US in 2010. Even after the Kyoto Protocol, the industrial countries continued to emit GHGs not in tune with the conditions laid down in the Protocol. This will be evident from the carbon emissions level from industrial countries as reported by Brown *et.al.*, (1998) (Fig.7)



Source: Brown et al 1998

Figure 7: Carbon emissions from major industrial countries during 1990-1996

Concluding Remarks

With this backdrop of various negotiations on GCC, nothing concrete has yet been achieved for formulation of a global agreement on reduction of GHGs emissions. The GHGs emissions of one US citizen is equal to 19 Indians, 30 Pakistanis, 17 Maldivians, 19 Sri Lankans, 107 Bangladeshis, 134 Bhutanese or 269 Nepalis in 1996. This clearly points to the fact that any limit on carbon emissions amounts to limiting economic growth. This has converted climate change mitigation into a tense political issue, which in turn resulted in a tug of war between developed and developing countries. In spite of the fact that the developing countries have minimum responsibility in GW and emissions of GHGs, the developed countries are insisting on their sharing the responsibility of this problem. The developed nations have been manipulating scientific data to placate the developing nations as major contributors of GHGs to the atmosphere. They are reluctant to accept the major responsibility for GW. In defence of their attitude towards GW the US based World Resources Institute (WRI) tried to demonstrate that the annual GHGs emission of developing countries equals to that of industrialised countries. They even project that the future emission level of South will overtake that of North. This projection put developing countries of Asia-Pacific region as top 10 emitters (Table 5). Centre For Science and Environment (CSE) challenged WRI's projection in 1991. WRI and CSE data are shown in Table 6.

Table 5: Comparative figures of total emissions if GHGs of WRI's top ten emitting nations as calculated by CSE in Million Tonnes of Carbon equivalent,

Country	Accumulation in the atmosphere (WRI)	Accumulation in the atmosphere (CSE)	Absorbed by natural sinks (WRI)	Absorbed by natural Sinks (CSE)
United States	1000	1532	1368	836
Soviet Union	690	730	882	842
West Germany	160	155	144	149
United Kingdom	150	132	160	178
Japan	220	140	202	281
France	120	69	121	173
Bazil	610	1017	826	418
China	380	32	793	1141
India	230	0.7	643	871
Indonesia	140	9.5	240	370

Source: Agarwal & Narain. 1991

Table 6: Percentage distribution of net emission of GHGs by industrialised and developing countries

Country	WRI Formula	CSE Calculation
United States	17.0	27.4
Soviet Union & Eastern Europe	16.0	17.6
Western Europe	14.3	11.9
Japan	3.9	2.5
Other Industrial Countries	1.4	7.5
India & China	10.3	0.6
Brazil	10.3	18.2
Other Developing Countries	26.7	14.3

Source: Agarwal & Narain. 1991

In fact it is an established fact that CO_2 emissions are closely related with higher standard of living. The best way to arrest GW is develop technology for change from fuel based energy production to alternative sources of non-fuel based energy sources. This needs an approach for equity, change of life style of rich North and technology transfer from North to South.

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GEOPOLITICS AND ECOGOVERANCE

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Abstract

The term 'geopolitics' was coined in the late nineteenth century and from the outset it invited considerable controversy. It grew with the out-break of the World War II. At the cessation of the World War II it disappeared and vanished from the academics and political scenario. However, it's disappearance was short lived. It reappeared again to play havoc with humanity in the sense that it provided a new dimension to the nature of rivalries between the nations in the post-war period with regard to their ambition for 'space' and 'power'. It could be held responsible for the out-break of the Cold War, in which the major 'participatory State' went beyond the constraints of nature/environment in producing weapons of mass-destruction. The Cold War geopolitics gave rise to 'satellite geopolitics' and 'geospheric-terrorism' with the result that the natural ecosystem and balanced structure of the planet earth became susceptible to irreparable damage. The end of Cold War however, did not bring any relief to humanity, which continues to be in distress of various natures. People-centred problems have increased manifold so as to raise question with regard to the *'raison d'etre'* of humanity and its terrestrial habitat. It was in the backdrop of this problem that an alternative is suggested in the form of a paradigm - 'ecogovernance', as an approach to conflict resolution. At the core of it, is the conviction that societal relations from personal to the intercivilisational can be addressed non-violently. Ecogovernance, in this usage, is concerned with equity and human distress as it is with stability and sustainability. It aims at creating a new world, given to peace and prosperity, and ascribes for a global policy to construct a positive form of world order.

Introduction

Geopolitics, since its emergence as a political paradigm in the early 30's of the last century, has never been fair to humanity and its terrestrial home. As a whole, it has brought distresses and sufferings to mankind and its natural habitat, from time to time, in the form of war, conflict, and destruction. Much of the human distress may be historically attributed to the application of the principles of geopolitics by powerful nations to attain political goals, and to achieve domination over man's terrestrial home. Frequent applications of the principles of geopolitics to achieve desired political goals, have raised serious doubts not only over the stability and sustainability of human habitats, but also,

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of 'the natural ecosystem. The global ecosystem has long sustained conflicts and territorial competitions between human groups, and between the nations for domination, supremacy and power. Much of the technical and scientific development in the field of war and strategy in the last century, was necessarily designed to control and use the earth-bound resources at the cost of the fragile nature of the ecosystem.

The present discussion addresses itself to the following pertinent questions : Firstly, to what extent does geopolitics bring distress to humanity and its terrestrial habitat? Secondly, what remedial measures, as an alternative to geopolitics, require to be developed to counter the evil design of it? And finally, to what extent does global change affect and/or condition geopolitics?

Geopolitics :
Disastrous to humankind and its terrestrial habitat

The origin of geopolitics can be traced back to the German natural scientist and geographer Friedrich Ratzel, the Swedish political scientist Rudolf Kjellen, and the British geographer Sir Halford John Mackinder. However, there is no evidence that the three ever met, but their idiosyncratic ideas produced a new dimension of thought within social science. The influence of the Darwinian heritage upon their ideas, particularly those concerned with 'evolution through time' and 'natural selection and struggle' cannot be ruled out. Rudolf Kjellen was the inventor of the term 'geopolitics', but the inherent philosophy and methodology of this new dimension of thought was intrinsically based on the writings of Freidrich Ratzel, particularly those concerned with the 'theory of state' as, an organic phenomenon and ideas of spatial conception *vis-à-vis* living space (lebensraum) during its formative stages (Ratzel. 1897).

The ideas of Sir Halford J. Mackinder, particularly his 'heartland' thesis provided the necessary input to further development of the new dimension of geopolitics, as Kjellen defined *"the theory of the state as a geographical organism or phenomenon space"* (Kjellen, 1916). Over the years, geopolitics (geopolitik) became a sort of synthesis of history, economics, politics and the physical sciences fused together by the application of the spatial or territorial perspectives. The state was looked upon as being an organism, a supra-individual living being which conformed to biological laws (Stoakes, 1986:148). This state organism was territorial and the requirements for its success were spatial.

The state existed in space (Raum) and its growth and development necessitated expansion of living space (Lebensraum). The science of living space (Lebensraumkunde) was the study of the significance of geography in the success of states. The possession of large space (Grossraum) was the key to the freedom and security of the powerful state. Larger spatial conception was the hallmark of a great power. Dynamic states expand and inevitably absorb the smaller and less powerful states. Those states with a truly global reach are the space-hopping states and they are to be contrasted with those lesser states which are space-bound, (Korinman, 1990:252-254; Parker, 1985:60).

During the inter world war period of the twentieth century, Munich emerged as the leading centre for geopolitical research under Professor General Karl Hausofer. The rise of German National Socialism during the period was a major event in the life of this new dimension of thoughts. It was inevitable that the paths of 'National Socialism' and 'Geopolitics' should have crossed. German national Socialism represented an adaptation of Italian Fascism to the conditions of weak and ruined Germany, whilst Geopolitics represented and adaptation of 'Politische Geographic' of Friedrich Ratzel and the 'Heartland Thesis' of Sir Halford J Mackinder to the needs of national recovery. In the melting-pot of Munich in the 1920s the two were to forge an uneasy alliance which lasted for a generation (Parker, 1998:30).

The main purpose of geopolitics being developed as a political paradigm was to produce an effective strategy for the recovery of Germany so as to enable it to resume its position as a great power. To the German geographer Otto Maul, "*Geopolitics is concerned with the spatial requirements of the state ..... is a discipline which weighs and evaluates a given situation and by its conclusion seeks to guide practical politics*" (Maul, 1936:31). Similarly, Hartshorne remarked that "*geopolitics was the application of geography to politics, and the estimate of its value and importance would depend on the value that one assigned to the political purpose it is designed to serve.*" (Hartshorne, 1939:404).

For Nazi Germany, it emerged as a political paradigm as it attempted to provide a model problem and solution to the German State, particularly, in its quest for domination, power and territorial expansion in the World-Island. It was all a struggle for space and power. The crisis that brought about untold miseries and sufferings to mankind in Eurasia during 1939-1945, may be attributed to the application of the principles of geopolitics to achieve the aforesaid political goals. The war devasted the fragile ecosystem. Similarly, the use of nuclear weapons made the finely balanced structure of environment susceptible to irreparable damage and loss, in Japan and the Pacific realm. As a result of this, after the end of World War II, German geopolitics was lumped together with the rest of the ideological baggage of Nazism and the whole lot was banished (Parker, 1998:1). The western world particularly renounced the word 'geopolitics' as being too dangerous for the survival of humanity and its terrestrial habitat.

But the opposition to geopolitik/geopolitics was short-lived and the return of the paradigm took place in the early 1950's, with the world having been split into two mutually exclusive power blocks : the Maritime American Block (First World) and the Continental Soviet Block (Second World). Rivalries between the blocks for control and/or extending influence over wider areas of the globe led to the beginning of the Cold War. A number of military alliances were formed around the World-Island to contain the expansion of the Soviet Block, and this led to intense rivalries between the two blocks. Rivalries reflected the struggle for space and power, which was manifested in a kind of 'east-west' spatial pattern (Taylor, 1985:36-37). Rivalries between the blocks sustained the superpower confrontation, which in turn sustained technological innovations and scientific achievements in the field of the production of weapons of mass destruction.

The nuclearisation of the global policy in the early 50's threatened the twentieth century once again. The *raison d'etre* of humanity and its terrestrial habitat was questioned. It exposed humanity to miseries of unspecified dimensions. It was in the backdrop of this horrendous situation endangering the global ecosystem and balance, that, the Australian geographer Griffith Taylor suggested an alternative paradigm, both for the protection of human species, and natural ecosystem, which he called 'geopacific' – *"an attempt to base the teachings of freedom and humanity upon real geographical deductions; in a sense it is humanised geopolitics. It shows from a study of world Plan, where the leading nations must arise; be it understood to lead not to conquer. It shows how the conflicts based on racial differences are usually absurd .... It shows that we should study environmental control, so as to advance in harmony with our environment ......"* (Taylor, 1951: 606).

While developing his paradigm as an alternative to geopolitics and its disastrous impact on man and his environment, Taylor seemed to have expressed his serious concern for environmental awareness and control. With regard to the relationship of humanity to his terrestrial habitat, he urged that humanity must act within the constraints of the environment and be aware of its limitations as well as its possibilities. It was a mere reflection of his philosophy of 'stop-and-go-determinism' (Taylor, 1957:479). However, his attempt to convince the world leaders to bring to an end to the struggle for space and power, had little impact. Humanity continued its efforts of manufacturing weapons of mass destruction. The stock pilling of missiles by both super powers and blocks was designed to achieve 'mutually assured destruction', which led to the balance of terror *vis-à-vis* the armageddon scenario. Within the confines of the biospheric layer, experiments continued, to achieve break-through in the manufacturing of the weaponry system. This largely endangered all earth-bound species, including humanity.

Geopolitics in the post-World War period experienced a paradigm-shift in the new situation arising out of the cold War. In this new geopolitics, the two dimensional strategic thinking in the past gave way to three dimensional thinking – for both super powers, the enemy was in the sky above (Bunge, 1982). This marked the beginning of the 'satellite geopolitics' with horrendous implications to mankind with experiments of strategic nuclear weapons in the sky above, on the surface and below the surface. This not only weakened the geosphere/biosphere, but, also marked the beginning of an era of bio-terrorism.

It was, probably, the philosophy of environmental possibilism which formed the central feature of the Cold-War geopolitics. It was essentially the people, not the places that tended to determine the spatial pattern of hegemony and rivalry in the world-systems. Those with superior technology sought to perpetuate their domination through their 'participatory-possibilities approach', and in the name of 'development', they have put the world at the threshold of environmental crisis. It has just strengthened the idea of mankind as the master capable of changing and/or transforming nature in such a way, so as to make the environment susceptible to irreparable damage.

The industrial developments which took place during the period between the 1950s and early 1970s, (especially those associated with the supply of energy and the related expansion in the mass use of the internal combustion engine) demonstrated all too clearly that a radically different approach was needed in order to stop the environmental degradation which was accelerating its pace. It has been rightly observed that humankind is capable of very little except destruction of its terrestrial habitat *vis-à-vis* the planet. This was the essence of the situation identified by Johnston and Taylor indicating 'a world in crisis' (Johnston and Taylor, 1989).

During the Cold War period, technological innovations and scientific achievements in the field of weaponry systems of the super powers, (which sought to perpetuate their dominance at the various spatial scales i.e. local, regional, national and international) necessarily demonstrated the misuse of 'possibilities' afforded by the environment. Making the wrong choice among these possibilities, tended to weaken the quality of environment. The super powers were to be blamed along with their followers for the crisis. In order to conquer nature, it is first necessary to obey her and not to tamper with her quality (Bacon, 1924). Environment has not been treated with care and respect by political decision makers of the various countries, who saw *'development as being all and nature as being something which was waiting to be 'altered'* (Parker, 1998:5).

