Impact of Climate Variability over Mahanadi River Basin

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***Abstract*— Climate change is meant by any change in the normal meteorological conditions (e.g. temperature, rainfall, humidity, pressure conditions etc.) of a particular area over a prolonged period. These changes significantly affect the water resources and hydrological conditions of various regions, particularly the river basins. The changes in precipitation, its intensity and frequency, can be detrimental, both on surplus or deficit side. The climate variability is mainly responsible for the arising of drought and flood conditions across various parts of the globe. Particularly, this is of a crucial issue in a country of agro-based economy like India. Also, the gradual increase in temperature caused by greenhouse effect affects the socio-economic life of people. Moreover, the water scarcity has been arising as one of the major problems and some countries have already been in a water stressed condition. Numerous attempts have already been made to analyse the effects of climate variability on the country. In this paper, some of the remarkable research works of the past in this field is being reviewed. Also, the varying precipitation across the whole country for 1901-2012 is presented. Using the available data and analysing the results of the prior researches, a detailed analysis and future prediction for Mahanadi river basin is being made. Further, trend of temperature and precipitation in some areas of Odisha and Chhattisgarh are also shown through graphs. The possible adaptation issues and the limitations of this analysis are also presented.**

***Keywords*— Climate change, meteorological conditions, river basin, droughts and floods.**

I. INTRODUCTION

India is having an agro-based economy. Over two-third of the population directly depends on agriculture. The agriculture in our country mainly depends on rainfall due to South-West monsoon. The South-West monsoon contributes rainfall for the period of June to September. Thus, any variability in the precipitation due to monsoon significantly affects the agriculture and thereby, the food security of the country. Moreover, according to the studies of NATCOM project under The Ministry of Environment and Forests, Govt. Of India, the countries with an Annual Water Resource less than 1000 cubic metres per capita are said to be in a water stressed condition. Till 2005, over 25 countries have become water stressed and in future water may become a primary constraint to life[7]. Fortunately, in India, it is more than 1700 cubic metre per capita per year. But, the climate change impacts are going to be severe in the developing countries like India due to poor coping abilities and less preparedness.

Therefore, it has become necessary to study the various factors responsible for the changing climate. But, as an element of hydrology, great uncertainty is associated with the intensity, frequency and spatial distribution of the rainfall.

Several studies have been undertaken to quantify the extent and impacts of the climate variability. Gosain et al. (2006) have modelled the 12 river basins of India and concluded that , there may be severe droughts and intense floods simultaneously in various parts of the country in future[5]. There will also be a general reduction in quantity of the available runoff. Again, Gosain et al.(2011) took up a study to quantify the climate change impacts using SWAT model bearing the constraints of the uncertainty of climate change predictions and assuming no change in land cover in future[6]. The analysis revealed about how it affects the irrigated agriculture, installed power capacity, environmental flows in the dry season and higher flows in the wet season. Deshmukh and Lunge(2012), using the regression and correlation analysis based on available rainfall data, presented the effects of global warming vulnerability on agriculture in 5 districts of Maharashtra[2]. It also concluded in a decreasing trend in monsoon period for those areas. Rathore et al.(2013) has assessed the climate sensitivity on Southern Rajasthan and concluded that the continuous changes in the nature of rainfall, increasing pressure of population, depletion of natural resources, rising atmospheric Carbon dioxide and consequential global warming, have led to the adverse effects on water resources of South Rajasthan and a decline in water table[9].

II. METHODOLOGY

The assessment of climate changes on river basin can be best handled from the various data related to hydrological conditions prevailing in an area. Since the hydrological response is a very complicated process affected by a large number of variables, it can never be guaranteed for an event to occur in hydrology. But analysis of a reasonably longer period may generate an idea. In this paper, from the available monthly precipitation data over the whole country for the period of 1901-2012, a graph is plotted through EXCEL PLOT and changing pattern of rainfall is analysed. Thereafter,

the rainfall for the duration of South-West monsoon (June-September), for the month of October, May and November-April for the same period is plotted through MATLAB. A plot of monthly variation of mean rainfall, maximum and minimum temperature for some areas of Odisha and Chhattisgarh are also drawn using MATLAB. Again, the EXCEL PLOT of daily maximum discharge in Mahanadi river basin for the monsoon period for 2001 and 2003 is presented, as these are the two years, in which maximum destruction occurred in the basin areas due to severe flooding in last 30 years. The data is collected from the websites of Indian Institute of Tropical Meteorology (IITM)[16] and Indian Meteorological Department (IMD)[14]. Moreover, the analysis and prediction by Gosain et al. (2006) for Mahanadi basin for the period of 2041-2060 using the predicted data by SWAT model is also incorporated for presenting a better assessment of the basin as that constitutes components like water yield and evapotranspiration along with the precipitation[5].

