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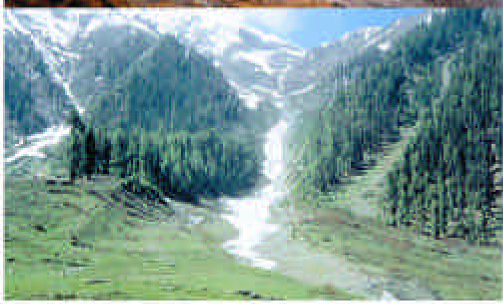
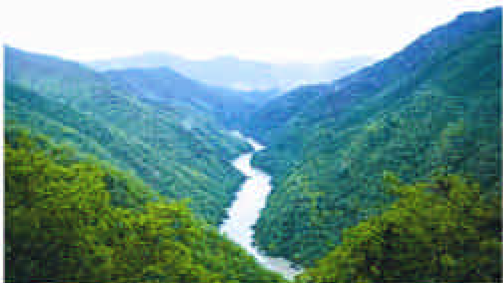


Special Issue on

MOUNTAINS

- Himalaya
- Forestry
- Fragile Ecosystem
- Earthquakes
- Glaciers
- Horticulture
- Terrace Cultivation
- Landslides

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ISG Newsletter

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In this issue

EDITORIAL

For the last few years, Indian Society of Geomatics has been bringing out special issues of the ISG Newsletter which are devoted to important themes and fields where Geomatics has been playing or expected to play an important role. This special issue is devoted to 'Mountains'. Mountains occupy 24% of Earth's land mass (52% of Asia). All the major rivers in the world originate from mountains. In fact, 50% of humanity depends on mountains for water supply and 10 % of the world's population lives in mountains. The latter are a major source of recreation - hiking, trekking, river rafting, skiing, etc. Geomatics has made rapid strides in studying various aspects of mountains during the last few years, particularly with the availability of high resolution satellite imagery with stereo capability. Initially this issue was planned to include various facets of mountains – resources, ecology, recreation, etc. and the threats faced by these ecosystems. We have, however, ended up in compiling an issue essentially covering the Himalaya and the 'Himalayan' problems faced by the people residing in the Himalayas. The Himalaya is the loftiest mountain system in the world containing 14 of the world's tallest peaks. The Himalaya has sublime scenery, recreation facilities, and numerous religious/pilgrimage places, which attract millions of people as tourists and pilgrims. However being a 'young' mountain range, geologically speaking, its ecosystem is rather fragile but with tremendous biodiversity. Human interference in this fragile ecosystem is compounding the problems created by nature due to the mountain system being 'young '.

Contributions in this issue address a very wide spectrum. The issue includes a comprehensive introduction to the Himalaya and its resources comprising forests, agricultural crops, horticulture, glaciers and perennial rivers which are the lifeline for Indo-Gangetic plains. Contributors have addressed problems arising due to complex geology, seismicity, ongoing tectonism, population pressure, human interference in the form of large scale deforestation to feed forest-based industries, and infrastructure development comprising hydro-electric power stations, river-valley projects, road-network, bridges, hotels, holiday homes etc. Additional problems are created by glacial retreat, glacier-dammed lakes, cloud-bursts, high seasonal variations in precipitation and run-off, cultivation practices on steep slopes, etc. All these cause degradation of lands, slope instability, frequent occurrence of landslides and floods. Use of high resolution satellite imagery and stereo capability for disaster monitoring, development planning, management of resources, creation of bio-geo databases and modelling of seismicity-induced landslides has been adequately discussed. We are happy to include here an article by a grassroot ecologist –Chandi Prasad Bhatt, famous for 'Chipko Movement' - on the use of Remote Sensing and GIS technologies in monitoring restoration of tempered terrain and fragile ecosystem of Central Himalaya, where his organisation, Dasholi Gram Swarajya Mandal, .is active in restoration activities

The issue was compiled by Dr. M.M. Kimothi of Space Applications Centre as Guest Editor. He deserves our sincere thanks

Baldev Sahai
Chief Editor

HIMALAYA -*THE NAGADHIRAJ*

B.R. Arora
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INTRODUCTION

The Himalaya is the loftiest mountain system in the heart of Asia extending from the east to the west for a distance of nearly 2500 kilometers, separating the Indian subcontinent from the Tibetan plateau (Fig.1). It varies in width from 240 to 330 kilometers and constitutes the four main parallel ranges from the south to the north popularly known as the Outer Himalaya, Lesser Himalaya, Great Himalaya and Trans Himalaya (Fig.2). Home to world's 14 highest peaks the Himalayan mountain system was formed as a result of the collision of the Indian subcontinent with Asia more than 40 million years ago. Since then there have been spasmodic uplift of its constituent sediments to attain the soaring stature evident today.

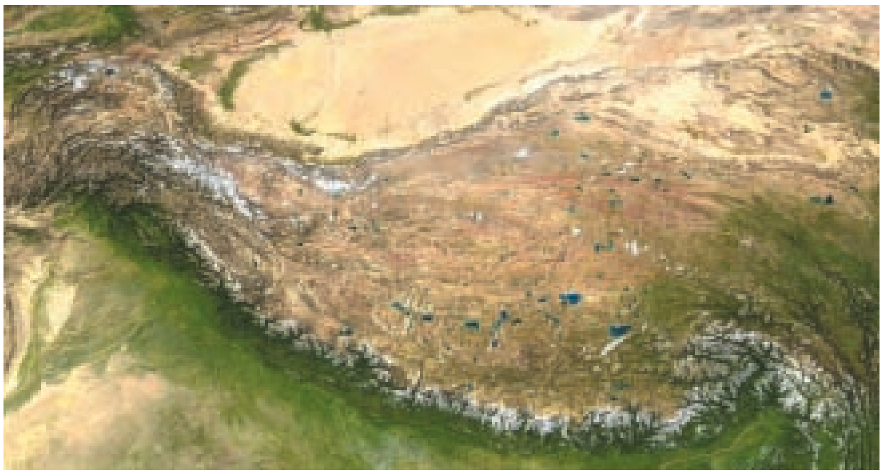


Fig.1 Composite satellite image of the Himalayan range. The top of the picture is directed towards the north northwest. The Tibetan Plateau is near the centre and the Taklamakan plain is visible as the lighter area near the top.

The Himalaya is the driver of the north Indian climate. As such there are a number of glaciers which feed the three mighty river systems of Indus, Ganga and Brahmaputra. These river systems are the lifeline not only in their catchments region but also the vast plains developed by them

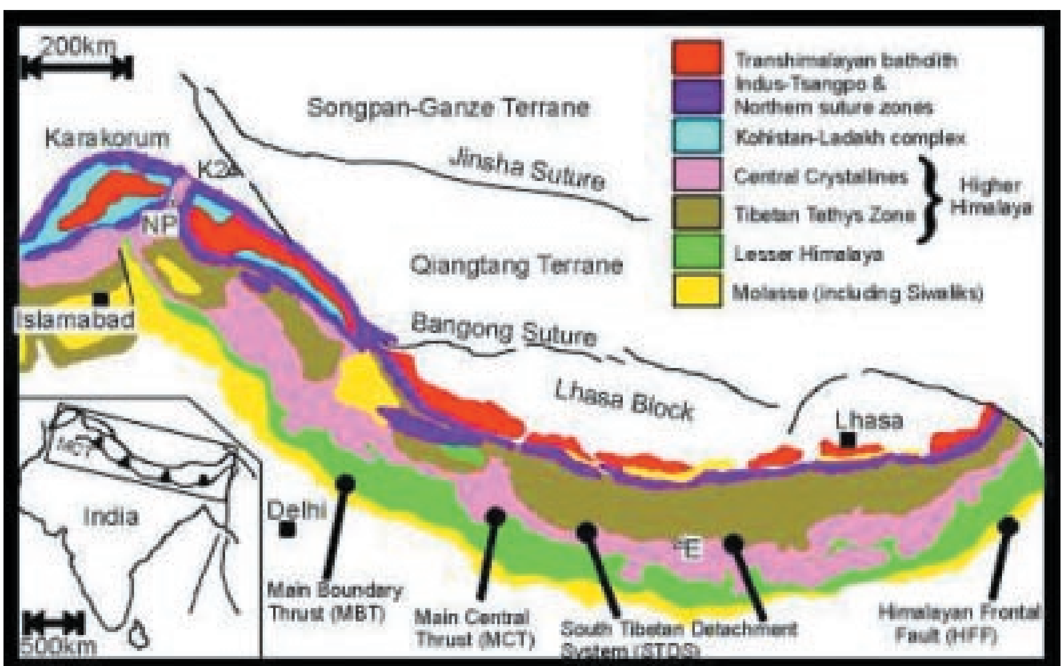


Fig.2 Tectonic belts of the Himalaya.

in front of this gigantic mountain system. Over 50 million people inhabit the Himalayan mountain terrain. While philosophers have glorified the Himalaya, spiritual seekers have found peace in its serenity, mountaineers have attempted to unfold its profound height and vastness, scientist have ventured to explore its evolutionary process and wealth of natural resources it has in its fold. In the myriad of the global ecosystems, mountains have their own characteristics and the Himalaya is a prominent ecosystem of its own. On the one hand, being the youngest mountain system and geologically the most dynamic, on the other there is pressure on account of both rising population and the development of its natural resources, rendering the whole mountain ecosystem extremely sensitive from the geoenvironment standpoint. The following aspects deal with but few of the characteristics inherent to this mountain system that is witnessing the impact of the global change as any other part of the world. While highlighting these aspects it is also intended to project the latest geoscientific developments that are significant to the society in general and the scientific understanding, in particular.

HIMALAYAN GLACIERS

The Himalaya constitutes one of the most important glacier systems in the world. These glaciers contribute fresh water to the main river systems of the Indian sub-continent. Resources of water in the form of ice and snow cover extensive areas in the Himalaya. It has been estimated that 38221 sq km of Himalayan ranges are glaciated. Updated Glaciers inventory data (Geological Survey of India) has identified more than 9000 glaciers in the Indian part of the Himalaya. Distribution of these glaciers in the long ranges of Himalaya is uneven; however, concentration of these glaciers is higher in the northwest than the northeastern part of the Indian Himalaya. Such complexity is due to criss-cross mountain ranges, altitudinal variation and different climatic environment. Melt water from theses glaciers forms an important source of runoff in northern India during the summer months. This runoff may be affected due to continuous recession of the glaciers.

With a view to better understand the current glacial processes as related to their applied aspects in area of surface water management, climate, environment, etc. in the Himalaya, a multi-disciplinary multi-institutional mode programme for studies of Himalayan glaciers was initiated by the Department of Science and Technology, Government of India, under the Himalayan Glaciology Programme (HGP) in 1986. In the first phase Chhota Shigri glacier in Himachal Pradesh was taken up for studies relating to mass balance, recession, ice thickness, glacial discharge, sediment transfer, isotopic and chemical characteristic of snow, ice and melt water and geomorphology mapping under the leadership of Wadia Institute of Himalayan Geology. Since then the institute is deeply associated with this programme and currently two glaciers, Dokriani (1991-continuing) in the Bhagirathi basin (Fig.3) and Chorabari (2003 - continuing) in Alaknanda basin are being monitored for detailed glaciological studies.

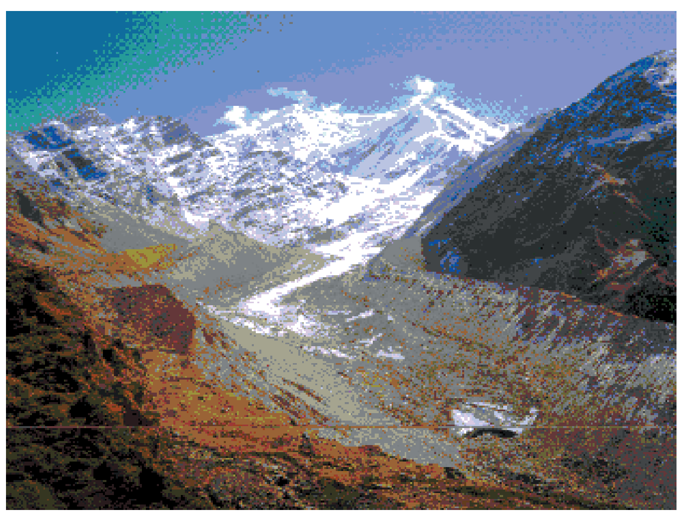
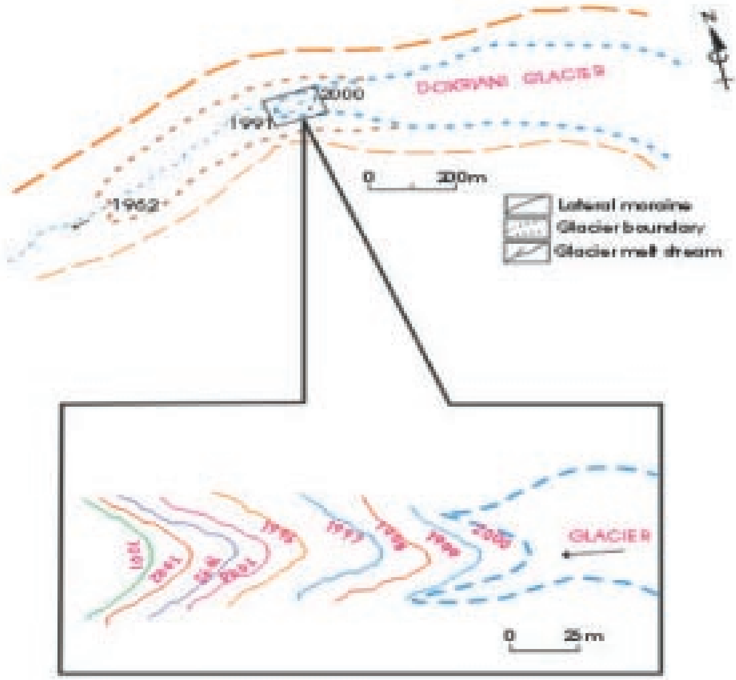
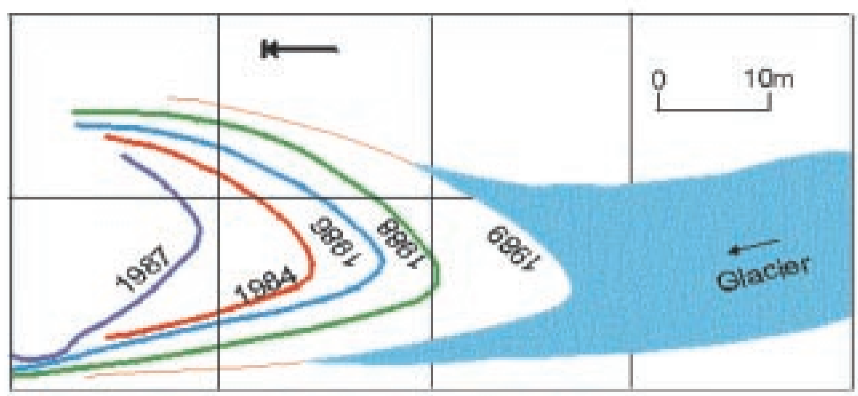


Fig. 3 Panoramic view of Dokriani glacier in the Bhagirathi basin showing the recessional trend.



a) Dokriani glacier (1962-2000)



b) Chhota Shgri glacier (1984-1989)

Fig.4 Recessional trends of the Himalayan glaciers.

Even after so many years of work on Himalayan glaciology by various organizations a clear picture is still not available regarding total snow covered area, number of glaciers and total ice volume in different river basins of the Himalaya. It is a well established fact that the glaciers are receding throughout the world, though the rate of recession is rather irregular in terms of amount and time of occurrence which depends upon the topography and climatic conditions of the area. It has been reported that Himalayan glacier are by and large in the state of recession. The fluctuation records of Himalayan glaciers are only 150 years old. Mayeswki and Jeschke (1979) studied 122 glaciers of the Himalaya and Karakoram region and concluded that most of the glaciers are retreating. Detailed work on the recession processes of Himalayan glaciers has been carried out by Indian scientists during the period 1970 onwards (Vohra 1981; Kumar and Dobhal 1994; Puri and Shukla, etc.). Our studies on the Dokriani glacier over the past 15 years or so show an average rate of retreat at 18 to 20m/year (Fig.4a) (Dobhal et al., 2004), and that of the Chhota Shigri glacier in Himachal Pradesh shows the rate of retreat at 21m/year (Fig.4b) during the study period of 6 years (Kumar and Dobhal 1994). It has also been observed that the recession rates of both small glaciers (<5 km) and large (>10) glaciers are more or less same, which indicates that the future of small glacier is not very encouraging. However, the majority of small glaciers are more than the large glacier

Glaciers and their environment hold essential key to our knowledge of the present, past and future environmental conditions. The great waxing and waning of glaciers have profoundly shaped large areas of the Himalaya by scouring out rock and sediment and re-depositing them as thick accumulation of glacial debris. A large section of the Himalayan population lives in these valleys and cultivate over the sediments laid down by the glaciers. With change of climate and developmental pressure, there can be serious geo-ecological changes in the near feature. Four major ice ages have occurred over approximately 4.6 billion years since the Earth was formed; we are currently in an interglacial (http://en.wikipedia.org/wiki/Interglacial) of the Pleistocene glaciation. Since the end of the last glacial 12,000 years ago there have been minor advances and retreats on a local or regional scale. In historic times, glaciers grew during the Little Ice Age (LIA), a cool period from about 1650 to 1850. Subsequently, until about 1940, glaciers around the world retreated as climate warmed. Glacier retreat declined and reversed, in many cases, from 1950 to 1980 as slight global cooling occurred. Since 1980, glacier retreat has become increasingly rapid and ubiquitous, so much so that it has threatened the existence of many of the glaciers of the world.

MOUNTAIN HYDROGEOLOGY (GROUNDWATER)

Himalaya is considered to be the water tower of northern India feeding its mighty river systems, streams, lakes, groundwater, etc. In spite of the mountain furnishing water to millions downstream, its people are facing acute shortage of water for the domestic consumption giving rise to social conflicts. Recent surveys have shown that Kumaun and Garhwal regions are witnessing reduction in the discharge of springs. Some of the springs have either dried up or have become seasonal, and the difference in the volume of water flowing down the rivers during dry and rainy seasons is more than 1000 times, resulting in the too-little and too-much water syndrome. The evaporation of moisture in the soil on the tree-less slopes is very high and Xerophytes have begun to find hold on the naked slopes.

Groundwater resources are highly variable in mountainous areas and are mainly dependent upon factors of geology, climate and topography. Most of the rainfall leaves the area as direct surface runoff; a little amount infiltrates to augment the groundwater. The availability of groundwater is manifested in the form of springs (Fig.5) and seepages and bore wells of limited yield. This also serves as the principal source of water for human existence, backing the perennial flows available in small rivers and streams. Direct infiltration of rainwater through joints, fractures and weathered zones is the main cause of recharge to the springs. Following six hydrogeological units can be recognized across the Himalaya (Bartarya, 2006). The capacity of absorption and retention of water of each unit is very distinct.

1. *Fractured hard rocks,* having secondary porosity and permeability, and characterized by springs and seepages. The groundwater/subsurface water in this

zone occurs largely as disconnected local bodies in favourable zones of jointing, fracturing and faulting. The springs in the rocks having secondary porosity show great variability in yield even within short distance.

2. *Fluvial and colluvial deposits,* lying along the lower and middle valley slopes in lower

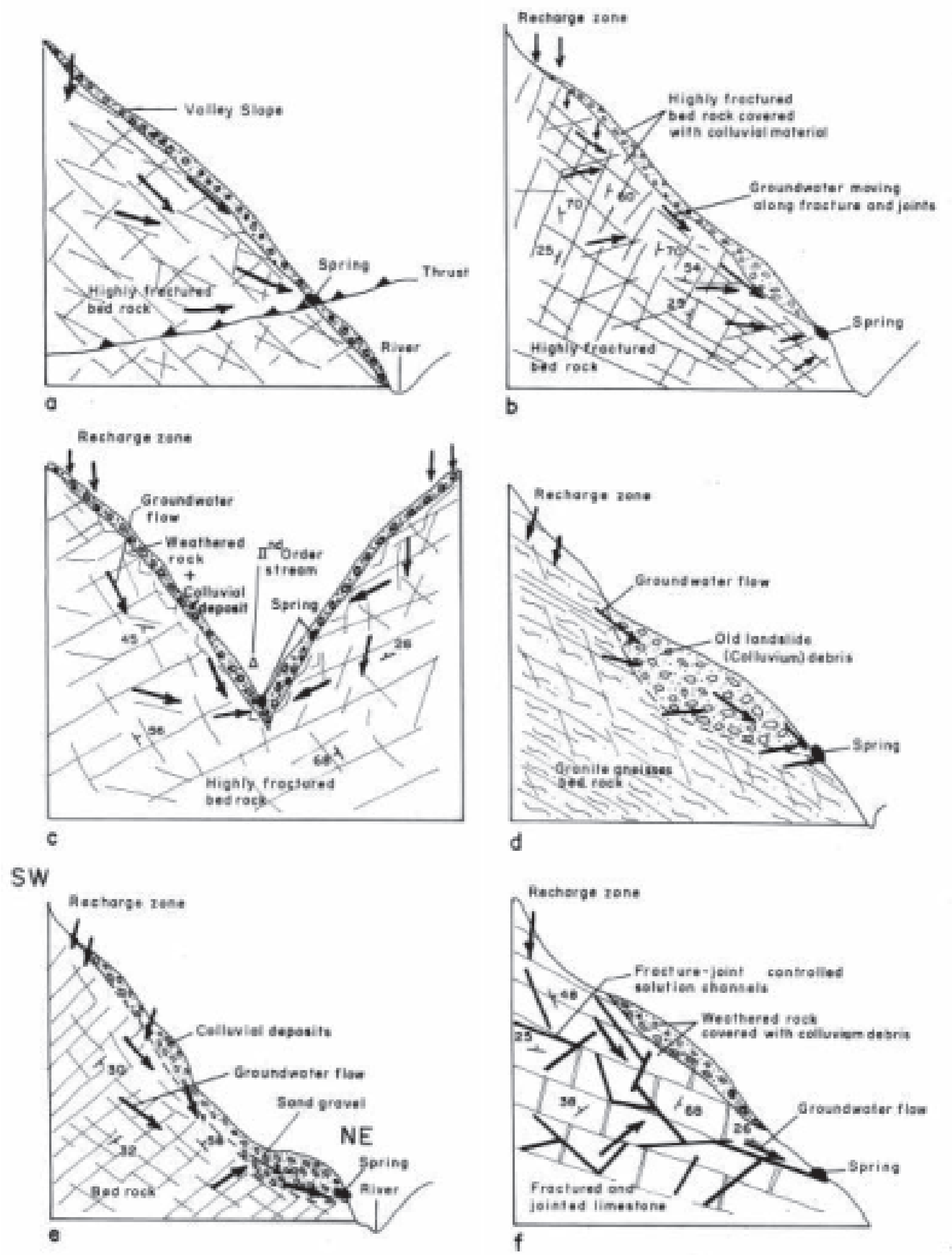


Fig. 5 Schematic diagram showing spring types: a) fracture-lineament related spring, b) and c) fracture-joint related spring, d) colluvial spring, e) fluvial spring, f) karst spring.

reaches of the river or near the confluence of two streams in the form of fans and terraces, old valley fill or lake deposits (such as at Pithoragarh) and old landslide deposits which are highly porous and permeable and therefore hold sufficient quantities of ground water. The springs show wide variability in discharge.

3. *Karst aquifer* is characterized by solution of joint controlled cavities and channels in dolomite and limestone. Fault and deep-seated fractures have played an important role in localization of springs in this type of aquifer.

4. *Permeable sandstone of Siwalik,* present in the Outer Himalayan region characterized by permeable sandstone inter-bedded with mudstone which acts as aquiclude and thus helps in the development of springs and perched aquifers. In spite of high porosity and permeability of sandstone, the springs of the Siwalik rocks do not yield large quantities of water due to high topographic slopes

5. *Piedmont alluvial plains*, present all along the foothills of the Himalaya. The vast zones of alluvial sediments were deposited in two distinct morphological units viz. Bhabhar and Tarai. The Bhabar unit consisting of coarse material is represented by piedmont fans bordering the Outer Himalayan belt, whereas Tarai unit constituted of finer sediments and having good groundwater potential lies down south of the Bhabar unit.

6. *Intermontane basins,* are situated in the 'intermontane synclinal valleys, locally known as 'd*un*' within the Outer Himalayan belt. Important *duns* are Pinjor Dun, Dehra Dun, Kota Dun, etc. The 'duns', consisting of boulders, cobbles, pebbles and coarse sand separated by clay beds, have high ground water potential and the multilayered water bearing horizons are present both in unconfined and confined conditions (Bartarya, 1995).

Environmental Constraints

The problem of water in the Himalaya can be summarized as *"**Water an abundant yet scarce resource**"*. The region gets abundant rainfall and is the source of most of the major rivers of North India. Yet complex geology, seismicity, high seasonal variations in precipitation and runoff, steep and inaccessible slopes, changing land use in the watersheds, population pressure, degradation of land and forests are some of the factors which place tremendous constraints on the discharge potential of springs and streams of the region. The decrease in average annual rainfall and change in rainfall pattern have their effect on the efficiency and efficacy of water recharge system specially in aquifers which are the main sources of water for springs. The impact of climatic change on water availability pattern needs to be studied under site-specific conditions.

Seismicity of the Himalaya and seismological network in the Himalaya

The Himalayan mountain range is the dramatic outcome of the collision of Indian and Eurasian plates, some 40 million years ago. The Indian plate is still penetrating deeper at an estimated rate of about 5 cm/year. The Himalayan collision zone has been marked by intense seismic activity. The Himalayan frontal arc is one of the seismically active regions of the world (Fig.6). The 50 km wide zone between two mega-thrusts, the Main Boundary Thrust (MBT) and the Main Central Thrust (MCT) is the most active seismically. This zone is also known as the Main Himalayan Seismic Belt (Ni and Barazangi, 1984) in which the great Himalayan earthquakes (M>8) occur along the detachment surface that separates the underthrusting Indian plate from the Lesser Himalaya, while most of the moderate earthquakes occur at shallow depth. Four great earthquakes (1897 Assam, 1905 Kangra; 1934 Bihar-Nepal and 1950 Assam) have occurred here in a short span of 53 years. The regions between the epicenters of these earthquakes are known as the seismic gap, which are the potential sites for future big earthquakes. Bilham et al., (2001) has shown the potential magnitude and respective potential slip along these gaps. The frequent moderate earthquakes and the infrequent great earthquakes suggest that episodic slippage is continuing. These ongoing processes also imply that future great earthquakes can be expected in the unruptured parts of the Himalayan front. Major uncertainties remain regarding the recurrence interval of great earthquakes. Seismic zonation map of a country is a guide to the seismic status of a region and its susceptibility to earthquakes. India has been divided into five zones with respect to severity of earthquakes. Of these, Zone V is seismically the most active where earthquakes of magnitude 8 or more could occur. Most part of Himalaya comes under zone IV and V.

The Wada Institute of Himalayan Geology has been operating a network of analog and digital stations in the NW Himalaya since 1984. A fresh earthquake catalogue of the Institute for the period 1985-2005 showing complete record of seismic events of magnitude M³3 reinforces the earlier observations that most of the earthquakes are concentrated along the Main Himalayan Seismic Belt. At the national level, the IMD operates and maintains 18 seismological observatories in the Himalaya and the contiguous region. Research organizations like IIT Roorkee, Regional Research Laboratory (Jorhat), Manipur University and many others operate local observatories in different parts of the Himalaya. The DST has launched a nationally coordinated

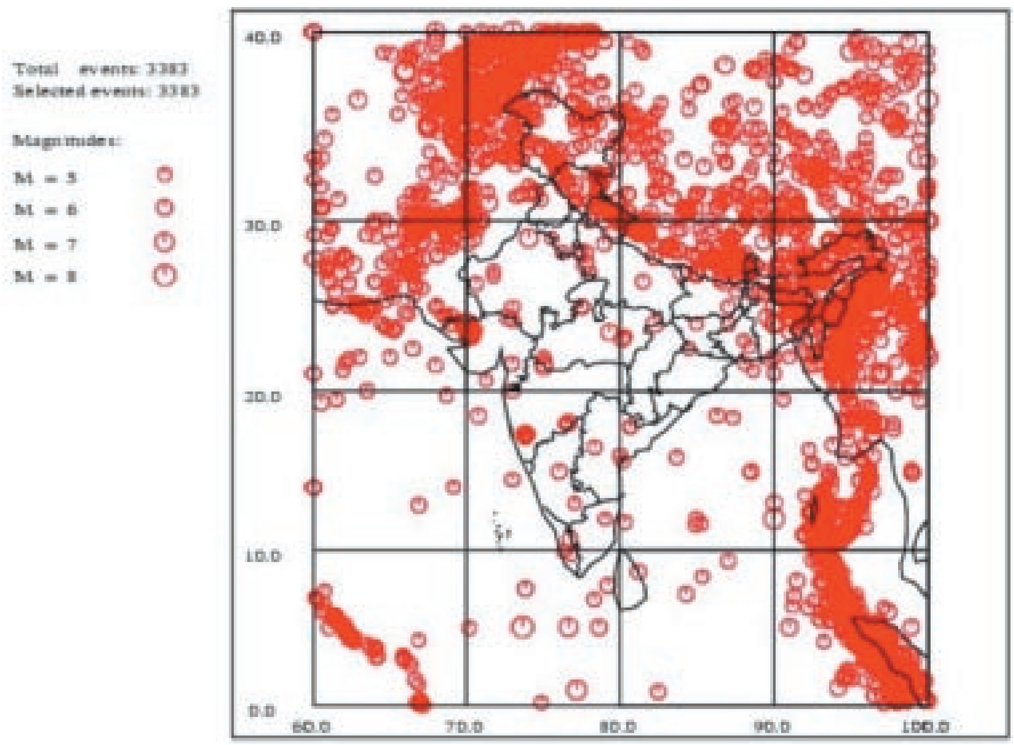


Fig. 6. Plot of earthquakes (M>=5.0) from IMD catalogue for the period 1800-2001.

project on the study of seismicity and seismotectonics in the Himalayan region involving several research organizations.

