ADAPTING TO RISKS OF CLIMATE CHANGE

By

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Risks Due To Climate Change

Throughout the 20th century, it was apprehended that the increasing use of fossil fuels and other emissions would accumulate in the atmosphere, and may cause warming of the earth. But opinions differed about the impact of such a change on the world's climate, humans and the eco-systems. Now the situation has reached a final and worrisome conclusion.

Over the past century, mean global surface temperature has increased by 0.4^0 to 0.8^0 Celsius (C). According to the IPCC, GHCs released by human action are likely to have been responsible for most of the warming of the past 50 years. Other observed changes are consistent with this warming. Sea levels rose 10 to 20 centimeters over the past century. Over the past 50 years, the summer extent of arctic sea-ice has shrunk by 10 percent or more, and its thickness by 40 percent. Outside the Polar Regions, glaciers are retreating, affecting mountain ecosystems and water flows. Droughts have become more frequent and intense in Asia and Africa. Many of the world's coral reefs have been damaged associated with higher sea temperatures. Animals and plants have shifted their geographic ranges and behavior.

Unchecked, these impacts are predicted to intensify, posing risks of varying kinds for different countries. Impacts will fall heavily on many developing countries, including those that have not contributed to climate change. They are more vulnerable and they have less institutional capacity to adapt to change.

Low-lying islands and coastal areas everywhere will be exposed to flooding and storm damage. Bangladesh, for instance, may be severely hit. A recent study predicts that by 2030 an additional 14 percent of the country would become extremely vulnerable to floods caused by increased rainfall. A 10-centimeter increase in sea level would permanently inundate 2 percent of the country, with the additional effect of making floods more severe and longer lasting. Saltwater intrusion, and more severe dry seasons, will reduce fresh water availability in coastal areas. As coastal populations swell worldwide, a 40-centimeter rise in the sea level would increase the number fo coastal dwellers at risk of annual flooding of more then 100 million; 90 percent of them in Africa and Asia. The starkest local impacts are faced by the low islands of the Pacific, some of which could lose their freshwater and be largely inundated during storm surges if sea levels rise.

Climate change could damage developing-country agriculture. Even taking into account crop substitution possibilities, one study finds that a 2^0 C temperature increase

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decreases the value of Indian agricultural land by 36 percent. Arid and semi-arid areas in Africa and Asia will probably face higher temperatures. Feedback between vegetation loss and reduced rainfall could result in faster desertification.

Impacts on industrial countries are thought to be mixed, but may be generally negative. Agricultural productivity will likely improve, in the medium term, in some northern area. But southern Europe will likely suffer drier summers; much of Europe could experience river flooding. The Atlantic coast of the United States will be vulnerable to rising sea levels, and Australia will likely be more subject to drought.

Current understanding also depicts the global climate as a finely balanced mechanism that goes awry when stressed, with prehistoric instances of 10^0 C global temperature changes occurring within the span of a decade. There is a risk of catastrophic consequences of climate change that could be irreversibly set in motion during this century. There could, for instance, be an abrupt failure of the great ocean "conveyor belt" currents that warm the North Atlantic and mix deep with surface waters. Biodiversity losses could be massive as habitat fragmentation makes it impossible for plants and animals to migrate in response to rapidly changing temperatures, the risks are difficult to evaluate, but they affect industrial as well as developing countries and are credible enough to demand attention. At the very least they put a premium, or option value, on maintaining lower levels of atmospheric GHGs while the world more carefully examines the consequences and develops options for mitigation.

"The futures of hundreds of millions of people across the world will be affected by declines in snow cover, sea ice, glaciers, etc." The Global Outlook for Ice and Snow report, published by the United Nations said;

> "Impacts are likely to include significant changes in the availability of water supplies for drinking and agriculture, rising sea levels affecting low lying coasts and islands and an increase in hazards such as subsidence of currently frozen land," it said.
>
> The Arctic ice sheet has shrunk by six to seven percent in winter and by 10 to 12 percent in summer over the past 30 years, the report said.

The snow-covered regions of the northern hemisphere have reduced by between seven and 10 percent during March and April during the same period, according to the report presented by the UN Environment Programme (UNEP).

The melting of the ice and snow is not only a consequence of global warming, it is also an accelerating factor, researchers presenting the report in the Norwegian Arctic town of Tromsoe said.

> "Snow and ice reflect 70 to 80 percent of the sun's energy, whereas water absorbs it. If snow and ice continue to melt,

this will amplify global warming," report author Paal Prestrud made his presentation."

"Six and a half billion people on this planet have built their way of life… around a certain reality. This reality is changing even more rapidly than expected," UNEP executive director Achim Steiner added.

The acceleration process also makes it more difficult to anticipate furture developments, he said.

"(This process) is of such magnitude that our ability to predict the future is severely constrained," Steiner said.

"This means that the adaptation process of coping with climate change is potentially so far-reaching in terms of economic costs and consequences tht we have t act now," he added.

For instance, an estimated 40 percent of the world's population could be affected by the loss of snow and glaciers on the mountains of Asia, according to researchers.

Many rivers of the continent, such as the Ganges, the Brahmaputra or the Mekong, rise in the Himalayas and less ice and snow would mean less water for drinking and agriculture.

Rising sea levels would affect low-lying coasts and islands, something of particular concern for countries such as Bangladesh and Indonesia.

"We have begun to understand how vital ice and snow are for our societies.

In Italy the reduction in snow means less water I the rivers which means power stations have to be shut down," Steiner said.

It is feared that melting ice and snow could trigger more abrupt climatic changes, such as hurricanes and floods, with wider-ranging impacts on people, economies and wildlife. Melting ice and snow were considered more likely to increase hazards such as avalanches and floods from the build-up of potentially unstable glacial lakes.

Rising temperatures and the thawing of permafrost, or frozen land, were also triggering the expansion of existing lakes and the emergence of new lakes and rivers I places like Siberia.

"If the permafrost thaws, it will (further) amplify global warming and will change current sea levels," Prestrud said.

According to one assessment report, submitted by the government to the secretariat of UN Convention, Combat Desertification, majority of the people in the country depend on arid and semi-arid areas to support their livelihoods through agro-pastoral activities.

"Desertification process resulting form degradation of lands is threatening most areas of the country and the underlying factors include a mix of natural and anthropogenic causes," says the report.

It listed at least eight main threats leading to further degradation of productive land in the country, which include climate change, rising temperature, extended droughts; diminishing supplies of fresh water resources for irrigation; erosion, land sliding and earthquake in dry uplands; wind erosion, moving sand dunes in deserts; deforestation and loss of biodiversity; mismanagement of arable lands; and overuse of grazing lands.

