Review Article

WEATHER PARAMETERS AND IT'S IMPACT ON AGRICULTURAL PRODUCTION- A REVIEW

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KEYWORDS:
Weather, climate, parameters, perilous effect

ARTICLE INFO
Received on:
10.09.2018
Revised on:
17.11.2018
Accepted on:
19.11.2018

ABSTRACT

Natural fluctuations of climate above or below a daily average value is termed as weather variability. Weather plays a major role to determine the agricultural improvement. Almost all the field crops are solely dependent upon weather parameters to deliver life sustaining water and energy. This weather change is one of the most important global environmental challenges that have significantly higher implications on agricultural sectors. This changes include increase in air, water, extreme temperature, elevated greenhouse gases concentration, enhanced the incidence of droughts and floods, changes in pests and diseases, regional monsoon variation, changes in atmospheric CO2 and ground-level O3concentrations, changes in the nutritional quality of some foods, recurrent rains pattern along with other factors such as chilling, water logging, dust-storms, thunderstorms and hailstorms, high winds, heat and cold waves, rise in extreme weather incidences in coastal regions and recession of Himalayan glacier etc. Globally, these parameters drastically reduce the agricultural production and productivity at the regional and local levels due to global warming. Changing of all the weather parameters under a prolonged situation are responsible for global warming that have negative impacts on agricultural crops. This leads to cause an array of morpho-anatomical, physiological, biochemical and molecular changes in plants that affects plant growth, development and may lead to severe diminishing in economic yield. To cope up with this weather-related hazard or adapt against this alarming situation, forecasting of weather is one of the important toolsfor agricultural production under climate change scenario.

INTRODUCTION

Weather describes the daily changes in the physical condition of the atmosphere (moisture, temperature, rainfall, pressure and wind) of a place over a short period of time. Whereas, climate refers to average condition of the atmosphere of a place over a long period of time i.e. long-term pattern of the atmosphere (average temperature and average rainfall pattern etc). Weather plays a major role in determining the success of agricultural pursuits. Weather is important for agriculture, as it can be both beneficial and detrimental to crop production. On a year to-year basis, weather influences the number of growing degree days, length of the growing season, and timing and amount of precipitation and evapotranspiration from crops.

Most field crops are dependent solely upon weather to provide life sustaining water and energy. Occasionally, adverse weather conditions can cause production losses, especially if experienced during critical stages of growth. Individual elements of weather influence crops in particular ways. However, the combination of all-weather elements occurring simultaneously can have additive effects. The purpose of this article is to provide an overview of effects the individual elements of weather (solar radiation, temperature, precipitation, humidity, and wind) have on the physiology and production of agricultural plants.

A changing climate leads to changes in the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events (IPCC, 2014). Global warming is predicted to increase the frequency and severity of heat stress leading to drastic reduction in the food production (Talukdar *et al*., 2014). Agricultural production is directly affected by main climate variables such as temperature and precipitation. These variables control crop growth and health, annual crop yield, and yield of the cropping system over time (Howden *et al*., 2007; Kang *et al*., 2009; Lehmann, 2013; Paudel *et al*., 2014; Liang *et al*., 2017). Climate extremes are expected to increase with climate change, which may negatively affect crop production (Troy *et al*., 2015). Estimating the effect of weather on crop output has long been a concern in agricultural production (Wallace, 1920; Stallings, 1961; Shaw, 1964; Oury, 1965). Given the non-separability of household production and consumption in developing economies, the role of weather

in crop production has also been of long-standing interest in international development (Rosenzweig and Binswanger, 1993; Rosenzweig and Wolpin, 1993; Townsend, 1994). The effects of weather on crop yields can, alternatively, be captured by statistical regression models (CABAS *et al*., 2010; YOU *et al.,* 2009). The advantage of the statistical regression models over crop simulation models is that they can integrate not only biophysical variables such as soils, temperature and precipitation, but also socio-economic and institutional factors that crop models cannot capture directly. Lunagaria *et al.* (2012 and 2015) analyzed long period climate parameters to find the trends and variability and of extreme weather events.

