ADDRESS OF WELCOME
By
ENGR. HUSNAIN AHMAD
PRESIDENT
PAKISTAN ENGINEERING CONGRESS
AT
WORLD ENVIRONMENT DAY – JUNE 2007

AT

"MASHHADI HALL" (4TH FLOOR)
OF CONGRESS BUILDING

Honourable Chief Guest, Dr. Anjum Amjad Sahiba, Minister for Environment Protection, Govt of Punjab, Dr. Anjum Jawaid Khan Sahib,
Attorney at Law, Member Law Commission, World Environment Union,
Distinguished Guests, Delegates, Members of Pakistan Engineering Congress

Assalam-o-Alaikum

I take this opportunity on behalf of Pakistan Engineering Congress in General and on my own behalf in particular to welcome you all, to this gathering, for ceremonizing "World Environment Day",

I also thank the right honourable Chief Guest & all of you for finding some time to attend this event of global significance.

I presume it to be my profound privilege to be with you & address this distinguished assembly of Engineers, environmentalists as well as all those who are deeply concerned with protection and conservation of the environment.

Ladies & Gentlemen:

Environment Protection and conservations development programme in Pakistan draws its inspiration from Stockholm Convention of 1972 held under the aegis of United Nations. An Environment Protection Ordinance was enacted in 1983 as a starting followed by National Conservation Strategy (NCS) in 1992. The culmination came in 1997 with enactment of Pakistan Protection Environment Act specifying the National Environment Quality Control Standards as a Bench Mark.

In 2001, the Government of Pakistan formulated the "National Action Plan" to arrest the ever increasing degradation of environment mainly due to man made errors of Commission. However, its objective has remained very sad to point out a far cry due to individuals & institutional apathy.

Ladies and Gentlemen:

Over the past 200 years concentration of Greenhouse gases has been increasing in the atmosphere. The reason of this increase has been human intervention in turn due to increase in population, increase in per capita use of energy, greater use of energy resulting in enhanced burning of fossil fuels such as coal, oil and natural gas to generate electricity and to fuel industry and transport etc. Furthermore increase in population has resulted in large scale urbanization and this in turn has depleted forests. Increasing food demand has also adversely affected the forests, more land was cleared for human activity in the past 100 years than in all of prior human history. The loss of forests and wetlands, which absorbs and stores greenhouse gases and regulates the atmosphere, has further enhanced the greenhouse effect. And it is this enhanced greenhouse effect, which is causing Global Warming and Climate Change.

If significant climate change occurs it will have serious consequences globally According to research carried out at IISD and reported in 2004.

I Quote "Climate Change is one of the most significant sustainable development challenges facing the International Community"

Already, the average global temperature has increased by about 0.6c since 1960, rising of global temperature may trigger a series of changes within the overall global climate system.

The year 2005 was the hottest on record with average global surface temperature of 14.77 degrees Celsius. The month of January, April, September and October of 2005 were the hottest of those months on record, while March, June, and November were the second warmest ever.

Ladies and Gentlemen:

Presently the World at large & the economically emerging economies like Pakistan are faced with the ever increasing global warming i.e. rising temperatures due to vast emissions being generated on the Roads, Factories, Homes & Offices of the industrialised as well as the rapidly industrializing economies such as (Brazil, China, India) which overwhelmingly depend out on burning of Fossil Fuels for meeting the ever increasing energy demands.

The Probable Rise in average global temperature by the end of the century will range between 1.8 to 4.0 (or even by more than 5 degrees centigrade). That shall result in a minimum loss of 5 per cent of GDP actively. Studies have revealed that if Greenlands Ice Cap (which is presently melting where it is in contact with surrounding oceans) entirely melts, it will increase the Sea level by 7 meters.

The UN Intergovernmental Panel on Climate Change (IPCC) have predicted that Global Warming will cause widespread drought, Floods & hunger in Asia. Countries most hit hard will be China, India, Pakistan, Vietnam, Thailand, Bangladesh. Flooding in Coastal areas due to Ocean rise will displace around 60 million people in South Asia including from Pakistan, India, Sri Lanka, Bangladesh. Myanmar, 250 million people will be displaced in China alone.

Thailand with 3.6 million Farmer Families is presently earning valuable Foreign Exchange through export of 7.5 million tons of Rice annually will even not be able to feed its people what to talk of exporting it. Mass migration of population from the Coastal areas to urban Centres will give another crippling blow.

Ladies and Gentlemen:

Pakistan is an emerging economy & is most vulnerable to Climate Change especially because its economy is over whelmingly dependent on Agriculture. Agriculture not only feeds the teeming millions but is also the main source of export of crops such as Cotton; Rice etc Agriculture is also the backbone of Textile & Garments industry fetching valuable Foreign Exchange.

Ladies and Gentlemen:

The Country is entirely dependent for its water supply on dry land glaciers, the World's largest Reservoirs of Fresh Water outside the Polar Caps. A report by Intergovernmental Panel of experts shows that the Himalayan glaciers are receding at an alarming pace & may disappear altogether if the rise in temperatures is not contained.

The receding Arctic Sea Ice Cap is reducing the habitat of vulnerable Species and Jepordising Socio-Cultural life of its habitants.

Weather changes resulting from "Climate Change will drastically affect Water-Supply the World over. It will have disastrous effect for Africa in the shape of drought, desertification & food shortage.

Climate Changes cause irregular rainfall causing devastating floods resulting in destruction of Infrastructure of Billions of Rupees as well as loss of human lives, Livestock & standing crops. It is heartening to note that the Govt of Pakistan is fully aware & alive of this grave situation.

In 2005 "Prime Minister's" Committee on Climate Change was established with GCISC (Global Climate Impact Studies Centre established in 2002) as its headquarter. to over-see the impact analysis of Climate Change in the Country. But this is not enough because it is the duty of every single person to contribute in saving the environment before it is too late.

In this context

Few humble recommendations in putting brake on the profligate burning of Fossil Fuels.

- Switching on to alternate & renewable sources of energy, Solar Energy, Wind-Power, Bio-energy & geo-thermal energy and even nuclear energy.
- Massive campaign to plant trees. They can slow Climate Change by absorbing carbon-dioxide, as they grow Trees work as lungs, reduce soil erosion as well as feed industry & provide valuable products.
- Financial & Technical assistance equivalent of 1% of their GDP by wealthy industrialized countries sans strings to help the emerging economies of Asia & Africa adopt cleaner uses of energy & to significantly reduce the carbon emissions.

- Collective & decisive political will & a Financial & Civil partnership to slow down greenhouse effects / Climate Change.
- To embark on policies to protect the dry lands from turning into deserts.
- Destruction & safe disposal of dangerous goods, Garbage & Waste Materials. Banning of use of plastic bags & such like items.
- Holding Seminars, Workshops, Marches, meetings for creating awareness in the Public about Environmental issues as well as printing of Articles, Books on the relevant issues.

As I mentioned let's do something before it is too late.
I also have a small presentation ready and would seek your very attention to it

(Presentation)

Let us do something, let us pledge that we contribute our share to protect planet earth before it is too late, before our future generation start paying a heavy price, before wrath of nature catches us and irreversible degradation of the magnitude we saw in the presentation becomes a reality.

Thank you very much

Pakistan Paindabad

Engineering Options for Managing and Mitigating Climate Change

By

Safia Shafiq

1. Introduction

Climate change and climatic variability are considered to be among the most imminent global threats to life as we know it on planet Earth. The phenomenon refers to variations in our planet's global climate or regional climates over time. This change can be caused by natural processes internal to the climate system (e.g. changes in ocean circulation), natural external factors (e.g. changes in the intensity of sunlight) or by human activity that alters the composition of the atmosphere or brings about certain changes in land use systems.

Today, the term "climate change," especially when used with reference to environmental policy, generally refers to recent changes in climate, including the increase in average surface temperature which we have come to call global warming. The rate of increase of global temperatures recorded during the 20^{th} century is unprecedented. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), which was released in 2007, states with a high degree of confidence that human activities are predominantly responsible for this increase. The increase in global temperatures affects the climatic equilibrium of the planet and causes changes in precipitation patterns, storm intensity, occurrence of droughts etc. Higher temperatures also precipitate the melting of polar ice caps and glaciers, leading to a rise in sea levels.

2. Anthropogenic Factors Contributing to Climate Change

Anthropogenic factors contributing to climate change are in essence human actions that are responsible for bringing about changes in the climate. Since climate change has become a global problem, numerous theories regarding human influences on climate change have been argued. Currently, the major cause of global warming and the resultant climate change is considered to be the rising levels of greenhouse gases in the atmosphere, which are emitted from fossil fuel combustion, land use change and some industrial processes such as cement manufacture.

3. Current Trends and Future Projections of Global Climate

The Working Group I to the Fourth Assessment Report (2007) of the Intergovernmental Panel on Climate Change (IPCC) has reported that average global temperatures have increased by approximately 0.74^{o}C over the period of 1901 – 2005. This is a larger increase than the corresponding linear warming trend of 0.6^{o}C reported in IPCC's Third Assessment Report (2001). The Fourth Assessment Report also states that "eleven of the last twelve years (1995 – 2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850)". It further projects a

warming of about 0.2°C per decade for the next two decades for a range of SRES emission scenarios.

This century, with the projected levels of global warming, serious consequences for humans (and other life forms) seem to be in store. These include a rise of 18 to 59cm in global average sea levels, which will be caused by a continued melting of ice caps, glaciers and sea ice; major alterations in rainfall patterns; and an escalation in the number and intensity of tropical cyclones. Extreme weather events are also expected to become more frequent.

Geographical patterns with regards to climate change are however expected to remain the same. Warming is projected to be the greatest over land and at the highest northern latitudes and smallest over oceans. It is also projected that temperatures and precipitation in various regions of the world will undergo significant increases as well as decreases. The subsequent impacts on different socio-economic sectors for example water resources, agriculture, forestry, biodiversity, energy, health etc. will vary regionally.

Box 1 - Summary of Projections of Future Changes in Climate

- For the next 2 decades, a warming of about 0.2°C per decade is projected
- An increase in the acidification of oceans caused by rising levels of carbon dioxide in the atmosphere
- Shrinking snow cover and sea ice along with decreased permafrost
- Hot extremes, heat waves and heavy precipitation events are expected to become more frequent
- It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense
- A movement of extra-tropical storm tracks towards the poles, with consequent changes in wind, precipitation, and temperature patterns;
- Increases in amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions.
- A slowing of the Atlantic Ocean circulation.
- Past and future anthropogenic CARBON DIOXIDE emissions will continue to contribute to warming for more than a millennium (this is because of the time scales associated with the removal of this gas from the atmosphere)

Source: IPCC Fourth Assessment Report (2007)

4. Climate Change Impacts and their Management (Mitigation and Adaptation)

The latent costs of climate change are far-reaching, mainly for people living in the developing world. Due to the lengthy time scales attached to climatic processes and feedback, even if greenhouse gas levels were to be stabilized immediately, the increase in temperatures and sea levels is expected to continue for centuries. If, in 2100, greenhouse gas levels in the atmosphere are somehow stabilized, a warming of about 0.5°C would still be anticipated around 2200. In fact, just the thermal expansion of the oceans would result in a rise of 30 to 80 cm in global sea levels by 2300.

Hence it is equally important to prepare for the inevitable impacts of climate change as it is to reduce the emissions of greenhouse gases which are the main cause of global warming and subsequent climate change. Today, climate change challenges us with a two-tier problem; which is why the answer lies buried in a double strategy: mitigation and adaptation. Figure 1 describes the link between climate change and its impacts on

human and natural systems, and how the strategies of mitigation and adaptation are employed for addressing the impacts.

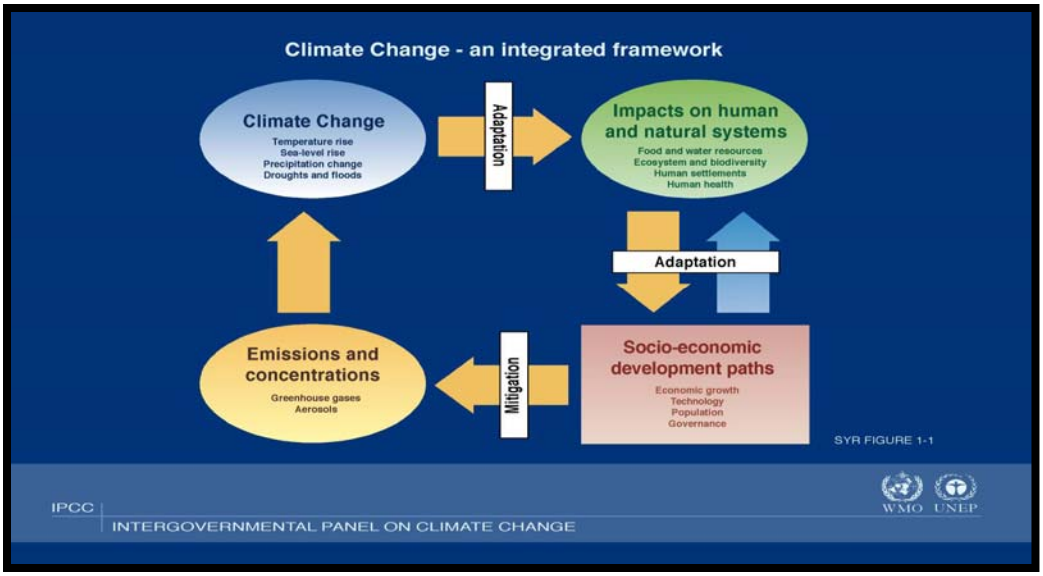


Figure 1 – The Integrated Framework of Climate Change

Mitigation refers to the approach that incorporates efforts to decelerate the process of climate change by decreasing the percentage of greenhouse gases in the atmosphere. It is imperative to initiate the reduction of greenhouse gas emissions immediately in order to control global warming and its consequences in the future. Mitigation is thus an essential point of action for the global community. At the international level, the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) addresses mitigation through a set of market based mechanisms/instruments involving both developed and developing countries.

Adaptation on the other hand refers to modification in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Even if mitigation efforts are successful, a certain level of climate change is inevitable during this century and beyond. Thus, we need to make a realistic assessment of the direct implications of the changes that we have already brought upon ourselves and adapt to them accordingly. This involves the development of strategies to minimize impacts on people and ecosystems by controlling their susceptibility to the effects of climate change. One example of an adaptation strategy is building seawalls and transferring buildings to higher ground levels while protecting communities against increased flooding due to storms.