The obvious devastation caused over half a century by much of the political activity within the period of 'development' together with associated events as the Chernobyl nuclear disaster of 1986, have had the effect of reinforcing the uneasiness about the general direction in which mankind is moving. In the back drop of the Chernobyl disaster, Bunge has made reference to 'the destruction of human space', and further remarked that 'this planet is not too small for peace but it is too small for war', and, therefore, urged for a collective action on a global scale to prevent the occurance of such disaster in the future (Bunge, 1989 : 355-57). He was in favour of an increased environmental consciousness so that the essential biospheric unity of the planet could be maintained, and homosapiens saved from destruction.

Such disastrous incidents have continued to occur in the sky above, on the surface, and below the surface because competitions between human groups and states, in the form of struggle for space and power continued unabated. Smaller nations, in the periphery of the world system, were also dragged into conflictual situations. Persistent tribal warfares in East Africa, in the recent past, have not only made the terrestrial habitat of the people susceptible to damage but also weakened the habitats of other species.

For several decades since the beginning of the Cold War, the political destiny of the world has been largely shaped by the elites of the most powerful and rich nations. War has been a major instrument in this process, both sustaining structures and mounting challenges at various spatial levels. But none seemed to have bothered about the severity of environmental decay as a result of the experiment and production of weapons of mass destruction. French nuclear tests in South Pacific for several years have, severely affected the fragile character of the marine species. Not only are the developed and powerful states carrying out such experiments to enrich their power-potentials, but even some 'poorer' nations in the periphery of the world systems are also dragged into the power game at regional and local scales, very much at the cost of the stability and sustainability of their environment.

The dissipation of cold war structures and patterns left intact the basic geopolitical framework and mindset of the modern world, that is control the whole resource base of the world for the sake of the richest, militarily strongest, and, most technologically advanced and assertive states and elites, with the focus of control remaining with the trilateralist North. This set of relationships is underpinned by the military dominance of the North, and by its willingness to spill blood in disproportionate quantities. Ending the East/West rivalry has not implied a comparable willingness to encourage the demilitarisation of international relations to any significant degree, astonishingly, not even with respect to nuclear weaponry. Especially bewildering is why the non-nuclear states have not mounted a strong denuclearizing campaign, especially given the option of threatening a collective withdrawal from the nonproliferation regime embodied in the Non-Proliferation treaty. Such passivity reinforces the disposition to stand on the part of the wizards of Armageddon "*.... the roots of nuclearision were much deeper than deterrent, and thus the end of deference does not imply the end of nuclearism*" (Folk, 1995 : 30-31).

Post-modern geopolitics, since the end of the Cold War, has become even more dangerous to the human interests and ecological survival than was the case during the Cold War days. The absence of bipolarity has left the United States undeterred. The idea of National Missile Defence (NMD) plan has been introduced with the aim of perpetuating its dominance in the sky above. Both Russia and India have responded positively to the US plan, forgetting the horrifying implications of the plan on mankind and its terrestrial habitat.

In the Gulf War, the North (the Atlantic Alliance) once again demonstrated its dominance by way of the superiority in military technology, arguably more spectacularly than ever before. The war greatly devasted not only the terrestrial ecosystem of the region but caused extensive damage to the marine life of the Persian Gulf. The devastating impact of the war on the terrestrial habitat of mankind became evident in subsequent months when it was learnt that thousands of war-induced casualties occurred among children under the age of five by the end of 1992.

Earlier, high-tech military intervention by the North in the Southern region occurred during the cold-war in Korea, Vietnam and Afghanistan and caused irreparable damage to mankind and its environment: the Gulf war was just a repetition of it. Those powerful and rich states which intrinsically sustain rivalries for domination and does not care for humanity, and pursue technological innovations in the field of weaponry for the sake of power in the destiny of their nations (Raum and Macht in Volkerschicksal) require to be blamed for the emerging environmental problems.

"...... *the geopolitical leadership of the world is not meeting the environmental challenge in a responsible fashion. There is reluctance by the rich countries in the North to accept the financial burdens of adjustment in the South, to encroach upon their own environmentally dangerous consumerist life-style ...... the world orders framework remain committed to maximum economic growth without a sufficiently serious regard for sustainability of resources in the years and decades ahead, thereby reinforcing the tendencies that producing environmental decay at an alarming rate and are especially damaging to the global commons (i.e., seas, atmosphere, space-those domains of earths ecosystem lying beyond the territorial reach of states). The unwillingness of several rich states in the North to back the main directions of substantive effort to increase global capacities to regulate environmentally harmful activities revealed vividly this refusal of the wealthy to acknowledge the urgency of environmental priorities or to join sufficiently in the campaign to redirect human aspirantion in the light of mounting evidence of the need for a more dedicated and intensive effort of the part of governments and international institutions*" (Folk, 1995 : 32-33). The end of the cold war has not initiated any serious move from above in the direction of global reform, as distinct from the atmospheres of global management.

Too much of adherence to the principles of geopolitics and frequent application of this paradigm by states of different power potential categories (with variable political perceptions, and human dimensions, to achieve desired political goals and ends) has resulted in the rise of poverty and social inequality, violence of human rights, genocide, terrorism and fundamentalism, intercivilisation conflicts, environmental pollution destruction, degeneration of health and well-being of those alive and those yet unborn. Those who talk of the sustainable development of resources and environment, are themselves involved in the competition and struggle for space and power. Geopolitics can be held responsible for all kinds of ills and evils, perpetrated on humanity and its terrestrial habitat for long. In view of its horrendous implications, there is a need for an alternative paradigm which can resist the contemporary pattern of geopolitics. At the same time, it should be able to prevent environmental deterioration that is rapidly approaching a point of no return.

For the sake of viability and legitimacy, the world must evolve structures of governance that may offer improved prospects of achieving sustainability (that is, protection to humanity and its terrestrial home with improving living standards) and decency. In fact, governance structures require to be as decentralised and localised as possible, consistent with such goals as equity, implementation of human rights, promotion of democracy, protection and maintenance of environmental quality. In the context, 'ecogovernance' appears to be a preferred form of governance, and as an alternative source of remedy and/or paradigm to that associated with geopolitics, it seeks to resolve conflict and establish order through peaceful means. Ecogovernance is concerned with equity and human development as it is with stability and sustainability.

Ecogovernance : An Alternative Paradigm

Ecogovernance implies a process and goal. As a process, it unites two elements to the institutional act of governing : 'transactions' legal, quasi-legal or informal, which provide the operational tools for the structural act, and the existence of overriding 'societal forces', including assemblages of past or contemporaneous transaction which provide meaning and direction to mankind. As a process, ecogovernance, therefore, attempts to change the present form of governance which is too close to geopolitics, through a succession of actions, events and operation. As a goal, it seeks, to perpetuate complete cessation of hostilities, war and conflicts, and to protect humanity and its terrestrial habitat. Ecogovernance presupposes environmental quality to protect the health and wellbeing of those now alive and those yet unborn. It attempts at the proper ordering of political life at all levels of social interaction. It emphasises the achievements of comprehensive rights for all peoples on the earth.

Philosophical Dimension Of Ecogovernance

Ecogovernance is a blend of tradition of assimilation, tolerance, consensus and synthesis, and is necessarily holistic as it encompasses the 'whole' with regard to man-environment relationship. It attempts to provide moralistic and ethical approach to governance not only for the political world but also for the ecological world. The essence of Ecogovernance is 'truth and 'non-violence'. 'Truth' in ecological perspective, may be concerned with the preservation of environmental quality that 'nature be treated with utmost care and regard'. Environmental constraints must be realised, and respected to the extent, as being required, for the *raison d'etre* of the human world. Similarly, 'non-violence' refers to the stability and sustainability of the physical, biotic and the political earth. It is all about the sustainable development of the planet Earth, as it attempts at the rediscovery of sustainable ways to collaborate at different levels of community and in relation to different types of technology for the sake of human survival and satisfaction, and the maintenance of the various forms of life on the surface.

Ecogovernance emphasises the people-centred criteria of success, as measured by decline in poverty, exploitation, oppression, torture, violence and pollution, and by increasing adherence/subscription to human rights and constitutional practices, especially in relation to valuable segments of society. At the same time, it is concerned with the well-being of people, individuals, and groups distributed throughout the planet in radically different geographical conditions and circumstances, animated by varieties of overlapping identity. Each and every step of ecogovernance leads on to consensus and synthesis between different human groups, so that social relations from the personal to the intercivilisational can be addressed nonviolently.

The struggle for space and power between human groups is the root cause of all kinds of evils on the surface of the earth, and it is in the application of the principles of geopolitics that the states and human groups are engaged in an endless struggle of conflict and competition. Ecogovernance, with its moralistic and ethical principles of attempts to reveal the effectiveness of nonviolence, and the disutility of military approaches to conflict resolution. It seeks to perpetuate a global polity which tends to manifest widely shared views about human interest in ethical, moral, cultural, political, environmental, ecological and even spiritual sustainability. It attempts at global constitutionalism to overcome the negative features of geopolitics as currently operational and to construct a positive form of world order dedicated to peace.

As an antithesis of geopolitics, ecogovernance renounces war and militarism but promotes economic policies that seriously address poverty, expresses and realises human rights in the face of political and social oppression and at the same time attempts to shape the development strategy that tends to reconcile growth with environmental quality. Ecogovernance is necessarily concerned with the : (i) strength and effectiveness of transnational citizens associations in areas such as human rights, environment and peace; (ii) historical move on the part of transformative political vision towards an ethos of democratization and non violence, rejecting arms struggle as tactics of challenge and discrediting militarist modes of governance; (iii) difficulties of states and international institutions in maintaining popularity and legitimacy in the light of the depending problems of world order and the encroachment of the relative autonomy of state/society relations by global market force; and finally (iv) state as a problem-solver and as guardian of territorial autonomy, independence, peace and security.

Thus, ecogovernance attempts to adopt and develop a human-centred ecological and economic global-view that seeks to uphold the life prospects of future generations while devoting 'peace dividends' to the reduction of avoidable suffering throughout the world, with special attention to alleviating the condition of the most victimised. The idea of ecogovernance is also a blend of 'meta-ethics' and 'normative ethics', because at one stage it seeks to perpetuate human good and ecological sustainability, and is necessarily concerned with ecological obligation, duty, good conduct for greatest general happiness of mankind and overall maintenance of man's terrestrial habitat, while at another stage, it is concerned with evolving an alternative paradigm to sustain these aspects and bring justice to humanity and its terrestrial home.

It is through the application of the idea of ecogovernance that conflicting aspirations could be addressed non-violently not only in human-territorial affairs but also in ecological-environmental condition. The globalising trends in the post-modern age, (as a result of the growing mutual inclusiveness between states and the emerging World Trade Organisation) are moving so rapidly in an integrative direction (especially with respect to economic, environmental and cognitive dimension of reality) that it seems almost inevitable that some form of ecogovernnance will eventually come into being.

The success of ecogovernance implies an adequate geographical knowledge about the *genre de vie* of different human groups with territorial identifications and habitat. However, geographical knowledge should not be prejudicial, otherwise, the very purpose of providing greatest happiness to humanity and sustainability would be defeated, and that may lead to injustice, distress, sufferings and exploitation. A comprehensive geographical knowledge, based on the traditions of assimilation, tolerance, consensus and synthesis, may cause 'geographical enlightment' which seems to be a precondition for a reasoned global polity, governance and constitutionalism for a new world order given to world peace.

"The construction of geographical knowledge(s) in the spirit of liberty and respect for others...... opens up the possibility for the creation of alternative forms of geographical practice, tied to principles of mutual respect and advantages rather than to politics of exploitation. Geographical knowledge(s) can become vehicles to express utopians visions and practical plans for the creation of alternative geographies. They can openly control and articulate the legitimate and frequently conflicting aspirations of diverse population. They can infuse cosmopolitan projects, founded on ideas of justice, tolerance and reasons with geographical understandings that do not systemetically negate their universal claims. They can become embedded in alternative politics to good effect. They can provide effective means to mobilise knowledge for those emancipated ends to which all learning and all science has traditionally aspired" (Harvey, 2000).

All geographical knowledge(s), based on the fundamentals of ethics and morality, is to be used to perpetuate the law of universal righteousness Ecogovernnance denounces race and space in the destiny of nations and militarism in thought and action and attempts to release human, economic and political resources to construct better civic relations at home while engaging in the struggle for a safe, just, and sustainable world.

Global Change And Geopolitics : A New Dimension

Global change and geopolitics are both concepts that mean different things to different people. The enlightenment that scientific discourse is supposed to bring suffers from ambiguities and misunderstandings. The versions and concepts should be compared and their implications clarified.

Some people are convinced that comprehensive shifts are occurring in the natural geosphere and the biosphere of the globe. Man's role has catastrophically changed the face of the earth. The debate concerning these global changes is about their social and economic impacts in different parts of the globe and their remedial actions.The sustainability of the natural environment and thereby of human development is the issue. Global changes, to others, refer primarily to the radical increase in human mobility. The mobility of humankind, their goods and bads (eg. weaponry), their symbols (eg. money) and the impact of the increased volatilities of social life and major tenets of social order, the units of territorially organised state system has major implications of human development in various corners of the globe. The global change therefore implies, either change in overall physical nature of the world or change in the capacity and realisation of human movement.

Geopolitics has divergent meanings. In the older definition of the term, states are assumed to be dependent on their physical features as far as their foreign policy and international relations are concerned. Their site and situation account for their position in international affairs or leave them at best with a very limited number of options. This knowledge is in the possession of a limited set of professional students. They apply these views to concrete cases.

In more recent years, this notion of physical features as a determining factor for the conduct of foreign policy has been increasingly challenged by the professional geographer. At the same time, the meaning of geopolitics has shifted in academic discourse. Henceforth, it is not so much considered as a theory of inhibiting factors known by professionals, but as an object of study : the geographical perceptions of foreign policy makers. They are no longer supposed to be driven by external forces, but they are supposed to share geographically specific world views, political maps of the world that indicate friends and foes, strength and weakness, and supply arguments for and against certain foreign policy options. Geopolitics should be concerned with the study of the ways in which such maps are constructed and how they function.