The global agriculture has adversely been influenced due to droughts and floods, cold and heat waves, forest fires, dust storms, hailstorms, thunder clouds associated with lightning and sea level rise. In the long run, the weather parameters could affect agriculture in several ways such as productivity (quantity and quality of crops); agricultural practices (changes of water use efficiency and use of agricultural inputs such as herbicides, insecticides and fertilizers etc; environmental effects (particularly in respect of frequency and intensity of soil drainage leads to nitrogen leaching, soil erosion, reduction of crop diversity); rural and urban hazardous (loss and gain of cultivated lands, land speculation, land renunciation, and hydraulic amenities etc); adaptation (organisms may become more or less competitive, as well as humans may develop urgency to develop more competitive organisms, such as water logging resistant (O_2 deficiency), drought or salt resistant or tolerance to crops, heavy metal stress to crops etc.

Weather components

Components of weather and climate or simply weather elements that have some impact on agricultural production include:

- Temperature
- Solar radiation
- Humidity
- Cloud
- Pressure
- Wind
- Precipitation

Factors controlling weather and climate

Weather refers to the atmosphere's evolution over short periods of time, climate is the expected distribution of weather; therefore, climate change refers to the statistical distribution of weather occurring over decades and centuries (Auffhammer *et al.,* 2011). Geographical factors influencing weather and climate are referred to as climate controls. They are:

- Latitude.
- Altitude.
- Land and water bodies.
- Mountains.
- Topography.

The distance from the equator, either from south or north, largely creates variations in climate. Based on latitude, the climate has been classified as tropical, subtropical, temperate and polar climates. The height from mean sea level adds to variation in climate. Temperature and pressure decrease with increasing height from mean sea level. Based on altitude, the climate is described as mountainous and valley climates. Nearness to large bodies of water also causes variation in climate. The climates are referred to as continental and maritime.

Weather parameters with favorable influence on agriculture

(1) Weather and climate are important factors to determining the success or failure of agriculture.

(2) All the agriculture operations from sowing to harvest of crops depend on the mercy of weather.

(3) Climate determines suitability of a crop to a region while weather plays a major role in the productivity of a crop in the region.

(4) The excess or shortage of elements of weather and climate exerts a negative influence on crop growth, development and final yield.

(5) The effect of weather and climate is complex as elements of climate operate simultaneously in nature.

(6) Due to complexity of environment in which a crop is grown, it is difficult to assign an optimum value of climatic element for maximum crop productivity.

Weather parameters with negative influence on agriculture

- Excessively and untimely rains.
- Scanty rains with prolonged dry spells.
- Heat and cold waves.
- Dust-storms, thunderstorms and hailstorms.
- High winds.
- Floods.

Weather variables having both positive and negative effects on crop productivity

- Solar radiation.
- Temperature.
- Humidity.
- Wind.
- Precipitation.

Elements of agricultural weather forecasts

An agricultural weather forecast should refer to all weather elements, which immediately affect farm planning or operations. The elements will vary from place to place and from season to season. Normally a weather forecast includes the following parameters:

- Amount and type of coverage of sky by clouds
- Rainfall and snow
- Maximum, minimum and dew point temperatures

- Relative humidity
- Wind Speed and Direction
- Extreme events like heat and cold waves fog, frost, hail, thunderstorms, wind squalls and gales, low pressure areas, different intensities of depressions, cyclones, tornados etc.

An agricultural weather forecast should contain the following information also

- Bright hours of sunshine
- Solar radiation
- Dew
- Leaf wetness
- Pan evaporation
- Soil moisture stress conditions and supplementary irrigation for rainfed crops
- Advice for irrigation timing and quantity in terms of pan evaporation
- Specific information about the evolution of meteorological variables into the canopy layer in some specific cases
- Micro-climate inside crops in specific cases.