III. GRAPHICAL ANALYSIS AND DISCUSSION

The variation of the observed mean monthly rainfall (averaged over 1901-2012) on the country as a whole is presented in the figure 1 below.

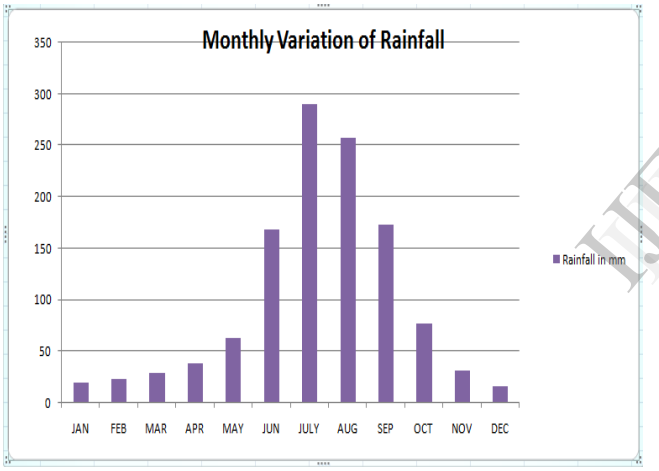

Figure 1: Monthly variation of rainfall in India

It is very clear from the graph that, the vast major contribution to the total annual rainfall is attributed to the rainfall in summer (south-west) monsoon i.e. June - September. Thus, in India, the word 'monsoon' in common practice, refers to the system that visits the country every year and gives us rain. The commencement of rainy season is associated with the onset of this monsoon and the end of the rainy season with retreat of the monsoon. Moreover, there is hardly any rainfall in November – April. The month of May and October contributes to some extent to the total annual rainfall.

Therefore, the comparative graph of precipitation occurring in summer monsoon period, for the month of May, October and November-April for the duration of 1901-2012 are presented in the graph plotted through MATLAB in figure 2. This graph provides an idea regarding the changing pattern of precipitation over years in different phases of a year.

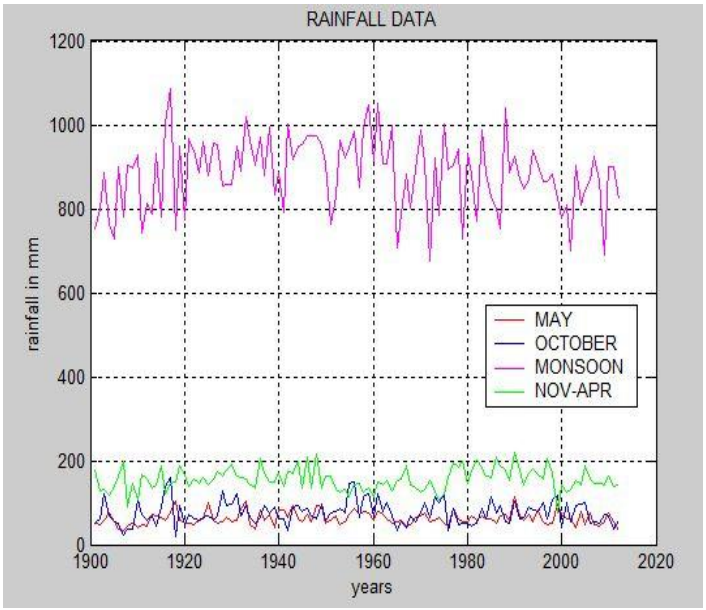

Figure 2

From the graph, it can be inferred that, there is a decrease in the rainfall during monsoon season. In last 30 years, the rainfall in monsoon is significantly lowered and an increased precipitation can be observed for the period of November – April. There is no much change observed for the month of May and October. This type of irregularities in monsoon may affect the agriculture adversely to a greater extent. Even the increasing rainfall in non-monsoon periods and decreasing rainfall in monsoon periods, may lead to severe droughts in various areas and some parts to floods, simultaneously.

