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Global Climatic Variations And Its Impact on Indian Hydrological Conditions

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Abstract

Globally changing climatic conditions have shown direct and indirect impact worldwide. In Indian continent drastic changes have been recorded in hydrological conditions, Himalayan glaciers, agriculture production and water resources. As per the IPCC studies the amount of energy reaching the earths atmosphere every second on a surface area of one square meter facing the sun during daytime is about 1370 Watts and the amount of energy per square meter per second averaged over the entire planet is one quarter of this. In one of the most productive regions of India i.e., Ganga Plain approximately 250 million people are facing severe problem of water and food scarcity. Climate warming and anthropogenic pressure has greatly threatened the meteorological conditions, agricultural production and causing large hydrological variations in different parts of India and surrounding continents. Prominent changes have been recorded in the drainage morphology, crop production and precipitation patterns. These changes are modifying the land use and land cover pattern, cropping pattern, drainage pattern and over exploitation of water resources are modifying the hydrological cycle. The frequency of floods and drought and its intensity has increased manifold. About 65% population of India is agricultural based and in the long run climate change will affect the quantity and quality of the crops and the crop yield is going to be down. This will increase the already high food inflation in the country. The aim of this study is to understand the globally changing climatic conditions and its impact worldwide and on Indian continents and come up with easily and economically feasible solutions effective it address the problem of water and food scarcity in future.

Key words: Global Metrological changes, Indian continent, water resources, glaciers, food production, rainfall.

Introduction

Global climate varies from region to region. As per the studies carried out by IPCC the one of the major reasons of climate change is the increased concentration of greenhouse gases in the atmosphere (IPCC, 2007) and the global climate is changing, largely because of human activities (Mitchell et al. 2001). Since the beginning of the 20th century drastic changes have been recorded in surface temperature, precipitation, evaporation and extreme events like floods, droughts and cyclone. The amount of energy reaching the earths atmosphere every second on a surface area of one square meter facing the sun during daytime is about 1370 Watts and the amount of energy per square meter per second averaged over the entire planet is one quarter of this. (IPCC, 2007A). The global mean temperature have increased by 0.74 ºC during (figure 1) the last 100 years.

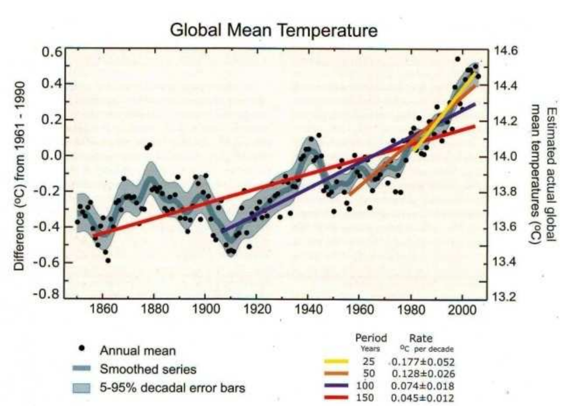

Figure 1. Global mean temperature during last 100 years. (Source: IPCC, 2007A)

Several human activities are continuously contributing to the climate change by escalating the amount of greenhouse gases, aerosols and cloudiness. Large amount of fossil fuel is still used in thermal power plants. Most of the aerosols and greenhouse gases are affecting climate by altering incoming solar radiation. Aerosol particles influence the radiative forcing directly through reflection and absorption of solar and infrared radiation in the atmosphere (IPCC, 2007A). In the 20th century, 1990s was the warmest decade and 1998 was the warmest year and one of the major causes of this global warming was the emission of greenhouse gases due to anthropogenic activities (Houghton et al. 2001). Studies are showing that changes are occurring in the precipitation intensity, frequency and different types of precipitation. More precipitation now occurs as a rainfall as compare to the snowfall.

Both droughts and floods are extreme climate events that percentage-wise are likely to change more rapidly than the mean climate (Trenberth et al. 2003). Further both drought and flood are among the world's costliest natural disasters and affect a very large number of people each year (Wilhite 2000) therefore there monitoring, understanding and prediction is necessary. According to the Palmer Drought Severity Index (PDSI), which is based on the measurement of the soil moisture using precipitation and crude estimates of changes in evaporation form 1900 to 2002 indicates (figure 2) widespread increase in the drought conditions.