Keeping in view the magnitude of the problem and possible measures to address land degradation issues in the country, the ministry of environment with the financial support of the GEF-UNDP has launched a full-scale project on sustainable land management to combat desertification in Pakistan.

Effect on fresh water of Pakistan

There are strong indications that climate change is likely to affect Pakistan in a number of ways as the Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers in a dramatic manner. While the science is still in its infancy, best estimates are that there will be fifty years of glacial retreat, during which time river flows will increase. This process in combination with predicted erratic rainfall—is likely to exacerbate already serious problems of flooding and draining, especially in the lower parts of the basin, in the next few decades. But then the glacial reservoirs will be empty, and there are likely to be dramatic decreases in river flows—as shown in fig. 3.6, conceivably by 30 % to 40 % in the Indus Basin.

Deglaciation is, of course, not the only way in which climate change is likely to affect the availability and timing of runoff in the subcontinent. The Intergovernmental Panel on Climate Change (IPCC) uses ten General Circulation models, nine of which project that precipitation during the summer monsoon will increase substantially.

The IPCC has used a regional model (curiously based on the one global model which showed reduced precipitation) to explore possible changes in the number of rainy days and in extreme rainfall in India (with obvious extrapolations to Pakistan). This model predicted a decrease in the number of rainy days but substantial increases in extreme precipitation events.

What does seem likely is that climate change will increase the variability of already highly unpredictable rainfall patterns, requiring greater investments in managing both scarcity and floods.

As a result of impending climate change following dangers are looming over the future of Pakistan;

- The subcontinent is dependant largely on the Himalayas for rain, drinking water and irrigation water. If the snows on the Himalayas and the Hindu Kush Range start melting at a faster rate, it will affect the entire ecosystem of the subcontinent, including river flows, fish stocks, flora and fauna. The rise in the sea level will submerge many coastal cities and areas.

- Three-fourth of the water flowing through the river Indus, Jhelum and Chenab originate in the Siachen and other Himalayas glaciers. If these glaciers start melting at a faster pace due to global warming, they could virtually disappear in the next half century. This means increased frequency of floods in the foreseeable future but serious shortage of water in the rivers after some time threatening the livelihood of people dependant on them.
- The quality of water is constantly deteriorating because of excessive pumping of underground water much of which is saline. Similarly the extraction of sweet water is eroding the centuries old aquifer,
- Air and water pollution due to the increasing use of fossil fuels is growing in all major cities like Karachi, Lahore, Peshawar, Faisalabad and Multan leading to health problems, particularly for the poorer segments of the population. The resources required to provide clean air and water to the populations are beyond the fiscal capacity of most developing countries like Pakistan.

"The long-term sustainable average annual net inflow of the Indus Basin is 175 billion m^3 and canal diversions over the same period have averaged 128 billion m^3, with an average of 35 billion m^3 flowing downstream of Kotri Barrage to the sea. In a system with little storage and considerable variability, however, averages can be deceptive and it can be said that 'Pakistan is now essentially at the limit of its surface water resources".

Our rivers are heavily dependant on the glaciers of the Western Himalayas which act as a safe deposit to capture snow and rain and subsequently release it into the rivers during summer. Therefore, it is quite certain that Global change in the climate will have serious influence on hydrology of the Indus Basin.

The phenomenon of deglaciation is likely to affect the availability and timing of river run-off in the subcontinent. The Inter-Governmental Panel on Climate Change (IPCC) predicts that decrease in the number of rainy days but substantial increase in extreme precipitation events. Therefore, there are chances that the climate change will increase the variability of already varying variable rainfall pattern, and therefore requiring more care in water management in situation of water scarcity and floods.

GCICS is actively involved for the assessment of likely climate change impacts on fresh water resources of Pakistan inline with IPCC climate change scenario for the current century, and identification of appropriate coping mechanism for the adverse impacts. They are using the following models for their Research Program;

1. University of British Colombia's (UBC) Watershed Model: Semi Distributed Model
2. Distributed Hydrology Soil & Vegitation Model (DHSVM): Distributed Model

The likely change in temperature and precipitation can be summarized as under:

	2020s	2050s	2080s
Temperature Change Δ T (^{o}C)			
Northern Pakistan	1.41±0.13	3.09±0.29	5.32±0.53
Southern Pakistan	1.04±0.11	2.47±0.14	4.33±0.28
Precipitation Change Δ P (%)			
Northern Pakistan	5.15±1.87	6.20±3.87	6.06±6.15
Southern Pakistan	18.83±4.76	20.24±10.15	28.30±11.73
% Change in Annual Volume on UIB Inflows			**- 14 %**
% Change on account of Glaciers			**- 21 %**

The impact of Climate Change and Glacier Melt on Indus Basin can be summarized as per following table;

Volume Unit	Total Annual Volume		Glacier Contribution Only	
	Base	Climate Change Scenario	Base	Climate Change Scenario
MAF	58.09	49.80	22.87	18.06
% Change in Annual Volume				
	- 14 %		- 21 %	

Similarly, on groundwater: 'Estimates of groundwater availability have been made in several studies, and average around 63 billion m^3 abstraction of groundwater for irrigation and for urban and rural drinking water supplies is estimated as about 52 billion m^3. While these figures may suggest some potential for further exploitation, they are based on very little actual monitoring of the resources or the abstraction and should be treated with caution. Other evidence, such as increasing salinity of groundwater due to redistribution of salts in the aquifer and declining water levels, suggests that there is little, if any, further potential for groundwater exploitation'.

The bottom line is clear—Pakistan is currently close to using all of the available surface water and groundwater, yet it is projected that over 30 percent more water will be needed over the next twenty years to meet increased agricultural, domestic, and industrial demands.

Adapting to risks of Climate Change

If there is universal awareness of these realities and dangers, then the collective efforts of governments, civil society, farmers, and the business community could make a difference before it is too late. We could, for example, adopt the following policies and programmes at the national and local levels:

— Mitigation of global warming covers all actions aimed at reducing the extent or likelihood of global warming. The world's primary international agreement on combating climate change is the Kyoto Protocol. Various other strategies include development of new technologies, wind power, nuclear power, renewable energy, biodiesel, electric cars (and hybrids), and fuel cells, Energy conservation, carbon taxes and carbon sequestration schemes.