The IPCC Working Group II that studies the aspect of impacts, adaptation and vulnerability in the context of climate change, believes that mitigation and adaptation should be complementing components of the control strategy for addressing climate change. Their report makes the following observations:

1. Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts;
2. Those with the least resources have the least capacity to adapt and are the most vulnerable; and
3. Adaptation, sustainable development and enhancement of equity can be mutually reinforcing.

5. Role of Engineers

Climate change affects our environment and challenges our ability to plan, design and construct infrastructure and systems that can protect people from harm and maintain acceptable standards of economic well being.

Engineering can play a major role in the processes of mitigation and adaptation by incorporating knowledge regarding climate change (and its impacts) in planning and product design. Furthermore, during the conception, design, manufacture, construction and operation of engineered facilities and products, engineers should take into consideration factors such as energy conservation and limitation of greenhouse gas emissions.

6. Engineering Options for Mitigation

As mentioned previously, mitigation is a strategy that incorporates efforts to decelerate the process of climate change by decreasing the percentage of greenhouse gases in the atmosphere. To most people, it may seem that the most important way to battle climate change is to develop strategies to adapt to the critical and far-reaching effects that are threatening us at this point in time. Some might even argue that mitigation is useless since it will take centuries to manifest its benefits, even though it will cost us a lot of time, money and concerted effort and cooperation at a global level.

However, if every country decides to push mitigation of greenhouse gases lower on the priority level, global climate trends will only accelerate - causing even more concern for the future. Furthermore, this is not a responsible position for any government to take. This is a matter of responsible governance and stewardship of the mother Earth, not just a problem that has to be solved based on the self interest of nations. Even though efforts aimed at mitigation may take centuries to affect climatic patterns, it is extremely important to adopt certain measures immediately so that global warming trends may be altered for the benefit of future generations. Furthermore, lowering the emissions of greenhouse gases in any area will lead to instant enhancements in the local environment and contribute to improved health and economic conditions that will be enjoyed by the present generation as well. The quality of air could improve, along with bringing health benefits reducing the occurrence of asthma and other respiratory diseases. The

opportunity cost of all these improvements would mean public funds being directed towards other beneficial practices.

Similarly, mitigation efforts could also result in significant economic benefits for the area. Sustainable building procedures would result in healthier interior environments, controlled energy use and a lessening in pollution. Also, if an efficient public transport system is introduced to lower green house gas production, costs might fall for families and the area would become less dependent on imported fuels.

All these improvements and advantages would manifest themselves in a few years or so, rather than in centuries and millennia. Thus, realistically speaking, mitigation strategies would most definitely contribute to improving the local environment and result in advantages that can be enjoyed in the present by us and by our children in the future.

With regard to mitigation some areas that engineers could contribute to include the following:

Energy Conservation and Efficiency

- Construction and urban infrastructure – efficient space & water heating, ventilation, energy efficient appliances, lighting, environmental design.
- Transportation – traffic engineering, public transportation systems, fuel efficient vehicles and hybrid cars, alternative fuelled vehicles (ethanol, hydrogen).
- Industry – energy efficient processes, waste reduction.

Energy Generation

- Clean coal technologies, combined cycle power plants.
- Diversification of fuels and switching to cleaner fuels, renewable sources of energy (wind power, hydro power, solar power, geothermal power etc.).
- Cogeneration (combined heat and power generation).

These options can be divided into the following steps to form a basis for effective mitigation strategies:

1. Reducing the level of energy use (per person)
2. Making the switch from carbon-based fossil fuels to alternative energy sources
3. Strategies involving carbon capture and storage
4. Geo-engineering procedures including carbon sequestration
5. Birth and population control, so as to lower demand for resources such as energy and land

7. Methods of Mitigation

Energy Conservation and Efficiency

The conservation of energy and its use in an efficient manner is imperative for reaping the utmost environmental benefits and usually results in substantial cost savings by the end user. Some of the most successful means of energy conservation include building insulation, fluorescent lighting, and public transportation, all of which by extension also contribute to the preservation of the environment.

By definition, the conservation of energy includes any practice that involves improving efficiency so as to achieve a higher useful output for the same level of energy consumption. This has numerous benefits, including an increase in human comfort, personal and national security, financial capital and environmental value. While direct consumers might want to practice conservation in order to cut down energy costs and promote environmental values, industrial users may just want to enjoy increased efficiency and maximized profits.

On a wider scale, energy conservation is also a significant part of energy policy. The problems associated with increasing the supply of energy would be curtailed if the demand itself was reduced. Thus, in a way, encouraging energy conservation is actually a step towards a more environment friendly alternative to increased energy production.

Urban Planning

Urban planning is also an important area with respect to energy use. In the years 1982 to 1997, the sum of land used for urban development by the USA rose to 47 percent even though the population only saw an increase of 17 percent. Inefficient urban planning practices have led to a rise in the cost of infrastructure along with an increase in the amount of energy required for transportation, buildings and community services.

A major problem that stems from the interconnection between energy and land use is the rigidity of the built environment in comparison to energy shifts. The supply of energy and its prices are extremely unpredictable and reliant on the ever changing economic and political circumstances. While shifts in energy are usually sudden and erratic, patterns in land development tend to be costly to change.

Recently, a clever approach to land use and planning is being adopted. These intelligent growth practices suggest the development of compact communities, varied options for transport, diverse land uses, and efficient practices to preserve green space. Not only do these programmes proffer environmental, economic, and personal benefits, they also operate to lower energy use and greenhouse gas levels.

Smarter growth methodologies including New Urbanism and Transit-Oriented Development aim to lessen traveled distances (specifically by private vehicles), promote public transit and present pedestrianism and cycling as viable alternatives. This can be accomplished by using medium-density, mixed-use land planning and concentrating houses around town centers and transport points.

Building Design

Emissions from housing are considerable, and energy efficiency practices geared towards countering these can be particularly effective. Hence construction technology should aim for low emission buildings for new construction, while the energy efficiency of existing buildings can be improved using insulation, outer window shades, multiple glazed gas-filled windows, appliances with high energy efficiency, and suitable building orientation.

Along with designing buildings that are more energy efficient, it is also a good idea to make use of light-colored, reflective materials in urban area land development, and plan

more tree plantation. This practice conserves energy as it cools buildings and lowers the urban heat island effect, in turn lessening our dependence on air conditioning.

Transport

In the battle against oil and increased carbon dioxide emissions, the development of recent technologies such as hydrogen fuelled cars and hybrid electric vehicles is a great step in the right direction. To further this cause, carbon dioxide emission standards could also be imposed on to standard vehicles so as to encourage further developments in technology and efficient vehicle sizing.

The use of bio-fuels such as bio-diesel also reduces emissions, especially when used with hybrids and Plugged-in Hybrid Electric Vehicles (PHEV). For electric cars, the emission problem can be further resolved if the electricity used is produced using green practices. Moreover, a move away from air travel and taking a train instead would also lower emissions significantly. In conjunction with urban planning, if areas were planned effectively so as to reduce distances and the urban sprawl, emissions from transportation would be effectively reduced.

Switching to Alternative Energy



Since the use of fossil fuels for energy production is the primary cause of global warming and climate change, switching to alternative and renewable energy sources forms a very important component of mitigation efforts. Currently there is a rapidly accelerating trend in developed countries, especially those in Europe, to increase the share of renewable energy in the energy mix. Alternate technologies such as hydro power are already in widespread use but the use of wind and solar power for energy production are being promoted. Research is being focused on making them cost effective and hence competitive with fossil fuel use. Other sources of renewable energy that hold potential but still require research to make them feasible options are geothermal and tidal energy.

Nuclear Energy

The issue of promoting nuclear power as a viable alternative to fossil fuel use is still being debated extensively internationally as well as within countries. Numerous studies cite comparisons of Life Cycle Analysis (LCA) of carbon dioxide emissions as proof to support the opinion that nuclear power is as good as – if not better – than renewable energy. When making an analysis, an important fact to remember is that most of the carbon dioxide produced comes from burning coal to create electricity (the most polluting form) for the uranium enrichment process. Now, if nuclear power plants opted to create this electricity, the carbon emission could be eliminated. Also, gas centrifuge technology has significantly decreased the amount of energy that is required for the enrichment

process. Simpler and safer plant designs promise to ensure longer lifetimes in the future, thus decreasing carbon emissions even more.

On the other hand the most dominant counter arguments offered are the long term availability of raw material for nuclear power generation, the safe disposal of nuclear waste, and the threat posed by the proliferation of nuclear technology in the current global political environment. Thus even though nuclear energy possesses the potential of solving our energy problems, the issues mentioned above need to be addressed before it can be considered a long term and sustainable solution.

Cleaner technologies and using less polluting fossil fuels

In view of the fact that the use of fossil fuels cannot be eliminated completely till the time viable and economically feasible alternative options are not developed, it is necessary that the least polluting technologies in terms of greenhouse gas production be employed when using fossil fuels. Several such technologies, particularly applicable to coal combustion, are now available and are being used worldwide. They basically aim to reduce greenhouse gas emissions at two stages. Firstly, the coal is cleaned of impurities and minerals before combustion so as to minimize harmful emissions, and secondly the emissions produced are captured after combustion instead of being released into the atmosphere. The captured emissions are either stored through various methods, or reintroduced into the combustion cycle and re-burned to make the recovery of carbon dioxide in the flue gas economically viable.

The use of less polluting fossil fuels such as natural gas for energy generation results in lower greenhouse gas emissions per energy unit gained as compared to oil, which is in turn better than coal. Statistically, natural gas combustion produces about 30 percent less carbon dioxide than oil, and a little less than 45 percent carbon dioxide than coal. However, although low in terms of carbon dioxide emissions, the production of NOx is an inherent problem in natural gas combustion. Nitrous oxide is a very potent greenhouse gas that has 310 times the global warming potential (GWP) of carbon dioxide. Hence available options need to be carefully evaluated for their overall feasibility before being adopted.

8. Engineering Options for Adaptation

As mentioned earlier, adaptation to climate change is a necessary strategy that is required to complement mitigation efforts. This is because, keeping the current trends and projections regarding climate change in mind, we need to be prepared for the inevitable fact that all climate change cannot be mitigated – even with the best and most efficient practices.

Through adoption of adaptation strategies, the negative effects of climatic changes can be reduced and the positive effects can be further enhanced. However, it is important to understand that adaptation entails costs, and is not the absolute solution for complete damage control.

To a certain extent, human and natural systems adapt to climatic changes on their own. Nevertheless, planned adaptation methodologies are essential to complement nature's response as more efficient options become available.

Some examples of options available to engineers for promoting adaptation in various sectors are listed below.

Construction

- Planning and designing structures to accommodate for changing weather patterns such as higher temperatures and precipitation, flooding etc.
- Developing appropriate practices for the operation and maintenance of new buildings.
- Designing and developing material more suitable to the altered climatic conditions.

Urban Planning and Infrastructure

- Adapting urban planning to altered conditions e.g. designing urban storm-water systems for higher rainfall intensity.
- Considering land use restrictions, specifically when it comes to flood plains, coastal shorelines and landslide-prone areas.

Water Sector

- Enhancing storage capacity for energy generation, irrigation and human consumption; adapting irrigation infrastructure to variations in water flow; design of coastal protection works.

Revising Strategies

- Revising codes (flood plain mapping, climate data and frequencies for hazard-prone areas) to cater to recent projections.

9. Methods of Adaptation

Examples of adaptation practices include building better flood defenses to protect against rising sea levels and altering patterns of land use so as to avoid vulnerable areas.

9.1 Adapting to Changes in Weather

Water Management

Agricultural Production

Agriculture, to be successfully practiced, greatly depends on the availability of irrigation water. Climatic changes result in modifications in rainfall patterns, runoff, evaporation rates, and soil moisture storage. Changes in both the amount and variability of rainfall can have dire consequences on crops. If there is too much moisture present during processes such as flowering, pollination and grain filling there are increased chances of crop failure or reduction in quality. High evaporation rates and increased transpiration can cause moisture stress, which will lead to an urgent need to develop crop varieties that have greater tolerance to drought.

Similarly, the cumulative demand for irrigation water is likely to increase in warmer climates, raising the competition for water between agricultural, industrial and urban users. To counter this better water management practices in all sectors will need to be adopted.

Urban Areas

Another critical adaptation strategy involves improving rainwater storage (unpaved gardens, domestic water butts etc.) and raising the capacity of storm-water systems (while also separating storm-water from black-water to prevent contamination) so as to prepare urban areas for severe storms.

Temperature

Weather control

In the past, many scientists have tried to control the weather using innovative solutions such as seeding clouds with chemicals to produce rain when required. Recently developments have seen investment in a new methodology which involves replicating the urban heat island effect, especially where areas are warmer than the countryside. This method increases precipitation by about 28 percent downwind from cities as compared to upwind. New weather control techniques are becoming increasingly more feasible and will become implementable in the timescale of a few decades.

Coastal Management

If steps are not taken towards necessary adaptation, the effects of global warming and rising sea levels would lead to the destruction of our coastal areas. Adaptation strategies related to coastal management entail more than just choosing a technical strategy to respond to rising sea levels (whether protective, accommodating or retreating). It is a complex process and there is no simple way out. Practices tend to be more effective when implemented alongside integrated coastal zone management, disaster mitigation programmes, urban planning, and other sustainable development strategies.

The capacity for adaptation for coastal management involves coastal resilience, which consists of numerous morphological, ecological and socioeconomic components. Improving resilience (and the technical, institutional, economic, and cultural capability to cope with effects) is extremely important when implementing any adaptive strategy.

9.2 Adapting to Changes in Ecosystems

With climatic changes in progress all ecosystems will be undergoing change, some more than others. Adaptation strategies will vary with the characteristics of the ecosystem in question. For the purpose of this paper, the example of glacier retreat, a significant issue in the context of Pakistan's Northern areas, has been presented.

The Retreat of Glaciers and Damming Glacial Lakes

Because of the retreat of glaciers, Glacial Lake Outburst Floods (GLOFs) threaten to become a concern of monumental proportions. GLOFs occur when glaciers retreat leaving behind lakes impounded by weak, terminal moraine dams. A failure in the

working of these dams can result in major property damage, injury and even deaths. Thus adaptation strategies need to be introduced where glacial lakes in danger of bursting can have their weak dams replaced with concretes ones, which could also assist in generating hydroelectric power.

10. Geo Engineering Strategies

Geo engineering strategies are defined as options that involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry.