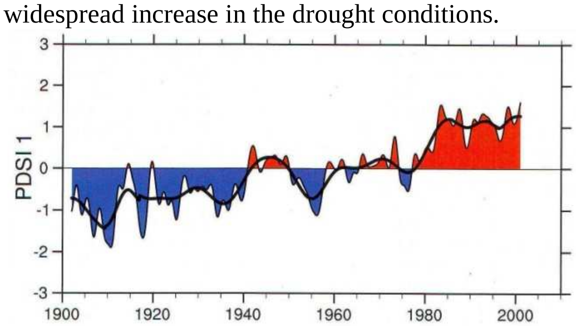

Figure 2. Palmer drought Severity Index (PDSI) , the black curve shows decadal variations in the surface land moisture conditions (Source: Dai et al, 2004, IPCC, 2007A)

World-wide there is consensus among the researchers and the scientists that global climate instability may occur if the current rate of greenhouse gas (GHG) emissions continues. There is strong evidence that global sea level is gradually changing. Figure 3 shows the evolution of global mean sea level changes in the past and in the future in 21st century.

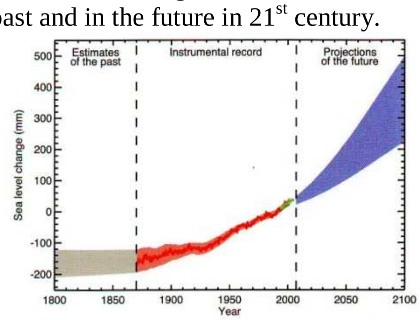

Figure 3. The global mean sea level since 1800 and the expected changes up to 2100 century.

The global changes in the climate have trigger long-term and potentially extensive, changes in the Indian continents especially on weather conditions, hydrological cycle, agricultural sector and water resources. Studies carried out by Indian Space Research Organization (ISRO) on 2190 Himalayan glaciers, revealed that approximately 75% of the Himalayan glaciers are on the retreat, with the average shrinkage of 3.75 km during the last 15 years. These findings raise serious concern over the accelerated retreat of glaciers in the Himalayan mountains because it will increase the variability of water flows to downstream regions and will affect the sustainable water use planning in one of the world's most populous country. The frequency of drought and floods has increased manifold in India has severely affected agricultural areas, water resource reserves and crop production. Most of the population in India is rural and agriculturally oriented depend on rivers and groundwater. Underground water is the main source for fulfilling the water demand of more than 80% of rural and 50% of urban population, besides fulfilling the irrigation needs of around 50% of irrigated agriculture. It has been estimated that 70 to 80 % of the value of irrigated production in India comes from groundwater irrigation. (Mall et al. 2006). Contribution of groundwater to India's Gross Domestic Product (GDP) has been estimated as about 9% (Burjia & Romani, 2003). In India the average food consumption at present is 550g per capita per day. The major challenges for the country is to increase its food production to the tune of 300mt by 2020 in order to feed its ever growing population, which is likely to reach 1.30 billion by the year 2020 (Misra 2011). To meet the demand for food from its increasing population the country's farmers need to produce 50% more grain by 2020 (GOI, 2003). It seems to be very difficult to fulfill the increasing food demand because climate warming is causing serious problems like soil salinity, soil erosion, desertification and depletion of water resources in the country. If necessary and effective actions were not taken in time, then in near future food production is going to be down sharply. The objective of this study is to understand the impact of global climate changes worldwide and Indian continent especially on meteorological conditions, agricultural sector, water resources and come up with solutions effective in addressing the water and food scarcity problems.

