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# Impact of Global Warning on Agricultural Pattern: A Case Study of Select agricultural spaces in Rajasthan

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**Abstract**

We all are witnessing a huge climate change and melting of glaciers, short duration of rainy season, increasing temperature are all its proof. Burning of fossil fuels, industries waste, deforestation increasing the concentration of Greenhouse Gases and hence the blanket is getting thicker, making earth warmer. Ithas been suggested by many climate scientists that the impact of changing climate can be seen maximum on tropical areas (IPCC, write the year). India being a tropical country and being totally depending on monsoon, becomes one of the most vulnerableregions in terms of experiencing climate change. At least, 60 percent of population in India, depends on agriculture. The consequences of climate change on agriculture are already alarming, consequently affecting the crop cycle, soil moisture, fertilizers and pest control. It is difficult to predict the crop cycle, with increasing temperature, land surface losing itsmoisture, indicating extra requirement of water. Moreover, a high temperature always favors the pest. The cumulative impact of these factors could be seen in the form of declining yield and production of crop.Rajasthan is abundantly endowed in the cultivation of a range of crops and has a significant animal husbandry industry. However, it has distinct vulnerabilities in terms of climate extremes and variable capacity for reacting to the expected dangers. Rajasthan has just around 1% of the country's total water resources, and its average rainfall is only 574 mm, compared to the national average of 1,100 mm. As Rajasthan lies at tropic of cancer effect of global warming becomes more prevalent. The present research attempts at analyzing the impact of climate change on the cropping pattern of Rajasthan with the help of secondary data. The paper analyses the degree of climate change by focusing on the select indicators of climate and weather and its association with the changing cropping pattern.

**Keywords**: *climate change, global warming, agricultural surfaces*

### 1.1 Introduction

Climate and agriculture both go hand in hand and hence any change in the environmental conditions imposes great impact on agriculture. One can self-experience the effect of global warming- the rise in temperature, meltdown of glaciers, the dry areas becoming drier, and the wet areas are now receiving aggravated rainfall. The worst affected economic sector isagriculture. As climate change not only affects the weather condition but alsohave a serious impact on the fertility, moisture, humus, minerals, and salts in soil. The frequent and continued abnormalities in climate are impacting the agriculture both directly and indirectly. Global mean temperature is increasing since few decades and as the models have predicted that the global mean temperature will increase 4-5degree Celsius by the year 2100According to early estimates for 2019-20, overall food grain output in the state would be 249.88 lakh tones, down 8.06 percent its harmonious growth. The abnormalities in weather from 231.25 lakh tones the previous year [22].Every crop require specific climatic conditions forand climate are responsible for affecting the rhythm of crop developments and resultant yield. The unpredictability of climate has severely affected the yield. Moreover along with this changing weather, the behavior of pests is also changing, which is again affecting the crops. Rising temperature generally favors the pest and microbes. So global warming is affecting the agriculture by not only impacting the land and the climate conditions but also by causing the pests to increase. As a result, an adverse impact on the productivity of the crops is further aggravated.

The same would push the farmers to use more pesticides which would have severe consequences on biotic elements including human beings. Agriculture, still plays a vital role in providing employment to at least 60 percent of people. The livelihood options mainly come from agricultural sector and allied activities in rural India. At this backdrop, it could be important to study the changing pattern of climate and agriculture and emerge with practices of mitigation, adaptation and resilience to address the issues of climate change and agricultural degradation.

### 1.2 GREENHOUSE EFFECT AND GLOBAL WARMING

Greenhouse effect is passing of solar radiation uninterrupted through the atmosphere and thus making the earth surface warm. Carbon dioxide, methane, nitrous oxide and water vapors are the major components of the greenhouse effect. Now, the molecules of these components absorb the solar radiation coming from the sun. As soon as the molecule absorb the rays, it start vibrating causing it to emit infrared radiations [1].

Some of these radiations get absorbed by molecules out of which some of it is transmitted to earth surface and some of it reflects back to the space. This phenomenon of abortion and emission taking place through these greenhouse gases act as a blanket to keep the earth warm. This greenhouse effect actually makes the life possible on earth, without this effect the earth would be way colder making it impossible to survive on the planet. Just like a glass greenhouse [2] where sunlight passing through the glass gets absorbed and trapped in the room which is vital for the plants to grow in winters.

