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Special issue on Impact of Climate Change

INDIAN SOCIETY OF GEOMATICS

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Editorial

During the year 2000, ISG Newsletter underwent a change - from a mere newsletter, it was transformed into a specialized 'magazine', publishing special issues on themes which were considered to be most relevant to the time of publication, apart from important news of interest to Geomatics community. During the same year, with December 2000 Issue i.e. volume 6, number 4, the Society started publishing ISG Newsletter in a printed form. The tradition of bringing out special thematic issues has been continued. The current special issue on 'Impact of Climate Change' a burning topic to-day, has been painstakingly compiled by Shri R.P. Dubey, our Guest Editor, who is not only deeply involved but is also an authority on the subject. This topic was also considered to be most relevant as the next Annual convention of the Society, Geomatics 2009, going to be held at Dehradun in February 2009, has chosen this theme.

The undersigned has been shouldering the prime responsibility of bringing out the newsletter with the help of dedicated editorial teams since 1996. With this issue, the undersigned is bidding farewell to members of the Society, readers and other well wishers of the Society who have supported this effort all though these years.

Baldev Sahai

Guest Editorial

The global warming and the ensuing climate change is now an accepted reality after years of debate and investigations. However, the acceptance is to be driven home by myriad of local proofs in all its dimensions. The well-known dimensions of climate change are indicators, agents and impacts. Satellite-based observations are proving to be a key means of gathering such proofs on local level. The present special issue of ISG Newsletter focuses on some of the latest findings by leading teams of India on various aspects of climate change.

Dr Chandiprasad Bhatt points out the implications of climate for Himalayan ecosystems in societal perspectives. Topic of physical changes in vegetation growth pattern is the subject relevant for Himalayan and other high altitude regions and has been dealt by Shri C P Singh. The well known effects of warming on glaciers again for Himalayas are given by Dr. I. M. Bahuguna. Possible impact on agriculture is a subject of research as it has wider implications in formulating the mitigation strategies. The issue carries an article on this by Dr S. S. Ray. Corals the rain forest of oceans are very good indicators of climate change and the current frontiers of efforts are documented by Dr. Anjali Bahuguna... The consequences of sea-level rise are described by Dr. Nageswara Rao et al. impact of climate change on this is the subject of the article by Dr P S Dhinwa and coauthors.

In sum, the current issue of ISG Newsletter provides a comprehensive and up to date coverage of all relevant topics of research related to impact, indicators and adaptation aspects of climate change studies in Indian context. The issue being brought out on the occasion of national conference of ISG (Geomatics 2009) will add value to the knowledge and ideas exchanged during the conference.

On behalf of ISG, I would like to thank all the contributors for time-bound submission of articles of excellent quality. Shri C P Singh is acknowledged for design of the cover page.

R P Dubey

हिमालयः पर्यावरण संरक्षण, संवर्द्धन एवं विकास के कुछ बिन्दु

दशोली ग्राम स्वराज्य मण्डल के अनुभव*

चण्डीप्रसाद भट्ट

भारतीय जियोमेटिक्स सोसाईटी (ISG) के इस सालाना समारोह में सहस्त्राब्दी व्याख्यानमाला के निमित्त देशके शीर्षस्थ वैज्ञानिकों एवं विद्वत्जनों के बीच आने तथा एक सामाजिक कार्यकर्ता के रूप में अर्जित अपने अनुभवों को आप लोगों के बीच बांटने का जो सौभाग्य मुझे दिया गया है, इसके लिए मैं भारतीय जियोमेटिक्स सोसाईटी के पदाधिकारियों एवं सदस्यों का आभारी हूं। इस आयोजन के निमित्त देश भर के भू–सूचना के क्षेत्र में कार्य करने वाले विज्ञानियों एवं शोधार्थियों के अनुभव का लाभ लेने का अवसर मुझे मिला है इसके लिए मैं पुनः आभार व्यक्त करता हूँ।

पृथ्वी पर बढ़ती मानवीय हलचलों और संसाधनों के अविवेकपूर्ण दोहन के कारण आज हमारे इस ग्रह के पर्यावरण के असंतुलन से नित नई–नई समस्याओं से हम दो चार हो रहे हैं। पृथ्वी ग्रह और भू–सूचना जैसे विषय पर इस साल का यह आयोजन निश्चित ही सामयिक है। अगले दो दिनों में धरती और भू–सूचना को लेकर मूर्धन्य विद्वान और विज्ञानियों के अनुभवों तथा इस दिशा में किए जा रहे व्यवहारिक व लोकोपयोगी ज्ञान व वैज्ञानिक प्रयोगों का लाभ जहां इस सम्मेलन में भाामिल हो रहे वैज्ञानिकों, प्रशासकों एवं शोधार्थियों को मिलेगा। वहीं भू–सूचना के क्षेत्र में हो रही इन नई–नई पहलों का प्रसार भी होगा और जिसका फायदा इस धरती के संसाधनों के संरक्षण तथा संवर्द्धन के लिए कार्य कर रहे समुदायों, संगठनों एवं सरकारों को मिलेगा। इस पहल का लाभ जहां देश और धरती के पर्यावरण में सकारात्मक वृद्धि लायेगा, वहीं इन सीमित संसाधनों पर निर्भर जन–सामान्य को भी निश्चित रूप से मिलेगा।

इस सम्मेलन के इस प्रयास के प्रति अपनी शुभकामनायें व्यक्त करते हुए मैं आशा करता हूँ कि इसमें हमारे विज्ञानी ज्यादा प्रतिबद्धता से आगे आयेंगे और अपने मिशन में सफल होंगें।

पर्यावरणीय संकट आज हमारे विश्व की प्रमुख समस्या बन गया है। हमारा देश इससे सर्वाधिक संकटग्रस्त बना है। हमारा शीर्ष, हिमालय पर्यावरणीय विकृति का दूसरा नाम बन गया है।

स्थावराणां हिमालय ' भगवान कृष्ण ने कहा है कि स्थावरों में मैं हिमालय हूँ। हिमालय केवल एक लम्बे, चौड़े और ऊँचे पहाड़ का नाम ही नहीं है बल्कि एक सर्वथा परिपूर्ण, सर्वांग सुन्दर और समृद्व पर्वत–श्रृखला का नाम हिमालय है। इसलिए कृष्ण ने अपनी तुलना उससे की।

हिमालय जिसे कालिदास ने पृथ्वी का मानदण्ड कहा है, सैलानियों का स्वर्ग, साहसी लोगों के लिए जोखिम से भरे खेलों का खेलने का प्रेरणा–स्थल कवियों का कल्पना स्रोत, विज्ञानियों का शोध–क्षेत्र और धार्मिक आस्थावान लोगों की देवभूमि, स्वर्ग आदि है। हिमालय प्रकृति की विविधता का पर्याय है। प्राकृतिक समृद्धता का दूसरा नाम हिमालय है। उसे ज्ञान–क्षेत्र भी कहा

* Millenium Lecture Geomatics - 2008

जाता है। हमारे ऋषियों ने हिमालय क्षेत्र में ही ज्ञानार्जन किया और उसे लोक–कल्याण के लिए समर्पित किया।

इस सबके बाद भी हिमालय का हमारे मिथक और यथार्थ पर कितना ही दबदबा क्यों न हो, पर है यह युवा पहाड़ ही। भू–गर्भविदों के अनुसार हिमालय दुनियां के पहाड़ों में सबसे कम उम्र की अत्यन्त संवेदनशील पर्वत–श्रृंखला है और अभी भी उपर उठ रहा है तथा चीन–तिब्बत की प्लेट को पीछे धकेल रहा है।

हिमालयः पृथ्वी का मेरूदण्ड

विशाल हिमालय पर्वत श्रृंखला, पूर्व से लेकर पश्चिम तक 2500 किलोमीटर लम्बी है, जो 250 से 300 किलोमीटर चौड़ाई तक फैली है। दुनिया के सबसे बड़े महाद्वीप, एशिया के मध्य में स्थित हिमालय पर्वत को पृथ्वी का मेरूदण्ड कहा गया है। हिमालय मौसम का नियंत्रक एवं मिट्‌टी–जल और वनस्पति के जनक के रूप में भी जाना जाता है। राजनैतिक रूप से हम देखे तो हिमालय क्षेत्र से जुड़े भारत, पाकिस्तान, नेपाल, भूटान, बांग्लादेश और म्यांमार दक्षिण में तथा चीन (तिब्बत) इसके उत्तर में स्थित है। भारतीय उप–महाद्वीप के नाम से जाने जाने वाले दक्षिण भाग में भारत में ही बारह राज्यों या इनके भू–भाग हिमालय में स्थित हैं। पूर्व में अरूणांचल से लेकर पश्चिम में जम्मू–कश्मीर के अलावा मेघालय, मिजोरम, नगालैण्ड, मणिपूर, असम, त्रिपूरा, सिक्किम, हिमाचल प्रदेश और उत्तराखण्ड तथा पश्चिम बंगाल राज्य का दार्जिलिग का भूभाग हिमालय में स्थित है। भारत के कुल भौगोलिक क्षेत्रफल का लगभग 16.2 प्रतिशत अर्थात 5.2 लाख वर्ग किलोमीटर भूभाग हिमालय क्षेत्र में पड़ता है। यहां की बिखरी हुई के बसावट के बावजूद कुल आबादी 3 करोड 96 लाख (2001, भारत की जनगणना) के लगभग है।

वर्षा

यहां के मौसम में विविधता है तथा वर्षा के आंकडे निम्नवत है जो कि क्षेत्र की जलवायु विविधता को दर्शाते है।

पश्चिमी जोन– मध्य हिमालय व शिवालिक 1000 से 2000 मि.मी., ग्रेट हिमालय 600 से 1000 मि.मी., व परा हिमालय जो कि सूखा व ठण्डा रेगिस्तान है के लेह में 75 मि.मी. के लगभग वर्षा होती है।

मध्य जोन– 2000 से 2500 मि.मी. तक वर्षा होती है।

पूर्वी जोन– इस क्षेत्र में सर्वाधिक 2500 मि. मी. से 5000 मि.मी. तक वर्षा होती है।

वनस्पति

सुदूर उत्तर की ओर पश्चिमी जोन सबसे ठण्डा व सूखा क्षेत्र है तथा पूर्वी क्षेत्र नमीयुक्त व गर्म है। यद्यपि कुछ सीमा तक इस जलवायु परिवर्तन से उत्पन्न वनस्पतिक बदलाव को उंचाई के प्रभाव ने दरकिनार किया है तथापि पि चमी क्षेत्र को शीतोष्ण (Temperate) प्रकार की वनस्पति से, पूर्वी क्षेत्र को चीनी वंश (Chinese Genera), मध्य व निम्न हिमालय में चौडी पत्ती वाली समशीतोष्ण (Tropical) वनस्पति से अलग किया जा सकता है। मध्य क्षेत्र पश्चिम व पूर्व के बीच वनस्पतिक बदलाव का क्षेत्र है।

स्थलाकृति

मध्य क्षेत्र की एक दूसरे को काटती घाटियां उप–जलवायु क्षेत्र व पारिस्थितिक बदलाव के प्रभाव को उत्पन्न करती है।

कभी–कभी कम दूरी पर ही यह क्षेत्र उच्चतम वर्षा ग्रहण करते है।

पश्चिमी हिमालय में नदियां पर्वतीय आकृति से जुडी है तथा अधिकांशतः पूर्व से पश्चिम की ओर बहती है। पूर्वी हिमालय में ज्यादातर उत्तर से दक्षिण की ओर बहती है। मध्य भाग इन दोनों के बीच बदलाव का क्षेत्र है।

हिमालय भूवैज्ञानिक दृष्टि से जवान है तथा प्राकृतिक रूप से अपरदन आदि क्रियाओं से प्रभावित है। इस कमजोरी को निम्न दो कारक और बढाते हैः–

- अधिक उंचाई व गहरी घाटियों में बहने वाली जलधारायें।

- माह जून से माह सितम्बर अन्त तक चार महीने होने वाली भारी वर्षा।

हिमालय की अवस्थिति के कारण मानसूनी बादल दक्षिणी ढालों पर भारी वर्षा करते है तथा जलधारायें अपने जलग्रहण क्षेत्र से भारी मात्रा में अवसाद नीचे लाती है जो कि विश्व के अन्य भागों से तुलनात्मक रूप से अधिक अपरदन व भूक्षरण की समस्या उत्पन्न करती है। मुख्यतः मध्य हिमालय में यह समस्या मानवीकृत भू–उपयोग के कारण और अधिक गम्भीर हो जाती है।

हिमालय की विविधता का कारण उसकी विकट स्थलाकृति है। हिमालय पर्वत–श्रृखला जितनी विस्तृत है, उतनी ही विविधतापूर्ण भी है। इसमें समुद्र सतह से लेकर सागरमाथा की ऊचाईयां विद्यमान हैं। इसके पाद–प्रदेश में जहां मैदानों का उच्च तापमान मौजूद है, तो वहीं सैकडों चोटियां और एक चौथाई ऊँचाई वाला भाग हमेशा हिमाच्छादित रहता हैं, जिनका तापमान शून्य अथवा इसके भी कई अंश नीचे रहता है। जलवायु की इस विविधता ने इसके अंदर बसे विभिन्न समाजों को भिन्न प्रकार की जीवन–चर्या अपनाने के लिए प्रेरित किया। लेकिन इस जीवन–चर्या में भी जीविका का प्रधान स्रोत्र प्रकृति ही रही है। जब प्रकृति ही मुख्य अवलम्बन हो तो उसके संरक्षण की स्वाभाविक प्रवृत्ति भी उनमें निहित होनी स्वभाविक है। इसलिए एक किनारे से दूसरे किनारे तक अनेक विविधताओं के बीच जो सामान्य व सहज प्रवृत्ति देखी जा सकती है, वह है प्रकृति का युक्तियुक्त उपभोग तथा उसका अधिकतम संरक्षण।

भारत के हिमालयी प्रदेश

हिमालय क्षेत्र वनों और जल का भण्डार है। एशिया महाद्वीप के मौसम के नियंत्रक के रूप में इसकी अपनी विशिष्ट भूमिका तो है ही, हिमाच्छादित पर्वत–श्रृंखलाओं व वनों की प्रचुरता के कारण यह भारतीय उप–महाद्वीप में जल का सबसे बड़ा आपूर्तिकर्ता है। सैकड़ों सदानीरा नदियों का उद्‌गम हिमालय ही है जो बहुत बड़े भूभाग को वर्षपर्यन्त पानी देते रहने में सक्षम है।

हिमालय पर्वत–श्रृंखला गंगा सिन्धु और ब्रह्मपुत्र का उद्‌गम–स्थल है। इन नदियों की सैकड़ों जल–धारायें हिमालय की विभिन्न हिमानियों {हिमनदों} से जीवन धारण करती है। गंगा, सिन्धु और ब्रहमपुत्र के बेसिन देश के कुल क्षेत्रफल का 43.8 प्रतिशत है । इनमें देश की कुल जलराशि का 63.21 प्रतिशत भाग भूमिगत एवं प्रवाहित रूप मे है।

गंगा,गंगोत्री तथा सतोपंथ भागीरथीखर्क हिमानियों से भागीरथी और अलकनन्दा के नाम से अपनी जीवन–यात्रा शुरू कर सैकड़ों जल–धाराओं को समेटते हुए देवप्रयाग में गंगा बन जाती है। आगे चलकर इसमें यमुना, रामगंगा, घाघरा, बागमती, कोसी नदियां मिलती हैं। बंगाल की खाड़ी में गंगासागर में समाहित हो

जाती है। गंगा बेसिन देश के संपूर्ण क्षेत्रफल का 26.2 तथा गंगा देश की संपूर्ण जलराशि के 25.22 प्रतिशत भाग की स्वामिनी है।

सिन्धु नदी तिब्बत से उद्‌गमित होती है तथा दक्षिण–पश्चिम छोर से जम्मू–कश्मीर में प्रवेश करती है। 1114 कि.मी. भारत में बहने के बाद वह पाकिस्तान में प्रवेश करती है। इसमें तिब्बत के पठार मानसरोवर के पास से निकलने वाली सतलुज,जो कि पंजाब की समृद्धि का पर्याय है, के अलावा रावी,चिनाव और झेलम नदियां मिलती हैं। सिन्धु बेसिन का क्षेत्रफल देश का 9.8 प्रतिशत है तथा जलराशि 4.28 प्रतिशत है।

दुनियां की आक्रामक नदियों में से एक मानी जाने वाली ब्रह्मपुत्र नदी हिमालय की कैलाश पर्वत–श्रृखला के उत्तरी भाग में स्थित फांग्यू तासू सरोवर के दक्षिण–पश्चिम में पूर्वाभिमुखी होकर, तत्पश्चात उत्तरामुखी होकर और अंततः दक्षिण–पश्चिम होकर शियांग–धियांग के नाम से अरूणांचल प्रदेश में प्रवेश करती है। असम में दिवांग और लोहित नदियों से मिलने के बाद ब्रह्मपुत्र बन जाती है। ब्रह्मपुत्र बेसिन का भारत में क्षेत्रफल 7.8 प्रतिशत है तथा यह 33.71 प्रतिशत जलराशि का योगदान करती है।

हिमालय वनों और खनिजों के कारण मानवीय समृद्धि का बहुत बड़ा आधार–स्तम्भ है। भारतीय ग्यारह राज्यों तथा एक राज्य के हिमालयी क्षेत्र में पड़ने वाले भूभाग की गणना करें तो इसके 596720 वर्ग कि.मी. क्षेत्रफल में 235603 वर्ग कि.मी. वन फैले हैं,जो कुल क्षेत्रफल का 37.77 प्रतिशत है। वनों का सबसे अधिक क्षेत्रफल अरूणाचल प्रदेश {81.22 प्रतिशत} है तो सबसे कम वन–क्षेत्र जम्मू–कश्मीर में {9.57 प्रतिशत} है। भौगोलिक क्षेत्रफल के हिसाब से सबसे बड़ा जम्मू–कश्मीर राज्य {222236.2 वर्ग कि.मी.} तो सबसे छोटा सिक्किम {7299 वर्ग कि.मी.} है। अरूणांचल प्रदेश क्षेत्रफल में दूसरा सबसे बड़ा राज्य {83743वर्ग कि. मी.} तथा हिमाचल प्रदेश {55673 वर्ग कि. मी.} तीसरा सबसे बड़ा राज्य है। क्षेत्रफल के हिसाब से चौथा स्थान उत्तराखण्ड {53483 वर्ग कि.मी.} का है।

हिमालय पर्वत श्रृंखला की भू–संरचना, जलवायु और मिट्‌टी की बनावट में भारी अंतर है। इसे चार मुख्य पट्‌टियों में बांटा जा सकता है। उपरी हिस्से में महा हिमालय है, जो 3000 मीटर से सर्वोच्च शिखरों 8598 मीटर तक फैला है। महा हिमालय में 92 चोटियां ऐसी हैं जिनकी ऊँचाई 8000 मीटर से अधिक है। परा हिमालय {ट्रांस हिमालय} जिसके अंतर्गत लद्‌दाख एवं लाहौल–स्पीति का क्षेत्र मुख्य रूप से शामिल है।

उत्तर में महा हिमालय की जंस्कार पर्वत माला है जिसके हिमाच्छादित पर्वत–शिखर गंगा व सिन्धु के जल–विभाजक क्षेत्र बनाते हैं। परा हिमालय के अन्तर्गत जम्मू कश्मीर का लद्‌दाख ,हिमाचल प्रदेश का लाहौल स्पीति तथा सिक्किम का एक छोटा सा भाग स्थित है।

मध्य हिमालय, जो 1000 मीटर से 3000 मीटर ऊंचाई तक है, 65 से 75 किलोमीटर चौड़ी पट्‌टी के रूप में है। इसके नीचे शिवालिक की पट्‌टी शुरू होती है, जिसे हिमालय का पाद् प्रदेश कहा जाता है। यह काफी घनी आबादी वाला क्षेत्र है।

विश्व की उच्चतम पर्वत–श्रृंखलाओं से युक्त हिमालय पर्वत में 7817 मीटर ऊंची नन्दादेवी, 7756 मीटर कामेट, 7138 मीटर बदरीनाथ, 7120 मीटर त्रिशूल, 7084 मीटर सतोपंथ, 7066 मीटर ऊचा दूनागिरी पर्वत

शिखर स्थित हैं। 6000 मीटर से ऊंची पर्वत श्रेणियां सदैव हिमाच्छादित रहती हैं। इनकी घाटियां हिमानियों से भरी–पटी रहती हैं। इन्हीं हिमनदों एवं हिमानियों के टूटने और रूकावट डालने से अनेकों झीलें एवं तालों ने स्वरूप धारण किया हैं।

मध्य हिमालय में अरवाताल, केदारताल, बैतरणी, नन्दीकुण्ड, हेमकुण्ड, काकभुषण्डी, सप्तताल, रूपकुण्ड {उत्तराखण्ड} आदि ताल एवं झीलें हैं। अलकनन्दा, मन्दाकिनी, नन्दाकिनी, पिण्डर, भिलंगना, भागीरथी, काली, गोरी, धौली आदि नदियां, जो गंगा की सहायक धारायें है, के उद्गम ये ही हिमानियां {हिमनद}, व बर्फानी ताल हैं। लद्दाख में पेंगोंग, त्सों–मोरारी और सिक्किम के औरूडोंग्मां और तीस्ता के उद्गम कंचनजंगा तक सिन्धु से ब्रह्मपुत्र तक विशाल तालों एवं झीलों की एक बड़ी श्रृंखला है जो अनेक नदी–धाराओं को जन्म देकर धरती की प्यास बुझाने में महत्वपूर्ण भूमिका निभाती ही हैं, प्राकृतिक कारणों से कभी–कभी उथल–पुथल भी मचा देती है। फिर इनसे प्रवाहित नदियों में बाढ़ आ जाती है जिसकी कम ही जानकारी मिल पाती है। इन चोटियों एवं चट्टानों में ऋतु किया होती रहती है,श्रृतु किया के कारण बने रेड़ों और हिमोड़ों के ढेरों एवं चट्टानों से जैसे ही बर्फ पिघलती है, मिट्टी एवं धूल–कण पहुंच कर वनस्पति को सिर उठाने का आमंत्रण देते हैं। यहां प्रकृति की अनुपमता काई से लेकर फेनकमल, ब्रह्मकमल आदि विभिन्न रूपों में देखने को मिलती है, जो चट्टानों की ओट में भी अपनी छवि से वातावरण में मोहकता फैला देते हैं।