The extreme weather impression on crop production

Crop production depends directly and indirectly on weather condition. The effects of weather on crop production depends on Solar Radiation, Air Temperature, Precipitation/Rainfall, Cold wave, Fog, Snow storms Relative Humidity, Wind Movement, Hailstorms, Thunderstorms and Dust storms, Heat wave, Tropical cyclones and Tidal waves, Floods, Heavy rain and Landslides, Droughts, Atmospheric Pressure and Clouds. The effects of weather on crop production is described as following:

Solar Radiation:

(i) Direct Solar radiation: It is the amount of radiation received directly from the Sun. The radiation scattered by the suspended particles is called *diffused radiation.* In *diffused radiation,* about 65 percent is *photosynthetically active radiation (PAR)* compared to 45 percent in direct radiation. As clouds are very effective reflectors, little solar radiation reaches the earth surface on a cloudy day. Snow is also a very effective reflector (especially when it is fresh). Water surfaces and sea are poor reflectors and thus serve as a good sink for solar energy. Rocks, sand and vegetation reflect 10 t0 30 percent of the incident solar radiation. Plants intercept direct and diffuse sunlight. The upper leaves receive both types of radiation, while the lower leaves intercept a small portion of direct radiation. Diffuse radiation, therefore, becomes more significant in the lower leaves due to radiation transmitted and reflected from the leaves and the soil surface. Solar radiation transmitted by the leaves is predominantly infrared.

(ii) Influence of Sunlight: Photoperiodism (periodicity of light) has direct influence on the behavior of flowering in plants. Day neutral plants (no relationship between flower formation and day length) viz. maize, soybean, cotton, tomato, sunflower, pea etc are independent of sunshine hours whereas short day plants (critical length of photo period 11-12 hrs plants that flower below the critical period. e.g. Jute 11.5hrs): Jute, tobacco, sweet potato; Long day plants (critical length of photo period 14-18hrs– Long day i.e. short night is required for flowering):Cabbage, potato, lettuce, radish (e. g Spinach flowers above 13 hrs day length or more but not less).Therefore, extreme influence of sunshine hours reduces the crop production.

(2) Temperature: Temperature is defined by the degree of hotness or coldness of a substance, determined by the extent of its molecular activity. Sea surface temperature has risen significantly in India since over the last 40 years i.e. by 0.602^0C along North-East India, by 0.597^0C along North-West India, by 0.690^0C along South-East India, and by 0.819^0C along south-west India (CMFRI-NICRA, 2016). According to the Lal (2001), annual mean area-averaged surface warming over the Indian subcontinent will range between 3.5 and 5.6^0C by 2080. These projection shows more warming in winter season than summer season. The spatial distribution of surface temperatures suggests a mean annual rise in surface temperatures in North India by 3^0C or more by 2050. It has been estimated that global mean temperature is rising at 0.3% per decade which may cause 50% decline in wheat yields in South Asia by 2050 (IFPRI 2009). The most significant impact of higher temperature is being experienced in the Eastern Gangetic Plains Zone in the form of shorter winters and the onset of significantly higher temperatures much earlier than normal (Chandra *et al*. 2017). Extreme temperature that negatively influences some morphophysiological as well as productive parameters of the plant as discussed herewith:

(i) Germination: Proper temperature is essential for seed germination. Too high and too low temperature prohibits seed germination. Different crops have different term requirement for germination and complete life cycle. Heat stress has negative impacts on seed germination of various crops though the ranges of temperatures vary largely on crop species (Kumar *et al*. 2011).

(ii) Photosynthesis: Photosynthesis is the most sensitive physiological process in response to elevated temperature (Wahid *et al.* 2007). Occurs within -6 to 37^0 Growth, development and yield: Production of dry matter occurs when soil temperature ranges bet 20-30 ^{0}C. Optimum temperature requires for photosynthesis of majority crops are in between 25-35^0C.According to Singh *et al.* 2017 under elevated temperature photosynthetic rates declined rapidly during grain filling period and the decline was significantly lower than ambient condition.