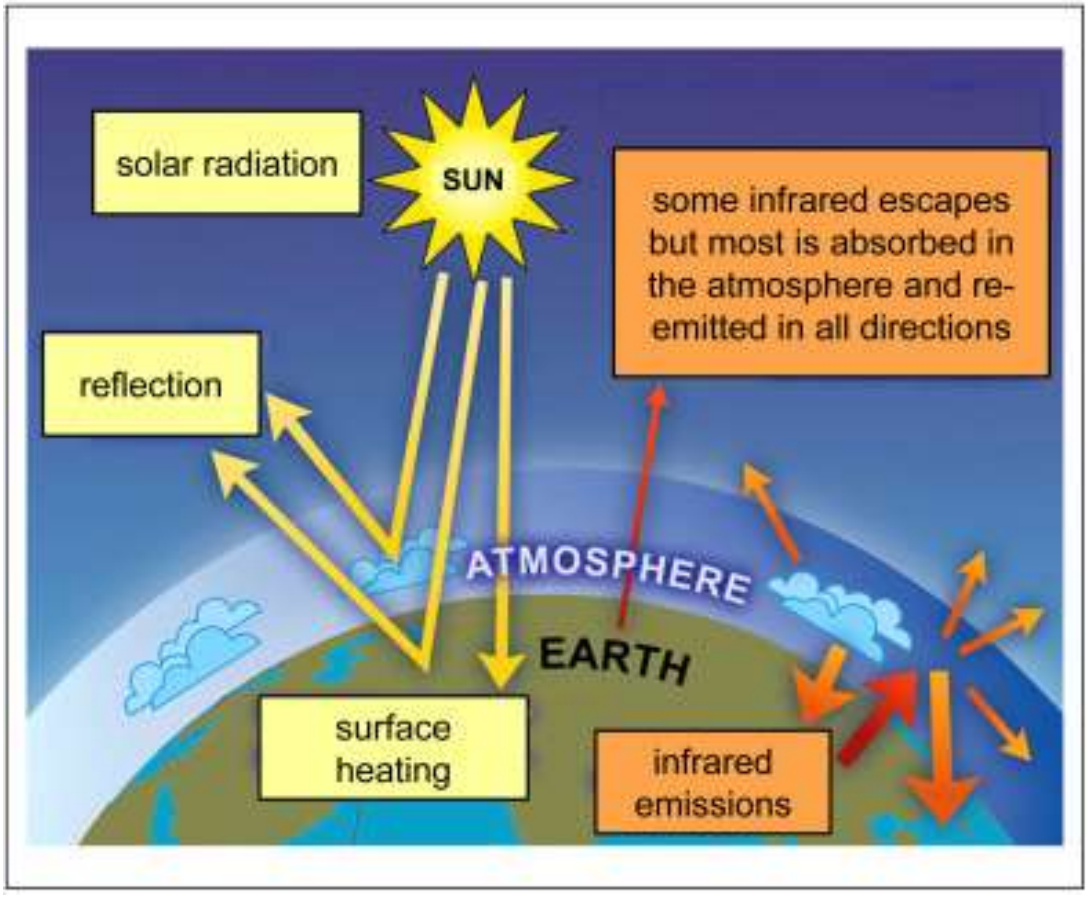


**Figure 1: Solar radiations reaching the earth atmosphere, out of which some are reflected back, some get absorbed and some penetrated the earth surface-maintain the right temperature and the process is known as Greenhouse Effect. Image source[3].**

Many of the sun radiations come under visible category and a few in non-visible and both of them are equally important. Most of the non-visible radiations get absorb in the atmosphere, but visible radiation have high wavelength and penetrates to the surface. This visible light is then absorbed by the plants, crops, land, soil, ocean etc. Now during the day the earth is warm and all the accumulated heat radiate back to space but Greenhouse Gases again act as a blanket by trapping some of the heat within otherwise the nights would be way colder.

As Greenhouse Gases serves a very important role in keeping earth temperature live able, this term was always considered in positive terms. But with increasing human activities now it poses some negative implications. Greenhouse gases like $CO_2$, methane, $N_2O$ emissions caused by human have serious impact on climate. The concentration of $CO_2$ and other greenhouse gases is increasing. These gases absorb the infrared radiations and trap heat in the atmosphere, preventing radiations from evading outer space, consequently increasing the natural greenhouse effect. Hence this enhanced heat trapped in the atmosphere causes a rise in the temperature of the earth and this phenomenon is known as Global Warming.

The fundamental of global warming is that earth needs to maintain a balance between radiation energy coming from the sun that warms the earth and the thermal energy radiated out from the earth. Now the global warming occurs because greenhouses gases absorb the thermal radiation and act as a blanket [1, 3, and 4]. Now the concentration of these greenhouse gases is increased mainly due to human activities and hence the absorption also. Consequently the earth temperature rises making the earth warm [4]. This changes the radioactive forcing of the climate system and results in increased temperature of Earth's surface, which affects crop growth and production.

### 1.3 Agents of Global Warming

Global warming occurs due to the fact that the most of the thermal energy absorbed by the greenhouse gases from atmosphere is reradiated back to the earth causing the temperature to rise. Now since the growth of industrial era the concentration of these greenhouse gases is increasing and hence the effect of greenhouse is enhanced. So the main agents of global warming are CO2, CFC, N2O and CH4.

#### 1.3.1 Carbon Dioxide

The burning of fossil fuel is the major reason behind the increasing concentration of CO2. Only one-fifth of the CO2 is cycled every year which is majorly due to respiration, photosynthesis and through physical and chemical processes occur through ocean surface. Here the major concern of is anthropogenic carbon which is not destroyed. The most important cause of this carbon is Industrial revolution. At present, there is about 30% increase in the amount of CO2 from the past. Currently, on an average about

1.5 ppm CO2 is increasing every year, adding 3.3Gt every year to the atmospheric carbon reservoir. In India farming land is of about 190 million hectare and the production of dry matter from farming is about 800 million t per year, out of which only a part of this is recycled and the rest is released back into the atmosphere.

### 1.3.2 Methane

Methane also known as marsh gas, usually observed in areas where organic material is decomposing and wetlands [5]. Some other sources of methane production are belching from cattle, decay in landfills, and leakage from natural gas pipeline. Floodedrice paddy fields, wood and peat burning. It has been observed that the concentration of methane is doubled in last few decades. The concentration of CH4 is lower than that of Carbon dioxide in the atmosphere but it still it contributes big to the global warming. The reason behind its contribution to global warming is lies in its molecule size. Since the size of the CH4 is almost 8 times in comparison to the carbon dioxide's molecule, so methane also poses almost equal threat as carbon dioxide to the environment.

In India major contribution towards CH4 comes from paddy fields. Rice fields need to be watered in rich quantity. These wet lands again contribute CH4 in the environment. Contribution of CH4 in India due to rice fields is about 4.2 Tg per year.

### 1.3.3 Nitrous Oxide

N2O has low concentration in the atmosphere but has a much larger lifespan of 120 years [4] which is way more than CO2. Moreover its concentration is rising at a high rate and is 16% higher than that of non-industrialized time. In India its largest sources are agriculture and fertilizers. In fact both the fertilized and unfertilized soils release N2O. But India's emission of N2O is much less than other developed nation due to the fact that India's land has low fertility rate and the use of fertilizers is also less.