हिमोढों एवं रोड़ों के बाद बुग्याल और चारागाह हैं जो मीलों तक फैले हैं तथा अनेकों मनोहारी घाटियॉ जीवनदायिनी अतीस, अर्चा, कड़वी, केदारपाती, गुगल, जटामासी, निर्विषि, सालमपंजा, सोमलता, फेनकमल, ब्रह्मकमल आदि वनौषधियां और वन्य पुष्पों व लघु वनस्पतियों से आच्छादित रहते हैं। मखमली बुग्यालों में वर्षा का पानी बड़ी मात्रा में रिसता है जो नदियों के लिए जल भण्डार का काम करते हैं। बुग्यालों का वानस्पतिक आवरण बर्फ और वर्षा से धरती की ऊपरी परत की रक्षा का एक अभेद्य कवच है। यहां कुछ झाड़ीनुमा वृक्षावलियां भी दिखाई देती हैं। बुग्यालों के बाद चौड़ी पत्तियों के जंगलों की एक मिश्रित श्रृंखला मिलती है।

भोजपत्र, मोरू, खरसू, देवदार, बांज, बुरांश, पापड़ी और थुनेर के पेड़ यहां एक ओर बर्फ के प्रहार से धरती को सुरक्षा प्रदान करते हैं, वहीं वर्षा की मारक क्षमता को नियंत्रित कर धरती की सतह पर वर्षा जल के प्रवाह को नियंत्रित करते हैं। धरती के सुरक्षा–प्रहरियों की भांती खड़ी ये वृक्षावलियां हिमालयी पारिस्थिति की आधार हैं, जो अपने जीवन–काल में धरती की सुरक्षा कर मृदा–क्षरण को रोकते हैं, और जल व नमी का संचय कर धरती की उत्पादक शक्ति को कायम रखते हैं । वहीं पतझड़ तथा उम्र पूरी करने के पश्चात धरती पर स्थित जीव–जगत की विविध आवश्यकताओं की पूर्ति के अलावा सड़कर उर्वरक बन कर धरती की उत्पादकता को बढ़ाने में महत्वपूर्ण भूमिका निभाते हैं। इन वृक्षों की छाया में वनस्पतियों का एक समृद्ध साम्राज्य कायम रहता हैं।

कुछ कम ऊंचाई पर चीड़ के जंगल उभरे हैं जो व्यावसायिक उपयोग के महत्व की ओर ध्यान दिलाते हैं। पिछली कई सदियों से चीड़ के पेड़ों का व्यापक विस्तार किया गया है। इसके आगे चौड़ी पत्ती के वृक्ष व मालू जैसी लतायें है और मैदानों में उतरते–उतरते साल,सागौन के पेड़ों के घने जंगल हैं।

हिमालय में ऊंचाई की विभिन्नता ने जलवायु को विविधता से परिपूर्ण किया है। शिवालिक के निचले छोर, जो समुद्र तल से 300 मीटर की ऊंचाई पर हैं, तो एवरेस्ट की चोटी 8848 मीटर ऊंची है। इतने बड़े अंतर से तापमान में आने वाली विविधता से जैविक विविधता का जो स्वरूप हिमालय में है, वह अन्यत्र सर्वदा दुर्लभ है। यही एक पर्वत श्रृंखला है जिसमें उष्ण, शीतोष्ण और शीतकटिबंधीय जीव–जगत व वनस्पति मौजूद है। पूर्वोत्तर हिमालय में सिक्किम और अरूणांचल प्रदेश विश्व के जैव–विविधता के *हाट–स्पाटों* में से एक है।

बर्फीले इलाकों में जहां हिम बाघ व सफेद भालू, च्यांकू {तिब्बती भेड़ियां}, मुरन्द, भूरा भालू, भरड़, कस्तूरी मृग, हिमालयी थार, रूण्डा {हिमालयी मारूसहेयर} जैंसे वन्य पशु सुनहरे बाज व मोनाल, लाल चोंच का कौंआ जैंसे पक्षी {3000 से 5000 मीटर} सरौं, घुरूड़, काकड, भालू, बाघ, गुलदार, साही, गिलहरी, उदबिलाव, चितरौला, नेवला, चकोर, तीतर, मोर मुर्गी और मैदानी क्षेत्रों में गैंडा, चीतल, हाथी आदि जीवों का अनूठा साम्राज्य हिमालय क्षेत्र में विद्यमान है।

आगे हिमालय की नदियों द्वारा निर्मित मैदान हैं, जो पहले घने जंगल थे और अब बड़े कृषि क्षेत्रों में परिवर्तित कर दिए गए हैं। अपने उपजाऊपन के कारण ये मैदान लंबे समय से मनुष्य की आर्थिक समृद्धि के आधार बने रहे हैं।

परम्परागत व्यवस्था में बाहरी हस्तक्षेप

प्रकृति द्वारा प्रदत्त संसाधनों का उपभोग हिमालयवासी निर्बाध रूप से करते थे, लेकिन लापरवाह होकर नहीं। प्राकृतिक संसाधनों का संरक्षण और पोषण उनके व्यवहार का एक महत्वपूर्ण अंग था। सामाजिक, सांस्कृतिक और धार्मिक व्यवस्थाओं में सदियों पहले से रचित साहित्य, मुख्य रूप से पौराणिक कथाओं और आख्यानों तथा लोक व्यवहार की मर्यादायें इसके उदाहरण हैं।

मध्य–हिमालय में उत्तराखण्ड के तीर्थों की यात्रा कई हजार वर्ष पहले से चल रही है। बुग्यालों और देववनों तथा वन प्रान्तरों में जाने और प्रकृति के अनुरूप व्यवहार करने के लोगों के अपने नियम थे, जिन्हें सामाजिकता और धार्मिकता का पुट देकर अधिक पुष्ट बनाया गया था। परम्पराओं में जल, वृक्ष, वनस्पति, पुष्प आदि की पूजा और संरक्षण के अनेक सिद्धान्त प्रतिपादित किए गए थे जिन्हें अभी भी कमोबेश हम लोक–व्यवहार में पाते हैं। लोगों में उन संसाधनों के संरक्षण और सम्वर्द्धन के परम्परागत संस्कार विद्यमान थे,जो लोकोपयोगी थे। फलों के वृक्षों को न काटना, सघन वनों में और बुग्यालों में शोर न करना, हिमशिखरों के समीप लाल कपड़े पहन कर चलना आदि वर्जनायें थीं। ये ही परम्परायें देव–वनों, देव–बुग्यालों के बारे में भी प्रचलित थी। जलस्रोतों की पूजा, वनस्पतियों और वन्य–पुष्पों का अनावश्यक और असामयिक दोहन न करना जैसे संस्कार एक पीढ़ी से दूसरी पीढ़ी तक पहुंचते हुए आज भी जीवित हैं, जबकि इनके लिए कोई 'एक्ट' नहीं था, न कोई कानूनी दण्ड–विधान ही तब मौजूद था।

दो शताब्दी पहले तक हिमालय के लोग एवं यहां का पर्यावरण बाहरी लोगों के सम्पर्क से अछूता था। हिमालयवासियों को भूमि, वन और जल के निर्बाध उपयोग से वंचित करने का सिलसिला उन्नीसवीं शताब्दी में तब प्रारम्भ हुआ, जब अंग्रेजों ने वनों तथा भूमि पर अपना अधिकार जताना और जमाना शुरू किया।

अंग्रेजी शासन व्यवस्था में जंगल केवल उपभोग की वस्तु बन गये थे और अधिकाधिक उपभोग को सभ्यता और समृद्धि का पैमाना माना गया । विकास के नाम पर ऐसे उद्योग–धन्धे खड़े किए गये जिनके पेट में प्राकृतिक संसाधन तेजी से समाने लगे। बड़े–उद्योग, बड़े–व्यवसायों और बड़े–ठेकों को जमाने का दौर चला जिससे बड़े पैमाने पर इन साधनों का अंधाधुंध शोषण किया गया। इस कारण हिमालय क्षेत्र के जंगल समाप्त होते गये। इसके अलावा विकास के नाम पर हिमालय की भू–संरचना और पारिस्थिति की जानकारी लिए बिना तेजी से भारी निर्माण किया गया।। हिमालय के अंतरवर्ती क्षेत्रों में पुराने भूस्खलनों के मलबों, हिमोड़ों के ढेरों तथा जहां हिमानियां पसरी रहती थी, को काट–काट कर पगडण्डियां बनाई गई। जहां पहले इक्का–दुक्का परिवार वास करते थे, वहां बड़ी–बड़ी बस्तियों और नगरों का निर्माण हो गया। इस प्रकार धरती की भूगर्भीय और धरातलीय स्थिति और धारण क्षमता का अध्ययन किए बिना किये गये निर्माण कार्यों ने हिमालय क्षेत्र की संवेदनशीलता को ज्यादा तेजी से बढ़ाया।

भू–विज्ञानी हिमालय–पर्वत को दुनिया के पहाड़ों में नवीनतम तथा कमजोर व अभी भी विकासमान स्थिति में मानते हैं। इसकी संवेदनशीलता, विज्ञानी तो वैज्ञानिक कसौटियों पर आंकते होंगे, लेकिन हिमालयवासी इसकी नाजुक स्थिति का कोप रोज ही झेलने को मजबूर हैं।

अतिवृश्टि और बाढ़

हिमालय से प्रवाहित नदियों में बाढ़ और भूस्खलनों का लम्बा इतिहास रहा है। पहले तो एक दशक से दो दशकों के बीच बाढ़ और भूस्खलनों का सिलसिला चलता था। इधर के वर्षों में इसके अन्तराल में कुछ कमी आयी है।

मध्य हिमालय के उत्तराखण्ड क्षेत्र में गंगा की सहायक नदियों में बाढ़ों का लंबा इतिहास है। इनमें गंगा की एक मुख्य धारा अलकनन्दा सर्वाधिक विनाशकारी सिद्ध हुई है। अलकनन्दा एवं उसकी सहायक धाराओं में एक दशक से दो दशक के बीच के अंतरालों में प्राकृतिक प्रकोप के कारण भूस्खलन हुए हैं और बाढ़ आयी है। हाल के डेढ सौ वर्षों के प्रकोपों के बारे में उपलब्ध जानकारी के अनुसार काली नदी तवाघाट के पास 1846 में तीन दिन तक अवरूद्व हो गई थी, जिसके टूटने से निचले क्षेत्र में व्यापक तबाही हुई थीं। 1857 में नन्दाकिनी नदी भी तीन दिन तक भूस्खलन के मलबे के आ जाने से रूक गई थी। उस पर बने अस्थायी तालाब से अलकनन्दा घाटी में भारी तबाही हुई थी। सन 1868 में बिरही नदी पर झिंझी गांव के निकट भूस्खलन से बने गोड़यार ताल के टूटने से अलकनन्दा घाटी में भीषण तबाही हुई थी। इससे आयी बाढ़ से 73 लोग मारे गए थे। चमोली का लाल सांगा पुल बह गया था तथा जगह–जगह नुकसान हुआ था।

हिमालयन–गजेटियर में एटकिन्सन ने लिखा है कि गोणा ताल, जो कि बिरही नदी में स्थित है, में भूस्खलन से तालाब का आधा पानी बाहर उछल गया था, जिससे अलकनन्दा नदी में बाढ़ आ गई। इससे चमोली में दो लकड़ी के पुल बह गए एवं 73 लोग मारे गए। सन 1893 में बिरही नदी के जलागम में ही गौणा गांव के पास चट्टान टूटने से भयंकर भूस्खलन हुआ और बिरही नदी रूक गई। हेम और गैनेस्सर {1939} नामक दो भू–वैज्ञानिकों के अनुसार सितम्बर 1893 में चट्टान टूटने से बिरही नदी का प्रवाह एक साल तक ठहर गया था जिससे वहां एक विशाल

झील बन गई थी। यह झील 26 अगस्त 1894 को टूटी जिससे पानी के तेज बहाव से निचली घाटी में भारी नुकसान हुआ। भूस्खलन का मलबा, जो कि लाईमस्टोन और डोलामाईटयुक्त था, का ढेर 1.5 वर्ग कि.मी. तक आया, जिसकी ऊंचाई 300 मीटर तक थी। उसका अनुमान 1500000000 क्यूबिक मीटर लगाया गया। तालाब चार किलोमीटर लंबाई एवं सात सौ मीटर चौड़ाई तक फैला था। इसके बाद लंबाई घट कर 2.3 किलोमीटर तथा गहराई 120 से 150 मीटर तक रह गई।

गौणा ताल 26 अगस्त 1894 को टूटा। इससे श्रीनगर में पूरानी बस्ती एवं जगह–जगह गांवों में नुकसान हुआ लेकिन इस बाढ़ में जान और सम्पत्ति का नुकसान नहीं हुआ। क्योंकि पहले से सबको सावधान कर दिया गया था।

आगे भी बदरीनाथ के पास अलकनन्दा में सन 1930 में बाढ़ आने की जानकारी है, जिससे अलकनन्दा का जल स्तर नौ मीटर ऊंचा उठ गया था। इससे कई मकान नष्ट हुए। सन 1957 में धौली नदी की सहायक द्रोणागिरी नाले में ग्लेशियर टूटने से भयंकर बाढ़ आयी और नाले के मलबे से भांप कुण्ड के पास धौली नदी रूक गई जिससे तीन किलोमीटर लम्बाई तक तालाब बन गया। जो बाद में मलबे से भर गया। इसी प्रकार 1967–68 में रैणी गांव के पास भी भूस्खलन हुआ। इससे पुल दब गया। एक तालाब भी बना जो सन 1970 में टूटा।

20 जुलाई 1970 को गंगा की मुख्य धारा अलकनन्दा में प्रलयंकारी बाढ़ आयी। बाढ़ का प्रभाव हनुमान चट्टी के पास से अलकनन्दा मे तथा रैणी में धौली गंगा, ऋषि गंगा के संगम से लेकर 320 किलोमीटर दूर हरिद्वार और पथरी तक पड़ा। अलकनन्दा ने उस दिन गंगा को भी अपनी साद बहाने को मजबूर कर दिया, जिस कारण गंगा नहर साद {सिल्ट} से पट गई। इसी प्रकार 1970 मे भी पिथौरागढ जनपद के धारचूला–तवाघाट में भयंकर तबाही हुयी तथा 1977 में काली और धौली नदियों के संगम पर भयंकर भूस्खलन से 45 लोग मारे गए। खेला से पल–पल्ला के बीच में गांव असुरक्षित हो गए थे। 1978 में भागीरथी, 1979 में कोंथा तथा 1983 में कर्मी के भूस्खलनों ने भारी तबाही मचाई जिसमें अनेक जानें गई। 1998 में माल्पा एवं उखीमठ के पास हुए भूस्खलन से सैकड़ों लोग दब कर मर गए। साल–दर–साल उत्तराखण्ड में यह सिलसिला लगातार बढ़ रहा है, जिससे हजारों लोग प्रभावित हो रहे हैं तथा विकास योजनाओं पर भी इसका बुरा प्रभाव पड़ रहा हैं।

ब्रह्मपुत्र की सहायक धाराओं में भी बाढ़ और भूस्खलन की घटनाओं से ये क्षेत्र त्रस्त हैं। आज स्थिति यह है कि डिब्रूगढ शहर से ब्रह्मपुत्र नदी का तल तीन मीटर ऊँचा है। अभी दो–तीन वर्ष के अंतराल में सिन्धु की सतलज, स्योंक तथा ब्रह्मपुत्र की सियांग नदी में आयी बाढ़ से जन–धन की अपार क्षति हुई।

आज हिमालय सबसे अस्थिर और संवेदनशील बन गया है। ऊपर से इस क्षेत्र में लगातार आने वाले भूकम्पों से इसकी संवेदनशीलता लगातार बढ़ती जा रही है। इस प्रकार हिमालय अपने ही अस्तित्व की रक्षा के लिए याचक जैसा बना हुआ है। जो हिमालय भारतीय उपमहाद्वीप का सिरमौर और उसकी समृद्धि व रक्षा का प्रतीक रहा है, आज उसकी यह हालत हो गई है कि उसकी रक्षा के लिए ही विभिन्न स्तरों पर चिन्ता व्यापने लगी है।

हिमालय की यह दशा केवल प्राकृतिक कारणों से हुई हो, ऐसा नहीं है। मानवकृत

कारण इसके लिए कम दोषी नहीं हैं। एक ओर बढ़ती आबादी तो, दूसरी ओर भोगवादी व्यवस्था के असीमित विस्तार ने हिमालय क्षेत्र के संसाधनों पर मरणान्तक दबाव बनाया है।इस प्रकार प्राकृतिक एवं मानवकृत कारणों से हिमालय में कई गंभीर समस्यायें उजागर हो रही हैं।

हिमानियों का पीछे सरकना

तापमान में बढ़ोत्तरी एवं प्राकृतिक परिस्थितियों के कारण हिमानियां तेजी से पीछे सरक रही हैं। विशेषज्ञों के अनुसार कई छोटी और मध्यम आकार की हिमानियां या तो सामाप्त हो गई हैं या समाप्ति के कागार पर हैं। विशाल हिमानियां भी तेजी से पीछे खिसक रही हैं।

कोलकाता विश्वविद्यालय के डा. एम.के. बंद्योपाध्याय ने उत्तराखण्ड हिमालय की हिमानियां के पीछे सरकने के बारे में अपने अध्ययन में बताया है कि नन्दा देवी नेशनल पार्क में स्थित त्रिशूल हिमानी 10 मीटर एवं भेथार तोली हिमानी 8 मीटर की रफ्तार से पीछे खिसक रही है। इसी प्रकार प्रकार धौली नदी में ईस्ट कामेट 5 मीटर, गगोत्रीं हिमानी 15 मीटर, अलकनन्दा बेसिन में भागीरथी खर्क, सतोपन्थ हिमानी 12 मीटर, गौरी गंगा बेसिन में मिलम हिमानी 13.5 मीटर, पोटिंग हिमानी 5 मीटर तथा संकल्पा हिमानी 23 मीटर प्रतिवर्ष की रफ्तार से पीछे खिसक रही हैं। इसी प्रकार अंतरिक्ष उपयोग केन्द्र के डा. कुलकर्णी जी, जो कि हिमाचल प्रदेश की हिमानियों पर अध्ययन कर रहे हैं, का कहना है कि छोटे और मध्यम आकार के चार सौ छयासठ के लगभग हिमानियां चौकाने वाली दर से सिकुड़ रही हैं।

यह भी जानकारी मिली है कि हिमानियों के सरकने से नये-नये हिम-तालाब बन रहे हैं और तापमान के बढ़ने से उनके टूटने की प्रकिया भी जारी है। इससे इन नदियों पर निर्मित एवं निर्माणाधीन परियोजनाओं पर दुष्प्रभाव पड़ रहा है। इनका स्थानीय आर्थिकी पर भी बुरा प्रभाव पड़ रहा है। हिमानियों एवं हिम तालाबों के बारे में हमारे पास सही जानकारी नहीं है और नहीं अभी तक इसके लिए सरकार की ओर से किसी विभाग को संपूर्ण जिम्मेदारी सौंपी गई है।

मिट्टी की ऊपरी परत का ह्रास

हिमालय में मिट्टी की ऊपरी परत का तेजी से ह्रास हो रहा है। इसके प्राकृतिक एवं मानवकृत कारण हैं। जंगलों का विना, ढालदार भूमि में खेती करना, विकास कार्यों में मृदा निस्तारण की पुष्ट व्यवस्था के अभाव में नये भूस्खलनों एवं भूक्षरण क्षेत्रों के विस्तार से यह स्थिति लगातार बिगड़ती जा रही है,जिससे इस प्रकार की भूमि का दिनों-दिन विस्तार हो रहा है।

भू-क्षरण और भूस्खलन

इसमें मिट्टी की ऊपरी परत का क्षरण तो जिम्मेदार है ही, प्राकृतिक कारणो मे ऋतु किय्रा {विदरिंग} के साथ ही छोटे-बड़े भूकंप भी इस किया को लगातार बढ़ा रहे हैं। इसमें मानवीय गतिविधियां भी कम जिम्मेदार नहीं हैं।

हिमालय क्षेत्र का विकास

हिमालय क्षेत्र के विकास का आधारभूत चिन्तन जल स्रोतों एवं मिट्टी व वनस्पति का संरक्षण एवं विकास होना चाहिए।

हिमालय क्षेत्र में वन क्षेत्रों का विकास होना चाहिए, यह एक सर्वमान्य चिन्तन है ।

हिमालय क्षेत्र में वनों का संरक्षण व विकास जिस तेजी से होगा, देश की समृद्धि का मार्ग उतनी ही तेजी से प्रशस्त हो जायेगा। हिमालय से मिलने वाली नदियों पर अनेक जलाशय, विद्युत परियोजनाएं, सिचाई नहरें बनी हुई हैं और बन रही हैं। इसकी उपयोगिता तभी स्थिर रह सकती है जब हिमालय क्षेत्र में प्राकृतिक स्थिरता हो। प्राकृतिक स्थिरता के लिए प्रकृति का संरक्षण व संवर्द्धन जरूरी हैं। इस परिप्रेक्ष्य में हिमालय में शेष वन क्षेत्र का बचाया जाना और नंगे–वीरान क्षेत्रों को हरा–भरा बनाया जाना आवश्यक है। इसके लिए संपूर्ण हिमालय को जलागम क्षेत्र मान कर कार्य करना होगा और हिमालय के संरक्षण का एक व्यापक व निरन्तर चलने वाला कार्यक्रम बनाना होगा।

हिमालय को हरा–भरा बनाना संरक्षण की पहली शर्त है। इसका कार्यक्रम भी बहुत सूझ–बूझ कर बनाया जाना चाहिए। इस कार्यक्रम के नियोजन व कार्यान्वयन में बहुत अधिक समन्वय स्थापित करना होगा, तभी अपेक्षित लाभ मिल सकेगा।

