ANALYSIS OF EFFECT OF CLIMATE CHANGE OF RAINFALL, TEMPERATURE AND DISCHARGE ON RIVER BRAHMAPUTRA

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ABSTRACT: This study analysed and presented to assess historical climate variations and how climate change effects the hydrological characteristics of Brahmaputra basin. Historical trends of temperature, precipitation and discharge are analysed from 1901 to 2014 for the Guwahati city of Assam. Temperature patterns are consistent with global warming and out of the 10% warmest years from 1901 to 2014. While temperatures show a clear positive trend, precipitation and generally discharge series did not show any trend at monthly scale. Greater changes have been observed at annual scale, with discharge increasing in May and October. Being the highest specific discharge river system in the world, the Brahmaputra river experiences a number of long-duration flood waves during the monsoon season annually. Trends observed that annual precipitation in the basin is mainly determined by the strength of the monsoon.

KEY WORDS: CLIMATE CHANGE, PRECIPITATION, TEMPERATURE, DISCHARGE, BRAHMAPUTRA RIVER.

INTRODUCTION:

The term “climate change” is synonymous to “Global Warming”, which refers to rising global temperatures. Warmer global temperatures in the atmosphere and oceans lead to climate change affecting rainfall patterns, storms and droughts, growing seasons, humidity, and sea level. The climate has continuously changed since the glacial periods (or "ice ages") when ice had covered significant portions of the Earth to interglacial periods when ice had retreated to the poles or melted entirely. Scientists have identified three major events of climate variability, known as the Medieval Climate Anomaly (also referred to as the Medieval Warm Period; 900 to 1300 AD), the Little Ice Age (1500 to 1850 AD) and the Industrial Era (the last 100 years). The linear warming trend over the last 50 years (0.13°C per decade ranging from 0.10°C to 0.16°C per decade) is nearly twice that for the last 100 years. The total temperature increase from 1850–1899 to 2001–2005 was 0.76°C ranging from 0.57°C to 0.95°C.

This study is focusing on the Brahmaputra basin, originating mainly in the eastern part of the Himalayas. The Brahmaputra is a major transboundary river and drains an area of around 530,000 km^2. The basin is located within four different countries: China (50.5%), India (33.6%), Bangladesh (8.1%) and Bhutan (7.8%). The Brahmaputra springs from a glacier in the Kailash range in Tibet (China) at an elevation of 5300 meters above sea level (m.a.s.l.), has a length of 2900 km and after its confluence with the Ganges, the Brahmaputra flows into the Bay of Bengal. Average discharge of the Brahmaputra is approximately 20 000 m^3/s. The climate of the basin is monsoon driven with a distinct wet season from June to September, which accounts for 60–70% of the annual rainfall. The seasonal temperature variation is largest in winter and smallest in summer. The annual rainfall is concentrated in the monsoon months June, July, August and September (JJAS) in all zones.

A precise understanding of the spatial and temporal behaviour of climate parameters and their projected change in mountain areas is hampered by the lack of observational data in complex topographic terrain and the difficulties to represent large mountain ranges in general circulation model (GCMs) (Beniston *et al*., 1997).

Climate change will affect the discharge characteristics significantly and will lead to more severe and more frequent flooding (Warrick *et al*., 1996) both through alterations in climatic conditions and sea level rise. Projected rise in temperature will lead to increased glacial and snow melt, which could lead to increased summer flows in some river systems for a few decades, followed by a reduction in flow as the glaciers disappear and snowfall diminishes. Satellite records have shown a decrease in snow cover extent of about 10% in the Northern hemisphere related to temperature increases in spring and summer since 1966 (Robinson, 1997, 1999). To what extent increased glacial and snow melt influence stream flow is varying strongly in space. Barnett *et al*. (2005) argue in a global study that the Hindu Kush Himalaya (HKH) region is the most critical area in which increased melt will affect water supply in the decades ahead. Within the Himalayan region there are however large differences in the contribution of melt water in total annual run-off. Rees and Collins (2006) show that the melt water component in the total run-off rapidly decreases rapidly from west to east. Summer precipitation declines from east to west. In the western Himalayas in winter at high elevations westerly winds provide precipitation while at lower altitudes arid conditions prevail. Total annual precipitation follows the east to west gradient. Therefore stream flow in basins in the west is for a major part determined by melt water while in the east run-off generated by monsoonal precipitation is the most important constituent of downstream discharge. Rees and Collins (2006) also argue that glaciers experience winter accumulation and summer ablation in the west, but there is predominantly synchronous summer accumulation and summer melt in the east.