Climate Change and Water Resources

There are large uncertainties among the nations vulnerable to climate change impacts over the availability of water resources in the future. In 1955, only seven countries were found to be with water stressed conditions. In 1990 this number rose to 20 and it is expected that by the year 2025 another 10 to 15 countries shall be added to this list. It is further predicted that by 2050, 2/3rds of the world population may face water stressed conditions (Gosain, 2006). Increasing temperature directly or indirectly controls the hydrological cycle and influences different hydrological processes. A warmer climatic condition intensifies the hydrological cycle, causes higher rates of evaporation and escalates the rainfall. These processes, in association with a shifting pattern of precipitation, may affect the spatial and temporal distribution of runoff, soil moisture, groundwater quality and quantity etc. and may increase the frequency of extreme weather conditions like droughts and floods.

Majority of the Arab countries do not have any major source of water; they have to depend on natural precipitation and water conservation techniques. Nile river basin is the home of approximately 190 million people of Ethiopia, Eritrea, Uganda, Rwanda, Burundi, Congo, Tanzania, Kanya, Sudan and Egypt. Since majority of nations of the Nile river basin are among the top 10 poorest countries of the world therefore it is absolutely difficult for them to adopt any strategy of water management, which required investment. Africa which is one of the world's driest continents is facing very severe water crisis. A recent WHO/UNICEF report reveals more than one billion people still use unsafe drinking water. The African river systems identifies three river systems (Maarten and Stankiewicz, 2006) i.e. the areas receiving very low rainfall have virtually no perennial drainage (dry regime), then the areas with an intermediate range in which drainage density increases with increasing rainfall (Intermediate rainfall regime) and the areas of high rainfall (High rainfall regime). The dry regime covers the largest area of the African continent i.e. approximately 41%, but most important is the intermediate rainfall regime which covers approximately 25% because this is the area where changes to precipitation would result in serious changes in drainage supply. The studies conducted by several researchers predict that the crop yield will decline and the crop water demand will increase in African continent especially in the dry land farms. A net 2.5 °C rise in temperature in Africa will result in decline of net revenues from agriculture by US$ 23 billion (Kurukulasuriya & Mendelsohn, 2007). The future climatic change will show its impact worldwide but it will severely affect developing countries with agrarian economies, like India.

Climate Change and Indian Water Resources

Climate change impacts are going to severely affect most of the developing countries, because of their poor capacity to adapt to climate variability. India also comes under this category and going to be water scarce by 2050. The water requirement in India by 2050 will be in the order of 1450 km^3, which is significantly higher than the estimated utilisable water resources of 1123 km^3 per year. Table 1. Show the available water resources of India.

S.No.	Water resources of India	Estimated Amount of water (km^3)
1	Estimated annual precipitation (including snowfall)	**4000 km^3**
2	Average annual potential in rivers	**1869 km^3**
3	Estimated usable water	**1123 km^3**
	(i) Surface	690 km^3
	(ii) Ground	433 km^3
4	Water demand ~ utilization(for year 2000)	**634 km^3**
	(i) Domestic	42 km^3
	(ii) Irrigation	541 km^3
	(iii) Industry, energy & others	52 km^3

Table 1: Water Resource of India (Source: MOWR, 2008)

Most of the prediction carried out by different government, non government and International organizations for Indian continent were projected by Ministry of Water Resources, Government of India (MOWR, 2008) are based on RCM (Regional Climate model) & GCM (General Circulation Model/ Global Climatic Model) . These models are used for generating future climate scenarios on regional basis there are downscaling models (RCM) which use output of GCMs. Based on the study of RCM and GCM models and hydrological models the major findings concerning water resources are as follows:

- The rainfall scenarios of the country will totally dependent on changing climate scenarios.
- There are substantial spatial differences in the projected rain fall changes. Probability of extreme weather conditions like floods

and drought may increase by 10 to 30 percent.

- Surface air temperatures are going to increase by as much as 3 to 4° C towards the end of the 21st century.
- The warming is widespread over the country, and relatively more pronounced over northern parts of India.

Water available in different water basins of India is shown in table 2 shows the As per the study Ministry of Water Resource (MOWR) Govt. of India, the estimated irrigation return flow (RF) from surface and groundwater irrigation to be 223 km^3 per year in the year 2050 for higher population growth rates giving 133 km^3 per year. The total recyclable wastewater is estimated to be 177 km^3 per year in 2050. Taking careful consideration of several factor, Gupta and Deshpande (2004) estimated the total resource availability in 2050 for higher population growth shown in table 3.