Supporters of geo engineering are of the opinion that the goals set for mitigating global warming and climate change cannot be achieved by just improving energy efficiency and reducing the concentration of greenhouse gases in the atmosphere. There is a need to step outside of the box and look for innovative methods to solve the climate change problem. At the moment, there are many options being considered but most of them have been criticized as being very unlikely to work. Some have even been characterized as "crazy" by more conventional minds. However, in the interest of science and advancement, these options are definitely worth being evaluated, even if they are to be dismissed later for being impossible to implement.

Sequestering Carbon Dioxide - Carbon Capture and Storage (CCS)

Carbon sequestration is a term that represents a plan to mitigate climate change by reducing the amount of radiative forcing through capturing carbon dioxide (e.g. around large point sources like power plants) and storing it away instead of releasing it into the atmosphere. A number of ways to artificially capture and store carbon dioxide are being explored.

CCS technology is currently available for large emitters such as power plants. The captured carbon dioxide may be stored in deep geological formations, oceans or in the form of mineral carbonates. It can also be injected into depleted oil and gas fields with the added benefit of forcing out the residual oil or gas.

An example of a CCS project is the Norwegian oil and gas producer Statoil's Sleipner West field in the North Sea. The carbon dioxide present in the natural gas excavated at this gas field is separated and then injected beneath the sea bed for storage. The project stores about one million tons of carbon dioxide per year. However, this is a new technology and there are several concerns regarding its sustainability and long term impacts. One such concern in the case of deep ocean storage is the issue of ocean acidification, a problem that is already being exacerbated by the increased concentrations of carbon dioxide in the atmosphere.

Seeding Oceans with Iron

Nick-named the *Geritol* solution to the climate problem (after a tonic used to treat effects of blood lacking in iron), this form of carbon sequestration was originally proposed by the oceanographer John Martin. Studies show that seeding oceans with iron causes a rise in phytoplankton populations, hence extracting a greater percentage of carbon dioxide from the atmosphere.

While seeding iron sounds like a viable approach, opponents of the strategy believe that not only is fertilizing the ocean a risky idea, but that is also carries no promise of efficiency. One of the major concerns is the final destination of the carbon that is absorbed by the phytoplankton. If it was reabsorbed by the water, instead of being pulled down to the ocean floor and stored in a carbon sink, the original purpose would be completely negated. Researchers also opine that geo-engineering strategies could alter the natural environment immensely. If studied on the basis of damage that results from dumping nutrients in water bodies like lakes, it would be logical to assume that the same environmental damage could occur when seeding oceans with iron. Furthermore, massive increases in the phytoplankton population may lower the amount of oxygen in the atmosphere, possibly resulting in zones where the ocean would not be able to support any marine life.

Insolation Management/ Albedo Enhancement

Another geo engineering approach for mitigating the climate problem is rooted in the concept of Earth's albedo (reflectivity), and aims to alter it so as to reflect a greater amount of solar insolation back into space. Research has proven that even minor increases in the albedo have the potential of lowering the global temperature considerably. This approach has led to the birth of a number of innovative methods, including the release into the atmosphere of dust and sulfate particles; aerosol emissions to augment global dimming; cloud enhancement; setting up a gigantic mirror/ diffraction grating in space; and creating a Saturn-like ring of small particles. However, none of these options are currently beyond the experimental stages.

11. Conclusion

Climate change affects our environments, challenges our ability to plan, design and construct infrastructure and systems that can protect people from harm and maintain acceptable standards of economic well being. Engineering can play a significant role in mitigation and adaptation by incorporating knowledge of climate change and its impacts in planning and product design.

Engineers should also take into consideration the potential effects on climate during the conception, design, manufacture, construction and operation of engineered facilities and products. In this regard the application of basic principles of "green engineering" can help in greatly minimizing, if not completely averting adverse impacts. Engineers should ensure that all resource and energy inputs and outputs are as non-hazardous as possible, and that operations are designed to minimize energy and resource consumption. Furthermore, maximum effort should be made to ensure that all resource and energy inputs are predominantly renewable rather than depleting.

AN OVERVIEW OF GLACIER DEPLETION IN TIBETAN PLATEAU

By

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Abstract

Glaciers serve as a natural regulator of regional water supplies. Tibetan Plateau is the most concentrated glacier centre in the lower latitudes on earth with a total area of glaciers 104,850 Km². About 40,000 Km ² falls in India & Pakistan, rest of this largest glacier cover is in Himalayas covering 34,660 Km ², out of which Pakistan's share is 16933 Km². These glaciers are source of water for half of humanity and feed to rivers in Pakistan, India, China, Burma and Bangladesh**.** Glacier depletion, especially recent melting can affect agriculture, drinking water supplies, hydroelectric power, and ecological habitats. This can also have a more immediate impact on Pakistan's economy that depends mainly on water from glacier melt during March to June. The paper presents an overview of glaciers depletion in Tibetan Plateau due to rise in global temperature, and its impact on Pakistan's water resources. Mean annual temperature around Skardu through the century has increased by 1.4˚C. Batura, one of the largest glaciers outside the polar region, has lost its glaciated area to 81 sq km as compared to 1992 and 2000 satellite images.

Introduction

Fresh water is a finite and vulnerable resource, essential for sustaining life and development. The water resource in Himalaya is partly stored as glacier ice, i.e. capital water. There are approximately 70 large glaciers in Himalaya covering about 166.12 km^2 or 17 % of the mountain area. This is the largest body of ice outside the Polar caps, and forms a unique water reservoir. The glaciers supply 303.6 million cubic feet every year to Asian rivers, including the Yangtze and Yellow rivers in China, the Ganga in India, the Indus in Pakistan, the Brahmaputra in Bangladesh and Burma's Irrawaddy. In fact these rivers are lifelines of millions of people (Ole R. Vetaas).

Table: 1 Showing Glacier Distribution in Countries of Tibetan Plateau (Yongping SHEN)

Country	Glacier area/km^2	Sources
China	49873	Liu Chaohai et at., 2000
India	23000	Kulkarni,A.V. and Buch, A.M., 1991
Pakistan	16933	http://www.pakembwaw.com.ol/SeePakistan.htm
Nepal	5322	Bajracharya, S.R. et al., 2002
Bhutan	1318	Bajracharya, S.R. et al., 2002
Sikkim	912	Hasnain, S.I., 2000
Tajikistan	7493	Liu Chaohai et al., 2000
Total	**104850**	

As global warming melts Himalayan Glaciers, (which is region's main water source), it is feared that about 40 percent of humanity living in South Asia and China could be living with little drinking water within 50 years.Excessive glacial melt can also result in increased hazards or disasters, glaciers storing up large amounts of water, release suddenly in a massive melt or calving episode, which may involve floods, landslides, or avalanches. The satellite images allow researchers to identify and monitor changes in glacial hazard indicators such as crevasses, avalanche and debris-flow traces, and glacial lakes. While current melting trends can't be slowed or reversed, the information collected through the satellite observations enable researchers to better understand the relationship between climate and glaciers, and to better predict areas of future glacier changes.

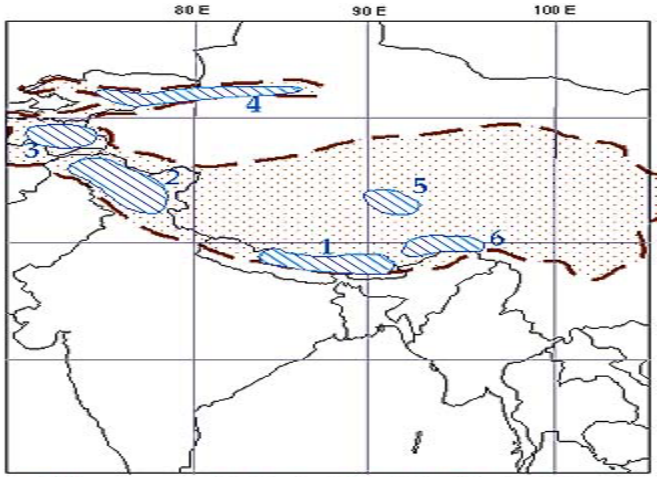


Figure: 1 Showing outline of Tibetan Plateau Topography Including: 1. Eastern Himalaya; 2. Western Himalaya / Karakoram; 3. Pamirs; 4. Tien Shan; 5. Tanggula Shan; 6. Southeastern Tibetan Plateau (Wake and Mayewski, 1996)

Global warming

Due to greenhouse effect absorption and emission of infrared radiation by atmospheric gases warm a planet's atmosphere and surface. On Earth, the major natural greenhouse gases are water vapor, which causes about 36–70% of the greenhouse effect Carbon Dioxide (CO_2), 9–26%; methane (CH_4), 4–9%; and ozone, which causes 3–7%. The atmospheric concentrations of CO_2 and CH_4 have increased by 31% and 149% respectively above pre-industrial levels since 1750. This is considerably higher than at any time during the last 650,000 years. About three-quarters of the anthropogenic [man-made] emissions of CO_2 to the atmosphere during the past 20 years are due to fossil fuel burning. The rest of the anthropogenic emissions are predominantly due to land-use change, especially deforestation.

The present atmospheric concentration of CO_2 is about 383 parts per million (ppm) by volume. Future CO_2 levels are expected to rise due to ongoing burning of fossil fuels, deforestation and land-use changes. The rate of rise will depend on uncertain economic, sociological, technological, natural developments, but may be ultimately limited by the availability of fossil fuels. The IPCC Special Report on Emissions Scenarios gives a wide range of future CO_2 scenarios, ranging from 541 to 970 ppm by the year 2100.

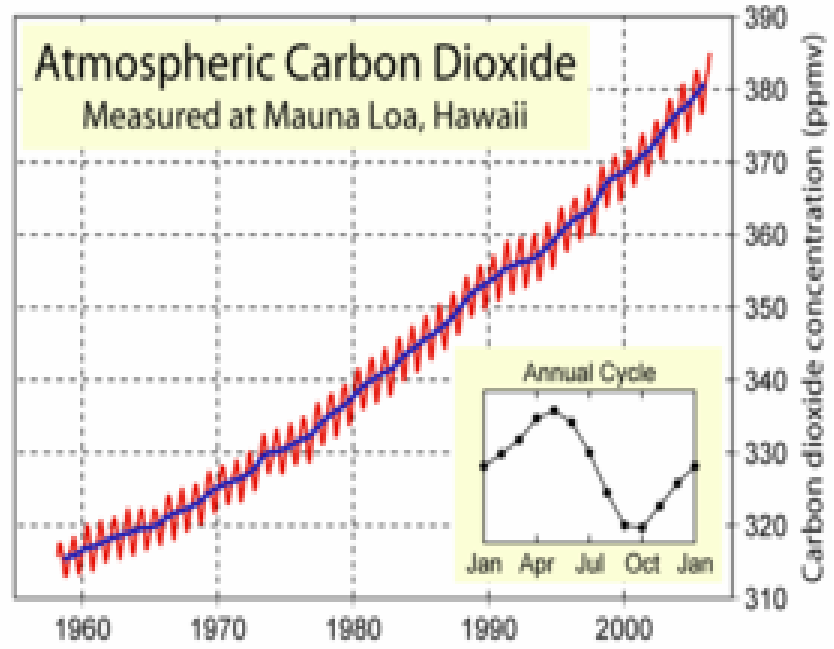


Figure: 2 Showing recent increases in atmospheric CO_2. The monthly CO_2 measurements display small seasonal oscillations in an overall yearly uptrend; each year's maximum is reached during the northern hemisphere's late spring, and declines during the northern hemisphere growing season as plants remove some CO_2 from the atmosphere.

One of the important factors relates to the evaporation of water. CO_2 injected into the atmosphere causes a warming of the atmosphere and the earth's surface. The warming causes more water to be evaporated into the atmosphere. Since water vapor itself acts as a greenhouse gas, this cause still more warming; the warming causes more water to be evaporated, and so forth. Another important feedback process is ice-albedo feedback. The increased CO_2 in the atmosphere warms the Earth's surface and leads to melting of ice near the poles. As the ice melts, land or open water takes its place. Both land and open water are on average less reflective than ice, and thus absorb more solar radiation. This causes more warming, which in turn causes more melting, and this cycle continues. Due to global warming, the average global temperature for 2004 rose to 14.60˚ Celsius making it the fourth warmest year on record. October and November of 2004 were the hottest of those months on record since record keeping began in 1880. February of 2004 was the second warmest, and March, April and December were the third warmest of those three months.

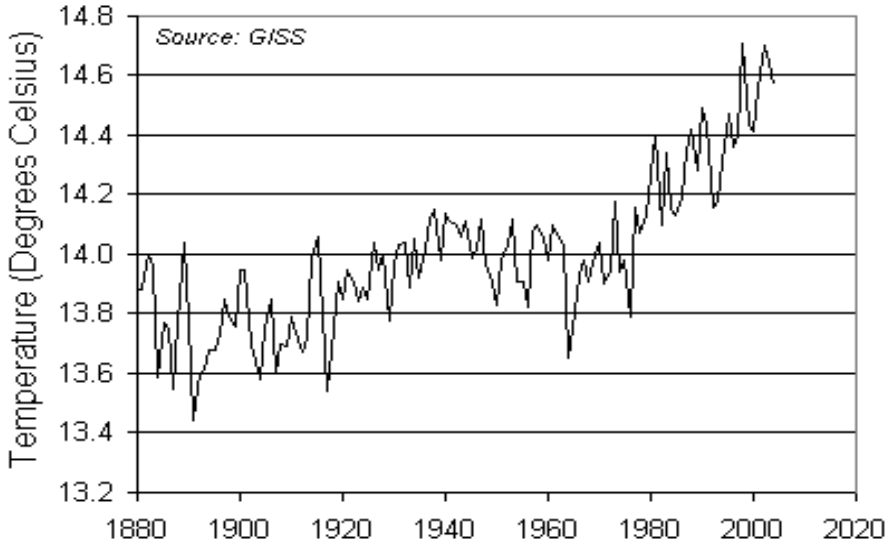


Figure: 3 Showing observations of NASA's Goddard Institute for Space Studies which come from the global series indicate continuous trend of rising global temperatures. The average temperature of 14.01˚ Celsius in the 1970s rose to 14.26˚C in the 1980s. In the 1990s it reached 14.40˚ Celsius and during the first five years of this new decade, it has averaged 14.59˚C (NASA, 2004)

Glacier Retreat

Receding and wasting glaciers are in fact signs of global climate change, in response to climate fluctuations; glaciers grow and shrink in length, width, and depth. Because glaciers are sensitive to the temperature and precipitation changes that accompany climate change, the rate of their growth or decline can serve as an indicator of regional and global climate change. Tracking and comparing recent and historical

changes in the glaciers can help understand global warming and its causes such as natural fluctuations and human activities (LPDAAC, USA).