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Singh and Bengtsson (2004) confirm the strong dependence of stream flow on melt water in basins originating in the western part of the basin and stress the difference in melt water contribution to stream flow between rain fed, snow fed and glacial fed river basins.

The Brahmaputra basin is located in the eastern Himalayas and river discharges are predominantly rain fed. Basin wide quantified assessments of climate change and its effects in the entire drainage area of the basin are scarce and not straightforward. Previous work indicates that specifically the TP is extremely sensitive to global climate change (Liu and Chen, 2000). A complete overview of the functioning of the Brahmaputra basin including the impact of climate change on runoff is lacking so far. Therefore this paper will focus on (1) analysis of historical trends in temperature, precipitation and discharge, and (2) the impact of climate change on hydrology.

The recently published fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 4AR) (IPCC, 2007) concludes that warming of the global climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. The report concludes that the average global temperature is very likely to increase between 1.8 ^{o}C and 4 ^{0}C by the year 2100. Warming is expected to be greatest over land and at most high northern latitudes, snow cover is projected to contract and that it is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent.

The spatial variation in observed and projected climate change is large and mountain ranges and their downstream areas are particularly vulnerable for several reasons:

- Firstly, the rate of warming in the lower troposphere increases with altitude, i.e. temperatures will rise more in high mountains than at low altitudes.
- Secondly, there is a large high natural variation in climates because of the large difference in altitudes over small horizontal distances. This renders mountain areas more susceptible to climate change.
- Thirdly, and probably most important, is the role mountain play in the water supply to downstream areas. More than one sixth of the global population depends on water supplied by mountains and changes in hydrology and water availability are expected to be large in mountain basins (Barnett *et al*, 2005). Climate Change is expected to intensify the hydrological cycle, e.g. more precipitation and more evapotranspiration. While snow and ice accumulation in mountain areas determine for a large part the surface hydrology and the temporal distribution of the availability of water will change significantly when surface air temperatures rise.

Meteorological characteristics: The general circulation over the basin area undergoes abrupt seasonal changes during late spring and early summer due to tropospheric warming over the Asian landmass, and causes early summer rains over the basin (He *et al* 1987). The mean annual value of such pre-monsoonal heavy rains shows a rainfall above 100 mm/day for 7.7 days and above 300 mm/day for 1.6 days for the observation period of 1993–2001 (Soja and Starkel 2007). The river basin receives high-intensity storm events frequently during the four monsoon months from June to September. Clusters of successive several rainy days are very frequent during the monsoon season. In the Cherapunji region in the basin, on an average 28.3 days with rainfall above 100 mm/day and 5 days with rainfall above 300 mm/day have been observed annually during 1993–2001 (Soja and Starkel 2007). Temporal variation of the basin average rainfall of two tributaries and for the whole basin is shown in figure 2. Different distinct rainfall spells can be observed during the pre-monsoon and monsoonal season. Overall, 66–85% of the annual rainfall occurs during the monsoon and 20–30% occurs during the pre-monsoon season, while a very small percentage of the annual rainfall occurs in winter (Sarma 2005).

Data utilized for the study:

i. Rainfall Data.
  a. Annual and Monthly Average Rainfall
ii. Temperature Data
  a. Annual and Monthly mean Temperature
  b. Annual and Monthly maximum temperature
  c. Annual and Monthly minimum temperature
iii. discharge data
  a. Annual and Monthly Peak Discharge

DATA COLLECTION:

Discharge data records of the river Brahmaputra are available for 43 years (1971 to 2013) gauged at Pagladia, and Puthimari , N.T. Road X-ing, district Nalbari, Assam and Discharge data records of the river Brahmaputra are available for 27 years (1987 to 2013) gauged at Pandu, Guwahati. Rainfall and temperature data of Guwahati were collected from the website of india Portals from 1901 to 2002 and the rainfall records are available for 10 years (2004 to 2014) gauged at Pandu, Guwahati and we approach for other gauged station data which is not available to us.