— A drastic switch from oil or coal-based generation of electricity to renewable sources of energy. In Pakistan, the proportion of hydroelectricity has already declined form 60 to less than 30 per cent.

— Adoption and enforcement of strict environmental standards for motor vehicles to reduce emissions. A time limit of two to three years should be fixed to switch all public transport i.e. buses and rickshaws in cities to cleaner fuels.

— Enacting and enforcement of strict legislation for controlling industrial pollution in polling industries.

— Preparing a comprehensive flood protection plan to mitigate the danger of increased flooding as a result of global warming.

— A major programme of aquifer recharge should be undertaken in sweet water zones to ensure sustainable agriculture and the price policy for water and tube-wells should be reviewed on the basis of environmental criteria.

— Large-scale afforestation through public-private partnership programmes. For this purpose, a "green Pakistan" fund can be created on the model of the Green Belt Programme in Kenya. This fund can work with community or non-governmental organizations, which are interested in planting trees in their areas. They can be given free seedlings and then a fixed amount per tree after it has reached a certain age at which it can grow automatically. Substantial funding can be obtained for such a programme from the UN or under various carbon trading schemes.

— We should not forget that it took 18 centuries for the world population to reach one billion. The next billion was added in 100 years, the third in 35 years, but it now takes less than 15 years to add another billion. By 2030, the world population would be nine billion. This will create additional strains on the earth's resources for food, water, fuel, transport and raw materials.

Key decisions must be taken within five years on measures to tackle climate change if the world wants to cope with an expected doubling energy demand over the next half century. Delay would expose the planet to dangerous warming within a lifetime or force even harsher and costlier measures that could cause significant damage to global economy, WWF International said in a technical report.

> “The question for leaders and governments everywhere is how to rein in dangerously high levels of carbon dioxide emissions without stunting development and reducing development and reducing living standards. We have only five years to take necessary steps to deal with the problem and we can’t afford to waste this time, the report said.”

The report set a target of limiting the increase in global average temperature to two degree centigrade by 2050 and a 50 per cent cut in greenhouse gas emission in the same timeframe. The WWF agreed with a recent report by a UN panel of scientists underlining that the worst consequences of global warming can be averted with known technologies, alternative energy sources and energy-saving measures. The report advocated six key solutions, including more efficient energy use, the reversal of deforestation, accelerated development of low emission technologies such as wind and solar power, as well as energy storage.

The WWF also wants coal-fired power stations to be replaced by gas, and more carbon capture and sequestration to cope with continuing emissions from fossil fuels like oil. Together they could cut carbon dioxide emissions about 60 to 80 % by 2050 provided they are implementation on time. Leape rated measures like investment in energy efficiency in buildings and transport as “no brainers” because they could bring huge against at relatively low cost and with little risk.

The report underlined that if concerted decisions are taken by every country within five years, the measures could start to have the desired impact in a decade “based on the real world constraints” of industry’s ability to adapt. The “Climate Solutions: WWF’s Vision 2050” was produced by a task force that includes 100 scientists and experts. It focused purely on the issue of what is known about the technologies and physical resources available as well as industry’s ability to cope with change. It did not examine the economic costs, or the exact policies needed to implement the steps. But the WWF said it was “acutely aware” that ending the dominance of oil and coal, phasing out nuclear power, or rapidly and unsustainably expanding biofuels could cause huge social, environmental and economic upheavals if they are badly managed. Reports by the UN’s Intergovernmental Panel on Climate Change this year underlined that efforts to stabilies the level of greenhouse gases over the next 20 to 30 years will be crucial in the fight against global warming.

The IPCC scientists said carbon dioxide emissions by industry, transport and households were already having an impact on the world’s climate and were set to wreak huge damage on human settlement and wildlife this century if they went unchecked.

The assessment points out that the living machinery of earth has a tendency to move from gradual to catastrophic change with little warning. Such is the complexity of the relationship among plants, animals and micro-organisms that these "tipping points" cannot be forecast by the existing science. Abrupt changes can have devastating impacts on human communities. The buildup of nitrogen and phosphorus in lakes, estuaries, enclosed seas for example, can continue for years before suddenly triggering an explosive growth of algae.

Impact Of Temperature Gradient With Time & Its Variation With Reference To Change Of State

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Abstract:

In Pakistan the water availability in the country from practical point of view and its applications for electricity generation and for irrigation purposes is highly dependent upon melting of snow. Temperature variations are responsible for the change of state of water particularly from solid to liquid state. Different stations with reference to temperature of different months are selected as independent variables in upper & lower catchment of Mangla and Tarbela reservoirs, which are country's biggest reservoirs. Cold winters are indicative of more snow over the mountainous regions, therefore, colder the winters, more snowfall and correspondingly more water in the reservoirs. As the snow starts thawing in post winter months when there is sufficient increase in atmospheric temperature in upper catchment areas of the reservoirs. The graphical results and trend line are indicative of direct proportionality and variability of low temperatures, which have direct bearing with upper catchment areas, unlike rainfall the temperature in lower catchment areas has an indirect relationship with inflows.

Key Words:

Temperature gradient, snow cover, water in reservoirs.

1. Introduction:

An effort has been made to investigate the impact of temperature gradient and its variations with reference to change of state. In physical science, atmospheric thermodynamics is the study of heat and energy transformations in earth's atmospheric system, which follows the fundamental laws of classical thermodynamics. Clasius-Clapeyron equation, which involves thermodynamic variables, explains change of state and transformation in different states of water. Temperature is an important thermodynamic variable responsible for the change of state, from solid to liquid and from liquid to water vapours in earth's atmospheric system. Main purpose of this research is to study the temperature variations with time and its effects on snow-melting and corresponding increase or decrease in inflow of the reservoirs.

2. Climate of Pakistan:

"Climate is the state of atmosphere over long period of time".

Pakistan lies in the temperature zone. The climate is generally arid, characterized by hot summers and cool winters, and wide variations between extremes of temperature at given locations. Therefore meteorological conditions over Pakistan are different from the other eastern countries of Asia in winter.

Generally, the southern part of Pakistan falls under the category of tropical region, however the area above Sindh province is part of subtropical climate region with the rainfall maxima in summer. The northern part of Balochistan has Mediterranean climate, with rainfall maxima in winter. The lesser Himalayas and the mountainous areas of northwestern mountains ranges including greater Himalayas, Karakorum and Hindukush fall under the category of tundra.