(iii) Flower initiation: Vernalization (certain crops require low temperature for flower initiation and development of flowering e.g. Cabbage, cauliflower, carrot turnip etc).

(iv) Chlorophyll content: Increase in temperature causes chlorosis in leaves and decrease in chlorophyll content that affects photosynthesis rate as because chlorophyllase

converts chlorophyll into chlorophyllide and phytol (Mishra *et al*., 2017). Temperature stress declined chlorophyll contents in cool-season cereal species which leads to physiological changes and thereby leaf senescence (Almeselmani *et al*., 2012).

(v) Life span: Sequences of crop duration of rabi is more than kharif crops due to comparatively reduced respiration rate.

(vi) Transpiration/evaporation: Crop transpiration is the most active and common method of cooling crop tissues, with plant cooling requirements increasing with temperature (Seginer, 1994). Kharif crops have higher transpiration rate than rabi due comparatively higher temperature.

(vii) Product quality: Low temperature imply relatively better quality of the product that vary with crops.

(viii) Respiration: Temperature impacts on respiration are driven by changes in enzyme activity (Brooks and Farquhar, 1985). According to Peng *et al.,* 2004, respiration increases under heat stress which result in reduced assimilates available for plant growth.

(ix) Canopy temperature: Canopy temperature depression is directly or indirectly affected by several physiological processes and is a good indicator of genotype fitness in a given environment (Saxena *et al*., 2016).

(ix) Yield: Generally, yield of the rabi crops are more than kharif crops due to comparatively reduced respiration rate and higher net photosynthetic rate.

(3) Precipitation/Rainfall: The falling off any type of condensed moisture to the ground is called precipitation. Rainfall is precipitation in the form of liquid drops larger than 0.5mm in diameter is falling on the earth. When water droplets in a cloud grow and become heavy enough, they fall in the form of rains. Ordinarily, rain drop size varies from 0.5 to 4 mm in diameter. Extreme rainfall conditions characterized by droughts and floods etc have devastating impacts on agricultural production. According to Lal (2001), a marginal increase of 7-10 % in annual rainfall is projected over the subcontinent by 2080.Rainfall is one of the major climatic parameters and is also a major influencing factor for crop production (Hauqe, 2009). Rainfall variation have devastating effects in areas where agriculture is predominantly rainfed and hence any irregularity in weather conditions has adverse welfare implications (Birhanu and Zeller, 2009). According to projections by the Intergovernmental Panel on Climate Change (IPCC), rainfall variability and extreme climatic events such as droughts are expected to adversely affect agricultural production and food security (Christiansen *et al.,* 2007).IPCC estimated that changes in precipitation in a warming world will not be uniform. In many mid latitude and subtropical dry regions, mean precipitation will likely to decrease, while in many mid-latitude and tropical wet regions, mean precipitation will likely to increase. Besides, extreme precipitation events over wet tropical regions will very likely become more intense and more frequent as global mean surface temperature increases (IPCC, 2007).

(i) Germination: Proper moisture is essential for seed germination. Different crops have different moisture requirement for germination and complete life cycle. Wheat seed requires 55% water absorption compared to its weight for germination. Mustard requires less water absorption. Jute requires more rainfall to grow. Chili and Potato seed damages with higher rainfall.

(ii) N Fertilization: Atmospheric N added to the soil through rainfall.

(iii) Tillage and intercultural operations: Better performed under field capacity and wet condition depending on crops. Upland farming needs special practices.

(iv) Insects, pests/diseases/weeds: Incidence of Insects, pests, diseases & weeds during kharif season is more than rabi due comparatively higher rainfall and excess moisture.

(v) Photosynthesis: Less net photosynthesis in more cloudy days due to rainfall.

(vi) Growth, development and yield: Rabi crops have more potentiality than kharif crops due to comparatively controlled moisture contents.

(vii) Soil erosion: Excessive rainfall creates higher soil erosion as well as land degradation.