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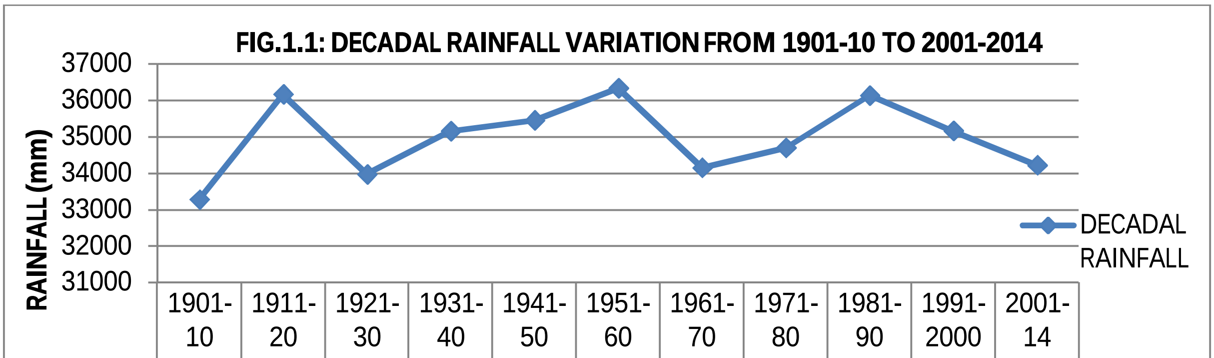
WEATHER ANALYSIS OF NORTH EAST INDIA

The North Eastern Region (NER) of India, by virtue of receipt of heavy rainfall, falls in low rainfall variability category and it ranges from 8-15%. For the North Eastern states of India, the normal annual rainfall ranges from 200-300 cm. Green vegetation, big water bodies and the nature's beauties and mega-biodiversity are the attraction of the NER. The rainfall pattern of Umiam, Meghalaya has been analyzed using 'Ranking order method' (Doorenbos and Pruitt, 1984). The main finding was that rainfall is, more or less, normally distributed. Of late, the region is losing its nature's gifted fame. In high rainfall areas distribution of rainfall is of more concern as compared to its amount received. Erratic nature of rainfall, its intensity and frequency often make crop planning a difficult task in rainfed areas. The world highest rainfall area Mawsinram/Cherrapunjee also falls within the region.

RAINFALL ANALYSIS:

The Fig.1.1 depicts the decadal rainfall distribution pattern of Kamrup, Assam, India for the period of 114 years (1901-2014). Trends observed indicate Decadal Rainfall between 33280mm to 36335mm per decade, a variation of 8.4%. Although the trend follows a fluctuating pattern of increase and decrease, gradual decrease in decadal averages from 1981-90 to 2001-2014 was observed at 1.1% per decade. No alarming deviations, over any sustained measure of time, above or below decadal averages were observed except gradual decrease in decadal averages from 1981-90 to 2001-2014.



	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-80	1981-90	1991-2000	2001-14
DECADAL RAINFALL	33280	36165	33971	35155	35452	36334	34153	34700	36133	35164	34220

Fig.1.1: Decadal rainfall distribution at Kamrup district.

The Fig.1.2 depicts the annual rainfall distribution pattern of Kamrup, Assam, India for the period of 114 years (1901-2014). The most deficit rainfall year was 2014 in which annual rainfall was 1211.00 mm. The most excess annual rainfall was 5429.84 mm during the year 1974 followed by 1988 (4737.12) and 1984 (4669.37). During the year 1901-71 the rainfall trend was same whereas, during 1971 onwards shown a significant erratic nature in the annual rainfall. And after 2002 there was deficit in annual rainfall then the previous rainfall.