योजनायें जिन स्थानों व लोगों के लिए बनती हैं उन्हें मानसिक रूप से उसे ग्रहण करने के लिए तैयार करना और अनुभूत आवश्यकता को पूरा करना नियोजन का मुख्य गुण–धर्म होना चाहिए। आज सिद्धान्त वहीं हैं किन्तु व्यवहार सर्वथा अलग है,। अनेक क्षेत्रों में वनीकरण के कार्य से उत्पन्न विवाद इसके प्रमाण हैं। कार्यान्वयन की एक बड़ी कमी यह रही है कि इसमें लोगों को पूछा तक नही जाता ।

उत्तराखण्ड में रचनात्मक कार्यों की संस्था दशोली ग्राम स्वराज्य मण्डल गोपेश्वर ने चिपको आन्दोलन के अगले चरण के रूप में वनीकरण, वन–सम्वर्द्धन और वनोपयोग के मिले–जुले कार्यक्रम आरम्भ किए। इन कार्यक्रमों में इस बात को मुख्य रूप से केन्द्र में रखा गया कि जहां ये कार्यक्रम चलें, वहां के लोगों को इसके लिए मानसिक रूप से तैयार किया जाय, इसे लोगों का कार्यक्रम बनाया जाय।

दशोली ग्राम स्वराज्य मण्डल ने वानिकी को बढ़ाने का एक प्रयोग अलकनन्दा के जलागम के गांवों में किया । वन्य जन्तुओं के द्वारा हमेशा फसलों का नुकसान किया जाता है। इससे ग्रामीण आर्थिक रूप से कठिनाई में पड़ जाते हैं। संस्था ने इसके तहत ग्रामीणों को कृषि रक्षा हेतु प्रेरित किया। इसके अनुसार कृषि भूमि के चारो ओर सुरक्षा दीवाल का निर्माण करवाया गया। इसमें अल्प व्यय पर ग्रामीणों ने श्रम किया,खेतों से कुछ दूरी पर दीवालें बनाई गई और दीवाल व खेत के बीच की खाली जमीन पर घास–चारा और फलदार पौध रोपित किए गए और इन पेड़ों का उपयोग ग्रामीणों की दैनिक आवश्कता के लिए करने को कहा गया। इससे फसल को जंगली जानवरों से बचाया गया और ग्रामीणों को अपने श्रम का मूल्य भी मिला। जिन गांव वालों को कई किलोमीटर दूर जाकर पशुओं के लिए घास व जलौनी लकड़ी लानी पड़ती थी, उन्हें आज अपने खेतों के छोर पर यह उपलब्ध हो रही है। इससे वे प्रसन्न और सन्तुष्ट हैं तथा अनेक ग्राम इस प्रकार के कार्यक्रमों के लिए लालायित हैं।

भारतीय अंतरिक्ष अनुसंधान संगठन अहमदाबाद,भारतीय विज्ञान संस्थान बेंगलूर,योजना आयोग भारत सरकार सहित अनेक संगठनों तथा संस्थाओं ने दशोली ग्राम स्वराज्य मंडल के पर्यावरण संवर्द्धन के कार्यो तथा उनके प्रभावों पर अध्ययन किया तथा उस पर सकारात्मक टिप्पड़ियां की है। भारतीय विज्ञान संस्थान के प्रख्यात पर्यावरण विज्ञानी प्रो.माधव गाडगिल के निर्देशन में किए गए शोध कार्य में संस्था व ग्रामीणों के माध्यम से वनीकरण को

उत्साहवर्द्धक बताया। अपनी रिपोर्ट में उन्होंने बताया कि दशोली ग्राम स्वराज्य मंडल द्वारा संचालित किए गए वनीकरण कार्यक्रमों में पौधों का जीवित प्रतिशत 68 से 88 के बीच पाया गया। इसके लिए विज्ञानियों ने लोक भागीदारी व लोक चेतना को प्रमुख कारण बताया।

योजना आयोग के सदस्य प्रों. हनुमन्त राव ने अपने 'अनुभवों से सीख' अध्ययन में टिप्पणी की है कि "दशोली ग्राम स्वराज्य मंडल" ने सहभागिता की एक पद्वति उपलब्ध करायी है। इसका नेतृत्व उत्साह से परिपूर्ण है। वे परिस्थितिकी विकास,परियोजनाओं के निर्माता, प्रेरक, शिक्षक, कियान्वयन–कर्ता सभी कुछ है। सर्मपण के गुणों से भरे वे लोगों में आत्म विश्वास और उत्साह पैदा करते हैं। चमोली जिले में दशोली ग्राम स्वराज्य मंडल के नेतृत्व में उच्च स्तर की जागरूकता है तथा वे परिस्थितिकीय विकास कार्यक्रम को आन्दोलन के रूप में चला रहे हैं। जिले के अधिकारियों को विभागीय कार्यों के संचालन के लिए लोगों की इस जागरूकता और भागीदारी की भावना का लाभ उठाना चाहिए"।

भारत सरकार के प्रधानमंत्री की विज्ञान सलाहकार परिशद ने भी संस्था के पर्यावरण संवर्द्धन शिविरों का अध्ययन करने के बाद अपनी रिपोर्ट में लिखा है– " दशोली ग्राम स्वराज्य मंडल गढ़वाल हिमालय की अलकनन्दा घाटी में पारिस्थितिकीय पुनर्स्थापना के कार्यो में निश्ठा व समर्पण भाव से जुटा हुआ है। महिलाओं और हरिजनों सहित ग्रामीणों को अपने संसाधनों के बेहतर उपयोग की योजनाओं और कार्यक्रमों सम्मिलित करने में वह नेतृत्वकारी भूमिका में रहा है। संस्था के परिस्थितिकीय विकास शिविरों में महिलाओं में जबरदस्त आत्म विश्वास जगाया है तथा विकास कार्यों में उनकी सकिय भागीदारी की आश्चर्यजनक पहल हुई है। लोगों में इतनी जागरूकता आ गई है कि वे वनों के विनाश और मृदा क्षरण के दुष्परिणाम को समझते हैं तथा वनों की आग, वाहनों के धुएं आदि से होने वाले प्रदूषण के खतरों की बातें करने लगे हैं। संस्था ने वृक्षारोपण की अच्छी तकनीकी व वृक्ष प्रजाति के चयन की उत्कृष्ट स्थिति बना दी है। संस्था के कार्यो ने लोगों मुख्यतः महिलाओं और विद्यार्थियों की जागरूक व सकिय भागीदारी द्वारा कार्यक्रमों को धरातल पर उतारने का अभिनव प्रयोग किया है।

भारतीय अंतरिक्ष अनुसंधान संगठन ने अपने अध्ययन में कहा है कि दक्षिण–पश्चिम में निंगोल गाड़ तथा उत्तर पूर्व में कल्प–गंगा के बीच के 53200 हैक्टेयर क्षेत्र में सन 1972 में जहां कुल वानस्पतिक आवरण 31901 हैक्टेयर पर था, वह सन 1991 में बढ़कर 33755 हैक्टेयर हो गया है। विगत 20 सालों में इस वानस्पतिक आवरण में 5. 8 प्रतिशत की वृद्दि हुई। यही नहीं वनावरण सघनता भी बढ़ी है। ये क्षेत्र दशोली ग्राम स्वराज्य मंडल के पर्यावरण संवर्द्धन शिविरों वाले अलकनन्दा, गरूड़गंगा, पातालगंगा, मैनागाड़, कल्पगंगा, बालखिला, निगोल आदि के तटवर्ती व जलागम क्षेत्र हैं।

संगठन ने अपनी रिपोर्ट में कहा है कि इन क्षेत्रों में सन् 1982 से 1991 के बीच 4396 हैक्टेयर भूमि में वानस्पतिक आवरण उभरा है और सन 1972 से 1991 के बीच 5113 हैक्टेयर भूमि में वनों का विस्तार हुआ है। यह क्षेत्र आरक्षित वन सीमा से बाहर मैनागाड़ व निंगोल गाड़ के बीच का है। अध्ययन में यह भी कहा गया है कि 1736 हैक्टेयर वन,जिसमें वन सघनता 40 प्रतिषत से कम है थी, सघन वनों में परिवर्तित हो गए हैं। मैनागाड़, अमृतगंगा, कल्पगंगा तथा

निंगोल गाड़ के जलागम क्षेत्रों में यह सघनता स्पश्ट परिलक्षित हुई है।

आगे का रास्ता

अब जब कि यह प्रायः तय सा है कि प्राकृतिक संसाधनों की स्थिति संभाले बिना कोई चारा नहीं है और सरकारों तथा जन–पक्षों की ओर से इस दिशा में बढ़ने की बातें की जा रही हैं तो ऐसी व्यावहारिक कार्य–योजनायें बनानी होंगी जो परिणाममूलक हों और वास्तविक तौर पर अवक्रमित व बंजर भूमि पर हरियाली का आवरण तैयार कर सकें।

इसमें सबसे पहला कार्य होना चाहिए नियमों–कानूनों को इस दिशा में सहयोगी बनाने तथा कार्यक्रमों को सरकार प्रणीत कार्यक्रमों के बजाय लोक कार्यक्रम के रूप में आगे बढ़ाने का। इसके लिए विधायी प्राविधानों की भी समीक्षा की आवश्यकता है और सरकारों के स्तर पर मानसिकता में बदलाव भी जरूरी है।

लोक–कार्यक्रम

हमारे अनुभव हैं कि लोगों को संसाधनों के संरक्षण के कार्यक्रम बनाने में जुटाया जाना चाहिए। इस संबंधी उनकी क्षमता का विकास करने का दायित्व सरकार ले। लोग अपने परिवेश, परम्परा और आवश्यकता के अनुरूप कार्य योजनायें बनायें तथा व्यवस्था–तंत्र आवश्यकतानुसार उनकी मदद करे। उन्हें विज्ञान व तकनीकी के सरल व सस्ते ऐसे विकल्प उपलब्ध कराये जॉय जिन्हें वे आसानी से ग्रहण व आत्मसात कर सकें।

इस प्रयोग से लोगों का सुसुप्त मनोबल जाग्रत होगा, उनका पुरूषार्थ और स्वाभिमान जागेगा तथा एक उद्देश्यपूर्ण प्रयास की दिशा में बढ़ने की गौरव की अनुभूति उन्हें होगी। जबकि आज यही कार्य सरकारी तंत्र के माध्यम से उन्हीं के द्वारा होता है लेकिन उसमें उनकी हैसियत मजदूर, दल–नायक या ठेकेदार से अधिक नहीं होती। इसके अलावा वर्तमान सरकारी कार्य–संस्कृति में लोक संगठनों की उपेक्षा एक सामान्य बात है।

प्रत्येक गांव का अपना वन

हिमालय क्षेत्र के अलावा भारत के अन्य पर्वतीय व वन क्षेत्रों को जोड़ें तो करीब दस करोड़ लोग वनों के बीच निवास करते हैं। उनकी जीविका का साठ से अस्सी प्रतिशत वनों से प्राप्त होता है। वहीं देश की चालीस प्रतिशत जनसंख्या खाना पकाने के लिए ईंधन के लिए कमोवेश वनों पर ही निर्भर है। कोई भी कानून उन्हें चूल्हा जलाने के ईंधन जुटाने से नहीं रोक सकता। इसके अलावा पशुओं की लगातार बढ़ती संख्या के बोझ एक बड़ा हिस्सा वनों पर अवलम्बित है। इसलिए वनों का क्षेत्र और सघनता बढ़ाये बिना इन जरूरतों को पूरा करने का दूसरा उपाय नहीं है।

इस पूरी स्थिति पर गहन और व्यावहारिक प्रयोग करने के बाद हमारा निष्कर्ष है कि वनों को अपनी आवश्यकता की पूर्ति में सक्षम बनाना है तो दो सदी पहले की ग्रामीण व्यवस्था को वर्तमान संदर्भ में व्यवहार में उतारना होगा। इस लिए हमारी कल्पना है कि प्रत्येक ग्राम का अपना वन हो।

यहां यह स्पष्ट करना जरूरी है कि प्रत्येक गांव का अपना वन कल्पना वर्तमान सरकारी पंचायती राज की तर्ज पर ऊपर से थोपी जैसी नहीं होगी। बल्कि लोगों के अपने विचार और इच्छा से उनके अपने प्रयासों से तैयार की गयी होगी।

हमारा मानना है कि गांवों, मुख्य रूप से पर्वतीय और वन–क्षेत्रों, में लोगों की वनों पर अधिकतम निर्भरता होने के कारण वे अपने वनों के ह्रास से होने वाले त्रासों को झेल रहे हैं तथा उनकी सहज जीवनचर्या अत्यन्त दूभर हो गयी है। अतःउनके सामने अपनी जरूरतें पूरी करने के लिए अपना वन बनाने का अवसर उपलब्ध कराया जायेगा और उसके लिए, भूमि, तकनीकी व वित्तीय संसाधन आदि उपलब्ध कराये जायेंगे तो वे निश्चित तौर पर उसे अपनायेंगे।

ग्राम वन की हमारी कल्पना है कि प्रत्येक गांव का अपना वन हो जिसके लिए राजस्व और जहां उपलब्ध न हो, आरक्षित वनों से भी भूमि लेकर ग्राम वन बनाये जाने चाहिए तथा उनके संचालन के लिए वन पंचायत गठित की जानी चाहिए। वन पंचायत को सरकारी हस्तक्षेत से मुक्त रखा जाना चाहिए। उसके सदस्य केवल वे ही लोग बनाये जायें जो उस गांव की सीमा में कृषि, पशुपालन, उद्यान अथवा इनसे संबन्धित ग्रामीण कार्यों से जुड़े हों। महिलाओ की बहुलता इनमें अनिवार्य बनायी जाय तथा यह प्राविधान रखा जाय कि जो इन व्यवसायों को अथवा गांव की सीमा से बाहर अपना कार्य–क्षेत्र बना लें, वे स्वतः ही वन पंचायत की सदस्यता से च्युत हो जायेंगे। वन पंचायत को ग्राम वन की योजनायें बनाने, क्रियान्वित करने तथा उसके लाभ वितरण के सर्वोच्च अधिकार हों। सरकारी तंत्र केवल तकनीकी मार्ग दर्शन,संसाधन उपलब्ध कराने, वातावरण बनाने तथा लोक–क्षमता के विकास तक सीमित रहे।

इसके लिए प्रशासनिक अहंकार, सत्ता के अभिमान और कानून की बंदिशों से ऊपर उठने की आवश्यकता होगी । इसी के अनुरूप वन पंचायत नियमावली को ढालना होगा और पंचायती राज में ऐसे प्राविधान करने होंगे कि गांव के संसाधनों का बहुमुखी विकास हो। ग्रामीण संस्थायें अधिकारों की टकराहट से बचें और अपने कर्तव्यों पर आधारित सामाजिक अवधारणा को पुष्ट कर सकें। जब विकास की अवधारणा के मूल में संसाधनों के विकास को स्थापित करना होगा, तभी हम प्राकृतिक संसाधनों के ह्रास से उत्पन्न चुनौतियों का सामना करने में सफल हो पायेंगे। हिमालय को हरा–भरा और वहां के वासियों को समृद्ध बना सकेंगे।

हिमालय क्षेत्र अपनी विकट भौगोलिक स्थिति के कारण सहज जीवन यापन के लिए दुष्कर है, इस ओर नियोजनकर्ताओं का ध्यान गया है किन्तु नियोजन और कार्यान्वयन में व्याप्त भारी विषमता के कारण अपेक्षित उपलब्धि नहीं हो पायी है, जिससे हिमालय में जल, मिट्टी और वन संपदा की तरह मानव संसाधन के मैदानों की ओर पलायन का सिलसिला चल रहा है। इस बात को ध्यान में रखा जाना जरूरी है कि किसी भी क्षेत्र के निवासी ही उस क्षेत्र के मौलिक विकास में भागीदार हो सकते हैं। इसके लिए जरूरी है कि हिमालय के विकास व नियोजन की प्रक्रिया में हिमालयवासियों का एक उत्तरदायी संवर्ग तैयार किया जाय।

यातायात और संचार के संदर्भ में यह किया जा सकता है कि हर ग्राम को ऐसे पैदल मार्ग से जोड़ा जाय जिन्हें धीरे–धीरे मोटर वाहनों के लिए तैयार किया जा सके। हिमालय क्षेत्र में बड़े वाहनों के मार्गों का मोह छोड़ कर छोटे हल्के वाहनों के मार्गों को बढ़ाने का कार्यक्रम तैयार करना होगा और मार्गों का निर्माण इस ढंग से करना होगा कि वह भूक्षरण और भूस्खलन का कारण न बने। इसके लिए कम चौड़ी किन्तु पक्की सड़कों का निर्माण किया जाना चाहिए।

हिमालय क्षेत्र अपनी असीम सम्पदा से राष्ट्र को समृद्धि दे सकता है, किन्तु नियोजन में दूरदर्शिता बरतनी होगी। हिमालय की जल–सम्पदा का उपयोग सिंचाई और ऊर्जा के निर्माण में किया जा सकता है, किन्तु इसमें सावधानी यह रखनी होगी कि इसके उपयोग से अन्य संपत्ति का विनाश न हो।

अकेले उत्तराखण्ड में जल शक्ति के परम्परागत उपयोग से हजारों पनचक्कियां चल रही हैं। उन्हें यदि आधुनिकतम तकनीकी से परिष्कृत व सज्जित किया जाय तो इन्हीं के उपयोग से हजारों मेगावाट विद्युत उत्पादन हो सकता है जिससे पर्यावरण पर भी कोई दुष्प्रभाव नहीं पड़ेगा और बिजली उत्पादन का लक्ष्य भी पूरा हो पायेगा। नदियों पर छोटी–छोटी पनबिजली परियोजनाओं की एक श्रृंखला स्थापित की जा सकती है जो विकेन्द्रीकृत नियोजन प्रणाली को मजबूत आधार दे सकती है। विद्युत–उत्पादन को हिमालय के लघु–उद्योग के रूप में विकसित किया जा सकता है। इसमें जिनकी भूमि और संपत्ति प्रभावित हो रही है,उनको साथ लेकर योजना में कार्यरत कारीगर और आर्थिक निवेश करने वालों की साझीदारी पर चलाया जाय जिससे स्थानीय लोगों को लाभकारी रोजगार और राष्ट्र को महत्वपूर्ण कच्चा माल ऊर्जा के रूप में मिल सकता है। इससे किसी बड़े प्रलय का खतरा भी नहीं होगा और स्थानीय लोगों को अपने परिवेश से कटने का क्षोभ भी नहीं होगा।

यह सोचनीय स्थिति है कि हिमालय क्षेत्र, जो कि पानी का सबसे बड़ा उत्पादक है, में सिंचाई सुविधाओं का विस्तार बहुत उत्साहजनक नहीं है। हिमालय की नदियों, नालों और निर्जन घाटियों में छोटे–छोटे अवरोधक बना कर जल–संग्रह किया जा सकता है और उसका उपयोग सिंचाई के लिए किया जा सकता है। इस ओर नियोजन प्रक्रिया को मोड़ना होगा।

हिमालय पर्वत जल, वायु, मृदा एवं वनस्पति के जनक के रूप में महत्वपूर्ण होने के साथ ही देश के मौसम का नियंत्रक भी माना गया है।यहां से निकलने वाली नदियां भारत के मैदानों की समृद्धि का आधार देती है। इसलिए पूरे देश के नियोजन का केन्द्र बिन्दु, हिमालय का संरक्षण मानते हुए चलना जरूरी है। इस पर अति प्राथमिकता के आधार पर कार्यवाही की जानी चाहिए।

इस प्रकार हम देखते हैं कि हिमालय की स्थिति अत्याधिक खराब बनी हुई है और अब हमें बिना कोई देर किए इसे न केवल अधिक खराब होने से रोकना है, अपितु पूरानी खराबी को भी दूर करने के वहुविध प्रयास भुारू कर देने है। इस कार्य में जहां आम जन को वि वासपूर्ण जिम्मेदारी दी जानी होगी तो दूसरी और व्यवस्था को उसके ईमानदार सहयोग के रूप में तत्पर रहना होगा। इस प्रयास में हमारे विज्ञानी भी महत्वपूर्ण भूमिका निभा सकते हैं।

अपने विज्ञानियों जिनके बूते देश ने विज्ञान व प्रौद्योगिकी की नई ऊँचाईयों को छूने में सफलता प्राप्त की है, पर हम बहुत भरोसा करते है। देश में औद्योगिक क्रान्ति, हरित–क्रान्ति, श्वेत–क्रान्ति आदि के प्रणेता हमारे वैज्ञानिक ही हैं। उन्हीं के अथक परिश्रम से हम विपरीत स्थितियों को अपने अनुकूल ढालने में सफल हो पाये हैं। मेरा अनुरोध है कि संकट में पड़े हिमालय की स्थिति में सुधार लाने के लिए जियोमेटिक्स के उपलब्ध संसाधनों का इस दिशा में और बेहतर उपयोग कर हिमालय के अस्तित्व के लिए खतरा बनी विकास की वर्तमान अवधारणा को बदलने तथा वीरान होते जंगलों के साथ ही लोगों, खासकर ग्रामीणों, गरीबों की मौलिक जरूरतों को

पूरा करने के लिए हरियाली जैसे अभियान को विज्ञान व प्रौद्योगिकी की नवीनतम उपलब्धियों द्वारा क्रियान्वित करने की ओर प्रवृत्त हो यह मेरा आग्रह है।

एक बार मैं पुनः आयोजको का आभार व्यक्त करते हुए कृतज्ञता ज्ञापित करता हूँ तथा आप सबको हार्दिक धन्यवाद देता हूँ।

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IMPACT OF CLIMATE CHANGE ON AGRICULTURE

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1. Climate Change

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. (Sathaye et al., 2006). The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities. Human activities have increased the atmospheric concentrations of greenhouse gases and aerosols since the pre-industrial era. Atmospheric concentration of CO_2 has increased form 280 ppm for the period 1000–1750 (pre-industrial era) to 379 ppm in year 2005. The increases in atmospheric concentration of Ch_4 are from 700 ppb during pre-industrial era to 1,774 ppb in 2005 and that for N_2O is from 270 ppb to 319 ppb. The weather indicators of global change include increased global mean surface temperature; decreased diurnal surface temperature range; increased continental precipitation (Northern hemisphere), increased heavy precipitation events and increased frequency and severity of drought.