### 1.3.4 Water Vapors

Water vapor is the most abundant greenhouse gas. The radiations coming from the sun gets absorb by vapors and radiated back to the earth making the earth warmer. These vapors follow a feedback process which is warmer air holds more vapors, if the temperature rises the evaporation also rises and hence the vapors. Thus with the increased amount of vapors the effect of vapors also increases in the greenhouse effect. But water vapor lifetime is much less than that of other greenhouse gases thus other gases are held more responsible for global warming [6].

### 1.3.5 Ozone and Chlorine-fluorine carbons (CFC's)

Ozone and CFCs both are greenhouse gases [7]. Ozone role is both positive and negative. In stratosphere it has positive role of absorbing solar ultraviolet radiations that could be harmful to humans and animals. While at surface of earth ozone has a negative role of pollutant by being the component of smog, threatening the lives of humans, animals and plants. For the use of aerosols, refrigerators CFC's have been created by the humans that are destroying the ozone layer in stratosphere.

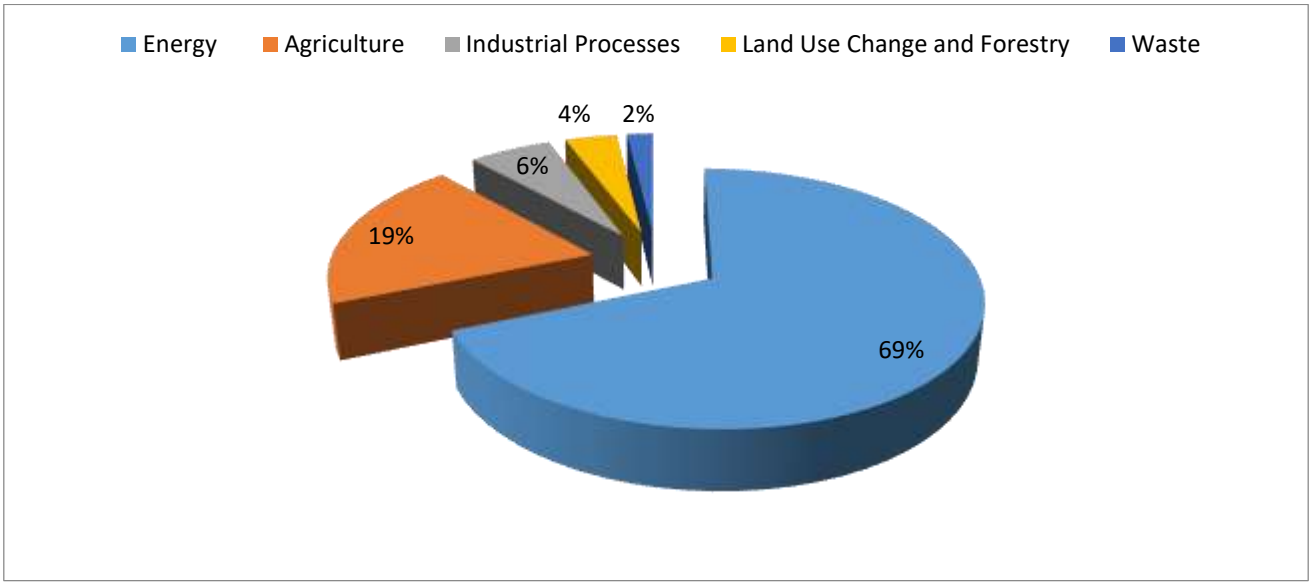


**Figure 2: Largest Sources of Green House Gases emission in India. Data source [7]**

One of the CFC's property is being chemically inert, means once they released into the environment - it would be there for long period of time like could stay for an era or even more. Soon CFC's negative impact was detected and countries started to ban its use. Now the ozone has started to recover but complete recovery may take years due to the longer lifespan of CFC's.GHG emission in India (Figure 2) according to [17] was maximum by Energy Sector of 69%, which includes emission due to electricity by 49% and by construction and manufacturing 24%. Next is due to agriculture by the use of enteric fermentation, burning of fields flooding paddy fields. Next are industrial processes, followed by land use and waste of 6.0%, 3.8% and 1.9% respectively.

### 1.4 Evidence of Global warming

We can clearly see and feel the climate change, as there is visible change in temperature of the earth due to the global warming. The warmer regions are now warmer with record of highest temperature every year. Global mean temperature was in 19th century

was recorded 0.7C above the normal and is further likely to increase by the estimate of 1.8-4.0 C [8] by AD2100. In fact in [9] some of the researchers has shown that the first decade of 21st century was .8 C warmer than that of first decade of 20th century. Human's anthropogenic activities, agriculture, deforestation all have played a big role in increasing the concentration of GHG's. Thus there is rise in temperature of earth. We can see the visual evidence of global warming in Fig2 [10].


**Figure 3: Evidence of climate change showing melting of glaciers. In Before, there is heavy glacier and In After, high melting of glacier is seen. Image source [10].**

This human created climate change is now well known, important, worldwide a green challenge and agriculture is highly affected by it. In [11] they concluded that 1C increase in average temperature would led to 6 million wheat yield loss in India. Directly or indirectly we can see the effect of climate change on land or soil. Due to rise average temperature there are more droughts, excess flooding in coastal regions, forest fires, powerful cyclones will affect the agriculture productivity. Moreover this change can give birth to more new changes like decrease in crops span, make changes in pest survival, photosynthesis will also get affected and hence the yield.