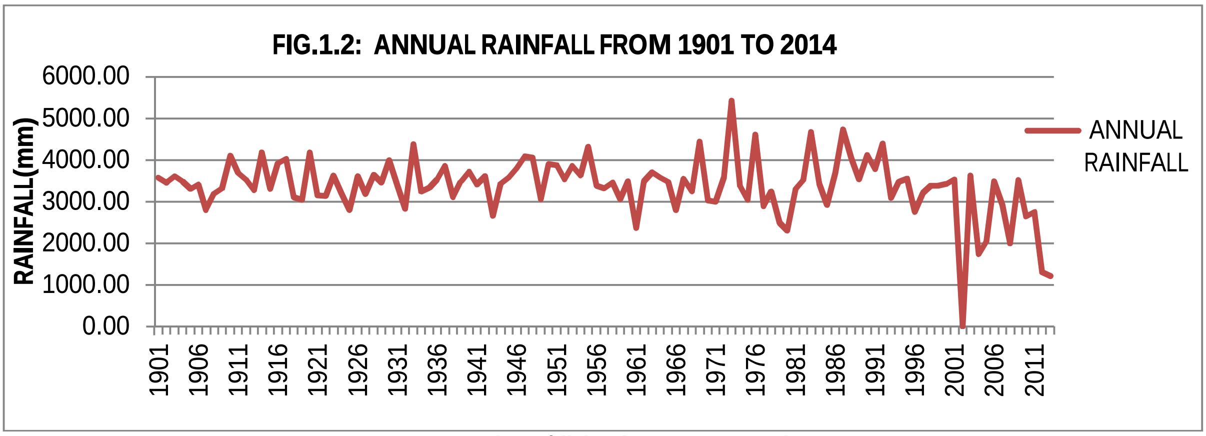


Fig.1.2: Annual rainfall distribution at Kamrup district.

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The Fig.1.3 indicates that the monsoon rainfall (*June-September*) distribution trend for the period of 113 years (1901-2013). It has significantly shown a consistently erratic pattern over the period 1901 to 2002 then there is deficit in monsoon rainfall from the year 2004 to 2013.

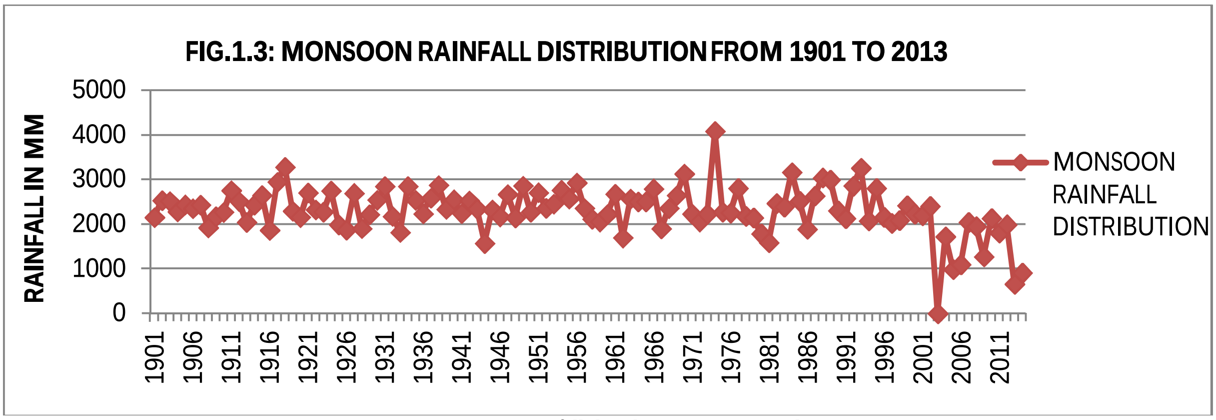

Fig.1.3: Monsoon rainfall distribution at Kamrup district.

TEMPERATURE ANALYSIS:

The graphs below represent the Decadal averages of Mean, Maximum and Minimum temperatures. The observed trends indicate a gradual increase in the last 4-5 decades, besides an increase in decadal temperatures between the 5th and 10th decade, although all of them below 1° Celsius. The Mean and Minimum temperatures follow an almost identical pattern.