Sl. No	Basin	ASW	AMR	EUSW	RGW	SGW
1	Indus	73.30	58.60	46.00	26.50	1338.20
2a	Ganga	525.00	401.30	250.00	171.60	7834.10
2 (b+c)	Brahmaputra+Meghana	585.70	477.50	24.00	35.10	1018.50
3	Godavari	111.40	107.10	76.30	40.60	59.40
4	Krishna	78.10	61.00	58.00	26.40	36.00
5	Cauvery	21.60	18.90	19.00	12.30	42.40
6	Pennar	6.70	6.20	6.70	4.90	11.10
7	EF*:Between Mahanadi & Pennar	33.50	15.30	13.10	18.80	41.30
8	EF:Between Pennar & K.Kumari	16.50	16.00	16.50	18.20	66.00
9	Mahanadi	66.90	60.20	50.00	16.50	119.70
10	Brahmani - Baitarni	33.00	32.60	18.30	4.10	43.40
11	Subarnaretha	12.80	9.70	6.80	1.80	10.80
12	Sabarmati	3.80	3.40	1.90	3.20	28.20
13	Mahi	11.00	10.70	3.10	4.00	12.60
14	WF: Kutchh, S'tra, luni	15.10	13.60	15.00	11.20	113.20
15	Narmada	46.00	36.90	27.50	10.80	18.40
16	Tapi	16.90	16.20	15.00	8.30	7.50
17	WF: Tapi & Tadri	87.40	80.30	11.90	17.70	11.20
18	WF: Tadri to Kkumari	113.50	97.80	24.30	0.00	0.00
19	Inland drainage: Rajasthan	0.00	0.00	0.00	0.00	0.00
20	MR: B'desh and Myanmar	31.00	24.80	0.00	0.00	0.00

Tot	1889.20	1548.10	683.40	432.00	10812.00

Table: 2 Basin wise Water in India (km ^{3}/ year) *Source:* MOWR(1999)

*EF: East Flowing : WF: West Flowing : MR: Minor Rivers; K'kumari: Kanyakumari : S'tra: Saurashtra : B'desh: Bangladesh ; Available Surface water (ASW); Average Monsoon Runoff (AMR); Economically Utilizable Surface Water (EUSW); Replenishable Groundwater (RGW); Static Reserve of Groundwater (SGW).

Water available during 2001	Water required during 2050	Anticipated water deficit	*Possible measures to meet the deficit*				
			EUSW+GW in excess of 1998	Recyclable waste water	Irrigation return flow	RAGWR	Water availability
500	973-1450	473-950	SW=420 GW=202	103-177*	33-133	125	1311-1485
			Total= 550**				

Table: 3 Represent Water Resources Availability Based on low and high population growth for 2050 (km3) ; Source: S.K.Gupta and R.D. Despande(2004)

RAGWR= Retrievable Artificial Groundwater Recharge; EUSW= Economically Utilizable Surface Water; GW= Groundwater.

* Ignored water quality issues

** After considering 17% decline in storage for surface sedimentation

Now it's become necessary to initiate work on the mitigation measures and take very seriously the impact of climate change on present water resources and create more water reservoir without any further delay to address future demands.

Meteorological Changes And Indian Weather Conditions

Continuous escalating global warming shows effect on rainfall and its pattern. When carbon dioxide and other greenhouse gases enter the atmosphere, they increase the temperature, which in turn leads to increases in the amount of water vapor in the atmosphere. Whenever the storm system develops, the escalated humidity causes heavier rainfall usually for longer duration that becomes more extreme as the climate warms. Increase in the frequency of heavy rainfall events are potentially one of the most important impacts on the human society of the changing hydrological cycle under global warming. Global mean precipitation is thought to be constrained energetically and increases at a modest rate of about 2% K^{-1} (Allen and Ingram 2002; Held and Soden 2006; O'Gorman and Schneider 2008). Further our understanding regarding general circulation of the atmosphere is based on dry dynamical theories which do not consider the effect of latent heat release on circulations. It is important to understand the atmospheric circulation changes associated with global warming because the latent heat release is more pressing, since the amount of water vapor in the atmosphere increases strongly with warming; zonal-mean column water vapor increases at a rate of 6% K^{-1} to 12% K^{-1} depending on latitude (O'Gorman and Muller 2010, O'Gorman, 2011). The implied increases in latent heating are a potential driver of many of the expected changes in the dynamics of the atmosphere under global warming (Schneider et al. 2010).