It is very clear from the above conceptual discussion that global change does affect and condition geopolitics, and so they seem to be mutually related. Changes in biosphere/geosphere seriously affect the resources bases of states and their rankings. Even fairly small upward changes in the general sea level will seriously threaten urban life, major infrastructure and important agricultural areas in many coastal lands, besides power potentials of territories. Some potential sites may disappear changing in the rankings of composite power indices as a result of global change, and the changes in mutual trade potentials result in changes in situation of countries *vis-à-vis* each other. Re-ordering of site qualities and situation characteristics would imply shifts in the pattern of harmony and conflict in international relations. Global change will seriously change parameters of international relation in the long run. Global changes causing degradation of natural/physical environment largely affect the mindset of those involved in the conduct of foreign policy.

Global change normally enters the perception of foreign policy makers. Its salience is very much dependent on the rest of the foreign policy agenda in a specific country as well as to the professional world. Global change affects perceptions of 'who are friends and foes' in the world and accordingly may transform existing coalitions. Increasing human mobility with tangible exchanges seem to have specific impact on the physical attributes of countries providing the setting of foreign policy. The 'built' environment and resource base of countries change as a result of increased mobility. Mobility needs physical infrastructure and its parts are assets that greatly affect qualities of a country's site and situation. Ports and airports, motor ways and rail roads that are connected with international network deeply influence the internal quality and international position. The natural landscapes of Nepal and Bhutan are now as important as their international connections. The competition between airports concerning their relative centrality in the networks of international connection is nervously watched by governments who consider this to be a major determining factor of their country's international position.

Resource bases that include population and the capital goods encompassed by their 'built' environment become more dependent- to the extent that physical characteristics indeed determine foreign policy, there is ample reason to expect incisive consequences of heightened international mobility. Ranks change more rapidly and interdependence grows. International human mobility increases and trade expands, but the exchange of intangibles (money, image) has caught up and surpassed these trends. World financial markets interconnect virtually all places on the globe and much economic activity is thus regulated from the few foremost financial centres that set the tone of the pattern of money flow in the world at large.

An extensive set of symbols and images is shared or at least understood by large proportions of the world population. A large part of that repertoire is manufactured in a few places that have a large impact on perceptions. The vicinity of the rest of the world is, although intangible, deeply felt by large proportions of the world populations. Foreign policy makers are confronted with a multitude of foreign signs and exchange of symbols that result in more tangible consequences, e.g. money flows. These come across international borders and have immediate impact on domestic politics. The construction of geopolitical world maps that underline the making of foreign policy has, in consequence, become more contested by the continuous flow of new information and the wider domestic arena in which foreign policy has to be debated.

The discussion reveals the fact mentioned at the beginning that global change and geopolitics are mutually related. The processes that affect the biosphere and the geosphere and that threaten to undermine existing equilibria in these two spheres, are driven by the ever expanding human use of the globe's natural assets. Population growth, non-renewable resource, and intensive socio-economic development accounts for these processes. Mobility, particularly of people and of goods, is a very important part of that kind of development.

The theory of geopolitics that assumes an immediate effect of the physical environment on a country's international position, i.e., geopolitics, has for a long time been discredited for the political manoeuvre and has a tendency to overestimate the military security arguments in the setting of international foreign policy.

Geopolitics has so far remained a suggestive research programme that is in danger of over-interpretation on the basis of a shortage of empirical data. It is evident that the construction of geopolitical world maps is an important and integral part of foreign policy making, more so as the signals that result from global change increase in number and become more difficult to interpret. A new emphasis on global change (deteriorating natural environment) necessitates a new look at the physical environment in which states operate. Thus, maps constructed as part of geopolitics will take more of their contents from modernised versions of geopolitics. The resource bases of the different fragments of the territorial state system have as a consequence of global change won a new sense of urgency. In addition, the resource bases of those different fragments turn out to be partially shared (Adhikari, 1996 : 53-57).

Conclusion

The study reveals certain salient points. Firstly, geopolitik (cs) evolved as a theory of the state as a geographical organism or phenomenon in space. In its development, the concept of space and race in the destiny of the nation, played a very significant role. Secondly, geopolitics as a political paradigm to provide model problem and solution to the practitioners of politics, emerged in Germany during the interwar period. Or, in other words, it (geopolitik) was an application of geography to politics. However, the estimate of its value and importance depended on the value that the practitioners of politics assigned to the political purpose that it was designed to serve. Thirdly, the philosophical part of it necessarily centered around the notion of determinism, and the Germans applied geopolitical techniques to achieve their political gains *vis-à-vis*-territorial (spatial) requirements. Fourthly, it was geopolitik that could be held responsible for the outbreak of the second world war which brought in territorial and ecological disasters to humanity. After the war, and for sometime afterwards, geopolitics vanished from the academic world.

Fifthly, its revival took place with the beginning of the Cold war, and geopolitik became 'geopolitics' and assumed a new dimension. It sustained rivalries between the powerblocks within the 'World-Island' and in the maritime vicinities of the World-Island, drowning a number of smaller and medium-sized states into the arena of war and conflicts. Traditional balance of power was replaced by the balance of terror which led on to the armageddon scenario *vis-à-vis* satellite geopolitics with horrendous implications on humanity and its territorial habitat. Sixthly, the end of Cold War and superpower rivalry has not brought in any relief to humanity, rather, the new patterning of geopolitics became more menacing for the human survival than was the case during the cold war years.

The post-modern World is now confronted with all kinds of human and territorial-ecological problems. Developments and innovations in the field of weaponry and their successful experiments have largely made the terrestrial habitat, susceptible to irreparable loss and damage. As a result of which, not only environmental degradation is taking place, but also human qualities are being eroded rapidly : war, conflict, violence of human rights, fundamentalism and terrorism, poverty, exploitation and pollution are the primary echoes and consequences of the post-modern geopolitics. Seventhly, in view of the menacing nature of the post-modern geopolitics *vis-à-vis* the new patterning of geopolitics, an alternative paradigm is suggested in the form of 'Ecogovernance' to address conflict resolution nonviolently, or in other words, to perpetuate the effectiveness of nonviolence and disutility of military approaches to conflict resolution.

Ecogovernance is concerned with equity and human distress as it is with stability and sustainability. It emphasises people-centred criteria of success as it is concerned with the normative values of humanism which give much weightage to ethics and morality, truth and non-violence with conduct of internal and external politics. Ecogovernance emphasises environmental quality to protect the health and well-being of those now alive and those yet unborn. As an alternative of geopolitics, it attempts at a global policy *vis-à-vis* global constitutionalism which can sustain the extension of regional and global institutional capabilities to address functional problems of environment and equity. Ecogovernance also emphasises that humanity must act within the constraints of the environment and be aware of both its limitations and its possibilities. Finally, global changes as a result of natural processes, largely affect and conditions geopolitics, but, geopolitical patterning, as a part of human process and ambition also causes global changes with far reaching consequences.

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LIVING ON THE EDGE : THE EXPERIENCE ALONG THE BANK OF THE GANGA IN MALDA DISTRICT, WEST BENGAL

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Abstract

The course of the Ganga upstream of the Farakka barrage continues to change unabated. This has resulted in problems of border dispute between Jharkhand and West Bengal and created a class of neo-refugees. While millions of rupees has been wasted every year on bank protection, the programme of rehabilitating the erosion victims has not been taken into account. About 191.42 sq.km. of fertile land have been eroded from the left bank of the river between 1931 and 1999. Since the flow of river intercepted at Farakka, the sedimentation on the riverbed has increased. The barrage authority has so far denied the progrmme of silt management. The huge load of boulders utilised in anti-erosion works are dislodged every year and deposited on the riverbed. This may ultimately compel the river to outflank the Farakka barrage and open a new outlet along a palaeo-channel named Kalindri.

Introduction

The deltaic rivers have the tendency to oscillate within wide limits. The swath of meander sweep is proportional to the size of the river. The principal river also throws off distributaries to facilitate delta building operation. The distributaries may be alternately rejuvenated and decayed with the passage of time. In an uncontrolled situation, the rivers enjoy the opportunity of free swing. But in the densely populated part of the Lower Ganga plain, human intervention exerts immense influence on the river system and interrupts its natural behaviour. The Ganga system in West Bengal has some unique characteristics in respect of its fluctuating discharge, sediment load, tidal intrusion in the lower reach, role of western tributaries, diminishing slope of the thalweg, reversible hydraulic gradient with high and low tide and subsurface geology of the delta. The various river training works exert considerable influence on the fluvial dynamics of the delta. Most important of these, was the 2.64 km. long Farakka Barrage, built across the river between 1963-1971. Other major interventions include, the construction of flood-control embankments, bank revetment with boulders, construction of spurs to deflect the impinging current, and enormous exploitation of groundwater causing substantial reduction of the effluent seepage

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into the river. A combination of these factors interrupt the fluvial dynamics of the delta. The mighty Ganga impinges its bank with immense power during the monsoon and causes damage to human settlements. This is particularly conspicuous from upstream of the Farakka Barrage in Malda district. The problem of erosion and population displacement is not of lesser magnitude in the downstream section from the Farakka Barrage in Murshidabad, discussed earlier

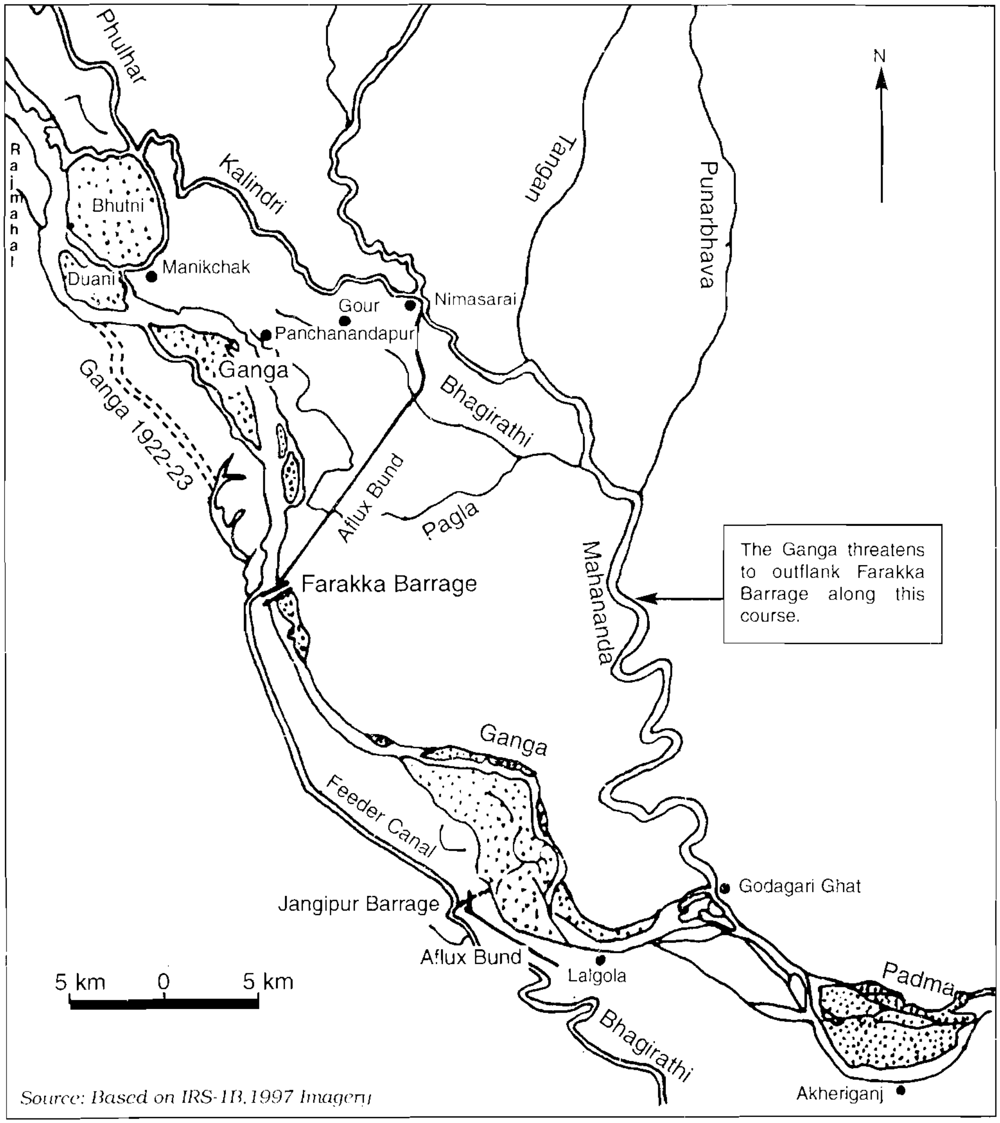


Figure 1: Drainage network system around the Farakka Barrage

by Rudra (1996). The present paper will examine the problem of the changing course of the Ganga in Malda district.

The earlier course of the Ganga

The Ganga enters the state of West Bengal after skirting the Rajmahal hills of Jharkhand (formerly Bihar) along the right bank and flows for about 72 km before it approaches the Farakka Barrage. The river does not get the opportunity of free swinging downstream from the Rajmahal hills as the outlier of hard rock along the right bank does not allow the river to encroach westward. In the second decade of the Twentieth Century, the course of the Ganga between Rajmahal and Farakka was straight and aligned in a southeasterly direction. This course is described in the Survey of India topographical Map No. 72P/13 (surveyed in the year 1922-23). This was not the course of the river during the earlier centuries when Ganga flowed along an altogether different course dashing Gour, the mediaeval capital town of Bengal.