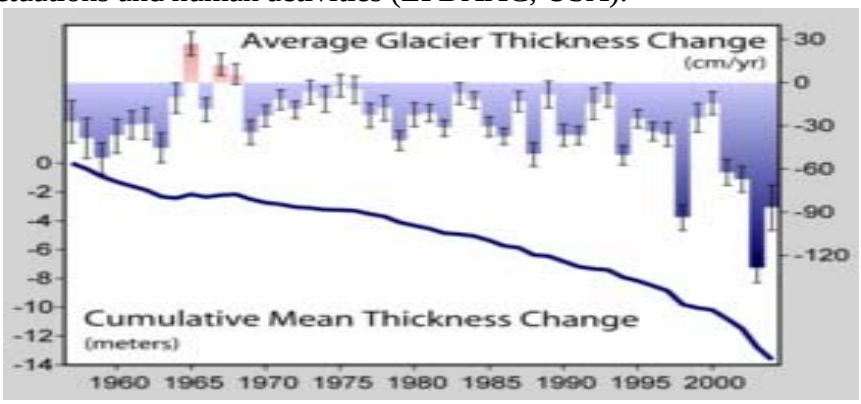


Figure: 4 Showing Global glacial mass balances in the last 50 years. The increased downward trend in the late 1980s is symptomatic of the increased rate and number of retreating glaciers.

Satellite images have been effectively used in various countries to track the size and movement of glaciers. Satellite images can be compared with historical maps and information to determine glacier's advance or retreat over the past few decades. Satellite imageries help reveal short or long-term trends in glacier activity that could impact water supplies or cause glacial hazards in areas with very large glaciers, increased melting could result in temporary increases in meltwater available for human use. As the world's glaciers continue to melt and shrink, over time there will be less water to sustain the communities that have come to depend on that meltwater. Glacial changes also have a more immediate impact on communities that rely on glaciers for their water supply, or on regions susceptible to floods, avalanches, or landslides triggered by abrupt glacial melt.



Figure: 5 The ASTER image shows the lakes left behind by retreating glaciers in the Bhutan-Himalaya, (Image courtesy of Jeffrey Kargel, USGS/NASA JPL/AGU)

The 20th century was a period of dramatic glacier retreat in almost all alpine regions of the globe with accelerated glacier and ice field melting in the last two decades i.e 1980-2000. In the last 25 years +0.3°C warming caused hemisphere temperatures to rise to unprecedented levels. The 1990s represented the warmest decade of the millennium and 1998 the hottest year of the millennium. Tibetan Plateau shows annual temperature rise of 0.16°C per decade and winter temperature increase of 0.32°C per decade from 1955 to 1996. Observations of selected glaciers in Himalaya indicate a general state of decline for at least the past 150 years. The Khumbu Glacier, along a popular climbing route to the Mount Everest Summit has retreated over 5 Km since 1953. The disappearance of mountain glaciers of the Tibetan Plateau is already affecting the supply of water. For the subcontinent a typical example of glacial retreat is Gangotri (Fig. 6) Glacier at the head of Ganges River which is retreating at a rate of 30 meters/year. It has been observed that glaciers are retreating faster in the Himalayas than any where else on earth.

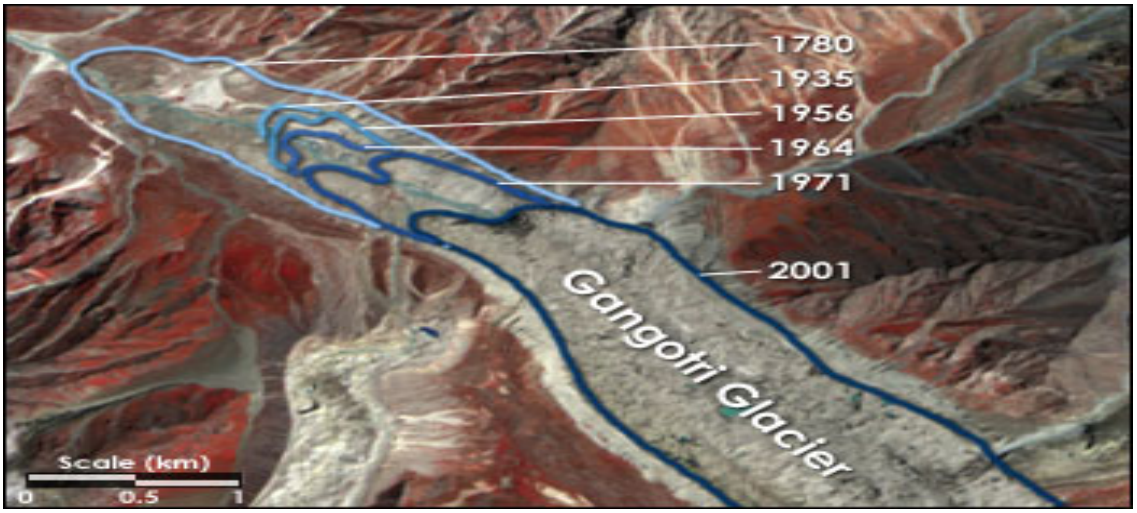


Figure: 6 This composite ASTER image shows how the Gangotri Glacier terminus has retracted since 1780. Contour lines are approximate, Image Courtesy of Jesse Allen, Earth Observatory,USA

Pakistan Scenario

Glacier region of Pakistan is shown in SPOT image acquired and processed at SUPARCO (Fig: 7). Studies have shown that land surface temperatures have risen more than sea surface temperatures and that temperatures in higher elevations are rising more rapidly (Liu and Chen, 2000; Beniston et al., 1997). Therefore mountain areas such as the Karakorums and Himalaya region of Pakistan have also been affected due to climate change.

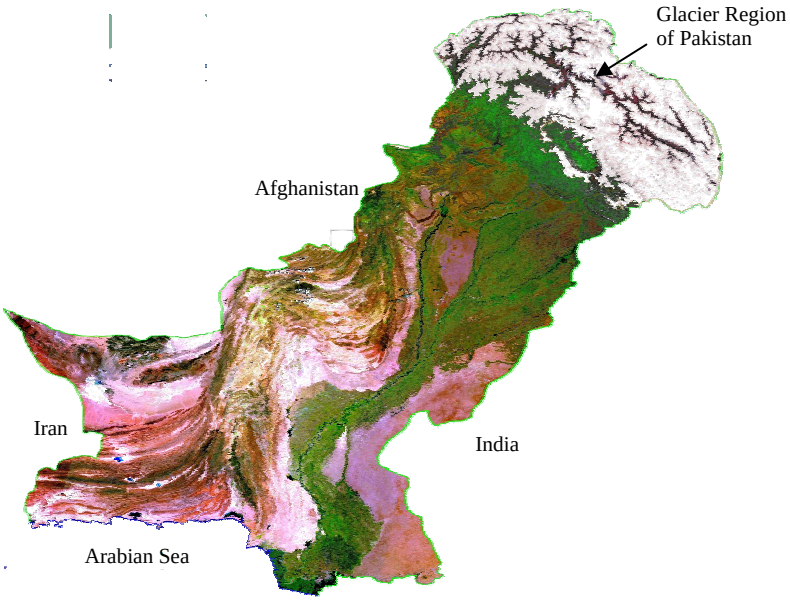


Figure: 7 shows Spot image mosaic of Pakistan, glacier region of Pakistan can be seen in northern Pakistan

According to a study carried out by GTZ for WAPDA analyzed trends in temperature and precipitation in the Northern Areas for the last century by making use of the climate data at the Meteorological Office in Lahore and Gilgit. It was found that at Skardu seasonal and annual temperature have risen over the last century. Mean annual temperature through the century has increased by 1.40˚C with the mean annual daily maximum rising more (2.35˚C) than the mean annual daily minimum (0.54˚C). But the study notes that winter temperatures have risen far more than summer, with an increase of about 30˚C during January-March or up to 0.51˚C in winter maxima per decade since 1961. This is a common feature within the Northern hemisphere and implies a link between regional and global climate (Fowler and Archer, 2004). This temperature increase is calculated to represent an upward shift of almost 400 meters in the frost line and hence whether the area will receive snow or rain and as a consequence how much snow will be available for melting during the warm season. During the spring to summer season a more modest warming trend is noted, with mean temperature rising by only 0.77˚C (Archer, D. R. 2001). 20 years (1986 – 2005) climatological data pertaining to 10 meteorological stations in northern Pakistan (at elevation 1500 meter or above mean sea level) collected and analyzed by Pakistan Meteorological Department indicates that a significant rise in temperature has taken place during this period.

SUPARCO has conducted studies based on the applications of satellite/ground based data for earth resources and environment monitoring. SUPARCO recently conducted a pilot study on Batura Glacier, which is one of the largest glaciers outside the polar region. Satellite images pertaining to different years were acquired and

analyzed to monitor various attributes of Batura Glacier. It lies in the north of Passu 7,500 meter above sea level. It feeds River Hunza in northern Pakistan which flows west to east. River Hunza is joined by the Gilgit and the Naltar Rivers before it flows into the Indus River. Temporal satellite images of Landsat of Batura Glacier were acquired and analyzed (Figures 8 to 11). It was observed that the ice covered and ice free areas in the year 1992 was 98 and 25 sq km respectively, whereas in the year 2000, the ice covered area reduced to 81 sq km, consequently increasing the ice free area to 42 sq km (Rahmatullah Jilani, 2006).

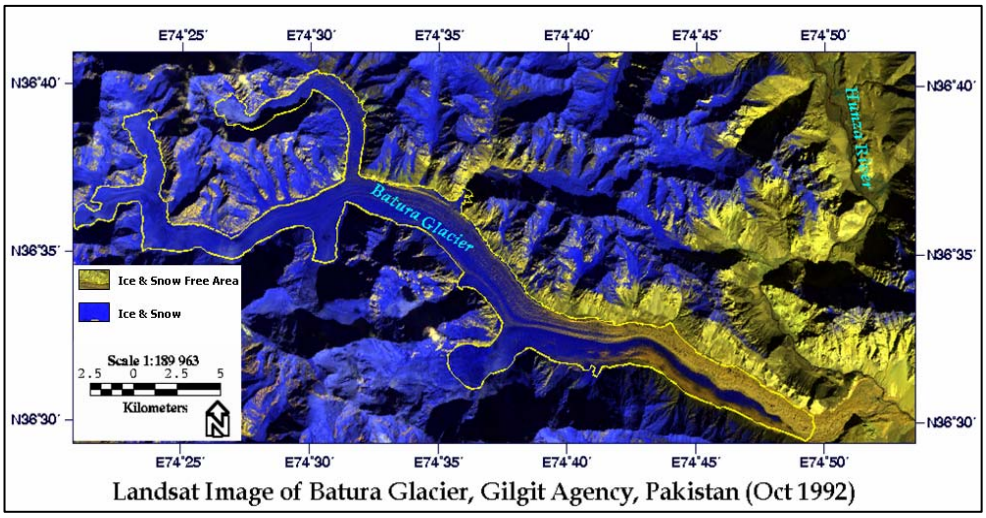


Figure: 8

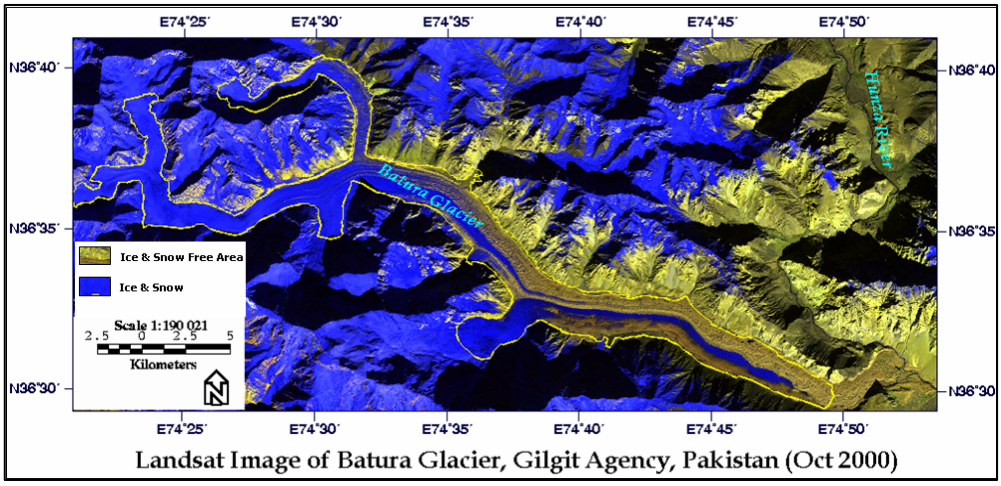


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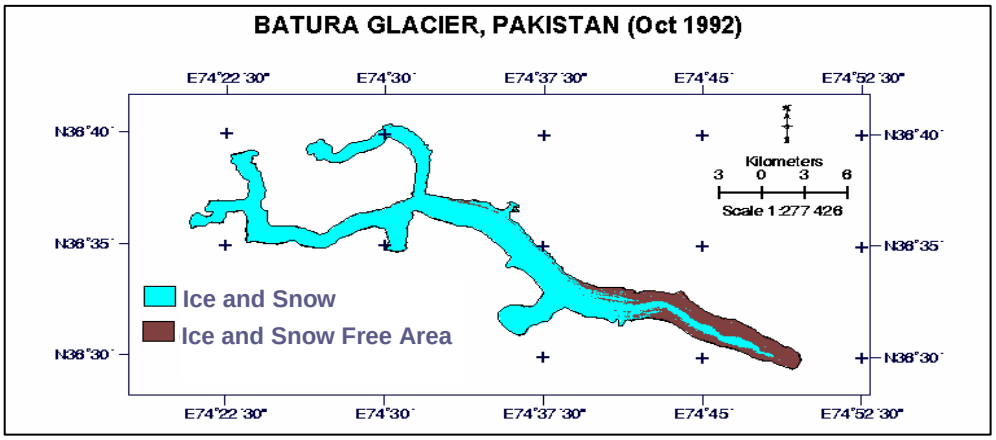


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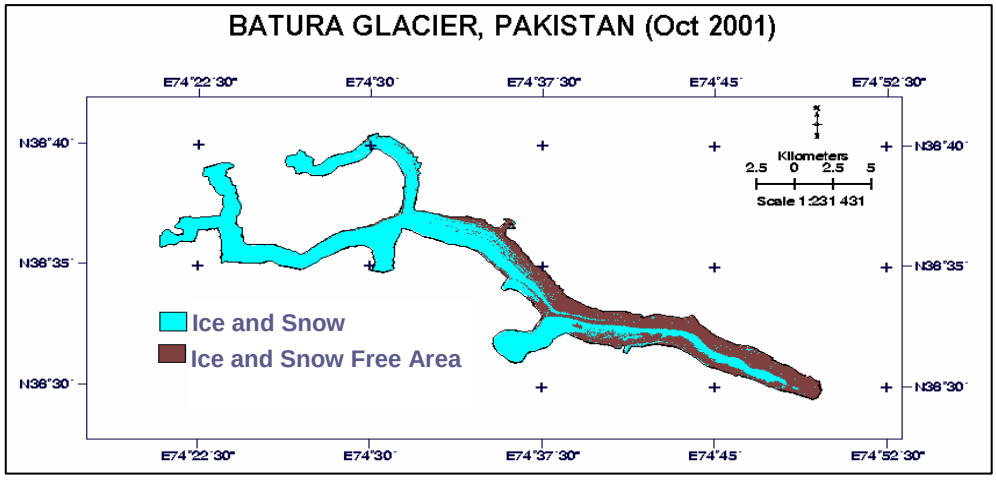


Figure: 11

Reduced Level of Water in the Indus River System

The Indus River, its tributaries originate in the Karakoram, Hindukush, and the Himalayan regions along the north and north eastern borders of Pakistan. The Indus System rivers form a link between two great natural reservoirs, the snow and glaciers in the mountains and the groundwater contained by the alluvium in the Indus Plains of the Punjab and Sindh Provinces of Pakistan (Figure 11). The water from the Indus River and its tributaries supports the bulk of the agricultural water supply for its 130 million people. Dams on the main stem of the Indus River and its tributaries produce about 45% of the electrical energy for Pakistan.

