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Short Communication

Use of Spatial Variability Data of Temperature and Yield to Assess the Impact of Climate Change on the Crop Yield Using Mustard in Haryana as an Example

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Abstract

This paper describes and illustrates how the regression analysis of spatial variability of crop yield and temperature can be used as a tool to easily assess the quantitative impact of climate change on crop yield in future. The long term crop yield and the temperature data are generally readily available. Temperature data can also be estimated from long term weather data in the FAO database, as is the case in the present study. The last 30 years average yield data of the mustard growing districts and the LocClim estimated temperature of the period of October to February for the same districts were used in this regression study to assess the impact of the long-term temperature on the average yield of mustard crop in Haryana. It was estimated that each degree increase in the temperature during the crop growth period will increase the mustard yield in the state by 136.7 kg ha^{-1}.

Keywords: Mustard, temperature, yield, climate change, regression model.

Introduction

Climate change is understood as the increasing trend in the global temperature as a result of the increasing concentration of the green house gases including carbon dioxide in the atmosphere due increased use of fossil fuels and other anthropogenic activities in modern times[1,2]. Agricultural vulnerability is a major contributor in the overall vulnerability of a region to climate change[3]. It is supposed to adversely impact the level of yield of various crops globally. Various greenhouse experiments under artificially controlled conditions of manipulated temperature are costly, cumbersome and time consuming. Besides, it is not easy to artificially replicate the natural conditions of crop growth of a region accurately. Another approach is to use the simulation models to estimate the impact of increased temperature on the crop yield[4,5]. Though the simulation experiments are flexible, easy and cheap to conduct but in the absence of validation of the models under real natural conditions the results may be more a matter of faith[6]. On the other hand, the historical data of crop yield and the temperature of a place or region is the real measured data and the results based on these can be expected to be more reliable. In the light of the above limitations the yield and the temperature data of the mustard growing districts of Haryana was used to illustrate how it can be an easy and more reliable way out for assessing the impact of the future projected temperature regime in a region.

Research Methodology

Methods and Data: Regression analysis is the tool of choice to discover relationship between the two or more variables in nature[7]. It was used to assess the impact of temperature on the yield of the mustard crop by relating the long term historical averages of the mustard yield and LocClim generated temperature data of the mustard growing districts of Haryana. The data and methodology is described in full detail by Shabnam elsewhere[8].

For temperature, the historical weather data of the different districts was explored from IMD and different agro-meteorological stations in Haryana. The continuous and quality weather data was available only from Agro-meteorological station, Hisar and to some extent from Bawal. Data from all other sources had poor reliability or too many gaps to be useful for this study. This made it difficult to infer about the temperature of different districts of the mustard growing region of Haryana from the existing meteorological data.

To overcome this problem, Local Climate Estimator software 'LocClim 1.0' of FAO Rome was used to estimate the Mean Monthly Temperature of different districts based on their coordinates (table-1) and altitudes[9].

Table-1
Co-ordinates of the mustard growing districts of Haryana

District (1979-80)	Latitude	Decimal Format	Longitude	Decimal Format
Sirsa	29° 28' 2"	29.467	74° 54' 45"	74.912
Hisar	29° 21' 37"	29.36	75° 54' 3"	75.901
Bhiwani	28° 43' 39"	28.728	75° 58' 6"	74.968
Rohtak	28° 42' 37"	28.71	76° 27' 37"	76.46
Mahendergarh	28° 13' 17"	28.221	76° 34' 38"	76.577
Gurgaon	28° 8' 46"	28.146	77° 01' 52"	77.031
Faridabad	28° 8' 52"	28.148	77° 24' 19"	77.405

Table-2
Temperature and mustard yield kgha^{-1} of mustard growing districts of Haryana.

District (1979-80)	Mean Temp. (deg. C)	Mean Mustard Yield kgha^{-1} (1979-80 to 2008-09)
Sirsa	18.13	1066.6
Hisar	18.25	1117.3
Bhiwani	18.10	1064.0
Rohtak	18.63	1082.4
M.Garh	18.98	1188.0
Gurgaon	18.71	1108.0
Faridabad	18.72	1245.3

The software uses the data of upto 20 neighboring stations of that place from its FAOCLIM Version 2, database for estimating the climatic parameters of the specified location[10].

The selection of the period for which the temperature parameters were generated was based on the period for which crop remains in the field. The mean value of 5 months temperature was taken as single aggregated parameters of temperature for each of the district. This temperature parameter, calculated from the LocClim temperature data of October to February period, for all the seven districts of the mustard growing region in Haryana is presented in table-2

The historical data of mustard yield of different districts of Haryana of the 1979-80 to 2008-09 period was collected from the statistical abstracts of Haryana issued by Bureau of Economics and Statistics (BES), Government of Haryana every year. The mean of 30 years of mustard yield of different districts, as in Table-2, was used to drive the relationship between the yield and temperature in Haryana.

Regression equations were fitted in 'Data Analysis tool in MS Excel to find out the relationship between yield of mustard as dependent variable and the mean temperature as independent variable.

Results and Discussion

Results: The long term (1979-80 to 2008-09) mean mustard yield (kg ha^{-1}) of the district was positively correlated with the long term temperature of the district. The regression equation

The mean monthly temperature of October to February was estimated for each of the districts using this software.

"Yield (kgha^{-1}) = -1405 +136.7 * Mean Temperature (°C)" with the associated R = 0.686; R^2 = 0.472 and the Adjusted R^2 = 0.366, is significant and show that an increase of each one degree centigrade of mean monthly temperature of November to February period will increase the mustard yield by 136.7 kg ha^{-1}. Surprisingly, in another study reported by the same authors elsewhere in this issue of the Journal, using different data set and a different approach of analysis, the impact of temperature on the mustard yield was estimated to be about the same.

The increased yield may be due to the better seed setting[11] which gets disturbed at very low minimum temperature in the month of December and January. It may also be the result of lower frost damage in the mustard once seeds are formed. The finding is surprisingly contrary to the prevalent apprehension of decrease in the yield of agricultural crops, in general, with the increasing temperature as a result of the climate change. The finding is also contrary to the results obtained using mustard growth simulation model showing decrease in yield with the increase in the temperature[4,5].

Conclusion

The study shows that the regression analysis of spatial variability in the temperature and crop yield in different districts of a region can be used to assess the quantitative impact of climate change on the crop yield. The approach is quick, easy and has a sound empirical basis. The approach should be useful

for other crops and for other regions as well, to assess the quantitative impact of future climate change as per the requirement of the study. In Haryana, the increase in temperature due to expected climate change is estimated to increase the mustard yield significantly.

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