### 1.5 Estimated changes in India and worldwide

The evident climate changes in 20$^{th}$ century raised a concern about crops and other agricultural productivities. There are various environmental factors that affect the crop growth like high temperature, heat waves, excess cold and high precipitation [12]. Moreover Climate change not only effect the various weather conditions but also disturbs the cycle and duration of a weather. These factors can pose both advantage and disadvantage to crops. During 1901-2010, almost 17% of the years were reported as drought years. On the other hand heavy rainfall causes physical damage to crops. Evan a minor change in temperature can cause significant loss in crop yield especially in dry tropical regions [13]. In India, crop agriculture is broadly divided into two categories - Rabi and Kharif. Rabi crops wheat, barley, peas, gram, etc. are which are majorly dependent on north east monsoon. A warm climate is required for seed germination and cold climate for the growth of crops.These crops are highly dependent on the cycles of weather. If cycle is altered due to some reason yield of these crops tend to decrease. Kharif crops are rice, maize, cotton, jowar, bajra etc. dependent on south-west monsoon.It requires a lot of water and hot weather to grow. These crops are a lot dependent on the amount of rainfall. If rainfall doesn't happen on time the productivity of these crops get affected.

### 1.6 Changes increasing temperature cause on crop growth

Climate change is evidently rising the globe temperature and hence have some serious effects on crop growth in various direct or indirect ways. Increasing temperature raise respiration rate of crops [16] which eventually reduce the duration of crop, grains yield. Also increasing temperature increases pest density. Moreover there are specific crops that require cold temperature for their growth and due to increasing temperature they are highly effected.

The projections stated in [14] whereby 2010 average temperature in khaki will increase by 0.4 -2.0 C and 1.1-4.5 C will increase in Rabi. In [15] they conclude that crop production at a lower temperature doesn't affect the yield and initially crop production will increases with increase in temperature. But further rise in temperature can adversely affect the yield as prediction at high temperature becomes difficult to guess. This pattern is same for both Rabi and khaki crops.

| Crop | Net Effect |
|---|---|
| **Rice** | Negative |
| **Wheat** | Negative |
| **Maize** | Negative |
| **Sorghum** | Negative |
| **Potato** | Mixed |
| **Groundnut** | Mixed |

| | |
|---|---|
| **Coconut** | Mixed |
| **Gram** | Positive |
| **Soybean** | Positive |
| **Onion** | Positive |
| **Castor** | Positive |
| **Mustard** | Mixed |
| **Marine Fish** | Mixed |
| **Fresh Water Fish** | Negative |

**Table 1: Different Farming reacting (Positive, Negative, Mixed) to Climate Change. Data source [17]**

In Table1 [17] have shown various crops have different reaction towards Climate Change in India. India's most population generally depends on wheat and rice for their food which are expected to have Negative impact due to climate change. Those crops having mixed reaction is due to the fact that crops sown in different regions like northern and southern India can act differently towards climate change.

### 1.7 Rajasthan Agricultural surface and climate change

Rajasthan, being the biggest state having area 342,239 km², has particular problems in terms of climate and diverse capacities for reacting to those potential threats.Rajasthan water resources is approximately 1% of the countries, and its average rainfall is 574 mm, in comparison to 1,100 mm for the entire country.Western Rajasthan, which is most vulnerable to drought and has the rainfall of 102.57mm and is lowest in the state. Moreover forests are worn to shreds for mining and other extractive industries.

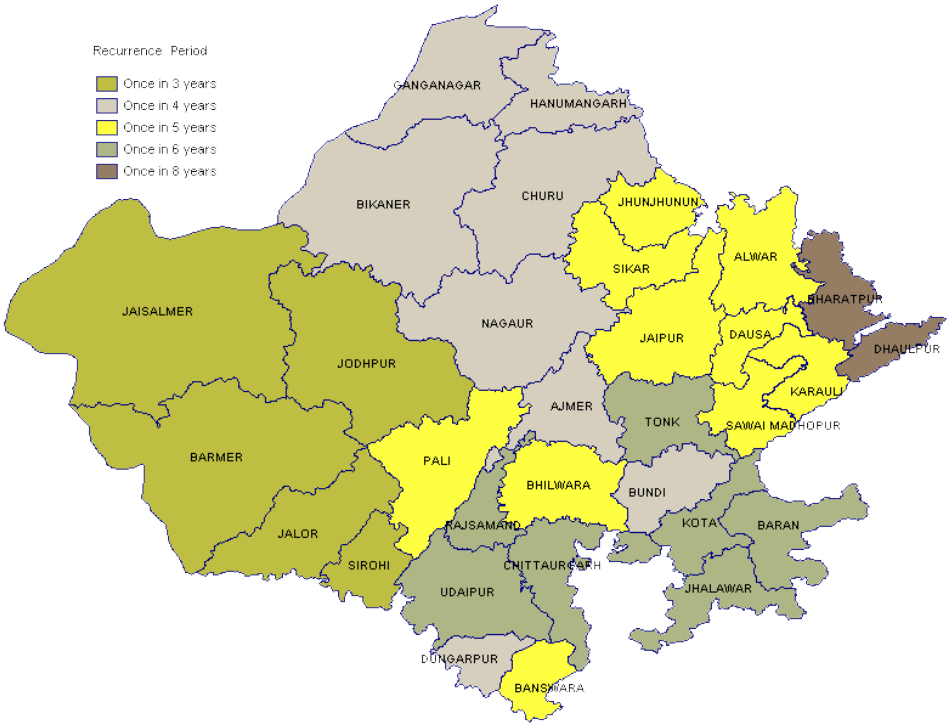


**Figure 4: Political Map of Rajasthan State, the study area of this work. Image source [18]**

Also Figure 5 shows the rainfall for number of days during the year [18] and its future trend. The future trend is calculated by the linear regression. It is clear from the graph that the rainfall has decreased drastically. According to the data maximum days of rainfall was during the year 1973 and receives a shortage of rainfall after 1983. The lowest rainfall was received in 1988, 2003, 2004 which was only for 40 days. Our expected future trends are also same as of 1983 afterwards and we even predicted the lowest point after 2030 onwards. It has seen that a monsoon arriving late and leaving early is a regular since 1980's. This decreasing trend is adversely affecting the dry land of Rajasthan leading to drought hence affecting crop production.