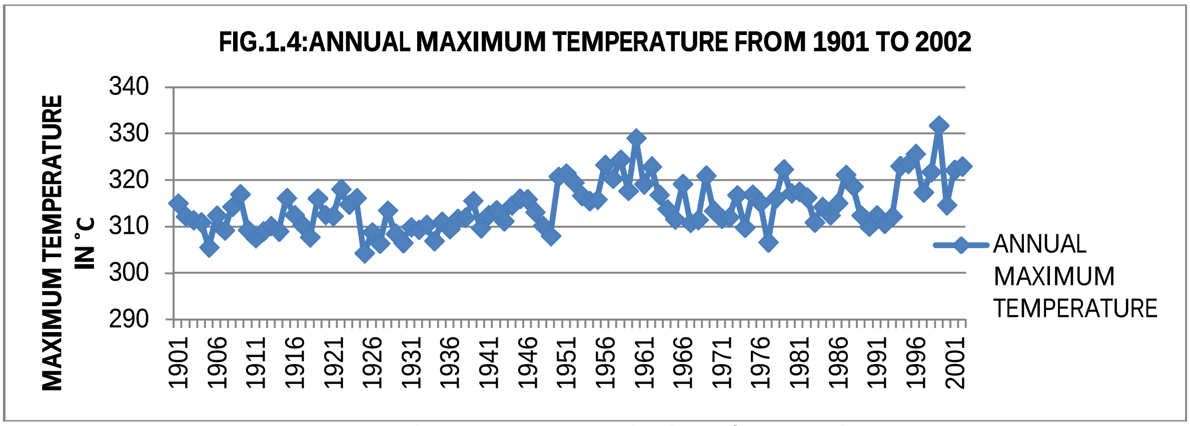

Fig.1.4: Annual maximum temperature distribution for Kamrup district.

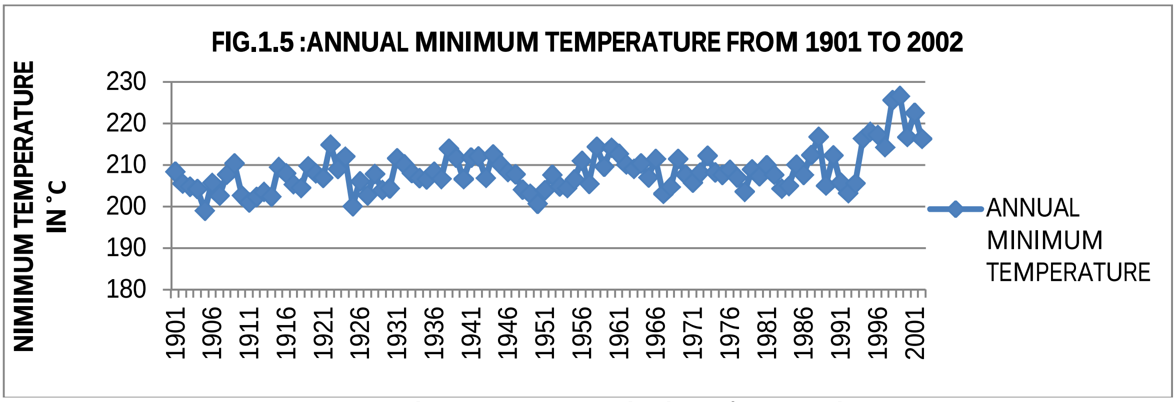

Fig.1.5: : Annual minimum temperature distribution for Kamrup district.

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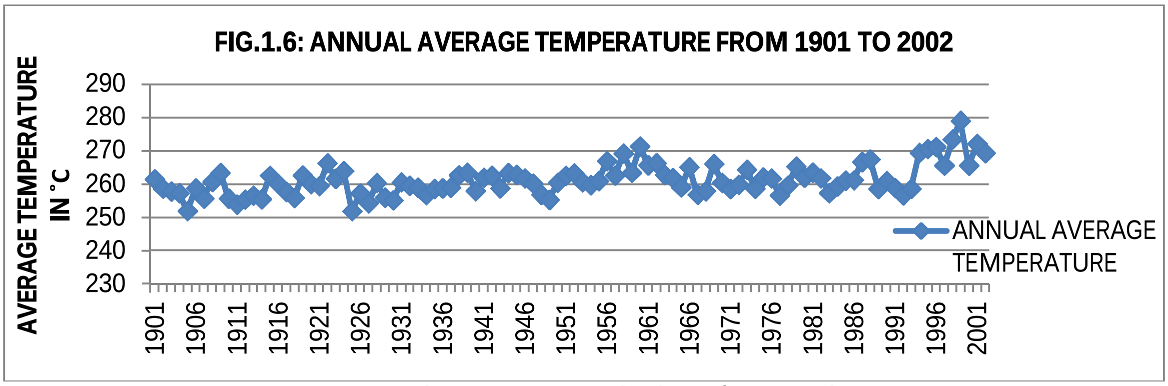