From arid hot deserts in the southwest to frigid mountain peaks in the north to southern and eastern parts of the country are under monsoon influences, with rainfall mostly occurring in the hottest of June & July. Precipitation in the drier western and northern areas comes in winters as snow. The Himalayan foothills of NWFP and northern Punjab, with 500 to 1500 mm of summer rain, are the most heavily forested regions. By contrast, the Punjab, Sindh and Balochistan plains and deserts, with less than 250 mm rainfall and with summer temperatures well over 40^{o}C.

3. Seasons of Pakistan

God blessed Pakistan with wonderful type of seasons. Temperatures can vary across the country with very high and very low temperatures at varying times of the year. During the summer on the plains, for example, the temperature can reach as high as 52^{o}C. Between July and August, the monsoon brings an average of 38 to 51 cm of rain to the plains and 152 to 203 cm in the Himalayan valleys of Murree, Kaghan, Swat and Azad Kashmir. Mainly there are four types of seasons in Pakistan like summer, autumn, winter and spring.

4. Topography of Pakistan

Pakistan is a part of South-Asian Subcontinent. God has blessed this country with vast variety of landscape and almost every type of climate. Before discussing climate variables of Pakistan it will be appropriate to have look on its physical features. Pakistan is a land of vast planes and majestic mountains alongwith its plateaus.

4.1 Upper Indus Plain

This plain starts from the southern foothills of Himalayas and extends upto northern limits of Sindh province. It is the land of five big rivers, the tributaries of Indus. This plain has also very gentle slope. The biggest irrigation system has also located in this plain.

4.2 Northern Mountains

These ranges include some of the world height mountains including Hindukush, Karakoram, and greater & lesser Himalayas. The average height of these ranges is from 3 to 6 Km.

5. Westerly Waves

These are the west to east moving extra tropical low-pressure systems originating from the westerly wave system from Mediterranean Sea. This weather system is present all year round moving along the longitudinal axis, which shifts southwards during summers and northwards during winters.

6. Seasonal Low

This system is created over South-East Balochistan adjoining parts of Sindh and Punjab provinces due to high temperatures during summer.

7. Thermal Low

A thermal low is an area of low atmospheric pressure caused by high temperatures produced by intensive heating of the earth's surface. Thermal lows are common to the continental subtropics in summer. They remain stationary over the area. Cyclonic circulations are generally weak and diffused and they are not fronts.

8. Methodology

Given data of temperature and inflows is statistically analyzed, the temperature values for the months of January, February & March for the stations Muzaffarabad, Chitral, Gilgit and Sialkot (Fig. 1 & 2) and inflow values of Tarbela & Mangla reservoirs are given in the table and graphical behaviour of temperature values with time against inflow values is shown in figures. Result of each graph is discussed.

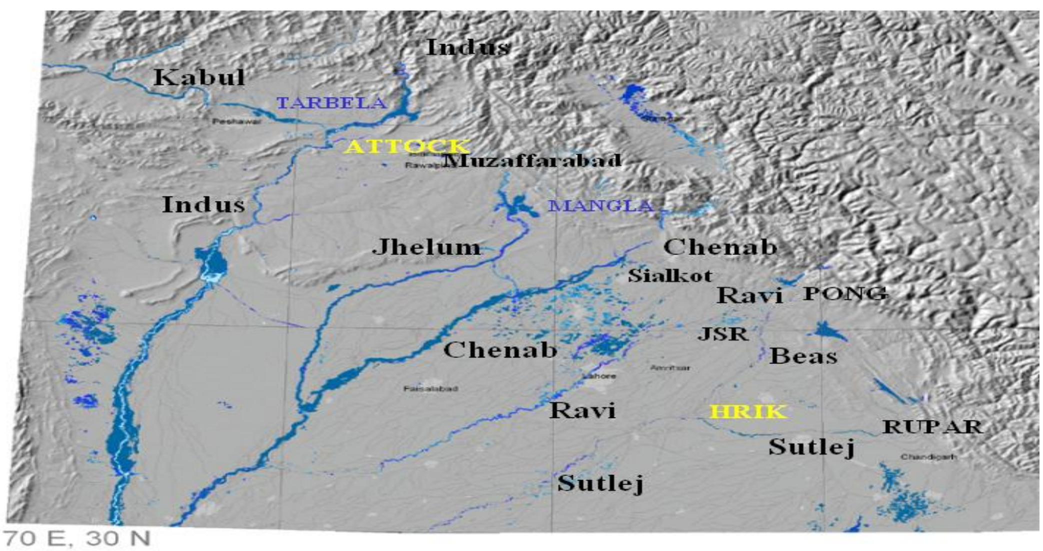

Fig. 1 Map of Muzaffarabad & Silkot area & location of Mangla & Tarbela reservoirs