#### 1.7.1 Why Rajasthan is effected by Global Warming

The reason we opted for Rajasthan as our case study topic is that the cities of Rajasthan lies in the Tropic of Cancer where the position of sun is directly overhead.

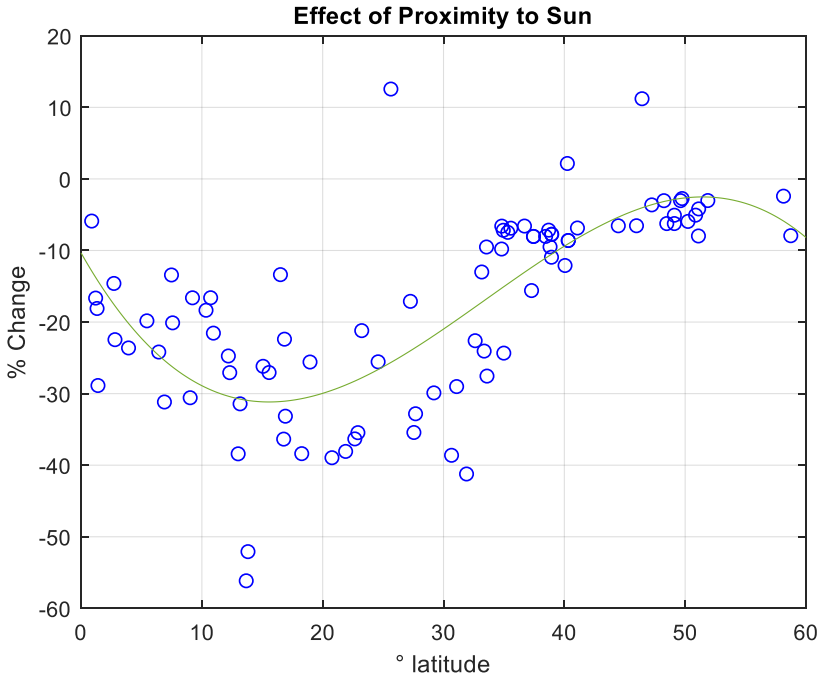


**Figure 5: This sine graph shows as the country comes closer to the sun the degree of change increases. Closer to sun means more heat eventually more effect of global warming.**

As the position of the sun is directly overhead of some of the cities of Rajasthan making the land drier due to the direct heat.

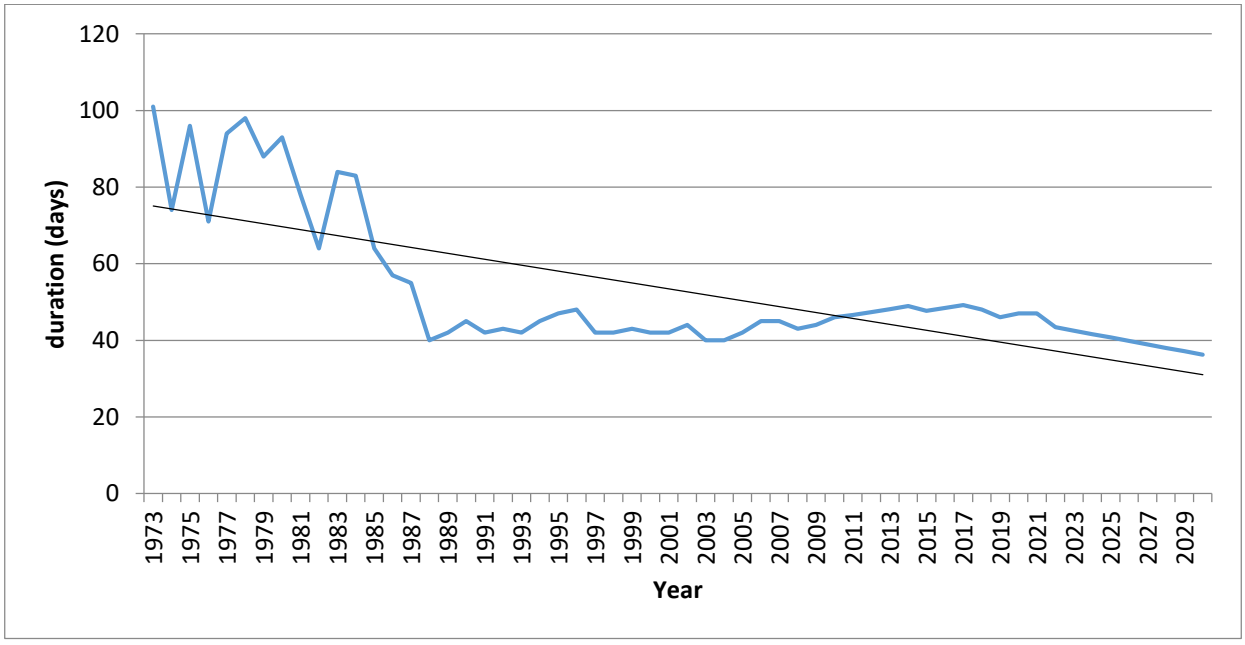


**Figure 6: Days of rainy season in Rajasthan from through 1973 to 2020 and its expected trend.DataSource [18]**

This direct heat along with global warming is again increasing. In Figure 4 [23] it is clear that position of sun is directly impacting the agriculture. The countries those lies closer to equator tend to suffer more because of global warming and the same effect is seen due to Tropic of Cancer. In India Tropic of cancer travels through few states like Rajasthan, Gujarat, and Mizoram where the high heat effect of sun along with global warming can be seen. These states suffer a dry heated atmosphere as they lie directly below the sun and pay the price for it. The land becomes dry, water resources become scare, the demand for evapotranspiration increases.