Active faults in the Himalaya vis-à-vis seismic hazard assessment

Seismic hazard evaluation in the tectonically active Himalaya is crucial because earthquakes pose a continual threat to the safety of the people inhabiting this gigantic mountain system of the world. It has now been widely accepted that active faults - *faults which have moved repeatedly in the recent geological time and have potential for reactivation in the future*-contribute significantly to the seismic activity (>80% seismic activity). Mapping and understanding of the nature of active fault systems in different segments of Himalaya is therefore of paramount importance. We however lack information about the distribution of these faults, their behaviour and characteristics. In India, the study of active faults and paleoseismological investigation is still in its infancy though information on distribution of seismicity including major (M6.5-7.5) and great (^{3}M8) events is available. The 8 October 2005 Kashmir earthquake which caused appalling devastation besides 86,000 fatalities has educated us as to how geological and paleoseismological information of the area is critical for our hazard preparedness. It has been discovered that this earthquake has occurred along the pre-existing active fault trace which generated ~ 65-km-long surface rupture with up to ~ 5.5 m vertical separation. It is now widely accepted that seismicity is generally associated with the generation as well as reactivation of active faults (Armijo *et al.*, 1996; Karakhinian 2002). Although only few site-specific studies have been reported in the NW Himalaya (Nakata, 1989; Philip and Sah, 1999; Wesnousky et al., 1999; Oatney et al., 2001) recent geodetic, GPS and seismic studies in the Himalaya have provided significant data on the ongoing crustal deformation in the Holocene on a regional scale (Banerjee and Burgman, 2002).

Remote sensing for the study of active faults

Satellite remote sensing has emerged as a powerful tool for earth scientists in various geological investigations. Remote sensing techniques and DEM based studies have been successfully employed in the field of tectonic geomorphology and active faults by many workers (Armijo *et al.*, 1996; Karakhinian 2002; Philip and Virdi, 2006; Virdi *et al.*, 2006; etc.). In a recent study carried out in Himalaya by Philip and Virdi (2006) demonstrated the significance of morpho-structural analysis using remotely sensed data along with selected field investigations in delineating traces of active faults, which are oblique to the Himalayan Frontal Thrust (HFT) in the northwestern Frontal Himalaya (Fig. 7 and 8). Topographic features indicate movement along a normal fault with upthrown southern block. This extensional behaviour of faulting is in contrast to the ongoing southward thrusting along the HFT with Siwalik sediments in the hanging wall overriding the alluvial fans in the footwall. Various tectonic landforms and the relative positions of the Quaternary deposits

Fig.7 IRS-LISS-III +PAN merged image (False colour composite date: 02 November, 2002) showing the Singhauli Active Fault zone (in box). The arrows show the trend of the fault.

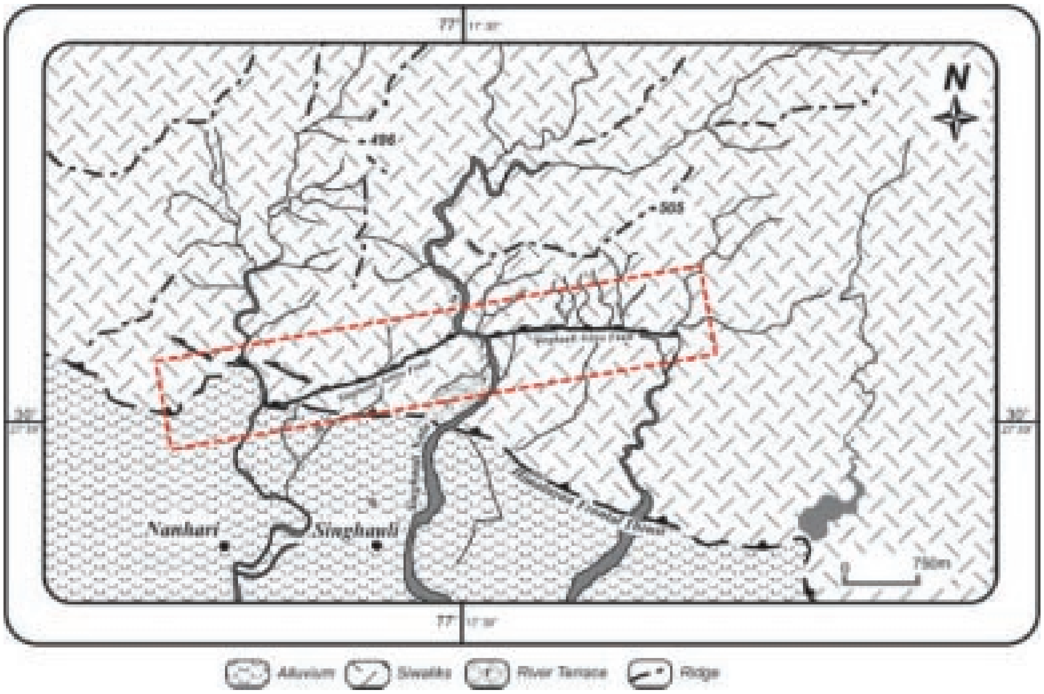


Fig.8 Singhauli Active fault, HFT and the broad geomorphic features of the Frontal Himalaya prepared using IRS data.

in the area corroborate that the Frontal Himalayan region has ruptured repeatedly in the recent past.

LANDSLIDE HAZARD IN THE HIMALAYA

Among the various natural hazards in the geodynamically active Himalaya are the recurrent landslides which cause heavy damage to property, disruption of road communication and loss of human lives every year (Fig. 9). The landslide and other mass movement activities are essentially periodic being generally limited to the monsoon rainfall which simply acts as the triggering factor for inducing the slope instability. The number, frequency and damage due to landslides are determined mainly by geological, geomorphological, hydrological, landuse, climatic and anthropogenic factors. The Himalaya is characterized by three distinct climatic zones from the south to the north viz. a) Subtropical (rainfall dominated), b)

Fig. 9. Landslide in the Dhauliganga valley.

Intermediate (Inner and Higher Himalaya), and c) Cold alpine (Trans Himalaya). Because of staggering relief which influences the intensity of monsoon rainfall over the Himalayan mountains there is general decrease of landslide activity from the north to the south. The increase in the atmospheric temperature brought about by global change has resulted in the shift of monsoon pattern accompanied by an increase in high intensity rainfall and cloudburst events during the past few years (Hewit, 1993; Gupta et al., 1995; Sah and Mazari, 1998). Even earthquakes are responsible for generating landslides on an extensive scale and further augmentation of the same during the monsoon period. This is evident in many parts of the Garhwal Himalaya after the earthquakes of Uttarkashi (1991) and Chamoli (1999).

Landslide distribution in the morphotectonic belts of the Himalaya *(Sah et al., 2003).*

1. Trans Himalaya – this belt essentially representing the Tethyan sedimentaries falls in the cold and dry climatic zone. Occasional rock falls are common in this belt due to freeze and thaw process.
2. Higher Himalaya – this belt constituted by the crystalline rocks is characterized by high relief zone of glaciation where slopes are generally devoid of vegetation, valleys are covered with glacial and periglacial deposits. Rapid erosion, avalanches and rock falls are common in this belt.
3. Lesser Himalaya – medium high relief belt consisting of sedimentary rocks overlain by nappes of crystalline rocks covered with vegetation in degraded conditions due to human interference. Prone to landslides and other mass movement activity due to the influence of high intensity rain and cloudbursts.
4. Outer Himalaya – low-lying hill range comprising sandstone, siltstone variations acts as the barrier to the low monsoon wind. Prone to landslides.

Factors responsible for landslides

1. Increase of pore water pressure due to high rainfall.
2. Increase in internal pressure due to physical or chemical alteration of rocks.
3. Saturation in the body weight of the overlying soil/sediment. Dynamic forces like earthquakes, neotectonic activity, blasting of rocks, passage of heavy vehicles.
4. Unscientific land use, like agriculture on steep slopes, shifting cultivation, overgrazing, deforestation, unscientific mining, etc.

Landslides become particularly vulnerable when they affect the road communication. That is why a well-conceived landslide mitigation policy needs to be in place, sooner the better, to manage the impact of this natural hazard in the Himalaya.

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RESTORING TEMPERED TERRAIN AND FRAGILE ECO-SYSTEM IN CENTRAL HIMALAYA: SOME THOUGHTS

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INTRODUCTION

Situated in the central part of Asian continent, Himalayan ranges have numerous snow-clad peaks, valley glaciers, diverse faunal and floral assemblages, and mineral wealth. According to geologists, the mountains are dynamic, ever-changing their surface morphology, which can be felt in the form of frequent earthquake tremors.

These lofty ranges extend 2500 km along east-west axis whereas along the north-south transect, the width varies between 200 to 300 km. In India, Himalayan ranges are divided into three zones along the east-west axis. The western Himalaya covering states of Jammu and Kashmir and Himachal Pradesh, the Central Himalaya covering Garhwal and Kumaun region of Uttranchal and the eastern Himalaya covering states of Sikkim, Assam, Manipur, Meghalaya, Nagaland, Tripura, Arunanchal Pradesh, Mizoram and a part of West Bengal (Darjeeling District). These states together constitute 594427 sq. km area, which is 18% of the total area of the country having 38% of forest cover and inhabited by 6% of the population (1991 Census).

According to geologists, millions of years ago, gigantic collision of Indian plate with Tibet led to the development of high mountains and deep valleys where glaciers grew feeding the rivers. According to an estimate nearly 15,000 glaciers are located in the Himalaya, the store house of perennial water. Major rivers like the Ganga, Indus and Brahmaputra originate from these glaciers and the drainage basin of these rivers is around 43.8% of the total geographical area of the country. In terms of water budget, together they contribute 63.21 % of the total water budget of the Country.

Terra in ruggedness and altitudinal variability (200- > 8000m) paved way for rich biodiversity. Below the permanent snowline (> 5000m) is the domain of lush green Bugyals (Alpine pastures), a bonanza of exotic flowers and medicinal herbs. The pastures act as spongy cushion for absorbing water and hence recharging the natural springs. Below the pastures are the broad-leafed forests of Oak, Rhododendron, Birch, Fur and Spruce etc. and provide uninterrupted supply of nutrients to the agricultural fields along with maintaining the soil moisture regime. Further below are the forests of Chir pine, a source of building material and are succeeded by the broad-leaved forest towards the foothills (Sivaliks). Similarly, diversity in the faunal assemblages can be found that ranges from the snow leopards, white bear, and musk deer in the higher altitudinal domain to the black bear, leopard, tiger, elephants and Rhinos towards the lower reaches.

Natural resources, geographical vividness and ecological diversity gave rise to a distinct hill society that drew strength from its environment for its survival and growth. People living in the region developed a symbiotic relationship with their terrain and resources; this is manifested in the local architect, resource utilization and management, religious practices and beliefs. A traditional 'Jor-Tor' technique was used in house building in which care was taken to provide enforcement against the threat posed by frequent earthquakes, such as provision for wooden tie beams at different level, slanting roof thatched by slates, using perpendicular corner stones for adjacent walls etc. Similarly, knowing the sensitivity and significance of high altitude pastures, drinking water sources and forests, certain religious practices were invoked and followed by the local people.

With the advent of modernization, lust for illusionary comforts led to senseless exploitation of the Himalayan resources. The pace of natural resource exploitation particularly of the forests has not only put a question mark on the very existence of the Himalaya and the hill people, but has created tremendous sense of insecurity in the thickly populated Indo-Gangetic plain. In the Himalaya, the impact of resource exploitation is alarming. Every year million tons of topsoil is being eroded from the fragile Himalayan catchments. Landslides and flash floods have become common phenomena. Our great leader Mahatma Gandhi warned us long ago that "*Nature has enough for everybody's need but not for every body's greed"*. Considering the state of affairs prevailing in Himalaya, it looks as if we have virtually crossed the threshold of human greed. This is manifested in the barren slopes, innumerable landslide scars, dwindling agricultural productivity, fast-vanishing traditional water resources, low biomass yield from the forests etc. They all point towards the fact that terrain is fast losing its carrying capacity and warns us that something urgently is required to rejuvenate the sustainability of the Himalaya. If our indifference towards the terrain continues it will have serious impact on the Himalayan eco-system that will have far reaching consequences.

UTTRANCHAL (CENTRAL HIMALAYA)

Presence of bountiful water, rich natural resources and fertile valleys encouraged people to inhibit this region. The local people built and developed many spiritual places and made it a region of spirituality. Today it is known as Deva Bhumi (abode of Gods). In ancient inscriptions, five divisions of Himalaya were mentioned out of which the Kedar Khand and Manas Khand are in Garhwal and Kumaun comprising two commissionerates covering 13 districts.

Flanked by Nepal and Tibet in the east and north, Himanchal Pradesh in the west, and fertile plains of Uttar Pradesh in the south, Uttrakhand due to its rich forest and water resources was a prosperous area. Even though the terrain was rugged and difficult, people inhabited the region because of the availability of rich forest and its produce. The fertile soil, availability of water and forest etc. helped local people in leading a self-contained life. These resources were under their command; they were the master of their surroundings, its harvester, protector and promoter. The forests fulfilled more than 60 percent of domestic requirements and the remaining 40 percent was procured from other resources.

This was a period during which there was tremendous development in social, spiritual and cultural fields. Many spiritual places were created; progress was made in areas like folk culture, art, literature and social system. Uttrakhand was considered as the seat of learning in the country. Rivers like the Yamuna, Bhagirathi, Bhilangana, Mandakini, Alaknanda, Pinder, Nandakini, Birehi, Vishnu Ganga, Ram Ganga, Koshi, Kali, Gori, Dhauli etc. have their source in Uttrakhand. The glaciers feed them with uninterrupted supply of water and the forest helps in assisting the recharge of the natural springs.

This all began after the colonial rulers in early 19th century set their foot in this region. In order to generate revenue from forests. They began commercial exploitation of the forest in addition to imposition of taxes on land. This was the beginning of external interference in village system that led to unrest among the local masses. Reflections of this unfortunate trend could be seen in local people becoming indifferent towards forests. Local people raised their voice from time to time in order to safeguard their resources and traditional rights on their forests but this legitimate outcry of the local people went unheeded.

VIOLATION OF TRADITIONAL RIGHTS

The beginning of encroachment on forests during 1817-23 led to the declaration of forest policy in 1988 Government campaign was to marginalize the locals from their traditional right. During pre-independence time locals were exploited by the colonial rulers and after independence government is depriving them in the name of development. Lack of appreciation for the terrain and the people, kept the instrument of exploitation moving. Forests that are today considered as one of the major component of environmental security were mercilessly exploited for generating revenue. The ultimate outcome was fast-declining forest wealth of the regions which ultimately culminated into innumerable calamities such as incidences of flash floods, landslides; soil erosion, etc. Women in the region are the pivot of hill economy; declining natural resource base severely affected this community. With mounting scarcity of fodder and declining natural water resources took heavy toll on their daily life. When during early 1970's world was concerned about the global environment, back in the remote locality of Uttrakhand, Dasholi Gram Swarajya Mandal (DGSM), the parent organization of the famous Chipko Movement was working towards better living condition of the hill society through protection and propagation of natural resources. A turning point in the history of Uttrakhand came when an unprecedented flood in the history known as the 1970's Alaknanda flood not only ravaged the mountains but its impulse was felt in far off region like the western plains of Uttar Pradesh.

1970'S ALAKNANDA FLOOD

After the flood, it was all out destruction in the upper catchment, people were unable to reconcile with the tragedy, and they required consolation, security and faith in themselves. We decided to reach majority of them. Our asset was faith in our self and wisdom acquired through experiences. We found that the genesis of the flood is linked with large scale deforestation to the tune of around 16082 acres of forest which was felled between 1959 and 1969. This was validated through the working plan of the forest department. In addition to this, new road construction in the upper catchment of the Alaknanda river led to the destruction of innumerable oak, pine, rhododendron and deodar trees. Thus, during the torrential rain, barren slopes became vulnerable leading to the formation of innumerable landslide dammed temporary lakes. These dams sequentially breached which released stored water down stream inundating the lower valley so much so that the 10 km stretch of the upper Ganga canal located 350 km downstream of the upper Alakananda basin was filled with Himalayan sediments.

Though our study lacked scientific database, it could demonstrate that in a dynamic terrain, the flood of 1970, was severely modulated by human folly. In the present case it was purely the human greed to exploit the rich forest wealth for getting more and more revenue. The above interpretation put forth by DGSM volunteers could convince the local people that their very existence lay on the protection and propagation of forests in the region. This awakening led to the birth of the historic Chipko movement (save the forest).

Restoring resources

Having won the major battle of protecting the forest from the commercial felling, it was realized that a community program of regreening the barren slopes is essential in order to safeguard the terrain and the people from future calamity. Depleting forest resources continue to put tremendous workload pressure on hill women who had to walk miles together to fetch fuel, fodder and drinking water. A series of education programs through eco-development camps were launched by DGSM to motivate people for volunteer participation in rejuvenating their lost resources. These eventually became the focal point of integrated development of the hill society in the region.

Today, the camps are not only witnessing overwhelming participation of the local people but also the government and non-governmental organizations. So much so that at times, the future planners and decision-makers are sent to these camps in order to get acquainted and learn the problem in the hill area. Since these camps have demonstrated successfully the impact on the land and the people, many NGO's who happen to be participants some time or the other, have taken up similar venture in their respective area of activity. Today the government of India is also carrying out large-scale forestation work. We have no hesitation to say that the path shown by DGSM, whether it is protection of the forest through Chipko Movement or undertaking community forestation drive, has become a national concern. We think that to a large extent we have achieved what we aimed at in the beginning. But nevertheless, much more needs to be done in order to regain the lost glory of these lofty mountains.

SPACE TECHNOLOGY

I was always fascinated by the Indian Space Program, particularly in the context of village level development planning. We were interested in knowing if this technology can help us to monitor the impact of eco-development work carried out in the Himalayan regions by a large number of Non-Government Voluntary organizations... We had no way to monitor our program though there were many indications suggesting that over the last 4 decades things have really improved by continued participation of the local people. But we wanted to quantify this development and wanted to know how we should be planning our future program. Towards this I approached scientists working at the Space Applications Centre (SAC), Ahmedabad who were considerate enough to help us in providing technical and scientific support. Based on the study conducted by SAC, which is first of its kind in Uttranchal, we know where we stand today. Now with the analysis of data from Indian satellites, it is possible to monitor the impact of the developmental activities implemented by various organizations. To give some essence of the study below is their major inferences.

1)The landuse/ landcover status indicate that the watersheds in which DGSM is working for past 30 years could reclaim 6224 hectares of forest out of which nearly 2664 hectare is grown exclusively on the village barren land.

2) Watershed in which DGSM is engaged in the afforestation drive represents ideal ecological setting with forest covering more than 60% of the watershed area.

3) Due to the enhancement of forest cover, the available biomass, unlike 30 years ago, far exceeds the local demand and if utilized judiciously and scientifically, it can be harvested and supplied to the biomass starved villages in the region.

4) In the watersheds, which were denuded during1959-1969 to the tune of 3235 ha of forest, nearly 2924 ha of forest, were reclaimed till 1991. This is significant viewing the proximity of the watersheds to the Main Central Thrust (MCT) which is a seismically active thrust in the Himalayan region.

Following the above study many projects were undertaken by SAC scientists in Alaknanada Valleys which helped us in understanding the kind of changes that are taking place, causes of such changes, and possible remedial measures. To name a few we know to what extent the damage was caused during Chamoli earthquake, Madhyamaheswari landslide, forest fire, Alaknanda flood etc. One of the major outcome of these joint ventures resulted in the formation of a high level committee to assess the landslide-induced floods in the Alaknanda watersheds. Not only this, we now have information about the areas that are vulnerable to such a calamity in future. This was beyond our comprehension few years ago. Today in our eco-development camps, satellite technology has become a common thing. Scientists from NRSA, ISRO, IIRS and SAC have helped us through their knowledge. A common villager in our area knows what a satellite picture is and which way it is useful for him. I think this is remarkable considering the remoteness of the terrain. This could not have been achieved if the constant support from ISRO was not there.

In this connection, our organization jointly with Space Applications Centre, Ahmedabad, organized a one-day workshop on " Role of Space Technology for Natural Resources Management and Disaster Mitigation in Uttaranchal Himalaya" at Birhi, in Chamoli district on 17th May 2002. Almost 70 participants, local villagers, Mahila Mangal Dal, Non-Government Voluntary Organizations, district administrators, developmental workers, school and universities teachers of Uttaranchal state along with scientists from ISRO, SAC, NRSA, IIRS &GBPIHED participated in the workshop.. In this workshop traditional and scientific knowledge was shared along with elaborate discussions and presentation on the aspects of utility of geospatial technology (Remote sensing, GIS and field information) for the natural resource management and disaster mitigation in ecological fragile terrain like Himalaya. Besides this, issues pertaining to how best the information can be translated at grassroots' level in a timely fashion and in their language were discussed.

In the foregoing I have tried to give an overview of what common people can do provided there is willingness and sincerity in approach. We are doing it at a very small scale for improving the state of our resources. However, the mighty Himalaya problems in this region are also of Himalayan magnitude.

What needs to be done?

Let me be a bit specific; with the availability of high resolution satellite technology and GIS, it is now possible to make high-resolution maps of various natural resources of this region where accessibility is hampered due to lack of communication. This is very important for any planning, be it disaster mitigation or development.

Over the years I have observed that in Himalaya a particular zone called by geologists as the Main Central Thrust (MCT) suffers maximum damage, be it due to earthquakes, landslides or flash floods. I understand that majority of these unfortunate events have a source in the vicinity of the MCT. I have seen many evidences of past caused by slope activation in this narrow zone. Considering the thickness of the relict sediments along the banks one can make some estimate about the magnitude of floods in the downstream region of these river basins.

It may sound unrealistic to people at times that how flood caused damage in a hilly terrain like Himalaya where rivers flow deep in the valleys and the settlements lie much above the valley floors. In order to appreciate this catastrophe in the Himalayan region one has to take into account the role of landslides, as the floods are intimately associated with the activation of slopes. The rolled debris along the constricted course of the rivers causes temporary damming of the river. This leads to development of temporary lakes which can last for hours, days, months or years depending upon the magnitude of blockage and the hydraulic pressure exerted by the accumulating water. When the backwater pressure of the lake water exceeds the retention capacity of the barrier; the accumulated water gushes downstream with a mighty force inundating settlements proximal to the riverbeds.

Way back in early 80's we undertook a systematic study of a micro hydroelectricity project called the Vishnuprayag near Badrinath. Based on our field observations and critical evaluation of the site, we warned that tempering with the mountain in a region which is already riddled with joints and fractures may prove fatal. We also showed that the project is located in avalanche-prone region hence such a big investment may not be a wise proposition. Our early warning was ignored and work on the project is going on. This year massive landslide in the vicinity of the project site not only wiped out the only link road to Badrinath, but also killed many people. This region has become a curse to the pilgrim as frequent landslide leads to the closure of the road traffic. In the name of exploiting the resources we have become blind towards the sensitivity of the mountains. What worries me is that we have failed to learn from our past mistakes.

With the few examples stated above, I would like to emphasize that much of the desired information on Himalayan ecosystem is either fragmentary or does not suit the requirement of protecting the terrain from natural calamities. Our experience suggests that we have to categorize the terrain based on its sensitivity (magnitude and frequencies) towards various calamities. Since we have the state of art Indian Remote Sensing Satellite i.e. Resourcesat-1, TES, Cartosat-1 with stereo data and planned cartosat-2 and its applications technology available in the country - a boon for authentic mapping of the diversified resources, a detailed database at micro watershed level should be created for the sensitive areas. It is also equally important that such information should not be limited to the technical reports or publication of scientific papers but disseminated in simple format to the district and village level officials and local village organizations. This would enable us to create a sensitized population towards fighting the eventuality with a sense of determination.

(1) I have been requesting the government and scientific organizations to pool their energy in bringing out a detailed blue print of the watersheds that lie in the vicinity of the MCT. Our observations suggest that majority of the calamity had their source in this zone. Considering this we need to create an authentic database for the Himalayan region in general and zone of MCT in particular. Though our space scientists and other organization in the Alaknanda basin have taken some initiative, however, this needs to be done on a regional scale covering the east-west extension of the Himalaya.

(2) Particular emphasis should be given on the river basins that are prone to the creation of artificial lakes due to slope activation. Massive conservation strategies should be worked out for preventing the processes that lead to lake formation. A multidisciplinary team of scientists and experts should be formed to address and redress this new emerging threat in the Himalayan region.

(3) We must have a rough estimate of the areas that are likely to be submerged during the event of lake bursts in major river basins. People living in the downstream region of such basins should be warned and prepared to face the eventuality.

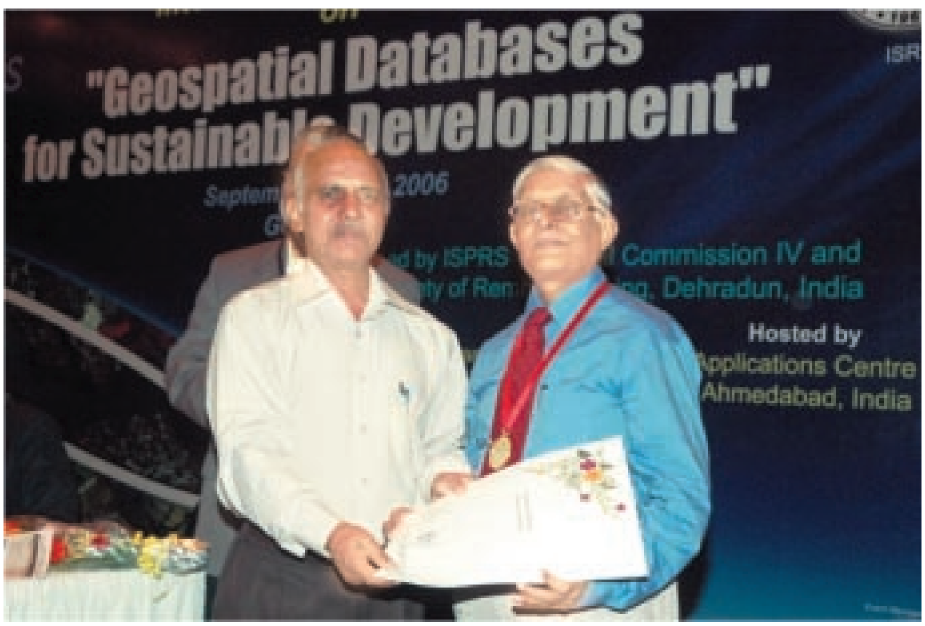
(4) Floods caused by outbursts from lakes dammed either by the moraines or glacier ice is considered as a major disaster in the Himalaya and Tibet. Studies have shown that since 1935, around 49 glacial lakes outbursts were recorded in Tibet. We have no idea how many such bursts had

consequences to our watersheds. With the availability of high-resolution remote sensing data, we can precisely map such lakes and monitor their growth. Since outbursts occur during July and August (summer monsoon time) due to increase in snow avalanche in higher Himalayan reaches, a close monitoring during these months can minimize the damage caused by flash floods in the lower Himalayan watersheds.

Finally, we must honor the unpredictable nature of Himalayan rivers. I have been observing that unregulated constructional activities have mushroomed in the vicinity of riverbeds. These structures that are permanent in nature are built either in the name of recreational tourism or due to the population over growth. We must ensure that people are discouraged from venturing into areas proximal to riverbeds. We have ample examples to show that in the recent times, settlements proximal to riverbeds experienced maximum damage; examples are Belakuch and Srinagar in the Alaknanda basin, Malpa in the Kali basin, Kullu and Manali in the Beas basin.

(Translated from original in Hindi by Dr. MM Kimothi)

NATIONAL GEO-SPATIAL AWARD FOR EXCELLENCE – 2005



Shri Arup Ranjan Dasgupta has been awarded the National Geo-spatial Award for Excellence - 2005 by Indian Society of Remote Sensing during the International Symposium (ISPRS) on Geospatial Databases for Sustainable Development (Sept 27 - 30, 2006) at Goa, India, in recognition of his outstanding life-time contributions to the development and extension of geospatial systems, and promotion of related educational and research activities in the country.

The award consists of Rs. 50,000 in cash, a medal and citation.

One of the founders of the Indian Society of Geomatics (ISG) in 1993, Shri Dasgupta was President of ISG during the period 2002-2005, Vice-President during the period 1999-2002 and Secretary during the period 1993-1999.