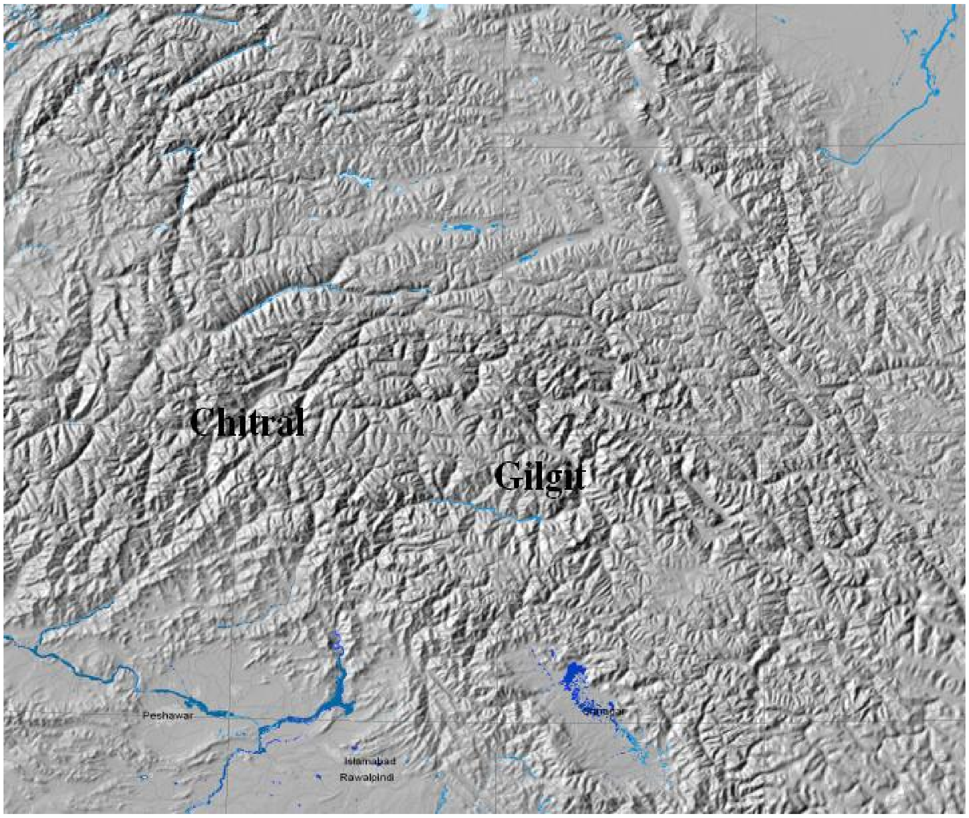

Fig. 2 Map of Chitral & Gilgit area

9. Statistical Analysis

Muzaffarabad, Chitral, Gilgit are in the upper catchment area of Mangla reservoir while Sialkot is in lower catchment areas of Mangla reservoir. Chitral & Gilgit are in the upper catchment area of Tarbela reservoir while Muzaffarabad & Sialkot are in lower catchment areas of Tarbela reservoir.

Temperature data is collected for the time duration 1960-2005, with the time interval of five years for the months of January, February and March of each thirty days. Average temperature values for each month has been calculated. Inflow data of reservoirs, which is based upon 10-daily time scale for the months of April, May, June & average value of each month is calculated.

Years are plotted along abscissa, temperature (January, February, March) along ordinate as primary ordinate and inflow values (April, May, June) are plotted against abscissa as secondary ordinate.

Finally the graph are plotted to investigate the impact of temperature variations with time against inflow, and results are discussed according to the behaviour and trend line of the graphs.

10. Results and Discussion

10.1 Mangla Reservoir

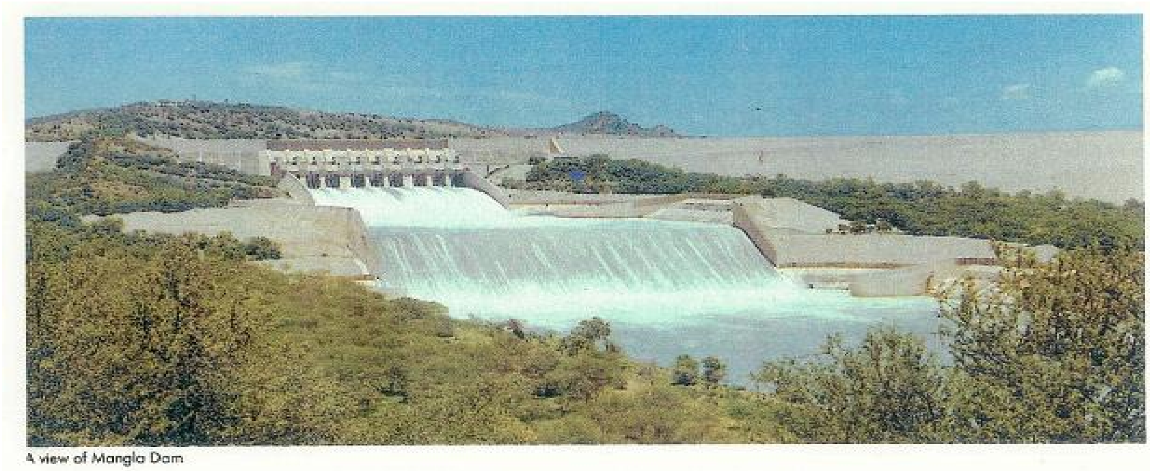

Fig.3 A view of Mangla Dam

10.1.1 Muzaffarabad

The temperature and inflow analysis on pentad basis (05 years average) indicates that there is gradual increase in temperature from 16°C to 20°C (Table-1 & Fig.4). However with the increase in temperature there is no significant increase in Mangla reservoir, which is indicative of fact that rise & fall in Mangla inflow can be dependant upon rainfall & snowmelt in the upper catchments i.e. areas located much north of Muzaffarabad.

Table-1: Temperature values of Muzaffarabad & inflow values of Mangla Reservoir

Sr. No.	Year	Temperature (°C)	Inflow (Cusecs)
1	1960	12.4	36600
2	1965	16.8	76200
3	1970	19.8	36500
4	1975	18.4	55130
5	1980	16.67	58100
6	1985	21.3	35900
7	1990	18.4	68700
8	1995	20	62400
9	2000	19.7	31200
10	2005	16.26	57700

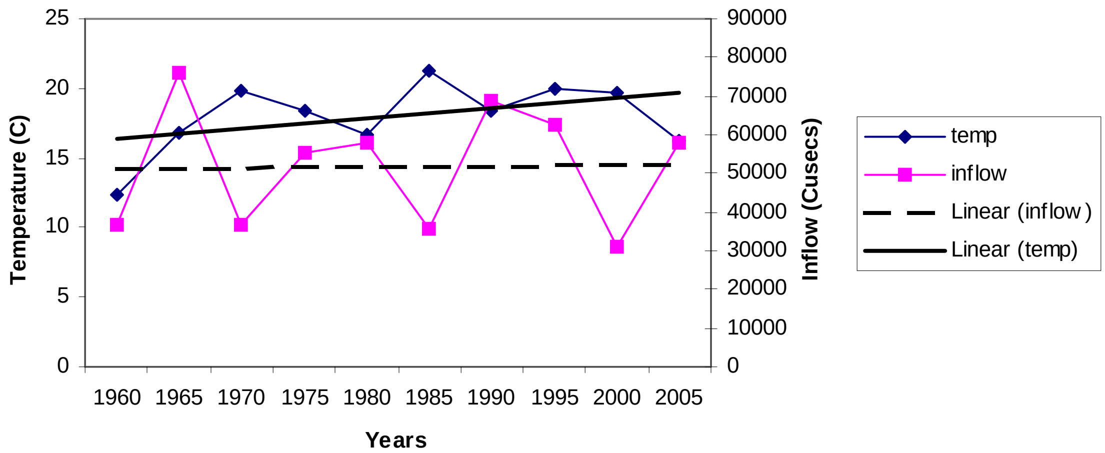

Fig. 4 Effect of Temperature (Jan, Feb, Mar) of Muzaffarabad on the Inflow (April, May, June) of Mangla Reservoir

10.1.2 Chitral

Pentad analysis (Table-2 & Fig.5) indicates significant increase in temperature in Chitral valley around 10^{o}C to 13^{o}C. However, the trend line is not indicative of increase or decrease of inflows which is indicative of that temperature of Chitral valley is not independent variable to determine the inflows in Mangla reservoir.