Further, according to the information provided by IMD (1981), the normal rate of rise of temperature across India is 0.35 ^{0}C/100 years[14]. But, for the regions of the states like Odisha, Chhattisgarh and Madhya Pradesh, the rise in temperature is about 1^{0}C/100 years. Hence, study of meteorological conditions of the some of the areas of Chhattisgarh and Odisha (whose data are available), is being carried. The monthly data of mean rainfall for 7 cities/towns (Ambikapur, Balasore, Bhubaneswar, Gopalpur, Jharsuguda, Raipur and Sambalpur) is represented in the plot of figure 3 and thereafter, monthly mean maximum and minimum temperature for these areas is plotted in figure 4.

From the figure 3 below, it is clear that, except Gopalpur, precipitation in all these areas are said to be from summer monsoon only. Gopalpur receives maximum rainfall in the month of October. Rainfall amount is quite significant in October for Bhubaneswar and Balasore too. But, one thing in which these areas differ from that of the averaged condition of the whole country is that, these areas receive maximum precipitation in the month of August (quite higher than July),

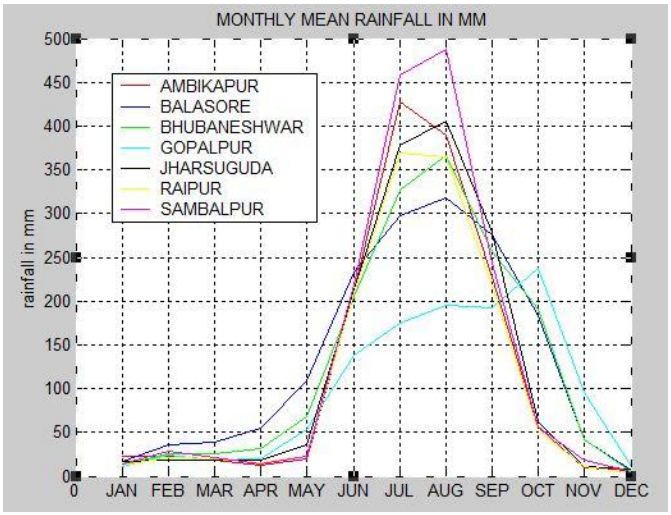

Figure 3

whereas most parts of the country receives highest precipitation in the month of July. This may be one of the reasons that attribute for these areas being more prone to flooding rather than droughts.

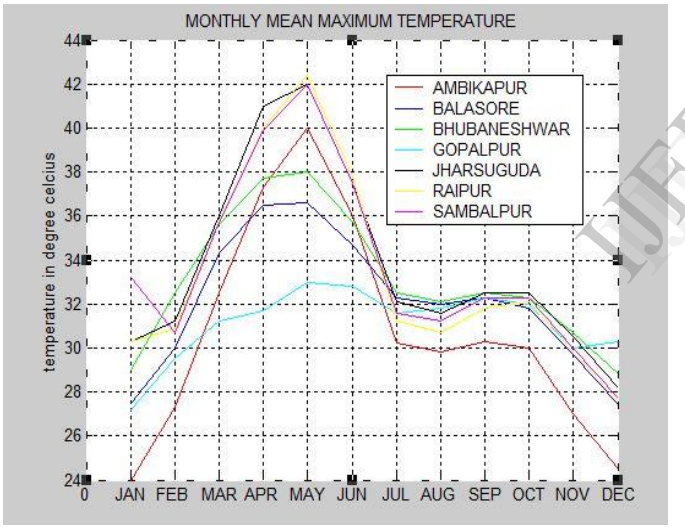

Figure 4 (a)

The graph in figure 4(a) reveals that, normally high temperature prevails in these areas, except for Gopalpur, which has a moderate temperature all over a year because of that being a coastal region of Bay of Bengal. The maximum temperature is over 40 ^{0}C in April-May for the regions of Jharsuguda, Raipur and Sambalpur when averaged over 100 years. Talking of the contemporary conditions in these areas, the maximum temperature in May even becomes more than 45 ^{0}C making it very difficult for people and in this way, it affects the socio-economic life of people.