Shri Dasgupta was with Space Applications Centre (ISRO) Ahmedabad till 2005 and is currently Distinguished Professor, Bhaskaracharya Institute for Space Application and Geo-Informatics, Gandhinagar, Gujarat

ESTIMATION OF GLACIAL RETREAT IN THE HIMALAYA USING INDIAN REMOTE SENSING SATELLITE DATA

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Over the past three million years, earth's surface has experienced repeated large period of glaciations separated by short warm interglacial periods. During peak of glaciations approximately 47 million sq km area was covered by glaciers, three times more than the present ice cover of the earth (Price, 1973). Natural cycle might have altered due to green-house effect, caused by man-made changes in the Earth's environment. Some of the hypotheses suggests this alteration might have started long before beginning of industrial revolution (Ruddiman, 2005). Invention of agriculture about 11,000 years ago might have led to large-scale deforestation and rice cultivation. However, this pace of change might have accelerated from the beginning of industrial revolution. This has led to an increase in global temperature by 0.6 ± 0.2 °C from 1900 A.D. (Lozan et al., 2001). In addition, recent development in climate modelling suggests that existing green-house gases and aerosols in atmosphere have led to absorb 0.85 $\pm$ 0.15 watts per square meter more energy by Earth than emitting to space. This means additional global warming of about 0.6 ^{o}C without further change in atmospheric composition (Hansen et al., 2005). Mass balance is one of the important parameters, which can be influenced by global warming. Mass balance is usually referred to as a total loss or gain in glacier mass at the end of hydrological year (Hook, 2005). Geographical parameters, which can influence mass balance is area-altitude distribution and orientation, as higher altitude has lower atmospheric temperature. In addition, orientation and amount of slope can influence amount of solar radiation received on the slope (Srinivasulu and Kulkarni, 2004). Influence of these parameters on glacial mass balance is studied in the Baspa basin (Kulkarni, 1992; Kulkarni et al. 2004).

The investigation was carried out using data from a number of Indian Remote Sensing Satellites. In Parbati basin LISS-IV data of IRS-P6 and in Baspa and Chenab basins LISS-III data of IRS-1 D were used. These basins are located in Himachal Pradesh, India. Spatial resolution of this sensor is 5.8 m and data is available in three bands. Therefore, this sensor can be used to monitor small glaciers and ice field. The oldest information about glacial extent is available on Survey of India topographic maps, surveyed in 1962, using vertical air photographs and limited field investigations. Mapping of glacial extent 2004 was carried using LISS-IV images and 2001 using LISS-III images. Images of July-September were selected, because during this period snow cover is at its minimum and glacier is fully exposed. Glacier boundary was delineated using topographic maps and then it was digitized using Geographic Information System. On satellite images glacial boundary was mapped using standard combinations of bands. Image enhancement technique was used to enhance difference between glacial and non-glacial area. Field investigations were carried out at five glaciers to assess position of snout. These include Shanue Garang glacier in Baspa basin, Parbati glacier in Parbati basin and Chhota Shigri, Samudra Tapu and Patsio glaciers in Chenab basin. Snout position of selected glaciers were marked using Global Positioning System (GPS) and by comparing relative position of snout with geomorphologic features such as moraines, origin of stream from snout and moraine-dammed lakes. Glacier retreat was measured along the centerline.

Since GPS instrument cannot be easily mounted on terminus, due to safety consideration, relative position of terminus was estimated using geomorphological features. This means glacial retreat can be estimated by combining field and satellite observations.

Areal extents of 466 glaciers were estimated. It was 2077 km^2 in 1962 and 1628 km^2 in 2001/04, an overall 21 percent deglaciation. Amount of retreat varies from glacier to glacier and from basin to basin, depending on parameters such as maximum thickness, mass balance and rate of melting at terminus (Kulkarni et al. 2005). In addition, loss in glaciated area depends on areal extent of the glaciers. This is possibly because glacier response time is directly proportional to thickness (Johannesson et al. 1989). Thickness is directly proportional to its areal extent (Chaohai and Sharma, 1988). Response time is known as the amount of time take by glacier to adjust to a change in its mass balance. If maximum thickness of glaciers varies between 150 and 300 m then the response time for temperate glaciers will be between 15 to 60 years (Paterson, 1998). In the Himalayas, if glaciers are not heavily covered by debris, areal extent of glaciers is less than 1 km^2 and rate of meting around snout is around 6 m a^{-1} and then response time can be estimated between 4 and 11 years. Therefore, if other parameters are constant then small glaciers are expected to adjust to climate change faster. This phenomenon is now being observed in the Himalayan region, as glaciers smaller than 1 km^2 have deglaciated by almost 38 % between 1962 and 2001/04 (Table 2). On the other hand larger glaciers have shown only 12 % loss in their area. Even though, total glacial extent has reduced, numbers of glaciers has increased.

Normally in the Himalayas retreat is measured at well-developed and easily accessible valley glaciers. This study is now extended to small mountain glaciers and ice fields. The investigation has shown that there is an overall 21 per cent reduction in glacial area from middle of last century. Mean of glacial extent has reduced from 1.4 to 0.32 km^2 between 1962 and 2001. In addition, number of glaciers has increased between 1962 and 2001 and total areal extent is reduced. The number of glaciers is increased, due to fragmentation. As glaciers are retreating, it was expected that tributary glaciers will detach from main glacial body and glaciologically it will form dependent glaciers. Systematic and meticulous glacial inventories of 1962 and 2001 have now clearly demonstrated that extent of fragmentation is much higher than realized earlier. This is likely to have profound influence on sustainability of Himalayan glaciers.

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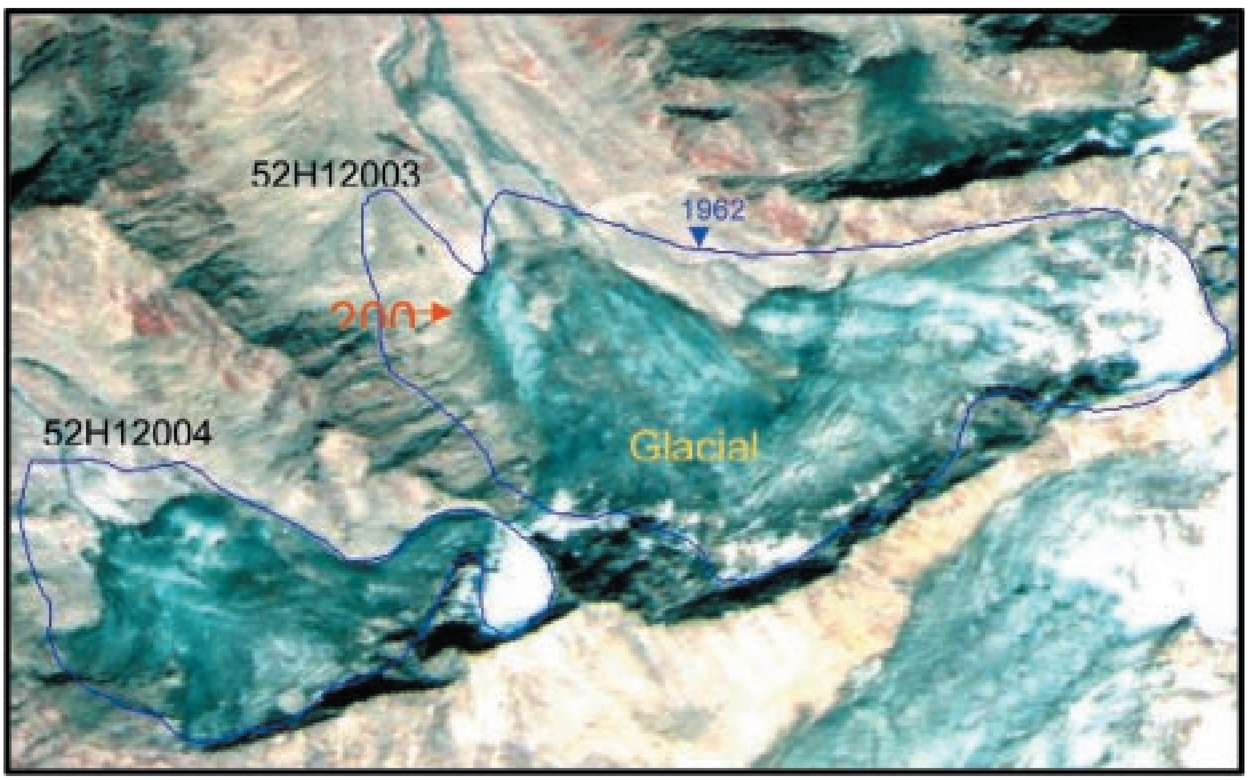

Fig. 1 : A satellite imagery of glacier number 52H12003 and 52H12004 of LISS-IV sensor showing glacial boundary of 1962 and 2004. These are small mountain glaciers, showing negligible accumulation area. Maximum altitude of these glaciers is around 5200 m. This is very close to snow line at the end of ablation season and such glaciers are expected to experience terminal retreat.

WHEAT PRODUCTION FORECAST IN HILLY TERRAINS OF HIMACHAL PRADESH

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ABSTRACT

Wheat production forecast was attempted in six districts of Himachal Pradesh, which account for 76.0% of wheat acreage and 73.2% wheat production in Himachal Pradesh. Single-date remote sensing satellite data of IRS-P6 LISS-III coinciding with flowering to grain-filling stage of wheat was analyzed for acreage estimation. Ground Truth data was collected near-synchronous to satellite pass from large contiguous and homogeneous sites. The maximum likelihood (MXL) supervised classification and district boundary mask approach, were adopted for district-level wheat acreage estimation. District-level yields were predicted using agro-meteorological models developed for the six districts. The meteorological indices viz. Growing Degree Day, Temperature Difference, Accumulated Rainfall and Accumulated Sunshine hours were computed from weekly weather data. These meteorological Indices were integrated over three growth phases of wheat viz. Active Vegetative Phase, Reproductive Phase and Maturity Phase, and the agromet models were developed separately for each district. Since wheat is mainly grown as rainfed crop in Himachal Pradesh, normal and abnormal rainfall conditions affect the wheat acreage and final wheat production. This report presents the methodology adopted for district-level wheat acreage estimation using Remote Sensing data and agrometeorological wheat yield model development for production forecasting. District-level wheat yields were predicted using these models and the performance was evaluated by computing Relative Deviations with BES estimates.

1. MATERIAL AND METHODS

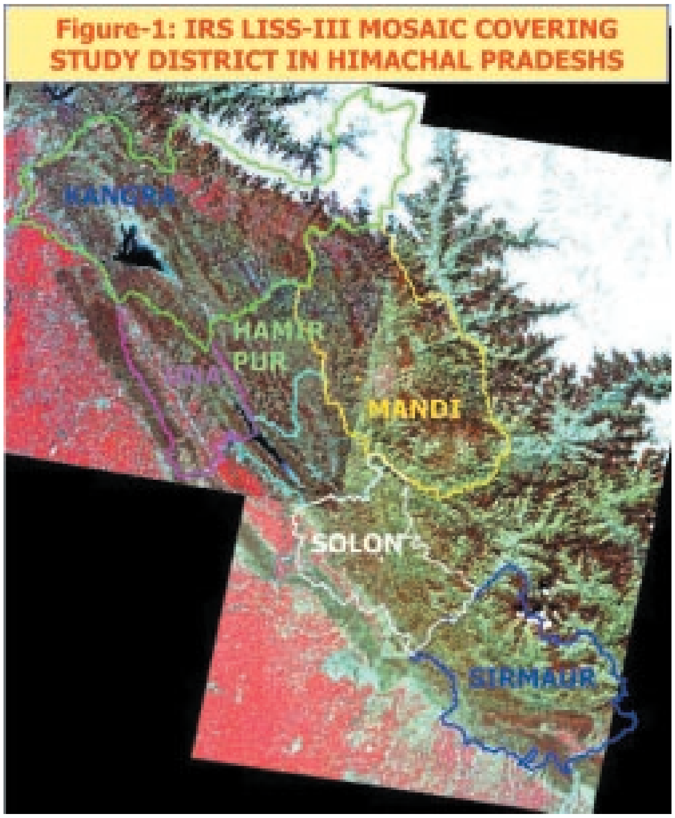
1.1 Study Area

Himachal Pradesh located between 32^0 22' 40" to 33^0 12' 40" N latitude and 75^0 37' 55" to 79^0 04' 22" E longitude, is a hilly state. Six major wheat-growing districts namely Kangra, Mandi, Bilaspur, Hamirpur, Solan and Una which account for 75.7% wheat acreage and 76.6% of total wheat production in the state were selected for wheat production forecast. Wheat is principal Rabi crop of Himachal Pradesh grown under different physiographic conditions namely, riverbeds, valleys and terraces. It is sown from last week of October to second week of December in low and mid hills. The crop reaches flowering stage around mid-February and harvesting commences from mid-April to first week of May. The crop duration is about 120-135 days. Wheat is predominantly grown as rainfed crop as a result yield levels are much below the national average yields being 1574.0 kg/ha only. The basic reason for overall low agricultural productivity lies in the traditional system of agriculture, small land holdings, hilly and mountainous terrain, soil erosion and dependence on rain for soil moisture.

1.2 Data Used

1.2.1 Satellite Data

Single date cloud-free IRS-P6 (Resourcesat) LISS III digital data of second fortnight of March-2004 and 2005, coinciding with flowering stage of wheat was acquired for acreage estimation. The mosaic satellite data covering study districts along with district boundaries is given in Fig. 1.



1.2.2 Wheat Statistics

Historical district-level wheat statistics published by Bureau of Economics and Statistics (BES) from 1980-81 to 2004-05 for Kangra, Mandi, Una and Solan districts and from 1985-86 to 2004-05 for Bilaspur and Hamirpur districts were compiled and used in trend-yield analysis. The State-level wheat acreage and production from 1972-73 to 2004-05 are presented in Fig. 2.

1.2.3 Meteorological Data

The meteorological variables such as minimum-maximum temperatures, rainfall and sunshine hours were collected from meteorological stations in different districts. The district-level agro-meteorological yield models were developed using this dataset.

1.3 Digital Data Analysis

Supervised classification of single-date data acquired during the optimum bio-window of wheat crop, using Maximum Likelihood (MXL) supervised classification is the standard classification approach adopted for wheat acreage estimation. The details of methodology adopted for wheat acreage estimation and development of district-level agrometeorological

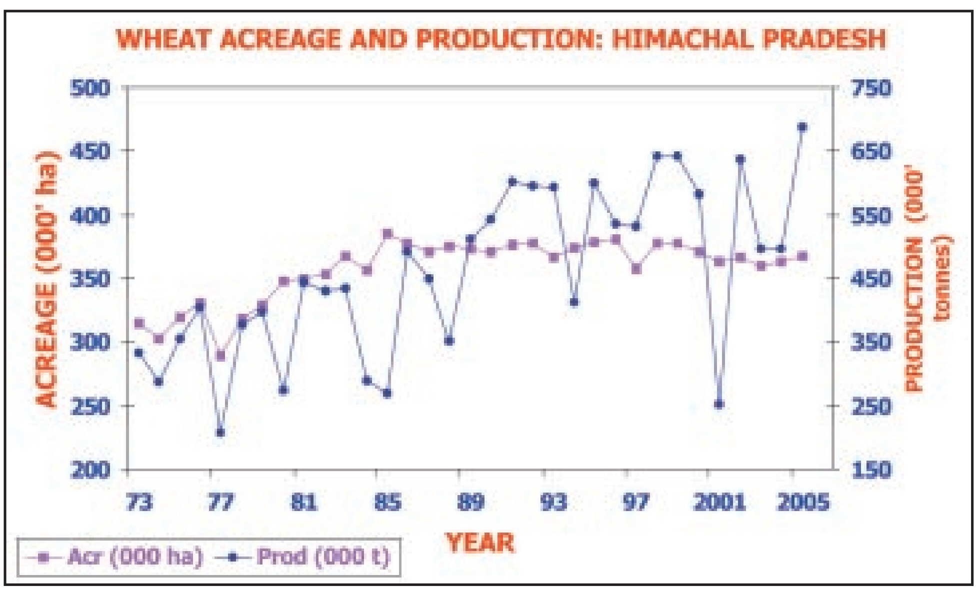


Fig.2: State-level Wheat Acreage and Production in Himachal Pradesh during 1972-73 to 2004-05

yield models is described in detail by Kalubarme et al. (2004). The major steps used for district-level wheat acreage estimation are as follows:

1.3.1 Digital Data Loading and Extraction

The digital data from Computer Compatible Tapes (CCTs) or the Computer Discs (CDs) was downloaded in the computer using the standard routines from the EASI-PACE software. The four-band digital data was displayed on the display terminal and using linear enhancement techniques False Colour Composite (FCC) was generated for identification of various features. Data corresponding to the study district is extracted for further analysis. This requires development of map-to-image transformation model using Ground Control Points (GCPs).

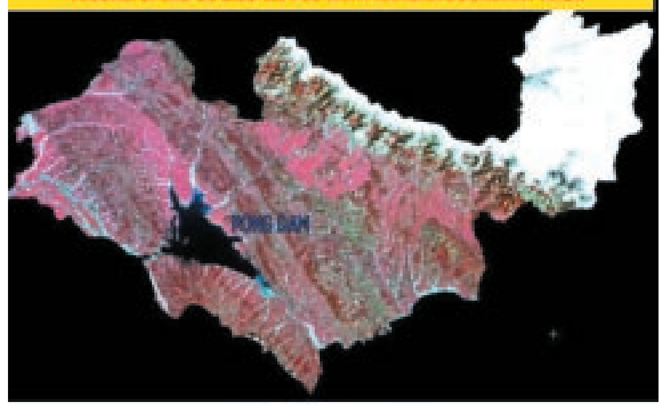
1.3.2 Geo-Referencing

IRS P6 LISS-III digital data was registered with geo-referenced master images using image-to-image registrations. Second order polynomials were applied for image-to-image registrations. Root Mean Square (RMS) errors for image-to-image geo-referencing were within ± 0.5 pixel (±12 m for LISS-III). These geo-referenced images were used for extracting the study districts using the boundary mask approach.

1.3.3 District Boundary Mask Generation

The approach adopted for district-level wheat acreage estimation is to overlay district boundary by transforming it to image coordinates and analyse pixels inside the boundary. For this, district-boundaries traced from the SOI topographical maps were digitized and Latitude-Longitude coordinates were obtained. These digitized Latitude-Longitude coordinates were converted to image coordinates using the affine transformation. The boundary mask image of each study district was generated using the point-in-polygon algorithm. These boundary mask images were superimposed on the geo-referenced image and the area inside the mask was extracted for further analysis. The georeferenced image with district boundary mask of Kangra is shown in Fig. 3.

FIGURE. 3: IRS-1C LISS-III FCC WITH KANGRA BOUNDARY MASK



1.3.4 Generation Of Training Site Statistics

The FCC) image of LISS-III bands 2, 3 and 4 was displayed on computer terminal. This FCC with linear stretching had sharper boundaries of land cover classes along with higher separation among different classes. The Ground truth maps on 1: 50, 000 scale were used for locating training sites

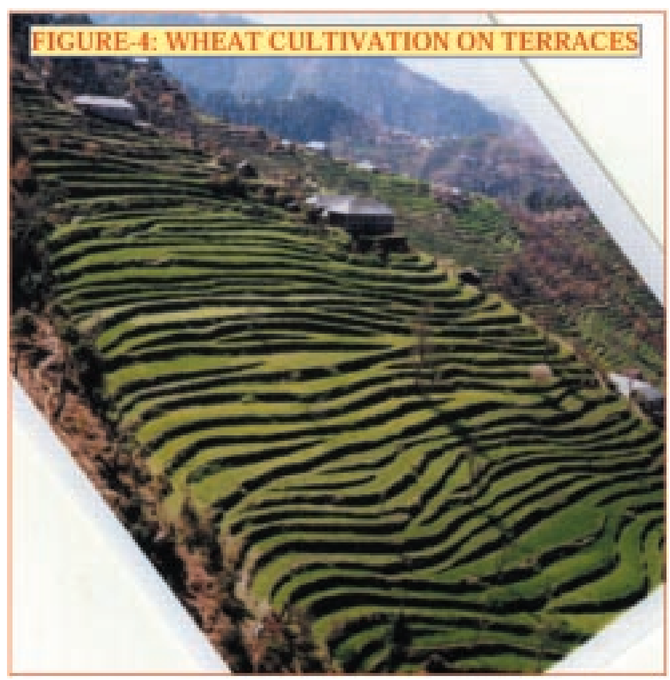


FIGURE-4: WHEAT CULTIVATION ON TERRACES

corresponding to different vegetation types and land-cover classes identified during the ground truth data collection in the study area. One of the field photographs showing wheat cultivation on terraces is shown in Fig. 4.

Five to six wheat sub-classes with different developmental stages and percent ground cover having different vigour classes were identified for training signature generation. The training signatures contain multi-band statistics such as mean, standard deviation, and variance-covariance matrix for each class are used in supervised classification. The training sites of wheat and other land use classes along with their training statistics is presented in Fig.5.

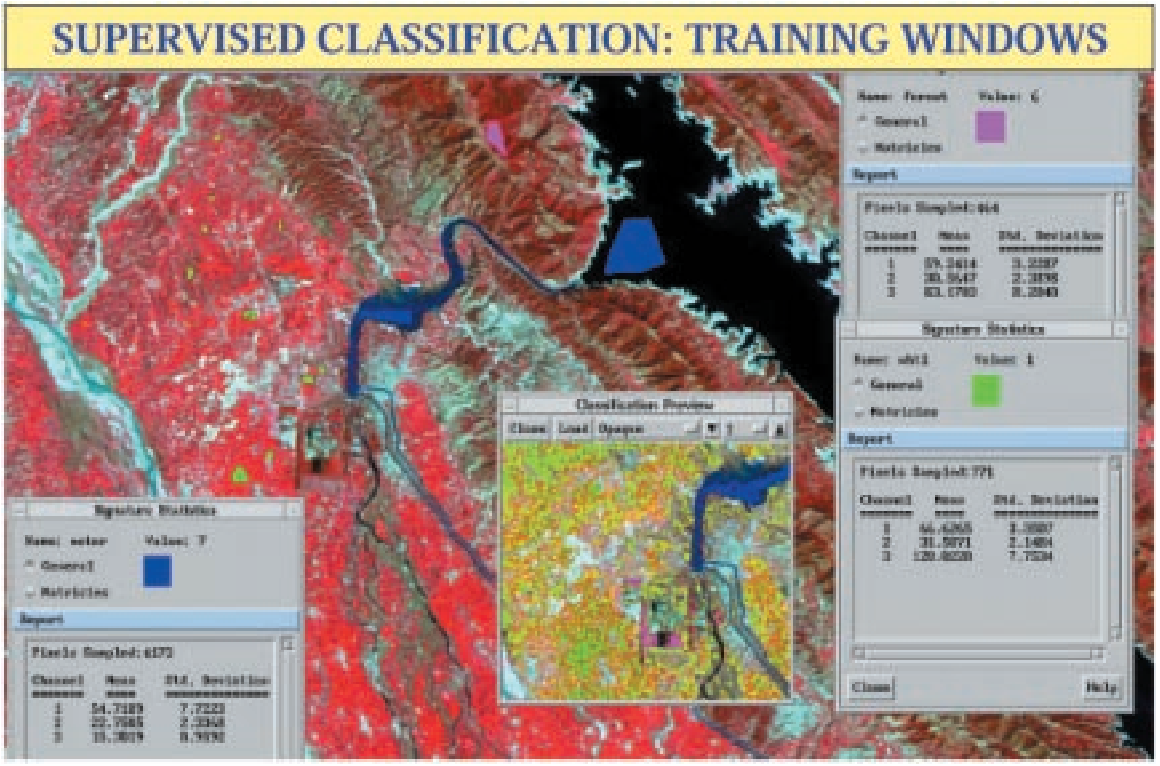


Fig. 5: The training sites of wheat and other land use classes along with their training statistics

1.3.5 Supervised Classification

MXL has been used for classification of data within each district using the boundary mask approach. For this digital boundary masks generated for each district were superimposed on the LISS-III digital data and all the pixels within this mask were classified. If the unclassified pixels were greater than 5 per cent, some more training sites within unclassified areas were marked and entire data was reclassified using additional classes. The classified image of Kangra district is presented in Fig. 6.

1.3.6 Wheat Acreage Estimation

The MXL supervised classification was performed with training statistics of wheat and other land-use classes using the district boundary mask approach. Each district data was classified using the training signatures generated using the ground truth sites identified in that district. The pixels under sub-classes of wheat were aggregated and total number of wheat pixels in the district were computed. The proportion of cotton with respect to geographical area for each district is computed and from this proportion, cotton acreage in each district is computed.

1.4 Agrometeorological Model Development

1.4.1 Computation of Meteorological Indices

a) Growing Degree Days and Temperature Difference

Growing degree-days (GDD) is widely used for describing the temperature responses to growth and development of crops. Hundal et al. (1997) reported AGDD as the best index to predict various phenophases in wheat crop under Punjab conditions. The GDD was computed by taking a base temperature of 5^{O} C. The total sum of degree-days for each phenophase was computed using the following formula:

$$AGDD = \sum_{ds}^{dh} \{[(T_{max} + T_{min})/2\} - T_b$$

$$TD = \sum_{ds}^{dh} (T_{max} - T_{min})$$

Where,

AGDD = Accumulated GDD

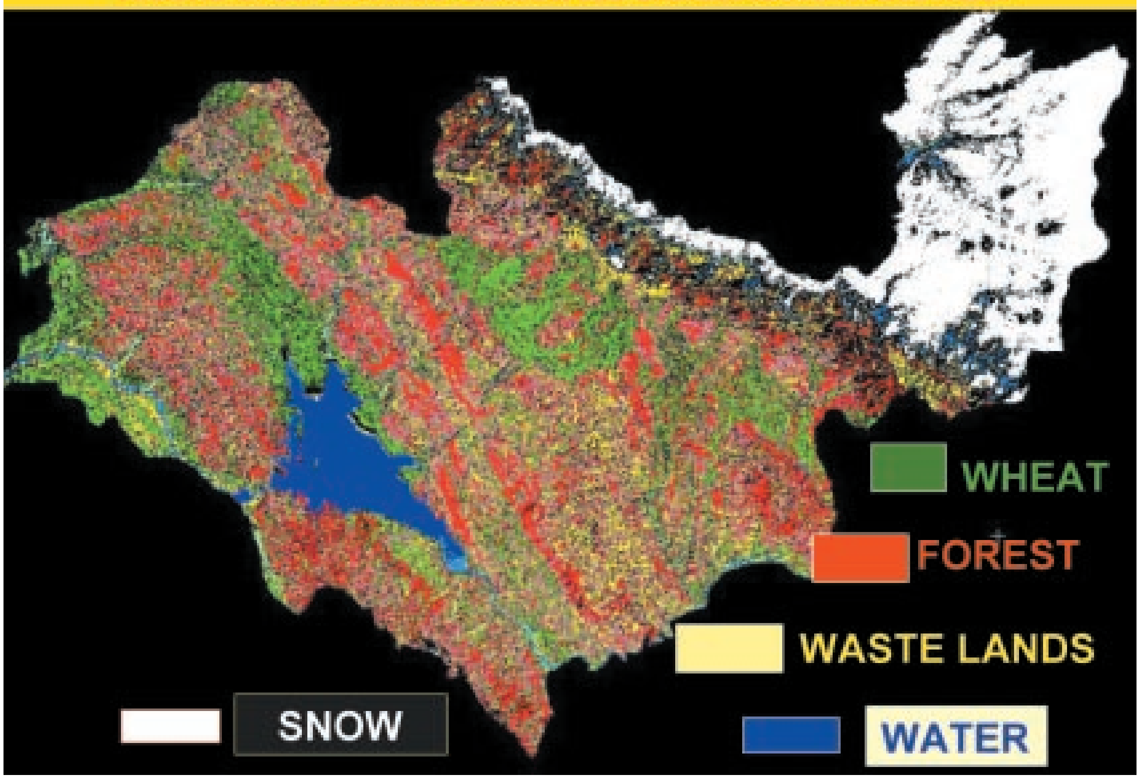
T_b = base temperature (5^0C)

T_{max}, T_{min} = Maximum and minimum temperatures, respectively,

ds = date of sowing or start of phenophase

dh = date of harvesting or end of phenophase

FIGURE-6: SUPERVISED CLASSIFIED IMAGE: KANGRA DISTRICT



b) Sunshine Hours and Rainfall

From rainfall and sunshine hour data, weekly Accumulated Sunshine Hours (ASH) and Accumulated Rainfall (ARF) were also computed. These meteorological indices were integrated over three growth phases of wheat.

The three phenological phases of wheat considered are Active Vegetative Phase (AVP), Dec.17 to Feb. 18 (Met. Week numbers 51 – 6), Reproductive Phase (RP) Feb. 19 to March 18 (Met. Week numbers 7 – 11) and Maturity Phase (MP), March 19 to April 22 (Met. Week numbers 12 – 16).