Rennell (1788) wrote that, *"Gour, the ancient capital of Bengal, stood on the old bank of Ganges: although its ruins are 4 or 5 miles from the present bank."* Prof. R. K. Mukerjee (1938), the eminent historian, noted in his book entitled "The Changing Face of Bengal", that, *"Leaving the hills of Rajmahal, Ganges seemed to have passed northwards through the modern Kalindri and then southwards in the lower course of Mahananda, east of the ruins of ancient Gour".* Sir J. N. Sarkar (1973 reprint) in "The History of Bengal: Muslim Period 1200-1757" also corroborated the view expressed by Mukerjee. Sarkar noted that, *"Time has levelled to the dust the glories of the Gauda under Hindu and Muslim rule and the ruins of their capital lies scatterred in heaps for miles along the eastern bank of Kalindri river through which flowed the main current of the Ganges down to the close of the Thirteenth Century."* Major Hirst (1916) attributed the subsequent changes of the course of Ganga to the tectonic causes. He opined, *"There was a severe earthquake in 1515 A.D. and shortly after it, the Ganges left its old course past Gour and retreated southwards."* There were two other distributaries of the Ganga, namely, Choto Bhagirathi and Pagla which joined each other near Mehdipur and flowed southeast to join Mahananda. The latter subsequently discharged into the Padma near Godagarhi Ghat of Rajshahi (Bangladesh). In the process of this migration, Kalindri, Choto Bhagirathi and Pagla were left moribund. The capital town of Gour, which flourished to its peak in the 15th and 16th Century, was located on the interfluve between Kalindri and Bhagirathi. The decay of these three distributaries might have been a slow process covering several centuries. While there are historical references of a mediaeval riverine route between Chittagong and Gour (Ray 1999), one cannot sail up the present river course of deltaic Bengal from Chittagong to Gour. The medieval navigation route must have been through Padma-Mahananda-Kalindri or Choto Bhagirathi. The bulk of the waters of the Ganga must have flown through this course, otherwise it could hardly have facilitated navigation. The lower Mahananda below old Malda must have been a part of the Ganga. The present course of the Ganga between Manikchak of Malda and Godaghari Ghat of Rajshahi was either non-existent or insignificant. The decline of Gour after 1575 A.D. may be attributed to the changing course of the Ganga system. These changes must have taken place much before Rennell pursued the survey during 1764-1777, as his map depicts the course of Ganga being far south of the Gour. The researches on the river system of medieval Bengal suffers from non-availability of true and correct maps. The first systematic survey and publication of map was done by Rennell in the second half of the Eighteenth Century.

The Ganga maintained its southeasterly course between Rajmahal and Farakka till the fourth decade of the Twentieth Century when it started to migrate eastwards (Singh *et.al.*, 1980). Banerjee and Chakrabarty (1983) measured the eastward migration of the Ganga near Panchanandapur based on multidated maps and aereal photographs. The objective of their study was to measure the gradual erosion of the Ganga-Pagla interfluve. It was estimated that the shortest distance between two rivers was 8.53 km in 1923, 2.05 km in 1966 and 0.95 km in 1975. It was reduced to 300 m in 1998. In the month of August 2001, the encroaching Ganga swallowed the narrow interfluve between two rivers. The newly constructed flood control embankment (Bund No.8) that has been built across the Pagla separates the two rivers and may be breached at any moment. The gnawing river has so far breached seven embankments. The official records regarding the land erosion in Malda is available since 1931. It was observed that 14335 hectares of fertile land was eroded from the left bank of the river between 1931 to 1978 and the total eroded land between 1979 to 1999 was measured to be 4806 hectares. Thus 191.42 sq.kms. of fertile land was swept away and almost equal extent of *char* has emerged along the opposite bank.

Land re-allocation and border dispute between Jharkhand and West Bengal

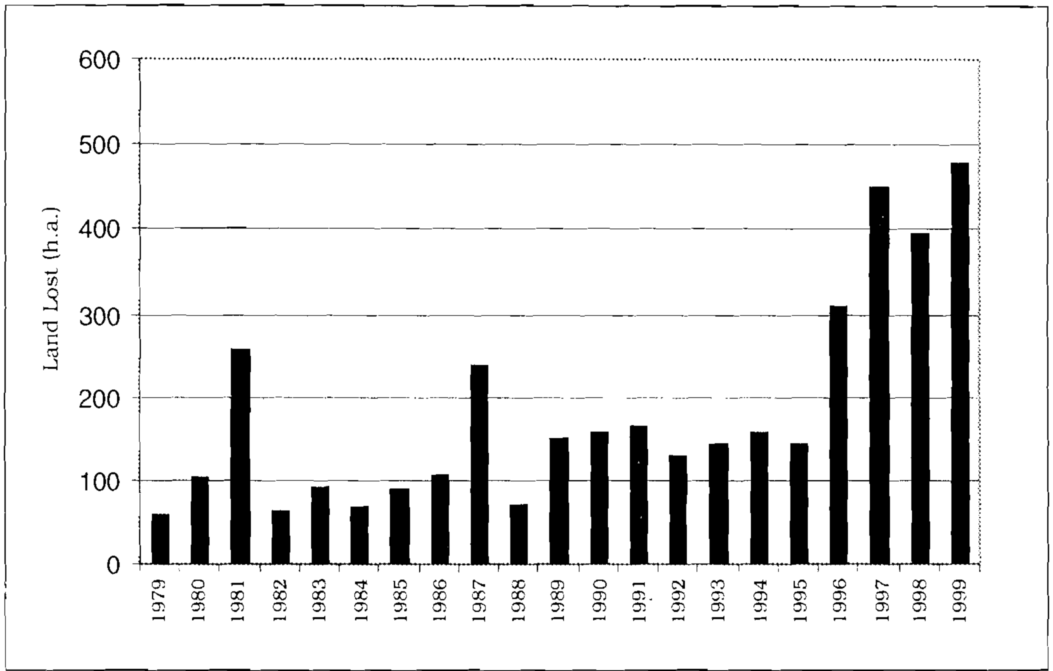
The uninterrupted encroachment of the river towards the left bank has posed the problem of interstate boundary between Jharkhand (formerly Bihar) and West Bengal. During the British rule, the course of Ganga was accepted as border between Santhal Pargana of Bihar and Malda district of Bengal. It was noted in the Survey of India topographical Map No. 72 P/13 (surveyed in 1922-23, published in 1924, reprinted in 1946) that, "*the province and district boundaries in the Ganges river follow the main deep water channel and will vary as the course of deep water channel changes*". The area was subsequently surveyed in 1970-71 and the map was published in 1975 with a footnote that, "*Owing to changes in the course of Ganga river, the state boundary between Bihar and West Bengal and the district boundary between Malda and Murshidabad should not be accepted as authoritative.*" The matter was also discussed in the Ganga Erosion Committee (Singh *et.al.*, 1980). The representative of Bihar in the Committee raised his voice against the proposal of constructing two long spurs near Manikchak Ghat of Malda to deflect the fast flowing current to the opposite bank, as it was likely to aggravate the problem of erosion thereon. The matter was referred to Survey of India and the then Director, Eastern Circle opined, *"The boundary in this portion of the Ganga follows the deep water channel and varies as the course of the deep water channel changes."* The note surprisingly contravenes the earlier note of the Survey of India expressed in Map No. 72 P/13 published in 1975. One of the representatives of the West Bengal Government declined to accept the opinion of the Survey of India and intimated the Committee that, *"The boundary between Bihar and West Bengal in this reach is under dispute."* More than two decades have elapsed since the Pritam Singh Committee submitted its report, but the problem still remains unsolved. The district map of Malda, published in 1994 by the Survey of India, described the border as unauthenticated. While the Indo-Bangladesh border has been declared

Table 1: Year-wise account of loss of land, approx. maximum discharge and approx. maximum water level in relation to river Ganga at Farakka in West Bengal

Year	Approx. Loss of land (Hectares)	Approx. Maximum Discharge (x1000 cumecs)	Approx. Maximum Water Level (metres)
1979	60	42.8	22.9
1980	104	73.0	24.8
1981	259	57.0	23.7
1982	65	68.0	24.8
1983	92	60.5	24.9
1984	68	61.4	24.8
1985	91	57.3	24.3
1986	106	49.8	24.2
1987	240	73.9	25.4
1988	72	68.0	25.1
1989	152	36.8	22.9
1990	160	55.4	24.2
1991	167	69.7	25.3
1992	130	46.4	23.9
1993	145	54.2	20.0
1994	160	67.9	24.9
1995	145	49.6	24.0
1996	310	71.0	25.1
1997	450	47.7	24.1
1998	395	75.9	25.4
1999	480	N.A.	N.A.

Source: Compiled from Report of G.Keshkar Committee, Parua, 1999 and Records of the Irrigation Dept., Govt. of W.B.

fixed irrespective of any change in the course of the Ganga (in accordance with the award of the Bagge Tribunal of 1948), the interstate boundary should not be oscillatory with the changes in deep water channel.

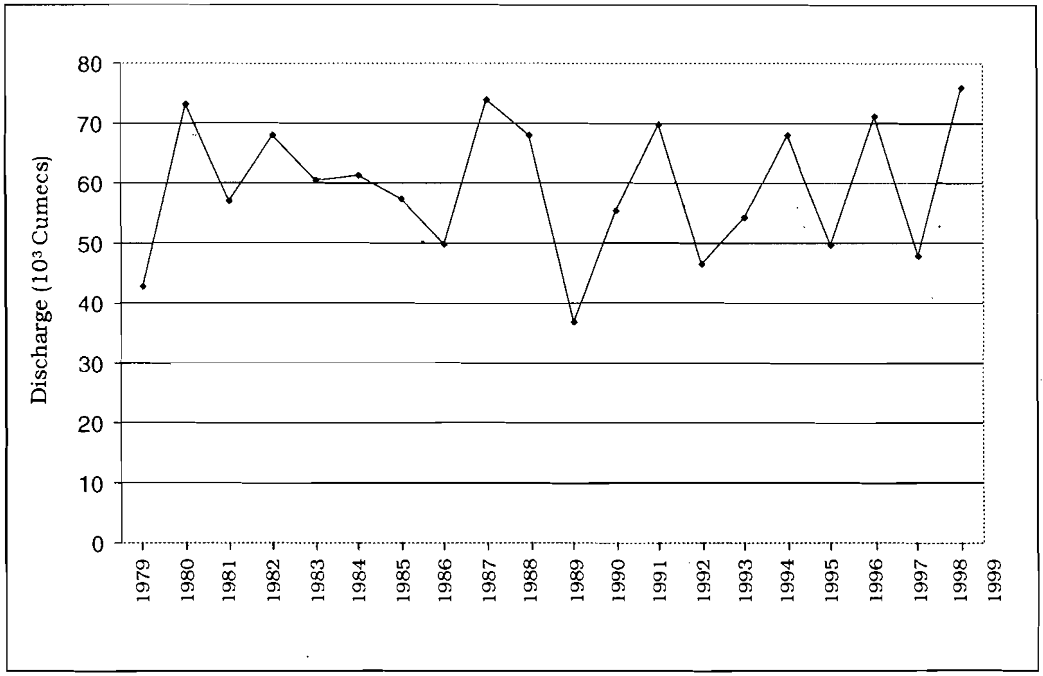


Source: Compiled from Report of G.Keshkar Committee, Parua, 1999 and Records of the Irrigation Dept., Govt. of W.B.

Figure 2: Land re-allocation during 1979-1999

Impact of the Farakka Barrage

The 2.64 km long Farakka Barrage was designed to divert 40,000 cusecs (1120 cumec) of Ganga water towards Bhagirathi so that the navigational status of the Calcutta Port could be resuscitated. This mighty intervention into the river impaired its dynamic equlibrium in many ways. Since the pond level at Farakka was elevated to 21.90 m above mean sea level, the hydraulic gradient of the Ganga above the barrage was flattened, thus leading to an increasing tendency of meandering. The outliers of Rajmahal hills along the right bank aggravated the situtaion further and the river started to impinge its left bank with immense force. The tendency of eastward migration of the river was observed long before the construction of the Farakka Barrage but the situtaion deteriorated further when the construction of the barrage started with partial blockade of the river by coffer dams in early 1960's. The river has now formed a mighty bend between the two nodal points of Rajmahal and Farakka. While the former is a geological node, the latter is an artificial node. Any artificial structure across the river, be it a dam or barrage, accelerates the problem of sedimentation on the river bed. The Farakka Barrage is no exception. The annual sediment load of the Ganga at Farakka is estimated to be 801 million tonnes (Abbas & Subramanium, 1984) and a subsatntial portion of this sediment load is being deposited above the barrage. In addition to this sediment load, tonnes of boulders, which are used for anti-erosion works along the banks, are frequently out-flanked and deposited into the river. The construction of a 100-m long spur requires 14357 tonnes of boulders. Twenty seven spurs have been constructed so far upstream of the

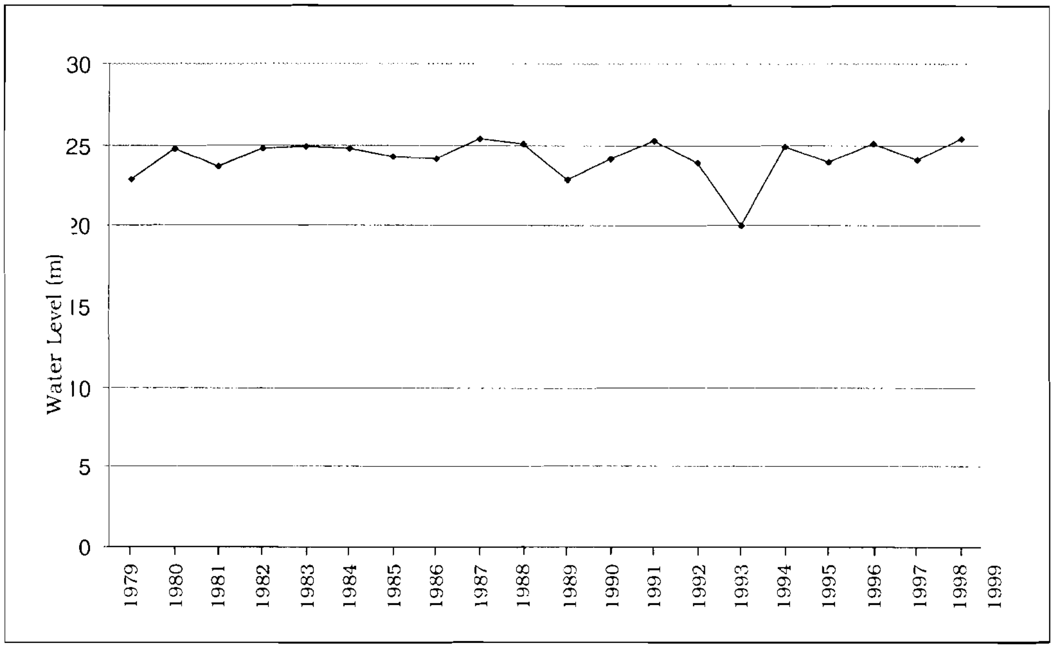


Source: Compiled from Report of G.Keshkar Committee, Parua, 1999 and Records of the Irrigation Dept., Govt. of W.B.