Referring to the plot in fig. 4(b), the mean temperature in all these areas are just very general, i.e. least in December-

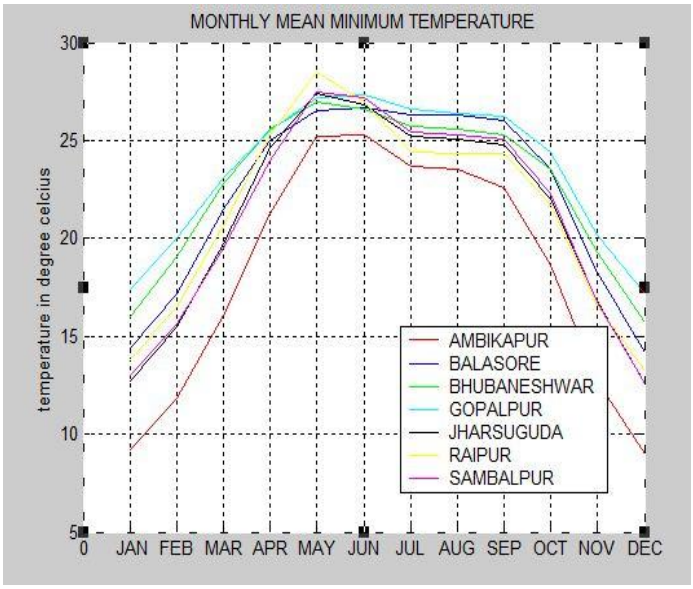

Figure 4 (b)

January and highest in April-June. There is also a year by year rise in minimum temperature over these areas.

IV. DETAILED ANALYSIS OF MAHANADI RIVER BASIN

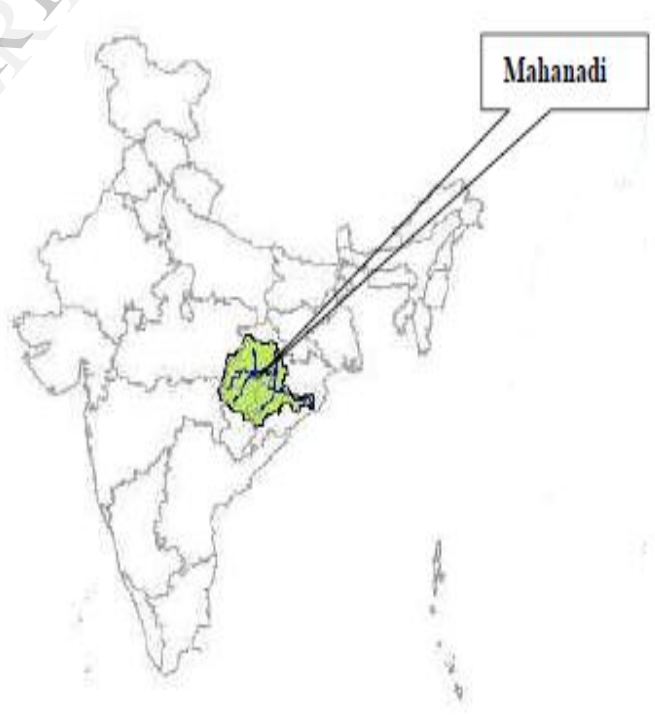

Figure 5: Mahanadi river basin in Map of India
Source: www.google.com (Google image)

The Mahanadi river basin is one of the major river basins of the country. It covers an area of 141590 km^2 (4.3% of the total geographical area of India) and has a mean annual river flow of 66640 Mm^3. It lies between east latitudes 80^0 30' to 86^0 50' and north latitudes 19^0 21' to 23^0 75'.The Mahanadi river is 852 kilometres long. Central India hills on northern side,

Maikala range on western side and Eastern Ghat in south as well as in eastern side surrounds this basin. The basin constitutes a major portion in Odisha and Chhattisgarh, and a tiny portion in Jharkhand, Maharashtra and Madhya Pradesh[12].

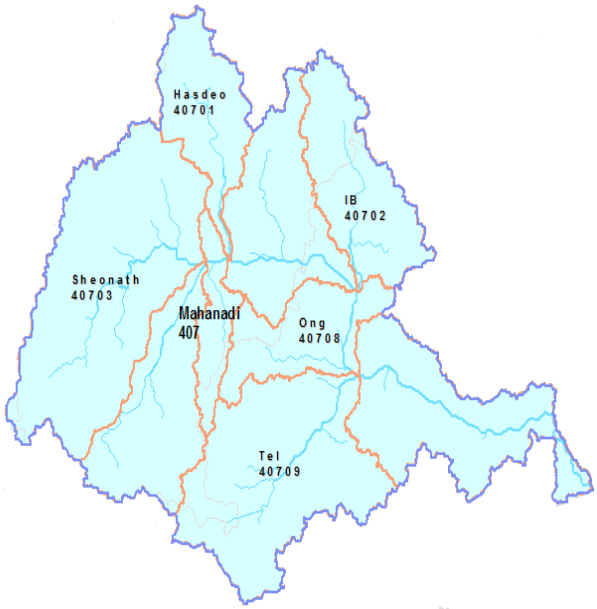

Figure 6: Shape of Mahanadi river basin
Source: http://gisserver.civil.iitd.ac.in/natcom