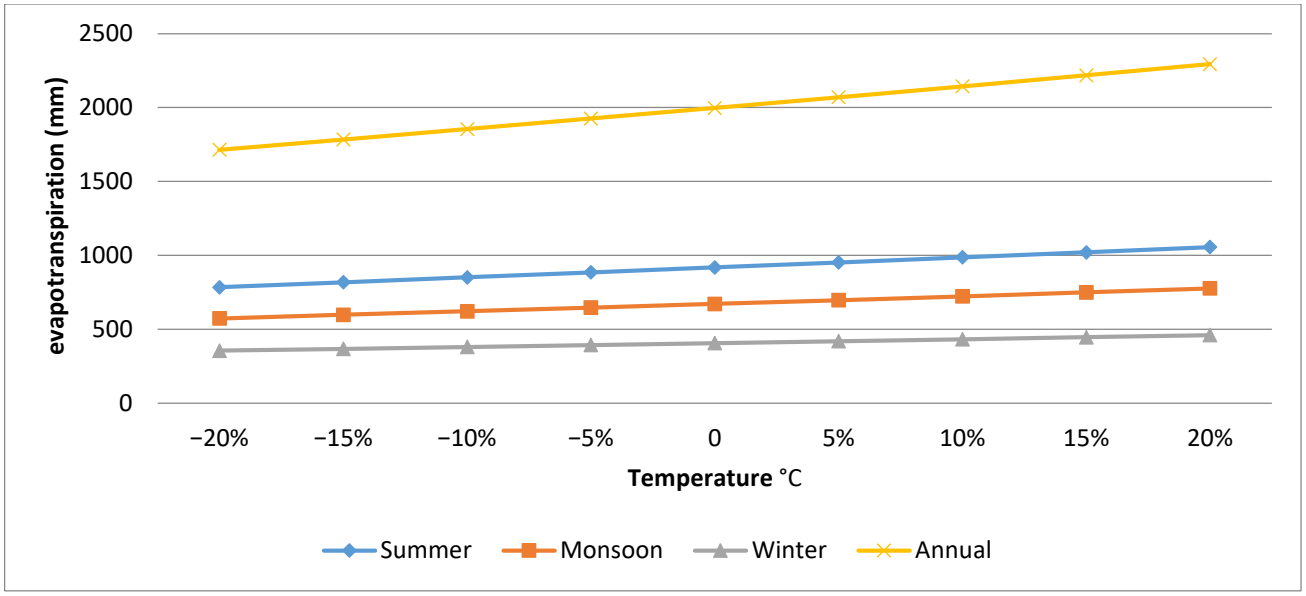


**Figure 7: Evapotranspiration during the three seasons and is highest during the summers due to heat rise through climate change in Rajasthan. Datasource[19]**

Frequently changing weather conditions due to global warming are changing the water requirement of land and surface, especially in Rajasthan who have a dry and arid surface. To fulfill that scarcity of water evapotranspirationplays an important role for future planning and management. Evapotranspiration is a vital hydrological component like soil moisture and ground water because it determines the crop water requirement. Evapotranspiration is actually the sum of evaporation from the land surface plus transpiration from plants. With this enhanced GHG effect definitely the rate of evaporation will also increase.