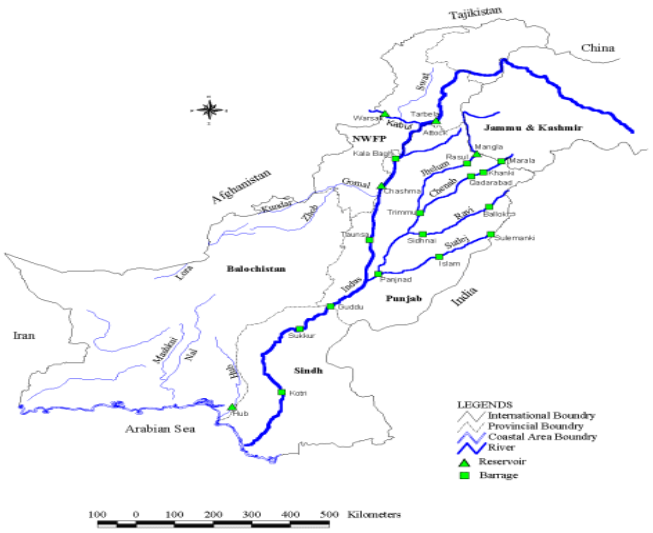


Figure: 12 Showing Indus River System and its Tributaries (Asim R. Khan)

Table: 2 shows average annual flow-rates of major rivers between 1922-61, 1985-1995 and 2001-02. The figures indicate sharp decrease in water flow in the rivers during last several years. The low level of water-flow in the rivers is an indicative of reduced quantity of water in the glaciers. The situation in River Indus clearly indicates decrease in quantity of water by 32% during 1922-61 as against the period of 1985-1995 and further reduced to 23.44% during 2001-02 compared to 1985-1995. It is in fact significant reduction of 51.6% in the last eight decades (IUCN Report).

Table: 2 showing annual flow-rates of major rivers between 1922-61, 1985-1995 and 2001-02

River	Average Annual Flow (1922-61) MAF	Average Annual Flow (1985-95) MAF	Average Annual Flow (2001-02) MAF
Indus	93	62.7	48.0
Jhelum	23	26.6	11.85
Chenab	26	27.5	12.38
Ravi	7	5.0	1.47
Sutlej	14	3.6	0.02
Kabul	26	23.4	18.9
Total	**189.0**	**148.8**	**92.62**

Conclusion

Glaciers are major sources of water, studying the aspects and temporal changes are vital for planning, development water resource conservation, flood monitoring and mitigation activities.Additional anticipated effects include reduced agriculture yield, increased intensity and frequency of hurricanes and extreme weather events and spread of diseases such as malaria and dengue fever. Some effects on both the natural environment and human life are, at least in part, already being attributed to global warming. As per IPCC 2001 report retreat, sea, changes in rainfall pattern, increased intensity and frequency of extreme weather events, are being attributed in part to global warming. Other expected effects include water scarcity, changes in mountain snow pack, adverse health effects from warmer temperatures, and the spread of diseases. Rising temperatures could bring large-scale drought in critical agricultural regions worldwide, extreme temperature drops in some regions and searing heat in others, and civil unrest and mass migrations from spreading insecurity about water and food supplies.

Recommendations

Tracking & comparing recent & historical changes in the glaciers should be carried out to:

- Assess size & movement of glaciers
- Assess short- or long-term trends in glacier activity that could impact water supplies or cause glacial hazards in areas with very large glaciers
- To recognize & track changes in glacial hazard indicators such as crevasses, avalanche & debris-flow traces & glacial lakes
- Predict areas of future glacier changes
- Understand global warming & its causes (such as natural fluctuations & human activities)
- Taking appropriate measures to control the emissions of GHG gasses to minimize the effect of global warming
- Prevent deforestation & increase plantations which works as CO2 sink
- Measures be taken to recycle the domestic & industrial waste water

Acknowledgments

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References

(a) Ole R. Vetaas, The Effect of Glacier Meltwater on An Agro-Pastoral Society,in Himalaya, Nepal

(b) Yongping SHEN, An Overview of Glaciers, Retreating Glaciers and Their Impact in the Tibetan Plateau

(c) 1996 Wake and Mayewski

(d) 2004 NASA's Goddard Institute for Space Studies, Global Temperature Rise Accelerating, Report by Earth Policy Institute, USA
(e) Report of Earth Observatory; based on data provided by the ASTER Science Team; glacier retreat boundaries, through Courtesy of the Land Processes Distributed Active Archive Center, USA
(f) Archer, D. R. 2001, The climate and Hydrology of Northern Pakistan with Respect to Assessment of Flood Risks to Hydropower Schemes, Report by GTZ / WAPDA
(g) Monitoring Disasters in Pakistan Using Satellite Data- 2006, Rahmatullah Jilani
(h) Asim R. Khan, Water Availability and Some Macro Level Issues Related to Water Resources Planning and Management in the Indus Basin Irrigation System in Pakistan
(i) IUCN Report on Water Resources of Pakistan
(j) Global warming and expected snowline shift along northern mountains of Pakistan, Rasul G and Q. Z. Chaudhry

Climate Change and Sustainable Development

By

Dr. Qamar-uz-Zaman Chaudhry *

1. Introduction:

Sustainable development and Climate Change are two vitally important and interrelated Challenges facing us in the 21st century. Our ability to develop more sustainable development will determine the speed and degree of Climate Change we experience, and as the Climate Changes the choices available to us to develop sustainable will change.

We need to significantly reduce our greenhouse gas emissions, so that we can change the course of Climatic Change. Furthermore, some Climate Change is now inevitable due to our past greenhouse emissions. We need to adapt - at the same time as we act to reduce emissions - to better manage the future impacts of Climate Change on the environment, economy and society Fair or not, Climate Change is very unfair. The bulk of impact will fall on the low-latitude countries-which are also the poorest. Most of the big emitters will have the least effect. Those that will suffer have hardly anything to do with the emissions.

2. Background:

Sustainable development is development that meets the needs of the present without compromising the ability of future generation to meet their needs. This definition of World Commission on Environment and Development (WCED) reflects three key concepts.

First is human need, in particular the basic needs of the world's poorest people for adequate food, water and shelter.

Second its intergenerational equity, our duty to future generation to leave them an environment with a sufficient variety and abundance of resources to meet their own needs.

The third embedded concept, intra-generational equity, draws attention to issues of access to resources and other development opportunities within the present generation.

2.1 Kyoto Protocol:

In December 1997, over 160 nations met in Kyoto, Japan to discuss the United Nations Framework Convention on Climate Change (UNFCCC). The outcome of the meeting was the Kyoto Protocol, in which developed nations set targets for limiting their greenhouse gas emissions. Countries that ratified the Protocol could engage in emission trading with each other, which would reward countries achieving reduction in excess of

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their targets. (The world's largest emitter-US has not yet signed the Protocol whereas Pakistan has signed it last year).

2.2 IPCC's WG-I, Fourth Assessment Report 2007:

Intergovernmental Panel on Climate Change IPCC's Working Group-I has concluded that Global Climate Change is "very likely" to have been human-induced. Very likely has been defined by the Panel as more than 90% probability of occurrence. This is the very significant conclusion.

Other key findings are given below:-

- Probable temperature rise by the end of the century will be between 1.8°C and 4°C.
- Sea levels are likely (Probability more than 50%) to rise by 28-43 cm.
- Arctic Summer Sea Ice likely (probability more than 50%) to disappear in second half of century.
- It is very likely (Probability more than 90%) that parts of the world will see an increase in the number of heat waves.
- Climate change is likely to lead increased intensity of Tropical Storms.

2.3 Knowledge:

Sustainable development is about making better-informed choices: finding ways to integrate economic, environmental and social dimensions into decisions about the development of natural resources. Governments at all levels require appropriate data and knowledge on which to base policies and programs. Organizations large and small require information that is specialized to their needs. Individuals also need objective information in this regard. In all cases we all must have access to scientific and community-based knowledge, in an easily accessible format.

3. The Climate Change Challenge:

Over the past decade or so, changes in Climate and the accelerated pace of the earth's warming have moved the issue of Climate Change to the top of the global agenda. Climate Change is a global problem that requires global action. It requires all of us, governments, industries and consumers, to come together to play our part in dealing with climate change.

The challenges of climate change illustrate the complexities of sustainable development. The build up of Green House Gases (GHGs) in the atmosphere-mainly a result of the production and combustion of fossil fuels – could contribute to climate change by increasing the earth's mean temperature, which many models predict could include an increase in the earth's temperature, altered precipitation patterns, rising sea levels and more frequent extreme weather events (tropical cyclones, floods, heat waves etc). At the same time, these fossil fuels have been a part of high standard of living and

contemporary life styles. As such climate change is a crucial sustainable development issue with implications for the environment, the economy and society.

4. Adaptation to Climate Change:

Conventional approach to understanding climate change was limited to identifying and quantifying the potential long-term climate impact on different ecosystems and economic sectors. But this science driven approach failed to address the regional and local impacts of climate change and the local abilities to adapt to climate-induced changes.

So, the impact-driven approach gave way to a vulnerability approach that assessed part and current vulnerability, existing adaptation strategies, and how these might be modified with climate change. Kelly and Adger (2000) define the vulnerability as the "ability or inability of individuals or social grouping to respond to, in the sense of cope with, recover from, or adapt to, any external stress placed on their livelihoods and well-being".

Since vulnerability and its causes play essential roles in determining impacts, comprehending the dynamics of vulnerability is as important as understanding climate itself.

In climate change research, vulnerability is used as an integrative measure of the threat to system (IPCC-2001). Broadly there are two interpretations of vulnerability – as an endpoint or as a starting point (O'Brien et al. 2004), As a starting point, vulnerability is a characteristic or state generated by multiple environmental and social processes, but exacerbated by climate change (Kelly and Adger 2000). Vulnerability provides a means of understating how impacts of climate change will be distributed, primarily to identify how vulnerability can be reduced, i.e., the focus is on adaptive capacity and systemic properties and solutions can be found is sustainable development. As an end point, vulnerability is viewed as a residual of climate change impacts minus adaptations. It serves as a means of defining the extent of the climate problem and providing inputs into policy decisions regarding the cost of climate change versus cost related to GHG mitigation efforts.

It is now important that we integrate adaptation issues into core policy and decision making processes. The question that needs to be addressed is how adaptation to climate variability and change can be more fully integrated into development policies and what are the funding instruments for adaptation? The rationale for integrating adaptation into development strategies and practices is underlined by the fact that interventions required to increase resilience to climate variability and change generally further development objectives.

Adaptation calls for natural resource management, ensuring food security, development of social and human capital and strengthening of institutional systems. (Adger et al.2003). Such processes, besides building the resilience of communities, regions and countries to all shocks and stresses, including climate variability and change are good development practice in themselves. Hence the inclusion of climatic risks in the

design and implementation of development initiatives is vital to reduce vulnerability and enhance sustainability.

5. Importance of Adaptation:

Traditionally, mitigation has received greater attention than adaptation, both from a scientific and policy perspective. One plausible reason for this could be that climate change emerged as problem related to the long-term disturbance of the global geo-biochemical cycle and associated effects on the climate system (Cohen et al. 1998).

The focus on mitigation was later reflected in the work of the IPCC, an organization jointly established by the UNEP (United Nations Environment Programme) and the WMO (World Meteorological Organization) in 1988 to, "assess the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change" (Najam et al. 2003).

However, there are convincing arguments for consideration of adaptation as a response measure. First, no matter how robust mitigation measures are, a certain degree of climate change is inevitable due to historical emissions and the inertia of the climate system (IPCC 2001). Second, while the effects of mitigation may take several decades to manifest, most adaptation activities take effect almost immediately. Third, such measures can be applied on a regional or local scale, and their effectiveness is less dependent on actions of others. Fourth, adaptation besides addressing the risks associated with changes in the climate in future typically reduces risks associated with current climate variability.

6. UNSC Debate on Climate Change:

In mid April, 2007 for the first time in the history of the UN Security Council a discussion was initiated about the impact of climate change on international peace and security. The very fact that a climate change debate has now moved to the realm of the UNSC, and the very realisation that the traditional concept of security at UNSC has moved beyond the application of brute diplomatic, economic and military force to a broader understanding of environmental sustainability, speaks volume about the emerging threat climate change pose to the world. The meeting was triggered by a landmark report released last year in London, in which economist and climate change expert Nicolas Stern Warns that climate change can create economic disaster on the scale of the world wars and the great depression of the 1930, unless urgent action is taken.

7. Impact on Pakistan:

The UNSC debate and recent IPCC-2007 reports on climate change were of special relevance to Pakistan, as millions of us are living along the Indus and its tributaries depend on Himalayan glaciers for water, and recent IPCC report says that these glaciers are retreating in the face of accelerating global warming. The country banks on thousands of dry land glaciers, some of them are the world's largest storehouse of frozen fresh water out side the polar ice caps. These frozen sheets of ice are like bank accounts storing snow in winter and releasing water when people living in the lowlands need it the most in the smouldering dry heat of the summer before the monsoon arrives. The water is then channelled to the irrigated plains or is being used for drinking purposes downstream.