The average annual rainfall is about 1500 mm. In last 100 years, 85% of the rainfall has occurred in Monsoon (June-September)[15]. Normally, sub-tropical climate prevails over the basin. The monsoon reaches the basin in the first week of June. The delta plain of river starts from Naraj. The delta areas are more prone to flooding. Also, the rate of increase of surface air temperature is 1.1^0C/ 100 years, which may be very harmful. Moreover, the silt deposition in Mahanadi basin is highest in the country[13]. This river basin is also highest influenced by the climatic change. The pressure deviation in Bay of Bengal may cause destruction in the delta regions. (Information from website of NIH and Water Portal).

Using the daily maximum discharge data for July-September available for delta head at Naraj, the graph plotted is shown for the years 2001 and 2003, in which flood of highest magnitude occurred in the basin area in last 30 years across Mahanadi river basin.

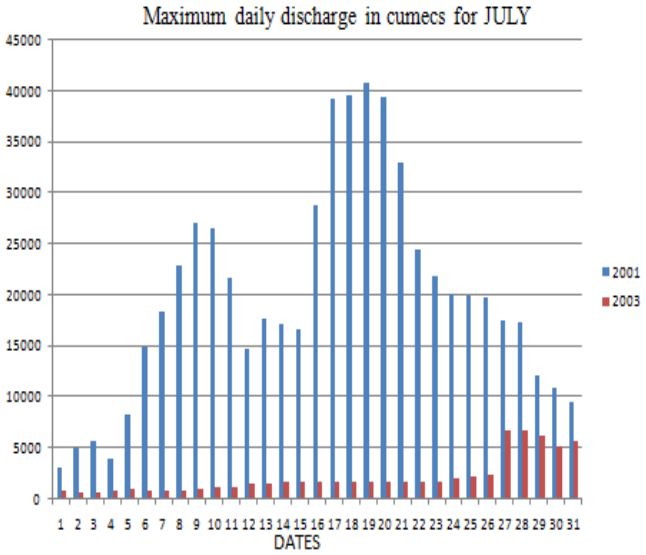

Figure 7 (a): Maximum daily discharge at Naraj for July in 2001 and 2003

It can be observed that the daily maximum discharge in 2001 exceeded 40000 cumecs and remained above 38000 cumecs for 4 consecutive days. Similarly, in 2003, the peak discharge was above 38000 cumecs. There was a fluctuation between 32000-38000 cumecs in daily maximum discharge for the days of high flooding in 2003. Not only in 2001 and 2003, intense rainfall leading to high flood level has also been observed in Mahanadi basin in 2005, 2010 and 2012.

