Effect of climate change on soil properties

Anil R. Chinchmalatpure
Central Soil Salinity Research Institute, Karnal-132 001
e-mail: anil@cssri.ernet.in

While climate change is a global phenomenon, arid, semi-arid and coastal regions are especially vulnerable to climate change. Increased human induced activities have accelerated the process of climate change in the recent past and increased the mean global surface temperature by 0.6 ^{o}C over 100 years, a phenomenon known as global warming (Singh, 2012). According to intergovernmental panel on climate change (IPCC), the rise in global mean surface temperature with the same rate would be 1.4–5.8 ^{O}C by 2100 (IPCC, 2001). The climate change predictions over India indicated that temperature rise is likely to be around 3^{o}C and rainfall increase is expected by 10-20 per cent over central states by 2100 A.D. Uncertainties in the minimum and maximum temperatures which may have adverse impact on agricultural production and productivity. Lal (2001) reported that an annual mean area averaged surface warming over Indian Subcontinent to range between 3.5 to 5.5 ^{o}C over the region by 2080. It is reported that a fall in rainfall by 5 to 25% in winter months and an increase of 10 to 15% in summer monsoon in India and the monsoon rainfall is without any trend, being highly random in nature over a long period of time (Mooley and Parthasarathy, 1984). India will also begin to experience greater seasonal variation in temperature, with more warming in the winter than summer (Christensen, 2007). The longevity of heat-waves across India have extended in recent years, leading to warmer temperatures at night and hotter days and this trend is set to continue (Cruz, 2007). Western India is expected to receive higher than normal rainfall as temperatures soar. This change in the amount of rainfall and shifts in the timing will adversely affect agriculture all over. The changes in soil moisture content, pests and weeds brought by climate change will affect the crops. Agriculture in coastal states will be worst affected where agricultural land is susceptible to inundation and salinity.

The extent and severity of soil degradation as well as vulnerability to degradation processes is alarming (Dejoux, 2001). Out of 329 million ha geographical area of the country, about 142 million ha is under cultivation and 120 million ha area is under degraded and waste lands. Salinity and sodicity has degraded about 6.73 million ha otherwise productive area in the country. Out of 6.73 million ha, 2.22 million ha (33% of the total salt affected area of the country) is occupied in Gujarat alone. In Gujarat 0.12 million ha is salt affected black soils covering Bara tract area (Amod, Vagra and Jumbusar taluka of Bharuch district), Bhal area and part of Vadodara, Surat and Ahmedabad districts.

Analysis of rainfall and temperature

Rainfall and temperature are the two parameters likely to be affected by climate change. To study the temporal trends, rainfall data for 36 years (1975–2011) and minimum and maximum temperature data for 18 years (1994-2012) were collected from agro-meteorological station at Navsari Agricultural University, Tancha farm (near Samni) in Bharuch district Gujarat. Its analysis revealed that average annual rainfall over 1975-2011 was 753 mm compared to 895 mm for the period 2000-2011(Table 1). The average annual rainfall during the period 2000-2011 was increased by 19 per cent over long term average (1975-2011). There was notable shifting in monthly rainfall during the monsoon period. Rainfall in the month of June to August during 2000-2011 increased by 11 and 40 per cent while no change in the month of September. The maximum and minimum temperature during

2000-2012 increased by 0.5 °C and 0.7 °C, respectively over the long term average (Table 2). Warmer winters are resulting in the increased incidence of pest attacks in the region. Consequently, farmers are being forced to incur a further burden of higher input/pesticide costs.

It is also observed that the intensity of rainfall was more during later period of monsoon for 2000-2011 as compared to 1975-2011 (Fig. 1). The water balance and length of growing period depends on the amount of rainfall and potential evapo-transpiration. Available water capacity and water holding capacity of soils play important role in determining the length of growing period. It is more affected in salt affected soils as the available water capacity is governed by the osmotic potential of these soils.