Figure 3: Fluctuating Peak Discharge at Farakka

Farakka Barrage and twenty of them have either been fully or partially swept away. The Spur Nos. 18, 20 and 24 which were recently re-constructed have also been out-flanked. The river-borne sediments, boulders and ruins of the eroded village are combined in the riverbed and creates formidable obstruction to the flow of the river. The current is deflected towards the left bank, causing erosion thereon.

The mighty meander bend formed between Rajmahal and Farakka has changed the direction of the flow, which is no longer co-axial to the barrage. The flow has rather become oblique and concentrates more towards the right side of



Source: Compiled from Report of G.Keshkar Committee, Parua, 1999 and Records of the Irrigation Dept., Govt. of W.B.

Figure 4: Fluctuating maximum water level at Farakka

the barrage. This causes swelling of water duirng the peak of the monsoon. One bay of the barrage cannot discharge more than 30,000 cusecs (840 cumecs) of water, but because of the obliquity of the flow, additional 40% water is aften concentrated along the right hand side bays. The diversion of more water towards the left-hand side of the barrage can be achieved by the regulation of the western gates. But such an attempt would result in the rise of the water level to the tune of 61cms at Farakka and 23 cms at Rajmahal (Singh et al, 1980 & Keshkar et al, 1996). The excavation of an 18 kms long pilot channel may revert the flow pattern to a co-axial state. The proposed pilot channel may be excavated along the abandoned path of the Ganga, which is locally known as *"Bohudubi Danra"*. The State Irrigation Department claims that this old channel is now being rejuvenated (GoWB, 1999), but no such sign was observed by this author during the recent field visit. The design of Farakka Barrage is unique in nature having unilateral feeder canal towards the Bhagirathi. The extensive deposition and resultant formation of shoal along the left-hand side has further complicated the situation. The old railway line, which was laid before the construction of the barrage, is now masked by superficial sediment deposition. This seems to be another cause of deflection of the current towards the right hand side.

There is a conflict between the State Irrigation Department and the Farakka Barrage Authority over the issue of bank protection and flood control. On the one hand, the Barrage Authority blamed the State Irrigation Department for constructing marginal embankments and anti-erosion spurs which *"...created a lot of problems, e.g., causing heavy shoal formation in the river bed, allowing villages to grow up in dangerouosly low-lying submersible flood plains within the marginal bund, expenditure of crores of rupees to protect these marginal and retired embankments every year and worst of all, causing havocs almost every alternate years with loss of lives, crops, cattle etc. whenever these embankments breached."* (Sen,2001).

But to our utter surprise, the boulder pitching continues in futile attempts of bank protection.

Economy of the bank protection

The cost involved in the anti-erosion work is monumental. The revetment of one meter length of the bank with boulders may require Rs.1,00,000. The cost of the construction of a spur maybe Rs.13 crores. Such engineering measures are expensive, but do not offer any guarantee against erosion, rather, the intensity of erosion increases upstream from the protected stretch. Since the scour depth is observed at generally 20-30 m below the bank level, any superficial measure cannot be effective for bank protection. This is the lesson we have been learning over the past decades. Unfortunately, those non-effective measures of bank protection are still practised by the State Irrigation Department. This has become an annual ritual, which benefits none other than some contractors. The Comptroller & Auditor General of India, in his Report for the year ended in March 1999, noted that, *"Implementation of anti-erosion scheme sufferred all through from recurring weakness in planning, execution and monitoring at senior level of the Department and also the Government. Disregard of the recommendation of the Experts' Committee, absence of master plan, delayed tendering, non-testing of soil before execution of work, hasty execution of work, appointment of large number of small contractors and work during full monsoon in unfavorable weather condition resulted in frequent and repeated failure of the work leading to wasteful and unfruitful expenditure". (CAG, 1999).*

Imminent danger

The changing course of the Ganga has posed a serious threat to the Farakka Barrage. The uninterrupted encroachment of the river towards the left bank may outflank the barrage and open a new course through the present Kalindri-Mahananda route. Since the programme of silt management was totally denied, the river bed continues to be elevated and opening of a new course in the near future cannot be ruled out. Such a possibility is also admitted by State Irrigation Department. In an unpublished Report, the Department expressed its anxiety saying that, *"The continued swing of the river Ganga on the left bank in the district of Malda upstream of the Farakka Barrage is not only eroding densely populated villages, fertile cultivable lands, roads and communication systems and causing floods almost every year, but also holds a possibility of the Farakka Barrage being outflanked once the Ganga if allowed to avulse into one of its abandoned paleao-channel on the left bank."* (Report of the Irrigation Dept for 1997-2001). Such an event would make the Farakka Barrage Project redundant and lead to the dessication of the Bhagirathi. Both the Singh and Keshkar Committees recommended in favour of dredging of the river upstream of the Farakka Barrage. But the project remains untouched, apparently due to non-availability of funds. The State Government however, continues to invest crores of rupees each year in futile attempts of bank protection.

Millions of erosion victims have so far been denied the right to rehabilitation. It is admitted in the official records that, *"the severity of erosion has increased after the conctruction of Farakka Barrage"*–thus, the affected population can rightly be treated as environmental refugees and the demand of economic rehabilitaion cannot be called unjustified. If the Ganga is allowed to swing freely as was proposed by the Irrigation Department in a Report published in 1999, the funds allotted for the bank protection work can be diverted and utilised for the rehabilitation programme. The piecemeal programme of bank protection has caused nothing but wastage of money. We need a positive approach to tackle the problem. The important question is whether we should wait further to witness the imminent disaster or take a positive step in order to save the millions of people from the danger at their doorstep.

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SUSTAINABLE DEVELOPMENT : EMERGING CRITIQUES

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Abstract

'Sustainable development' continues to remain one of the most significant themes of the present times. Yet, the concept has received intensive criticism from several perspectives. It is universally acknowledged that the concept is fuzzy. No absolute and single guideline has been produced to indicate what it exactly is and how it can be achieved. There are many visions of the concept, and a distinct North-South difference is clearly discernible. This paper discusses the emerging critiques of sustainable development, and outlines the overall tendency towards a rethinking of the concept beyond its pure economic or ecological connotations and cautions the reader about the possibility of erroneous generalisation of its applicability.

Introduction

'Development' has now become a goal of all countries in the post-second world war times, especially among the large numbers of poor, recently independent nations of Asia, Africa and Latin America. The question that often remains unasked is how has one particular model of the economy come to obtain such a primacy that it has become a universally acceptable model? Escobar (1988) in his various writings have traced how this happened: on 20th January 1949 United States President Harry Truman delivered an address that split the world's nations into two distinct categories of 'developed' and 'underdeveloped' Developed nations were characterized as modern, urban, industrial, capitalist and civilized. By contrast, underdeveloped nations were characterised as rural, traditional, subsistent and uncivilized (Slater, 1995; Todaro, 1994). Discourses have since been produced based on the constructed notion of underdevelopment and the corollary notion of the 'Third World' or 'developing' nations.

Since 1950s, development theorists began to place modernization at the core of development strategies. The transformation from the traditional, subsistent, rural economy to the modernl industrial, urban economy provided the inspiration for western development paradigms (Schuurman, 1993).

Some of the development models proposed during the 1950s were those by Nurkse (capital formation and 'balanced growth' as a means to break through the 'vicious circle of poverty'), W.A. Lewis (with his well-known 'dual economy' model), P. Rosenstein Rodan (who emphasized a 'big push' in investment to

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mobilize the rural underemployed for industrialization), H. Liebenstein (who postulated the existence of a 'low-level equilibrium trap'), A. Hirschman (with his emphasis on 'backward and forward linkages' in the industrialization process). Rostow's famous Stages of Economic Growth (Rostow, 1960) in many ways crowned these efforts.

Several changes began to take place in the world economy that made a rethinking necessary. The concepts of scarcity and finiteness of resources have always troubled economists, but then, there was no concrete evidence that the entire growth process of the world could ever come to a halt. Till then, resource experts like Zimmermann were classifying resource into 'ubiquitous', rare categories, and the notion was that humans could create a 'phantom pile' mainly through the improvements in technology out of the physically limited amounts present.

Several publications brought about a new way of thinking about resources, environment and development in the 1970s (Barbier, 1987; Pezzey, 1989). These were significant and controversial publications such as *The Limits to Growth* (Meadows *et al.*, 1972). Similar publications (such as *Only One Earth*, written by Barbara Ward and René Dubos for *the UN Conference on the Human Environment* held in Stockholm) and the associated debate in the 1970s and 1980s (Eckholm, 1982, was another notable publication of this time) played an important role in bringing about a change in conventional views which hinged upon economic growth leading to the total conquest of nature. Still, there was an increasing global concern in respect of developmental objectives and the limited resources of the environment posing significant constraints. This was reflected when Schumaker (1973) wrote at the beginning of his book *Small is Beautiful* that "*... economic growth ... must necessarily run into decisive bottlenecks when viewed from the point of view of the environmental scientist.*" The concept of sustainable development may be directly attributed to these new trends of thought at the international level. It can be put in a historical context in relation to wider social processes operating in the world since the 1960s. *The World Conservation Strategy* (1980) announced for the first time, the need for conservation and how it might be achieved. The idea was doing the rounds, when in 1987, *The World Commission on Environment and Development* (WCED) first thrashed out the concept in detail. Mitlin (1992) noted in her survey of literature that there are two components in the definition of sustainable development: *the meaning of development* (that is, what are the main goals of development – economic growth, basic needs, i.e.,); and *the conditions necessary for sustainability.* Clearly, ecosystem sustenance is not the same as sustaining an economic form of development. The meaning of development, as it is understood by most people is equivalent to modernisation. Modernisation as development may be traced back to Max Weber's theory of modernisation and traditionalism. Weber's views are part of the ideologies of the Age of Enlightenment in which 'progress' was modeled after Newton's physics, which with its scientific methodology and secure growth was supposed to provide a solid foundation for a paradigm of knowledge in general. A dualistic construction of the economy became significant for the development discourse. For example, tradition was equated with 'backwardness, a burden to be disposed of as quickly as possible and a part of the economy with nothing to contribute to the process of development' (Escobar, 1995, p. 78).

We see that since the middle and late 1980s, a relatively coherent body of work (see Rist, 1997 for a representative sample) has emerged which highlights the role of grassroots movements, local knowledge and popular power in transforming development. Authors representing this trend (see Esteva, 1987, for example) state that they are interested not in development alternatives but *in alternatives to development*, that is, the rejection of development paradigm altogether. These authors (see for a sample the work of Guha, 1998; Shiva, 1995) are characteristically critical of established scientific discourses, interested in local culture and knowledge, and defend and promote pluralistic grassroots movements. Through these, challenges to development are multiplying. As a result, the critiques of the concept of sustainable development have been strengthened – both on the theory side as well as on the application side. Whether development is indeed a universal goal or not is now disputed especially as many towers of resource planning have fallen to disgrace in recent years. The process of unmaking development is slow and there are no easy solutions or prescriptions.

Defining Sustainable Development

'Sustainable development' is not just an abstract idea, nor is it a scientific definition in the true sense in that there is yet to be provided a distinctive guideline towards its attainment. Many definitions have been suggested from different perspectives; many of them are incompatible and reveal contrasting worldviews. Many international bodies like the World Bank use the terms as sacred; still confusion prevails at every step in operationalizing it.

The first of these international bodies, *The World Conservation Strategy*, stressed three main objectives of 'living resource conservation': to maintain essential ecological processes, to preserve genetic diversity, and to ensure the sustainable utilization of species and ecosystems. It is notable that this document was concerned with ecological sustainability rather than sustainable development. Also, the political and economic forces behind unsustainable practices were not given attention to.

WCED (or *The Brundtland Commission*) provided the most popular definition of sustainable development "*... to ensure that it (development) meets the needs of the present without compromising the ability of future generations to meet their own needs*". This definition has given rise to a large, diverse and rapidly growing body of literature about sustainable development. What, for example, constitutes a 'need', as opposed to the economic term 'want'? Also, whose needs are to be given priority and over whom? The WCED highlighted *"the essential needs of the world's poor, to which overriding priority should be given"*. But if it is to be taken as economic development that endures over the long run (as defined by Pezzey in 1992), then the implications of growing resource consumption by the millions of people in the poorer countries are bound to cause discomfort.