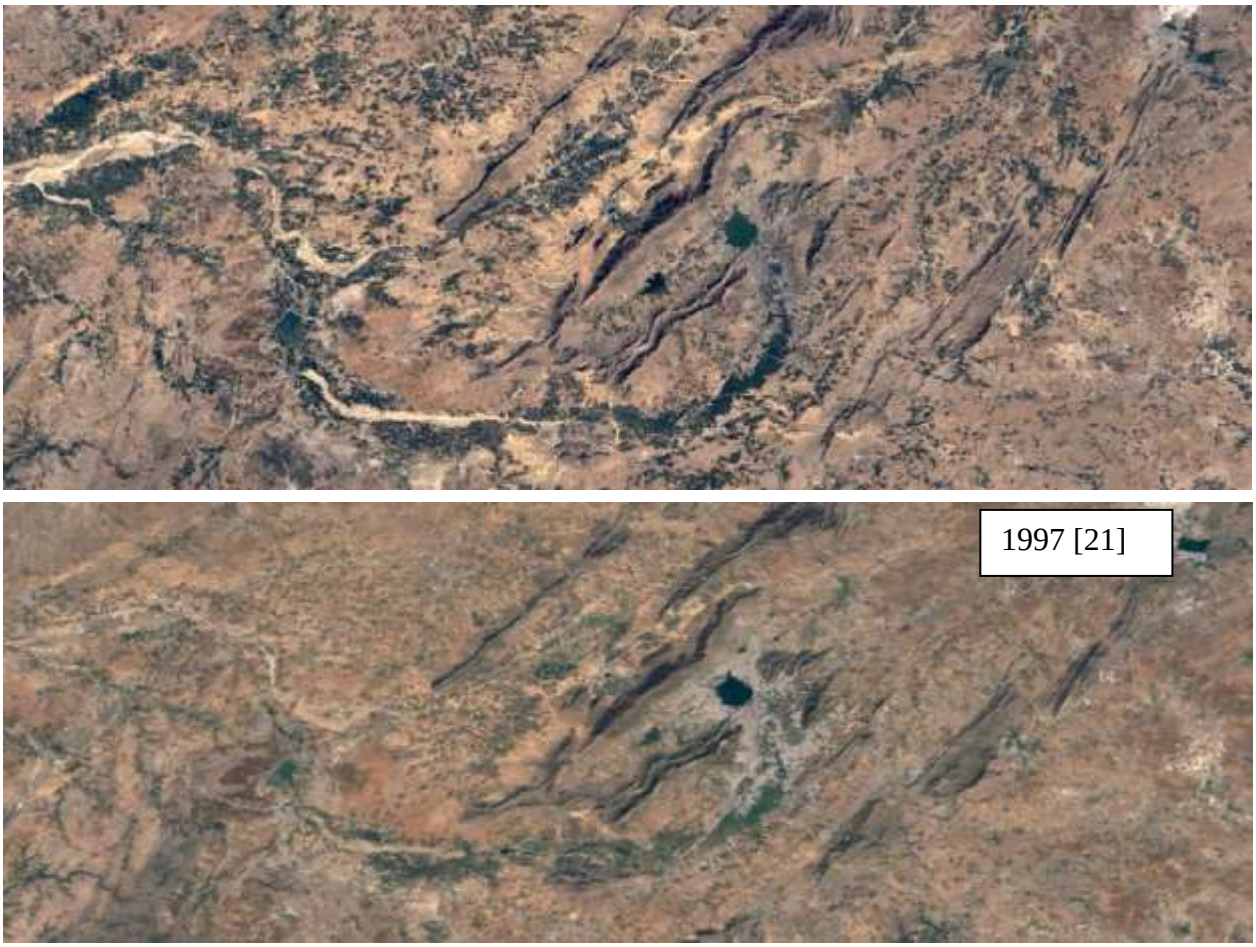


**Figure 8[21]: Clearly drought stress has increased from 1997 (top) to 2020 (bottom) in city Ajmer (Rajasthan). Image source [21].**

So in [19] they have conducted an experiment that if the vary temperature of Rajasthan what will be the effect on evapotranspiration need of crops. It is clear from graph in the Figure6 that increase in temperature, increases the evapotranspiratione.g. in summers which means the water requirement of the surface also increases.

### 1.7.2 Rajasthan Erratic Rainfall

Rajasthan is facing this erratic rainfall issue since 2011. The monsoon being erratic is again creating a lot difficulty in farming. It's difficult for crops to survive erratic rainfalls [20]. Below average rainfall bring drought stress and above average bring floods with them [20], both ways agriculture surface suffer. The same is the case in city Ajmer of Rajasthan. In Figure7 taken from [21] has clearly shown that Ajmer is losing its greenery even after receiving heavy rainfalls as more rainfall causes floods and thus soil erosion.

**Figure 9: Bottom dry surface of Sambhar Lake. Image source [20]**

Moreover around three decades ago, Rajasthan once had largest inland salt water lake known as Sambhar Lake but has now disappeared due to heart. Figure8[20] shows the bottom of sambharlake which is all dried up. In fact there various other lakes which are all disappeared due to rising heat. Figure9 [20] is a satellite view of all the lakes around Jaipur (capital of Rajasthan), where red dots are the lakes which are either dried up or shrunk in size. Green dots show increase in the size of lakes and lastly black dots symbolizes the lakes which are similar in size.

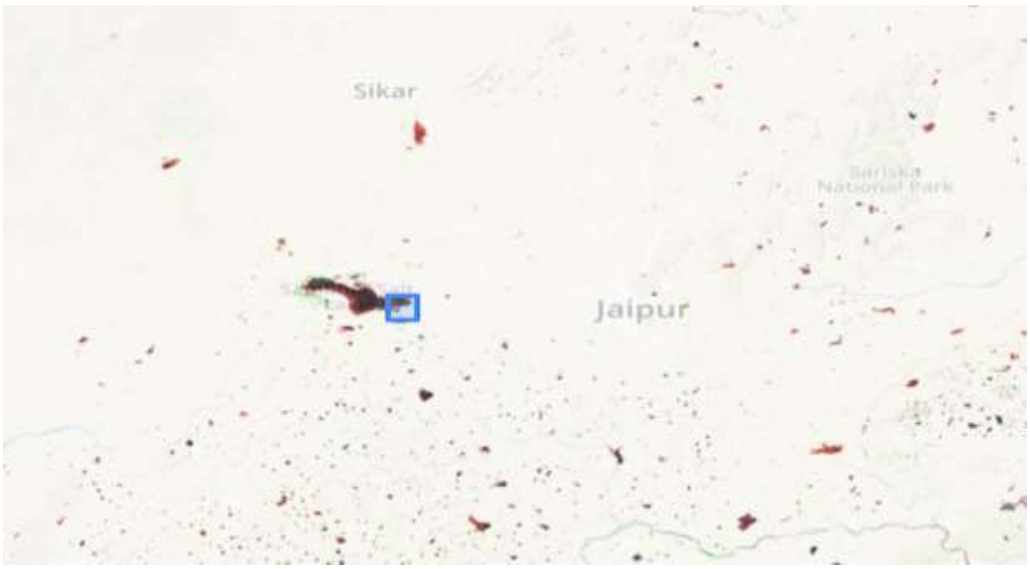


**Figure 10: Blue Box containing red dotis the satellite view of Rajasthan Sambhar Lake and other red dots that show lakes which are either dried up or shrunk in size. Image source [20].**