(viii) Product quality: Rabi plays better than kharif due comparatively controlled moisture contents.

(ix) Moisture contents: Moisture regulates the food quality e.g. Grapes ate sour in rainy seasons.

(4) Heat waves: Extreme positive departures from the normal maximum temperature result in heat waves during the summer season. The rising maximum temperature during the pre-monsoon months often continues till June, even in rare cases till July over the northwestern parts of the country. Notably the period roughly coincided with last two decades of the twentieth century which witnessed unprecedented high temperatures globally because of the global warming.

(5) Drought: Droughts have an immediate effect on the recharge of soil moisture resulting in reductions of stream flow, reservoir levels and irrigation potential and even the availability of drinking water from wells. Drought often creates economic and financial difficulties for agricultural producers. Drought that persists for several years can create substantial and devastating agronomic difficulties and genuine economic hardship for agricultural producers and agriculturally-based businesses in rural communities. The cultivation of lands subject to a high degree of rainfall variability makes them extremely susceptible to wind erosion (and desertification) during prolonged drought episodes, as the bare soil lacks the dense vegetative cover necessary to minimize the effects of aeolian processes. Due to uncertainty of rains during the drought, farmers sometimes make several attempts at sowing of seeds leading to a drastic reduction in seed reserves which in due course are neither enough for planting nor for consumption. In 2015, the Government State Committee for Emergency and Disaster Management (SCDEM) reported that nine percent of agricultural land became unsuitable for

cultivation due to a prolonged drought in 2014/15. In 2015, total production in terms of cereal equivalent was 5.06 million tonnes which fell below the production level of 2014 (5.71 million tonnes) by 11 percent. The Ministry of Agriculture has attributed this decrease in production to the 2014–2015 drought.

(6) Clouds: Solar radiation provides energy for evaporation. Evaporation supplies water vapor to the air. Air rises upwards because of increasing temperature. As the mass of air goes up, it expands due to low pressure and cools. If the cooling proceeds up to saturation, water vapor condenses, and cloud formation takes place. Clouds are also formed when a current of warm air strikes a parcel of cool air, or when a moist air from sea blows over cold land. Thus, the cloud is an aggregate on minute drops of water suspended in the air at higher altitude. Clouds are at a basic height of 1950 m. If it is formed above that height, the word, 'alto' is associated. If the cloud is associated with rains, word, "nimbus" is associated.Thunderstorms help in fixing atmospheric N into the soils in the form fertilizer.

(7) Carbon Dioxide: Plants help keep the planet cool, but rising levels of carbon dioxide in the atmosphere are turning down this global air conditioner. Agricultural productivity will also be affected due to increased carbon dioxide in the atmosphere. It was also reported that global release of CO2 triggered by human activities had reached a record high in 2011 and will likely increase in successive years, thus contributing to the global increase in temperature (Maraseni *et al.,* 2009; Smith and Olesen, 2010). The hazardous effects of CO2 on crop production are discussed herewith as under:

(i) Increase in CO2 will increase temperatures throughout the earth. Plants will need extra water both to maintain their larger growth as well as to compensate for greater moisture evaporation as the heat increases. While rainwater is not enough for current agriculture farmers will have loss in crop productivity due to lack of enough water.

(ii) Increased carbon dioxide has also created a problem of land fertility degradation. This excess CO2 has increased the fine root structure of the plants. This leads to almost doubling of the carbon dioxide in the soil in which they grew, leading to the loss of important nutrients of the soil.

(iii) With increased levels of carbon dioxide, plants would require a higher quantity of fertilizers to compensate for the degrading soil fertility. A higher production of artificial fertilizers would be required to keep up with the crop production.

(iv)With increased carbon dioxide levels, the defenses of the plants go down. They become more susceptible to insects.

(v) Quality of food crops is affected as well due to increased CO2 levels. For e.g. It inhibits the ability of the wheat crops to convert nitrates to proteins. Trace elements are affected as well, with the percentage of iron decreasing and that of lead increasing.