The fourth assessment report of International Panel for Climate Change (IPCC, 2007a), predicts the surface air warming: 1.8°C to 4.0°C (under different scenarios, see Figure 1), Sea Level Rise of 0.18 – 0.59 m, high frequency in heat waves and heavy precipitation events and Increases in the amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100).

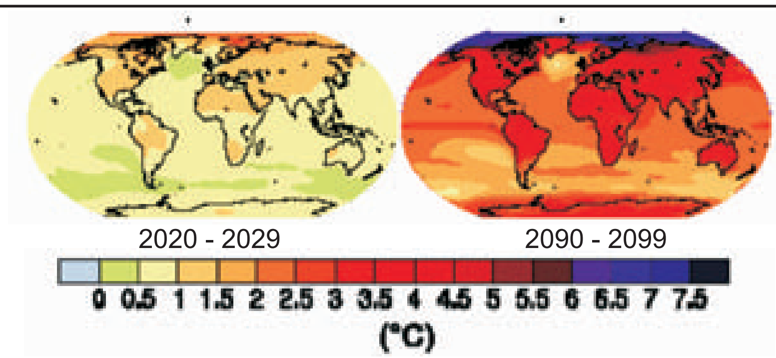

Figure 1.1 Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999 based on the SRES A1B scenario. (Source: IPCC)

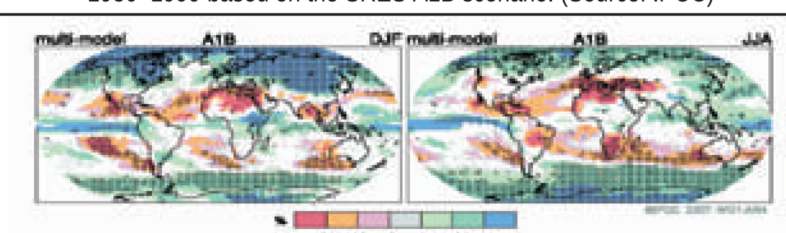

Figure 1.2 Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999 based on the SRES A1B scenario. (Source: IPCC)

Indian Institute of Tropical Meteorology (IITM) has used regional climate model PRECIS (Providing Regional Climates for Impacts Studies) to give detailed climate projections for Indian region (Rupa Kumar et al., 2006). The projections of PRECIS includes: i) An annual mean surface temperature rise by the end of century, ranging from 3 to 5°C under A2 scenario and 2.5 to 4°C under B2 scenario, with warming more pronounced in the northern parts of India, ii) A 20% rise in all India summer monsoon rainfall and further rise in rainfall is projected over all states except Punjab, Rajasthan and Tamil Nadu, which show a slight decrease, iii) Extremes in maximum and minimum temperatures are also expected to increase and similarly extreme precipitation also shows substantial increases, particularly over the west coast of India and west central India.

2. Impact of Climate Change on Agriculture

Agriculture is an economic activity that is highly dependent upon weather and climate in order to produce the food and fibre necessary to sustain human life. Hence it is obvious that, agriculture is deemed to be vulnerable to climate variability and change. According to FAO, climate change over the long-term, in particular global warming, can hit agriculture in many ways. Some of them are listed as follows:

- The overall predictability of weather and climate would decrease, making planning of farm operations more difficult.
- Climate variability might increase, putting additional stress on fragile farming systems.
- Climate extremes - which are almost impossible to plan for - might become more frequent.
- The sea level would rise, threatening valuable coastal agricultural land, particularly in low-lying small islands.
- Biological diversity would be reduced in some of the world's most fragile environments, such as mangroves and tropical forests.
- Climatic and agro-ecological zones would shift, forcing farmers to adapt, as well as threatening natural vegetation and fauna.
- The current imbalance of food production between cool and temperate regions and tropical and subtropical regions could worsen.
- Distribution and quantities of fish and seafoods could change dramatically, wreaking havoc in established national fishery activities.
- Pests and vector-borne diseases would spread into areas where they were previously unknown.

According to IPCC (IPCC, 2007b) crop productivity is projected to increase slightly at mid- to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger.

Various workers have utilized crop simulation models and different climate projection scenarios to understand impact of climate change on yields of specific crops and at different regions of the world. Table 1 summarizes some of these studies. In many cases the GCM model projections have been used along with various downscaling procedures such as statistical downscaling (Holden et al., 2003) or using weather generators (Semenov, 2007; Zhang & Liu, 2005). Impact assessment models are either empirical models (Lobel, 2007) or crop simulation models, like DSSAT (Hoden et al., 2003), WEPP (Zhang & Liu, 2005), EPIC (Izaurralde et al. 2003), or others. Among all the crops, wheat is the most studied crop for climate change impact assessment.

In one detailed study Lobell (2007) working on yields of three crops (rice, wheat and maize) of different nations and eleven climate projection models found that, there is negative impact projected increase of average temperature. However impact due to the change in daily temperature range was comparatively small on crop yields.

Table 1. A few examples of the studies carried out to understand the impact of climate change on crop yield.

Authors	Crops Studied	Area	Climate Data Used	Impact Assessment Model	Salient findings
Hoden et al., 2003	Barley & potato	Ireland	Statistical downscaling of HADCM3 for BL, 2055 & 2075	DSSAT Simulation model	Barley yield will increase, potato yield will decrease
Lobell, 2007	Wheat, rice & maize	Different nations (incl.India)	11 climate model projections	Regression model with Temp. range (DTR) & avg. temp (Tavg)	Impacts of DTR changes on yields were generally small; Negative impact of projected warming of Tavg
Semenov, 2007	Wheat	UK	UKCIP02-based scenarios downscaled using LARS-WG weather generator	Crop simulation model (Sirius) including the effects of extreme weather events.	Relative impact on yield due to drought stress is smaller as wheat matures early in a warmer climate avoiding summer heat and drought stress.
Wolf & Oijen, 2002	Potato	Europe	Hadley Centre's unified model (HADCM2)	LPOTCO simulation model	Rainfed potato tuber yields in the EU slightly decreased with temperature rise and with increasing radiation; considerably increased with increasing rainfall and Co_2, and slightly decreased with increasing O_3.
Lobell et al., 2006	Perennial Crops	California	Six climate models	Statistical models with temperature & precipitation	Projected losses range from 0 to >40% depending on the crop and the trajectory of climate change
Zhang & Liu, 2005	Wheat & Maize	Loess Plateau of China.	3 Emission scenarios of HadCM3, downscaling by weather generator (CLIGEN)	Water Erosion Prediction Project (WEPP) model	Increases of 15 to 44% for wheat grain yield, 40 to 58% for maize yield
Izaurralde et al. 2003	Soybean, Corn & Wheat	United Sates	HadCM2 GCM	EPIC agro ecosystem model	Yields of irrigated corn and wheat increases in both 2030 and 2095

3. Climate Change & Indian Agriculture

3.1 Agricultural Situation in India

Agriculture is one of the major sectors of Indian economy. Along with its allied sectors, agriculture contributes around 18.3 % (2005-06) to the Gross Domestic Product. Agriculture provides 57% of India's total employment and 73% of India's total rural employment. With a net area sown of around 142 Mha, the total food grain production of the country is 201.56 Mt (avg. of 5 years). Indian agriculture has a remarkable position in the world scenario. India is home to 23.3% of the world's farming population. It is 2nd in World's wheat and rice

Production and occupies 1st position in pulses production. It also occupies highest irrigated area (55 Mha) in the world

However, the average annual growth rate of Agricultural & Allied sector during 10th Five Year Plan was only 2.3 % compared to the growth in GDP being.7.6%. Indian agriculture is limited by many problems. These include (Data Source: Survey of Indian Economy, 2007, Agrl. Statistics at a Glance, 2006):

- Low crop yield: If we compare the statistics of the year 2004-05, India's average rice yield was 2.9 t/ha compared to Japan's 6.4 t/ha. Similarly wheat yield was 2.71 t/ha (UK: 7.77); Maize 1.18 (US: 9.15); Cotton 4.64 (China: 11.10); Oilseeds 0.86 (China: 2.5)
- Indian Agriculture is highly dependent on monsoon (Net Irrigated Area/ Net Sown Area being only 38.8%)
- Very low Average Operational Holding Size of 1.32 ha, which inhibits technological advancements in agricultural practices.
- Low Cropping Intensity of around 135.3 %
- Low Fertilizer Consumption. The average annual fertilizer consumption of India is only 92.9 kg/ha, while that of Japan is around 249.3 kg/ha.

Thus because of low technological inputs in agriculture and high dependency on monsoon rainfall, Indian agriculture is very much prone to impact of climate change.

India grows large number of crops, the important of them being, Rice, Wheat, Maize, Coarse cereals (Bajra, Jowar and others), pulses (Tur, Gram and others), Groundnut, Rapeseed & mustard, Soybean, Sunflower, Sugarcane, Cotton, Jute & mesta, Potato and Onion. Among the foodgrains rice occupies 1st position with around 42.5 per cent contribution to the production, while wheat contributes 34.6 per cent. Hence, rice and wheat are two important crops which need to be studied with respect to climate change.

3.2 Studies on Impact of Climate Change

Agricultural productivity, in India, is sensitive to two broad classes of climate-induced effects(1) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations, and (2) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases (Bhadwal et al., 2003).

There have been a few studies in India to understand the impact of climate change on individual crop yields, only considering the temperature and CO_2 rise effect (Table 2). Both positive and negative impacts of climate change on crop yield have been shown. It seems the overall effect of climate change on agricultural production is dependent upon crop type, location, magnitude of the warming and direction and magnitude of precipitation change, and crop models used fro impact assessment. The CO_2 fertilisation is also an important factor, which needs to be considered to study the impact.

The Energy and Resources Institute (TERI) has generated the global change vulnerability map for agriculture in India as a function of three componentsexposure, sensitivity, and adaptive capacity (TERI, 2003).

3.3. Gap Areas

Though the above studies and few others provide some insight into the impact of climate change on crop production, these studies are limited by following gap areas.

Indian Agriculture is highly dependent on monsoon (Net Irrigated Area/ Net Sown Area being only 38.8%)

Detailed regional projections (RCM) have not been used.

No work has considered precipitation changes and other extreme climate events.

Loss of agricultural area due to sea-level rise has not been considered.

No study on understanding the impact on agricultural system productivity under different agro-ecological conditions in India.

Very few information available for suggesting adaptation measures.

Table 2. Example of some Indian studies to understand the impact of Climate Change on crop productivity

Crop	Model	Inference	Authors
Soybean	CROPGRO	Combined effect of doubled CO_2 and anticipated thermal stress (likely by middle of the next century) is about 36% increase in yield	Lall et al., 1999
Rice	CERES-Rice	Rice yields increased by 1.0 to 16.8 % in pessimistic scenario and by 3.5 33.8 % in optimistic scenario	Aggarwal & Mall 2002
Wheat	WTGROWS	The shift of iso-yield lines of wheat northward at 425 ppm CO_2 and 20 rise in temperature	Kalra et al., 2003
Soybean	CROPGRO	There was a decrease (ranging between 10 and 20 %) in yield in all three future scenarios when the effect of rise in surface air temperature at the time of doubling of Co_2 concentration was considered.	Mall et al, 2004
Wheat	CropSyst	Wheat yield reduction (in 2070-2099 vis-à-vis 1961-1990) by 12.1%, considering IPCC A2 scenario	Ray, 2008

4. Conclusions

The impact of climate change on agriculture is imminent. However, there are uncertainties in quantifying the impact. The inaccuracies are associated with uncertainties in climate change projections and impact assessment model errors. According to Mall et al (2004), while agriculture may benefit from carbon dioxide fertilisation and an increased water use efficiency of some plants at higher atmospheric CO2 concentrations, these positive effects are likely to be negated due to thermal and water stress conditions associated with climate change. Considering the requirement of detailed study on climate change impact assessment, Space Applications Centre has initiated a programme called PRACRITI (PRogrAmme on Climate change Research In Terrestrial envIronment), to explore the role of earth observation data for climate change studies (SAC, 2008).

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CLIMATE CHANGE AND SEA-LEVEL RISE: IMPLICATIONS TO COASTAL ZONES

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Human activities in this modern era overwhelm the natural regulatory mechanism of the Earth's environment leading to climate change. The global average temperature has increased by 0.8°C over the past century, out of which the past three decades alone recorded a rise of 0.6°C, at the rate of 0.2°C per decade as greenhouse gases became the dominant climate forcing in recent decades (Hansen et al. 2006; IPCC 2007; Rosenzweig et al. 2008; Wood 2008). Arctic ice sheet is rapidly retreating and if this trend continues, scientists fear that the polar bear population would decrease by two-thirds by mid-century (Courtland 2008). Recent studies indicated that the climate warming has resulted in a significant upward shift in the forest plant species optimum elevation averaging 29 m per decade (Lenoir et al. 2008). The warming is also worsening the public health problems such as the alarming spread of malaria in Africa and elsewhere, and the increasing risk of respiratory diseases and metabolic disorders owing to poor air quality and rising temperatures (Hoyle 2008). Even the steep increase in food prices that is currently witnessed all over the world is probably the first genuinely global effect of greenhouse gas warming, as the demand for supplies is aggravated by the drought in food-producing regions (Parry et al. 2008)..

Perhaps the most commonly recognized impact of global warming is the eustatic rise in sea level due to thermal expansion of seawater and addition of ice-melt water. Already there are evidences of large-scale ice melt in the three major ice repositories of the world – the Arctic, the Greenland and the Antarctic regions. It is believed that even if the global temperatures are leveled off at this stage (which are most unlikely given the continued increase in greenhouse gas emissions into the atmosphere), the sea level will continue to rise over the 21 century (Meehl et al. 2005). The intergovernmental Panel on Climate Change has predicted in 2007 that the global sea level will rise by about 18 to 59 cm by 2100 (IPCC 2007). However, many feel that there are inconsistencies in the IPCC estimates as the more recent studies based on a new model allowing accurate construction of sea levels over the past 2000 years suggest that the melting of glaciers, disappearing of ice sheets and warming water could lift the sea level by as much as 1.5 m by the end of this century (Strohecker 2008). The most direct impact of the sea-level rise is on the coastal zones around the world. The coastal zones, by and large, are highly resourceful and densely populated. These narrow transitional zones between the continents and oceans, though constitute just about 10% of the land area, sustain as much as 60% of the world's population. Since these narrow zones that fringe the world oceans are low-lying, the sea-level rise would lead to accelerated erosion and shoreline retreat, besides leading to saltwater intrusion into coastal groundwater aquifers, inundation of wetlands and estuaries, and threatening historic and cultural resources as well as infrastructure (Pendleton et al. 2004). The increased sea-surface temperature would also result in frequent and intensified cyclonic activity and associated storm surges affecting the coastal zones. The fact that there were at least three major cyclones of unprecedented intensity (Orissa super cyclone - October 26-29, 1999; Gonu - June 3-7, 2007 Gonu; and Sidr -

November 9-16, 2007) during the past 10 years in the Indian Ocean is perhaps a glaring example of the climate change.

As the modern era is witnessing the loss of biodiversity with many endangered species of plants and animals, the rising sea level is creating what are called ‘endangered nations’. This is particularly true in the case of some island countries such as Tuvalu, Maldives, etc., which are barely 2 m above the sea level. Millions of people in low-lying regions of many other countries including Bangladesh, China, and Vietnam face the danger of being displaced. The situation in India is no different. Many parts of Andaman and Nicobar Islands and especially the Lakshadeep Islands are at peril. Even in mainland India, many of our major cities are in the coastal regions. Besides, densely populated river deltas, especially along our eastern seaboard are at risk of rising sea levels. Studies based on the analysis of long-term tide-gauge data from various stations along the Indian coastal regions have indicated that the sea level is rising (Unnikrishnan et al. 2006).

The Space Applications Centre (SAC/ISRO), has taken up a major project funded by the Ministry of Environments and Forests, Govt. of India, on coastal zone studies aimed at analyzing among other things the impact of predicted sea-level rise. SAC has involved many universities and institutes in the country to collaborate in this endeavour. Andhra University, as one of such collaborating agencies, has taken up the study on Andhra Pradesh (AP) coast, which is a densely populated region with more than 6.5 million people (2001 census) living within 5-m-elevation above the sea level including the port cities of Visakhapatnam, Kakinada and Machilipatnam. These studies based on remote sensing techniques revealed large-scale erosion along AP coast even along the river deltas which are normally the major depositional zones. The shoreline shifted landward due to erosion at a number of locations over a combined length of 424 km accounting for a loss of 93 km^2 coastal area while the land gained by deposition was only 57 km^2 during a 16-year period between 1990 and 2006 along the 1030-km-long AP coast. What is more significant is the pronounced erosion rather than deposition in the 300-km-long Krishna-Godavari delta front coast in the state, during the recent decades as evident from the photographs shown in Fig. 1. The land lost by erosion in these deltas between 1990 and 2006 was about 62 km^2 as against 41 km^2 of land gained by deposition resulting in a net loss of 21 km^2 at an average rate of more than 131 ha. per year.

The impact of the rising sea level would be variable depending upon the characteristics of the coast such as geomorphology and slope and the variability of marine processes such as waves and tides along the coast. The significance of coastal geomorphology and coastal slope as the two most important factors in the response of a coastal zone to sea-level rise was amply demonstrated by the 2004-tsunami that devastated the Indian coasts besides many other nations around Indian Ocean. Several studies made along the east coast of India indicated the role of geomorphology and coastal slope in tsunami impact. Ramanamurthy et al. (2005) observed that the worst affected Nagapattinam area in the southern state of Tamil Nadu along the east coast of India had longer penetration of tsunami inland due to gentle slope of the coastland. Chadda et al. (2005) noted that the coastal morphology made large difference in loss of life as the low swales behind shore-parallel dune ridges claimed several lives due to lateral flows from tidal inlets or breaches in dune ridges. Banerjee (2005) observed that the landforms of the coastal zone have relation with tsunami devastation. The overall inundation limit decreased along the shore from south to north in the state of Tamil Nadu, from a maximum of about 800 m in the southern part to about 160 m in the northern parts (Chadha et al. 2005). However, the tsunami inundation limit has significantly increased again to 700-800m much further northward in the Krishna-Godavari delta region in the central part of AP state, where number of deaths were also reported, owing to extremely gentle slope of the area (Nageswara Rao et al. 2007).

In this background, identification of vulnerable zones of the coast is needed for a proper coastal zone management. We made a coastal vulnerability assessment aimed at identifying the degree of vulnerability of different segments of AP coast. We considered five physical variables namely (1) coastal geomorphology, (2) coastal slope, (3) shoreline change history, (4) mean spring tide range, and (5) significant wave height for coastal vulnerability assessment of the AP coast. Depending upon the nature of each of these variables vulnerability ranks ranging from 1 to 5 were assigned to different segments of the coast, with rank 1 representing very low vulnerability and rank 5 indicating very high vulnerability as far as that particular variable is concerned. Once, the ranking is done for all the five variables, a coastal vulnerability index (CVI) was prepared by integrating differentially weighted rank values of the five variables through additive mode using the formula: $CVI = 4g + 4s + 2c + t + w$. The five letters in the formula represent the five variables in the order of 1 to 5 listed above, and the numbers 4 and 2 indicate the relative weightage given to different variables, keeping in view their relative significance in influencing the coastal response to sea-level rise.

The entire range of CVI values 15 to 57 thus obtained for the 307 geographic information system-generated segments of the 1030-km-long AP coast were divided into four equal parts each representing a particular risk class, such as low-risk (CVI range: 15-26); moderate risk (27-36); high risk (37-46); and very high risk (47-57) as shown in Fig. 2. The risk classification indicated that 43% of the AP coast over a length of 442 km is under very high-risk category mostly along the Krishna, Godavari and Penner delta front coastal sectors. Similarly, about 364-km-long coastal segments, which account for 35% of the total length are under the high-risk category mostly in the southern part of the AP coast near Pulicat Lake; north of Penner delta; south of Krishna delta; and between Krishna and Godavari deltas in the central part of AP coast. In the remaining part, 194-km-long coast (19% of the total) mainly the non-deltaic dune-front sections, come under the moderate-risk category, while the rocky coast on both sides of Visakhapatnam and some embayed/indented sectors over a combined length of 30 km (3%) are in the low-risk category.

If the sea level rises along the AP coast by 0.59 m (the maximum possible rise predicted by IPCC 2007), an area of about 565 km^2 would be submerged under the new low-tide level along the entire AP coast of which 150 km^2 would be in the Krishna-Godavari delta region alone. The new high tide reaches further inland by another ~0.6 m above the present level of 1.4m, i.e., up to 2.0 m. In such a case, an additional area of about 1233 km^2 along the AP coast including 894 km^2 in the Krishna and Godavari delta region alone would go under the new intertidal zone thereby directly displacing about 1.29 million people (according to 2001 census) who live in 282 villages spread over nine coastal districts of Andhra Pradesh state. Notably, the inhabitants of these villages are mainly hut-dwelling fishing communities who are highly vulnerable in socio-economic terms as well. Further, there is every possibility of increased storm surges reaching much inland than at present with the rise in sea-level.

The study, therefore, provides a future scenario for AP coast so that appropriate coastal zone management may be considered in order to save life and property in the region from the imminent danger of sea-level rise. This type of coastal vulnerability assessment of the entire Indian coastal region would be a useful input for any management program aimed at protecting the highly resourceful but endangered national asset, i.e. our coastal regions.