These changing climatic conditions are directly or indirectly showing its impact on Indian weather conditions. The exceeding green house gases or aerosols input due to excess human activities, such as land use pattern, exceeding use of different fossil fuels etc. Studies have proved that aerosols are acting directly as well as indirectly on the issue of climate change by changing the energy budget of the earth atmosphere system and acting as cloud condensation nuclei to change life time of the clouds (Warner and Twomey, 1967). The studies carried out worldwide indicate that the increasing number of anthropogenic aerosols can create smaller cloud droplets, and may slow down the collision and coalescence growth of precipitable droplets. Once smaller cloud droplets are formed, the process of precipitation is hindered, and the 'immature' cloud-systems start floating freely in the atmosphere with increased lifetime and changed cloud albedo in an overall-changed radiation budget scenario (Twomey, 1974). Further the long-term relationship between high- (Changnon, 1981, Liepert, 1997, Zheng et al., 2008) and low-cloud (Rebetez and Beniston, 1998) with sunshine show that radiation balance is compromised in either of the cases. A quantitative assessment study indicates that global annual high cloud occurrence increased 2.9% to 4.6% for land and ocean, respectively, over the principal flight corridors in Europe (Boucher, 1999).

In India winter season, is characterized by the months of December, January and February while the northern regions are found under the influence of western disturbances. The southern portion of India is under the influence of northeast monsoon as well as retreating southwest monsoon. In this season, the cold and drier wind reaches to northern part of India from northwest azimuth, whereas humid wind from northeast azimuth, passing through the Bay of Bengal, reaches to southern part of India (Srivastava et al, 2012). During March-April-May (hot weather season), effects of western disturbances, cases of thundershowers (Pandey et al., 2010) and cases of desert dust of Thar Desert origin (Srivastava et al., 2011) are seen intermittently in northern India.

To understand the behavior of cloud as a proxy for aerosol presence and change in environment due to aerosols, the quality checked data of sunshine hour (SH) for 21 Indian stations during 1988 to 2007 was carried out by Srivastava et al, 2012. These stations are spread all over the Indian subcontinent and shows (table 4) trend of changes in sunshine hours in each station regions.

Considered Stations	Lat/ Long	Region	Average value (Hours)	Maximum value (Hours)	Minimum value (Hours)	Trend of change (hrs/yr)
Thiruvananthapuram	08.5N, 77.0E	**West Coastal India (WCI)**	196.04 ± 11.28	212.37	172.23	**+0.50**
Panjim	15.0N, 74.0E					
Mumbai	19.0N, 72.0E					
Chennai	13.0N, 80.3E	**East Coastal region (ECI)**	197.43 ± 13.94	233.94	177.48	-2.00
Machilipatnam	16.2N, 81.0E					
Bhubaneswar	20.3N, 86.0E					
Kolkata	22.6N, 88.4E					
Amritsar	31.6N, 74.9E	**Inland North Indian (INI)**	201.00 ± 19.82	239.29	175.55	-2.82
New Delhi	28.6N, 77.2E					
Allahabad	25.5N, 81.9E					
Ahmedabad	23.0N, 72.7E	**Central-Southern region (CSI)**	217.22 ± 07.69	231.04	202.67	-0.72
Pune	18.5N, 73.9E					
Indore	22.7N, 75.8E					
Nagpur	21.1N, 79.1E					
Hyderabad	17.4N, 78.5E					
Bangalore	13.0N, 77.6E					
Dibrugarh	27.5N, 94.9E	**Northeastern region (NEI)**	166.48 ± 08.07	181.48	149.08	-0.96
Guwahati	26.2N, 91.7E					
Srinagar	34.4N, 77.0E	**Mountainous Region (MRI)**	180.99 ± 19.97	209.50	136.00	**+0.43**
Port Blair	11.7N, 92.7E	**Island Location (ILI)**	192.96 ± 11.38	213.50	167.00	**+0.36**
Minicoy	08.3N, 73.0E					