(vi) Due to increasing pollution, ground-level ozone volume has been found to increase as well. O3 or ozone is only beneficial in the upper layers of atmosphere and is toxic at lower levels. Its reaction with increased CO2 causes damage to the internal tissues of the leaves. This leads to decreased growth of the plants as well photosynthesis.

(vi) A study shows that excess of carbon dioxide reduces the rate of transpiration of plants. This is so because the stomata openings of the leaves, used for exchanging both gases, and water vapor get smaller. As the lesser volume of water gets evaporated by the leaves, the lesser volume is absorbed from the ground, thus causing an increase in runoff water.

(vii) The rapidly rising levels of carbon dioxide in the atmosphere affect plants' absorption of nitrogen, which is the nutrient that restricts crop growth in most terrestrial ecosystems.

(viii) CO2 enhanced plants will need extra water both to maintain their larger growth as well as to compensate for greater moisture evaporation as the heat increases.

(8) Cold waves: Occurrences of extreme low temperature in association with incursion of dry cold winds from north into the sub-continent are known as cold waves. The cold waves mainly affect the areas to the north of 20°N. Long periods of extreme cold weather combined with other meteorological phenomena result in the loss of winter crops, fruit crops etc due to frost or freezing injury results ice nucleation while temperature of 1-5°C for 24 to 36 hrs. Causes chilling injury. Low soil temperature at the depth of plant roots causes frost injury. Such reduction in soil temperature occurs with strong frosts, in the absence of snow cover and with deep freezing of the soil. Most frost injury to winter crops takes place in the first half of winter before enough snow cover has formed. In the second half winter, frost injury happens in regions with unstable snow cover. Under low temperatures basically a plant dries out, increased protein degradation, membrane leakage, inhibition of photosynthesis, translocation of photo assimilates, decreased respiration and ultimately the protoplasm (the living cell) dies because of intracellular freezing i.e. invariably lethal.

(9) Atmospheric Pressure: The Pressure exerted by the atmosphere of the earth's surface is called atmospheric pressure. Generally, in areas of higher temperature, atmospheric pressure is low and in areas of low-temperature pressure is high. Atmospheric pressure has no direct influence on crop growth. It is, however, an important parameter in weather forecasting. Instruments for measuring atmospheric pressure are aneroid barometer and barograph.

(10) Fog: Prolonged foggy weather has adversely affected vegetable and fruit crops. Heavy fog for several days, indicate that horticultural crops, including vegetables and fruits and flowering plants, especially in the nurseries, have shown signs of stunted growth and even initiation of withering. Immediately after the passage of a western disturbance, a lot of moisture is available in the atmosphere

provides the trigger for the formation of fog. Even though this phenomenon is not directly related to the extreme weather events, it has an effect in all forms of transport and wind speed at the soil surface and to increase the cohesion of soil particles are both crucial.

(11) Thunderstorm, Hailstorm and Dust storm: Winds in dry climatic zone also affect growth of the plant mechanically and physiologically. The sand and dust particles carried out by wind damage plant tissues. Winds also cause considerable losses by inducing lodging, breaking the stalks and shedding of grains and ultimately decreasing the yield. As winter season gives way to spring, the temperature rises initially in the southern parts of India, giving rise to thunderstorms and squally weather which are hazardous in nature. While the southernmost part of the country is free from dust storm and hailstorm, such hazardous weather affects the central, northeastern, north and northwestern parts of the country.

(12) Winds: The wind is air in the horizontal motion which travels from a high-pressure area to a low-pressure area. Variations in incident solar radiation due to earth's position and angle of incidence cause low and high-temperature regimes in different areas. Air from high-pressure areas rushes to the low-pressure areas causing horizontal movement of wind. Wind direction and velocity is important for agricultural crop production. Wind velocity is measured by the anemometer.