Fig.1.6: : Annual average temperature distribution for Kamrup district.

DISCHARGE ANALYSIS:

River Brahmaputra and their major tributaries shows a seasonal fluctuation in their discharge pattern typical of a tropical monsoon climate. The enormously large variations in the river's daily discharge over different seasons is a remarkable feature of its flow regime. Since the time lags and peaking characteristics of flood flows are different in different rivers draining in to the Brahmaputra due to variations in catchment physiography and monsoon precipitation, the tributary inflows generate large and variable perturbations on the Brahmaputra's discharge hydrograph. Fig.1.7 shows the annual peak discharge variation over the period (1987 to 2013) for Brahmaputra river gauged station at Pandu, Assam. Highest peak discharge is recorded in 1988,1991,1998 and 2012 and the flow pattern is almost similar. Fig.1.8 shows the annual peak discharge variation over the period (1971 to 2013) for Pagladia river gauged station at Pandu, Assam. From figure it is observe that the discharge flow pattern follows the decreasing order. Fig.1.9 shows the annual peak discharge variation over the period (1971 to 2013) for Puthimari river gauged station at Nalbari, Assam. Both peak discharge pattern shows the normal variations. From figure 1.8 and 1.9 , it is observe that the discharge flow pattern follows the decreasing order.

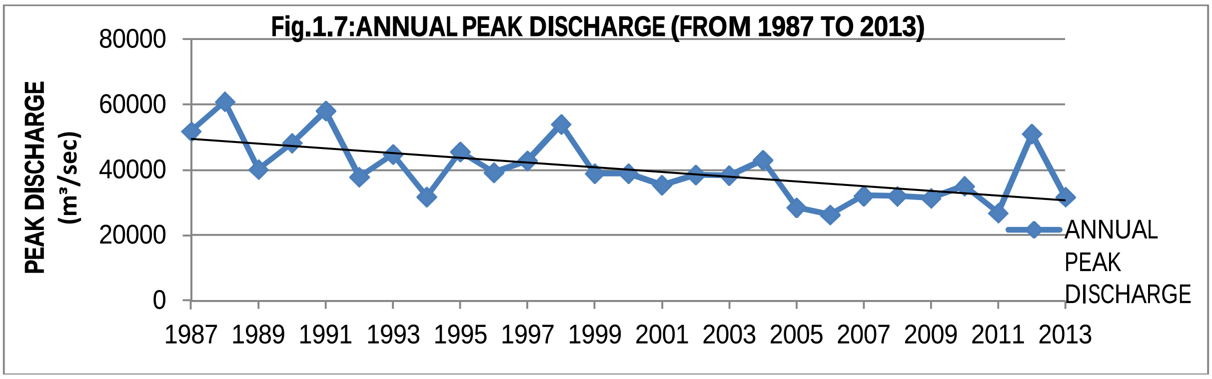

Fig.1.7: Annual peak discharge for Brahmaputra river from Pandu site.