Table 4: Different regions of India along with their average, maximum, minimum sunshine hours and the trend of changes in sunshine (Source: Srivastava et al, 2012)

The study shows (figure 4) the sunshine hour anomaly of annual average of India (considering all the 21 stations together mentioned in table 4) from 1988 to 2007 along with its 5-year running average. Figure 4 also indicates that the mean sunshine hour for India is decreasing at the rate of 1.10 hrs per year and suggests that this dimming is caused by escalating density of aerosols together with increasing cloud-mass in the atmosphere as an impact of land-use changes.

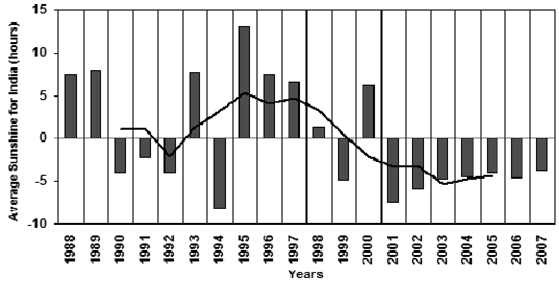

Figure 4. Average annual sunshine hours over India for the period 1998-2007. The solid line represents 5 years running means (Source: Srivastava et al, 2012).

Another biggest problems associated with climate change in India is the melting of majority of the glaciers. About 75 % of the Himalyan glaciers are on retreat. The three main rivers of the Indian continent i.e., the Indus, Ganges and Brahmaputra are depend on glaciers and it is estimated that glaciers contribute between 40 to 50 percent of the total river flows for these rivers. Approximately 600 million people depend upon water from these three rivers to support agricultural, their livelihood and economic activities. The rate of Himalayan glaciers retreat is recorded between 20 to 25 meters per year and with this rate of retreat many of the glaciers might extinct by 2025 to 2030.

Impact on Agriculture

Agriculture industry or sector plays a very important role in developing economies like India. In India agriculture makes around 20% of GDP and provides nearly 52% of employment (as compared to 1% of GDP and 2% of employment for the US), with the majority of agricultural workers drawn from poorer segments of the population (FAO, 2006). Studies carried out in developing country like India and Brazil indicates significant negative effects, with a moderate climate change scenario (an increase of 2ºC in mean temperature and seven percent increase in precipitation) leading to losses on the order of 10% of agricultural profits (Sanghi et al., 1998, 1997). India's population is currently more than 1.2 billion people and it is predicted that by 2050, the population will grow by another 500 million (UN 2008). The impact of climate change on agriculture is going to show very serious impact on countries food inflation, poverty and economy. Increase in population escalates strain on all type of resources, especially when coupled with the impacts of climate change. Moreover it is also expected that such affects on agriculture, available water resources and rural livelihoods will lead to greater migration from rural areas to urban areas within India.

Increasing CO2 concentration in the atmosphere and global warming are likely to affect future global agricultural production through changes in rate of plant growth (Lemon, 1983) and transpiration rate (Morison, 1987). In India the share of agriculture in GDP has declined from 39% in 1983 to 24% in 2000–01. The average food consumption at present is 550 gm per capita per day whereas the corresponding figures in China and USA are 980 gm and 2850 gm respectively. At present annual requirement based on present consumption level (550 gm) for the country is about 210 Million Tonnes (Mt), which is almost equal to the current production. (Mall et al, 2006a). The country is going to face major challenges to increase its food production to the tune of 300 million toones by 2020 in order to feed its ever-growing population, which is likely to reach 1.30 billion by the year 2020. To meet the demand for food from this increased population, the country's farmers need to produce 50% more grain by 2020 (Paroda and Kumar, 2000; DES, 2004). Weather conditions, such as extreme floods and droughts, cyclones and hailstorm, are capable of completely destroying the crops. Studies estimated the impacts for a range of temperature changes revealed that the temperature response function is of inverted 'U' shape, i.e., with higher climate changes the loss would be greater. The spatial distribution of impact on different Indian states is shown in figure 5.