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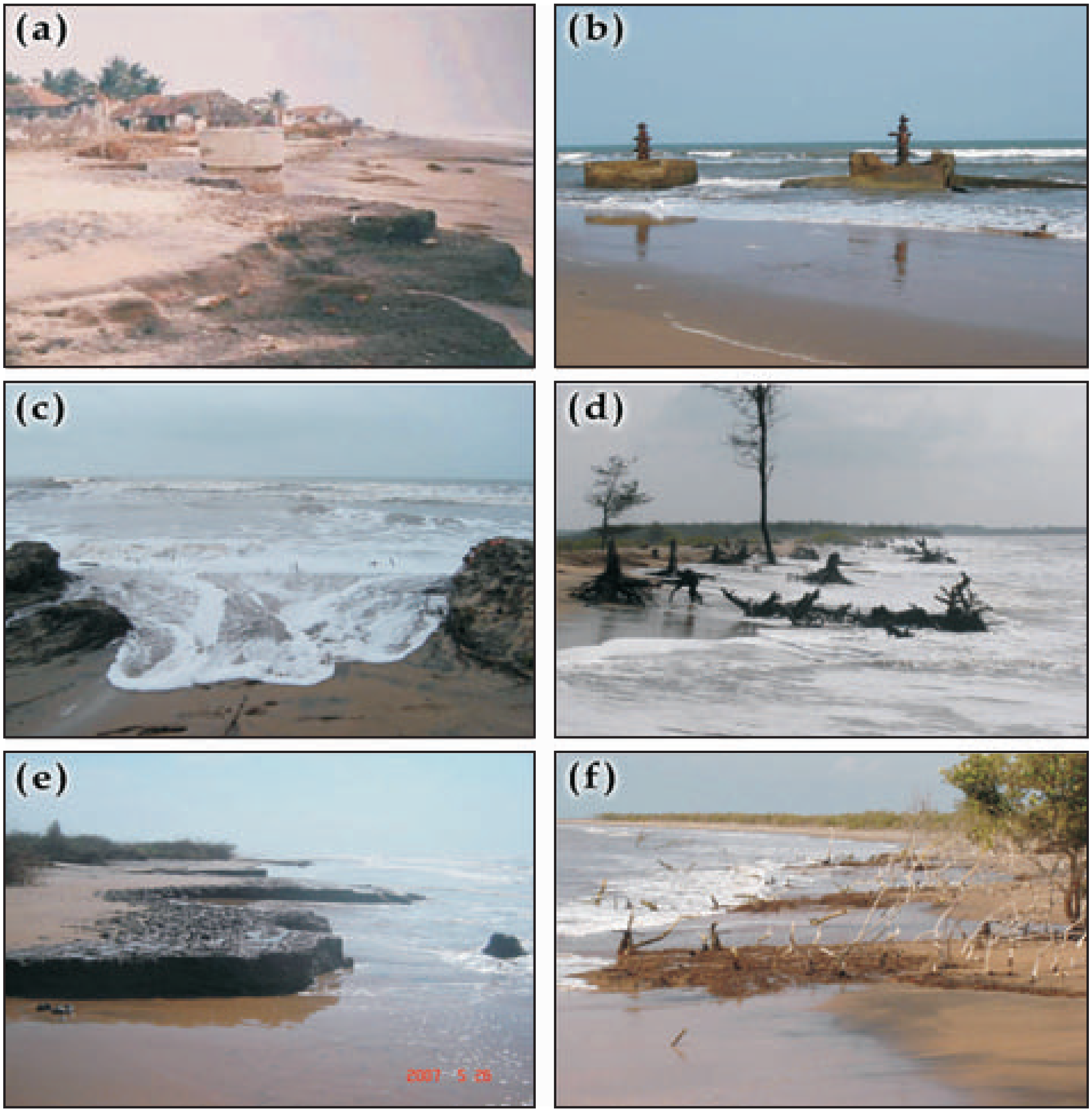

Fig. 1 *Coastal erosion and shoreline retreat along the Krishna-Godavari delta region in Andhra Pradesh during the 16-year period (1990-2006). (a) The shoreline at Uppada village in the northeastern end of the Godavari delta retreated by 200 m with the sea engulfing almost one half of the village; (b) ONGC test drill site in the central part of the Godavari delta, which was more than 200 m inland about 10 years ago is now in the intertidal zone; Beach ridges which were behind the beach and fore dune are being breached (c), and the casuarina plantations over them (d) are uprooted in the southern part of the Godavari delta; (e) the bottom-set prodelta clay beds are exposed due to heavy erosion in the central part of the Krishna delta where the shoreline retreated by 400m in 16 years; and (f) the shoreline retreated by 500 m and mangrove vegetation is destroyed by the advancing sea in the western part of the Krishna delta.*

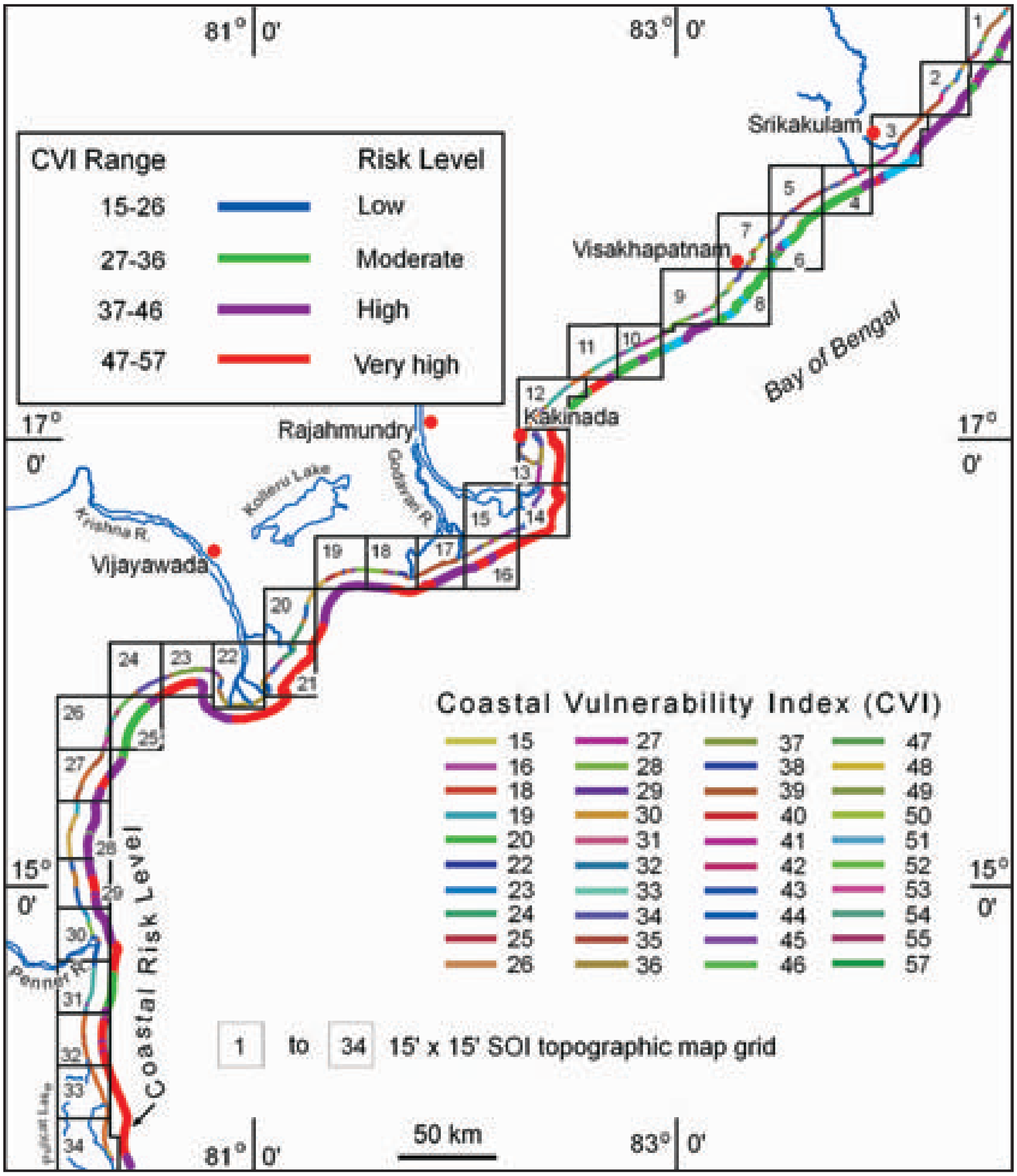

***Fig. 2** Coastal vulnerability index (CVI) and risk levels of different segments of AP coast. Each colour of the coastline indicates a particular CVI value from 15 to 57 (Note that no coastal segments with CVI values of 17, 21 and 56). The thick coloured parallel line all along the coast shows the risk levels of the coast based on the categorization of CVI values into four risk classes as shown in the upper left legend. The black coloured squares along the coastline (from 1 to 34) represent the grids.*

GEOMATICS GATEWAY TO SEA RISE DISASTERS

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1. Introduction

The global warming has become a matter of great concern, as it is expected to cause a series of adverse impacts over the geo, hydro and biological systems including biological productivity. That too, the impacts are expected to be more in the coastal zones in the form of anticipated sea level rise (SLR) due to snow melt and the thermal expansion of the sea water triggered by the global warming. Hence, the scientists were stimulated to critically study the anticipated impacts along many parts of the global coasts (French et al. 1995, Nicholls 2002, Singh 2002, Van Goor et al. 2003, Nakada and Inoue 2005, Unnikrishnan et al. 2006, IPCC 2007, Criado-Aldeanueva et al. 2008 and many others). These studies seem to have focused more on the methods of estimating the probable Sea Level Rise (SLR) and the related environmental impacts. However few studies have also centered around the estimation of global population at risk for the different scenarios of sea level rise, feasibility of predicting the sea level rise in advance, time series analysis on the changing pattern of the sea level rise etc. The Intergovernmental Panel on Climate Change (IPCC) has predicted that the sea level may rise to the tune of 0.26 m to 0.59 m in the next 100 years. Accordingly, scientific projections have also been made to visualize the probable pattern and areas of submergence along some coasts. Specific studies were again carried out in parts of Tamil Nadu coast, visualising the areas prone for submergence due to IPCC predicted Sea Level Rise (SLR) or the Predicted rise of Mean Sea Level (PMSL) and the areas prone to inter tidal activities due to the shift of Predicted High Tide Line (PHTL) in another 100 years (Ramasamy et al, 2008).

However, the Geomatics technology comprising Aerial Remote Sensing, Satellite Remote Sensing, Digital Image Processing, Global Position System, Geographical Information System, Digital Cartography, 3D visualisation of terrain systems using the stereo satellite images, Radar images, SRTM Data etc., and it's advanced credentials are yet to be capitalized deservingly in visualizing the various environmental impacts related to sea level rise.

2. SLR Visualisation along Static Coasts

For example, the digital elevation models generated from the SRTM (Shuttle Radar Topographic Mapper) data and the wrapping of the high resolution satellite data over them can give a perspective topographic view of the coastal geosystems (Fig.1).

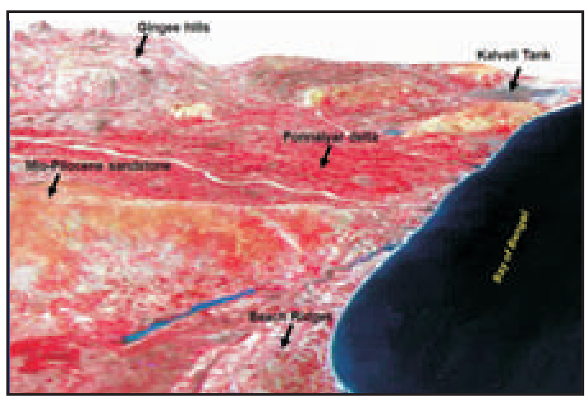

Fig.1 IRS P6 FCC Wrapped over SRTM DEM – Pondicherry/Cuddalore coast, Tamil Nadu

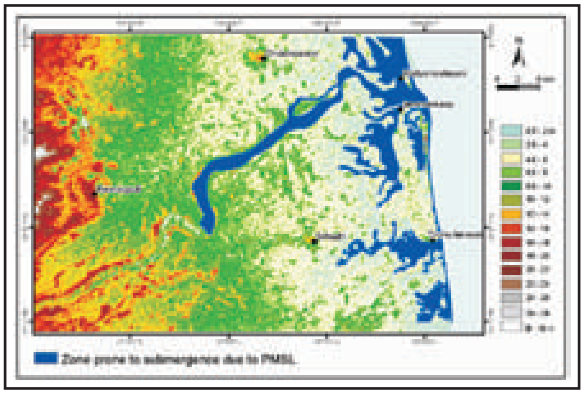

Fig.2 SRTM DEM showing the areas prone to submergence due to predicted SLR-MSL South of Cuddalore

From the same, the areas prone to submergence due to IPCC predicted SLR in the next 100 years can be visualized by duly buffering those pixels having lesser elevations than the predicted SLR in such DEM or DEM wrapped FCC (Fig.2). Such Geomatics based interpolative analysis can lead to the precise estimation of resources at loss or the resources at risk, thus aiding the planners for taking preventive measures and protective developmental planning.

3. SLR Visualisation in Active Coasts

Such Geomatics aided visualizations of SLR impacts are also possible along the coasts of active tectonic movements in the form of ongoing tectonic emergence or submergence. Geomatics technology, especially the Remote Sensing revealed geomorphic features like palaeochannels, beach ridges, withdrawal of creeks etc, their age and the present elevations, can provide information on the ongoing rate of land emergence or subsidence along the coasts. Such rate of tectonic movements can be calibrated with IPCC predicted SLR and the exact zones prone to submergence and other related environmental impacts can be mapped. For example, the C14 dating of the preferentially migrating river systems of Chennai coast has indicated a rise of roughly 8 mm/year or 0.8 m/100 years (Ramasamy, 2006). Similarly, the C14 dating of beach ridges of the recently progradated Vedaranniyam coast, Tamil Nadu indicated a rise of 1.1 mm /year or 0.11 m/ 100 years (Ramasamy et al, 1998). Such rate of tectonic movements can also be thus estimated using geomatics and accordingly, the IPCC predicted SLR value can be calibrated and exact scenarios of submergence and the predicted inter tidal activities can be visualized.

4. Tsunami Lessons & SLR Impacts

While, Geomatics has its own credentials in visualizing and estimating such disasters, related to SLR, the lessons learnt from the recent tsunami (2004) offer value added information not only in visualizing the impacts of SLR but also in developing suitable protective strategies.

For example, the studies carried out in different parts of the Indian coasts in general and in Tamil Nadu coast in particular have shown that the coastal geomorphology has played a very significant role in controlling the pattern of tsunami inundation (Nair et al.,2005; Ram Mohan, 2005). Especially, the studies by Ramasamy et al (2006) have classified the various coastal geomorphic landforms into Facilitators (mud flats, bay mouth bars, salt flats etc.), Carriers (rivers, creeks), Accommodators (palaeo and present backwaters), Absorbers (beaches) and Barriers (beach ridges) etc of the tsunami surge. Such knowledge based information can be amalgamated with IPCC predicted SLR value in precisely visualizing the impacts of predicted sea level rise and also predicted shift of high tide line by duly analyzing the pattern of interface dynamics of these geomorphic features. Ramasamy et al (2006) have also made suggestions for the suitable management of the coastal land forms so that tsunami inundation is less and the adverse impacts are minimal. For example, the study has suggested that the facilitators like mud flats, bay mouth bars etc need to be kept untouched with out any obstruction or constructions so that these softly surrender to the tsunami surge and facilitate its smooth entry into the drainages and creeks. The unaffected settlements at either abutment of the Adayar mouth region of Chennai city and the washing off of the only bay mouth bars (Fig.3) indicate that, as the bay mouth bar was kept untouched, the tsunami surge safely glided into Adyar river by destroying such soft bay mouth bar and receded back. In contrast, at many segments of Tamil Nadu coast, wherever such bay mouth bars were abused, the tsunami surge shattered the towns and settlements located on either abutments of the river mouths (e.g. Tirumullaivasal) and the adjacent parts too (e.g. Nagapattinam).

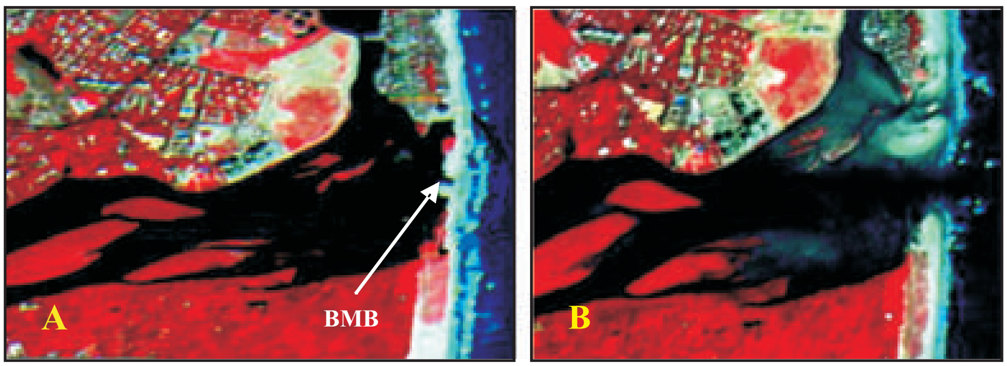

Fig.3 IRS P6 LISS III image showing the bay mouth bar (BMB) prior to tsunami (A) and its absence after the tsunami (B)

In the same way, studies have recommended for keeping the river paths undisturbed and the palaeo and present backwaters barren so that the former act as carriers and the latter as accommodators of tsunami surge. The maximum inundation of Tsunami surge to the tune of 2-2.5 km along the cleanly kept path of the Ponniyar river in Cuddalore (Fig.4) and the filling up of the tsunami water in the backwaters of Vedaranniyam region (Fig.5) stand as testimony for the same.

Similarly the beaches have behaved as absorbers of tsunami waves as witnessed in Marina beach and because of it only the Triplicane part of Chennai city was saved. Again the long and elevated beach ridges have acted as barriers of tsunami waves and protected many settlements in Nagapatinam coast. Hence Ramasamy et al (2006) suggested for the development of beaches in warranting and suitable locations by trapping the sands brought by the littoral currents and for the protection of the beach ridges through afforestation. In the same way, the stony embankments have protected the land and the other resources from the tsunami as witnessed from Kannaki temple, located in Poompuhar, Nagapattinam district (Fig.6).

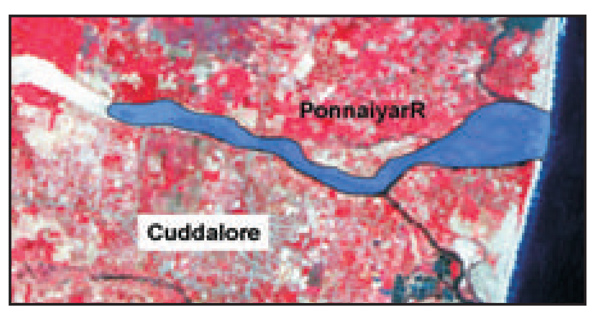

Fig.4 IRS P6 image showing the controlled flow of Tsunami surge along the least aberated Ponnaiyar river course in Cuddalore

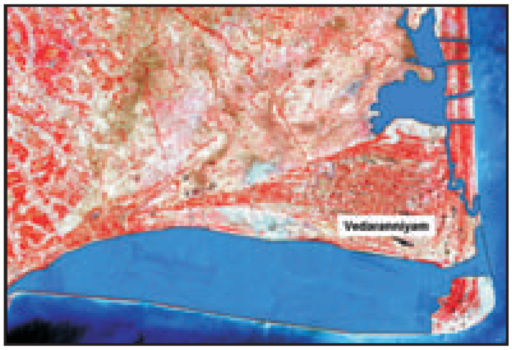

Fig.5 IRS P6 FCC image showing the palaeo and present backwaters of Vedaranniyam region acting as Tsunami accommodators and the east –west and the north-south beach ridges (BR) as barriers

Fig.6 Field photograph showing the stony Embankments (SE) which protected the Kannaki temple (KT), Poompuhar during tsunami (2004).

So from such lessons learnt from the recent tsunami (2004), the fine resolution Geomatic visualizations can be made on the pattern of submergence due to SLR by plotting the different SLR values in various landform segments like creek mouths, mud flats, river sand creeks, backwaters, beaches, beach ridges, etc. and geospatially modeling their interface dynamics. Similarly the various geo systems based management plans can also be evolved like nourishment of bay mouth bars and mud flats, keeping the river paths clean, least disturbance to backwaters, development of beaches, aforestation of beach ridges etc so that these act as facilitators, carriers, accommodators, absorbers and barriers etc for the sea level rise and the related flooding also. These protective land management strategies will be successful , because the phenomenon of tsunami inundation and the sub mergence submergence due to SLR are same and infact ,the SLR is a slow process and hence these measures will be very effective in controlling the sea water inundation.

5. Conclusion

The Geomatics possesses advanced virtues in all types of developmental planning. In this, a brief account has been made as how the Geomatics technology can be effectively and deservingly used in visualizing the impacts of sea level rise.

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CHANGING DIMENSIONS OF

HIMALAYAN GLACIERS

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Introduction

Glaciers are mass of snow, ice, water and rock debris slowly moving down a gradient. Out of these ice is an essential component. Glaciers are formed due to recrystallization and metamorphism of naturally fallen snow on land surface. Snow is a type of precipitation in the form of crystalline ice, consisting of a multitude of snowflakes that fall from clouds. Snow is composed of small ice particles and a granular material. The process of this precipitation is called snowfall. The density of snow when it is fresh is 30-50 kg/m^3.Later it becomes firn and the density becomes about 400-830 kg/m^3.snow becomes glacier ice when density is 830-910 kg/m^3. Snow becomes firn when it survives minimum one summer and becomes glacier ice in many years. Density increases due to remelting and recrystallization and reduction in air spaces within the ice crystals.

Required atmospheric conditions for snow fall are met at higher latitudes and altitudes of the earth. There are three major classes of snow cover i.e. temporary, seasonal and permanent. It is the permanent snow cover which gives rise to formation of glaciers. Glaciers are formed on the earth when rate of accumulation of snow is higher than rate of ablation and falling snow gets enough time and space to get metamorphosed to form ice. Nonetheless the glacier ice must move down under the influence of gravity to be called as glacier. Presently, glaciers are distributed either in Polar Regions of earth or in high mountainous regions. The glaciers in Polar Regions of the earth cover the topography and appear on the surface as ice sheets or ice caps. The glaciers in the mountainous regions are constrained by topography and the shape of valley influences their flow and such glaciers are classified as valley glaciers, cirque glaciers and ice fields. There are two parts of glaciers accumulation zone and ablation zone separated by snow line. In the Accumulation Area, total accumulation from winter snowfall is more than summer ablation. Its spectral reflectance is higher in all three bands. Hence, it appears white on the FCC and can be easily demarcated. In ablation area, total summer melting is more than winter snow accumulation. Therefore, glacier ice along with debris gets exposed on the surface. Glacier ice has substantially lower reflectance than snow, but higher than rocks and soil of the surrounding area. Therefore, it gives green-white tone on FCC and can easily be differentiated from the accumulation area and surrounding rock and soil. The part of ablation zone of the glacier from where river or stream appears on the surface is its terminus or snout. Though it has been defined in many ways but most appropriate definition could be that the part of the glacier at its lowest altitude is called the terminus or snout of glacier. Many Himalayan glaciers do not have clean surfaces (figure 1 and 2) as these are covered with varying amounts of moraine cover, consisting of dust, silts sands, gravel, cobbles and boulders. Moraine covor is one of the most important components of a glacier system in view of the control it exercises on rate of glacier melting. Its areal cover and thickness should be known in order to estimate effect of climate on retreat of glaciers.