(13) Tropical Cyclones: Though several studies by De and Joshi (1995, 1999); Srivastava et al. (2000) showed a decreasing trend in the frequency of Tropical Cyclones (TCs) and Monsoon Depressions (MDs) over the north Indian Ocean (The Bay of Bengal and the Arabian Sea) in recent years, their potential for damage and destruction continues to be significant. A severe super cyclonic storm with winds of up to 250 km/h, crossed the coast in Orissa on October 29, 1999. This proved to be the worst cyclone of the century in the Orissa region and was responsible for as many as 10,000 deaths for rendering millions homeless and for extensive damage Over the past decades, the frequency of tropical cyclones in the north Indian ocean has registered significant increasing trends (20% per hundred years) during November and May which account for maximum number of intense cyclones (Singh *et al.,* 2000). Coffee and bananas suffer the direct loss of fruits and mechanical damage due to tropical cyclones.

(14) Floods (Water logging): Floods and droughts over India are the two aspects of weather associated with the abundance or deficit of monsoon rains. Many studies are available on various aspects of floods and droughts. In general, the greatest damage to agriculture results from high intensity rainstorms with enough duration as opposed to the low intensity, long duration storms. Direct damage to growing plants from floods is most often caused by depletion of oxygen available to the plant root zones known as (Oxygen deficiency). Flooding creates anaerobic soil conditions that can have significant impacts on vegetation. Low oxygen concentration in soil (hypoxia) or complete absence of oxygen (anoxia) affect the nutrient uptake, synthesis and translocation of growth regulators, respiration and carbohydrate partitioning, as well as photosynthesis decreasing the yield of crops grown in soil with insufficient drainage. Chemical reactions in anaerobic soils lead to a reduction in nitrate and the formation of nitrogen gas. The de-nitrification can be a significant cause of loss of plant vigour and growth following flooding. Soil erosion, disruption to critical agricultural activities, the logging of crops, increased moisture leading to increased problems with diseases and insects, soil moisture saturation and runoff, soil temperature reduction, grain and fruit spoilage and transportation interruption are the more significant agricultural impacts from heavy rainfall.

In case of barley, waterlogging causes chlorophyll, protein, and degradation of RNA, and reduces the concentration of nutrients like nitrogen, phosphorus, metal ions, and minerals in shoot. Maize is also susceptible to waterlogging which causes loss of yield in tropical and subtropical region. Damages of soybean because of waterlogging are chlorosis, necrosis, stunting, defoliation, reduced nitrogen fixation, and plant death which causes yield loss and all these symptoms occur at various vegetative and reproductive stages of the plant. Only 2 days of flooding can cause 18% of yield loss at late vegetative stage while it may exceed to 26% if flooding occurs at early reproductive stage of soybean.

We cannot control all the effects of weather on crop production.

Strategies and adaptation under weather change scenario

A comprehensive strategy of utilization of up to date knowledge, strengthening research and development, evolving policy frameworks that enables sustainable use of natural resources under weather changes. Adaptation can significantly reduce the negative impacts of climate change, but also enhance its potentially positive impacts in some parts of the region. The evidence gathered from household surveys in Central Asia indicates that majority of agricultural households (83% of the surveyed) have already perceived the ongoing climatic changes, but only a third of the same households have taken adaptation actions (MIRZABAEV, 2013). Adaptation measures when important, we must also focus simultaneously on mitigation measures so that we contribute to a reduction in the pace of global climate change (Venkateswarlu and Arun Shankar, 2009). Different strategies on various aspects we can adopt for adaptation under weather change situation viz.

(i) Adjustment of planting dates to minimize the effect of temperature increase-induced spikelet sterility to reduce yield instability, by avoiding having the flowering period to coincide with the hottest period.

(ii) Changing the cropping calendar to take advantage of the wet period and to avoid extreme weather events (e.g. cyclones and storms) during the growing season.