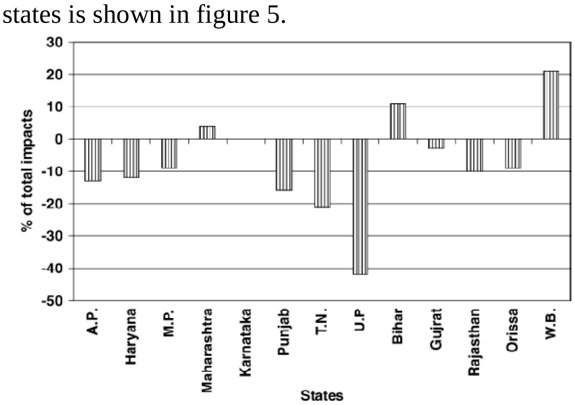

Figure 5. Graph showing the distribution of impacts on net revenue across different states of India, as percentage of total absolute impact. (Source: Kumar and Parikh, 1998).

There are several major and minor concerns related with climate change and its impact on agriculture but the two acute problems that are changes in mean temperature and precipitation and large scale changes in the frequency and variability in weather/climate, especially unpredictable short- term extreme weather conditions may have following impacts on Indian agriculture:

- Increased droughts and floods condition may destroy crops within the fields and will directly affect production.
- The productivity of most of the crops may decrease with increase in $1^{o}C$ in atmospheric temperature. There will be much higher losses at higher levels.
- Increase in sea and river water temperatures can severely affect fish breeding and may cause migration, at large scale which will indirectly escalate the pressure on more food production.
- It will be very difficult to address the escalating food demand due to continuous escalating population increase.

More efforts are needed to assure food security for the country. A second green revolution is urgently needed in India to raise the growth rate of agricultural GDP. Entire agricultural sector in India is dominated by small-scale subsistence farmers who are poor and equipped with very limited resources. In such situations the identification and adaptation of suitable and economically feasible techniques and strategies can only ensure sustainable agriculture in future. The important mitigation and adaptation strategies required to cope with anticipated climate change impacts include adjustment in sowing dates, breeding of plants that are more resilient to variability of climate, and improvement in agronomic practices. Researchers suggested that adaptation measures to mitigate the potential impact of climate change included possible changes in sowing dates and genotype selection (Attri and Rathore, 2003). In a country like India where approximately sixty five percent of the population is dependent on agriculture, it is very important that the effects of such drastic changes in temperature are studied and the mitigation and adaptation strategies should rely only scientifically proven facts about global climate changes.

Discussion and Conclusion

Global warming changes are affecting entire world but the poor and developing countries like India is on the front line. Agriculture is the main source of income for approximately 1.0 billion people in India. The climate changes have affected metrological conditions, crop production, and water resources severely. Impacts can be seen in the form of unprecedented heat waves, floods, drought, stalinization of the groundwater, and decrease in snow cover etc. Due to erratic climatic conditions drought and floods has become more common in the region, which are severely affected the agriculture sector. The crop yield per hectare has gone down and it has started showing its affect on food inflation.

The findings of the study demonstrated following points:

- The sunshine hour for Indian continent has decreased at the rate of approximately 1.10 Hrs/year. It can be interpreted as increasing number density of aerosols caused by various formats of land use changes and human activities. This trend may be due to climate change related changes and can severely affect agricultural activities in future which are dependent on sunlight.
- Parts of the Indian continents are facing extreme weather conditions like frequent droughts and flood with greater intensity. Such extreme weather conditions are affecting the crop growth rate, development and yield due to changes in rainfall and temperature. Agriculture production has gone down and food inflation has escalated manifold. Season crop failure becomes a common phenomenon.
- There is growing imbalance between demand and supply of food and water, which is going to increase in the future due to continuous escalation in population and climatic uncertainties.
- The urgent need for agricultural research to develop new crop varieties which are less or not vulnerable to climate changes and training to farmers on agriculture are not getting enough importance. Further programs like social security to provide insurance against supply changes are not in place.
- Despite continuous warning from IPCC, more emphasis has not been given on the use of renewable energy sources like solar and wind. The use of fossil fuels and its demand is increasing.