The distribution of glaciers as what we see today is the result of last glaciation. Glaciation and deglaciation are the alternate cycles of cold and warm climate of earth. During Pleistocene, the earth's surface had experienced repeated glaciations over a large land mass. The most recent glaciations reached its maximum advance about 20,000 years ago due to fall of temperatures by 5 to 8ºC. A Little ice age has been recognized during 1650-1850 AD. During peak of glaciations approximately 47 million km^2 area was covered by glaciers, three times more than the present ice cover of the earth.

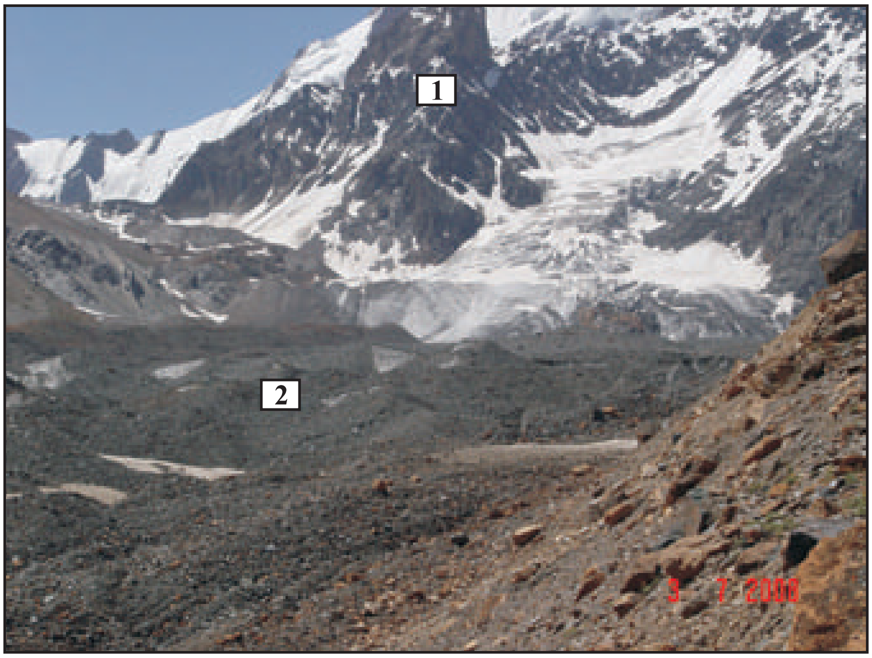

Figure 1: A ground picture of accumulation (1) and ablation zones (2) of a glacier. The ablation zone is covered with rock fragments

Figure 2. Ice exposed on the ablation zone (1) of a glacier

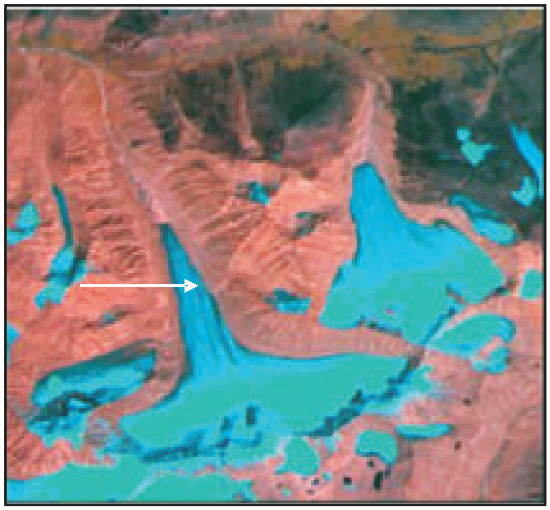

Figure 3: IRS LISS III image showing glaciers with ice exposed on the surface

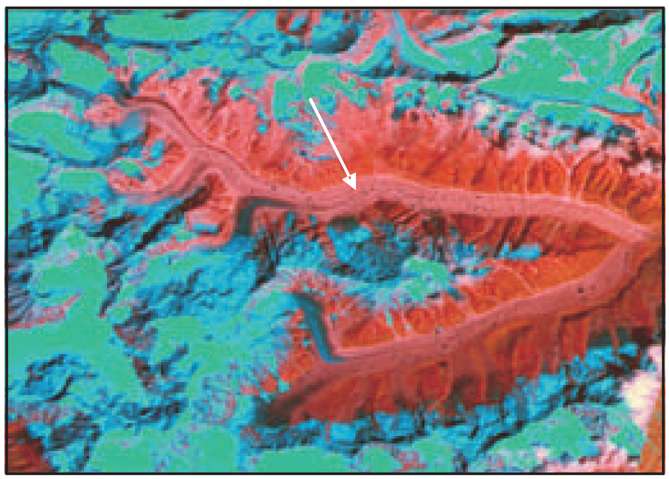

Figure 4: IRS LISS III image showing moraine-covered glaciers

Himalayan Glaciers

Glaciers are very vital to human kind as these natural resources are (i) reservoirs of freshwater, (ii) control global climate as the albedo over snow and glaciers is very high, and (iii) sensitive indicators of climatic variations. Since glaciers of Himalaya constitute the largest concentration of freshwater reserves outside the polar region, a great significance is attached to the fact that these natural resources are the source of fresh water to almost all minor and major rivers of northern India and sustain the civilization for irrigation, hydroelectricity and drinking water. Concentration of glaciers in Himalaya varies from northwest to northeast according to the variation in altitude and latitude of the region. Siachin glacier in Kashmir, Gangotri glacier in Uttrakhand, Bara Shigri glacier in Himachal Baltoro glacier in Karakoram and Zemu glacier in Sikkim are a few famous glaciers of Himalaya. But does our nation have complete information on our glacier resources? Though an approx. number of glaciers in Himalaya could be as high as 10000 but in very near future we will have this number. Though number and location of glaciers is important to be known but more important is the size of the glaciers. It is the volume of glacier which matters the most. Based on the work for a few basins carried out so far it appears that approx. 85 % of glaciers are less than 5 sq. km and 60 % of glaciers are less than 1 sq.km in area. There is already an inventory going on at SAC for finding location and size of glaciers besides other attributes. Earlier the glacier inventory was carried out for Satluj basin, Chenab basin and Tista basins etc. at 1:50000 scale based on interpretation of LISS III images. Prior to this an inventory programme for entire Indian Himalayas was accomplished at 1:250000 scale in early nineties.

Retreat of Himalayan glaciers

Retreat and advances of glacier snout in the mountain areas have been systematically observed in various parts of the world and their snout fluctuations are considered to be highly reliable indicators of worldwide climatic trends. Change in snout position is a result of glacier mass balance and provides quantitative information about acceleration, relative climatic changes etc. Climatic fluctuations cause variation in amount of accumulation of snow and ice of glaciers and its melting. Such changes in the mass initiate a complex series of change in the flow of glacier that ultimately results in a change of the position of terminus and area of glaciers. Thus advancement and retreat of a glacier closely depends on the conditions of replenishment of an accumulation area and the intensity of ablation i.e. faster melting due to climatic changes. Hence glaciers are considered as excellent indicators of global climatic changes.

Though, there have been limited number of studies in Himalayas by field methods, yet the results indicate the loss in area of glaciers over a period of time. For instance, glaciers in the Western Himalaya are retreating at an average rate of 15m per year, consistent with the rapid warming recorded at Himalayan climate stations since the 1970s. Winter stream flow for the Baspa glacier basin has increased 75% since 1966 and local winter temperatures have warmed, suggesting increased glacier melting in winter (Kaul, 1999).

In Central Himalaya, India, since the mid 1970s the average air temperature measured at 49 stations has risen by 1oC, with high elevation sites warming the most. This is twice as fast as the 0.6°C average warming for the mid latitudinal Northern Hemisphere (20° to 40°N) over the same time period, and illustrates the high sensitivity of mountain regions to climate change. (Shrestha et al., 1999).

In Eastern Himalaya, Mt. Everest, the Khumbu glacier, popular climbing route to the summit Mt. Everest, has retreated over 5 km since 1953.The Himalayan region overall has warmed by about 1°C since the 1970s (Shrestha et al., 1999). In Eastern Himalaya, Bhutan, as Himalayan glaciers are melting the glacial lakes are swelling up which may lead to a catastrophic flooding. Average glacial retreat in Bhutan is 30-40m per year. Temperature in the high Himalaya has risen by 1°C since the mid 1970s (ICIMOD, 2002).

One of the medium size glacier known as Dokriani in the Garhwal Himalaya shows rapid frontal recession, substantial thinning at the lower elevation and reduction of glacier area and volume and the glacier has vacated an area of 3957 sq m during 1991 – 1995 (Dobhal, 2004). The Dokriani glacier was mapped in 1962-1963 which was remapped in 1995 by survey of India. The snout, surface area and elevation determined by the comparison of the topographical maps an field data. The surface elevation was calculated by profiling the distance between the pair of contours along the centerline. Volume change during the period was calculated by preparing area average thickness map of both the survey years. Ground Penetrating Radar has been used to estimate the volume of glacier ice in 1995.

Also there are evidences of glacial surges in Himalyas. Hewitt (2007) found that four tributaries of Panmah Glacier in Karakoram ranges have surged (advanced very fast) in less than a decade, three in quick succession between 2001 and 2005. Since 1985, 13 surges have been recorded in the Karakoram Himalaya, more than in any comparable period since the 1850s. Ten were tributary surges. Interpretations must consider the response of thermally complex glaciers, at exceptionally high altitudes and of high relief, to changes in a distinctive regional climate. It is suggested that high-altitude warming affecting snow and glacier thermal regimes, or bringing intense, short-term melting episodes, may be more significant than mass-balance change.

Wagon et al., (2007) have estimated four years of mass balance on Chhota Shigri Glacier, Himachal Pradesh, India, in the western Himalaya from 2002. Overall specific mass balances are mostly negative during the study period.

Remote sensing in glacier retreat studies

Due to limitations of field methods in assessing a large number of glaciers, methods based on remote sensing have occupied a pivotal role in generating quick and reliable information on glaciers. Because of emphasis on the rate of retreat of glaciers in the last 2-3 decades due to impact of global warming on snow accumulation and melting rates of glaciers, the use of images has been much more demanding. Though there are limitations of data selection for glaciological studies since glaciers are exposed only for about two months in August-September time frame and these two months also coincide with cloud cover, it has been possible to get a few good images to carry out either glacier inventory or monitoring of retreat. Two major zones i.e. accumulation and ablation zone of glaciers can be identified on the glaciers in addition to peri-glacial features. The two zones are separated by equilibrium line. The EL is the snow line at which mass balance for a hydrological year is zero or the line above which mass balance is positive and below which it is negative.

Use of remote sensing for estimation of glacial retreat in Himalayas began with the work carried out by Kulkarni and Bahuguna, (2002) for a few glaciers of Baspa Basin. The authors used satellite stereo data from IRS 1C/1D panchromatic sensor to generate DEM and orthoimages to estimate the glacial retreat and altitude of snout and other dimensions of glaciers. The studies wore further extended when Kulkarni and Alex (2003) while estimating glacial variation in Basapa basin found the loss of 19% area during the period of 1962 to 2001. The authors had used IRS LISS III data of 2001 and SOI topographical maps of 1962 to carry out monitoring of 19 glaciers of the basin. It was also found that the percentage of loss in area varies at different altitude ranges. Interpretation of satellite images has been highly useful to determine the retreat of Parbati glacier in Parbati valley of Himachal Pradesh. Ground validation of its snout was also carried out (Kulkarni et al., 2005). Similarly retreat of Samudra Tapu glacier in Chandra valley was estimated by using IRS LISS III data (Kulkarni et al., 2006). Significant amount of work has been reported on retreat of 466 glaciers of Chandra, Bhaga, Parbati and Basapa basins of Himalaya by using satellite images of years 2001/2004 and Survey of India topographical maps of 1962. The total loss in glacial area for glaciers estimated in these basins is 21%. (Kulkarni, et. al. 2007). Glacier retreat studies are now extended to 14 sub-basins of Himalayas namely Alaknanda, Bhagirathi, Dhauliganga , Goriganga and

Mandakini basins contributing to Ganges in Uttrakhand , Chandra, Bhaga, Miyar, Warwan and Bhut contributing to Chenab basin in Himachal Pradesh and J & K, Ravi and Spiti basins in Himachal Pradesh , Suru and Zanskar basins in J & K and Tista basin in Sikkim. The loss in area of glaciers is being estimated viz., with respect to SOI maps of 40 years ago and changes observed on satellite images with an approx interval of 5-10 years (Figure 3). This is being done under a joint programme on snow and glaciers of the Department of Space and Ministry of Forests and Environment. Earlier the retreat by conventional methods was being monitored based on movement of snout of glacier. There was ambiguity in rate of retreat since various workers were not able to follow standard location or due to difference in methods of observation. More over finding a shift in snout in V- shape valley is not a correct procedure as followed by earlier studies. It is because the rate of shift will depend on the size and shape of the valley. Two glaciers losing same amount of ice but having different size of valley will show different rates of retreat. Therefore, finding loss or gain in area of glaciers using remote sensely data is more logical procedure.

Full view of Gangotri Glacier

Full view of Gangotri Glacier

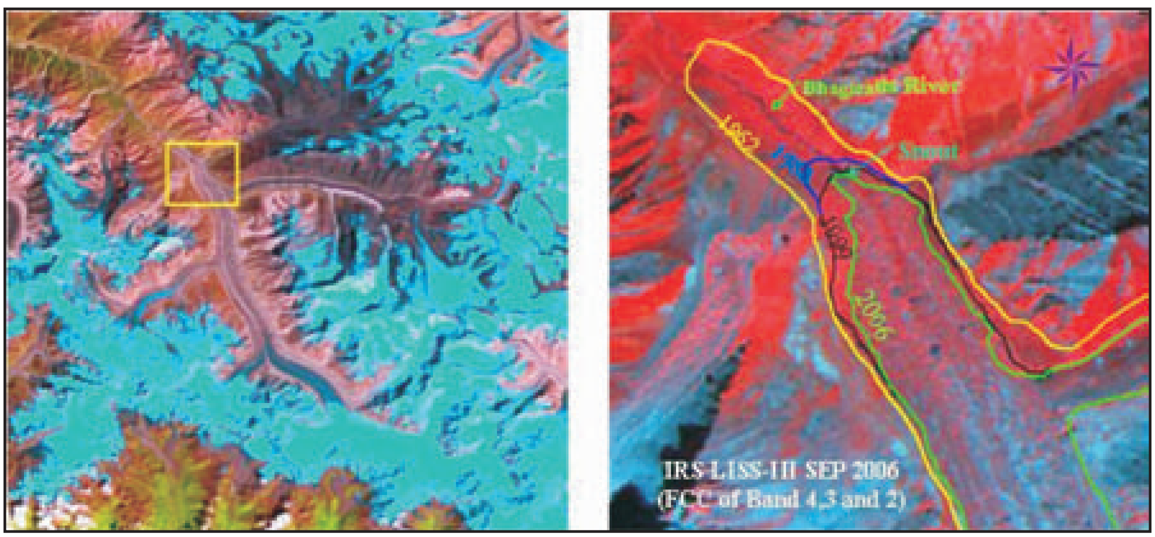

Figure 3: retreat of gangotri glacier as observed on satellite images of 1999 and 2006.

Fragmentation of glaciers

Sometimes due to retreat the large sized glaciers fragment into smaller glaciers. This results in the rise of number of small glaciers. For instance, fragmentation has been observed in 42 glaciers of the Warwan basin. Glaciers less then 1 sq km in 1962 were 159 but due to the retreat this number rose to 187. The glaciers which had more then 40 sq km area were 4 in 1962 but during 2001 this number became 2. Similarly nos. of glaciers with area 20-40 sq km were 5 in 1962 which became 3 in 2001. Conceptually the fragmentation takes place at the snout of terminus of the tributary glacier because the retreat of the tributary glacier is governed by reduction in accumulation of snow of the tributary glacier. The overall reduction in the mass of a glacier has implications in the movement of terminus of the tributary glaciers and therefore the tributary glacier gets detached from the main glacier at its snout.

Photogrammetric techniques

Besides estimation of loss in area of glaciers, the photogrammeric methods of estimating long-term changes in volume of glaciers are being developed to deermine a change in surface elevations of glaciers of Himalaya . In this technique satellite stereo data is used to generate DEM and identification of snout in a 3-D perception in a Digital Photogrammetric Work Stations (Bahuguna et al., 2004 , 2007 & 2008). A volume change can be estimated by subtracting the surface elevation of a glacier and the glacier extent at two different times (figure 4). This method can be applied using topographic maps, Digital Elevation Models are obtained by aircraft, satellite imagery, SAR Interferometry and by airborne laser scanning. Satellite imageries must be analysed for average mass balance of a glacier over a period of 5 - 10 years. This is a convenient and time-saving method is only applicable for determining the average mass balance of the entire glacier.

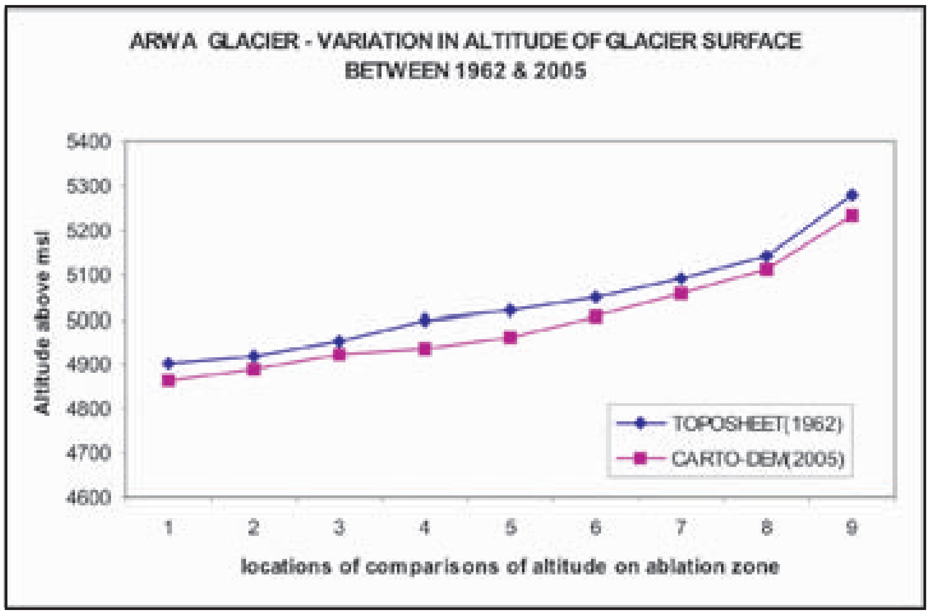

Figure 4: Approximatiopn of lowering of glacier surface based on altitude taken from SOI maps and DEM generrated from cartosat-1 stereo data

Conclusions

Retreat and advancement of glaciers are slow proceses and happen in geological time scales but the climate scientists are concerned not about the reatreat of a glacier but its rapid rate of retreat. In order to use remote sensing for assessing rate of retreat (approx. 15 m or so for movement of snout annually) multispectral with high spatial resolution data is required on annual basis. For monitoring changes in volume of glacier DEM with high vertical accuracy (in tens of cms) is required from orbital platforms. For moraine covered glaciers techniques based on textural classification are required to identify glacier boundaries, high albedo over snow and glaciers which regulate the atmospheric tempereture. So if global warming reduces the snow and ice on earth it will also reduce the albedo thus lowering of tempereture. On one side there would be warming and on other cooling due to reduction in albedo. So it is a complex phenomenon which requires deeper understanding of atmospheric system before concluding the net impact of global warming.