1.4.2 Trend Analysis

Scatter plots of year vs. yield were created for evaluating the time trend. Based on the assessment of scatter plots, single or piece-wise linear analysis is performed and appropriate regression equations and their significance is obtained. If, however, the regression line showed significant slope and the data points were uniformly distributed around this line, then a single trend line was assumed to apply to the entire yield time series. The significance of the slope of the equation was tested by using two Tailed t-test at 95% confidence interval. The trend-predicted yields were computed, using the following equation:

$Yt_i = a + b * Tm_i$ (Linear)

Where,

a = intercept of trend line

b = coefficient of regression of trend line

Tm_i = modified year for i^{th} year (crop year 1971-72 is treated as 1971 in data base and as 71 (year-1900) for computations in equations)

Y_i = wheat yield of i^{th} year

Yt_i = trend predicted yield for the i^{th} year

1.4.3 Computation of Normalized Yield Deviations

Trend predicted yield values were plotted against the observed yields to assess the visual fit of model to data. The option giving the best fit is selected for computation of normalised yield deviations using the following formula:

$\Delta Y_i = Yt_i - Yo_i$

$NDY_i = \Delta Y_i / Yt_i = (Yt_i - Yo_i) / Yt_i$

Where,

ΔY_i = absolute yield deviation for i^{th} year

Yt_i = trend predicted yield from trend for the i^{th} year

Yo_i = observed yield for the i^{th} year

NDY_i = normalized yield deviation for i^{th} year

1.4.4 Correlation and Regression Analysis

Correlation matrix of weekly average weather variables and the NDY was generated and examined for magnitude and sign of correlations. Response variables, showing significant correlations at 95 per cent confidence level with the yield deviations, were noted in ascending order of magnitude. The final sub-set of significant variables was used for regression analysis. Based on two tailed t-test (95% confidence) of the regression coefficient, non-significant variables were eliminated, one at a time, using backward elimination procedure. Thus, the final equation contained variables returning significant slope as well as overall adjusted R^2. In case individual slope of none of the variables was significant, an equation giving significant adjusted R^2 with minimum number of response variables was selected. The general form of the models realised is as follows:

$NDY = a_0 \sum (b_i * X_i)$

where,

NDY = normalized deviation of yield

a_0 = intercept of multiple regression equation

b_i = regression coefficient of i^{th} variable

X_i = i^{th} Met index (response) variable

3 RESULTS AND DISCUSSION

3.1 Agrometeorological Wheat Yield Models

In the first step, from the correlation matrix of meteorological indices and NDY, best possible sub-set of independent variable were selected. The response variables, showing significant correlations at 95 per cent confidence level with the yield deviations, were noted in the ascending order of magnitude and final sub-set of significant variables was used for regression analysis. In the second step, multiple regressions of all the sub-sets was carried out and based on two - tailed t-test (95% confidence) of the regression coefficient, the non-significant variables were eliminated, one at a time, using backward elimination procedure. Thus, the final equation contained variables returning significant slope as well as overall adjusted R^2. Table 1 shows the regression coefficients of selected variables along with adjusted R^2 and SEOE values for all the six districts. Table 1 indicates that the adjusted R^2 for all the districts ranged from 0.90 to 0.96, which indicates that around 90 to 96 per cent of variability in the wheat yields is explained by these yield models. The most significant variables in the regression equation are Crop Condition (CC), GDD, Temperature Difference (TD) and total rainfall at Active Vegetative and Reproductive phases of wheat.

3.2 Performance Evaluation of Yield Models

District-level wheat yields were predicted using these models and the performance was evaluated by computing Relative Deviations (RD%) with BES estimates. The model predicted and observed wheat yields in Kangra district is presented in Fig. 7. The results reveal that the performance of agromet-yield models in general is comparable with BES estimates, in all the six districts. The CC term along with meteorological variables was very effective even during very severe drought conditions of 1985, 1988, 1993 and 2001 seasons as observed from the performance of model predicted wheat yields.

ARF during AVP and RP show positive correlation with yield. Wheat is mainly rainfed crop in these districts. Rainfall is one of the important parameters affecting yield during AVP and RP. Temperature is another crucial factor appearing in the agromet models of various study districts influencing crop growth through different physiological processes and the rate of phonological development. The temperature derived meteorological parameters

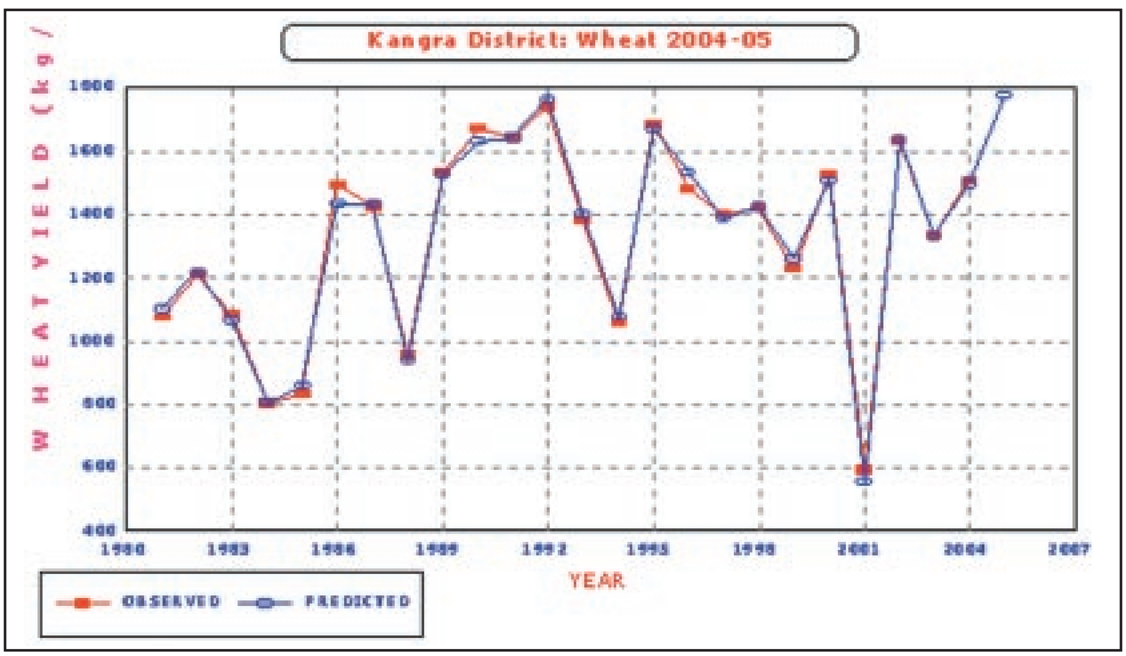


Fig. 7: Observed and Predicted Wheat Yields in Kangra District

GDD and TD indicate significant correlation with wheat yield. TD and GDD during AVP and RP show negative correlation with wheat yield. The rapid rising temperature (max. 30^0 C or more) and increasing water-stress at RP frequently terminate grain filling (Evans, 1975). The grain size is reduced with rise in temperature from 25^0 C to 31^0 C (Asana and Williams, 1965). Peters et. al (1972) found that a rise in night temperature from 9^0 C to 26^0 C, reduced grain yield of wheat almost by half by reducing the period of grain filling at maturity phase.

3.3 Wheat Acreage and Production Estimation

The MXL supervised classification was performed with training statistics of wheat and other land-use classes using the district boundary mask approach. Each district data was classified using the training signatures generated using the ground truth sites identified in that district. The district-level wheat acreage and production estimates along with its comparison with BES estimates in terms of Relative Deviations (RD%) for one of the wheat seasons (Rabi 2004-05) are presented in Table 1.

4 CONCLUSIONS

- IRS-P6 (Resourcesat) LISS-III digital data, coinciding with flowering to grain-filling stage of wheat was analysed for wheat acreage estimation using maximum likelihood (MXL) supervised classification and district boundary mask approach.
- Agrometeorologial yield models were developed using the meteorological indices *viz.* Growing Degree Days (GDD), Temperature Difference (TD), Accumulated Rainfall (ARF) and Accumulated Sunshine Hours (ASH), which were integrated over three growth phases of wheat.
- The Accumulated Rainfall (ARF) during Active Vegetative Phase (AVP) shows positive correlation with yield. Temperature and rainfall are important factors affecting yield during AVP and Reproductive Phases.
- The performance of wheat acreage estimates and yield models is evaluated by computing Relative Deviations (RD%) with Department of Agriculture (DOA) estimates. Since, wheat is cultivated mainly as rainfed crop in these districts, the accuracy of wheat acreage estimates also varies to some extent with normal and abnormal rainfall conditions. However, the

Table-1: District-Level Wheat Production Forecast in Himachal Pradesh: 2004 - 05

Sr No	District	REMOTE SENSING		BES		RELATIVE DEVIATIONS %	
		Acreage (000 ha)	Prod. (000' t)	Acreage (000 ha)	Prod. (000' t)	Acreage	Production
1	Bilaspur	26.70	41.03	28.11	67.32	- 5.0	- 39.1
2	Hamirpur	33.30	48.92	34.69	71.44	- 4.0	- 31.5
3	Kangra	93.20	165.78	94.42	170.28	- 1.3	- 2.6
4	Mandi	64.35	96.50	66.49	121.40	- 3.2	- 20.5
5	Solan	22.65	37.65	24.69	47.48	- 8.3	- 20.7
6	Una	31.60	54.51	32.41	63.46	- 2.5	- 14.1
	TOTAL (6 Dist)	271.80	444.39	280.82	541.39	- 3.2	- 17.9
	STATE	356.4	573.71	367.77	687.45	- 3.1	- 16.5

performance of agromet yield models in general, is comparable with Department of Agriculture estimates.

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PRECISION FORESTRY USING HIGH RESOLUTION CARTOSAT-1 AND IRS LISS-IV IMAGES

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1. INTRODUCTION

Indian Earth Observation Satellite Cartosat-1 launched on 5th may 2005 into a 618 km circular polar sun-synchronous orbit was primarily designed for cartographic applications. This satellite carries two state-of-art panchromatic cameras that take black and white stereoscopic images of the earth surface in the optical region of the electromagnetic spectrum. The swath covered by these high resolution PAN cameras is 30 km and their spatial resolution is 2.5 m. The cameras are mounted in the satellite in such a way that near simultaneous imaging of the same area from two different angles i.e. at +26 degree (with respect to nadir in the direction of transit by fore camera) and 5 degree (with respect to nadir trailing the satellite's local vertical by aft camera) is possible. This facilitates the generation of accurate digital elevation model (DEM) of large area (Kirankumar and Kurian 2005). DEM is also a necessary input for orthoimage generation which, in turn, provides a valuable input to topographic mapping and natural resource base mapping at micro level (Navalgund, 2005).

With the availability of high resolution satellites, Resourcesat-1 (5.6 m multispectral), TES (1 m Panchromatic resolution) and Cartosat -1 (2.5 m Panchromatic with stereo), have provided an opportunity for precision forestry applications. This will be useful for microlevel planning; for example forest stock mapping, identification of potential joint forest planning and management (JFPM) programme, monitoring of plantations & afforestation activities, forest encroachment, grassland / grazing land area mapping and monitoring, mapping of trees outside forest area (TOF), non-forest timber resources, mapping of bioprospective underutilized wild trees/shrubs, detection and spread of invasive species in forest area. Planning of new road and developmental activities, fragmentation and wildlife habitat losses, etc. are a few other areas, where high spatial resolution data is of paramount importance.

In recent times concerted efforts have been made for the retrieval of structural and biophysical properties of the forests from remotely sensed data which are required by forest managers, planners, conservationists and policy makers for estimation and assessment of forest volume, biomass and updation of growing stock conditions of the forests. In the national and global perspective such information is needed for understanding of existing carbon stock in the systems, climate modelling, bio-geochemical cycle, and wildlife habitat modelling and fire management (Anonymous, 2004, Franklin et al., 2000). Some of these properties are measured using photogrammetric methods, such as tree height using parallax (Lillesand and Kiefer, 2000). Other vegetation properties are inferred from the tone, colour, shape, texture, pattern, site, context and association observed in the aerial photographs based on interpreter's knowledge, augmented with field visits. The conventional approach of mapping and forest stock inventory involved detailed field surveys, which were found to be time consuming, costly and lack uniformity and accuracy

In the present study, use of Cartosat-1 stereo data, LISS-IV image along with DGPS and field measurements have been carried out for precision forestry applications. Major concern was to:

(i) Retrieval of forest tree height, stand density, canopy gap and crown diameter and empirical relationship between Cartosat stereo data and measured field tree parameters. Generation of plot-wise forest type stand-height map using input from Cartosat-1 stereo data derived DEM and texture image in GIS environment (ii) Detection of invasive plants i.e. *Lantana camera* and its spread

This study was carried out at three sites: i) Experimental plots of Forest Research Institute estate, Dehradun. with elevation ranging from 584 to 617 m above mean sea level (msl). The area is representative of country's major forest species i.e. Sal (*Shorea robusta*), Teak (*tectona grandis)* Chir pine *(Pinus roxbhughii),* tropical Pine (*Pinus caribaea*), Michellia champaca, Syzigium cumini, termenalia *tomentosa,* Eucalyptus species, Bamboo etc. Average forest stands age of these plots dates back to approximately 1925 to 1927. ii) Rajaji National Park (Mohand Reserved block) ranges from altitude of 400 to 530 m above mean sea level. and iii) near Chandrabani (600 to 700 m) in Dehradun, Uttaranchal forest (Fig. 1). The general climate of the area is subtropical and humid in nature.

Fig. 1 Study area

2. ESTIMATION OF TREE HEIGHT AND CROWN DIAMETER

2.1 Conventional Techniques

Measurement of forest stand tree heights, canopy cover, crown size, stand density, and tree Diameter at Breast Height (DBH) are crucial entities for assessment of forest volume, biomass and growing stock of the forest area. These parameters are highly correlated, and influence the reflectance properties of canopies (Anonymous 2004). In the past, estimates of tree height and crown diameter of dominant and co-dominant forest tree species were derived based on photogrammetric principle using parallax measurements of aerial photographs and rigorous ground sampling inventory. In India, stand volume tables were derived by multiple regression analysis that can be used to analyze the relationship between dependent variable and one or more independent variables measured on photographs or by traditional field surveys (Maslekar 1974, Anon 1996)). This kind of forest measurements on photographs covering large areas can become a tedious endeavour and to some degree rely on the interpreter's ability. Since it is generally not feasible to measure and count every tree in the area of interest, hence, a sampling process analogous to field procedures is often used.

The image spatial structure is only a two dimensional representation of forest structure. High resolution satellites have undoubtedly, provided structural characteristics of the forests on ground, but do not give the information on the third dimension, height, which is essential for forest inventories and other forest management. Thus three-dimensional (3D) information in digital form with good resolution in planimetry and height direction becomes essential for retrieval of forest stand tree height, crown diameter and other topographical features. This could be achieved by Cartosat – 1 high-resolution panchromatic stereo data, generating image in three dimensions through Digital Elevation Model (DEM).

2.2 Satellite based Technique

2.2.1 Data Set

Improvement in spatial and spectral resolution of optical sensors has made prospects of remote sensing technology to provide information for precision forestry. Further, stereo data has made it possible to provide the tree height information. In order to develop the methodology, data from Cartosat-1 satellite was used. Cloud free Cartosat -1 image were acquired over the study area in November, 2005 and used for detailed analysis. Other ancillary data like Survey of India topographical maps, forest working plan maps, DGPS survey points, forest tree measurement (measurement of tree height, crown diameter and DBH for tree species in sample plots (5x5 m). Major steps involved in the development of techniques are mentioned below.

2.2.2 Extraction of DEM and Orthoimage

Cartosat-1 panchromatic data was corrected for geometric distortion using Differential Global Positioning System (DGPS) by taking points at different altitudinal locations in forested and non-forested area. All these DGPS points were identified on the Fore and Aft stereo images. The registration of image was performed using nearest neighbourhood re-sampling algorithms with first order polynomials.

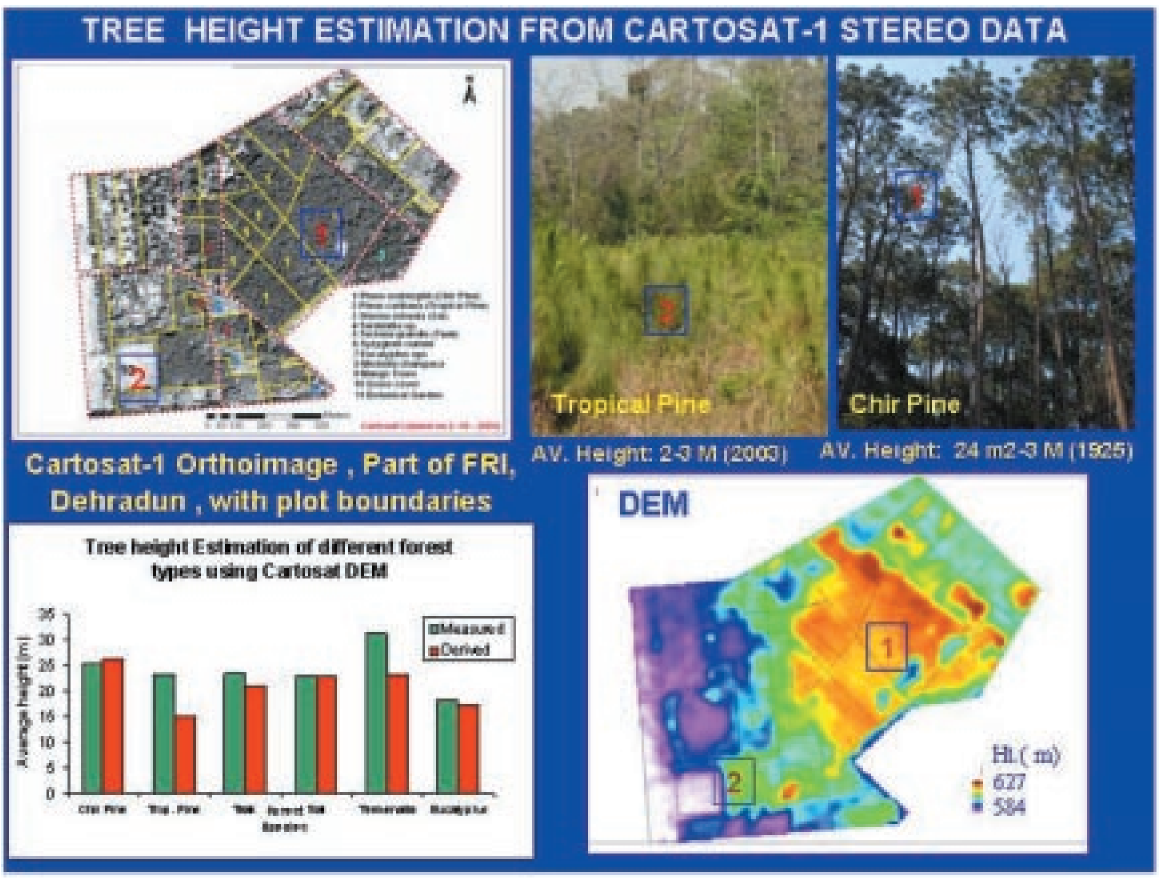


Fig. 2. Extraction of Orthoimage and DEM retrieval of tree height and crown diameter. [1] Chir Pine (*Pinus roxbhurghii*), [2] young plantation of tropical Pine (*Pinus carebea*) shown on field and Cartosat-1 (ortho & DEM) image.

Based on this, orthoimage and DEM were derived which have been used for facilitating large-scale cartographic forest stock information /plot boundaries and retrieval of various biophysical parameters (see Fig. 2). The accuracy of the extracted DEM has been evaluated by comparing corresponding reference DEM and ground DGPS points taken from forested and non-forested area (Nadeem et al. 2006). RMSE (m) error of Cartosat-1 derived DEM has been found to be1.86 (m) easting, 1.81 (m) northing and 4.38 (m) elevation. Figure 2 shows the DEM derived from Cartosat-1 data with Cartosat-1 orthoimage.

2.2.3 Textural Analysis

To derive the level of variation of spatial textural information between high resolution Cartosat-1 image pixels and its neighbours for separation of forest species, homogeneity of forest stand, stratification and measurement of crown area, canopy gap and stand density, the most commonly used Gray –level Co-Occurrence Matrix (GLCM) statistical measures were used for generation of texture features from Cartosat-1 data. Based on these six texture measures (i.e. mean, variance, contrast, homogeneity, dissimilarity and entropy) that calculate the relative frequencies with which pixel values occur in processing windows i.e.3x3 pixels are presented in Fig. 3.

Among the six GLCM, contrast, mean and variance has been found to be strongly related to structural attributes i.e. stand density, individual tree crown diameter and canopy gap of the forest tree stands, and maturity of the forest stands (Kimothi et al 2006).

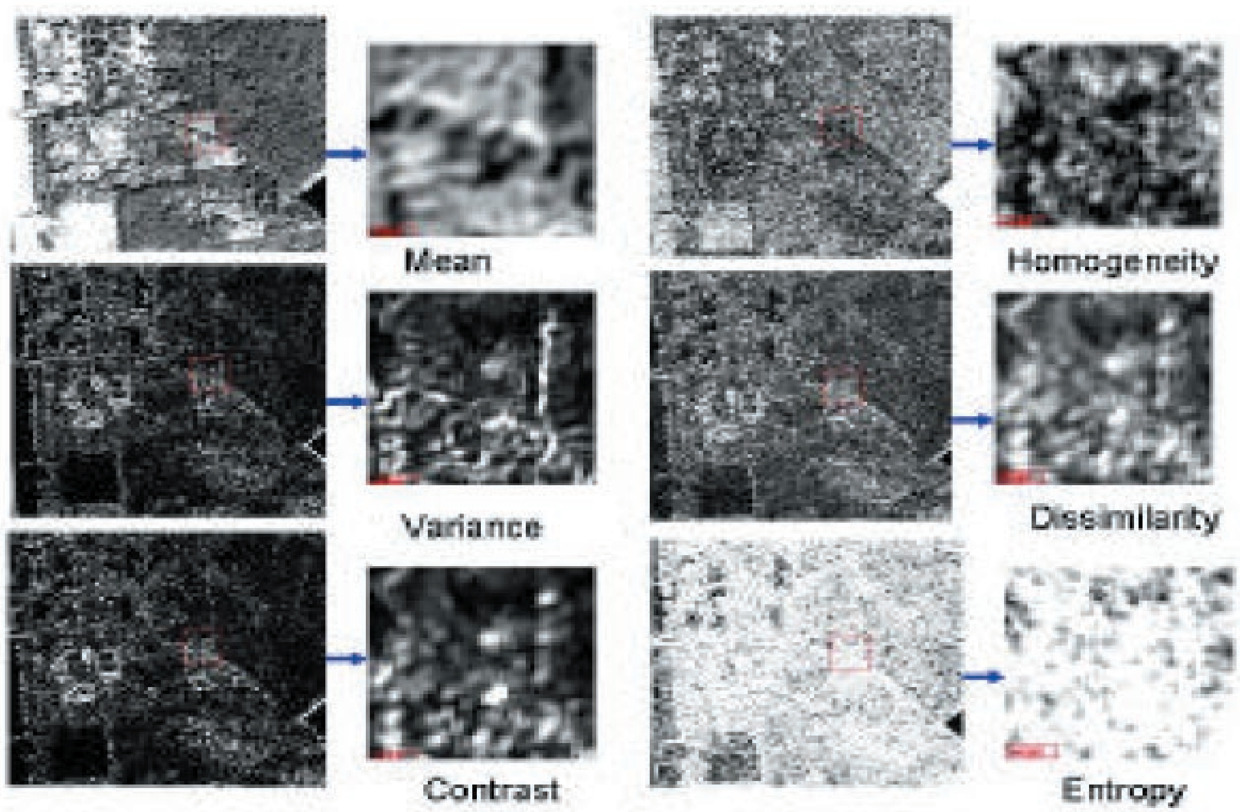


Fig. 3 [A]

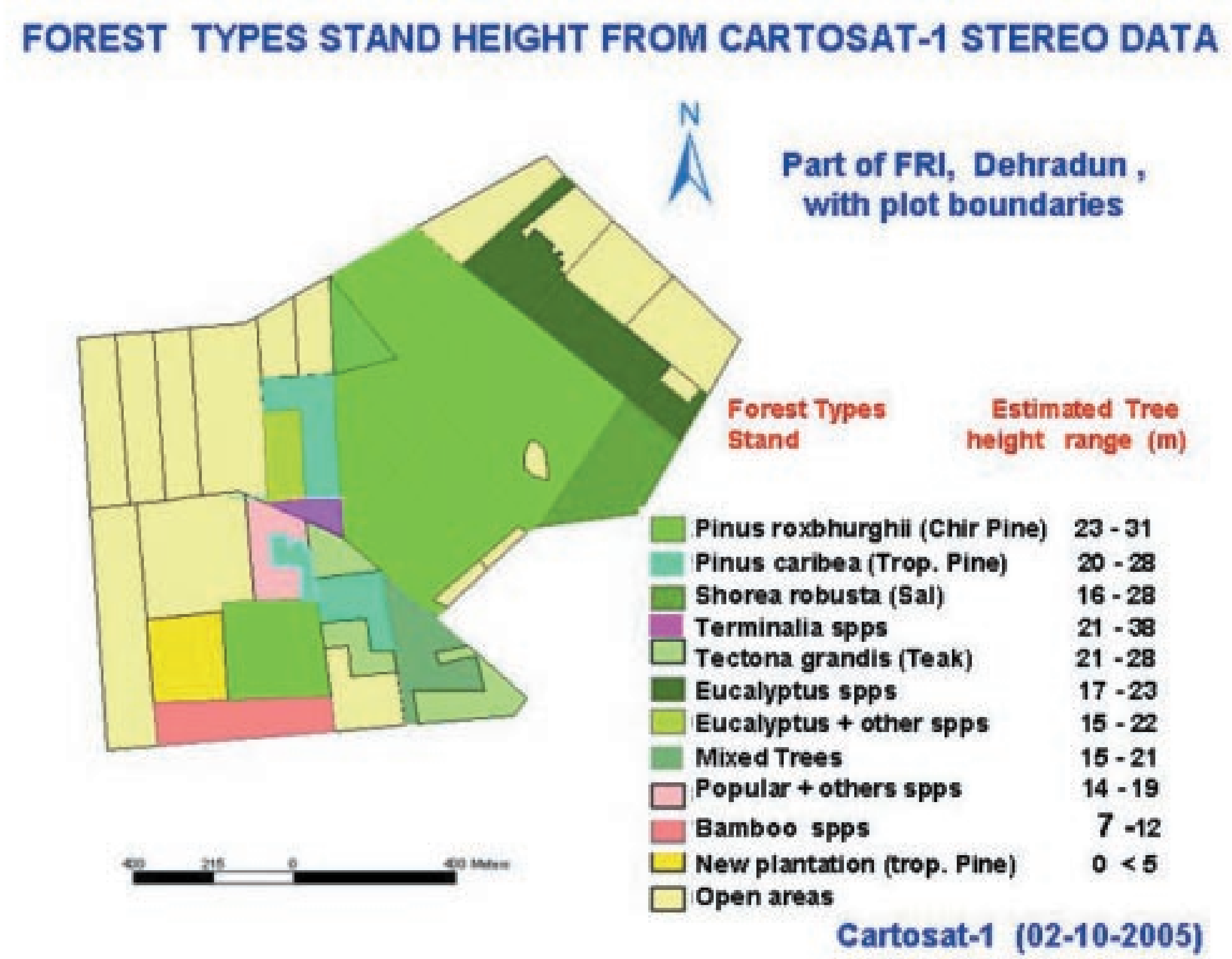


Fig. 3 [B]

Fig. 3. [A] Different Texture measure generated based on (GLCM). [B] Maximum textural information were found in mean, variance and contrast measures

2.2.4 Estimation of Tree Height and Crown Diameter

Stand tree height for each species was measured from sample plots (5 x 5 window size) using stereo image and stereo derived DEM. When the forest clearing was perceived to be horizontal, tree height was computed from the difference of the means between all elevation stereo measurement outside and inside the clearing, respectively. To determine the crown diameter of the same tree/ stand polygons were traced manually around the tree crowns. Height and crown size of the individual tree species/stand was then linearly correlated with tree height, DBH and crown diameter measured in the field. Set of rules were used to isolate individual crowns (Fig. 4). Statistically, high correlation coefficient (r^2 = 0.90) was found between DEM - derived average tree stand height and measured tree stand height and crown diameter for all the forest species studied (Fig. 5a & 5b). Empirical models for the estimation of DBH were developed and validated with Cartosat derived height and crown diameter (Fig. 6) Measured and predicted values were found in close proximity to each other as is shown by the values of Pearson's coefficient (Kimothi et al. 2006).