IPCC recent report says that if the current rate of melting of glaciers continues our Himalayan glaciers may disappears altogether. If the planners in the country fail to build additional water reservoirs and to work towards conservation of glacier ecosystem, the glaciers, natural God gifted water reservoirs may eventually get empty causing catastrophic consequences for the entire Indus valley civilisation.

Most of the regional experts say that the flow of water from glacier fed rivers in the whole of the Himalaya, Karakoram and Hindukush mountain ranges are on the decline, primarily due to climate change patterns and resultant reduction in glacial cover in the mountains. Mountain ecosystem particularly glaciers are considered extremely sensitive to climate change. They generally provide early glimpse of what may occur in the lowlands. According to scientist, the worldwide glacier-melting rate has doubled since 1980, which is not entirely surprising given the fact that the 1990 was the hottest decade of the earth during the last 1000 years.

However, the most disturbing point about this whole situation is the sheer lack of awareness and anticipation concerning the conservation of glacial resources in the country. Though Pakistan is known for its rich glacial resources worldwide, and people from all parts of the world come down to catch a glimpse of these wonders of nature, but within the country awareness about glaciers is abysmally low at both public and policy level.

Similarly, Pakistan is witnessing increased frequency of extreme weather events in recent past. In the years 2001-2003, country experienced worst drought of its history. In July, 2001 Islamabad / Rawalpindi received the heaviest rainfall of its recorded history about 625 mm in 8 hours. This caused loss of billions of rupees and death of over 50 persons. In the year 2005, Balochistan received very heavy winter rains which caused devastating flooding in the province. In June, 2006 Northern areas suffered from historic snowmelt flooding which caused extensive damages to property and loss of human lives. All these events indicated that as far as Pakistan is concerned the climate change has already started affecting us.

Conclusion:

After the release of recent IPCC 2007 Fourth Assessment Reports, now there is hardly any doubt that the Global Climate Change is human-induced. The economic cost of inaction would be too high and Nicolas Stern has warned that climate change can create economic disaster on the scale of world wars.

Thus integrating climate change adaptation considerations into policy processes and decision-making across a range of sectors and scales is critical in managing the impacts of climate change. Efforts to achieve this objective, might be undertaken under the direction of the UNFCCC, and through actions supported by private sector, finance ministries and international financial institutions.

There is a need to develop, disseminate and implement the knowledge, tools and technologies required to effectively engage in an integrated approach. There are several assessment frameworks in place that can potentially help to reduce vulnerability to climate change. Financing adaptation activities and costs associated with impacts of

climate change is a key concern for developing countries. Long term, firm and regular support is indispensable.

References:

- Adger, W.N., Khan, S.R., and Brooks, N., 2003, Measuring and Enhancing Adaptive Capacity, UNDP Adaptation Policy Framework Technical Paper 7, New York.
- Cohen, S., Demeritt, D., Robinson, J., and Rothman, D., 1998, Climate Change and sustainable development: towards dialogue, Global Environmental Change, Vol. 8(4), pages: 341–371.
- IPCC 2001, Climate Change 2001: Impacts, Adaptation and Vulnerability, McCarthy, J.J., Canziani, O.F., Leary, N.A., Dokken, D.J., and White, K.S., (eds.), Cambridge: Cambridge University Press.
- IPCC 2007, Climate Change 2007: Working Group I, Fourth Assessment Report.
- Kelly, P.M., and Adger, W.N., 2000, "Theory and practice in assessing vulnerability to climate change and facilitating adaptation", Climatic Change, Vol 47, pages: 325–352.
- Khan, M. Ismail, 2007, “Changing Climate and Melting Mountains”, The News.
- Najam, A., Rahman, A.A., Huq, S., and Sokona, Y., 2003, "Integrating sustainable development into the Fourth Assessment Report of the Intergovernmental Panel on Climate Change", Climate Policy 3S1, pages: S9–S17.
- O’Brien, K., Eriksen, S., Schjolden, A and Nygaard, L., 2004, "What’s in a word? Conflicting interpretations of vulnerability in climate change research", CICERO Working Paper 2004: 04.
- United Nations, 1997, Kyoto Protocol to the United Nations Framework Convention on Climate Change, Kyoto, Japan, www.unfccc.int/text/resource
- UNDESA, 2006, Adaptation to Climate Change in the context of Sustainable Development. Paper by TERI.

Glaciers – The Barometer of Climate Change

By

Rakhshan Roohi*, Arshad Ashraf** and Rozina Naz***

Abstract

The northern mountainous region of Pakistan houses numerous glaciers and glacial lakes many of which have been created in this region over centuries. However, these glaciers are particularly vulnerable to climate change, and in the recent past due to global warming accelerated glacier melt has resulted in the increase in size of existing lakes and creation of new ones. Recently as glaciers retreat, glacial lakes are formed behind the exposed terminal moraines. Such environment is quite susceptible to glacial lake outburst flood (GLOF) hazards in Hindu Kush Himalayan region. The GLOF hazards are caused by the rapid advance, high melting of glaciers due to climate effect and snow avalanche from hanging glaciers. A digital repository of valuable knowledge on glaciers, glacial lakes, and GLOF events is essential to inform policy makers on the vulnerability, risk mitigation and action/adaptation measures. In Pakistan where irrigation network and power generation is heavily dependent on the snow melt in summer, such information can provide a basis for future planning of water resources and flood hazard monitoring in the country. An inventory of glaciers and glacial lakes of Himalya-Karakoram-Hindukush (HKH) region of Pakistan has been completed which is primarily based on Landsat ETM+ image data supplemented with the topographic maps. The potentially dangerous glacial lakes susceptible to GLOF hazard are also identified.

A total of 5,218 glaciers covering an area of about 1,5041 sq. km have identified which house 2738.51 sq. km of ice reserves in ten river basins of HKH region of Pakistan. Similarly 2,420 glacial lakes are also identified. About two third of these lakes are found in Gilgit, Indus, Swat and Shingo River basins. Among total glacial lakes, 1,328 are characterized as major lakes having an area of more than 0.02 sq. km. Out of these major lakes 52 are identified as potentially dangerous lakes. Most of these potentially dangerous lakes are identified in Indus, Astor and Gilgit river basins. The results of the inventory provide base line information for future monitoring of glaciers and potentially dangerous glacial lakes especially in the context of global warming.

The presence of high number of potentially dangerous lakes is the indication of impact of global warming on the glacial reserves. Recently comparison of current

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satellite data of a target site in Astor River basin with the inventory results is also indicating the impact of increasing temperature on the glaciers.

Introduction

The northern glaciated region of Pakistan comprises some of the highest peaks, large glaciers, deepest gorges and canyons of this region. It constitutes parts of the watershed of Indus River that contributes more than 50% of water supply to the Indus River System. Crests of the high ranges in the Karakoram–Himalayan region are largely snow bound. It has greater ice and snow cover (27 to 37%) than any other mountain system outside the polar region (Wissman, 1959). During most of the summer season, high flows in the Indus River system are due to snow and ice melting. In the past no comprehensive study has been carried out to register the details of this resource. There are scattered studies on individual glaciers but due to extensive area and inaccessibility no attempt was made to document the glaciers of this region. Knowledge of glacier storage, transfer of ice down slope in the form of melt water and area altitude relations of ice cover are integral parts of the water balance. The study of the glacial lakes is important not only for water resource management but also in the context of climate change that indicates the possibility of glacial advances which may in turn cause Glacial Lake Outburst Floods (GLOF). Due to the gentle slope at the lower reaches and the accumulation of debris derived from the headwater, the glacial lakes develop in the form of supra glacial or moraine dammed. Generally, the stability of glacial lakes is poor and there is always a chance of avalanche from Mountain glaciers, which may break the dam and cause Glacial Lake Outburst Flood (GLOF) downstream. The flood risks associated with monsoonal storm are common in summer especially in low-lying areas of Pakistan.

Remote sensing provides a synoptic view of inaccessible areas in a quick way thus helping in detail inventory of glaciers in an economical way. The technique of digital image analysis facilitates image enhancement and spectral classification of the ground features and, hence, greatly helps in the study of glaciers and glacial lakes.

In the present study, glaciers, glacial lakes and hazardous lakes susceptible to GLOF in Hindukush-Himalayan region of Pakistan are inventoried and characterized using SRS data supported by topographic data of the area.

Glaciated Region of Pakistan

The glaciated area of Pakistan stretches over an area of about 128,730.8 sq. km within longitudinal range of 71º 00' to 77º 50'E and latitudinal range of 33º 55' to 37º 05'N. The elevation in the region varies from 1,500 meters to more than 8,500 meters above sea level (masl). The region is bordered in the west and northwest by Afghanistan, north and northeast by China and east by Indian held Kashmir. The major rivers flowing in this region are Swat, Chitral, Gilgit, Hunza, Shigar, Shyok, Astor, Shingo and Jhelum. These rivers which are the major tributaries of the main Indus River form distinct river basins in the northern glaciated region of Pakistan (Figure 1). A part of the Indus basin drains directly into the Indus River.

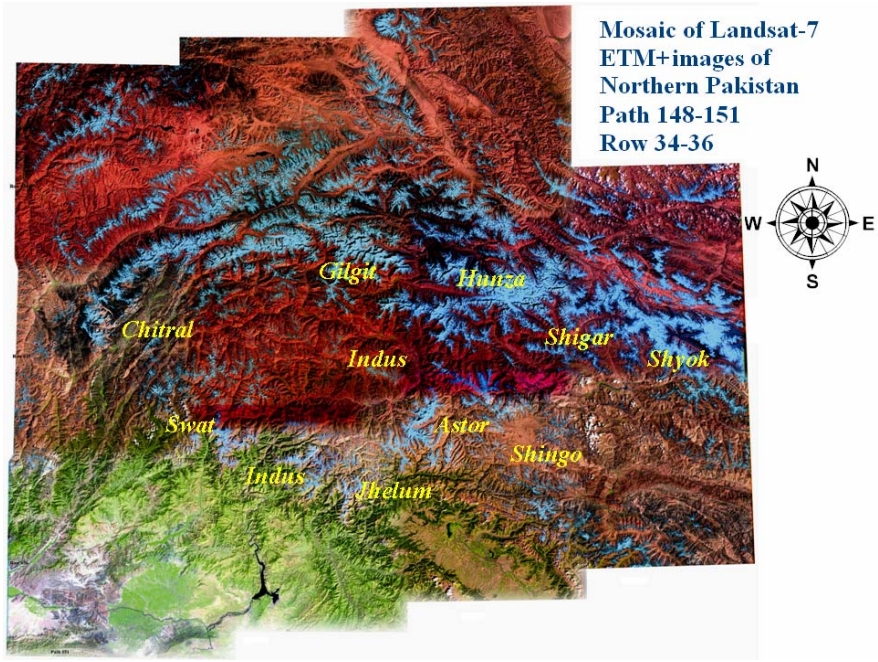


Figure 1: Major river basins in glaciated region of Pakistan

The region is of unusual interest and perhaps sensitive to climate change, since its glaciers lie within the influence of variable weather systems. Snowline is at 5,100 masl to 5,600 masl in southern Karakoram and 4,700 masl to 5,300 masl in the northern part of the Karakoram (Kick, 1964). Historical record of glacier fluctuations in the Himalayas and the Karakoram indicate that in the late nineteenth and early twentieth century the glaciers were generally advancing followed by predominant retreat during 1910-1960 (Mason 1930 and 1935 and Goudie et al. 1984). The present glaciers of the Karakoram are considered remnants of the great ice-sheet that covered the northern Pakistan much below Gilgit basin. Almost eight glacial phases have been recognized over the last more than 150,000 years; the last phase having acted only 200 years ago (Khan K., 1992). The glaciers in Karakoram region are high activity glaciers and have some of the steepest gradients in the world. It is interesting that the long glaciers originate from frozen sources above 7,000m height, but then descend down to sub-tropical desert-like conditions at only 2,500m high low land.

Materials and Methods

Data used

The primary data of Landsat Satellite (Landsat -7 ETM+) of period 2000-2001 was used, supplemented with the topographic maps available with Survey of Pakistan at scales of 1:250,000 and 1:50,000 covering partially the study area. The Landsat-7 ETM+ sensor is a nadir-viewing, seven-band plus multi-spectral scanning radiometer that detects spectrally filtered radiation from several portions of the electromagnetic spectrum. Nominal ground sample distances or pixel sizes include 30 meters each for the six

visible, near-infrared, and short-wave infrared bands, 60 meters for the thermal infrared band, and 15 meters for the panchromatic band. The RS images with least snow and cloud cover were used in the study. The digital topographic map (ARC digitized Raster Graphics (ADRG) published in January, 1996 by the National Imagery and Mapping Agency (NIMA) and Defense Mapping Agency (DMA) of the U.S. Government at the scale of 1:500,000 were also used.

Methodology

The images of Landsat ETM+ were geo-referenced using the NIMA topographic maps. The Transverse Mercator projection was used to incorporate topographic and image data in GIS system. In order to develop detail inventory of the glaciers, the northern glaciated region of Pakistan was divided into ten major river basins. Through image interpretation of RS data, glaciers were identified and demarcated in ILWIS 3.1 GIS software.

The glacier margins were delineated on the image of panchromatic mode and compared with other individual bands as well as in different color composite bands, and the exact boundaries between glaciers and seasonal snow cover were delineated. The classification of glaciers is adopted from the morphological classification of glaciers by the World Glacier Monitoring Service (WGMS) defined by Muller et al. 1977. Generally, six types of glacier having variable basin characteristics are observed in the region i.e. Mountain, Valley, Cirque, Niche, Ice caps, and Ice apron. To estimate the ice reserves, it is of an utmost necessity to have the mean thickness of the glaciers. Since, the data for the measurement of glacial ice thickness in the northern parts of Pakistan are available for only selected glaciers and no such information is available for most of the glaciers in these areas, therefore, it is based on the formulation developed for the Tianshan Mountains (Chaohai Liu and Liangfu Ding, 1986) and applied in Nepal and Bhutan (Mool et al., 2001).

Similarly glacial lakes were identified and delineated through visual interpretation of RS data. For the inventory of glacial lakes, only the lakes with sufficient amount of water mass and extending with a free surface in, under, beside, and/or in front of a glacier and originating from glacier activities and/or retreating processes of a glacier are considered. The lakes are classified into Erosion, Cirque, Valley Trough, Supraglacial, Moraine-dammed (Lateral and End Moraine) and Blocked lakes.