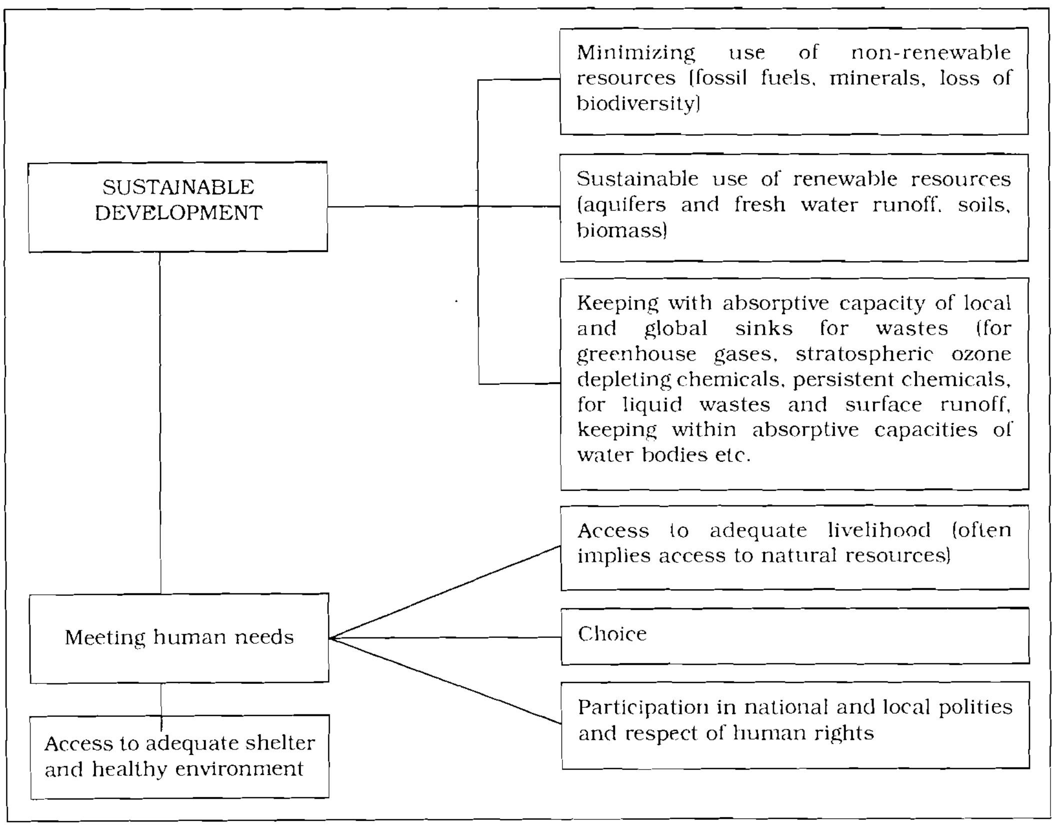
The use of the term 'development' rather than 'economic growth', implies acceptance of the limitations of the use of measures such as gross national product (GNP) to measures well being of nations (Pearce *et al.*, 1990). Instead 'development' embraces wider concerns of the quality of life (Daly, 1989) and may be represented by welfare indicators such as educational attainment, health and nutritional status, access to basic freedoms and spiritual welfare. The conflict that arises is whether to adopt a 'basic needs' approach with an emphasis on helping the poorer countries cross the threshold in terms of income and other economic criteria or whether 'real' development can ever be attained in that way. Rees' definition of sustainable development is also pointed: *"...positive socio-economic change that does not undermine the ecological and social systems upon which communities and societies are dependent"* (Rees, 1988). A similar definition is advanced by the economist Robert Repetto (1986): *"sustainable development is a development strategy that manages all assets, natural resources, and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being"*.

The term 'sustainable' indicates that these developmental achievements must last well into the future; the implication clearly being that at least some of past development efforts had produced only short term gains. The introduction of the concept, however, was significant in a way that it started a dialogue between economists and environmental experts, so far living in two entirely different worlds and speaking two different languages that were never understood by each other.

Consequent to WCED, the *United Nations Environment Programme* (UNEP) significantly supported the idea of sustainability in international fora. Clearly, the interface of environment and development was throwing up interesting conflicts that needed to be addressed at the global level. The 1992 *UNCED* meeting in Rio de Janeiro contained a diverse agenda with wide-ranging and complex elements. Here sustainability was the unifying basis especially as substantial physical and economic interdependence prevailed among the various elements. *Agenda 21* – the report prepared by the meeting – was to be regarded as a 'comprehensive programme for sustainable development', an 'investment in the future' and a preliminary statement of the 'environmental rights' of citizens throughout the world. As a follow-up measure, a *UN Commission on Sustainable Development* was created in 1993 to cooperate with UNEP.

The meeting at Rio, however, brought to the fore the political economy of environmentalism: issues such as distributional equity, poverty-related environmentalism, relevance to economic development, urban settlements, welfare and trade are now significantly debated along with sustainable development. Consequently, the concept has become wider and deeper, more complex, and has attracted new intellectual ideas into its scope and application.

The continued urgency of addressing the environmental crisis has been affirmed recently by the publication of *Global Environment Outlook 2000* (GEO2000) by the United Nations Environment Programme. At the core of GEO2000's recommendations is a call for 'integration of environmental thinking into the mainstream of decision-making relating to agriculture, trade, investment, research and development, infrastructure and finance is now the best chance for effective action'. The following figure (Fig.1) elaborates graphically, the components of sustainable development.



Source : Serageldin and Steers (1994)

Figure 1: Components of Sustainable Development

'Sustainability' implies survival that is desirable, but reaching a consensus on what is desirable is nearly impossible in a plural society dividend in many ways. What constitutes development depends on what social goals are being advocated by the development agency, government analyst or adviser. Usually the society seeks to achieve or maximize the following in development process:

- increases in real income per capita;
- improvements in health and nutritional status;
- educational achievement;
- access to resources;
- a 'fairer' distribution of income; and
- increase in basic freedoms.

Barbier (1987) identified two additional futures: development consistent with local social and cultural values, and development which is participatory. This approach has been clarified by Redclift (1987) who showed how 'environmental issues are socially constricted'. He noted the importance of a neo-Malthusian perspective resting on Malthus's conclusions (made in 1798) that a population cannot exceed its resources without famine or disease providing a natural check on population growth. In fact, a sizeable lobby has grown in the United States of America who explored thoroughly, the relationship between population growth, resources and sustainability of development.

At the same time, sustainable development has been viewed as 'eco-development' associated with the satisfaction of basic needs, participation and appropriate technology. Sachs (1979) described it as *"an approach to development aimed at harmonizing social and economic objectives with ecologically sound management, in a spirit of solidarity with future generations"*. In this way, sustainable development recognizes the need for political change and deals directly with the concept of power.

The World Bank devoted its *World Development Report, 1992*, on the main theme of sustainable development. The focus was on key conceptual issues with potentially important operational implications. So far, the economists and technical-ecological experts set up the arguments for sustainable development leading to what has been described as 'econo-mythical invocation' of 'get the economics right' in development projects (Cernea, 1994). In order to achieve this, it is important to attrbute economic values to environmental assets (Fig. 2) The determinant role of the 'social actors' were relegated to a comparatively neglected corner and led to the non-performance of many development programmes. However, it has increasingly been realized that the environment is at risk not from extra-terrestrial enemies, but from human beings, including both local and distant resource users. Thus, the call for 'putting people first' in policies and investment programmes for inducing development means recognizing the centrality of the social actors and their institutions. Sustainability must be 'socially constructed' – human beings use the natural resources of the environment. The patterns of social organization must be carefully studied for devising viable solutions to achieving sustainable development.

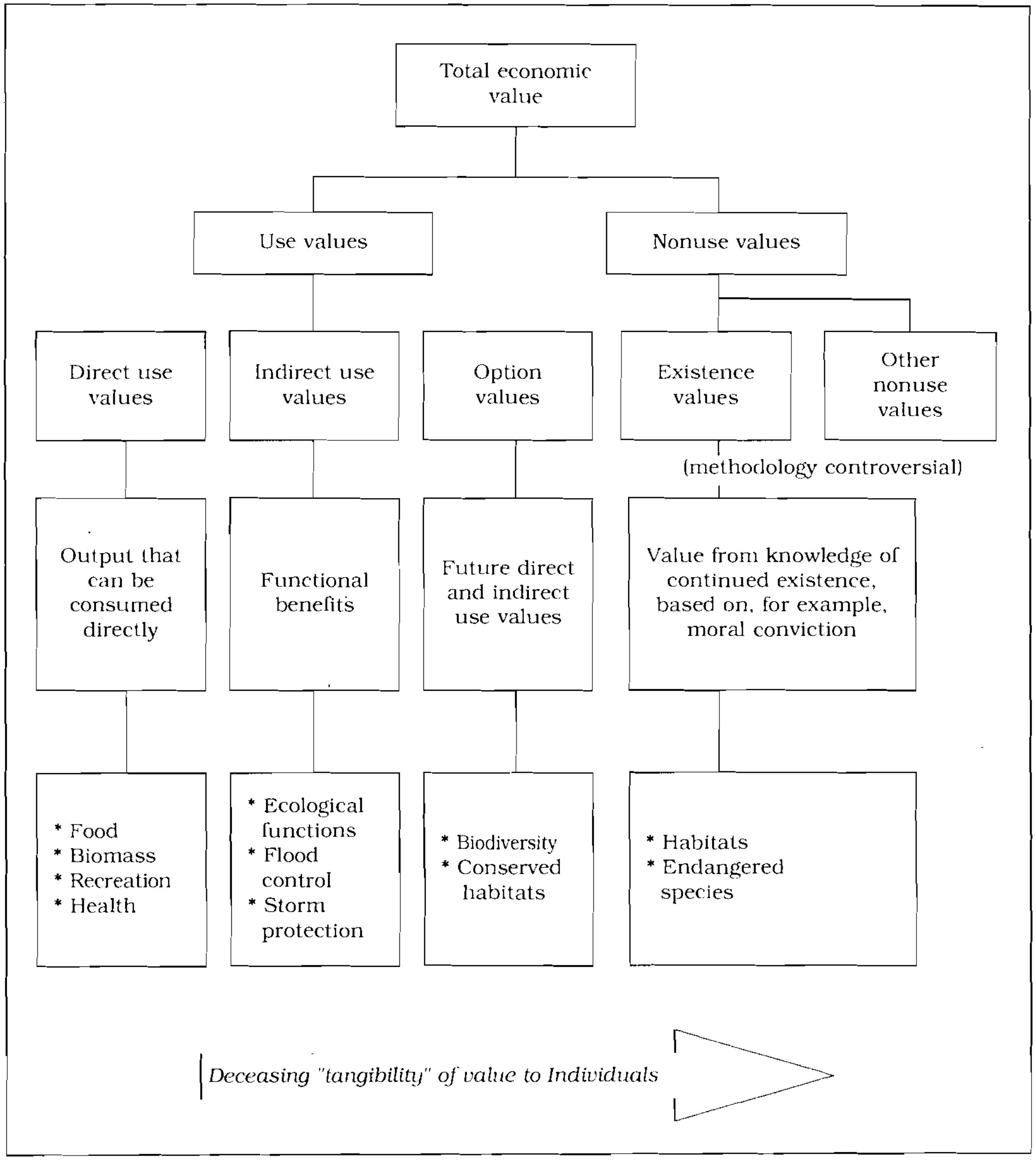


Figure 2: Economic values attributed to environmental assets

Sustaining What?

Houghton and Hunter (1994) suggested that in cases of application, the ideas of sustainable development range from 'strong' to 'weak' versions. Strong versions would be based on environmentalism as fundamentalism. They would include an approach to economic development that suggests an immediate restraint on the use of certain resources leading to a reformulation of production, consumption and ways of life. A weaker environmental political economy would, by contrast, emphasize the adaptation of the status quo on the basis of the argument that it is feasible, realistic and adequate.

However, we have seen that 'development' is a word laden with innumerable values. As the relationship between economic development and the environment are fundamental in causal and consequential interdependence, there is now a rethinking of what development itself constitutes to different people at different places. Sustainable development, as a goal, rejects policies and practices that support current living standards by depleting the productive base, including natural resources, and that leaves future generations with poorer prospects and greater risks than our own'. Although not intended for the purpose, Rawls' theory of justice offers a moral basis for arguing that the next generation should have access to at least the same resource base as the previous generation (Rawls, 1972). His 'maximin' strategy suggests that justice has to be equated with a bias in resource allocation to the least advantaged in society. Unless that is achieved, a development project cannot be called sustainable.

It is now recognized (Serageldin, 1994) that failure to pay sufficient attention to social factors in the development process seriously jeopardizes the effectiveness of various development programmes and projects. Three viewpoints are operationally significant in sustainable development:

(i) That of the economists, whose methods seek to maximize human welfare within the constraints of existing capital stock and technologies. Economists are now relearning the importance.of natural capital.

(ii) That of the ecologists, who stress the importance of preserving the integrity of ecological subsystems viewed as critical for the overall stability of the global ecosystems, although a less extreme view aims at maintaining the resilience and dynamic adaptability of natural life support system. The units of account are physical, not monetary, and the prevailing disciplines are biology, geology, chemistry and the natural sciences generally.

(iii) That of sociologists, who emphasize that the key actors are human beings, without understanding whose perception and active participation and involvement development projects often fail. Human groups are the instruments and beneficiaries, as well as the victims, of all development process is the key to success. Unless the need to continue to improve the welfare of the people is kept at the foreground, environmental programmes will certainly fail.

The challenge is to make participation more than an empty catchword. On a practical level, three areas need attention:

(i) Those potentially affected by development projects need to be more involved at the design stage;

(ii) Local knowledge needs to be better used in the design and implementation of programmes.

(iii) Capacity must be built to access social impact of policies and investments – a particularly important but difficult task requiring a different skill mix among environmental experts.

The poor are in most cases the hardest hit by environmental degradation. They are also the least equipped to protect themselves. Yet, at the same time, poverty causes much of the damage out of short-term necessity, and lack of resources. The poverty-environment nexus can be assessed from Fig. 3 as follows.