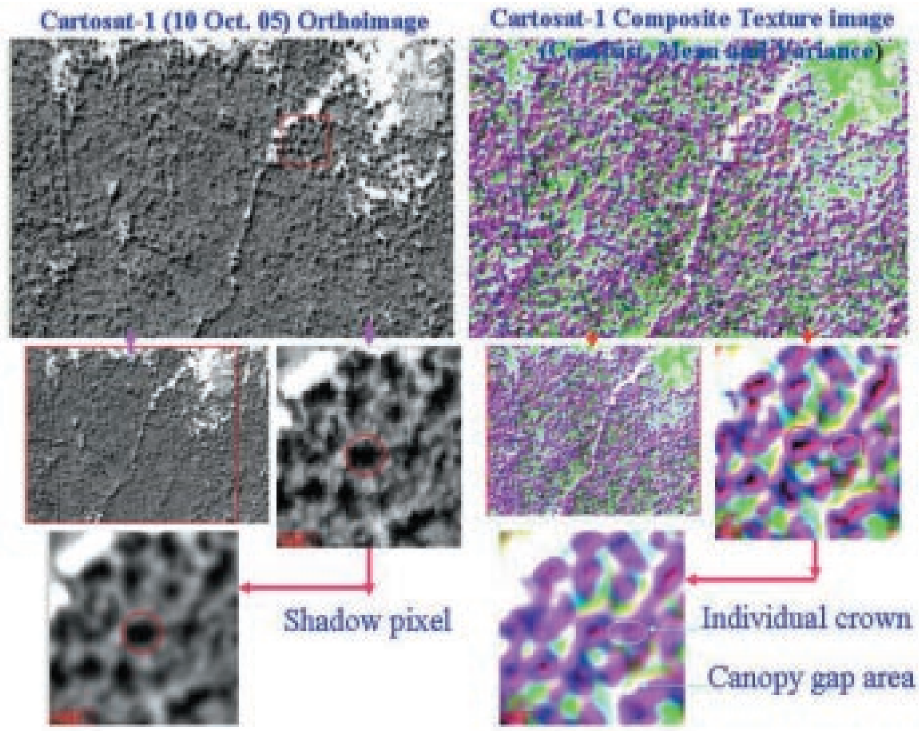
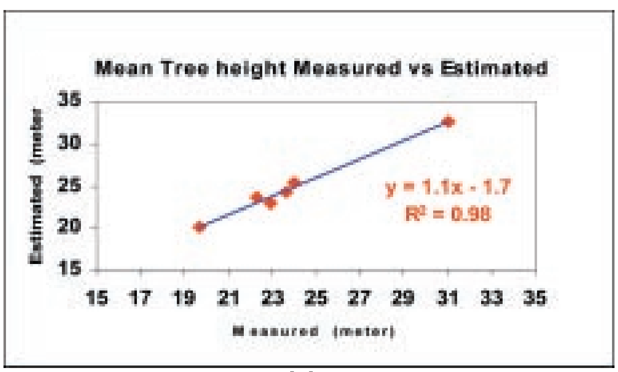
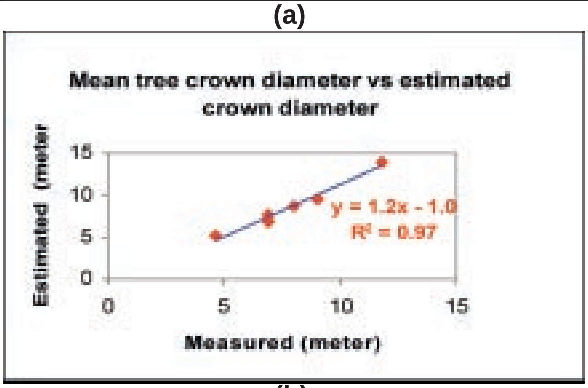


Fig. 4. Tree crowns and canopy gap delineation process using Cartosat-1 ortho and texture image



(a)



(b)

Fig. 5 Regression plots showing measured and estimated height (a) & crown diameter (b)

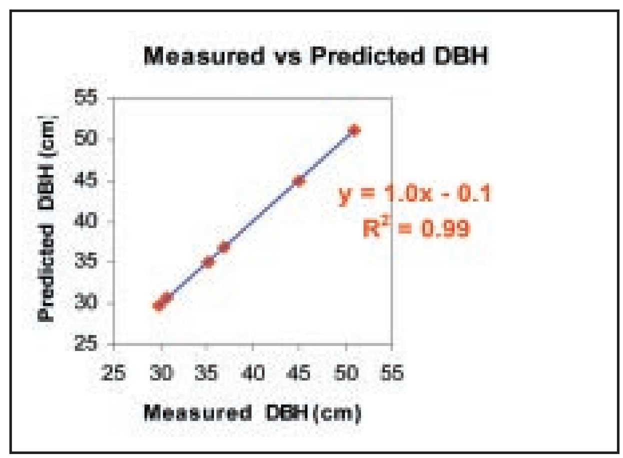


Fig. 6 Regression plot showing measured and predicted DBH

2.2.5 Plotwise Tree Height Map Generation

Various features i.e. forest vegetation classes, average tree height, blank area; plot boundary layers extracted from Cartosat-1 analysis were made by onscreen digitization. All the vector layers extracted were imported in ARC/INFO environment. Editing of various vector layers

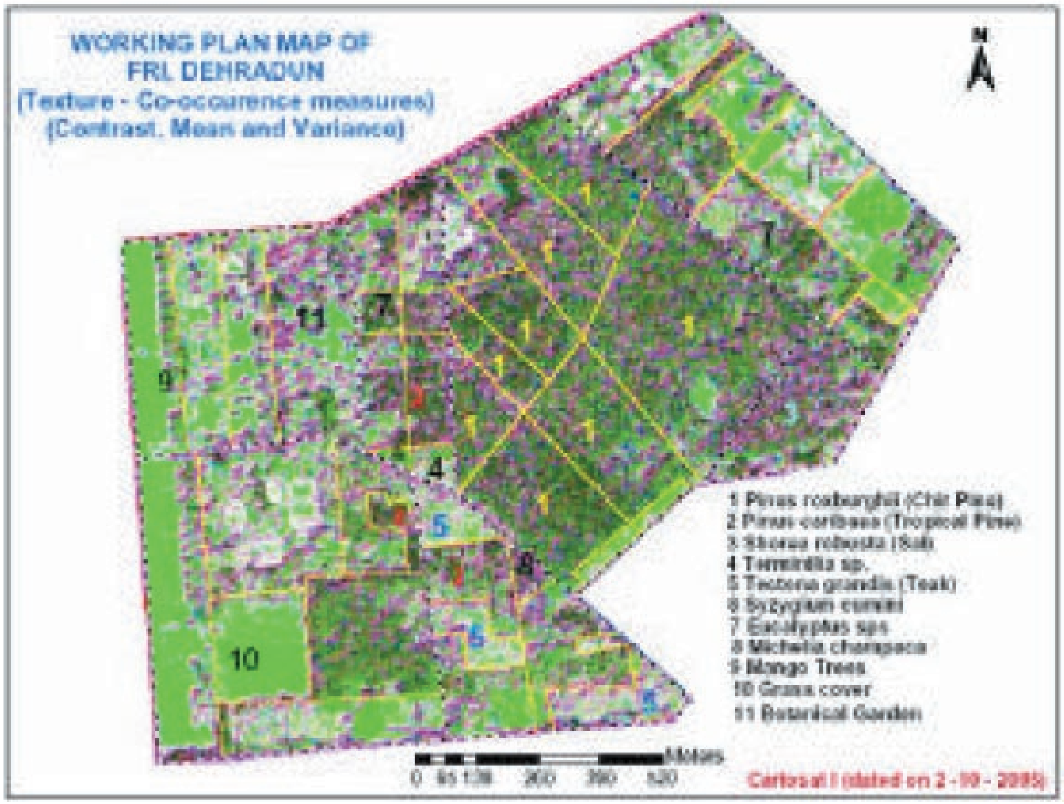


Fig. 7. Plot - wise forest type tree height map generated from Cartosat-1 stereo data

were carried out. Final map showing average heights of the seven vegetation classes with plot boundaries have been generated in GIS at 1:10,000 scale (Fig. 7). The base maps were prepared in WGS-84 datum and UTM projection. The accuracy of the map was validated using Working plan map and DGPS control points.

3. DETECTION AND MAPPING OF INVASIVE PLANTS

The rapid spreads of alien plant species, especially those with aggressively invasive capabilities, have caused considerable negative impact on the biodiversity and ecosystem in India. Among them, *Lantana camera (*Kurri*) of* family *Verbinaceae is* one of the most serious invasive plant species and has colonized large areas of forest lands in the Himalayan foothills (Shivalik range), in particularly, the Dudhwa, Corbett and Rajaji National Parks (Fig. 8). The altitudinal range of this species is between 400 m to approximately 1400 m. above amsl (Joshi 2002). In some of the areas of these parks, lantana growth has completely replaced original native forests, palatable grasses, the main food of several species of herbivorous animals and become the only vegetation type. As a result of this, food chain and movements of wildlife has been disturbed drastically. There is urgent need to develop strategies and remedies for this threatening problem. In this endeavour, first task is to obtain quickly the accurate spatial information and progression about the invasions of lantana camera and other alien species into native forest ecosystem. This will help the State Forest Departments and decision makers in developing and planning a suitable strategy of its ingression. Determining the extent of invasive plant populations in forest area by ground surveys is difficult because of the generally great expanse and inaccessibility of these areas.

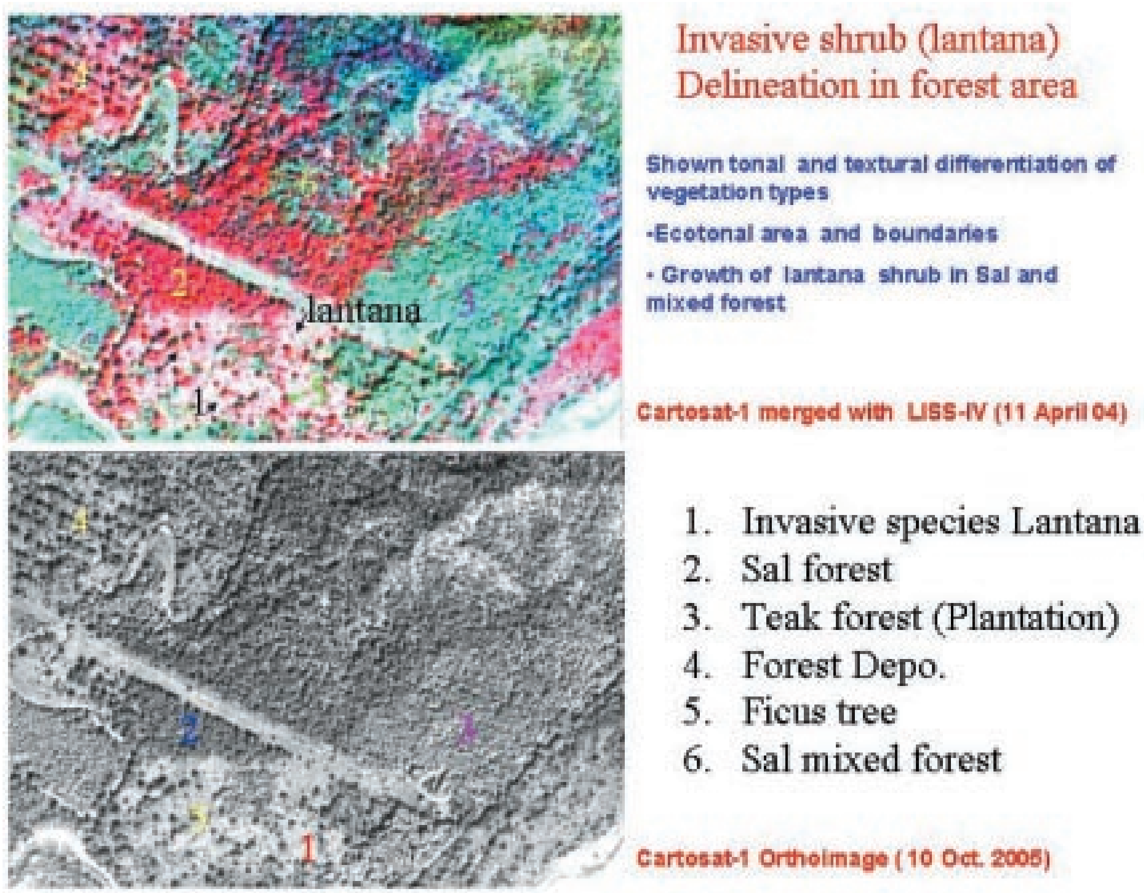


Fig. 8 detection of lantana in forest area using Cartosat-1 orthoimage and LISS-IV merged with Cartosat-1 orthoimage

Identifying invasive plants in a heterogeneous landscape using moderate spatial and multispectral resolution satellite imagery has been found difficult, because healthy vegetation exhibits similar spectral response in the VIS and NIR portion of the spectrum and coarse spatial resolution does not permit to distinguish species-composition in the forest stand. The availability of high resolution Cartosat-1 stereo data along with multispectral IRS-LISS-IV satellite data merged product provides an opportunity to investigate the potentiality of the data for discrimination and mapping of spread of invasive plant species.

This study presents a work in progress of developing a method for distinguishing *lantana camera* from part of forest of Rajaji National Park, Near Mohand Block using high resolution LISS-IV, Cartosat-1 and future Cartosat-2 data The major vegetation present in the area comprises of Sal, Sagwan and other mixed forests. Two level analysis procedures have been used using Cartosat- 1 (stereo and orthoimage) and LISS-IV data to identify and map the distribution of *lantana camera* species (Fig. 8). The first phase of the procedure is to analyze multi-season multispectral LISS-IV data; the second phase is to isolate the lantana area from forests.

To establish a trend in vegetation phenology or to detect changes in species-community composition, canopy structure and biomass a multi-temporal observation analysis in lantana area has been made using georeferenced IRS-LISS-IV data. Selection of suitable season georeferenced LISS-IV image (when Lantana was in full bloom and forest trees have shed their leaves) was selected for fusion with Cartosat-1 orthoimage using principal components analysis merging approach. On screen class delineation was carried out on LISS-IV merged with Cartosat-1 data using tone texture, size, patter, association and other image characteristics. Cartosat-1 orthoimage and Stereo derived DEM was also used for getting vegetation profile and texture analysis was used for better discrimination of the spatial domain information of high resolution data. Finally after discrimination of the target class a map was generated using segmentation approach

This study has demonstrated the potentiality of LISS-IV and Cartosat-1 stereo data for discrimination and mapping of *Lantana camera* with high degree of accuracy. Merged product from LISS-IV and Cartosat-1 image has sharpened boundary delineation of *Lantana camera* and its spread. Additionally, information from Cartosat-1 derived textural image provides structural attributes i.e. stand density and canopy gap and individual tree crowns of the over storey forest trees and under storey Lantana very clearly.

4. CONCLUSIONS

The study has demonstrated that Cartosat-1 extracted high spatial textural information and three dimensional vertical height measurements from stereo data have been found potentially useful for precision forestry applications. Significant statistical correlations (r^2 ³ 0.90) were found between Cartosat estimated height and crown diameter, and field measured data. Empirical models for the estimation of DBH were developed and validated.

Orthoimage and DEM provided by Cartosat-1 and future Cartosat-2 along with IKONOS and LISS-IV will provide information at micro-level (1:5000 scale) at Working plan level (1:15,000 scale). Most of the information (topographical, structural/ biophysical) can be generated in geospatial format directly from Cartosat-1 and future Cartosat-2 type of data.

Retrieval of such important biophysical information from Cartosat-1 stereo derived DEM have potential for estimation of forest biomass, stand volume, growing stock condition and generation of site index for important timber species with reasonable accuracy, time and cost effective manner.

The invasion of lantana camera has caused significant impact on local forest ecosystems and biodiversity in protected areas, reserved forests and grassland areas in foothills of Himalayan mountain region of Uttranchal. The state needs more understanding of its distribution and spreading status and trend using Cartosat-1 and Cartosat -2 and hyperspectral studies.

At present baseline data on natural resources of the Himalayan mountains regions is not available in the country. Cartosat-1 and 2 along with multispectral IRS-LISS-IV and IKONOS and future hyper spectral sensors will provide very useful detailed information on Himalayan Ecosystems, its habitats, biodiversity and resource base, invasive and commercial species at micro planning level.

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REMOTE SENSING FOR APPLE ORCHARD CHARACTERIZATION COVERING PARTS OF SHIMLA DISTRICT

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INTRODUCTION

Remote sensing technology has potential in estimating crop acreage and production at district, regional and national level due to its multispectral, synoptic and repetitive coverage. This technology is being used operationally by many advanced nations.

Applications of space-borne remote sensing are relatively new to horticultural applications. India is the second largest producer of fruits (469 lakh tonnes per year) and vegetables (580 lakh tonnes per year) in the world. Yet our foreign exchange earning from horticulture is only a small fraction of the amount, small countries like Netherlands and Israel earn. Weak data base on area, production and productivity of horticultural crops is one of the major constraints in the development of Indian horticulture.

A few horticulture based studies have been carried out using remotely sensed data (Panigrahy et al., 1999; Mehta et al., 2000), which aimed at identification of crop, area estimation, condition assessment, separation of diseased stands from healthy ones, differentiation within same plantation in a given area based on age, crown density, different altitudes, different stages of pruning, optimal seasons for identification of horticultural plantations etc. A study of horticultural plantations in Kumarsain Tehsil of Shimla district indicated that, it is possible to identify and map apple and almond plantations using IRS LISS II data (Kimothi. 1997).

OBJECTIVES AND STUDY AREA

The main objectives of the study are:

- To carry out apple orchard identification using IRS LISS III data.
- Development of procedures for area estimation under apple crop.
- Apple orchard characterization using digital elevation model (DEM).

For the pilot study Jubbal–Kotkhai block of Shimla district was considered for apple orchards inventory and acreage estimation. Apples are grown over 85,000 hectares in Himachal Pradesh (H.P). Shimla is the biggest apple growing district in H.P. Apples are grown on 83 % of horticultural land in the district. The area under apple during 1980-81 alone constituted 82.87 % of the total area under fruits. Despite unfavourable weather conditions, the total production of fruits during the year 1980-81 was of the order of 74844 metric tones (Bhatt; 1997). Out of total 8 community development blocks, Jubbal–Kotkhai is a major apple-growing block of Shimla district. It occupies around 270 sq. km of geographical area consisting of hilly terrain where dense forest and valleys occur. The agro–climatic conditions prevailing in the block are most suitable for growing of temperate fruits.

Apple *(Malus pumila)*, an important temperate fruit, grows normally over height of 1400–3600 m and is in general round in shape, having height between 8.0 – 10 m. It needs chilling below 4° – 5°C for about 40 – 60 days for buds to open. Loam, sandy loam and silt loam are suitable soils. Plant to plant distance for apple is around 3.0 – 4.0 m, Flowering starts in April, fruiting in May and by the end of June it has maximum foliage. Main varieties grown are: Royal Delicious, Rich–a–Red, Red Delicious and Golden Delicious.

METHODOLOGY

For the present study IRS 1C LISS III digital data of May-June 1999 season were used to monitor and estimate acreage under apple orchards. The phenology of the major orchards was studied in temporal LISS III data and the optimum period of data i.e. May 1999 was selected. Geo-referencing of IRS data was carried out using topographical maps and area corresponding to Jubbal–Kotkhai block was extracted after overlaying the block boundary. Different unsupervised classifiers like: ISO data clustering, K–means clustering were tested over the block area. Detailed ground truth was carried out using paper prints on 1:50,000 scale of FCC's and unsupervised classified maps. Information on various land cover features vis-à-vis signatures on unsupervised classified maps were collected and compared. Pure apple sites were identified in the field as well as on the FCC paper prints. Signatures for training sites were generated and LISS III data were analyzed using maximum likelihood (MXL) classifier. Supervised classification was used to delineate broad apple and other vegetation classes. An apple mask was generated and apple orchard area was separated from remaining land cover classes. Normalized Difference Vegetation Index (NDVI) range for apple orchards was calculated and based on ground truth and ancillary data, apple area was categorized into three classes i.e. dense, moderately dense and sparse apple orchards. The database for the block was created using ancillary data and used to generate the Digital Elevation Model (DEM). Terrain parameters like elevation, slope and aspect were calculated for different orchard classes using DEM. Areas occupied by different apple classes at various apple geographical parameters were calculated, which led to the selection of optimum set of terrain parameters suitable for apple orchard which can be further used for apple area expansion in the block.

RESULTS AND DISCUSSIONS

On the basis of ground truth data collection and variability in signatures on the image, it was possible to delineate total block area into three major land cover classes i.e. apple orchards, forest and fallow areas. Total variability in gray values of apple orchards were divided into seven signature classes and they were later on grouped into three major classes using supervised classification and NDVI based logical modelling. These classes are namely: dense, moderately dense and sparse apple orchards (Fig.1). Dense apple orchards are appearing in bright red to red colour depending on growth, location and direction with respect to Sun, these orchards are mainly facing opposite side of the Sun i.e. towards snow side or slopes facing North, such orchards have better density and growth of apple gardens, because they are falling in the low sun light region hence moisture available is more due to less evaporation. Moderately dense orchards are appearing in medium red to dull red colour and sparse apple orchards are appearing in light red colour. Location of apple orchards falling under these two categories are mostly Sun facing side, hence they are scattered and small in size. Forest areas are mainly dominated by Deodar species. On the basis of signatures, broad leave mixed forest are appearing in bright red colour. This category of forest include species like: Moru (Carcus), Wallnut, Chestnut, Haselnut, Mapple, Popler, Cileta etc. Pure Deodar forest appears in dark tone. Open spaces within apple orchards appear in blue tone, whereas other agricultural fallow appears in bluish–green tone.

Table 1: Acreage under apple orchards in Jubbal–Kotkhai block

Year	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00 (Project.)	RS-99
Area(ha)	6045.85	6271.95	6668.94	6825.91	7043.34	7291.63	8958.49

(Source: State Department of Horticulture, Shimla)

Fig. 1: IRS LISS-III FCC of study area

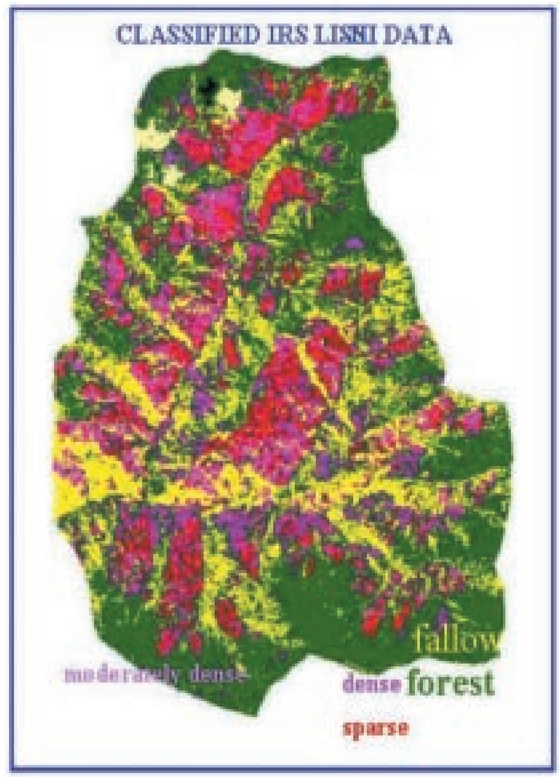

Fig. 2: Classified IRS LISS III data

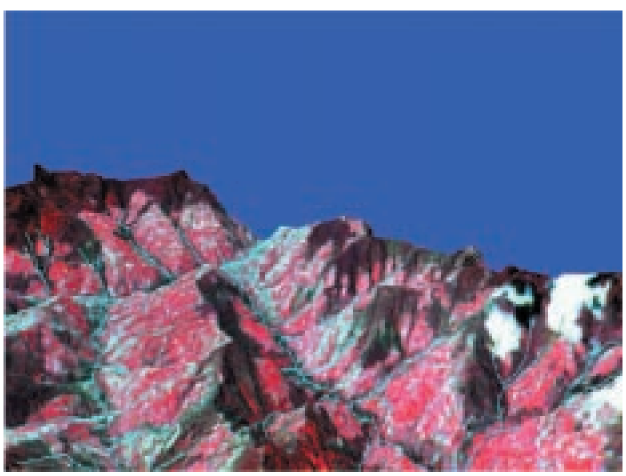

Fig. 3: IRS LISS III image draped on DEM

The False Colour Composite (FCC) image and classified map output using three-band data of Jubbal–Kotkhai block are shown in Fig. 1 & 2. Comparison with classified map shows good visual agreement with the ground truth data. Table 1 shows comparison of acreage under apple orchards in Jubbal–Kotkhai block.

It was observed that around 85 per cent of the apple orchard area lies on the elevation range 1800 – 2600 m and 88 per cent of apple orchard area lies on the 0 – 30 degree slope. The east and south facing slopes occupy around 75 per cent area of the apple orchards (Table 2). This may be due to better availability

Table 2: Area under various terrain parameters for apple orchards in Kotkhai block of Shimla district

Parameters	Total Block Area	Total Apple Orchards Area	Dense Apple Orchards	M. Dense Apple Orchards	Sparse Apple Orchards
Elevation (m)	Area in Percent				
<1800	7	9	6	8	11
1801 – 2000	12	16	15	16	17
2001 – 2200	18	26	27	26	26
2201 – 2400	23	29	35	29	23
2401 – 2600	21	15	13	15	15
>2600	18	5	3	5	6
Total	100	100	100	100	100
Slope (Deg.)	Area in Percent				
<10	21	21	18	21	22
11 – 20	32	38	43	39	33
21 – 30	31	32	30	32	33
>30	15	9	8	8	12
Total	100	100	100	100	100
Aspect (Deg.)	Area in Percent				
North	24	19	30	18	12
East	25	35	33	38	33
South	27	33	27	31	42
West	22	11	10	11	12
Plane	1	1	1	1	2
Total	100	100	100	100	100
Suitable	Area in Percent				
Elevation- (1800-2600)	74	86	90	86	81
Slope -< 30	85	91	92	92	88
Aspect – East & South	52	68	60	69	75
Suitable Combine	33	54	52	56	53

of sunlight in the morning hours when sufficient moisture is available for the plants.

After critical evaluation of terrain parameters listed in Table 2, it is observed that 90 per cent of dense apple orchards, 86 per cent of moderately dense apple orchards and 81 per cent of sparse apple orchards lie on the elevation ranges 1800 – 2600 m. Similarly areas under these classes below 30 degree slope are: 92, 92 and 88 per cent, respectively, If we see the aspect of these classes then 60 per cent of dense apple orchards, 69 per cent of moderately dense apple orchards and 75 per cent of sparse apple orchards occur on East- and South-facing slopes. Hence, based on above observations, it can be concluded that optimum suitable parameters for monitoring apple orchards are: elevation range 1800 – 2600 m, slope below 30 degree and aspect east and south facing. In particular these optimum parameters can be further used for apple orchard characterization / expansion in the Kotkhai block and elsewhere in the district / state in general.

CONCLUSIONS

Data base of various layers overlaid on LISS III data has been created for the Jubbal-Kotkhai block. The data base can be used for evaluation and monitoring of apple orchards. The data base will also serve as base for infra-structure planning for the block. Following are the conclusions of the study:

- It is possible to delineate apple orchards from other land cover classes using IRS LISS III data. Apple orchards were further grouped into three major categories namely: dense, moderately dense and sparse apple orchards. Other major land cover units present in the block are forests, mainly dominated by Deodar forest, and agricultural fallow land.
- In the block 33.25 per cent of geographical area is occupied by apple orchards, which is on higher side as compared to projected acreage for the year 1999–2000 (27.06%) season based on acreage provided by State Department of Horticulture, Shimla. This variation may be because their system of acreage estimation is based on apple output recorded at various checkpoints in the block.
- Optimum suitable parameters for apple orchard characterization / expansion are: elevation range 1800–2600 m, slope below 30 degree and aspect east and south facing.

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SOME OBSERVATIONS ON SLOPE INSTABILITY IN UTTARANCHAL HIMALAYA

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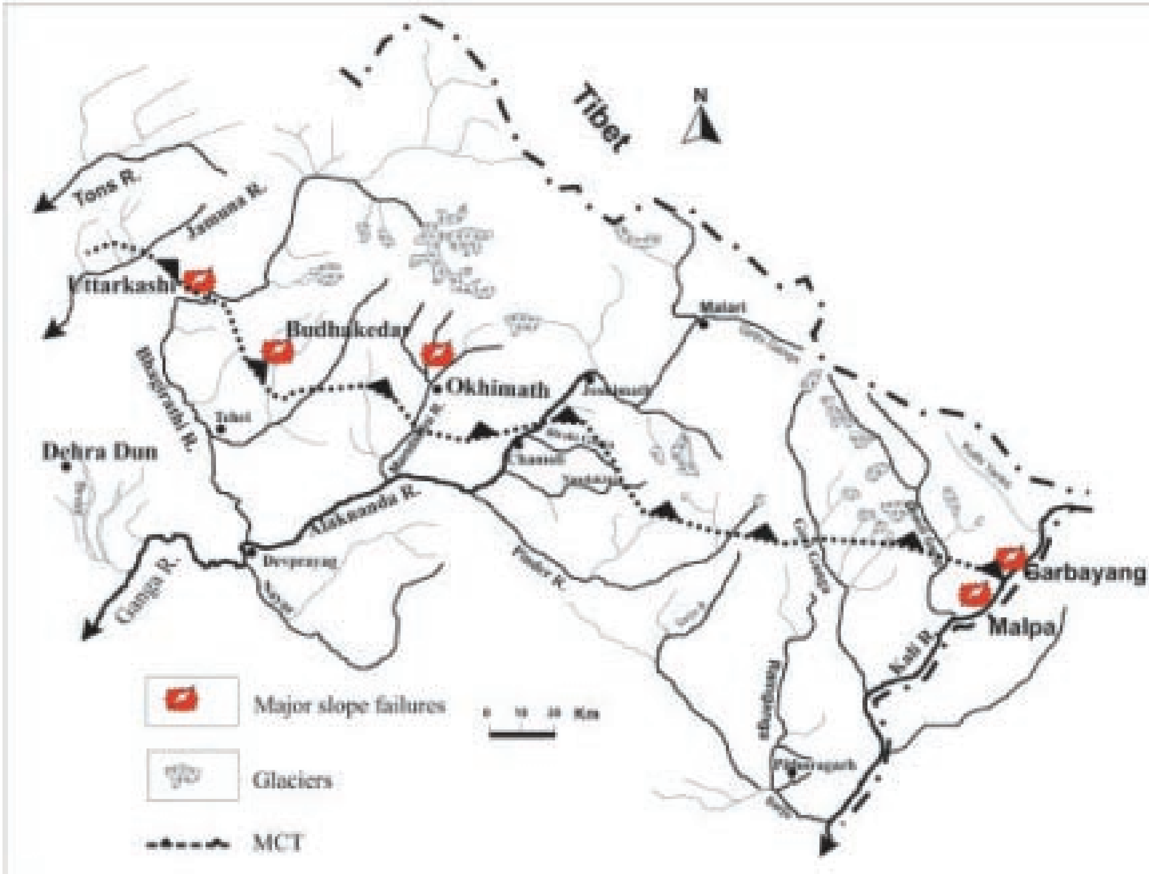
ABSTRACT

The paper presents some case studies undertaken during major slope failures in Uttaranchal in recent years. Synthesis of the existing data and authors' own observations suggest that watersheds proximal to the Main Central Thrust (MCT) are susceptible to slope instability. This is attributed to weak lithology, ongoing seismicity, high rainfall and biotic interference. A mitigation strategy involving acquisition of spatial and temporal data base on natural resource conditions using satellite remote sensing technique at micro-watershed level is suggested.