Table 1. Changes in average annual rainfall in Bharuch district

	Average annual rainfall for 1975-2011 (mm)	Average annual rainfall for 2000-2011 (mm)	Deviation
Total	753	895	+18.85%
June	159	177	+11.32%
July	232	293	+26.29
August	206	288	+39.80
September	120	120	0

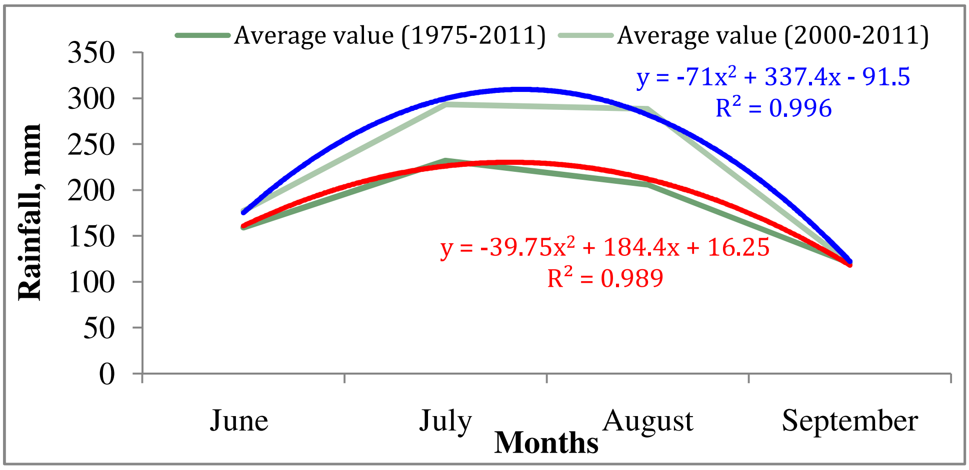

Fig.1. Average annual rainfall during 2000-2011 and 1975-2011

Table 2. Variation in temperature during 1994-2012 and 2002-2012

Month	Temperature (^oC)					
	Av. Max (1994-2012)	Av. Max (2002-2012)	Deviation	Av. Min (1994-2012)	Av. Min (2002-2012)	Deviation
Jan	29.5	30.0	0.5	12.3	12.5	0.2
Feb	32.5	33.0	0.5	14.3	15.0	0.7
Mar	37.0	37.4	0.4	18.5	18.8	0.3
Apr	39.7	40.2	0.5	23.4	24.0	0.6
May	39.6	39.9	0.3	26.9	27.2	0.2
Jun	36.7	36.8	0.2	27.2	27.3	0.1
Jul	32.8	33.3	0.5	26.1	26.1	0.0
Aug	31.5	31.1	-0.4	25.3	25.3	0.0
Sep	33.6	34.0	0.4	24.8	24.9	0.1
Oct	35.7	36.1	0.3	21.6	21.5	-0.1
Nov	33.9	34.0	0.1	17.1	17.7	0.6
Dec	31.0	31.2	0.2	13.2	13.7	0.4

Effect of climate change on soil properties

Change in rainfall patterns and increase in average temperatures brought about by climate change are playing an important role. A rise in global temperature accelerates carbon losses from soils, driving up the concentration of carbon dioxide in the atmosphere. The changes in rainfall patterns will, of course, additionally contribute to an increase in erosion in vulnerable soils, which often already suffer from low organic matter content. Climate change will thus put further pressure on soil quality and will increase the risk of desertification and land degradation, which is already affecting in many areas. Climate change influences the pedogenic properties of soils. The main potential changes in soil-forming factors directly resulting from climate change would be in organic matter supply from biomass, soil temperature regime and soil hydrology, the latter because of shifts in rainfall zones as well as changes in potential evapo-transpiration. Other changes due to climate change (temperature and precipitation) are expected to be relatively well buffered by the mineral composition, the organic matter content or the structural stability of many soils. However, decrease in vegetation/crop cover due to scanty rainfall could lead to soil structure degradation and decreased porosity, as well as increased runoff and erosion on sloping sites and by the concomitant more extensive and rapid sedimentation. In certain fragile soils, the nature of the dominant soil-forming process may change for the worse with increased, decreased or more strongly seasonal rainfall. The changes in temperature but particularly in rainfall to be expected as a result of global warming are subject to major uncertainties for several reasons. In monsoon climates, increased intensities of rainfall events and increased rainfall totals would increase leaching rates in well-drained soils with high infiltration rates, and would cause temporary flooding or water-saturation, particularly in black soils with high clay content. Soils most resilient against such changes would have adequate cation exchange capacity and anion sorption to minimize nutrient loss during leaching flows, and have a high structural stability and a strongly heterogeneous system of continuous macropores to maximize infiltration and rapid bypass flow through the soil during high-intensity rainfall.