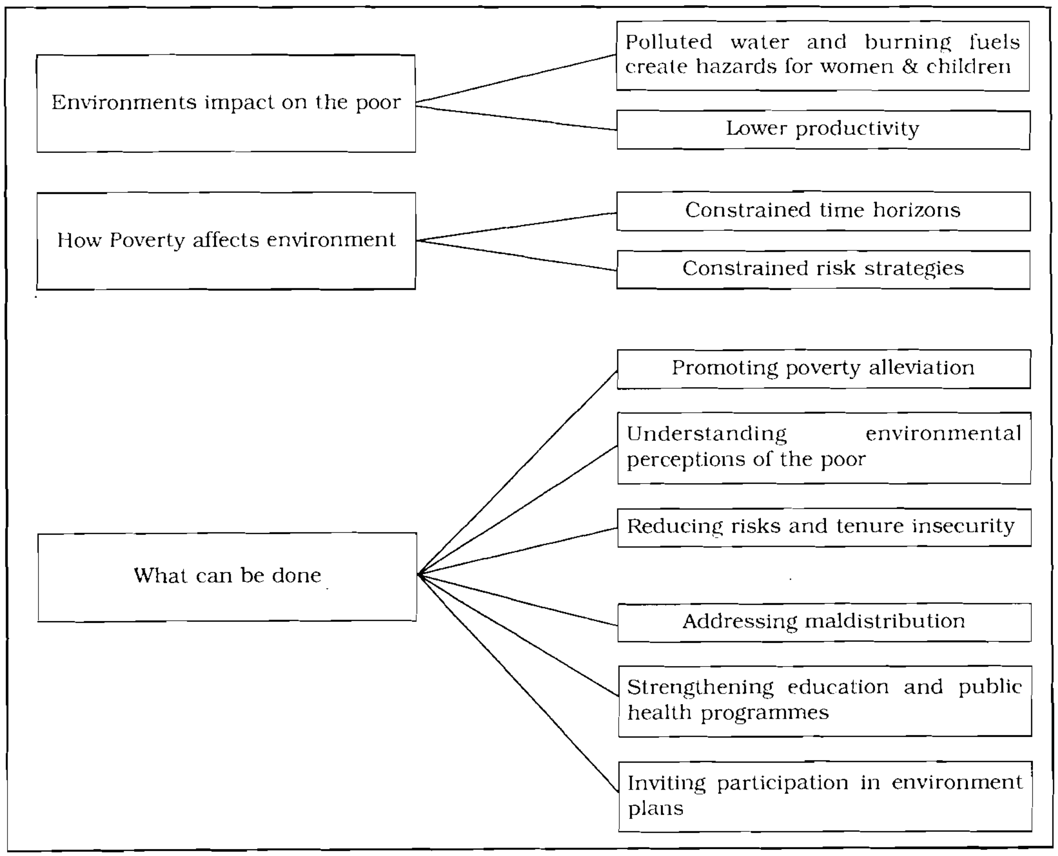


Figure 3: The Poverty-Environment nexus

Rethinking Sustainability

The concept of sustainable development, however, has come under much criticism in recent years as much by development agencies as by economists and academic scholars. It may be noted that the concept is somewhat fuzzy; it proposes the sustainability of development as viewed by the mainstream society. From this point of view, even globalization is a welcome initiative that is to be maintained. This single free-market development model denies room for other conceptions of development, provides technology-fixes for the problems created by it, and avoids the boomerang effect of human poverty.

The concept of sustainability refers to not only ecological aspects of our environment, it also means economic sustainability and social sustainability – three quite different aspects (Munasinghe, 1993). Some of the social structures and systems may not be consistent with the broader goal of sustainable development. The society as it stands now is unequal, where certain groups of people often do not receive justice in full measure. The question that third world countries now face is: *whether developmental intervention sustains these inequalities and injustices within the society?*

Robert Chambers (1986) therefore proposed a 'sustainable livelihoods' approach characterized by a primary focus on livelihoods rather than on the environment or production, and the main criteria by which preferred decisions are identified are the immediate satisfaction of basic needs and security, and low risk. The approach is primarily development oriented; poverty, and specifically lack of livelihood security, is seen as a source of environmental degradation. The reduction of poverty will therefore result in better environmental management.

Poor people in the rural areas of third world countries using simple technologies of production possess a fund of information about their environment and can effectively manage that environment in ways that are sustainable in the long run. Among indigenous people sustainable practices are adhered to because they were the only guarantee of survival (Redclift, 1987).

Hardoy *et.al.*, (1993) noted that there is also an opinion stressing 'cultural sustainability' because of the need within human society to develop shared values, perceptions and attitudes which help to contribute to the achievement of sustainable development. It is clear that development should include as a critical component a respect for cultural patrimony. Culture implies knowledge and a vast wealth of traditional knowledge of relevance to sustainable natural resource us (and to development) is ignored or given scant attention in development plans. However, he also mentions that culture itself is a dynamic thing; to argue that it should be sustained is to deny its changing and developing nature.

It is now seen that the impact of development intervention has been negative for such disadvantaged people. The model of development in a western model that is superimposed upon the society without a thought to the knowledge systems that sustained such groups of people for thousands of years.

Sustainability is both an honourable goal for carefully defined purposes, and a camouflaged trap for the well-intentioned unwary. 'Sustainability' accepted as a universal slogan is, therefore, not appropriate at all; no one who is interested in social justice wants to sustain things as they are now. Marcuse (1998) has argued as follows :-

- Sustainability is not a goal for a programme - many illegitimate programmes are sustainable - but a constraint; its absence may limit the usefulness of a good environmental programmes;
- Sustainability suggests a conflict-free consensus on environmental policies whereas vital interests do conflict; it will take more than simply better knowledge and a clearer understanding to produce change;
- Environmental policies must take into account considerations of social justice - sustainability can not be the sole criterion by which programmes are judged;

Sustainability as a goal in itself, if we are to take the term's ordinary meaning, is the preservation of the *status quo*. It would then involve making only those changes that are required to maintain that status. *The World Economic Forum*, in 1995, even called for a 'sustainable globalization' process! The problem for most of the world's poor is not that their conditions cannot be sustained but that they should not be sustained.

We therefore argue that the *status quo* is not sustainable in strictly environmental terms; that indeed was way the concept originated. But changes within the present system may be targeted at problems of environmental degradation, global warming etc., while leaving other key undesirable aspects such as social injustice intact. Presumably 'development' calls for social justice as well as environmental sustainability, not just one or the other. It is ethically unsound to impose from above conservation practices that emanate from people with power and privilege onto indigenous communities leading to an erosion of traditional knowledge and patterns of resource conservation.

In a plural society, the costs of moving towards environmental sustainability (like the costs of environmental degradation) will not be borne equally by everyone. In the complex balancing act, the simple criterion of sustainability will not take us very far (Harvey, 1996, has elaborated this point extremely well).

Moreover, the very definition of 'better environment' varies by class, ethnic group and poverty level, or gender. For the poor, the issues tend to be immediate and very local: water supply and waste disposal are immediate environmental problems. The richer groups can escape these problems and their problems tend to be on a larger scale such as automobile pollution or global warming.

Finally, taking up a long-term concern may not help much. Scientifically, our knowledge is limited and the further into the future we wish to project it, the more the uncertainties grow. When talking about development related initiatives, the mandatory adoption of a limited set of specific policies where a great deal about the future is uncertain should not be encouraged.

In any case, environmental long-term considerations are not the only ones that need to be taken into account when making decisions. Matters of social justice, of economic development, of international relations, of democracy, of democratic control over technological change and globalization also have both short and long-term implications.

Sustainable development has to be viewed as that which open up a much larger number of choices in front of the disadvantaged groups of people with appropriate technology providing the appropriate solutions for local labour and local labour resource case. Thus sustainable development would mean empowering marginalized groups. Recently, the concept of sustainable development has been bitterly criticized by Sachs (1996) on the ground that it is culturally branded, that it is represents a project of the developed North. 'Survival insurance' (at which sustainable development is aimed) 'can only become a dominating imperative in a society that cannot keep itself from constantly testing the limits of nature. For any other society, this has no importance'. One can also question, for instance, the significance of the notion of future among the eastern cultures, which do not have the same relationship to time as the western cultures. Thus, not only is the notion of sustainable development conceptually problematic, it also lacks ethical scope and displays an obvious cultural slant As it is not yet clear how sustainability can be achieved, that is it is undefinable in operational terms.

If an environmental plan aims at redistributing wealth or opportunity, or the power-sharing pattern, or at reducing oppression, then 'sustainability' does not get us far. Especially in third world countries where aspirations of people to obtain a better standard of living are increasing, how can one define how long is sustainable?

Conclusion

Even though the challenge of how to sustain life on earth in all its forms has become a pressing issue, the idea of 'sustainable development' is yet to free itself from controversies. Social scientists seem too preoccupied with their rejection of western idea of progress to engage satisfactorily with environmental issues; and natural science is still pursuing a relentless quest for prediction and assessment rather than being committed to examining the social and political origins of environmental issues. Our disciplinary knowledge, characterized by homogeneity, atomises our sense of reality so that we can not see parts in relation to the whole. What is needed is knowledge that is carried out in the context of application, that is non-hierarchical, trans-disciplinary, and socially responsive to a diversity of needs, that is, knowledge that is characterized by heterogeneity, deals with diverse paradigms of understanding and assumptions about the way the world works.

The term 'sustainable' has been used without discrimination in environmental and development spheres leading us to believe that these are policies that are of universal benefit; that everyone, every group, every interest will or should or must accept them in their own best interests. Indeed, a just, humane and environmentally sensitive world will, in the long run, be better for all of us. But getting to the long run entails conflict and controversy, issues of power and the redistribution of wealth.

The term 'sustainable development', therefore, now represents a complicated concept; when an international monetary/funding organization talks about 'our responsibility for the environment', it should be taken with a pinch of salt. This is because they take for granted an approval from the rest of the society. Let us try to rescue the concept to its rightful place of honour as a critically important aspect of environmental policy by confining its use only to where it is appropriate. It will serve us well to recognize its limitations and avoid the temptation to take it over as an easy way out of facing the reality.

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Short Communications

MEASUREMENT OF SEASONAL CHANGES OF BEACH PROFILE IN TROPICAL ENVIRONMENT BY "TOPO-SCALING FACTOR"

Sirs,

As a researcher I have been investigating upon the various aspects of the coastal environment around Digha-Sankarpur area of Medinipur district of West Bengal over the last four years. During the course of my research upon the geomorphology of the beach through seasons a number of dynamic characteristics associated with the beach profile has attracted my attention. On the basis of this experience and the field data collected by instrumental investigation I would like to put forward a very simple mathematical model to measure the seasonal variation of beach condition which normally occurs in such tropical coastal environment. Sets of data collected through field investigation by simple levelling survey method (using Dumpy Level, Ranging Rods, Staff and measuring tape) have been used for this mathematical testing. I believe seasonal nature of morphodynamics of a sea beach of this type can be easily explained by *Topo-scaling factor*. This method is particularly applicable for beach-profile investigation in the tropical environments as well as in the cases of temperate environments.

It is well accepted that the coastal geomorphology is controlled by the actions of waves and tides. Wave characteristics change remarkably through seasons under the variable nature of wind speed and direction and the changing rate of water density, which in turn affects the coastal morphodynamic system. The sea beach continues to be sweeped at a regular interval by the waves of a wide range of hydraulic power generated in different seasons. Tropical monsoon environment experiences three major seasons, namely pre-monsoon or summer season (March to May), monsoon or rainy season (June to October) and post-monsoon or winter season (November to February). As the seasons are very sharply separated from each other in this part of the world, they are likely to play a very vital role in the geomorphological modification of the beach.

The study area:

Digha, a well-known sea resort along Medinipur coastal area, is one of the most attractive wave dominated coasts in India. The north-south stretch of the coastal tract is approximately 15 km from the sea. This area has been covered in the Survey of India Toposheet 73 O/10 and Indian Remote Sensing Satellite Image No. 73010. This area suffered from rapid erosion during the last 30 to 40 years and now exhibits very interesting features to the geologists and geomorphologists. Geologists and geomorphologists are of the opinion that his coastal zone has experienced numerous stages of deformations particularly over the last 6,000 years and the existing landform is also changing at a very distinct rate as a continuation of this process (Chakrabarti, 1991; Chowdhury, 1999; Go WB, 1994; and Niyogi, 1970).

Philosophy behind the mathematical model for coastal geomorphic measurement:

Coastal geomorphological study using the method of mathematical explanations has become very popular during the last 20-25 years with the increasing use of computer in all scientific research works. Mathematical models are very useful for the expression of shoreline changes, wave actions and other relative changes along the coast. The mathematical or software models can explain field survey or hardware data more scientifically and logically. Hence, for any scientific explanation, perfect data generation from the field is very important.

As the coastal geomorphological processes change through seasons in tropical monsoon climate different morphological forms tend to occur in different seasons. During the monsoon season, Bhagirati-Hooghly and its tributaries bring an excass of water to the Bay of Bengal causing a certain amount of periodical rise of the sea level and the width of the beach of the Digha-Sankarpur area decreases (due to submergence) of the order of 10-30m at places. By contrast in the post-monsoon season, with subsequent lowering of the sea level, the width of the beach regains the previously lost stretches of its cross-profile of the order of 10-30m at places. It is likely that relatively strong wave action during the monsoon season causes relatively low-angle cross-profile development of the beach while markedly feeble low wave action in the post-monsoon season give rise to steeper cross-profile of the beach. From this point of view, it is possible to explain the seasonal changes of the cross profiles of the beach by the simple mathematical models.

Mathematical explanation of the beach profile variation through seasons

From the above discussion, it is clear that beach angle and width are most common variable features during different seasons. Firstly, seasonal change of beach width is an important indicator of local seasonal rise of sea level and morphological change. In the tropical area, maximum beach width is found in dry season when local sea level is lowered to certain extent and minimum width of beach profile is found when the sea level remains comparatively higher. Difference between high tide-time beach width and low tide-time beach width is maximum at the height of the monsoon season. The variation of beach width through successive seasons and its characteristics can be analyzed mathematically by "R" factor or "*Range factor*", proposed by this author as follows:

$$R = W/w$$

Where R=Range factor, W=Widest beach at low tide time, w=Shortest beach width at high tide time *(Equation-1)*

Secondly, Beach angle is another prominent seasonally variable feature in tropical coastal environment. It is related with the wave height. Low waves cause development of steeper cross profile of the beach and high and stronger waves stand responsible for the development of low angle cross profile or flattish beach.