The criteria for identifying the potentially dangerous glacial lakes are based on the geo-morphological and geo-technical characteristics of the lake and surroundings, field observations, processes and records of past events and other physical conditions.

The behavior of the glaciers and glacial lakes are studied in an area of 10 x 10 km^2 in the southwestern part of Astor River basin between longitude and latitude range of 74º 24' to 75º 14' and of 34º 45' to 35º 38' respectively and the temporal analysis was carried out. The image data of Landsat-5 TM (July 14th, 1993), Landsat-7 ETM+ (September 30th, 2001) and SPOT (September 1st, 2005) were analysed to assess the behavior of glaciers and glacial lakes and their correlation with climatic parameters.

Results and Discussions

Glaciers

The total geographic area of the selected ten basins under investigation namely Swat, Chitral, Gilgit, Hunza, Shigar, Shyok, Indus, Shingo, Astor and Jhelum is 128,730.8 sq. km. Over the vast track of these ten basins, 5,218 glaciers are identified (**Table 1**). These glaciers are mainly distributed in the northern part of HKH region covering higher Karakoram and Hindu Kush ranges (**Figure 2**). These glaciers are also present at the higher elevations of Himalayas. Maximum number of glaciers i.e.1098 and 1050 is in the Indus and Hunza river basins respectively. Among these two basins, the glaciers are larger in size in Hunza River basin compared to Indus River basin. The southern basins like Swat, Shigar, Shyok and Jhelum have relatively less number of glaciers. Astor and Gilgit River basins contribute equal number (11% each) of glaciers **(Figure 3a)**. Among various types of glaciers the maximum number of glaciers is of Mountain type (1918) followed by Cirque and Niche type. The Ice cap type glaciers are minimum in number. Among these ten basins, generally the mountain and sub types of mountain glaciers are higher in number compared to Valley glaciers. In the southern basins like Swat, Jhelum and Shingo the number of Valley glaciers are especially low whereas in the northern basins like Chitral, Hunza and Shigar the number of Valley glaciers is relatively high.

Table 1: Summary of glacier inventory in ten basins

Basins	Basin Area (km^2)	No. of Glaciers	Glacier area (km^2)	Total Length (km)	Ice Reserves (km^3)
Swat	14656.23	233	223.55	329.84	12.221
Chitral	15322.43	542	1903.67	1416.06	258.817
Gilgit	14082.46	585	968.10	1185.45	83.345
Hunza	16389.48	1050	4677.34	2914.81	808.794
Shigar	7381.70	194	2240.08	829.07	581.268
Shyok	10235.40	372	3547.84	1093.48	891.801
Indus	32571.20	1098	688.00	1042.37	46.381
Shingo	4679.50	172	36.91	99.65	1.009
Astor	4214.00	588	607.03	549.05	47.931
Jhelum	9198.40	384	148.18	258.43	6.943
Total	**128730.80**	**5218**	**15040.70**	**9718.21**	**2738.510**

All the ten basins contribute to a total glacier area of about 15,040.7 sq. km which is 11.68% of the total geographic area of the glaciated region of Pakistan. The Mountain glaciers contribute 18% to the glaciated area while the subtypes of Mountain glaciers collectively contribute only 7% **(Figure 3b)**. Ice cap glaciers are smallest and therefore, contribute the minimum area. In Swat, Shingo, Astor and Jhelum River basins the area coverage of Valley glaciers is less than Mountain glaciers while in rest of the basins the Valley glaciers have more area than Mountain glaciers. The Shingo and Jhelum river basins contribute less than one percent to the glacier area. On contrary only 194 (4%) glaciers in Shigar River basin contribute about 15% to the glacier area and 1098 (22%) glaciers in Indus River basin contribute only about 5% of glacier area.

The total length of glaciers in ten basins is more than 9,718 km (**Table 1**). The glacier length in Hunza River basin is the highest (about 2,915 km) followed by Chitral (1,416 km) and Gilgit (1,185 km). Shyok and Indus basins have about the same total length of glaciers. The longest glacier Siachen which has length of more than 76 km and area of more than 1056 km^2 lies in the Shyok River basin. In Shingo River basin the glaciers are small in size as well as short in length.

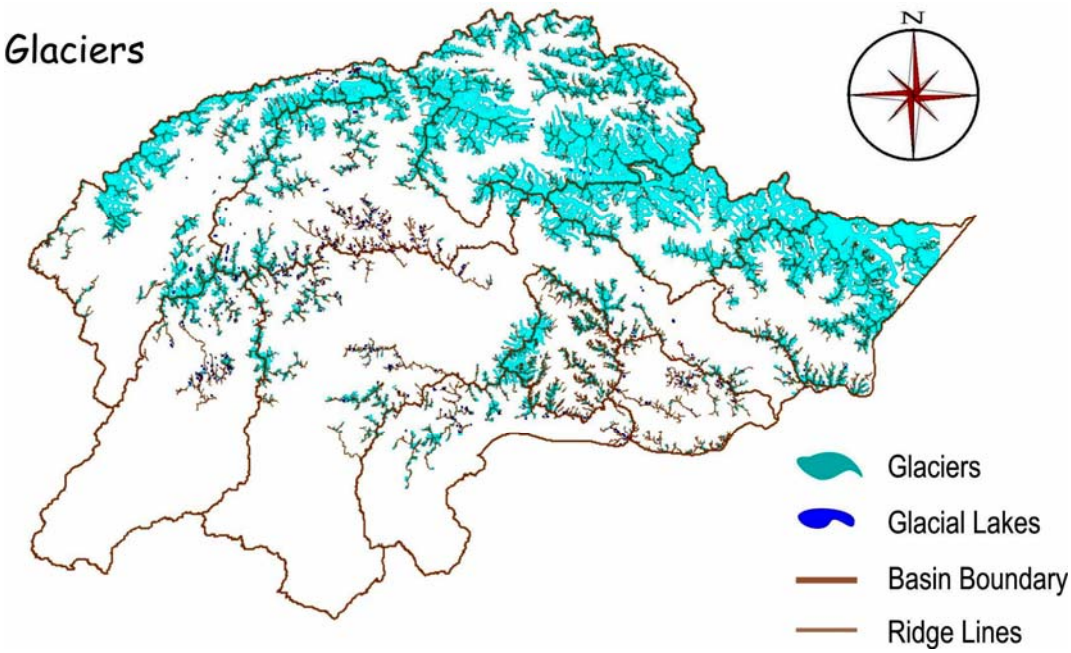
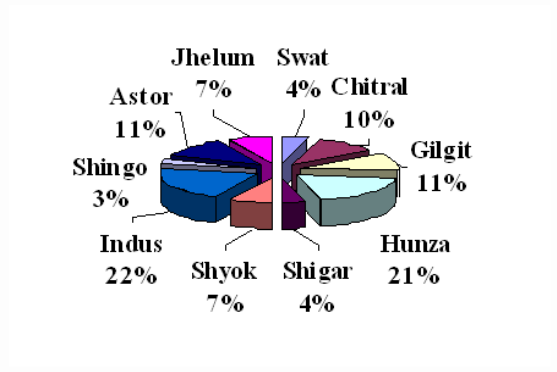


Figure 2: Distribution of glaciers in Northern Pakistan



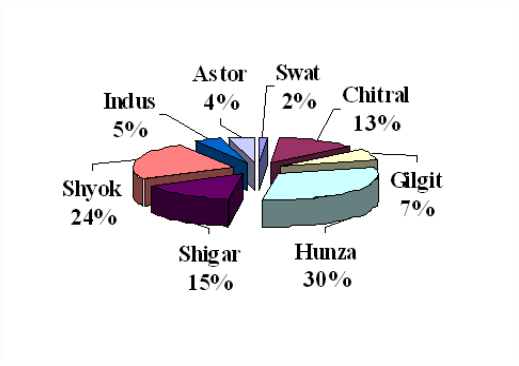


Figure 3a. Proportion of Glacier Number **Figure 3b. Proportion of Glacier Area**

Out of the total of 2,738.5 km^3 of ice reserves of 10 basins, more than 82% of ice reserves of the basins are contributed by Shyok (32%), Hunza (30%) and Shigar (21%) river basins (**Table 1 and Figure 3c).** Another 9% is contributed by Chitral River basin. The contribution of Shingo and Jhelum River basins is very low. To the total ice reserves generally the Valley glaciers are the major contributors followed by Mountain glaciers. The contribution of southern basins especially Swat, Jhelum and Shingo is extremely low for being 0.74% altogether (**Table 1**).

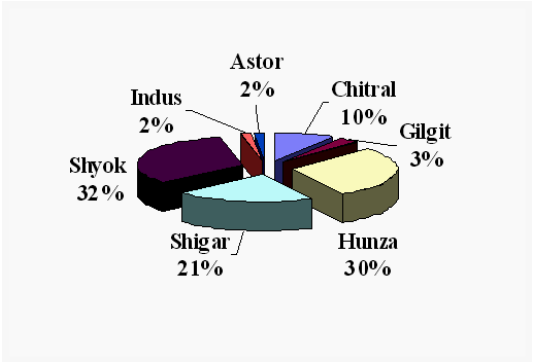


Figure 3c. Ice reserves (percent).

Aspect wise, maximum glaciers are oriented towards N and NE. Each basin behaves differently as far as the orientation of the glaciers in various ordinal directions is concerned. The glaciers in Indus, Jhelum and Shyok River basins are generally oriented towards northern and eastern aspects. In Shyok River basin besides the northern aspects the southern aspects have also higher number of glaciers. The Shigar River basin has

glaciers in all direction but predominantly in north and north eastern aspects. In this basin north western aspects also have higher numbers.

Glacial Lakes

A total of 2,420 glacial lakes have been identified in ten river basins of HKH region of Pakistan (**Table 2**). The maximum glacial lakes are identified in Gilgit River basin (614) followed by Indus (574), Swat (255) and Shingo (238) River basins. The lowest number of glacial lakes is in Shigar (54) and Shyok (66) River basins. Among various types of lakes the highest number is of Erosion type (1,064). In Hunza River basin the lakes are lowest in number and in Shigar these do not exist. The Erosion lakes are followed by Valley lakes (412) and End Moraine Dammed lakes (322). Blocked lakes are lowest in number (51) out of which 21 are present in Shigar River basin while in Shingo and Jhelum river basins these are one each. The Cirque lakes are more common in Gilgit, Indus, Jhelum, Astor and Shingo River basins. Similarly the End Moraine lakes are also common in these basins along with Swat River basin while Lateral Moraine lakes are highest in number in Indus and Gilgit River basins. The Supraglacial lakes are common in the basins where there are large size glaciers like Indus, Hunza, and Shigar. Very few Valley lakes are present in the northern basins like Shigar (2) and Shyok (8) River basins. Distribution of these lakes in different river basins is shown in **Figure 4**. Generally the lakes are distributed all over the ten basins but mostly concentrated at different locations. The maximum concentration is observed in the northern part of Indus River basin and adjoining southern part of Gilgit River basin. In the northern part of Jhelum River basin and eastern part of Shingo River basin bordering the Indus River basin clusters of lakes are found. In the center of Astor River basin the glacial lakes are quite prominent. **Figure 5** shows image glimpses of some major glaciers and glacial lakes in HKH region of Pakistan.

Table 2: Summary of glacial lakes in selected ten basins

Basins	Number of lakes			Lake Area (km^2)	Largest lake (km^2)
	Total	Major	Dangerous		
Swat	255	163	2	15.862	0.81
Chitral	187	70	1	9.365	1.86
Gilgit	614	380	8	39.17	2.72
Hunza	110	47	1	3.215	0.29
Shigar	54	11	-	1.092	0.24
Shyok	66	31	6	2.682	0.27
Indus	574	328	15	26.063	1.35
Shingo	238	139	5	11.59	1.36
Astor	126	64	9	5.528	0.54
Jhelum	196	95	5	11.786	1.04
Total	**2420**	**1328**	**52**	**126.353**	

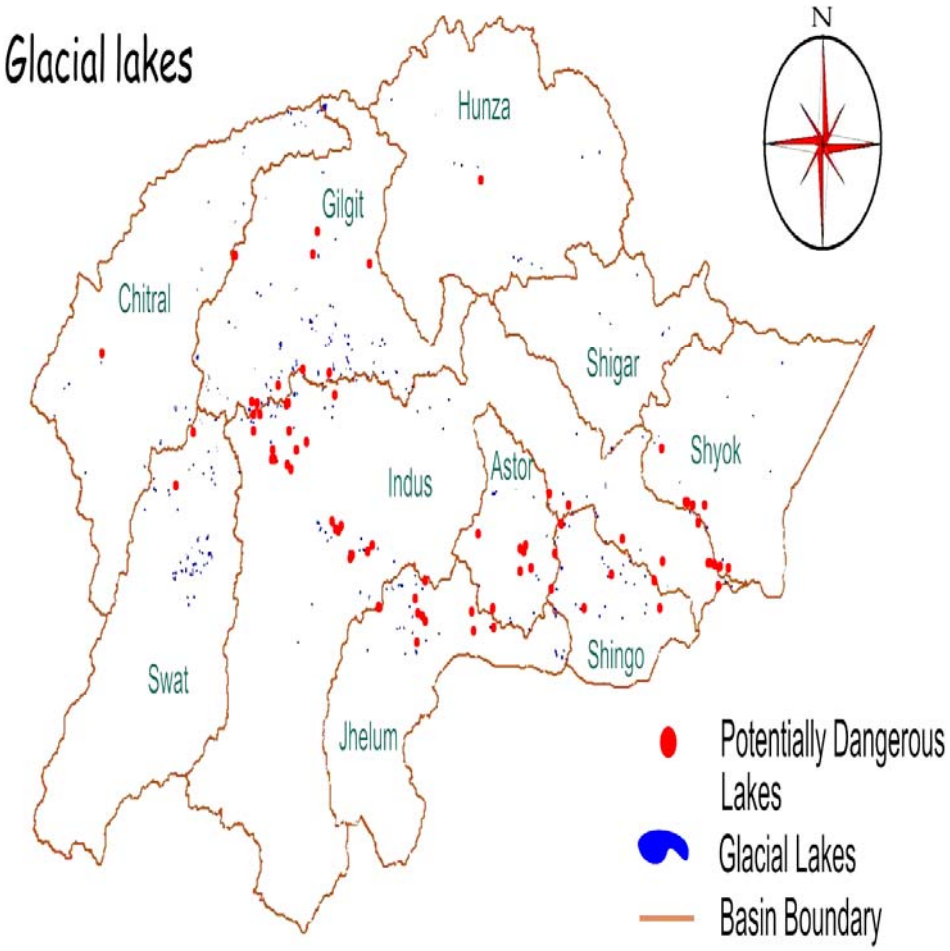
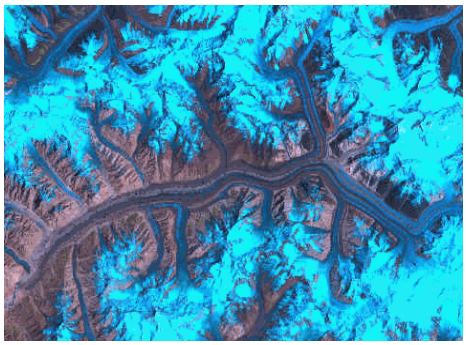
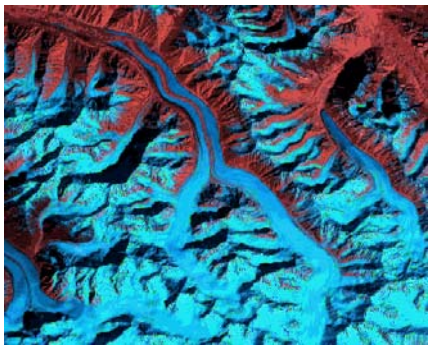