Table-2 Temperature values of Chitral & inflow values of Mangla Reservoir

Sr. No.	Year	Temperature (^{o}C)	Inflow (Cusecs)
1	1960	8.7	36600
2	1965	10.6	76200
3	1970	12.3	36500
4	1975	9.6	55130
5	1980	10.9	58100
6	1985	13.8	35900
7	1990	11.8	68700
8	1995	12.4	62400
9	2000	13.2	31200
10	2005	11.13	57700

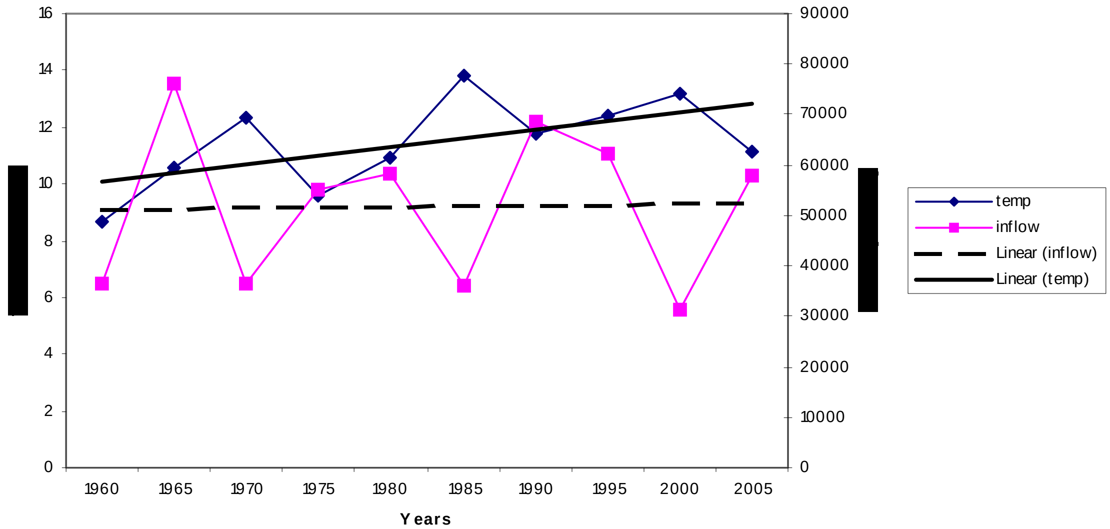

Fig. 5 Effect of Temperature (Jan, Feb, Mar) of Chitral on the Inflow (April,May,June) of Mangla Reservoir

10.1.3 Gilgit

The temperature variations (Table-3 & Fig.6) over Gilgit valley have almost remain constant and similarly the inflow variations have also constant, which can be indicative of fact that there can be a linkage between these two.

Table-3 Temperature values of Gilgit & inflow values of Mangla Reservoir

Sr. No.	Year	Temperature (^{o}C)	Inflow (Cusecs)
1	1960	13.6	36600
2	1965	13	76200
3	1970	13.7	36500
4	1975	12.03	55130
5	1980	12.67	58100
6	1985	14.7	35900
7	1990	13.2	68700
8	1995	12.8	62400
9	2000	14.4	31200
10	2005	13.2	57700

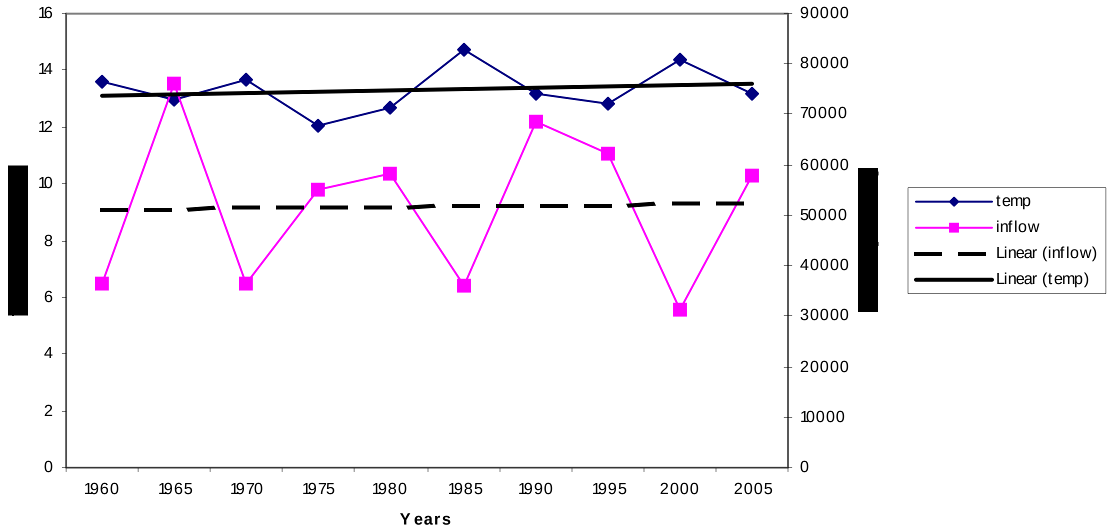

Fig. 6 Effect of Temperature (Jan, Feb, Mar) of Gilgit on the Inflow (April, May, June) of Mangla Reservoir