Thus simple *Topo-scaling Factor (Topographical Scaling Factor)* or *Ts Factor*, in short, proposed by this author, may be calculated by the equation as presented below:

$$Ts = W/w.\tan\beta$$

Or

$$Ts = R \tan\beta$$

Where, Ts = Topo-scaling factor, β = Beach angle *(Equation-2)*

It has been found that this mathematical model not only suggests the scale and range of the morphological form of the beach profile but also establishes the two most important controlling factors of coastal morphodynamics, namely, (1) the seasonal change of sea level and (2) seasonal variation of wave height. The following table presents an analysis of the beach condition by applying *"Topo-scaling Factor"* or the *"Ts factor"*

Table 1: Measurement of seasonal variations of the sea beach along Digha by *Ts factors*

Seasons	*Maximum Width (in meter)*	*Minimun Width (in meter)*	*R Factor*	*Beach angle (in °)*	*Ts factor*	*Observed sea level condition*	*Intensity of wave action*	*Beach condition*
Pre-Monsoon (March)	246	157	1.56	1·00	0.33	medium	Increase of action by influence southeast w	Beach modification is higher post-monsoon. Neo-dunes are for just behind the flat beach, which comparatively than the monsoon period.
Monsoon (J	198	52	3.80	0·49	0.05	High	Strong action by Influence Southwest Monsoon wi	Ramarkable beach modification Action by the erosional works of wave is Beach narrowing and lowering place. neo-dunes are eroded by wave action. Rate of erosiojn is High.
Post-Monsoon	258	197	1.31	1·07	0.02	Low	Very low of waves minimum action southwest disappears northeast takes place.	Beach modification by the ero works of wave becomes very almost negligible. Accreti found at the western part of the area

Source: Data compiled from field investigation 2000

Main features of *Topo-scaling Factor*:

a) Increase of *Ts Factor* indicates the rise of local sea level. In case of the present study area in monsoon season, Ganga and its tributaries carry excess water, which causes the local rise of sea level in the Bay of Bengal along the coast. Decrease of *Ts Factor* on the contrary indicates fall of local sea level.

b) Comparatively highly value of *Ts Factor* is the indicator of high wave action on the beach.

c) Comparatively lower value of *Ts Factor* indicates the high beach angle.

Scope and content of *Topo-scaling factor* in short-term analysis:

This is actually a comparative study of beach morphological variation through seasons by the influences of climatic factors and sea level change.

- *Topo-scaling Factor* is very simple to calculate as compared to other mathematical equations, as the main parameters are easily available by simple survey techniques.
- Seasonal variation tendency of the beach morphology can be understood clearly in tropical coastal regions and even in the temperate regions where seasonal changes are not very prominent.
- This model is directly involved with two of the main variable characteristics like beach width and beach slope, which have a clear seasonal nature.
- Seasonal changes of a very small part of the beach can be interpreted.
- Graphical variations of *Ts Factor* of seasonal coastal morphodynamics under different physical conditions of the world can be superimposed to understand the actual seasonal effect on coastal geromorphology all over the world.
- This mathematical model can estimate present trend of seasonal morphodynamics and future conditions.
- This can be very useful for the planners and engineers.

Topo-scaling Factor can be used only locally and the user should fix the scale, as for example high, medium or low according to collected field data. Though it can be used in the study of seasonal variations of beach profile condition, maximum wave affected part of the beach can be identified. This can be another important field of application of *Ts Factor*.

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AN ECOLOGICAL STUDY ON DUNE STABILISING PLANTS OF DIGHA FOR APPROPRIATE COASTAL AFFORESTATION

Digha (Lat. 21°37′ N and Long. 87°30′ E), an important dune-based sea resort of West Bengal, has been experiencing coastal erosion for several decades. The 7 km. long Digha coast which trends in east-west direction contains both erosional and accretional zones (Chatterjee and Ghosh 1995). Although the erosional activity of the sea at Digha and its environs is causing damages since historical times (O'Malley, 1914), the problem drew attention of planners only during the sixties when the coast was chosen to be developed as a tourist spot and a centre for marine fishery. To save the township from the encroaching sea, a four-km long boulder laden sea wall was constructed part-by-part. But recurring expenditure for regular maintenance of the wall and a continuing threat of erosion demands a new approach to save the coast (Chatterjee and Ghosh 1999).

It is in this context that, revegetation of the highly eroding areas would be an alternative and long term effective approach to check erosion. Although there are various attempts to study the coastal vegetation of Digha (Rao et al. 1974, Paul 1994 and Bhakat 1999), there is virtually no attempt to prevent coastal erosion by revegetation. The purpose of this study is to decipher the nature of plant succession on coastal dunes and to identify the dune stabilising plants, a prior knowledge of which is essential for taking up any coastal afforestation programme.

Coastal dunes being dynamic, provide habitats for pioneer plant community, which by their nature have to establish themselves on the young soil starved dunes. These sand dunes, once colonised by pioneer species, trigger the process of plant succession. Of all the plant communities, the coastal dune system is the one that lends itself best to the study of its development in terms of plant succession. Dune systems are unfailingly ordered by age in relation to their proximity to the sea (Crawford 1989).

Keeping this in mind, a preliminary survey of the coastal dunes at Digha was done which reveals a gradual and orderly process of plant development from seaward to the landward side. The process of plant succession shows three distinct formations. These are: *Spinifex littoreus* formation on the foreshore, *Ipomoea biloba* formation on mobile dunes and *Casuarina-Ipomoea-Pandanus* association on fixed (stabilised) dunes.

Since the coast is very exposed, the unconsolidated substratum of the shorefront is in constant movement. In highly unstable conditions only low-growing *Spinifex littoreus* with deeply penetrating root system survives.

Behind the shore, the freshly deposited dunes, besides being soil and water-starved, are highly porous and prone to removal by the prevailing direction of the wind. In such a changing environment only *Ipomoea biloba* survives and proliferates. Its long creeping stems and much branched surface roots and form a network of close-set vegetation on sand surface. Thus, it consolidates and stabilises freshly deposited, uncovered and mobile dunes. This species later alters the substrate in a way that renders the habitat less favourable for its own survival, but more congenial for the development of other species. Dunes thus fixed by *Ipomoea* invite *Casuarina equisetifolia* and *Pandanus* species, among others. These species, once established, stabilise the shoreline and acts as a buffer against erosion, thus accelerating shore development and building new coastlines. This capacity of plants to anchor sand, build soil and help coastal accretion is observed at the duneface of Digha.

In recognition of *Casuarina* and *Ipomoea*'s miraculous protective functions, the Forest Department of West Bengal Government has undertaken a unique experiment to afforest the vulnerable seashores of Digha with *Casuarina* plants. The step-by-step exercise of this afforestation programme is as follows:

1st year: Mechanical fencing at foreshore to obstruct the inland moving sands and allowing them settle thereon.

2nd year: Greening of the freshly deposited sands by planting *Ipomoea* and letting it stabilise the sands for a year or two.

3rd/4th year: Plantation of *Casuarina* saplings on nearly fixed sandline.

In this way erstwhile seashore may be converted to an "inland" habitat. This process is repeated as and when required. As a result, rows of *Casuarina* trees, the first being the oldest at the extreme backside and the last being the new at the sea edge, of different heights assume a shape of "gallery forest".

The aim of this novel project is to guard the coast and its adjoining inland environments, particularly crop fields and human settlements, from the fury of cyclones and blow-out sands that come hand-in-hand every year during the summer months.

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Book Review

A Research Report on the Informal Economy of Solid Waste Disposal in the City of Calcutta, Satyesh C Chakraborty, Ekta Ecological Foundation, P-1, Raipur, Raja S.C. Mallick Road, Kolkata 700 084, pp 166, Price Rs.250/-

We do not often notice how important are the roles played by the workers who are not employed by any statutory institutions or by big corporate business organisations. Recently, our attention has been drawn through a very comprehensive study by the Ekta Ecological Foundation (EEF),an NGO, on one such group of workers functioning within Kolkata. The workers under study constitute a complex system engaged in the disposal of recyclable solid wastes. On the front of this system are the familiar itinerant traders who visit all the residential quarters every day, calling for *'shishi-botal-purano kagaz bikri'* (vials, bottles, old papers for sale). They are visible not only Kolkata, but in nearly all major urban centres on the country. Yet, they have hardly attracted the attention of the social scientists or the city planners. At least there is no known urban policy about what to do with this system in any part of our country that takes pride in sponsoring economic development for the people. This Report has shown that this socio-economic system belongs to the informal sector and should be given due credit for keeping the city cleaner than what would otherwise happen had they not pursued their profession.

This research study has made a detailed analysis of the physical and economic functions performed by these roaming traders and their support system, to lift varieties of solid wastes from thousands of domestic units of this big city. They buy the solid wastes like paper, metals, glasses, rubber, leather and certain varieties of plastics for purposes of feeding many recycling units. To reach the recycling units, roaming traders are hierarchically placed within a well-built system, which together can be defined as belonging to the informal sector. The recycling units are, in turn, producing diverse commodities that are used by both the rich and the poor in this city.

Recycling involves use of lesser amount of energy than what would have been required to produce the virgin materials. Recycling ensures conservation of matter. At the same time, recycling may produce useful consumer goods. The system offers economic stimulants to ordinary housewives to practice segregation of waste by type and at source. Anybody conversant with the issues of environment management would consider these functions, especially the involvement of the waste generators, as essential. The whole of this informal economic system, including the collectors, the despatchers and the users of diverse kinds of solid wastes, have emerged on its own without any support of the State Government or even the Municipal Corporation of Kolkata. As is expected, both these types of statutory institutions are oblivious to the useful role that this informal economy is performing even when the people are being asked by them to cooperate to keep the city cleaner.

Apart from a truly erudite exposition of the attributes of the informal economy, this study is an extensive and penetrating review of the literature on solid wastes disposal systems in the major metropolitan cities of the developing world. A fourteen page exposition on the history of Kolkata, as it has conditioned the management of wastes disposal, is worth studying by any scholar interested in understanding this complex urban entity. Similarly, with extreme patience and sympathy, the report analyses the limitations of the Calcutta Municipal Corporation in maintaining its conservancy service. Thus providing the background, the EEF takes us into the informal economic system of solid wastes disposal by exploring the attributes of each class of actors engaged in this part of the world, ranging from the private households, the rag-pickers from the waste dumps, the itinerant traders, the local receivers and finally the upper level dealers. The report covers the socio-economic profile of the actors with comments on gender differentiation, origin, quality of life and aspirations. The economic benefits of the trading system, notwithstanding the quality of life enjoyed by the participating actors, call for survival of the system.

Obviously the system can survive only with public support. The EEF has chalked out in details the nature of options for supportive public actions that each category of participating workforce would need and has shown that these public actions can be steered by the NGOs with some training. The idea is to understand how to forge ahead with these public actions towards a national demand for policy support for sustaining this informal system of solid waste disposal.

The EEF has very correctly shown that environmental management would be possible only when the generators of wastes become sensitive enough to agree to segregation of wastes by types at the source. The larger number of such generators is located in the private homes. The informal economy of solid waste disposal system deserves credit for having sensitized these private households to segregate the wastes by type at the very source. This they have achieved by offering economic incentives- a factor that our National Government, by being a signatory to GATT, should feel proud of and look at these ill fed workers of the informal economy as useful contributors toward accumulation of wealth in our society.

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Joint Forest Management and Community Forestry in India : An Ecological and Institutional Assessment. N.H. Ravindranath, K.C. Murali and K.C. Malhotra (eds.), Oxford and IBH, New Delhi, pp. 326, 2000. Price not stated.

Community involvement in natural resource management, recently identified as a highly beneficial venture in terms of economy and ecology, is getting a newfound significance everywhere; more so, when the issue revolves around forest management. People's participation in forest management, appropriately called Joint Forest Management (JFM), whose motto is sustainability and equity, envisages a formidable partnership between the people and the foresters in a reciprocal manner to protect and (re) generate forests.

With the exciting beginning in 1990, the experiences in JFM have many positive as well as negative outcomes. Studies on JFM and other similar initiatives in various states have documented increases in forest cover and biodiversity, and thus productivity along with the increased NTFPs. But what needs to be addressed about this decadal exercise are the "grey areas" in the otherwise "all green" JFM programme. These issues, although overlapping in most cases, ranges from social to technical in nature, and are location specific.

India is one of the few countries in the world, whose Constitution enshrines the concept of environmental protection and specifies this as the duty of the state as well as of the citizens. Although the per capita forest area in India is among the smallest in the world, yet a large portion of the rural population not only depends to a significant extent on forests for its livelihood but also protects forests traditionally through a network of sacred groves and other forms of sylvan environs spread over many states. Thus India's long history of community involvement in the management of its forests has attracted worldwide attention recently. And this early form of Community Forestry Management (CFM), while operative in many states, seems to be a precursor for a more bureaucratised system of JFM, attempting to make the forest policy socially responsible. This form of initiative of the state forest departments – first originated in the *Arabari* forest range in Midnapore district of West Bengal having a long history of conflicts between forest officials and local forest-dependent people. Regular negotiations and dialogues later led to joint explorations of future arrangements that promised to ensure the well-beings of both the parties. As a result of this, a village-based committee was formed to negotiate with the forest department, and all verbal understandings in the matter of contributions and benefits were kept unchanged. Villagers were allowed to collect NTFPs and when sal trees were harvested they received 25 per cent of the sale value and the cullings. News of the experiment spread resulting in more and more committees gradually being formed with successful improvements of forest area.

Thus the programme on JFM, which began as an experiment, has now become a major national issue in environmental management. And majority of the country's states have adopted the June 1990 guidelines on JFM, with minor changes to suit their socio-economic and legal conditions. The rate of spread of JFM is convincing too. Within the past decade, nearly 10.24 million hectares of forestlands have been brought under co-management systems between forest department and over 36,000 forest protection committees.

The book under review is a collaborative study of the participatory forest management in general and JFM in particular. It is a synthesis of field studies conducted by the Ecology and Economics Research Network (EERN), a part of the National Support Group on JFM of Society for the promotion of Wastelands Development (SPWD). It consists of 15 chapters delving deep into the status of community forestry covering 8 states. While assessing the other relevant aspects of co-management, the book strives to highlight concerns in institutional and ecological terms. The important policies with respect to participatory forestry in India have been reviewed additionally. Moreover, it provides an appendix giving details of methodologies followed in studying economic, ecological and institutional systems. The book being a rare combination of field study, social insights and policy studies shows that far from being an unified programme, co-management, specially JFM is a complex outcome of the constantly evolving debates, policies and practices.

Notwithstanding the monotonous style of writings overloaded with data, the book will be of widespread interest to researchers, resource managers, policy makers, ecologists, economists, sociologists, foresters, activists and students alike.

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