Increased microbial activity due to higher CO_2 concentration and temperature produces greater amounts of polysaccharides and other soil stabilizers. Increases in litter or crop residues, root mass and organic matter content tend to stimulate the activity of soil macrofauna, including earthworms, with consequently improved infiltration rate. The greater stability and the faster infiltration increase the resilience of the soil against water erosion and consequent loss of soil fertility.

Higher temperatures, particularly in arid conditions, exhibit a higher evaporative demand. Where there is sufficient soil moisture, for example in irrigated areas, this could lead to soil salinization if land or farm water management, or irrigation scheduling or drainage are inadequate as has been observed in the Sardar Sarovar Canal command area of Gujarat.

The depth of water table over the period (2005-2010) at some benchmark locations in Bara tract area under Sardar Saroval canal command of Gujarat showed a rising trend of groundwater level. In the year 2005, where groundwater depth was between 16-18 m below ground level (bgl) while in the recent years (2010) it raised up and depth was between 14-15 m bgl. It was observed that there was an increase in the groundwater depth over a period of five years (2005 to 2010) to the tune of 1.5 to 2.0 meters estimating a rate of rise of water table was 0.30 to 0.35 meter per annum.

Coastal regions of Gujarat are predicted to be mostly negatively affected. Studies indicated that extremely carbon depleted soils like salt affected soils have quite high potential for sequestering carbon in vegetation and soil if suitable tree and grass species are grown along with best management practices like rain water conservation. In saline Vertisols, the quasi-equilibrium value (QEV) of soil organic carbon (SOC) under the different land use systems showed that the agriculture system at 0-15 cm soil depth had the smallest value of 0.57% as compared to the forest (0.85%) and pasture land use system (0.95%). The QEV of SOC under the pasture was highest as compared to forest and agriculture systems. At this depth the carbon decreased to 0.57% after 8 to 10 years of agricultural practices indicating the decrease of 40%. This indicated that the pasture had the capacity to sequester more SOC than forest and the agriculture system on saline Vertisols. Soil organic matter sustainability under different systems were estimated for the saline Vertisols at various soil depths (0-15, 15-30 and 30-50 cm) under three different land uses comprising of agriculture, woody perennials and pasture based systems. Woody perennials and pasture based systems was found to have higher index than agriculture based system (Chinchmalatpure *et al.,* 2011). Pasture and woody perennials helps in sequestering more carbon than the agriculture systems under climate change scenario.