Figure 4: Distribution of glacial lakes and potential GLOF lakes in Northern Pakistan

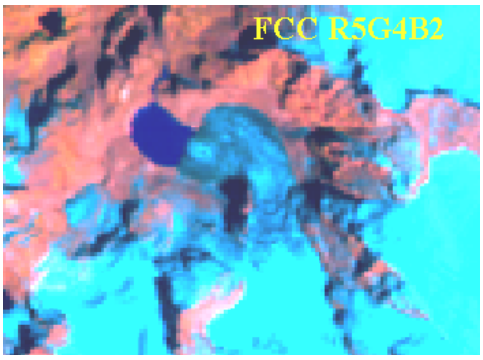
A total of 2,420 glacial lakes in HKH region of Pakistan contribute 126.35 sq. km of lake area. The maximum lake area is recorded for Gilgit River basin (about 39.2 sq. km) followed by Indus River basin (26 sq. km). Just like the lowest number, the lowest lake area was recorded in Shigar and Shyok River basins **(Table 2)**. The southern basins especially Shingo and Jhelum contribute equal lake area (about 12 sq. km each). Among the various types of lakes, Valley lakes are the largest and altogether contribute about 33% of the total lake area followed by Erosion (26.5%) and End Moraine Dammed (18%) lakes. Generally Blocked, Supraglacial and Later Moraine lakes are small in size and contribute very low lake area.



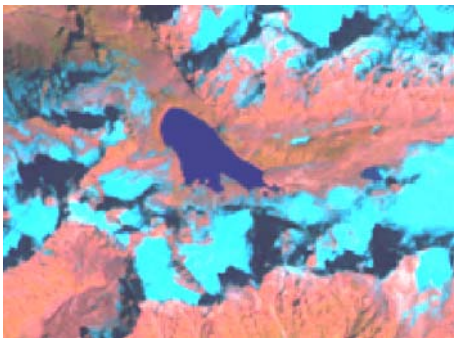
Baltoro-a gigantic Valley glacier in Shigar River Basin



Virjerab glacier in Shimshal Valley in Hunza River Basin



A potentially dangerous lake in Astor River Basin



A glacial lake in Jhelum River Basin

Figure 5: Image clips of some glaciers and glacial lakes in Northern Pakistan

Potentially Dangerous Glacial lakes

Out of total 2420 glacial lakes, 1328 lakes having area greater than 0.02 sq. km are characterized as major lakes. Among these major lakes, a total of 52 glacial lakes are characterized as potentially dangerous lakes based on the earlier defined criteria. Generally the lakes identified as potentially dangerous lakes belong to Cirque, End Moraine and Valley type lakes. Out of 52 dangerous lakes 31 are End Moraine, 13 Cirque and only 8 Valley type lakes. Potentially dangerous Cirque lakes are present in four southern basins namely Indus, Shingo, Astor and Jhelum. Similarly the potentially dangerous Valley lakes are distributed in these basins along with Gilgit River basin. End Moraine type potentially dangerous lakes are present in the entire basin in variable numbers except Shigar River basin.

Glacial Behavior in the Context of Climate Change

Generally the glaciers have reduced in size over the study period. The large size glaciers have relatively less impacted by the climate change as compared to the small size glaciers. In the base year i.e. 1993 there were five glaciers and three glacial lakes in the target sub-basin under study. The individual measurements of all the glaciers and glacial lakes were made and for their behavior over time, the values were compared.

Overall there is a decrease in area, length, ice thickness and ice reserves of glaciers over the period of 12 years **(Table 3)**. Generally the annual rate of decline is more pronounced during the period from 1993 to 2001 compared to 2001 to 2005. Though there is a slight increase (0.47%) in ice thickness during 2001-2005 yet overall there is a decrease in ice reserves.

At the cost of glacial retreat/melt the total area of glacial lakes has increased over the time **(Table 3)**. The total lake length increased over the period from 1993-2001 which reduced in the following observation period i.e. 2001-2005.

Table 3: Behavior of glaciers and glacial lakes in sub-basin of Astor River basin

Glaciers/ Glacial Lakes	Parameters	Year		
		1993	2001	2005
Glaciers	Total Area (km^2)	13.103	9.20	9.12
	Length (km)	11.629	8.178	7.929
	Ice Thickness (m)	276	215	216
	Ice Reserves (km^3)	0.911	0.65	0.639
Glacial Lakes	Total Area (km^2)	0.141	0.289	0.342
	Length (km)	0.881	1.289	1.196

Climatically, in the study area the mean maximum temperature indicates a rising trend during period 1962-2005. The mean maximum temperatures of both Rabi (October-March) and Kharif (April-September) seasons indicate rising trends. Precipitation shows an increasing trend from January to April and than a decreasing trend up to month of June. The winter discharge of Astor River is contributed mainly by precipitation while summer increase in flow is mainly contributed by snow and ice melt besides summer precipitation.

Conclusions

The study reveals that remote sensing technique could be utilized effectively for exploring and observing the glacial resource of northern Pakistan. The results of the study provide baseline information of glaciated region of Northern Pakistan for researchers and planners not only for better management of the fresh water resources for future use but also for developing strategies for regular monitoring of potentially dangerous lakes. On the basis of actively retreating glaciers and other criteria, the potentially dangerous glacial lakes can be identified using the spatial and attribute database complemented by

multi-temporal, remote sensing data sets. Medium to large scale aerial photographs are also useful for detailed geomorphic studies and for evaluation of the active glaciers and potentially dangerous lakes.

The resources can be monitored regularly using high resolution RS data integrated with the GIS technique for climate change studies since the glaciers are highly sensitive to slight changes in climate. The behavior of glaciers and ice masses of the region need to be studied at a larger scale especially in context of climate change scenarios in order to develop better strategies for resource use planning and management at regional level.

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References

Chaohai, Liu and Liangfu, Ding. 1986. The Newly Progress of Glacier Inventory in Tianshan Mountains. In Journal of Glaciology and Geocryology, 8(2): 168-169.

Goudie S., et. al. 1984. The geomorphology of the Hunza valley, Karakoram mountains, Pakistan., published in book "The International Karakoram Project-2" edited by K. J. Miller, Cambridge University Press, p-400.

Khan K. 1992. Glaciers of the Karakoram, Northern Pakistan. Mountnews, No. 5, Centre for Integrated Mountain Research, Punjab Univ. Lahore, 59 pp.

Kick W. 1964. The Chogo-Lungma glacier, Karakoram. Zeitschriff Gletscherkunde udn Glazialgeologie, 5(1): 59p.

Mason K. 1930. The glaciers of the Karakoram and Neibourhood. Geological Survey. India, Rec, 63: 214-278.

Mason K. 1935. The study of Threatening Glaciers. Geog. J., 85: 24-41.

Mool, P.K.; Bajracharya, S.R.; and Joshi, S. P. 2001. Inventory of Glaciers, Glacial Lakes and Glacial Lake Outburst Flood Monitoring and Early Warning System in the Hindu Kush-Himalayan Region, Nepal. 364P. ICIMOD in cooperation with UNEP/RRC-AP, ISBN 92 9115 331 1, Published by ICIMOD, Katmandu, Nepal.

Muller, F., Caflish, T. and Muller, G. 1977. Instruction for Compilation and Assemblage of Data for a World Glacier Inventory. Zurich: Temporary Technical Secretariat for World Glacier Inventory, Swiss Federal Institute of Technology, Zurich

Wissman H. Von. 1959. The Present Day Glacier Cover and Snowline in High Asia. Akad. D. wiss. Und.d. Litt. 14: 1101-1436.

Climate Change and Tree-limit status: A case study Based on comparison between an optimistic scenario for European mountains and a pessimistic one for Pakistan

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ABSTRACT

In the European sub-alpine areas the climate warming in the 20th century has forced the tree-limit advance by 100 metres. This progressive shift with respect to high elevation is in concert with glacial retreat. A survey carried out in this context shows that in Pakistan the situation is reversed, resulting in lowering of the tree-limit position by several kilometer down-slope. Human impact seems to be the common denominator, and is used here for interpreting the emerging patterns in the two situations. Comparative assessment suggests that in Europe, unlike in Pakistan, the extensive utilization of alpine and sub-alpine areas by man for summer farming was abandoned in the early part of 20th century, which lead to the stabilization of the tree-line ecotone. Measures are suggested for conservation of tree-line ecotones and adoption of a sensitive bio-monitoring system by putting an economic value on the indirect benefits provided by the tree-line species. Adoption of such measures by the planners will help them in appreciating and predicting, in a more precise fashion, the likely, immediate and future costs of climate change to the country.

INTRODUCTION

The natural elevational tree-limit is assumed to represent an ideal 'early warning line', predicted to respond positionally, structurally and compositionally even to quite modest climatic fluctuation (Kullman, 2001). In Europe in the beginning of the 20th century the abandonment of extensive farming in the intrinsically fragile areas lead to the adoption of new participatory and integrated approach by agencies which were initially responsible for environmental degradation in the sub-alpine and alpine ecosystems (Young, 1991). This practice based on conservation of fragile areas lead to the present optimistic scenario of climate change and tree-limit rise in Europe. This paper is based on a comparative assessment of the policies and methodology adopted by the European countries derived from published literature, with that of a reconnaissance survey carried out in the Naltar National Park Northern Areas of Pakistan. The protected area was

selected as a representative site to examine the status of trees beyond timber line. The general decline of the status of tree-line ecotone is attributed to the attitude of the Government which has not defined lawful rights and concessions enjoyed by local people in this zone (Khan, 2003). This attitude is partially because of the inaccessible location and partially because of low market values of the species growing there. Since rights practiced by the local people are substantial, therefore herders at sub-alpine and alpine region are allowed unrestricted grazing of livestock, and timber extraction for construction and firewood for domestic purposes (Ahmad, 2000; Champion et. al, 1965). Consequently the sub-alpine forest in these regions have receded several thousand meters downhill, giving way to bare eroded landscape (Khan, 2003)

The main objectives of this paper is firstly, to identify the status of tree-line ecotone in Pakistan, secondly, to identify gaps on the basis of comparative assessment with the European scenario, and finally, to develop a rationale emphasizing the adoption of sensitive bio-montoring by integrating patterns of glacier retreat with the tree-limit status and suggest measures to improve the good governance of sub-alpine and alpine areas.

METHODS

The methodology adopted for identification of major issues in the two situation are based on information gathered from a survey report and published literature. The dominant tree-limit ecotone species 'Birch', is considered in this paper as an indicator for sensitive bio-monitoring of climate change. The following section list the criteria adopted in the two situation.

I Treelimit status in Himalayan context

The reconnaissance surveys in Pakistan is based on the following methods. A general survey of the tree limit area was carried out in the Naltar National Park, and six sites were identified. The sites were then classified on the basis of criteria that was used at each site to assess status of Birch, the dominant tree in the tree-line ecotone.. The following criteria was adopted for the classification of the sites.

a. Distances from settlement areas
b. Distances of relict trees from the tracks.
c. Amount of litter (thickness)
d. Presence of ground vegetation
e. Recruitment of trees and age structure
f. Pattern of extraction
g. Appearance of Spruce in the Birch formation.

II Tree-limit status in the European context

The information on "Tree limit rise" the European scenario was based on the published literature (Hofgaard, 1999; Kullman, 1979; 1981; 1986; 1993; 1998; 2001; MacDonald, at. El., 1998; Payetter and Filion, 1985) and was classified under the following categories to evaluate the situation in Pakistan:

i. Ecological equivalence between the tree limit ecotone of two biogeographical regions
ii. Anthropogenic utilization of tree-limit ecotone.
iii. Climate change scenario and growth in height of established individuals and upslope migration of new individuals.
iv. Establishment of regional baseline network for the quantification of data.

RESULTS

The results are discussed in three sections. In the first two sections the sites are discussed and classified according to the criteria identified in the method section. The final section is based on identifying gaps and recommendations for improving the existing conditions**.**

I 'Tree limit fall' the Pakistan scenario

The status of the surviving fragments of tree-line ecotone was compared and evaluated in terms of their long term survival and impending threats of accelerated degradation and climate change. Since the outcome is to be appreciated in terms of indirect significance of the tree-line ecotone in perspective of public value and predicted climate change, therefore, the criteria listed in the method section is used here to classify sites into the following three categories.

i. Intact fragments on inaccessible slopes

These intact fragments can be seen on steep slopes (above 4000, m.a.s.l) situated away from the well-trodden routes, used by the herders to reach the alpine meadows. Even here occasional extraction of the wood is observed, but is mostly restricted to the perimeters. The central part has intact cover of Birch forest with scattered Spruce downhill. It has plenty of regeneration, and has a thick layer of litter. These fragments can survive over long period of time as the anthropogenic influence is less significant. The transition from Spruce-Birch to Birch are clearly marked, with vertical extent of 100-300m above the pure coniferous forest. It appears to be an ideal site to monitor tree limit status. But since sites are sandwitched between steep slopes on very fragile terrain that could make them susceptible to decimation in case of any stochastic or deterministic events.

ii. Disturbed fragments near settlements

This is located on flat terrain with a large lake (Blue lake), and appear to be ideal sites for the birch forest. Unfortunately, such sites are also ideal for the establishment of temporary settlements (Fig. 1).