INTRODUCTION

Himalaya is an outcome of continental-continental collision during the geological past which led to the formation of ~ 2500 km long chain of mountains flanking northern boundary of Indian Sub-continent. The process of mountain building is still going on and is manifested by frequent earthquake turmoils of various magnitudes. In the last 100 years, innumerable earthquakes have hit this region, which has made the terrain highly vulnerable. Superimposed on the natural vulnerability, the infrastructure developmental activities, harnessing natural resources, particularly the forest and in the recent times the rivers for hydroelectricity have enhanced the natural fragility of the terrain. Based on the negative changes observed such as increased frequency of landslides, sedimentation, drying up of natural springs etc. led to the growing concern that Himalayan eco-system is fast approaching a stage of disequilibrium (ESCAP 1989). Although the entire Himalayan ranges are prone to landslides, however in areas proximal to the terrane boundary thrust, situation is very alarming (Fig.1). Due to the frequent movement along the thrusts rocks have been pulverized, fractured and crumpled making them vulnerable during the summer monsoon (Valdiya, 1985; Naithani, et al., 2002). Looking at the kind of development planning that is being pursued; it gives a feeling that it has failed miserably in taking into account the inherent fragility, inaccessibility, bio-diversity and traditional man-nature relationship etc. As a result natural hazards become routine in the region. Another important factor responsible for high landslide activity in the region is its increased seismicity in recent years. After many years of quiescence during last decades of the previous century, the area was jolted by two moderate earthquakes (1991, Uttarkashi and 1999, Chamoli). Earthquakes, besides causing landslides during the event itself, also pave the way of several future landslides. Ground fractures developed during earthquake facilitate landslides in heavy rains. In the last few decades frequent incidences of landslides and flash floods have caused significant damage to the lives and property of the people besides permanently modifying the landscape in many places. Significant contribution can be done in reducing the size of landslide disaster by using advanced techniques viz. Remote Sensing and GIS. This paper summarizes few incidences of slope instability in Uttranchal Himalaya in order to ascertain their causes and implications. It also emphasizes how the remote sensing and GIS techniques are helpful in finding the solutions of the landslide problems in the region.



Malpa

In August 1998, a massive landslide buried a village called Malpa (30^0 13’ 56”N and 80^0 48’ 25” E) located at the confluence of Malpa Gad and Kali Ganga. Kali Ganga is a geographical boundary between Nepal and Uttranchal. Geologically the village lies on the SE facing spur comprising higher Himalayan crystalline rocks. Major structure around Malpa is Pindari Thrust. There are evidences to suggest that this thrust was active in the recent geological time. Besides this, numerous transverse tear faults pass through the area which has rendered the rocks vulnerable to landslides (Kumar and Sattyal, 1999). During the prolonged rainfall (August 13–16, 1998), rocks above the village yielded to the increased pore-water pressure causing slope activation which blocked the Malpa Gad above the village. Breaching of the lake led to the wholesome destruction (Kumar and Sattyal, 1999).

Garbayang: a Sinking village

Garbyang village is situated 10 km north of Malpa village in a NE-SW trending Kali Ganga basin (30°5’30’’N; 80°50’20’’E). River Kali Ganga has incised the lake deposits giving rise to four levels of flat-topped surfaces. Garbayang is located on the uppermost terrace. Towards the north N-S trending calc-silicate ridge protects the village from natural hazards such as snow avalanche, debris slide etc. Chiyalek demarcates the southern extent of Garbayang basin which is also a geomorphic expression of the Trans Himadari Fault (THF) which is considered to be active in recent times (Juyal et al., 2004).

In the past, Garbayang was the largest and wealthiest village where majority of the villagers were involved in trade with Tibet which was disrupted after 1962 China war. One of us had the opportunity to visit this village during 1997 before the Malpa tragedy to get some idea about why the village is in a state of demise. There is folklore in Garbayang village which says that prior to the settlement of village; a huge lake existed in the basin. Since the land was scanty people prayed to their local God *Namjung* to drain the lake water which the almighty did by opening the Chiyalek barrier in the south. This story goes on very well with the recent study suggesting existence of Paleo Lake in the basin (Juyal et al., 2004). Today the village is situated on top of the lake deposits which are dominantly clay rich. For past few decades, ongoing subsidence has destroyed many houses. Land subsidence in Garbayang basin is unique in the Uttaranchal Himalaya in the sense that it did not claim single life. That is because subsidence is a continuous process, quiet and steady which affects the static structures (built structures). At places we have observed that in last 10 years nearly 20 m of subsidence has occurred (Fig. 2).

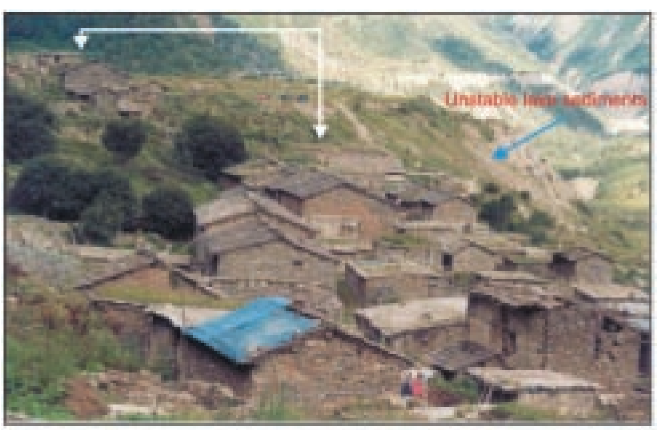


Fig. 2

The cause of subsidence is a combination of factors such as clay rich sediment, no provision for regulating or diverting the rainwater and unabated toe erosion caused by the turbulent Kali River. Since the village has been largely deserted for many years except occasional visit by people. There were no efforts by the locals or the government agencies to evolve methodology for safeguarding this historical village of Uttaranchal.

Okhimath tragedy (Madhyamaheshwar basin)

In Madhyamaheswar basin, innumerable landslides ravaged the terrain killing more than 100 people during August 1998. Madhyamaheshwar river basin (30^0 31'–30^0 38'N and 79^0 02'-79^0 10' E) is located in the higher Himalayan crystalline belonging to the Munsiari, Bhatwari and Joshimath formation (Bisht and Sinha, 1982). Contact between the Munsiari and Joshimath formation is designated as the Main Central Thrust (MCT, Valdiya, 1998). During August 1998, unprecedented scale slope instability led to the death and destruction in this basin. According to local people the basin witnessed such incidences in the past, however the loss of life and property was relatively low compared to 1998 tragedy. During our field investigation carried out soon after the incidence, it was seen as if a giant's paw scratched the slopes. There was hardly any village that did not bear the brunt of landslide. Geological investigation suggested that the terrain is riddled with fractures and lineaments and the steeply inclined crystalline rocks were inadequately covered with regolith (Fig. 3). In addition to this MCT, which passes close to the basin, has created a wide zone of fractured rocks. Looking at the land use changes, we were told that mounting population pressure led villagers to move in areas which were otherwise considered unsafe for habitation. Majority of the affected villages were found located on old landslide deposits and the agricultural field created without adequate levelling and support. At many places houses were constructed close to the seasonal stream courses. Kimothi et al. (1999) carried out study on temporal changes in land use and land cover over last three decades. According to them, there was virtually no increase in the built-up area. However a marginal decrease of ~2% in forest cover was observed between 1966 and 1998. Considering 57% forest cover in the basin, a direct relationship between the number of landslides and land use / land cover changes was not observed. However, when assessed at different contour grid level, it was found that

Fig. 3

over slopes lying between 1000 m to 2000 m the forest cover was scanty. This is the zone where maximum landslides occurred.

Besides this a rock mass above Bhenti village broke down without any warning which not only buried the Bhenti village at the bottom but also Paundar village located on the opposite flank without any trace. Thus a lake was created on the river Madhyamaheswari in the upper reaches near erstwhile Paundar village. Dimension of the mountain slip was ~ 900 m (height) with a width ~ 500m (~ 4 km^2).This was one of the few gigantic landslide witnessed in Uttranchal during the last few decades. Structural mapping of the landslide scar showed presence of three sets of penetrative joints which would have been widened due to earthquake activity in the past (Rautela and Thakur, 1999). We were told that N-S trending fissures developed above the Bhenti after 1991 Uttarkashi earthquake which was never considered a serious threat. Considering above it can be suggested that lithology, presence of fissure and torrential rain together led to this mountain failure. This has raised concern that there may be many more such localities in the region which are waiting for some triggering mechanism to set them in motion. A recent example is the breaking down of Varunawat Parvat above Uttarkashi town during September 2003. For days together people of the town were reeling under the threat.

Budhakedar

A massive cloudburst (August 2002) caused large-scale destruction in the watersheds of Medh Gad, Dharam Ganga and Bal Ganga located in Thati-Kathud panchayat of Ghansali Tehshil in Bhilangana block of Tehri district. According to government estimate 17 villages spread over in three watersheds viz. Medhak Gad, Dharam Ganga and Bal Ganga were affected.

A detailed documentation of the causes of this tragedy was done by Doval and Juyal, (2004). According to their report, evidence of old landslide activity in the basin is well preserved suggesting the sensitivity of the terrain towards slope failures. Majority of the villages are located on the old landslide deposits and are surrounded by fast flowing steep-gradient streams. For example, Agunda village where maximum human loss was reported is divided into two halves by Ghunguti Gadhera.

Tributary streams in Himalaya are known for their high stream power due to steep gradient. During monsoon the increase in hydraulic discharge further enhances their capacity to erode their banks. In poorly vegetated catchment, raindrops eventually move down slope as surface runoff. In the process they act as scavenger removing the topsoil and precariously balanced boulders. In areas where the stream course is constricted, entrapment of boulders and tree stumps creates temporary lakes and breaching of such lakes sends flood surges downstream.

It was found that series of temporary lakes were created along the course of Ghuguti Gadhera. A major blockade occurred at the jeep bridge immediately above the village which diverted the reservoir water into the village. If the span of the bridge would have been large enough it would have allowed boulders and tree stumps to be carried into the trunk river downstream (Doval and Juyal, 2004). A lesson learnt is that at times man-made structures for communication may turn out to be death traps.

DISCUSSION

With the few examples cited above it can be suggested that during the last one and a half decades, increasing incidences of landslides leading at times to flash floods have raised concern both among the planners and the local inhabitants. This is reflected in the recommendation of a working group constituted for the eighth five-year plan where it was suggested that *unless adequate programs are evolved for conservation and proper utilization of the resources of the hill areas, not only will the problems of these areas continue to remain unsolved, but the economy of the plains may also come to grief. Therefore, the paramount need for conceiving an integrated strategy for development of the hill areas should be based on sound principle of ecology and economics*.

Major landslide events in Uttaranchal Himalaya were concentrated in the vicinity of the Main Central Thrust (MCT). MCT is not only a tectonic boundary between the higher Himalayan crystalline and lesser Himalayan meta-sedimentary rocks but also acts as orographic barrier for the southwest monsoon. Besides this, majority of cloud-burst events are located on this barrier. Rainfall data for the last 100 years indicate that there were periods when 200 to 500 mm rainfall occurred in one day (Aggrawal and Chak, 1991). There exists a linear correlation between the intensity and duration of rainfall and landslides in Himalaya (Deoja et al., 1991). Further, landslide types also depend on the relative values of rainfall intensity and saturated hydraulic conductivity of the ground (Cendrero and Dramis, 1996). If the former is higher, overland flow will develop and surface erosion will be the main process. Whereas hydraulic conductivity would lead to increase subsurface pore pressure. This excludes the landslide dammed lake outburst events such as Malpa and Budhakedar. In Madhyamaheswari basin, the smaller landslide scars were caused due to channel erosion whereas, Bhenti landslide was the outcome of increased pore water pressure.

Studies have shown that deep-seated landslides and extreme flood events are manifestation of rainfall, local geology, structure and topography (Bruijnzeel et al., 2005) and are independent of forest cover. However, this can be generalized particularly in case of Himalaya. Though the studies are limited in number but some indication to the role of forest in preventing landslide and flash flood was observed in the upper Alaknanda catchment. Using the satellite remote sensing technique supported by forest working plan and field observations, Kimothi and Juyal, (1996) demonstrated that the 1970's Alaknanda flood considered to be the largest flood of the century was the outcome of large-scale deforestation in the sub-watersheds proximal to the MCT during early 1950 and 70's.

Considering above, it is suggested that a combination of various factors were responsible for the slope instability proximal to the MCT. For example, on-going seismic activity along the MCT (Khatri, 1987), recent examples are the 1991 Uttarkashi and 1999 Chamoli earthquakes, fractured and fissile lithology (Valdiya, 1985), frequent incidences of cloud bursts (Aggrawal and Chak, 1991) and large-scale commercial forest felling in the past (Nityanand and Prasad, 1972; Prasad and Rawat, 1979; Kimothi and Juyal, 1996) led to the vulnerability of the watersheds discussed above.

According to an estimate, the rivers of Himalaya are eroding its watersheds five times higher then during the geological past. These rivers are carrying incredibly large amount of sediment approximately around 16 ha m per 100 square km each year (Valdiya, 1985). Considering that per capita agricultural landholding is <1 acre, thus besides the high erosion, each year during monsoon, large chunks of agricultural land are either washed down due to flash floods or buried under the landslide debris.

Recently, remote sensing and geographic information system (GIS) technology has been used to better integrate and analyze data collected from the field and other sources. The greater numbers of investigators are utilizing DEM to study slope processes and evolution of topography in the Himalaya (Burbank et. al, 1996, Gupta and Joshi, 1990). In the study area though the use of remote sensing in landslide-related studies is increased in recent years (e.g. Kimothi and Juyal, 1996, Kimothi, et al., 1999, Rautela and Thakur, 1999, etc.). Barring few studies there is paucity of high resolution satellite data on state of natural resources and their spatial and temporal changes. One of reasons could be limitations associated with the spatial and spectral resolutions of some sensors that are used for assessing geomorphic features. In addition, the extreme, topographic relief of the Himalaya introduces a component of differential illumination or shadows, in the multispectral data, which can cause analysis problems (Franklin, 1991).

In recent times, tempering with terrain for various developmental activities has further aggravated the situation. Though there is paucity of data on the implication of .programs like road building and river water harnessing projects but nevertheless, a cautious approach is required because of the sensitivity and inherent fragility of the terrain. Currently numerous hydroelectricity projects have been launched in this region. No one denies their need in a time when energy is needed for better future but at the same we should ensure that such projects should not disturb the ecosystem.

SOME SUGGESTIONS

In order to evolve a scientifically sound and environment-friendly mitigation planning for the prevention of frequent incidences of slope instability, we suggest the following.

1. It is desirable to consider watershed, as a functional unit, which means we should not view the incidences of landslides in isolation but as a component of a system which in case of Himalaya should be a watershed.
2. There is still serious dearth of authentic database on the state of natural resources. With the availability of high resolution and multi temporal satellite data, we can not only generate required dataset on slopes, vegetation, drainage density, major and minor structures but also can monitor changes taking place through time.
3. Forest is a major component of any watershed which not only helps in regulating the hydrological cycle but also protects the slopes from the onslaught of torrential rains. In turn, forest kind, their growth etc. depends upon the soil/regolith which is dependent upon rock types. Therefore, efforts should be made on war footing to create data base of soil geology and to regreen the barren watersheds with this vital protective cover.
4. Communication and power are two major ingredients for the growth of a society. Construction of roads in order to connect remote villages is essential. However, at the same time one has to take into consideration

the sensitivity of the slopes. Use of dynamites should be restricted in ecologically fragile watersheds. Similarly, sites for the river valley projects are invariably located at the gorge section which is also the location of a major fault. Due care needs to be taken for the stability of the area while constructing a barrage or dams.

5. Remote sensing and GIS techniques are useful in demarcating old landslide zones, prominent fractures in the rocks, periodic assessment of micro-level land use change, landslide frequency distribution in the region and finding remedial measures in the form of alternate site selection for developmental activities and rehabilitation. Therefore, these techniques are strongly recommended in order to minimize transformation of landslide hazards into disasters.

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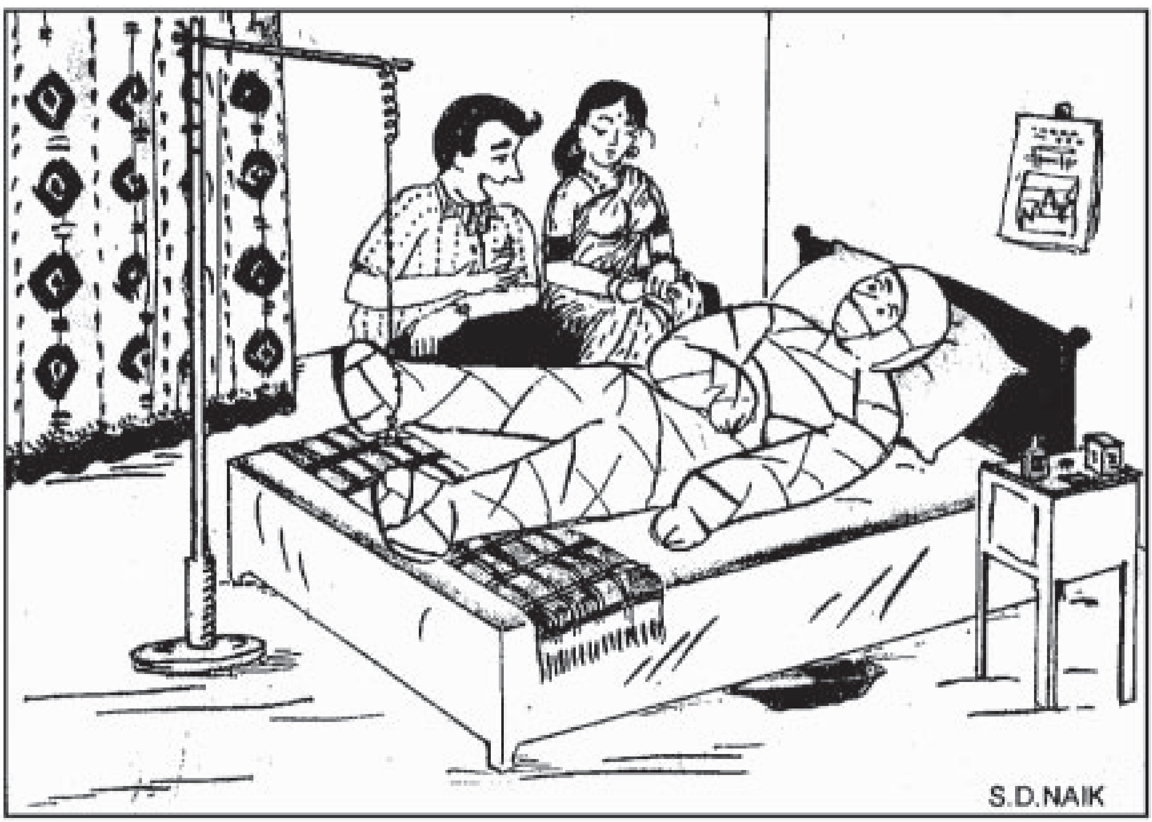

YOU SHOULD NOT HAVE SELECTED MOUNT EVEREST AS A TEST SITE FOR GENERATION OF DEM AND ITS GROUND VERIFICATION

Digital Camera

BIO-GEO DATABASE AND ECOLOGICAL MODELING OF HIMALAYAS USING REMOTE SENSING AND GIS TECHNIQUE

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INTRODUCTION

Generation of Bio-geo database on Natural resources is oriented towards providing information for decision makers and encompasses information on natural resources related to land, water, forests, minerals, soils, oceans, etc. and socio-economic information such as demographic data, amenities, infrastructure, etc. The integration of these data sets would aid decision making process for systematic resources utilisation and also aid sustainable development. The project is visualized as a repository of resource information in the spatial domain and will provide vital inputs to decision-making at the local levels.

Himalayas are the largest reservoir of biodiversity with its unique physical and cultural diversity. Diversity in the physical landscape has resulted in many different types of land uses. Increasing pressure on land for agricultural and non agricultural need has extended to less favourable environments leading to accelerated soil erosion and excessive land degradation. These area / watersheds require scientific management using modern techniques of GIS and Remote Sensing.

For overall scientific development of an area, database is the prime requirement. This database helps in analyzing prevailing trends in the area as well as to visualize future trends. This programme is in the process of evolving a programme on Bio-Geo Database generation and Ecological Modelling on the basis of this data in the Himalayan region. This project focuses on the Bio-Geo database generation and development of the watershed in a sustainable manner. The project emphasises the evolution of digital database and its analysis using the remote sensing techniques and Geographical information System.

In the past the use of non-standard definitions and classification systems adopted by different organizations for making inventory of watersheds has resulted in varying statistical estimates. Therefore to overcome this problem, an attempt has been made for standard definitions and classification system and a method has been developed and adopted for mapping watersheds using remotely sensed satellite data supplementing with temporal ground based information. The State Council has taken the initiative in this direction. A team of scientists from various fields like land use, soil, flora, fauna, hydrology, sociology, geology etc. have contributed towards building a comprehensive database, based on uniform baseline data derived from the latest satellite imageries and ground truth surveys.

Bio-Geo database consists of both spatial and non-spatial data elements, which include spatial inputs, based on remote sensing, maps obtained from conventional sources, and non-spatial data on demography etc. The data elements are grouped into primary elements collected and entered into the system as well as certain elements derived within the database using some of the database elements themselves. The layers of primary data elements include both spatial as well as non-spatial for the Bio-Geo database generation. Each of the layers has associated with it an attribute code. Bio-Geo data derived layer is extract from the primary layers in spatial and non-spatial layers, respectively.

Multitemporal and multispectral IRS satellite images is being used to map the natural resources like watershed, land cover/vegetation, lineament, fractures and faults, soil, etc. surveyed maps, forest maps, geological maps and other available maps are also used to extract information on slope, topography, altitude, lithology and geological structures and other diverse information. The spatial information on the watersheds is generated in map form by using geo-coded data at the scale of 1:12,500 using the latest IRS PAN + LISS-III satellite imageries. The spatial information of thematic maps like lithological, geomorphologic, lineament, landuse, soil, slope, etc.has been generated by interpreting satellite data. The above information has been integrated with attribute data in the GIS environment using the ARC/INFO software.

OBJECTIVES

The major objectives of this study are:

- Identification of user's need and requirements in watersheds of different agro-ecological zones in H.P.
- Database collection using satellite data interpretation and ground truth surveys using Global Positioning System (GPS).
- Development of standards/mapping codes and classification system for watersheds using high resolution remotely sensed satellite data.

GIS-BASED METHODOLOGY

Using remote sensing mapping technique the thematic maps were scanned and digitized in the GIS environment with the help of ARC/INFO software. This GIS approach was used to generate the information regarding the natural resources, vegetation, habitation, flora and fauna. The integration of spatial and non-spatial data sets will be done to arrive at locale-specific action plan. GIS-based query shells will be utilized to retrieve the land resources information and also generate the action plans for each land use parcel.

Finally the land resources development action plan is generated with the available spatial and non-spatial statistics considering the users queries for all the three different Himalayan watershed transacts for the use of planners and the field level users.

DATA USED

PAN +LISS III FCC merged data at 1:12,500 scale, published Forest Survey of India maps at 1:15,000 scale enlarged up to 1:12,500 scale., published Survey of India maps enlarged up to 1:12,500 scale, and aerial photographs at 1:50,000 scale and digital data on CD-ROM IRS-1C LISS-III have been used.

The geo-coded satellite data was visually interpreted and all the land use/ land cover categories were delineated using standard codes (specially designed for the mapping of the land use at the enhanced scale of 1:12,500).

Thematic Map Generation

Base map is the prerequisite for any mapping project as it depicts the major and minor approach roads prominent drainages, important locations and features etc. Drainage maps were generated from the published Forest SOI maps at 1:15,000 scale. These maps were enlarged up to 1:12,500 scale and the same was overlaid with the interpreted satellite data at 1:12,500 scale. The drainage details available at 1:15,000 scale from the Forest SOI maps and the Survey of India maps were limited. Therefore the information derived from the Forest Survey of India maps were updated using high resolution PAN + LISS –III satellite data. This process facilitated identification of all the major as well as minor details of the drainage which was otherwise not possible to extract from any other survey map.

Micro-level Sampling Unit

On the basis of this detailed drainage map the Minimum Sampling Units were generated for the purpose of field study. The minimum sampling unit was designed for the purpose of field survey and data collection based on the homogeneous micro-watersheds. These micro-watersheds have been further sub-divided into the micro sampling units. As per the norms of the All India Soil and Land Use Survey, the watersheds were delineated based on size. These watersheds were further sub divided into sub-watersheds, mini-watersheds and micro-watersheds, also based on the size of the individual hydrological units of 30-50 sq. km, 10-30 sq. km, and 5-10 sq. km. respectively as per the codification of the Integrated Mission for Sustainable Development Project of the Department of Space, Government of India. However for the Bio–Geo database project for the purpose of delineation of the minimum sampling unit, the first order drainage and its subsequent drain orders with their individual hydrological entity were taken into consideration. This methodology of delineation of a homogeneous hydrological land parcel gives a complete picture of the individual sampling unit for the purpose of data collection, may it be the data collection of Flora, Fauna, Microbial diversity or any other.

This method of data collection using the individual micro sampling unit is complete in itself as each unit experiences a homogeneous micro environment. The size and number of the minimum sampling unit increases or decreases depending on the topography and drain order. Smaller the length of the drain, smaller is the size and greater is the number of minimum sampling units per unit area. The codification of the minimum sampling unit has been taken up in the clockwise direction starting from the mouth of the main drainage system and thereafter starting from the right bank; after completion of the micro-watershed the next adjoining watershed is taken into consideration.In this way the entire watershed is completed. This method will identify each minimum sampling unit with a unique code.

It has been observed that in hilly area with dendritic drainage pattern the watershed has greater number of minimum sampling unit in comparison to the relatively plain area as in the case of Madhala watershed in district Solan. Whereas in the.case of Moolberi watershed in district Shimla which is uniformly hilly the distribution of the minimum sampling unit is more or less uniform in nature.

WORKING MANUAL AND STANDARD CODES

For the preparation of the uniform database for all watersheds a working manual was required to be devised. The manual was based on the standard codes specifically prepared for this project. The Land cover /use units are derived by interpretation of the satellite data based on the image characteristics like tone, texture, shape, colour, association, background etc. The land use /cover map which formed the basis of the project was prepared using geo-coded FCC imagery and land use categories up to the fourth level of classification were delineated.

During pre-field interpretation work whenever a doubt crops up the same was noted for the ground truth survey. During the field traverses based on minimum sample unit i.e. Sub-micro watershed polygon involving first order drainage all the necessary information was observed and the same was incorporated in the map. This information was incorporated on the map based on the chronology. The digital image analysis system facility was also incorporated for obtaining more detailed information which is otherwise not available in the PAN + LISS III FCC paper print.

Ground truth survey was undertaken as per the season and date of satellite passes over the study area. Emphasis was to coincide the satellite passes within ground truth survey, so as to obtain the actual ground truth conditions with respect to seasonal variations. All the doubtful units encountered during pre-field interpretations were verified and correctly incorporated on the final map. During the ground truth survey effort was made to check all the land units/ parcels with respect to individual micro watershed to enhance its accuracy. The final thematic maps were generated at 1:12,500 scale.

Creation of the Coverage in GIS Software

Using the final, updated and corrected maps at 1:12,500 scale, through the process of map scanning and digitization various coverages on Flora, fauna and microbial diversity were created using Arc/ Info software some of the themes prepared under the project for integration and analysis.