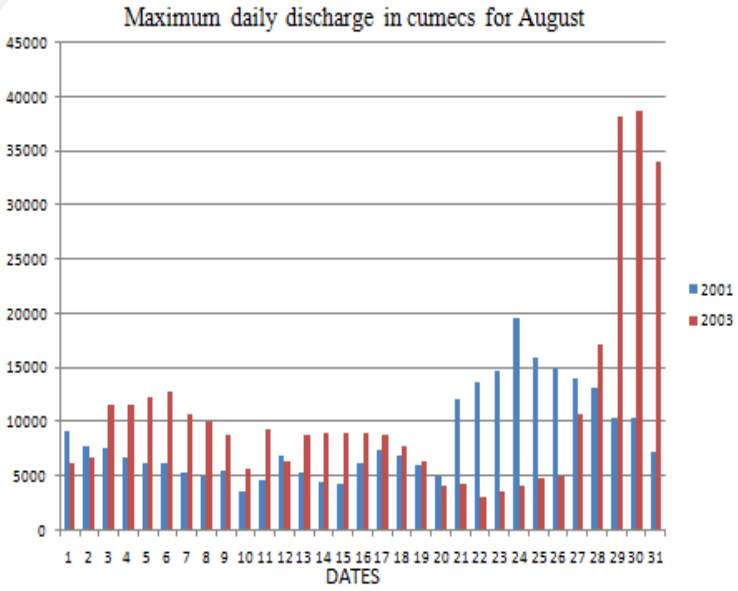

Figure 7 (b): Maximum daily discharge at Naraj for August in 2001 and 2003

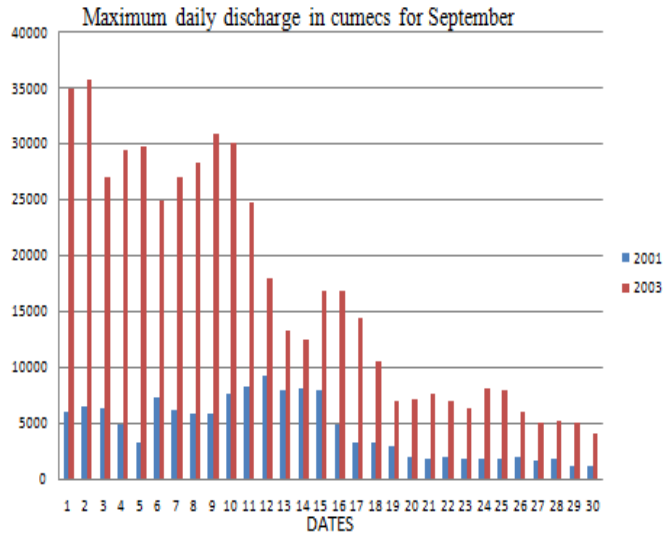

Figure 7 (c): Maximum daily discharge at Naraj for September in 2001 and 2003

The analysis of Mahanadi basin using the predicted data for the period of 2041-2060 (Greenhouse gas scenario) by Gosain et al.(2006) revealed that, in future, due to climate variability, severe flooding will occur in delta region causing destruction in low lying areas[5]. The SWAT model has projected a comparison between the actual values of 1981-2000 and modelled values for 2041-2060, and infers for an increase in intensity of flooding in future.

V. LIMITATIONS OF THIS ANALYSIS

The major drawback associated with any hydrological prediction is the uncertainty dealt with future climatic condition. It always acts as a constraint to the analysis. Moreover, Rao (1993) studied the temperature and precipitation variation of Mahanadi basin by considering data from 125 stations and revealed that, no single station shows a significant trend in either precipitation or temperature variation for a period of 1901-1980[10].

The analysis by Gosain et al. (2006) using SWAT model assumes no change in land cover in future. But, in practice, due to anthropogenic activities, the vegetation cover is reducing day by day implying a more dangerous condition in future. Dadhwal et al (2010) have analysed the land use change effects on basin areas and concluded that, the increasing interventions with environment, reduction of vegetation cover, change in land use etc. will increase the streamflow discharge and hence, flooding conditions will deteriorate[1].

Also in this paper, only flooding in Mahanadi basin is studied. But, the coastal areas are also prone to storms. The depression formed in Bay of Bengal normally during pre-monsoon and retreat monsoon period becomes detrimental for the basin and its neighbouring areas.

The sediment deposition in Mahanadi river basin is also another major issue. Mohanti and Swain (2005) have concluded that, the problem of silt deposition is causing an advancement of delta region towards the sea[8]. This problem may become fierce if a storm will hit the basin area.

Moreover, many other factors like population change, management activities, projects, political issues etc. may alter the projected consequences.

VI. STRATEGIES FOR ADAPTABILITY

As we cannot operate the natural phenomena, we must be prepared to cope up with the changing circumstances. The coping strategies are just like other sustainable development measures of the present days, where we need to think of our future generation too. Encouragement to extensive research on the present systems, water conservation practices, early disaster warning facilities, integrated information system, proper management of existing resources and implementation of necessary actions, identification and evaluation of various control aimed options, water marketing etc. are some of the strategies that need to be focussed.

VII. CONCLUSION

The impacts of climate variability are going to be severe for the river basins of India. The condition is further going to be deteriorated due to increasing human intervention. Based on monthly mean rainfall data and maximum daily discharge data at Naraj, analysis of effects on Mahanadi river basin due to climate change is studied. The results show that the basin possesses vulnerability to floods and the intensity may be severe in future. Also, the rising mean temperature and many other issues like silt deposition, depression at Bay of Bengal leading to storms etc. may further worsen the condition. Since the demand of the present is sustainable development, we need to develop and maintain various coping strategies simultaneously. These adaptation issues should be analysed time to time and necessary actions should be taken to control the problems to a greater extent.

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