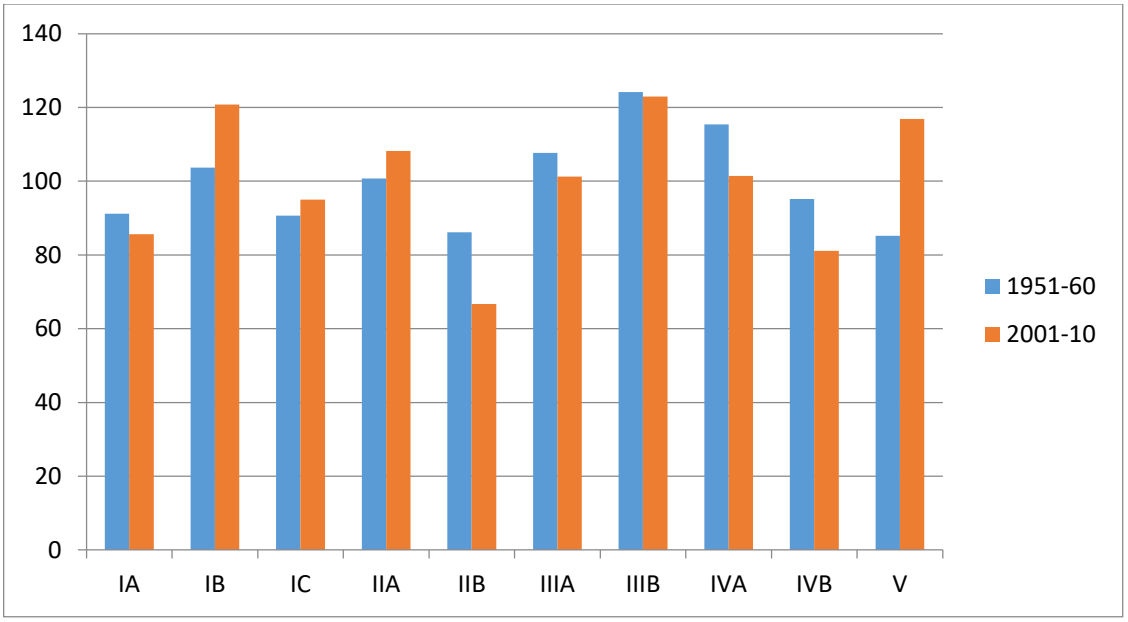


**Figure 11: A comparison of crop yield between decades 1951-1961 and 2001-2010 among various regions of Rajasthan. Data source [23]**

### 1.7.3 Effect on Rabi (Wheat) Crops

Major Rabi food crop of Rajasthan is wheat. In Figure 10 [23] a comparison of wheat productivity between decades 1951-1961 and 2001-10 has been made. A clear effect of global warming on crop yield has been seen, as in few regions the crop yield is increased but in majority of the regions the crop yield is decreased. As increased heat makes the land drier and water scare. This will eventually raise the demand for water and evapotranspiration.

### 1.8 Effect on Kharif (Pulses) Crops

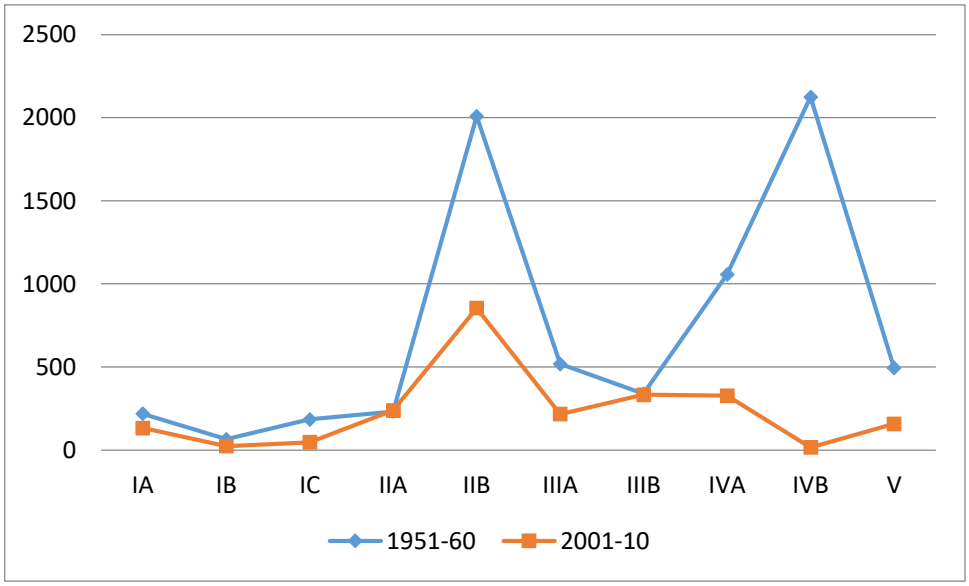


**Figure 12: A comparison of Kharif crop yield between decades 1951-1961 and 2001-2010 among various regions of Rajasthan.Data source [24].**

Major Kharif crop of Rajasthan is pulses. In Figure 12 [24] a comparison of pulses productivity between decades 1951-1961 and 2001-10 has been made. A clear effect of global warming on crop yield has been seen, as the yield of pulses is decreases in all the regions. The yield of pulses during decade has been decreased substantial because kharif crops require more time water to grow and both the rains and water resources of Rajasthan are depleting.

### 1.9 Summary

The climate change is indeed happening.Consequently the dry zones are becoming drier and are building drought stress. Sea level is also rising, risking the lives near coastal areas. Both the condition are affecting agriculture as its difficult to sow crops in drought areas and land surface is decreasing due to melting of glaciers. Flooded zones are draining soil. The requirement of water

resources is increasing in Rajasthan. Moreover in the research study of Rajasthan we have learned that not only a normal surface but the water bodies are also either drying up or have shrunk in size. In fact now we can see the cracked lines, all dried bottom surfaceof the lakes. Majorly the position of Rajasthan is playing crucial role here as it lies in Tropic of Cancer and hence paying the price.According to the findings of this study, global GHG emissions are anticipated to raise CO2 levels in the atmosphere, rising global temperatures owing to the greenhouse effect. Land masses, on the other hand, have seen a greater rise in temperature than seas. The precipitation outlook has changed, and more weather extremes are expected in the near future. Rajasthan's agricultural output is expected to suffer as a result of climate change. The favorable effects of increasing Carbon dioxide on plants are most likely to be negated by increased warmth and changing precipitation. Climate change's future and its consequences are very uncertain, particularly for Rajasthan, which has only 1% of the country's total water resources.This makes planning for mitigation and adaptation a very difficult.

1. In addition to planned agronomic management and crop pest control, suitable varieties that can respond to climate changes must be developed.
2. Farmers must be informed about climate-smart technology and given training to make their usage in the field as simple as possible.
3. To reduce climate change, technically sound and commercially viable climate-resilient technology must be defined through a multidisciplinary approach.

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