Fig. 1

Fig. 2a Field view of Mandhala watersheds in Lesser Himalayas

Fig. 2b Field view of Moolbari watershed Middle Himalayas

Fig. 2c Field view of Me Gad watershed Higher Himalayas

Fig. 2d. Ground truth survey Gad watershed

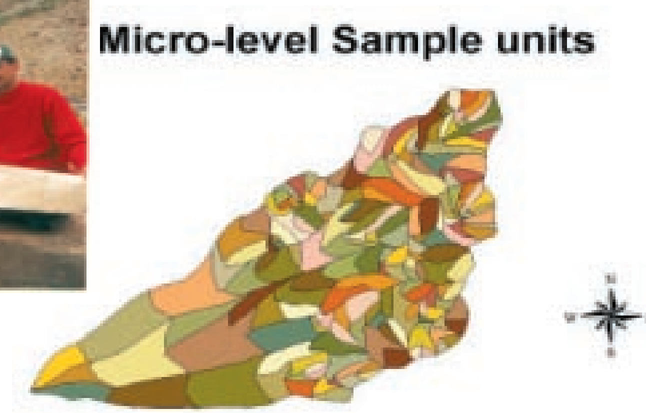

Figure 3 Micro sampling unit of Mandhala watershed

RESULTS AND CONCLUSIONS

Studies based on interpretation of satellite remote sensing data with substantial ground truth surveys along with the modern tools and gadgets for mapping have great potential for identifying the diversity of flora, fauna, soil, land use, hydrology, socioeconomic parameters etc. Subsequent transformation of the database into user - friendly and cost - effective GIS software packages provide the much needed scientific approach to scientists, managers and planners. The database analysis along the altitudinal gradients provides a comprehensive insight into the distribution of the biodiversity in the complex agro - ecological zones of the Himalayan terrain

The study resulted in the most accurate data of its kind under the guidance of expert groups The study not only brought forth the result related to the quantitative description of the available species within the specific watershed but in addition it represented their spatial location as per the season. The GIS methodology adopted for the study on the basis of the micro sampling unit, high resolution satellite data, and GPS - identified certain species and polygon layers. It was also observed that the characterization of the species and their spatial distribution in a GIS environment is of advantage as compared with the digital processing of remotely sensed images. The present methodology of data collection, data storage, data analysis and retrieval in a GIS environment provides a systematic and consistent framework for the study of the databases in this complex and rugged Himalayan terrain.

The above methodology would assist in mapping biodiversity richness of certain specie; the seasonal assessment of biodiversity for monitoring purposes; identification of spatial location of the habitat:, identification of the hydrological regime; and understanding the distribution of the soil along with its properties. The altitudinal variation provides the necessary inputs for the in-depth understanding and inter relationship of biodiversities within the Himalayan ecosystem. To further substantiate the result an intensive research is required to establish the distribution of biodiversity and its interrelation with other essential parameters. These parameters would thus assist in addressing the requirement of the users and target group within the specific watershed. However, remote sensing and GIS techniques would provide the essential tools for future biodiversity mapping in the Himalayas.

SPATIAL MODELLING OF SEISMICITY INDUCED LANDSLIDES

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Abstract

Landslides, induced by an earthquake, depend primarily on the amount of permanent deformation the slope has experienced. The study is concerned with the assessment of simplified Newmark's block-on plane model for evaluating the permanent earthquake displacement. The analysis calculates the cumulative permanent displacement of the block relative to its base as it is subjected to the effects of an earthquake acceleration-time history. The moderate magnitude Chamoli earthquake that occurred in the Garhwal Himalaya in the early hours of March 29, 1999, caused intense damage to the ground and mountain slopes in Alaknanda river valley and adjoining region. The earthquake has triggered several new landslides and reactivated some of the existing ones. In the present study this model is applied in Chamoli region and its surrounding areas falling in a high landslide hazard zone as well as high seismic zone (Zone V) that has experienced a large number of seismicity-induced landslides of varying size and types in the recent past.

Key words: earthquake, landslide, displacement

INTRODUCTION

The hilly tracts of the Himalaya are prone to landslides and earthquakes due to ongoing tectonic activities. The seismic events can cause ground acceleration which in turn can activate mass movement processes, especially in high relief areas of Himalaya, aggravating the slope stability problem. Earthquakes having magnitudes greater than 4.0 can trigger landslides on very susceptible slopes near the epicentre, and earthquakes having magnitudes greater than 6.0 can cause widespread landsliding (Keefer, 1984). The study area lies in the Chamoli district of Garhwal Himalaya, bounded by latitudes $30^0 15'30"$ to $30^0 31'00"$ and longitudes $79^0 15'00"$ to $79^0 33'00"$. The Chamoli earthquake of 1999 triggered new landslides and reactivated old landslides (Sah and Bartarya, 2002). The seismic parameters have been derived from source characterization data of USGS and IMD. Parameters on terrain characteristics *viz.* geology, structure, geotechnical properties etc. were derived from IRS-LISS-III, IV and PAN data supported by ground observations and laboratory test. These satellite data products show three types of landslides: old, reactivated and new slides, most of which are rock and debris falls. The database is organized in ARC GIS and result shows simulation of slope response to reference seismic event and its effect on slope stability.

GEOLOGICAL SETUP

The Garhwal Himalaya is located at the eastern end of the North-west Himalaya in northern India and is situated in a seismic gap, in the vicinity of the Main Central Thrust (MCT) that separates the Lesser Himalaya to the South from the Greater Himalaya to the North (Valdiya, 1988). The study area is underlain by Garhwal Group of rocks (Kumar and Agrawal, 1975) consisting of quartzites which are well exposed at Chamoli and extend 2-3 km to the northeast followed by limestone and slate sequences of the Pipalkoti Window, locally known as 'Carbonate Suite of Chamoli' (Gaur et al, 1977). The Carbonate Suite of Chamoli consists of alternating sequence of slates and dolostones that form the doubly plunging Pipalkoti anticline. It is thrust over by

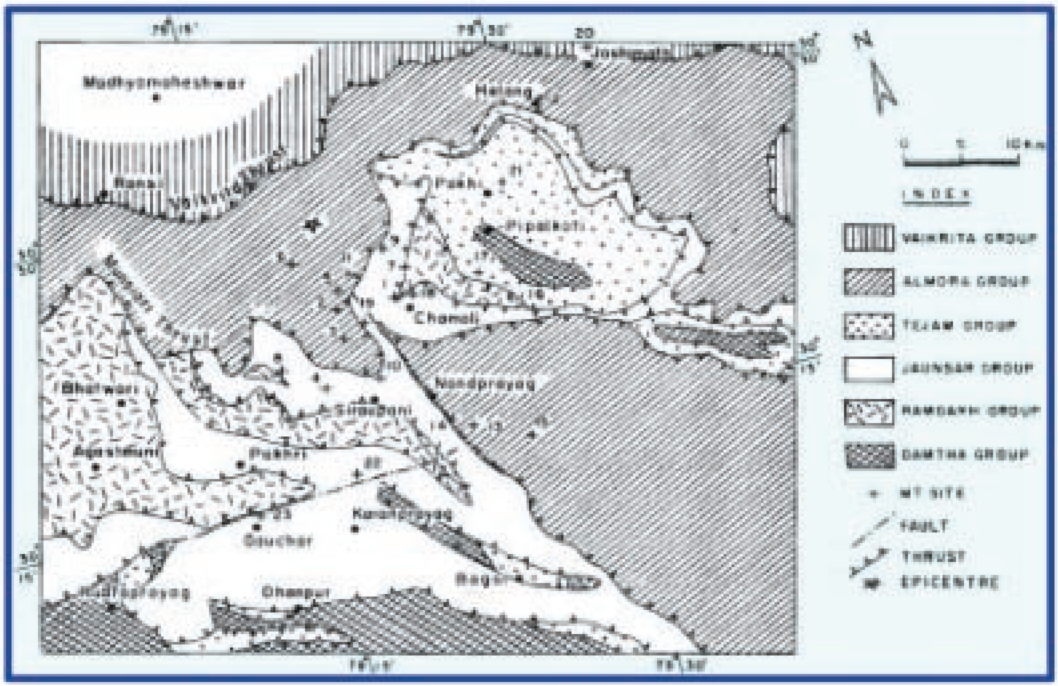

Fig. 1. Regional geological map of the study area (After Valdiya, 1980)

the thick quartzites of Gulabkoti and the Chinka formations, which are thrust upon by the Central Crystallines along the .MCT, locally trending in NW-SE direction and dipping at 15-20^0 towards north. Tectonically, the MCT represents a ductile shear zone at depth, comprising a duplex zone with three distinct thrust planes: MCT I, MCT II and MCT III from south to north. Based on the degree of metamorphism, lithostratigraphy and tectonic setting, these thrust planes are also referred to as Chail (MCT I, lower thrust), Jutogh (MCT II, middle thrust) and Vaikrita (MCT III, upper thrust) (Valdiya, 1980). The Chamoli earthquake appears to be associated with the ongoing deformation along Chail Thrust.

MODELLING OF SEISMICITY INDUCED LANDSLIDE

Several models have been developed to evaluate the stability of geotechnical structures under earthquake loadings. These models include: the limit equilibrium model that uses the slope safety factor in which the failure occurs when the safety factor is less than unity; the stress-strain analysis using the infinite element technique, and the block-on-plane model which is based on calculating the cumulative earthquake induced displacement. Development in the first group of models includes the work of Fellenius (1936), Bishop (1955) and others. The second group of models is more sophisticated and requires accurate input data, as demonstrated by Al-Homoud (1990) and Al-Homoud and Whitman (1995), who used the finite element method to model dynamic behaviour of gravity walls under earthquake loading. The third group, block-on-plane model, was introduced by Newmark (1965) to obtain the earthquake-induced displacement of embankment slope. Many attempts were made to improve this model, resulting in models for obtaining the earthquake-induced displacement (Ambraseys, 1972; Richard and Elms, 1979; Zarrabi, 1979; and Wong and Whitman, 1983).

Newmark method of analyzing the dynamic performance of slopes bridges the gap between simplistic pseudostatic analysis and very sophisticated, but generally impractical finite-element modelling. Although Newmark introduced his method to analyze the performance of artificial embankments, Wilson and Keefer (1983) showed that Newmark's method to model the dynamic behaviour of landslides on natural slopes yields reasonable and useful results. Jibson (1993) used the Newmark method for predicting earthquake-induced landslide displacement. Based on Newmark method, Miles and Keefer (2001) have prepared seismic landslide hazard map for the city of Berkeley, California in GIS environment.

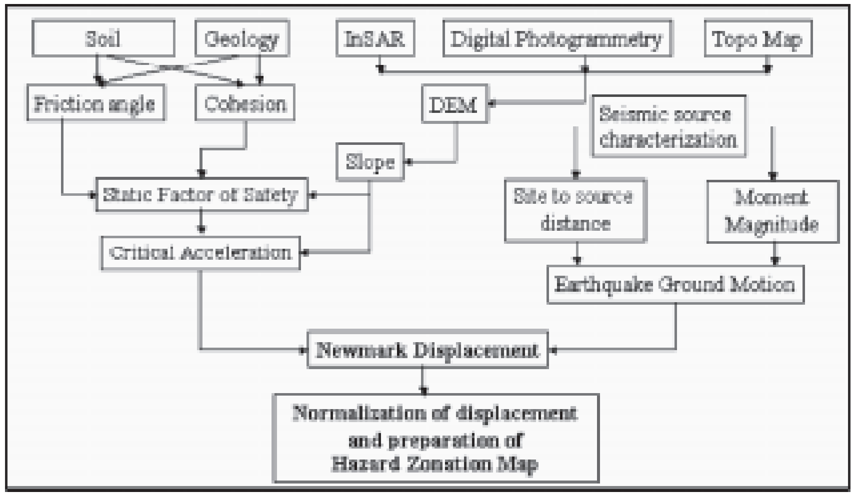

Fig. 3. Methodology for seismicity induced landslide hazard zonation using Newmark model.

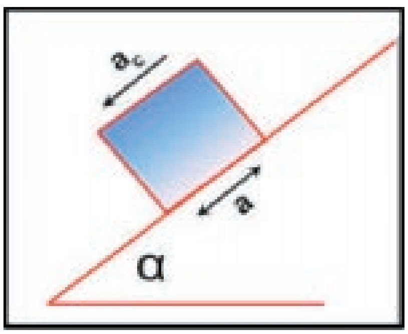

Fig. 2. The potential landslide is modelled as a block resting on a plane inclined at an angle (á) from the horizontal. The block has known critical (yield) acceleration (a_c), the base acceleration required to overcome shear resistance and initiate sliding with respect to the base. The block is subjected to a base acceleration (a) representing the earthquake shaking.

Newmark's method models a landslide as a rigid friction block that slides on an inclined plane (Fig-2). The analysis calculates the cumulative permanent displacement of the block relative to its base as it is subjected to the effects of an earthquake acceleration-time history.

Newmark analysis can be extended to regional analysis using Geographical Information Systems (GIS). The procedure is summarized by the flow diagram (Fig. 3), where each labelled box, except for earthquake magnitude, represents a map grid. Conducting a conventional Newmark analysis requires selection of an appropriate earthquake record and determination of the critical acceleration (a_c) of the selected slope. Critical acceleration (a_c) can be calculated using the equation:

$$a_c = (FS-1)\ \sin \alpha \qquad (1)$$

Here, FS is the static factor of safety of the slope and α is the angle of the landslide block, which is typically approximated by the slope angle. The angle for each pixel is approximated by calculating slope from a digital elevation model (DEM), which has been generated using IRS-1C stereo-pair. The most common means of calculating the static factor of safety, in the context of spatial analysis, is to apply the infinite slope model to each pixel. Using the infinite slope model, the static factor of safety of a slope (FS) can be expressed as follows:

$$FS = (\acute{c} \,/\, \gamma\ d\ \sin \alpha) + (\tan \phi' \,/\, \tan \alpha) - (m\ \gamma_w \tan \phi' \,/\, \gamma \tan \alpha) \qquad (2)$$

Where, $\acute{c}$ is cohesion, ϕ' is effective angle of internal friction, γ is material unit weight, γ_w is unit weight of water, α is the angle of the slope from the horizontal, δ is normal depth to the failure surface, and *m* is the ratio of the height of the water table above the failure surface to δ.

The above equation is organized so that the first term on the right side accounts for the cohesive component of the strength, the second term accounts for the frictional component, and the third term accounts for the reduction in frictional strength due to pore pressure. In present analysis pore-water pressure is neglected (m=0) because almost all failures in the Chamoli earthquake occurred in dry conditions; thus, the third component is dropped from the equation.

Conducting GIS-based Newmark analysis requires characterization of expected regional earthquake ground motions. In this method the required ground motion descriptor is Arias Intensity (*Ia*). Expected mean Arias intensity can be estimated using the following equation (Wilson, 1993).

$$I_a = \frac{\pi}{2g}\int_0^T [a(t)]^2 dt \qquad (3)$$

Where, I_a is Arias intensity in units of velocity, g is the acceleration of Earth's gravity, a(t) is the ground acceleration as a function of time, and t is the total duration of the strong motion. It can also be calculated from the moment magnitude as per the following attenuation law (Wilson and Keefer, 1985):

$$\log I_a = M - 2\log\sqrt{R^2 + h^2} - 4.1 \qquad (4)$$

Where, I_a is Arias intensity, *M* is moment magnitude, R is closest distance to surface projection of fault rupture, and h is the focal depth of earthquake.

Newmark displacement, an index of seismic slope performance, can be estimated as a function of critical acceleration (dynamic slope stability) and Arias intensity (ground-shaking intensity). In the final step, Newmark displacement D_N is calculated based on the maps of critical acceleration and earthquake ground motion, as per the following equation:

$$\log D_N = 1.521 \log I_a - 1.993 \log a_c - 1.546 \qquad (5)$$

PARAMETER DERIVATION AND DATA ANALYSIS

The Chamoli earthquake of magnitude mb 6.3 / MS 6.6 USGS occurred on 29th march 1999 at 00:35:13.59 hours (local time) near the town of Chamoli in the state of Uttaranchal in northern India. The pre and post event satellite data of IRS-1C/1D PAN (26 March 1999 and 05 April 1999) and LISS-III (26 and 30 March 1999) were georeferenced and digitally enhanced. A comparison of pre and post earthquake data images reveals about 57 new landslides of various dimensions in and around the epicentre region (Chamoli, Ghingran and Gopeshwar). Similar visual assessment of satellite images to map new and reactivated landslides has been reported by Ravindran and Phillip (2002). The earthquake has reactivated old landslides mainly along Alaknanda, Birahi Ganga and Garur Ganga (Fig. 4).

IRS PAN images acquired before and after the earthquake were used for change detection analysis using synthetic colour composites, where in the post event image was assigned to red channel and pre event image was repeated on blue and green channels. Changes related to ground deformation associated with seismically induced landslide were highlighted in red colour. Similar attempts have also been made by earlier workers in highlighting surface changes due to earthquakes (Champati ray et al., 2001; and Saraf, 1998). Additionally,

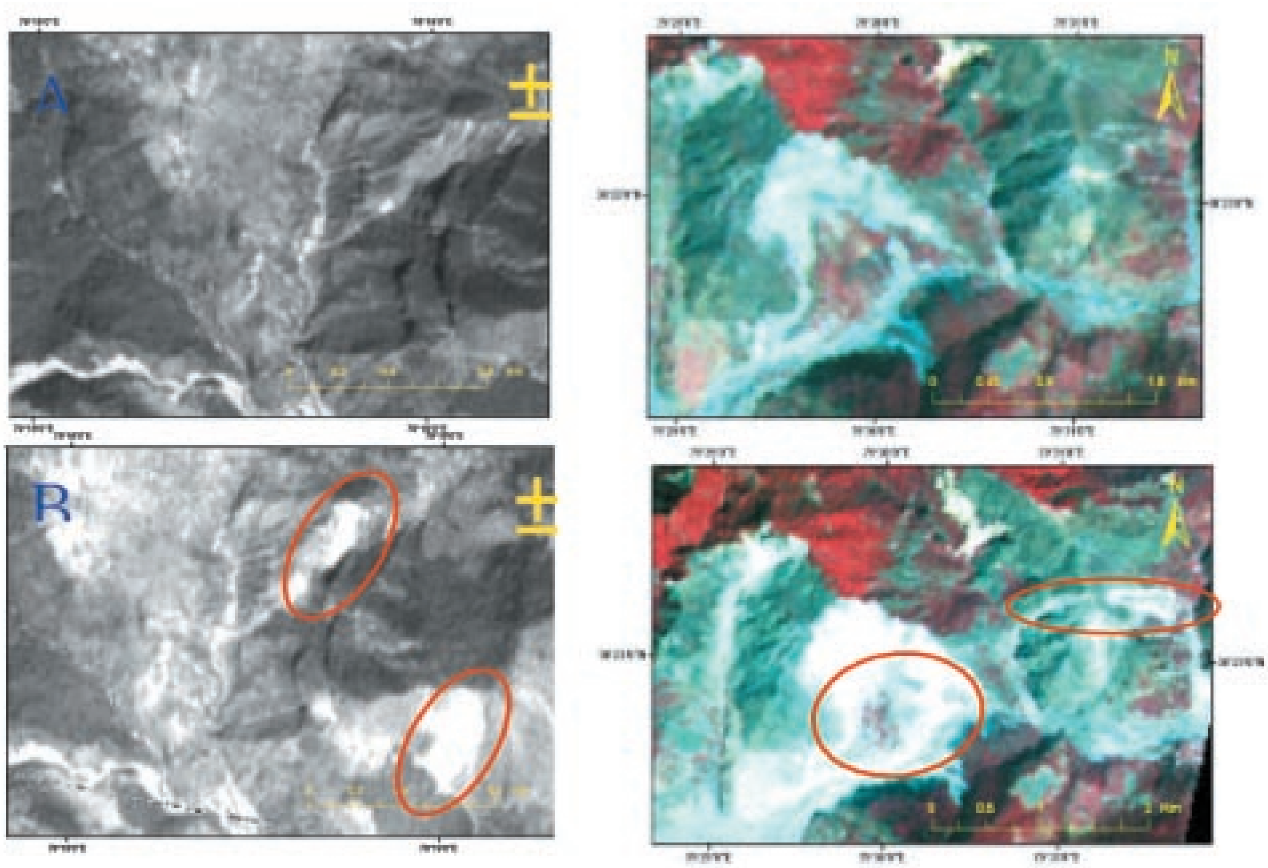

Fig. 4. Satellite images (IRS-1C-PAN and LISS-III) acquired before and after earthquake show a) fresh rock fall in quartzite near Gopeshwar, and b)reactivation of old landslides near Gauna Tal.

thresholding was applied to unimodal histogram of post and pre difference image. The threshold point is selected at a pixel intensity value that maximizes the perpendicular distance between the line and the histogram distribution (Rosin, 2001). In spite of image comparison, synthetic colour composition and unimodal thresholding, the detection of landslide was not always possible in a straight forward manner. It was still necessary to consider contextual information on slope, shape, size and association to map new and reactivated landslides.

Identification of landslide was primarily based on spectral differences, morphologic features and contextual information. Morphologically defined lineaments, e.g. drainage lines or scarps were interpreted to be the traces of high angle faults in those places where a lineament displaces rock units at least along part of the lineament. Different litho units and surficial deposits were interpreted based on available literature and satellite data products. A detailed lithological map of the study area has been generated on 1:25000 scale and geotechnical property of the rock and soil (cohesion, angle of friction and unit weight) were obtained from triaxial test of representative samples from different litho units. Slope gradient has been derived from the DEM generated from IRS-1C Stereo pair. Seismic parameters were taken from data provided by the United States Geological Survey (USGS) and IMD. USGS. located this moderate magnitude earthquake (M_b=6.3, M_s=6.6, M_w=6.4, M_o=5.2*10^{18}) at 30^{0}.49' N, 79^{0}.29' E at 12 km depth.

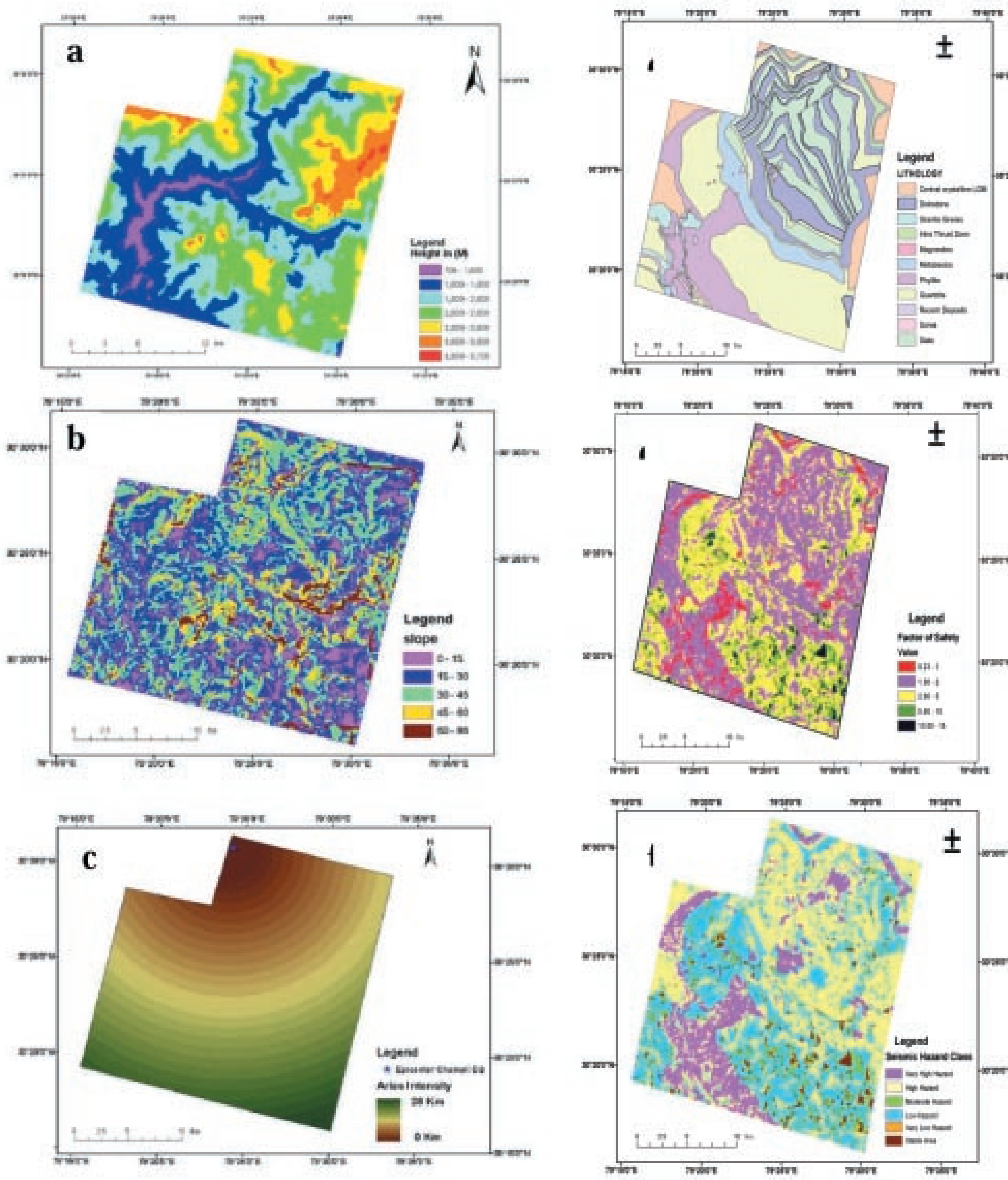

Figure 5: a) DEM generated from IRS-1C Stereo pair, b) Slope map, c) Lithological map, d) Distance buffer from epicenter of Chamoli earthquake, e) Factor of safety map, f) Seismic Landslide Hazard Zonation Map.

A raster database is organized in Arc GIS and static factor of safety was calculated as per eq. 2. The critical acceleration (a_c) is calculated by combining the factor of safety grid with slope grid to yield the critical acceleration grid which represents seismic landslide susceptibility. Arias intensity is calculated based on moment magnitude distance to epicenter and focal depth as per eq. 4. Newmark displacement has been estimated based on empirical relation combining the critical acceleration and shaking intensity values from the Chamoli earthquake (eq. 5). The modelled displacement is then compared with the inventory of landslides triggered by the Chamoli earthquake and it was observed that 80 % of the area where landslides were triggered due to earthquake was falling in very high to high hazard zone derived from Newmark displacement map.

RESULTS AND DISCUSSION

The study reveals that pre and post earthquake event IIRS-LISS-III and PAN satellite data products provide information on changes related to seismicity induced landslides using various change detection techniques. It is possible to map landslides triggered by earthquake except for very small slides and slides in shallow region. Orthorectification is highly essential for high positional accuracy in this rugged terrain. Although an integrated surficial geological map has been used for parameter characterization by analyzing representative field samples, it would be better to have actual angle of friction, on-site cohesion and unit weight for different rock types. Additionally, it was not possible to map thin layers of unconsolidated material on gentle to steep slopes which often fails during earthquakes.

In Newmark method, displacement depends on the critical acceleration, which, in turn, depends on the static factor of safety. Therefore, a landslide at or very near static equilibrium should have a very low critical acceleration (theoretically, $a_c = 0$ if $FS = 1$) and thus should undergo large displacements virtually in any earthquake. Predicted Newmark displacements do not necessarily correspond directly to measurable slope movements in the field; rather, modelled displacements provide an index to correlate with field performance. For the Newmark method to be useful in a predictive sense, modelled displacements must be quantitatively correlated with field observation. Therefore, with all above limitations, this method can still be used to study slope response in the event of an earthquake.

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HIGH RESOLUTION IRS DATA FOR DISASTER MONITORING AND ITS MANAGEMENT PLANNING IN HIMALAYAN MOUNTAINS

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1. INTRODUCTION

The Himalayan belt is geologically very young and complex. The rugged topography, in combination with commonly occurring earthquake/other natural hazards and occasional high intensity rainfall, areas of weak earth material and complex geological structures contributes to significant mountain hazards. In the wake of these hazards the Himalayan region is leading towards degradation. The occurrences of various types of landslides/mass movement, depleting spring sources etc. are a few examples of these changes. The frequency of landslides in the Himalayan terrain varies from area to area depending on the underlying structures, physiographic settings and anthropogenic changes taking place. Monsoon (mid-June - mid-September) is the time when landslides take place most frequently, as water is an important catalyst for initiation of landslides. During the three months of monsoon, heavy downpour accelerates many large and small landslides, paralyzing normal life, and all transport and communication network. Okhimath and Uttarkashi incidents are a few examples of such landslides, triggered during rainy season, causing severe loss to life, property and other resources of the area (Kimothi et al 1999, 2005). This not new in Uttaranchal hills (Joshi, 1997, Joshi and Maikhuri, 1997, Joshi et al 2001, Kimothi et al. 1999, 2005). Similar examples have been recorded from other parts of the Indian Himalaya. Occurrence of other disasters at different times in various parts of Uttaranchal and their cumulative effect also aggravates landslides and associated activities (Kimothi et al, 2002, Joshi et al, 2003 and Naithani et al, 2004). Therefore, the whole Indian Himalayan belt requires an extensive in-depth study for the identification of potential zones for landslides and associated phenomena. Potential zones have already been identified by various workers using hazard zonation studies in some of the areas of Uttaranchal Himalaya. But emphasis on risk and vulnerability of such areas for measures taken to cope up in high to very high hazard zones has not been undertaken. The high resolution IRS data could be an important tool to carry out in-depth study for formulating disaster mitigation/ management plans for the safety of dwellers staying in adjacent vulnerable areas. Present study was carried out in Okhimath and Uttarkashi landslide-effected areas of Uttaranchal State using high resolution IRS data.