10.2 Tarbela Reservoir

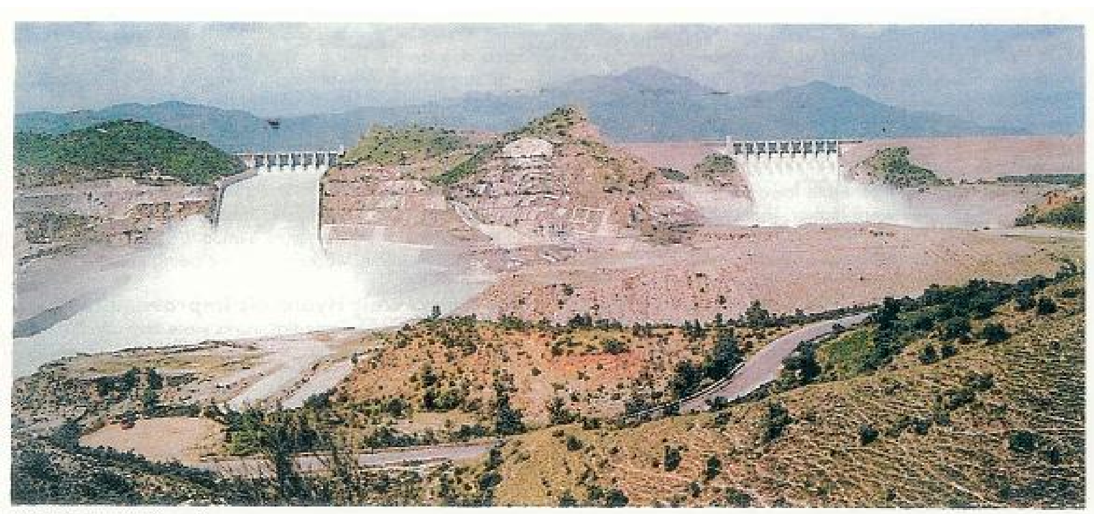
Tarbela Spillways in Operation

Fig. 7 A view of Tarbela Dam

10.2.1 Muzaffarabad

The temperature and inflow in (Table-4 & Fig.8) there is direct linkage between the temperature increase in Muzaffarabad and corresponding increase of inflow in Tarbela reservoir. This linkage is indicative of the similar temperature increase in the northern parts of NWFP as well. This is because of the some westerly disturbances affects Azad Kashmir which affect upper NWFP in beginning.

Table-4: Temperature values of Muzaffarabad & inflow values of Tarbela Reservoir

Sr. No.	Year	Temperature (^oC)	Inflow (Cusecs)
1	1960	12.4	69200
2	1965	16.8	90800
3	1970	19.8	87600
4	1975	18.4	80300
5	1980	16.67	91800
6	1985	21.3	63600
7	1990	18.4	122800
8	1995	20	88890
9	2000	19.7	82000
10	2005	16.26	99800

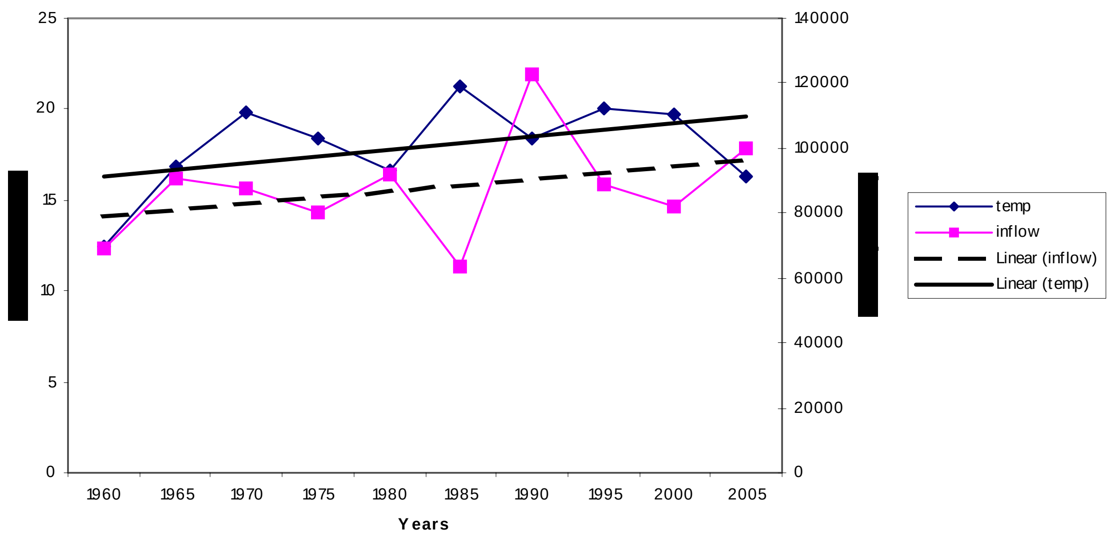

Fig.8 Effect of Temperature (Jan, Feb, Mar) of Muzaffarabad on the Inflow (April, May, June) of Tarbela Reservoir

10.2.2 Chitral

Table-5 & Fig.9 indicate direct relationship of temperature increase in Chitral valley linked with inflow increase in Tarbela reservoir.

Table-5: Temperature values of Chitral & inflow values of Tarbela Reservoir

Sr. No.	Year	Temperature (^oC)	Inflow (Cusecs)
1	1960	8.7	69200
2	1965	10.6	90800
3	1970	12.3	87600
4	1975	9.6	80300
5	1980	10.9	91800
6	1985	13.8	63600
7	1990	11.8	122800
8	1995	12.4	88890
9	2000	13.2	82000
10	2005	11.13	99800

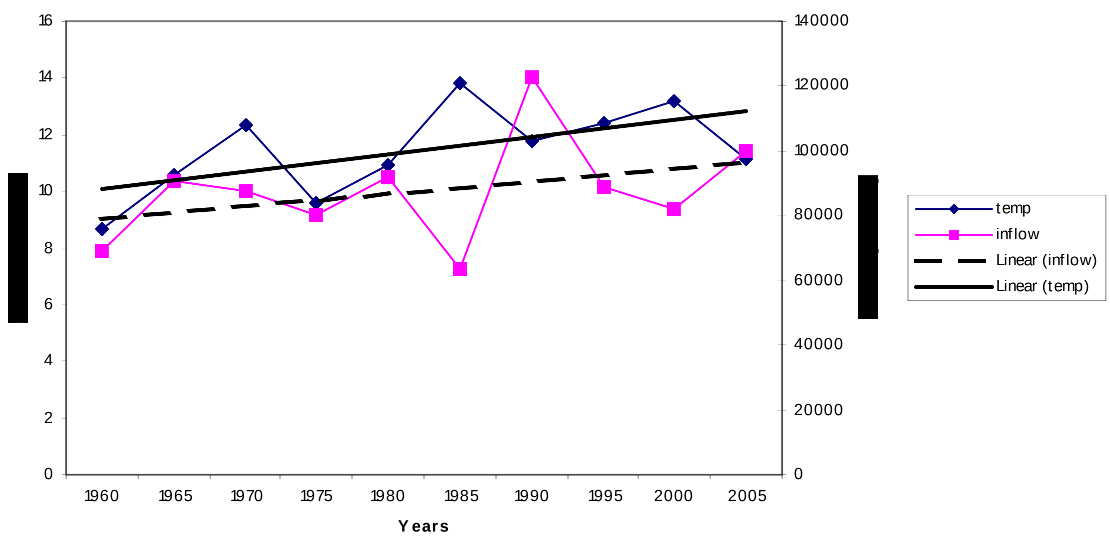

Fig.9 Effect of Temperature (Jan, Feb, Mar) of Chitral on the Inflow (April, May, June) of Tarbela Reservoir

10.2.3 Gilgit

On most of the occasions the increase & decrease in temperature fluctuates with increase & decrease in Tarbela inflows except in 1985 & 2000 where because of increase in temperature there were still decrease in inflows, which can be indicate that this increase in temperature has been limited to be a very small area and also less snowfall which could not generate required inflows (Table-6 & Fig.10).