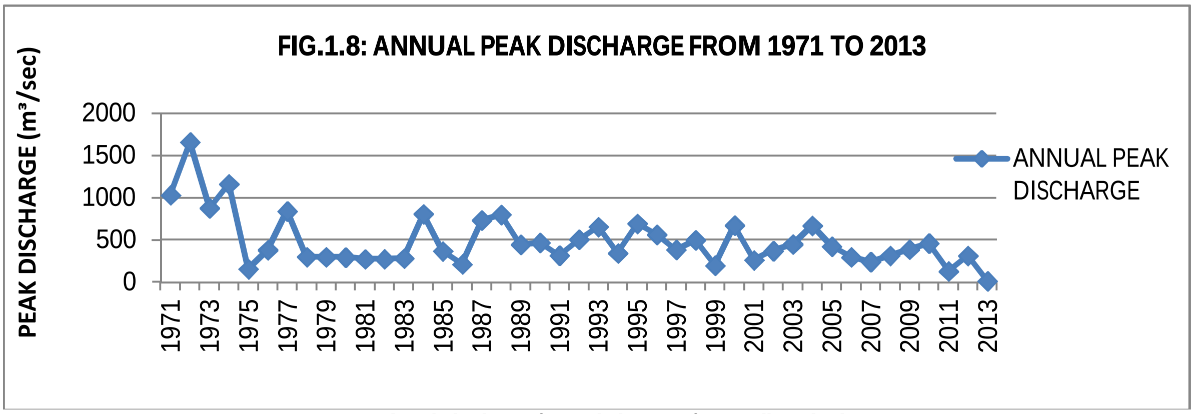

Fig.1.8: Annual peak discharge for Pagladia river from Nalbari discharge site.

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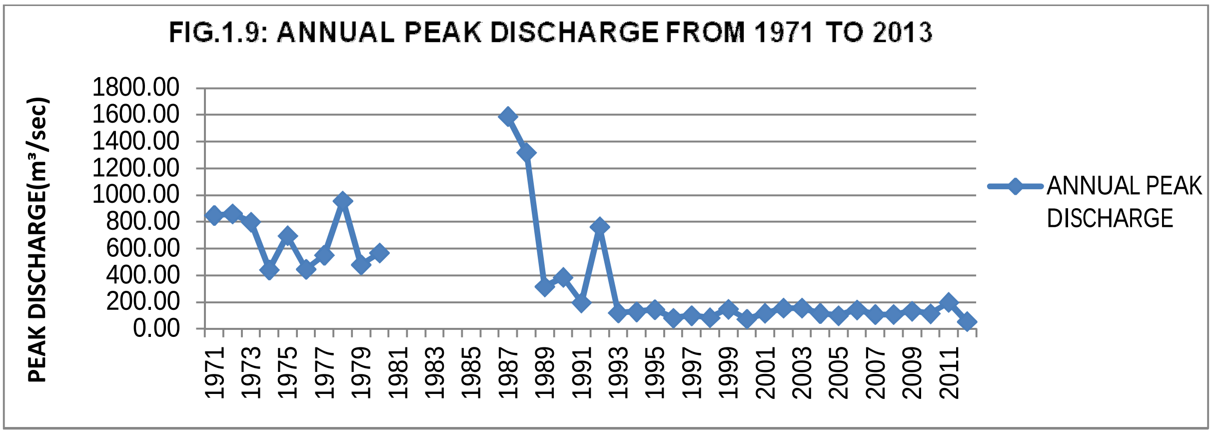

Fig.1.9: Annual peak discharge for Puthimari river from Nalbari discharge site.

CONCLUSION:

The goals of this analysis were to (i) briefly report some preliminary assessment of the consistency of long-term discharge data over the Brahmaputra basin, including two sub-basins, and (ii) to investigate potential decadal variations in discharge, precipitation, and temperature in sub-basin. This study provides a preliminary analysis of discharges, precipitation and temperature data since 1901 to 2013 for Brahmaputra valley. At annual scale, a clear increasing in temperature appears, while no general trends are observed, considering discharge or precipitation data. Precipitation shows a similar trend, with higher values in monsoon (june-september). The Brahmaputra is characterized by marked seasonality and high variability of daily flow. The discharge in the river between summer high flows and winter low flows fluctuates, on an average, by 12 times although in certain years it has been as high as 20 times (Goswami and Das, 2003). The flowing pattern of peak discharge is almost similar for Brahmaputra river but in case of Puthimari and Pagladia river, a decreasing order of discharge is observed. Finally, though this work is a preliminary investigation, but can set the base to start with deeper future research in order to gain a better understanding helpful to establish a more rational water management.

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