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IMPACT OF CLIMATE CHANGE ON CORAL REEFS

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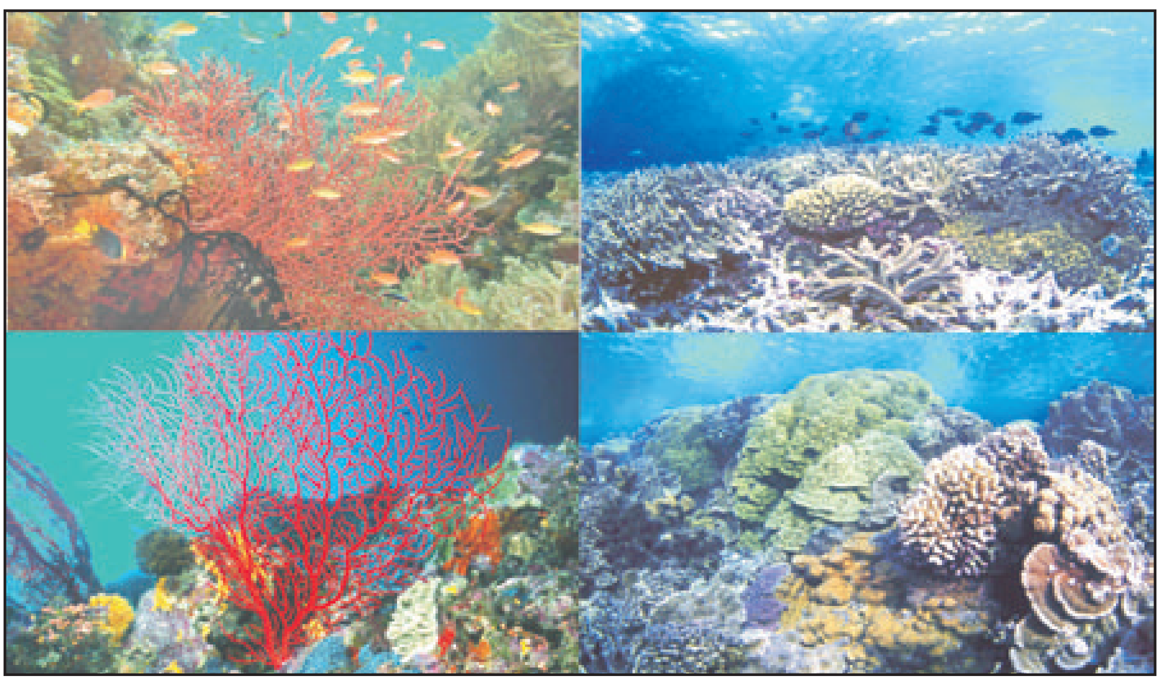
The coastal zone represents a comparatively small but highly productive and extremely diverse system, with a variety of ecosystems extending from coastal terrestrial habitats to deep-water regions approaching 200 m in depth. The critical habitats of the Indian coast include coral reefs and mangroves. **Coral reef** is a massive, wave-resistant structure, built largely by coral, calcareous algae and other organisms and consisting of skeletal and chemically precipitated material, being best developed where mean annual temperature is 23 to 25 degrees C. The reef builds slowly towards the surface of the water, at the rate of a few millimeters per year. Once the reef reaches sea level, the corals cannot survive, and the reef grows horizontally. Coral reef is a multi-faceted ecosystem with a plethora of species having genetic, ecosystem as well as medicinal importance. Exploitation together with the growing threat from climate change may result in permanent degradation of the coral reef ecosystem at a planetary scale. Coral reefs may be the first major biological system to respond to human and global change impacts at this scale and in such a short time. About 1200 marine species (mostly coral inhabitants) are already extinct and up to 1.2 million reef species could be extinct within 40 years

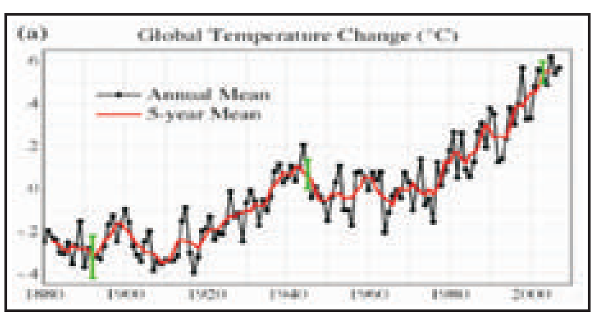


A Typical Healthy Coral Reef

Coral reefs are critically important because they contain the world's largest reservoir of marine biodiversity, they provide food security, cultural support and physical protection from storms for approximately 500 million people, they are the major natural resource for many countries in the world such as small island developing states. They are the basis for one of the world's fastest growing industries like coral reef tourism, but they are declining rapidly from a range of human pressures.

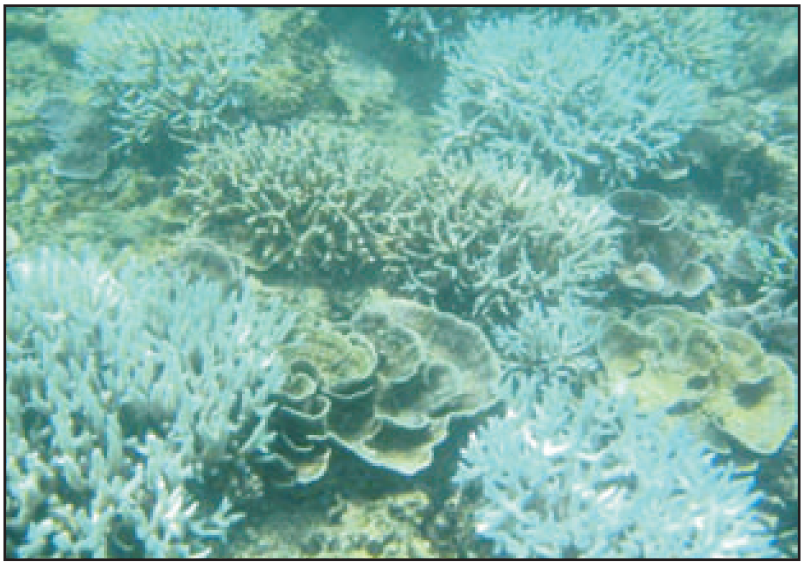
Coral reefs are sensitive indicators to changing environmental conditions like pollution, release of effluents, global warming, sea level changes, etc. They are one of the "keystone ecosystems" in reference to the issue of global climate change. As an ecosystem, they are sensitive enough to display any kind of changes occurring within the very narrow range of biophysical parameters of their common marine habitats i.e. the shallow tropical seas of the world. Human activities linked to climate change and changes in the global nitrogen cycle are having profound impacts on coral reefs. Bleaching, increased outbreaks of disease (both in frequency and type), and greater storm frequency and intensity are acting as major system drivers along with more direct human assaults on reefs. The future of coral reefs will be determined both by the rate and severity of climate change and by the effectiveness of management action to address local and regional stressors to reefs, with land-based sources of pollution, over-fishing & destructive fishing, and recreational misuse or overuse typically being the most significant local/regional stressors.

A common stress-response phenomenon observed worldwide in the events of any kind of stress to, the coral reef ecosystem is Coral Bleaching. Coral bleaching, or the separation of coral algal symbionts (zooxanthellae) from a host coral, is a process that was first described over 75 years ago (Boschma 1924; Yonge and Nicholls 1931a; Yonge and Nicholls 1931b). The interruption of vital functional relationships between corals and their zooxanthellae that occurs with bleaching is considered symptomatic of various stresses. When stresses are prolonged or extreme, bleaching leads to mortality of the coral host. The widespread bleaching events that have repeatedly occurred since the early 1980s have resulted in dramatic changes in reef environments, some apparent coral extinctions, and concern that corals and coral reefs are in danger of serious decline over the next century as a major tropical marine biotope. Under conditions expected in the 21st century, global warming and ocean acidification will compromise carbonate accretion, with corals becoming increasingly rare on reef systems. The result will be less diverse reef communities and carbonate reef structures that fail to be maintained. Climate change also exacerbates local stresses from declining water quality and overexploitation of key species, driving reefs increasingly toward the tipping point for functional collapse.

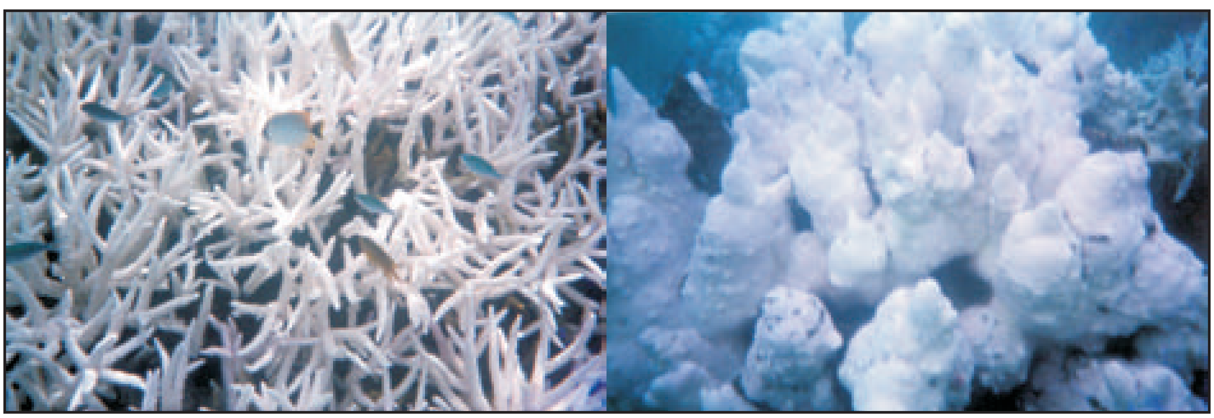


Trend of Global Temperature Change (Source: Goddard Inst. For Space Studies NASA)

Corals are stressed when water temperatures are as low as one degree Celsius warmer for a week or more, especially when there are no winds to mix surface waters and provide relief from the strong sun and ultraviolet (UV) rays.



Partially Bleached Coral Colonies



Totally Bleached Coral Colonies

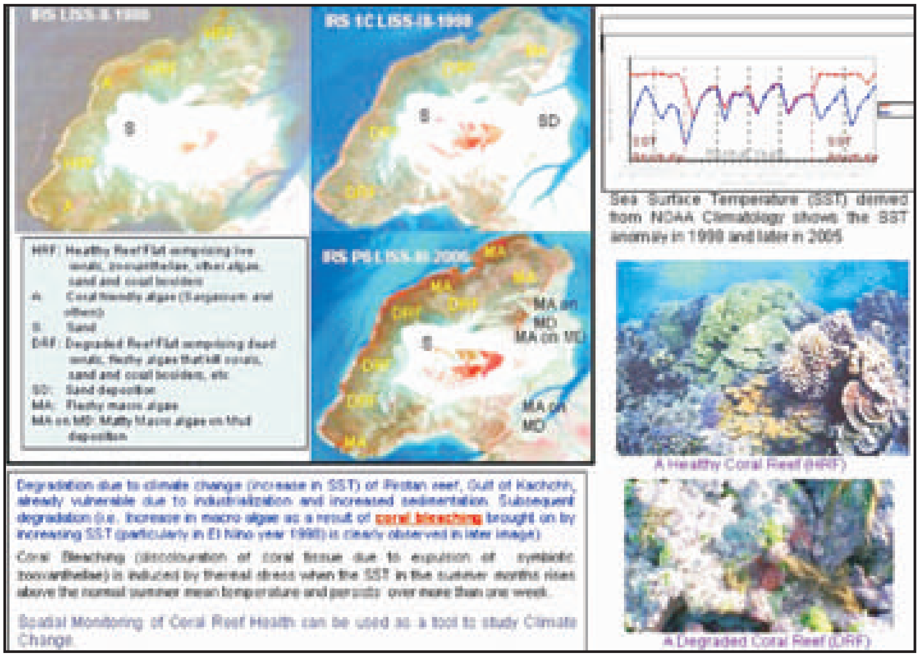
At the ecosystem level, post-bleaching periods are marked by a Phase Shift from a Live Coral dominated habitat to Macro-algae dominated one. Within some month's time in post bleaching, macro-algae proliferate and overgrow corals to the extent that significant proportion of the reef flat area is lost to macro-algae.

Fleshy macro-algae overgrowing the bleached and degraded corals

Space-borne remote sensing, with its repetitive, broad scale coverage providing quantitative data in a spatial context, is often seen as the potential alternative tool for monitoring these ephemeral and often remote bleaching events. Remote sensing of coral reefs has so far proved its potential as a cost-effective approach for determining reef-community structures and reef-substrates (Bahuguna and Nayak 1998, Nayak et al. 2003, Miller and Mûller, 1999). While currently available satellite sensors have global mapping and monitoring capabilities, the accuracy and precision attainable is relatively low due to the coarse spatial resolution, fewer bands and broad spectral bandwidths of these sensors. Thus, challenges still exist in individual substrate discrimination because of spatial heterogeneity on reef-scales. In the current scenario, the operational imaging systems, which provide more spectral information (e.g. MODIS, SeaWiFS, Oceansat-1 OCM) have coarser spatial resolutions. On the other hand systems like IRS-LISS IV and LISS-III, Ikonos, Landsat-ETM, and Quickbird, spatially resolve reef bottom types but have the broad, discrete wavebands not optimized for spectral discrimination of reef-substrate types.

Space Applications Centre has initiated studies on changes in the coral reefs related to environment as well as global climate. Two habitat-diverse reefs have been taken up as study areas, viz., i) coral reefs of the Gulf of Kachchh that exist in extreme conditions both by way of location (they are distributed in the northern most latitudinal limit of the reef distribution), extreme environmental conditions and intense anthropogenic pressure), ii) coral reefs of Lakshadweep (do not have significant anthropogenic pressure).

The study is underway using SATLANTIC underwater hyperspectral radiometer-HyperOCR along with Indian Remote Sensing satellite data (RESOURCESAT LISS IV), Hyperion satellite data and NOAA SST data. Preliminary studies have found that already environmentally vulnerable reefs of the Gulf of Kachchh are not able to withstand further stress due to increased SST and their degradation is irreversible. Lakshadweep reefs on the other hand are rich in diversity and health and have shown instance of recovery from the bleaching of 1998 and 2005.



The elimination of coral reefs would have dire consequences. Coral reefs represent crucial sources of income and resources through their role in tourism, fishing, building materials, coastal protection and the discovery of new drugs and biochemicals. Globally, many people depend in part or wholly on coral reefs for their livelihood. About 15% (0.5 billion people) of the world's population live within 100 km of coral reef ecosystems. Tourism alone generates billions of dollars for countries associated with coral reefs. The fisheries associated with coral reefs also generate significant wealth for countries with coral reef coastlines. Coral reefs also protect coastlines from storm damage, erosion and flooding by reducing wave action across tropical coastlines. The protection offered by coral reefs also enables the formation of associated ecosystems (e.g. seagrass beds and mangroves) which allow the formation of essential habitats, fisheries and livelihoods. The cost of totally losing coral reefs would run into hundreds of billions of dollars each year. The survival of coral reefs in all times is not only thus important for the human generation but for the oceans as well.

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IS CLIMATE CHANGE RESPONSIBLE FOR DESERTIFICATION?

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Desertification has been recognized as one of the major environmental problem having global concern and affecting 250 m people directly and with over one billion at risk. One of the impacts which global warming may have on the surface of the Earth is to exacerbate the world - wide problem of desertification. A decrease in total amount of precipitation in arid and semi-arid areas could increase the total area of drylands world-wide and thus also the total amount of land potentially at risk from desertification. In addition, desertification may enhance global warming, through a variety of climate feedbacks. Desertification has been defined by United Nations Conference on Environment and Development (Rio de Janeiro, 1992) as "land degradation in arid, semiarid and dry sub-humid areas resulting from various factors including climatic variations and human activities". Desertification involves the depletion of vegetation and soils.

Drylands cover 40 per cent of the total land area of the world (6,150 million ha). They are most prevalent in Africa, Asia and Latin America. They are defined as those areas where precipitation is low and where rainfall typically consists of short, erratic and high intensity storms. Traditional farming and grazing techniques, suitable for wetter regions, are becoming increasingly less sustainable owing to inadequate precipitation in these areas. Although climatic extremes may exert considerable pressure upon those who farm the land, weather conditions are not usually cited as direct causes of desertification. Rather, it is the factors such as overcultivation, overgrazing, deforestation, poor irrigation practices and poverty which arise due to a variety of socio-economic reasons that are the immediate cause. Land degradation occurs all over the world, but it is only referred to as desertification when it takes place in drylands.This is because these areas are especially prone to more permanent damage as different areas of degraded land spread and merge together to form desert like conditions. 70 per cent of these drylands are affected by degradation, which support over 1 billion people in more than 110 countries.

Arable land per person has declined from 0.32 ha. per person in 1961-63 to 0.21 ha in 1997-1999 and is expected to drop further to 0.16 ha by 2030 (Kofi Annan,2003). Because the poor often farm degraded land that is increasingly unable to meet their needs. Desertification is both a cause and consequence of poverty. Fighting desertification must, therefore, be an integral part of our wider efforts to eradicate poverty and ensure long term food security. Remote sensing data, along with GIS has been useful for desertification, monitoring and assessment. The indicators of desertification amenable to remote sensing include salinity,erosion and sand sheets etc.(Navalgund,2006)

The effects of Desertification

Direct physical consequences of desertification may include an increased frequency of sand, dust and snow storms and increased flooding due to inadequate drainage or poor irrigation practices. This can contribute to removal of vital soil nutrients and bring about a loss of vegetation cover. This undermines local food production and can act as a contributing factor towards famine as well as reduced biodiversity.Desertification can also initiate regional shifts in climate which may enhance climate changes due to green house gas emissions. Furthermore, desertification reduces the availability of removal sinks for carbon dioxide, the main greenhouse gases. In the Indian cold desert region lying in states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh, various processes of desertification which have been observed are – Frost Heaving, Frost Shattering, Mass Movement, Wind Erosion, Water Erosion and Vegetal Degradation.

Mass movement is defined as a process of desertification which leads to down-slope movement of rock, regolith and debris through the action of gravity for example, scree cones. Figure 1 shows satellite images and ground pictures for mass movement, along the Shyok river.

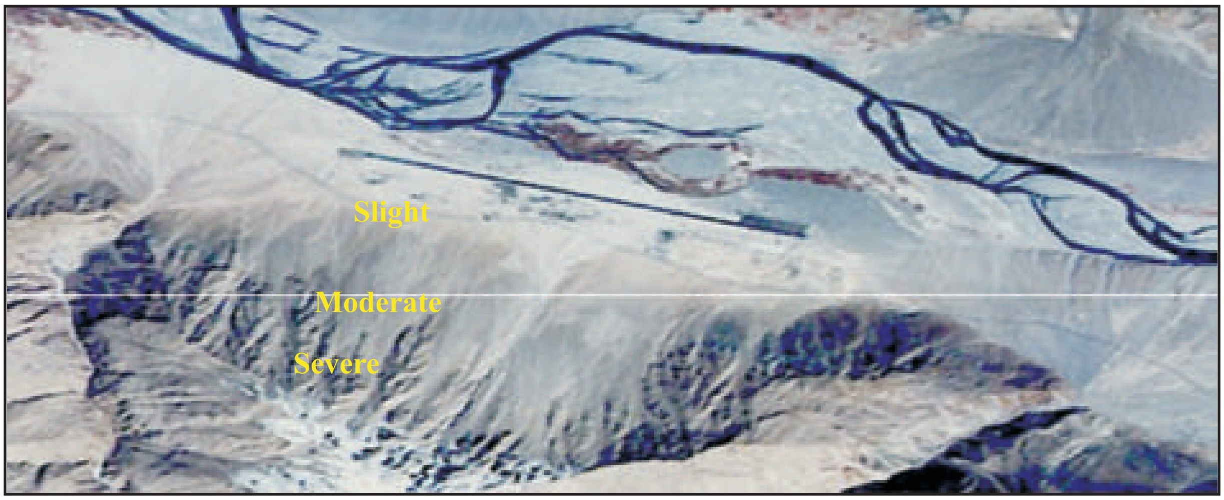

Fig.1 Mass movement along the Shyok river

Frost heaving occurs when soil expands upward or outward and contracts due to freezing and thawing. It generally occurs after a thaw when soil is filled with water droplets and when a sudden drop of temperature below freezing changes the water to ice crystals with consequent expansion and upward movement of soil. It is observed in glacial and periglacial environment and results in typical irregular pattern grounds (Figure 2).

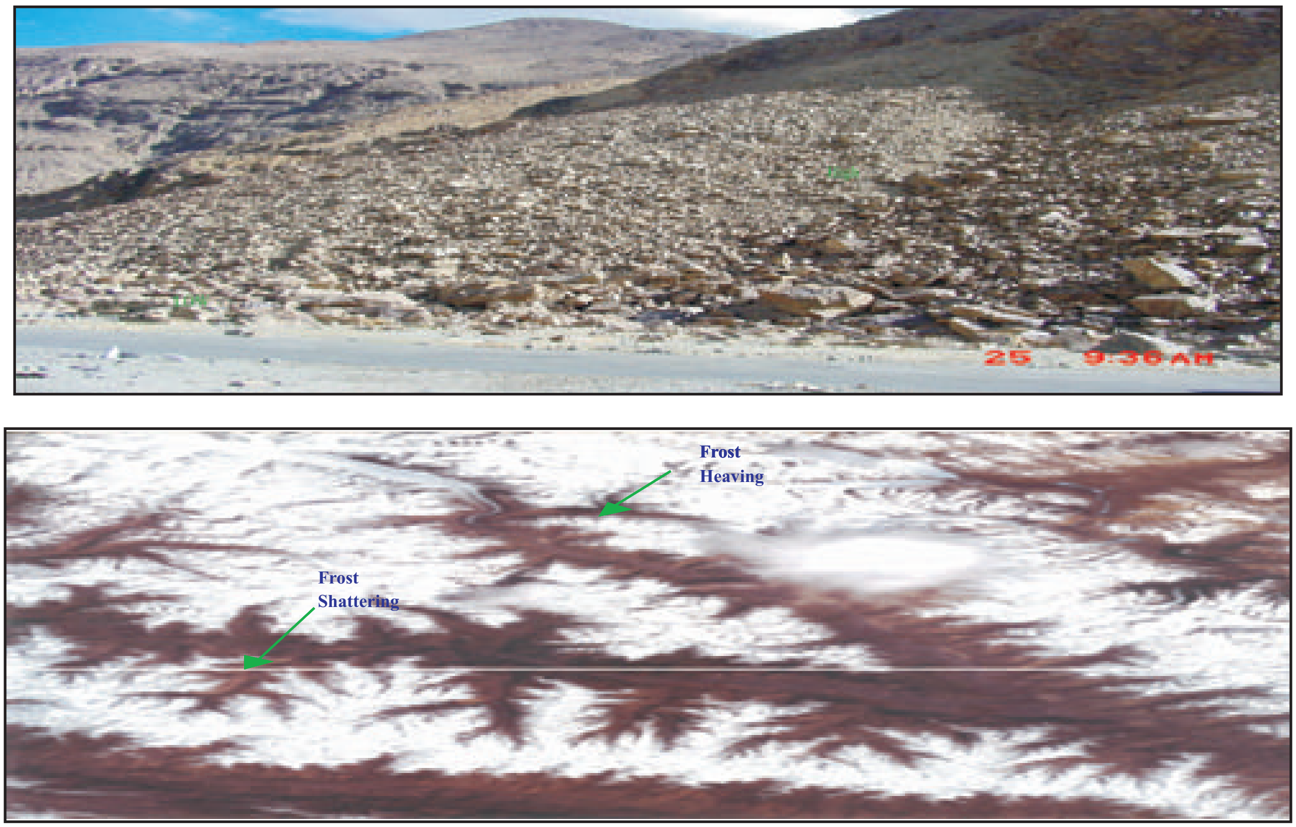

Fig. 2 Frost shattering and frost heaving along Shyok River

Frost shattering is defined as a freeze and thaw action operating mostly in periglacial environment. When water that filters through the crevices and pores in rock freezes, it expands almost ten times. This puts enormous pressure on the surrounding rocks as at –22^0 C, ice can exert a pressure of 3000 kg on an area half a square inch. The process is most active where the periglacial environment exists, usually in areas adjoining glacial margins; with long cold winters and short mild. Frost shattering as observed on satellite image is shown in Figure-2 along with ground photo.