Table-6: Temperature values of Gilgit & inflow values of Tarbela Reservoir

Sr. No.	Year	Temperature (^oC)	Inflow (Cusecs)
1	1960	13.6	69200
2	1965	13	90800
3	1970	13.7	87600
4	1975	12.03	80300
5	1980	12.67	91800
6	1985	14.7	63600
7	1990	13.2	122800
8	1995	12.8	88890
9	2000	14.4	82000
10	2005	13.2	99800

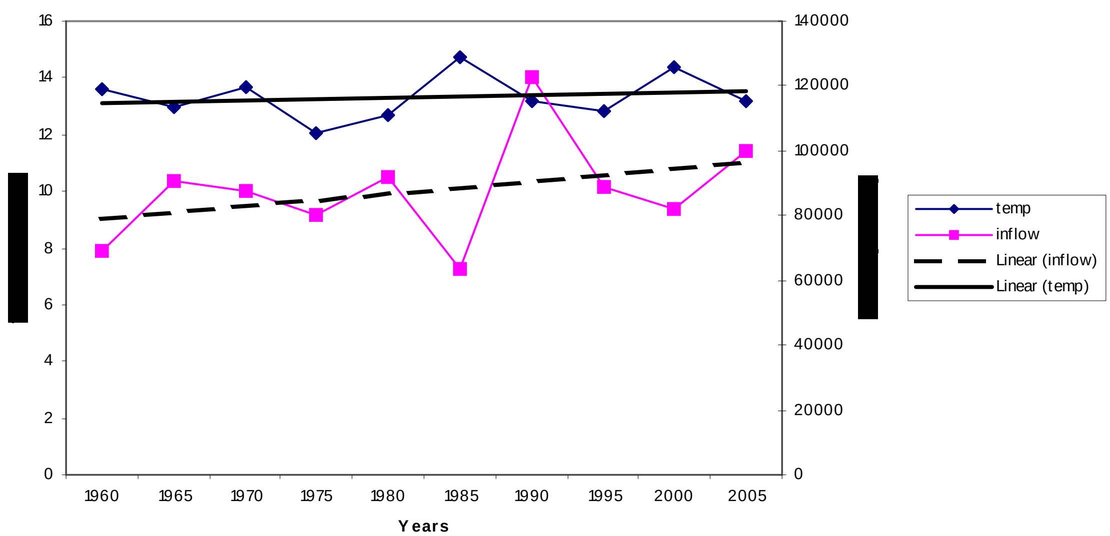

Fig.10 Effect of Temperature (Jan, Feb, Mar) of Gilgit on the Inflow (April, May, June) of Tarbela Reservoir

10.2.4 Sialkot

The affect of temperature increase is reflected in increase in inflow of Tarbela reservoir however, in 1985 & 2000 there is disagreement in the values the reason for which can also be temperature increase restricted to smaller spatial disturbances and not widespread in whole Indus catchment (Table-7 & Fig.11).

Table-7: Temperature values of Sialkot & inflow values of Tarbela Reservoir

Sr. No.	Year	Temperature (^oC)	Inflow (Cusecs)
1	1960	16.97	69200
2	1965	20.7	90800
3	1970	18	87600
4	1975	21	80300
5	1980	21.2	91800
6	1985	23.8	63600
7	1990	20.5	122800
8	1995	20.9	88890
9	2000	21.1	82000
10	2005	19.9	99800

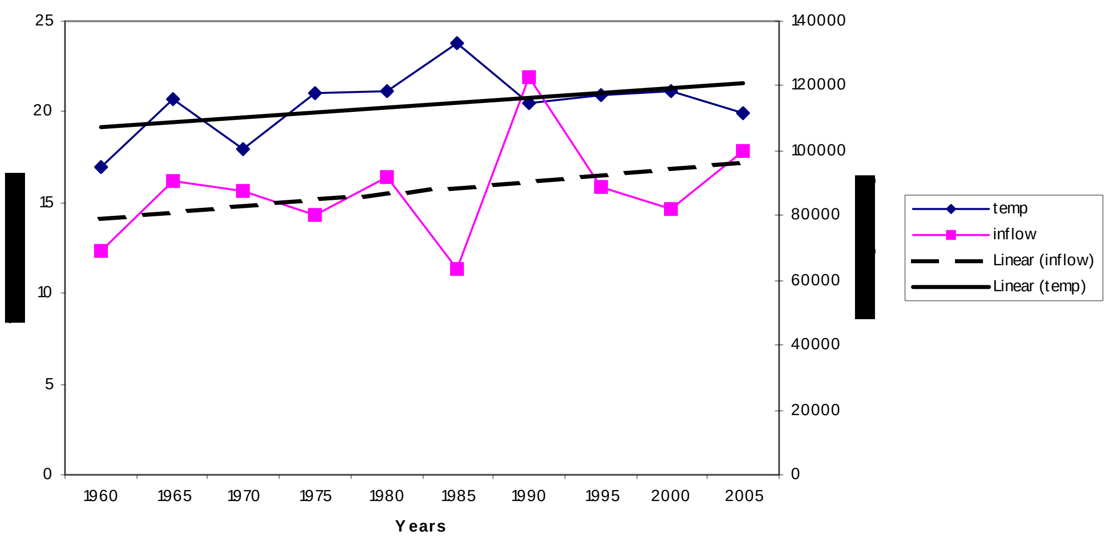

Fig.11 Effect of Temperature (Jan, Feb, Mar) of Sialkot on the Inflow (April, May, June) of Tarbela Reservoir

11. Conclusion:

The increase in temperature in some catchments particularly in Sialkot, Chitral & Muzaffarabad have a direct relationship with increase in inflows. However, the increase in temperature in Chitral & Muzaffarabad have no direct impact on increase in inflow of Mangla reservoir. Rather there is inverse relationship of increase in temperature with decrease in inflow. In case of Gilgit there is direct relationship except with the variations of three extreme years 1970, 1985 and 2000.

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