2. DESCRIPTION OF THE STUDY AREA

Two locations, affected by huge landslide in Garhwal Himalaya (Uttaranchal, Fig 1), were taken up for present study i.e. Okhimath, district Rudrapryag (Lat. 30^0 31'- 30^0 38' and Long. 78^0 00'- 78^0 26' E) and Uttarkashi in district Uttarkashi (Lat. 30^0 31'- 30^0 38' and Long. 79^0 02'- 79^0 10' E) in August, 1998 and September, 2003, respectively. Both the areas represent a range of altitude, land cover, topography, badly effected population and also having mythological importance. The causative factors of occurrence of landslides in the study area seem to be similar in both the localities. The climate of this region is mainly governed by monsoon. Rainy season is between mid-June to mid-September and receives > 75

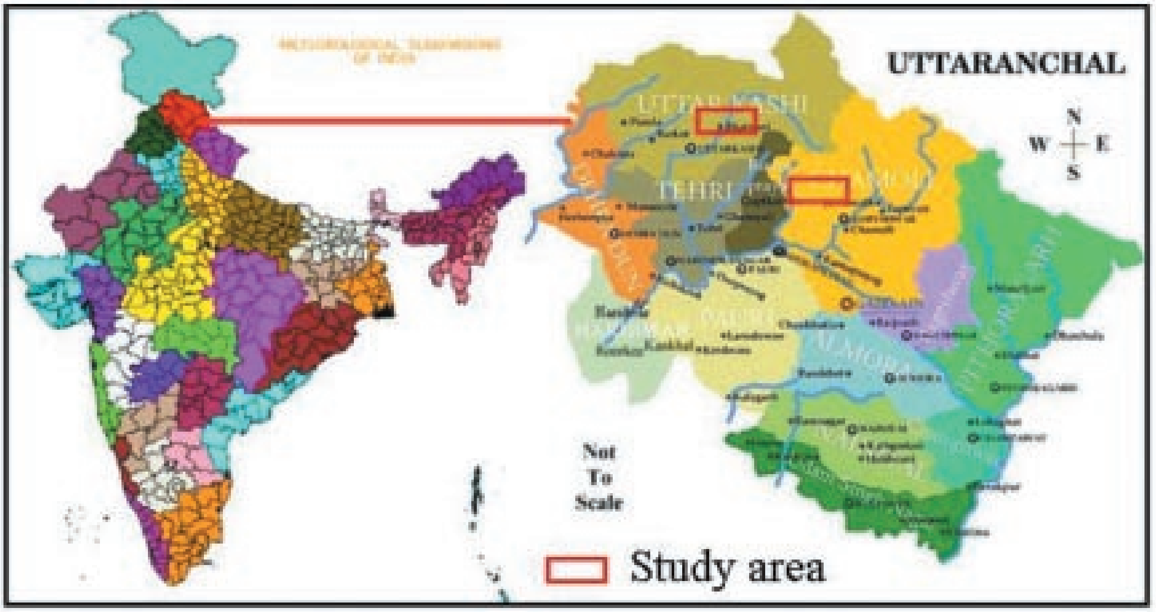


Fig. 1 Study area

percent of rainfall during this period. The mean annual rainfall is about 2000 mm. In general, humidity in the air is found throughout the year causing moistening and weathering of rocks under day and night temperature rhythm. Forests are the major support system for stabilization of watersheds, recharging of natural spring/streams, providing fuel, fodder, timber, grazing and minor timber produce etc. to the dwellers of the area. The incidence of forest fire is a regular phenomenon.

2.1 Geology of the Area

Okhimath area lies in the Central Crystalline zone with high grade metamorphic rocks like granite gneiss, sericite schist, micaceous schist, migmatite etc. These high grade metamorphic rocks with prominent foliage and flow structures along with multiple joints have been compressed due to crustal shortening which has been estimated to be around 69 per cent due to southward migration of Vaikirta, Jutogh and Budhakedar thrusts, which together constitute Main Central Thrust (MCT) in this region (Kimothi et al. 1999, Joshi et al. 2001). The crustal shortening suggests that the rocks are under high compressive stress.

Uttarkashi area lies in the Lesser Himalayan zone and mainly covered by the rocks of the Garhwal Group. The low grade sedimentaries of inner Lesser Himalaya lie between the Main Central Thrust (MCT) and North Almora Thrust (Dharasu Thrust) in the area. The lithology of the underlying zone is mainly the sedimentary sequence (Garhwal Group) mostly constituting quartzite, metavolcanics, limestone and phyllites. These are tectonically overlain by crystalline rocks largely granite gneiss, variants of mica schist and granite intercalated with metabasics forming the Central Crystallines. The general attitude of the rocks is WNW-ESE dipping due NNE at moderate angle with oblique as well as parallel relationships with slope facets. The rocks exposed in the area are highly fractured, jointed and moderately weathered. The relationship of these joints with the slope orientations and regional bedding foliations shows that they play a major role in the slope failures. Further seismic and high rainfall conditions of the area make this a vulnerable zone for mass movements. In general, the rocks of both the areas are inherently sensitive to mass movement under the influence of external forces e.g. rainfall slope modification etc.

3. METHODOLOGY AND DATA USED

Base map of the study areas was prepared using Survey of India toposheets. The other information related to damage etc were collected from the respective district administrations. Available published maps on geology, lineament, hazard zonation, geomorphology, land use etc. were also utilized for in-depth study. After preparing the maps and generating information, extensive field surveys/ground truth survey were conducted in both the areas. Local people were interviewed about various disasters, their views and damage caused in the area. For Okhimath area remote sensing data analysis (pre and post damage period) was carried out using visual analysis of IRS 1A (LISS II FCC) and IRS-1D (LISS III FCC) on 1:50,000 scale and IRS-IC/1D (PAN) photographic prints at 1:25,000 scale. In order to assess the impact of the calamity on the terrain, pre-damage (April, 1998) and post-damage (October, 1998), IRS LISS III and PAN data. Digital datasets of two different dates of IRS -1D (PAN & LISS III, March 30, 1999) and IRS–P6 LISS-IV (May 05. 2004), were georeferenced using an image – image rectification technique in ERDAS Imagine Image processing Software. LISS III and PAN digital data (March 30, 1999) were merged using principal component analysis based image fusion technique. This data set has been chosen for comparison purposes with multispectral LISS-IV data, Digital change detection was carried out by computing the difference brightness values between IRS PAN (March 30, 1999 pre-disaster) and LISS-IV band 3 (05 May, 2004 post disaster) images. Since the IRS-PAN sensors provide only one band Information, the post disaster scene is therefore kept in the red channel (band 2 of LISS-IV). Thus the change difference file showing the changes brought out highlighting change image showing perceived changes in the area due to landslides etc. was generated with white tone-depicting change in terms of reflectance between two dates, and black depicting no change. Methodology used for the present study is shown in a flow chart (Fig. 2).

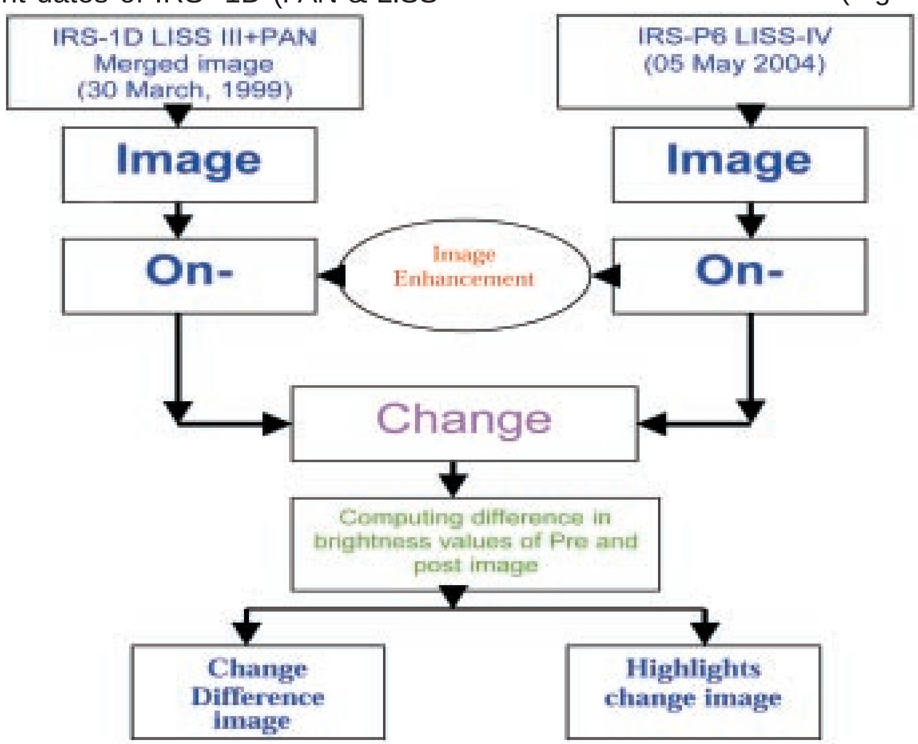


Fig. 2

3. RESULTS AND DISCUSSION

3.1 Mapping of Landslides and Monitoring

Okhimath and Uttarkashi landslides occurred in August, 1998 and September, 2003 respectively. Okhimath landslide caused huge loss to life and property, while in Uttarkashi landslide only property was damaged. The scars of earlier landslides existed in both sites as informed by the local people, which was confirmed later using IRS high resolution data. To understand the phenomena/process of long term and short term damage, two broad time frame datasets of pre and post damage period i.e. (i) between 1988 to April 1998 (pre damage long term) (ii) between April 1998 to October 1998 (pre and post short term) have been analyzed for monitoring active and old landslides (Fig. 3). April 1998, IRS LISS III/PAN (pre damage) data has been as a baseline data for assessing the extent of landslide occurring in the area as working references for delineating active landslides magnitude of the area effect by the landslide during August 1998. Similarly, 1988 data were analyzed to assess the old landslide scars. Temporal satellite data supported with historical records has indicated the presence of old landslides at many places. Some of them are 45-50 years old. These old landslides are under the process of stabilization by natural growth of alder forest (*Alnus nepalensis*). As seen on the pre landslide LISS III/PAN data. majority of them got activated during 1998 incident.

IRS ID PAN DATA OF OKHIMATH (UTTARANCHAL) AREA SHOWING LANDSLIDES

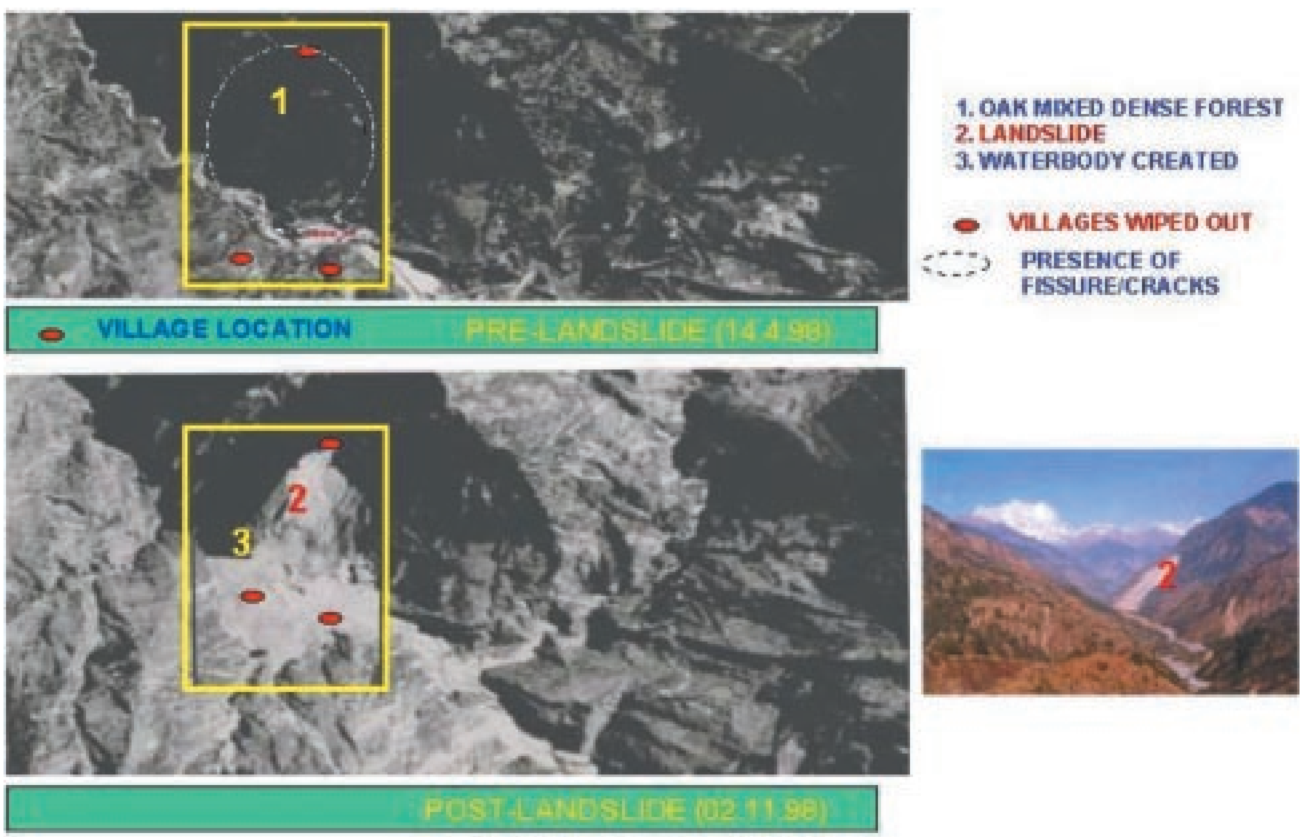
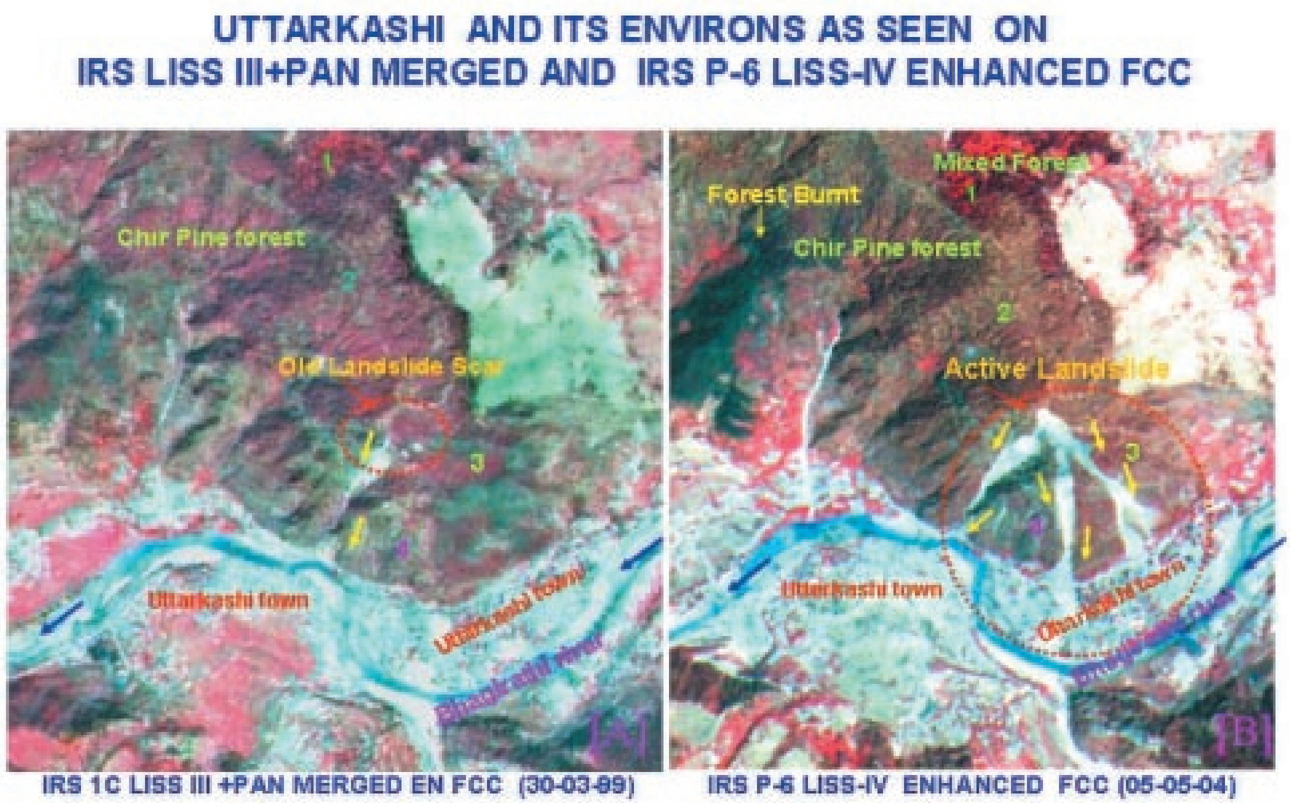


Figure 3 IRS: -1D PAN data of Okhimath area showing presence of fissures/cracks in pre-landslide image (14th April 1998) and active landslide and damage caused in post-landslide image (2nd November 1998).

Geotechnical setting of these areas has demonstrated that the terrain is quite sensitive to various natural processes. The inherent fragility is always there due to its proximity to local and regional structures and seismically active MCT. There is no reliable estimate to prove that 1991 Uttarkashi earthquake shattered the local lithology of both the area. However, according to the local people, many new fissures and fracture developed in and around these areas. Some fissures are also seen on 1998 PAN data in Okhimath area, which confirm the observation of the villagers. Further Uttarkashi area fissures/fractures developed by the earthquake of 1991 might have been influenced by Chamoli earthquake of 1999. Earlier studies in Uttarkashi area for hazard zonation (Anonymous, 2001) marked the area as high hazard zone. Tambakhani landslide adjacent to present slide was already active for last 12-13 years. To understand the phenomena/process of Uttarkashi landslides and its impact, IRS 1D PAN & PAN merged with LISS III of March 1999 and IRS-P 6 LISS-IV of May 2004 have been analyzed. March 1999 IRS 1D LISS III/PAN image has been used as baseline data for assessing the extent of landslides, working reference for delineating the active landslides and extent of the area affected by the landslides (Fig. 4). The landslides scar (old and active), debris flow track and depositional debris material and damage caused by landslide in Uttarkashi town (buildings, road, communication network, forest vegetation) have been easily identified on high resolution PAN and LISS–IV images based on tone, texture, pattern, shape and location of the features (Fig. 4)



[A] [B]

Fig. 4.[A] PAN merged with LISS-III enhanced FCC (30 March 1999) showing old landslide, debris flow and vegetation degradation (B) IRS-P6 LISS-IV enhanced FCC showing active landslide, debris flow, forest burnt area and impact area very clearly.

The IRS-1D PAN and LISS III & PAN merged image of 30 March, 1999 depicts an old landslide scar in Varunavat Parvat (80 m wide) near Uttarkashi town at the height of 350 m above the road level altitude This landslide is locally named as Tambakhani landslide and since last 12-13 years is causing continuous blockade of Uttarkashi Road especially during monsoon season. On the western side of the slopes, just 10-20 m away from the old landslide, two small new scars (white tone) in the open forest of Chir Pine were observed on IRS-PAN merged with LISS III (1999) image (Fig. 4). As shown on the LISS-IV enhanced FCC, the landslide is mainly divided into two parts on the western side of the Varunavat Parvat i.e., mass of the landslide at the top and the slided debris. The latter gets further divided into two directions as the material was sliding downward continuously for more than one month. Due to continuous falling of rock and other debris material, two old gullies widened excessively and were full of dust and smoke Similar mechanism was observed in Tambakhani area. As seen on IRS LISS-IV image debris flow track has widened the pre-existing drainage channel with huge quantity of detached rock fragments, boulders, soil etc accumulated on road and nearby residential areas. Accumulation of such debris on road not only causes traffic hindrances but could block the river Bhagirathi (Ganga) in future in Tambakhani side. As a result of landslides (24 September, 2003), enormous amount of debris was released from the Varunavat Parvat, which has caused damage to multistoreyed buildings, shops, parking place, National Highway, communication network etc of Uttarkashi town and loss of vegetation cover of the Varunavat Parvat.

Comparison of IRS 1D PAN & LISS III merged with PAN (1999) and recent IRS – P6 LISS IV (2004) enhanced FCC has pointed towards the fact that the presence of old landslide (Tambakhani) and two nearby small new scars on western slopes in open Chir Pine forest of Varunavat Parvat indicates the pre-existing weak zone. This is one of the main reason for activation of September 24, 2003 landslides from the Varunavat Parvat on the top edge of the Uttarkashi town. Vegetation on Varunavat Parvat is dominated by Chir pine forest of open and degraded categories. Moreover, frequent forest fires in the pine forest as seen on the IRS-LISS-IV image coupled with thin soil cover and near absence of undergrowth have resulted in creeping of soil during the calamity.

3.2 Causes of Landslide

It has been observed that natural tectonic processes and biotic pressure in the area are contributing to triggering of Uttarkashi landslides. The first and foremost cause of both the landslide is Uttarkashi earthquake 1991, Chamoli earthquake 1999 and their cumulative effect on its fragile geology. The local people reported that the cracks have developed above the crown of Okhimath and Uttarkashi landslides after the earthquake of 1991. The widening of these cracks was being observed by the locals. This widening was a matter of discussion among locals. In case of Uttarkashi landslide to avoid the overland flow of rainfall in the cracks, an unlined catch water drain was constructed just above the present crown in year 2002. Good rainfall has been recorded during the rainy season in both affected areas. Local people informed that before the triggering of the landslide there were good rains and probably a good amount of water percolated along the cracks. In the meanwhile a heavy lightning on the day of occurrence of landslide has also been reported by the locals, probably causing widening of cracks, which supported more overland flow to get into the cracks and subsequent increase in pore water pressure, decreasing the shear strength of the material and finally triggering the slide

4. CONCLUSIONS

Landslide and allied phenomena is a common feature in Himalayan region. The loss of life, property and environment degradation is associated with the occurrence of landslides in some way or the other. In many parts of the Himalaya landslide hazard zonation has been carried out and various potential areas have been marked. Many of the important town/villages fall in such zones. Already identified areas for landslide vulnerability could encounter disaster in future. In the present study it was observed that both the areas having pre-existing fracture/fissures in the zones of occurrence and the area also demarked as hazard potential zone. The study carried out in Okhimath and Uttarkashi area has successfully demonstrated that high resolution multispectral data can prove to be a useful tool to map landslide, debris flow and associated land cover/land use changes accurately and speedily at micro-planning level in the inaccessible mountainous terrains, where we have a limitation of data accessibility during disaster. If studies with the help of high resolution IRS data are done in advance then at least life and some valuable property of several dwellers could be saved. Therefore, it is suggested that studies using recent high resolution remote sensing data in conjunction with geographical information system should be carried out in various parts of the Himalaya specially the areas marked as high hazard or the areas having some information about the pre-existing fissures. Such studies will help in identification of potential/sensitive zones, probable occurrence of landsides and plan strategies for disaster reduction. The safe areas for rehabilitation can also be suggested with the help of such studies.

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HONOURS FOR MEMBERS

Shri Shashikant A. Sharma, Scientist, Geo-Informatics and Database Division, Geo-Informatics and Techniques Development Group, Space Applications Centre (ISRO), Ahmedabad has been awarded Indian National Geospatial Award - 2006 by Indian Society of Remote Sensing during International Symposium (ISPRS) on Geospatial Databases for Sustainable Development (Sept 27 - 30, 2006) at Goa, India, in recognition of his significant contribution in developmental work on geospatial utility software for cost effective e-governance.

He was under deputation to Bhaskaracharya Institute for Space Applications and Geoinformatics (BISAG), Gandhinagar, Gujarat from June 2000 to March 2006.

Earlier, he was awarded “Vikram Sarabhai Award in Information Technology 2001-2002” by the Department of Science and Technology, Govt. of Gujarat for his developmental work on low-cost utility software for Remote Sensing & GIS users.

Shri K.R. Manjunath, Agro-Ecosystem and Management Division, Agriculture, Forestry and Environment Group, Space Applications Centre (ISRO), Ahmedabad has been awarded P.R. Pisharoty Memorial Award - 2006 by Indian Society of Remote Sensing during International Symposium (ISPRS) on Geospatial Databases for Sustainable Development (Sept 27 - 30, 2006) at Goa, India, in recognition of his significant research contribution in newer areas of applications of remote sensing in agriculture.

FORTHCOMING EVENTS

Duration	Venue	Title	More Info.
Oct. 05-07-2006	Hyderabad	1st International Indian Geography Congress	www.osmania.ac.in
Nov. 09-11-2006	Bangalore	5th Congress of Asian Federation on IT in Agriculture	afita_2006@yahoo.com
Nov. 10-12-2006	Bihar	Environment & Regional Development	gg_raja@yahoo.com
Nov. 20-21-2006	Hyderabad	GIS & GPS Applications with Special Reference to Irrigation Projects	hyd2_ieiapsc@sancharnet.in
Nov. 23-25-2006	New Delhi	26th INCA International Congress on 'Cartography - Expanding Horizons'	siva_k@nic.in
Dec. 06-08-2006	Trivandrum	b_GIS@India	www.gisesociety.org
Jan. 18-19-2007	New Delhi	2nd ESRI Asia-Pacific Users Conference	www.esriindia.com
Jan. 22-25-2007	Hyderabad	Map World Forum	www.mapworldforum.org

NATIONAL GEOMATICS AWARDS

Indian Society of Geomatics has instituted two National Geomatics Awards to be given each year a) for original and significant contribution, b) for innovative application(s) in the field of Geomatics. Each award comprises a medal, a citation and a sum of Rs. 25,000

The guidelines for the award are as under

❖ Areas of contribution considered for the award

1. Geographical Information System
2. Global Positioning System
3. Photogrammetry
4. Digital Cartography

❖ Eligibility

Any citizen of India engaged in scientific work in any of the above-mentioned areas of research is eligible for the award.

- The awards are to be given for the work largely carried out in India.
- First award will be given for original contribution in the field of Geomatics supported by publications in a refereed journal of repute.

- Second award will be given for carrying out innovative application(s)
- The contribution for the first award should have been accepted by peers through citation of the work.
- Work based on the applications of existing technologies will not be considered for the first award.
- The work should have made impact on the overall development of Geomatics

❖ How to Send Nomination

Nominations should be sent in the prescribed format, completed in all aspects to the Secretary, Indian Society of Geomatics, Space Applications Centre Campus, Ahmedabad 380 015 by August 31, 2007.

Nominations should be signed by two Life Members of the Society and sent by Registered / Speed Post.

❖ Selection Process

An expert committee, consisting of at least three members, constituted by the Executive Council of the Indian Society of Geomatics, will scrutinize the nominations and recommend the awardees' names to the Executive Council. The Council will decide on the award based on the recommendations.

FORMAT FOR NOMINATION FOR NATIONAL GEOMATICS AWARDS

1. Name of the Candidate:
2. Present Position:
3. Positions held earlier (chronological order):
4. Academic qualifications (Bachelor's degree onwards):
5. Names of at least three Indian Scientists / Technologist in the area as possible referees*:
6. Brief write up on the work (500 words) for which award is claimed:
7. Publication(s) on the above work (reprint(s) to be enclosed):
8. List of other publications of the candidate:
9. Citation of the work for which award is claimed:
10. Impact of the work (for which award is claimed) on the development in the field of Geomatics (500 words):
11. Whether the work has already won any award? If so, give details:

The Applications in the above format (five copies) should be submitted (by Registered Post or Speed Post) to The Secretary, Indian Society of Geomatics, Space Applications Centre Campus, Ahmedabad 380 015 so as to reach by August 31, 2007.

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* ISG is, however, not bound to accept these names and can refer the nomination to other experts/peers.

FROM ISG SECRETARIAT

i) Change of Address of Members

Members are kindly requested to inform us about any change in mailing address and also send us current email address to update our database.

ii) National Geomatics Awards

The details of these awards were announced in ISG Newsletter of March-June 2006. The members are requested to send their applications for awards for the year 2005-06, if they have any outstanding contributions in the field of Geomatics.

iii) Chapter Activities and related issues

a) Active Chapter of Year Award (2005-06)

Each chapter Chairman/Secretary is requested to send the applications for this award in the prescribed format to the President/Secretary, ISG. The prescribed format for this award is available on ISG website.

b) Mandatory Activities:

Chapter Chairmen/Secretaries are requested to celebrate mandatory activities announced in the ISG Newsletter of March-June 2006 and send the reports for publication in the ISG Newsletter.

c) Chapter Reports and Audit Statements

The chapter Chairman/Secretary are requested to send the report on the activities of the chapter during FY 2006-2007 for publication in the ISG newsletter. They are also requested to get their accounts audited by end of May-2007 and send to ISG HQ to include in the audited report of the Society.

ISG FELLOWS

1) Dr. A.K.S. Gopalan, HYDERABAD
2) Dr. George Joseph, AHMEDABAD
3) Shri Pramod P. Kale, PUNE

ISG - PATRON MEMBERS

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P-1	Director, Space Applications Centre (ISRO), Jodhpur Tekra, AHMEDABAD 380 015
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P-4 Commissioner, land Records & Settlements Office, MP, GWALIOR 474 007

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JOURNAL OF GEOMATICS

Indian Society of Geomatics is launching a peer-reviewed journal named ‘Journal of Geomatics’ with effect from January 2007. It will be a six-monthly publication to begin with. If there is enough demand, its frequency will be increased. All members are requested to use the opportunity of submitting articles for publishing in the Journal. The guidelines for authors have been put on ISG web site: http://www.isgindia.org

INDIAN SOCIETY OF GEOMATICS (ISG)

(www.isgindia.org)

MEMBERSHIP APPLICATION FORM

To: **The Secretary Indian Society of Geomatics**
Building No. 40, Room No. 04,
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.

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Place: Signature

1. Name: ______________________________
2. Address: ______________________________
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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.