Water erosion is observed in both hot and cold desert areas, across various land covers and with varying severity levels. The sheet erosion (mostly within agricultural lands) and rills are categorized in slight category, the narrow and shallow gullies are categorized as moderate erosion, while the deep / wide gullies and ravines are classified as severe erosion. Figure-3 shows the image and field characteristics of water erosion in cold desert along the Nubra river.

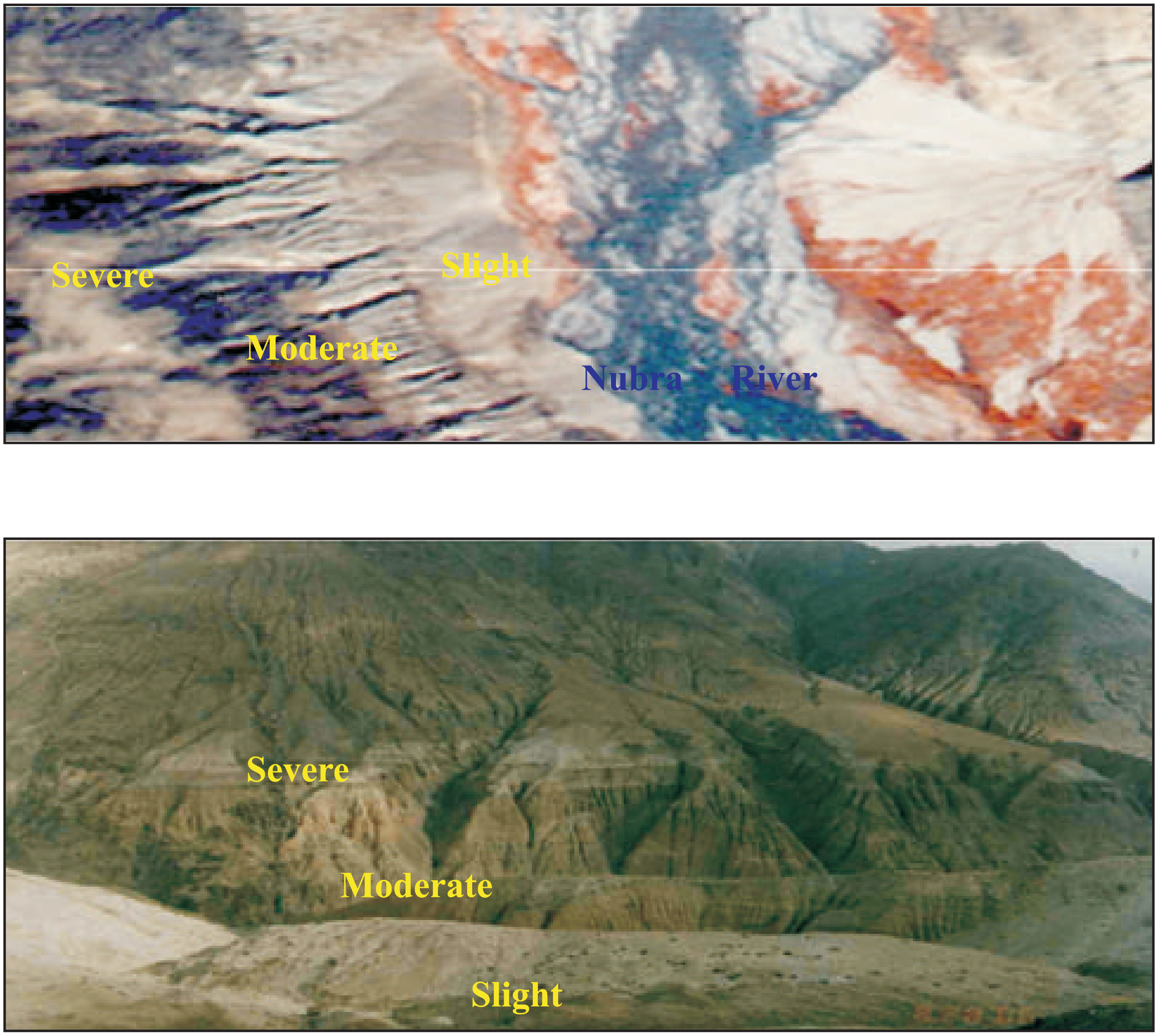

Fig.3 Water erosion along the Nubra River

Wind Erosion pertains to the aeolian activities. It denotes the spread of sand by virtue of lift and drift effect of wind, even up to lofty altitudes of Himalayas. Various categories of sand cover and their severity are classified based on the depth and spread of sand sheet/ dunes and barchans.

Figure-4 shows the satellite image and field disposition of wind erosion in the Shyok river bed.

Basically, desertification is mainly a process of land degradation which is accelerated by climate change. India occupies only 2.4 percent of world's geographical area, yet supports about 16.2 percent of the world's human population. India has only 0.5 percent of the world's grazing area but supports 18 percent of the world's cattle population. India is endowed with a variety of soils, climate, biodiversity and ecological regions. About 228 mha (69%) of its geographical area (about328 mha) fall within the dryland (arid, semi-arid, dry sub-humid) as per Thornthwaite classification.According to NBSSLUP, about 50.8 mha (15.8%) of the country's geographical area is arid. In addition, an area of about 15.2 mha of cold desert are located in Jammu and Kashmir and Lahul –Spiti region in Himachal Pradesh. About 123.4 mha (37.6%) of the country's geographical area consists of the semi-arid region (NBSSLUP,2001). About 54.1 mha (16.5%) of the country's geographical area falls within the dry sub-humid region. As per the inventory of Desertification and Land Degradation Atlas of India, 105.48 mha. i.e., 32 per cent of the geographical area of the country is undergoing the process of land degradation.

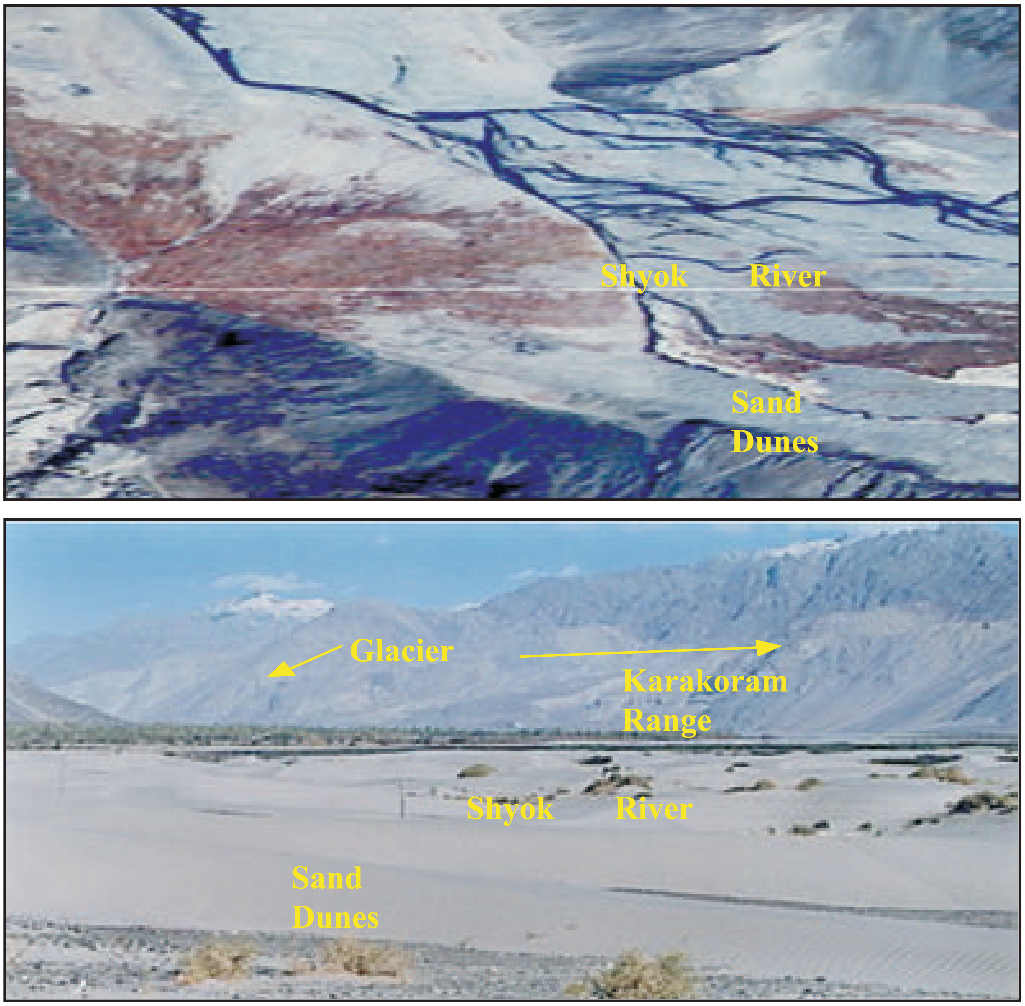

Fig. 4

ALPINE ECOSYSTEM IN RELATION TO CLIMATE CHANGE

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ABSTRACT :

Global climate change is a reality, a continuous process that needs to be taken seriously, even though there are large uncertainties in its spatial and temporal distribution. Many evidences have been gathered to depict that climate change is taking place. Over the past 100 years, the global average temperature has increased by approximately 0.6° C and is projected to rise at a rapid rate (Root, 2003). The Fourth Assessment Report of the Intergovernmental Panel on Climate Change shows that the warming of the global climate system is undeniable and is very likely due to increased greenhouse gas concentrations in the atmosphere resulting from various human activities (IPCC, 2007). Predictions of surface air warming of 1.8 to 4.0o C (under different scenarios) may significantly alter existing biosphere patterns. All ecosystems are projected to experience climate change, but ecosystems of the alpine life zone (i.e. the high mountain environments above the tree-line) are considered to be particularly sensitive to warming because they are determined by low temperature conditions. The alpine ecosystem is among the most sensitive to climatic changes occurring on a global scale, and comprises glaciers, snow, permafrost, frozen ground, liquid water, and the uppermost limits of vegetation and other complex life forms. The assessment of impacts of projected climate changes on natural ecosystems is largely based on current vulnerability and global level projections of impacts from the literature. Both climate models and observational studies sometimes give conflicting and foggy pictures of the impact of climate change on vegetation. There is a strong need to have a predictive system to study the impacts of climate change over alpine ecosystem using Geomatics tools and long term field based as well as space observations assimilated with regional climate model.

1. INTRODUCTION

In the international literature the term *alpine* is commonly used to describe the uppermost vegetation zone of high mountain system, from the treeline upwards to the limits of plant life. Himalayan Mountain ecosystems consist of cold desert biomes and alpine biomes found in the upper tree-line zone, and tundra ecosystems occurring above treeline. The alpine forests at high elevations in Himalayas exist where they do, because the plants that comprise these are adapted to the cold conditions that would be too harsh for other species (Mc Murtrie, 1992). The species in these ecosystems are so strongly adapted to the long-prevailing climatic conditions that these are vulnerable even to modest changes. It is noted that, alpine ecosystems in many parts of the world including the Himalayan region are susceptible to the impacts of a rapidly changing climate. It has already been proved by various authors that the mountain flora is moving upwards, with competitors reaching the habitats of less competitive species (Grabherr *et al.,* 1994).

Himalayan glaciers cover about three million ha, or 17% of the global mountain area. They are the largest bodies of ice outside the polar caps. The total area of the Himalayan glaciers is 35,110 sq km. The total ice reserve of these glaciers is 3,735 km^3, which is equivalent to 3,250 km^3 of fresh water. The Himalayas, the water tower of the world, is the source of nine giant river systems of Asia: the Indus, Ganges, Brahmaputra, Irrawaddy, Salween, Mekong, Yangtze, Yellow, and Tarim. They are the water lifeline for 500 million inhabitants of the region, or about 10% of the total regional human population (IPCC, 2007).

Although regional differences exist, growing evidence shows that the glaciers of the

Himalayas are receding faster than in any other part of the world. For example, the rate of retreat of the Gangotri glacier over the last three decades has been more than three times the rates of retreat during the preceding 200 years. A retreat of 1510m from 1962 to 2000 was estimated in Gangotri glacier using remote sensing data by Bahuguna *et al.,* 2007. Rapid deglaciation is taking place in most of the glaciers studied in Nepal: the reported rates of glacial retreat range from several metres to 20 m/year. On the Tibetan Plateau, the glacial area decreased by 4.5% over the past 20 years and by 7% over the past 40 years (CNCCC 2007). If present retreat trends continue, the total glacier area in the Himalayas will likely shrink from the present 500,000 to 100,000 sq. km by the year 2035. In northwest China, 27% of glacier areas equivalent to an ice volume of 16,184 km^3 will disappear; so will 10-15% of frozen soil area by 2050 (Qin, 2002). Glacial retreat was estimated in Indian Himalaya for 466 glaciers in Chenab, Parbati and Baspa basins from 1962 by Kulkarni *et al,* 2007 using remotely sensed data (IRS-LISS-III, LISS-IV). This investigation has shown an overall reduction in glacier area of 21%. However, the numbers of glaciers are found increased due to fragmentation. This indicates that a combination of glacial fragmentation, higher retreat of small glaciers and climate change induced conditions are paving the way for vegetations to grow in higher reaches.

An assessment of the impact of projected climate change on forest ecosystems in India has been done by Ravindranath et al., 2006 which is based on climate projections of Regional Climate Model of the Hadley Centre (HadRM3) using the A2 (740 ppm CO_2) and B2 (575 ppm CO_2) scenarios of Special Report on Emissions Scenarios and the BIOME4 vegetation response model. According to this study, under the climate projection for the year 2085, 77% and 68% of the forested grids in India are likely to experience shift in forest types under A2 and B2 scenario, respectively. Indications are a shift towards wetter forest types in the northeastern region and drier forest types in the northwestern region in the absence of human influence. Increasing atmospheric CO_2 concentration and climate warming could also result in a doubling of net primary productivity under the A2 scenario and nearly 70% increase under the B2 scenario. Given the projected trends (with due considerations of the uncertainty in climate projections) of likely impacts of climate change on forest ecosystems, it is important to incorporate climate change consideration in long-term planning process.

2. IMPACTS ON ALPINE ECOSYSTEMS

Direct and indirect impacts of climate change may affect biodiversity and may lead to the extinction of a variety of species. How severe such “extinction scenarios” will be can only be documented by long-term in situ monitoring. However, almost no systematic long-term observations exist for detecting the impacts of climate change on alpine ecosystems of Himalayas. However, since 1970s, satellite measurements have been made to monitor changes in the environment. Myneni et al. (1997) have analyzed this data to detect if there were indications of widespread global warming over land in the northern hemisphere. From their NDVI (Normalized Difference Vegetation Index) data for 1981 to 1991 they found a surprisingly large increase over large regions. They found an earlier greening of vegetation in spring of up to ten days and a later decline of a few days in autumn over large parts of the northern hemisphere. Change in plant phenology may be one of the earliest observed responses or evidences to rapid global climate change. For plants, the phenological events (appearance of leaf primordia, leaf fall, opening of flowers, maximum bloom period etc.) can be critical to survival and reproduction (Bawa, 2003). These parameters generate authentic data to study the effect of climate change on phenology. An understanding of how vegetation responded to past climate is needed for predictions of response of plants to future climate change. We urgently need to develop a scientific database on chronology of major phenological events for Indian flora. Remote sensing can play a crucial role in observing the phenological changes. Eddy covariance flux towers and field experiments can provide detailed insight to forest-atmosphere interactions. Advances in remote sensing science can aid extrapolation of this knowledge to larger spatial scales.

In addition to phenological changes, it is also known that an upward migration of plants in alpine ecosystem, induced by recent climate warming, is already an ongoing process. Recent literature based on remotely sensed data analysis provided ample evidence of ecological impacts on alpine ecosystem. According to a study over Nanda Devi Biosphere Reserve (NDBR), significant reduction in snow/ice cover and increase in scree cover was observed in year 1999 and 2004 satellite data. Vegetation regeneration was found in areas that belonged to snow/ice area in year 1986. Thus, the vegetation cover changed from less than 1 % area in year 1986 to more than 22 % in year 2004 (span of 18 years). This is so far highest reported vegetation ingression in mountainous regions. It was also reported that, the snow/glaciers reduced to 35.0 % area in 2004 compared to 90 % area cover in year 1986, while scree area increased from 9.0 to 42 %. The timberline is reported at 4300 m AMSL, the scrub line at 4900 m AMSL and the tundra vegetation line at 5300 m AMSL (Panigrahy et al., 2007). This indicates that, the high altitude areas beyond 4000 m are now conducive for tree growth in such regions. The vegetation ingression and timberline shift can be used as indicators of climate change to simulate the future scenario.

3. OBSERVATIONAL NEEDS AND GEOMATICS

Long-term records provide evidence for an ongoing climate warming in high mountain environments (Haeberli et al., 1996). Ground-based observations are rather poor in many parts of the region. Meteorological stations are also clustered around low altitude belts and settlements, whereas hydrometric stations are located far away from the glaciated regions needs to be observed. Glacier monitoring work is largely limited to a terminus survey. Systematic observation and monitoring of glacier ice volumes through mass balance studies are scanty, isolated, and not standardized. Ecosystem monitoring stations are at best patchy and limited. Remote sensing can augment the existing ground based monitoring to get regional level observations on time. The glacier monitoring through remote sensing is already being done, and there is also a thrust in alpine vegetation monitoring.

The ability to examine spatial relationships between environmental observations and other mapped and historical information, and to communicate these relationships to others, makes Geomatics tools valuable in such environmental forensics. Digital remote sensing and the use of GIS, GPS make it possible to rapidly collect and analyse spatial data, yielding a powerful set of tools for the analysis of the source, and extent of phenomenon like Alpine hiking.

5. CONCLUSION

Research initiates on climate change is now focused on the alpine ecology. Since, most plant species have upper altitudinal limits that are set by various climatic parameters and by limitation of resources, alpine ecosystems are considered to react sensitively to climate warming. Simulation studies show that climate change impact will result in invasion of alpine vegetation to higher altitudes. This has been already witnessed in the Alps that show significant increase in the alpine pioneer species cover but loss of many nival species (Grabherr *et al.,* 1994). Thus, detailed observations on vegetation ingression are being carried out under the GLORIA project (Pauli *et al.,* 2006). Some observations have been made on vegetation ingression and timberline changes over the last four decades in high altitude Himalayan ranges using satellite remote sensing data. More such studies are required to take total stock of the situation. It is also required to create an updated database of timberline, snow line and simulate the future scenario. Geomatics based approach is of particular significance for mapping and monitoring this vast and difficult terrain and design a proper sampling plan for detailed field/laboratory based study. *GLORIA* (Global Observation Research Initiative in Alpine) project's *Multi-Summit approach* (web1) is required in Indian Himalayas also so that the data from different mountain regions can be compared. In many countries, high mountain vegetation experiences less pronounced or no direct human impacts compared with lower altitudes. For these reasons, the alpine life zone provides a unique opportunity for comparative climate impact monitoring.

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INDIAN SOCIETY OF GEOMATICS (ISG)
(www.isgindia.org)

MEMBERSHIP APPLICATION FORM

To: The Secretary Indian Society of Geomatics
Building No. 40, Room No. 34,
Space Applications Centre (SAC) Campus
Jodhpur Tekra, Ambawadi PO, AHMEDABAD – 380 015

Sir,

I want to become a Life Member/ Sustaining Member/ Patron Member/Annual Member of the Indian Society of Geomatics, Ahmedabad from ------------Month of --------- year.

Membership fee of Rs./US$ _____ /- is being sent to you by Cash/ DD/ Cheque (In case of DD/ Cheque: No.__________, drawn on Bank __________________________________ payable at Ahmedabad. For outstation cheques add clearing charges Rs 65.00/US$ 10.00). I agree to abide by the constitution of the Society.

Date:

Place: Signature

1. Name: (Dr / Mr / Mrs/ Ms) ______________________________________
2. Address: ____________________________________

   ____

   ______________________________________ PIN: _______

   Phone: ___________ Fax: ___________ Email: ____________________
3. Date of Birth: __________
4. Sex (Male/Female): ______
5. Qualification: ___________
6. Specialisation: ___________
7. Designation: _____________
8. Membership in other Societies: ________________________________

   ____
9. Mailing Address: ________________________________

   ____

   ________________________________ PIN: _______

Proposed by:

(Member's Name and No) Signature of Proposer

For Office Use

ISG Membership No: ISG- -
Receipt No.: **Date:**

MEMBERSHIP SUBSCRIPTION				
Sr. No.	Membership Category	Admission Fee Rs. (Indian)	US $ (Foreign)	Annual Subscription Rs. (Indian)
1.	Annual Member	10.00		200.00
2.	Life Member a) Admitted before 45 years of age b) Admitted after 45 years of age	 1000.00 750.00	 250.00 200.00	
3.	Sustaining Member	---	----	2000.00
4.	Patron Member	15000.00	2500.00	----
5.	Student Member	10.00	---	50.00

MEMBERSHIP GUIDELINES

1. Subscription for Life Membership is also accepted in two equal instalments payable within duration of three months, if so desired by the applicant. In such a case, please specify that payment will be in instalments and also the probable date for the second instalment (within three months of the first instalment).

2. A Member of the Society should countersign application of membership.

3. Subscription in DD or Cheques should be made out in the name of '**INDIAN SOCIETY OF GEOMATICS'** and payable at Ahmedabad.

4. Outstation cheques must include bank-clearing charges of Rs. 65.00/US$ 10.00.

5. For further details, contact Secretary, Indian Society of Geomatics at the address given above.

6. Financil year of the society is from April 1 to March 31.

7. ISG has chapters already established at the following places: Ahmedabad, Ajmer, Chennai, Hyderabad, Indore, Mangalore, Mumbai, New Delhi, Pune, Tiruchirappalli and Vadodara. Applicants for membership have the option to contact Secretary/Chairman of the local chapter for enrolment. Details can be found at the website of the society: www.isgindia.org

8. Journal of the society will be sent only to Patron Members, Sustaining Members and Life Members.