In Bara tract area of Gujarat, farmers perceived that seasonal cycle for agriculture was no more usual as it was 30 years back, and now climate became highly uncertain. They mentioned that there was an increase in winter temperature and a consequent loss of dew (atmospheric moisture) for the winter crops; irregularity in rainfall; delays in the southwest monsoon and a decline in rains in June; more intense rainfall events, a lot of rain in fewer days; patchiness in rainfall over a region; and a rise in summer temperatures and heat. Weather predictions made by indigenous indicators (flora and faunas) and astrology (*Panchang*) are now not much reliable. Farmers of Bara tract perceived that duration of summer was enlarged and winter was postponed. They say "Earlier, we simply could not sit in the cold, like we are now". They also said that the size of grain of wheat had reduced because of the warmer winters and over the last 4-5 years the weather had been much less cold than necessary for proper growth of wheat crop. Scientific studies confirm that night-time temperatures and maximum winter temperatures are rising. The dew, essential for soil moisture and crop growth on non-irrigated lands, had either lessened or stopped in recent years because of warmer winters. Dew forms and falls at a particular temperature and gets affected if the temperature rises above it. The numbers of rainy days decreased while average intensity of rainfall had increased over the period. The most common complaint was the irregularity in rainfall when the southwest monsoon begins. Three fourth of annual rainfall in Gujarat and in the country as a whole falls in these four months (June to September); hence erratic rainfall behaviour at this time has even weightier consequences. The southwest monsoon used to start on 20 June or thereabouts with reasonable punctuality during years it used to rain well. The Gujarati term itself for the period of the southwest monsoon rains, *chaumasu*, reflects rains over a four-month period. Other irregularities are lot of rain in fewer days and patchiness in rain over a region. Earlier, when the rains came, one would be assured it would rain evenly over a region. Whenever rainfall becomes erratic and intensity of rains increases, the cropping intensity under black cotton soil decreases due to waterlogging. The vulnerability of farmers growing *desi* (indigenous) cotton increased due to its long duration (8-9 months). Due to late cessation of monsoon, about 25 % farmers adapt indigenous varieties of catch crops like *Vigna radiata*, *Cicer arietinum* and *Vigna aconitifolia* to harvest the reserved soil moisture in black cotton soils with objective to increase productivity and multiple cropping index. Heavy heat in daytime and cold nights has resulted in withering away of flowering from fruit trees, and non-formation of seeds in small fruits has become a common feature in many citrus fruits. In Gujarat during 2011 climatic changes have affected yield production to the tune of 50 and 30 per cent in mango and chick, respectively.

Conclusion

Arid, semi-arid and coastal regions are more vulnerable to climate change. Western India is expected to receive higher than normal rainfall as temperatures soar. The average annual rainfall during the period 2000-2011 was increased by 19 per cent over long term average (1975-2011). There was notable shifting in monthly rainfall during the monsoon period. Rainfall in the month of June to August during 2000-2011 increased by 11 and 40 per cent while no change in the month of September. The maximum and minimum temperature during 2000-2012 increased by 0.5 ^{o}C and 0.7 ^{o}C, respectively over the long term average. Climate change will thus put further pressure on soil quality and will increase the risk of desertification and land degradation, which is already affecting in many areas. Climate change influences the pedogenic properties of soils. Woody perennials and pasture based systems was found to have higher sustainability index than agriculture based system. Pasture and woody perennials helps in sequestering more carbon than the agriculture systems under climate change scenario. So reclamation and management of salt affected soils and waters will help in sustaining food security and also help moderating climate change related risk in near future.

References

Chinchmalatpure, Anil R., Arora, Sanjay, Rao, G. Gururaja and Khandelwal, M. K. 2011. Quasi-equilibrium of soil carbon stock in saline Vertisols under different land use systems. In: 76th *Annual Convention of the Indian Society of Soil Science*, Dharwad, 16-19 November 2011.

Christensen, J. H., 2007. Regional Climate Predictions. Climate Change 2007. The Physical Science Basis. Contribution of Working Group 1 to the 4th Assessment Report of the Intergovernmental Panel on Climate Change. Solomon, Cambridge University Press: Cambridge

Cruz, R. V., 2007. Asia. Climate Change 2007. Impacts, Adaptation and Vulnerability. Contribution of Working Group 2 to the 4th Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge.

Dejoux, C. 2001. *The Earth System in Danger. Resource Document. Centre National D'EtudesSpatiales (CNES) Magazine #19.* http://www.cnes.fr/web/CNES-en/print-1698-the-earth-systemin-danger.php.

IPCC, 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS. (eds.), Cambridge: Cambridge University Press.

Lal, M. 2001. Future climate change: Implications for Indian Summer Monsoon and its variability. *Current Science* **81**:1205.

Mooley, D.A., and Parthasarathy, B., 1984. Fluctuations in All-India summer monsoon rainfall during 1871-1978. *Climatic Change*, **6**: 287-301.

Singh Gurbachan 2012. Climate change and sustainable agriculture: Haenessing the potential of salt affected soils. 43rd Foundation Lecture of Central Soil Salinity Research Institute, Karnal, India, 1-26pp.