The following measures are proposed to tackle the existing problems:

1. Regional Scale Research Programme:

Global climate change and its impact on the hydrology and water resources need to be assessed at river basin scales. More emphasis should be given to improve existing capabilities to forecasting short and long-term drought and flood conditions and to make this information more useful and timely for decision making. Priority should be given to the studies related with climate changes and its impact on water quality, biogeochemical changes, soil cover and agriculture production.

2. **Soil Erosion and its Management:**

According to European Commission report Soil is both "a source and a sink of greenhouse gases". Therefore ignoring soil management can make the problems more complicated relate with climate change. Usually soils compositions are highly variable and depend on local geology, topography, climate, vegetation and management. Problems of soil erosion and its degradation are continuously increasing in India requires immediate preventive action. Such agricultural practices are adopted, which ensures that soils are covered with permanent vegetation so that it can be protected against water, rain and have least climate impact.

3. Strategies for minimizing the Climate Change:

World-wide there is consensus among researchers and scientists that global climate instability may occur if the current rate of greenhouse gas (GHG) emissions is not reduced. This view has been strongly supported by United Nations Intergovernmental Panel on Climate Change (IPCC, 1992), and called for rapid and immediate actions. Strong actions and research is needed for the identification and selection of actions to mitigate GHG emissions at international level because no one country or group of countries can provide its remedy. Therefore it is necessary that world-wide countries should co-operate each others through regional and international mechanisms such as the United Nations Framework Convention on Climate Change (UNFCCC). UNFCCC is working to solve the global climate problems.

4. Development of new technologies

All the developed and developing countries are anxious and do not want to cut or restrict existing energy policies, which will affect their industrial growth or competitiveness. All the countries want easily and economically feasible solutions, which are not only good for the planet, but also good for business and good for development. Emphasis should be given on the development of new technologies and improvement in the existing technologies for using the renewable energy sources, such as wind energy, solar energy, biofuels, biomass, and hydropower. Further studies and developments are required for crop rotation, and adaptation of improved irrigation techniques to cope with drought, and new plant varieties which are resistant to drought or to salt water.

5. Promote Recycling & Reuse of Wastewater

In today's world recycling and reuse of wastewater has become one of the best solutions for addressing the increasing water demand in agriculture and industrial sector. India which is perhaps facing the fastest urban development is putting great stress on the natural water cycle and is not capable to satisfy the continuous increasing demand of water for domestic, agricultural and industrial sector. Changing climatic conditions have worsened the situation in the area and need imperative actions. Water scarcity problems can be addressed by adopting and promoting recycling and reuse of wastewater.

6. Climate and water conservation education and development

Climate affects directly or indirectly our lives. Good knowledge about the climate and its impact can help us in the management of crops and water resources at the right time, and planning for the possible climate change and minimizing its impact. Climate and water conservation education and development includes people's perceptions and their consciousness towards water usage and conservation, awareness of their civic responsibilities towards water, cultural beliefs and practices in relation to water. Awareness should also be raised among the people by taking the help of media and NGO's regarding climate and water conservation education and development

7. Promoting afforestation and forest conservation:

Through afforestation excess carbon dioxide from the atmosphere can be absorbed and can effectively help in reducing the global warming. Forests absorb carbon dioxide, and even after the cutting, trees are able to store carbon for decades if used as building materials. Further if the woods are used as biomass energy, a reduction in the use of oil and other fossil fuels can be achieved. Moreover afforestation costs less than energy conservation and other methods. Since the last decade there has been drastic change in the landuse and land cover within India. To accommodate the increasing population large scale deforestation was carried out, which has increased the problems associated with climate change. Entire Indian continent imperatively needs large scales afforestation projects and forest conservation programmes.

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