(iii) Cultivation of crop varieties that are resistant to lodging (e.g. Short rice cultivars) which withstand strong winds during the sensitive stage of crop growth.
(iv) Development of cultivars resistant to climate change as well as stress tolerance; adopting new farm techniques that respond to the management of crops under stressful conditions, plant pests and disease.
(v) Shifts on sowing date of crops for more effective use of the soil moisture content.
(vi) Moving forward the dates of crop sowing in a crop rotation calendar and farmers to plant a second crop that could even be vegetable with a short growth period.
(vii) Cultivation of heat resistant crop varieties by utilizing genetic resources that may be better adapted to warmer and drier conditions.
(viii) Growing of suitable cultivars (to counteract compression of crop development), increasing crop intensities (i.e., the number of successive crops produced per unit area per year), or planting different types of crops.
(ix) Providing modern knowledge and guidelines about various crop production risks associated with weather change.
(x) Creation of awareness among farmers, farm workers, stockholders etc those are involved in food production chain on the impact of weather change through extensive education.
(xi) Adaptation of strategies to battle against the incidence on the emergence of newer pest and disease attacks through Krishi Vigyan Kendra's (KVKs).
(xii) Crop insurance provides indemnification for yield losses due to drought, but it is long way to go. Prevented planting on dryland due to drought is usually not compensated. In some years the ad hoc Crop Disaster program provides producers compensation in addition to crop insurance indemnities.
(xiii) Weather insurance plays an important role in mitigating the climate risks in the whole world. In India, the small holders are more prone to risks in agriculture production under climate change whereas weather-based insurance is as important ameliorative approach for Indian farmers.

CONCLUSION

Weather change is a global environmental threat to all economic sectors—specifically the agricultural sector. India has faced extreme weather events like untimely and heavy rainfall and flash floods in mountainous areas affecting huge damage to the major crops and properties of large number of farming communities. The situation was predicted that the global disbalancing will increase as a function of climate change. Therefore, adaptation to the negative impacts due to climate variability may be essential to encourage food security for the country and to protect the subsistence of rural households.

The prime aim of this study was to analyze the impact of climate change (e.g., maximum temperature, minimum temperature, rainfall, relative humidity, and sunshine) on major food crops including wheat, rice, maize, and the cash crop sugarcane. Some of the climate variables affect the crop yield negatively and drastically and whereas other climatic factors remain insignificant. The most influential climatic variables for crop production were observed to be maximum temperature, rainfall, and relative humidity. The susceptibility to high temperature in plants varies with the stage of the plant development, affecting to a certain extent vegetative stage and reproductive stage in particular (Saxena *et al.,* 2016). Vegetative and reproductive phases in wheat differs in their sensitivity to temperature (Ramani *et al.,* 2017). The finding confirmed that maximum temperature is significant and negatively influenced the yield of wheat crop, while rainfall and relative humidity are both insignificant and negatively influenced wheat crop yield. By the end of the 21st century, the earth's climate is forecasted to be warmer by an average of 2-4^{0}C (IPCC, 2007) due to both human activities and natural factors (Eitzinger*et al*., 2010). Climate change will impact upon the mean and variability of rice crop yields (Chen, 2004; Kim, 2009).The influence of maximum temperature is significant for the rice crop. Both temperature and relative humidity displayed positive interrelation with sugarcane crop yield. Overall, climate change has adverse impacts on the yield of major food crops. India has set a target of halving greenhouse gas emissions by 2050 (Gautam and Sharma, 2012). In this alarming situation, the coordinated assessment for strengthening the research for the impact of weather on agriculture production and productivity as well as other living beings is really treated as most urgent requirement. Moreover, the population is growing rapidly, and the country will face the problem of food security andscarcity soon. The government of the country requires to take appropriate steps immediately to mitigate the problems whatever possible or overcome this situation or minimize the harmful effect of weather changes and try to safeguard food security for the over increasing populations and maintaining the economical balance under this frightening situation.

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How to cite this article?
Sanjoy Shil. 2018. Weather parameters and it's impact on agricultural production- a review. *Innovative Farming*, **3**(4): 141-149.