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DEVELOPING A WEATHER-BASED INDEX FOR CROP INSURANCE TO PROMOTE SUSTAINABLE AGRICULTURE AND MITIGATE AN AGRARIAN CRISIS, A CASE STUDY IN INDIA

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Abstract

A case study was conducted for Yavatmal district of Maharashtra state of India where dryland agriculture dominates and where a significant number of farmers have committed suicides in recent years due to the lack of support systems necessary to manage an agrarian crisis. Using monthly temperature and the precipitation data during 2001-2013 period, a weather-based index was developed for the main crops of the district (sorghum, soybean, and pigeon pea; cotton was excluded) to assess the agrarian crisis due to low crops yields, in a more objective and less disputable way that could be preferred by a crop insurance company. While the mean value of WI was 1.0, its range was 0.64 to 1.32 for pigeon pea, from 0.94 to 1.12 for sorghum, and from 0.31 to 1.72 for soybean. These ranges could be further divided appropriately into qualitative categories of to define agrarian crisis for the purpose of designing crop insurance plans to support farmers at their hard times thus making agricultural profession more sustainable.

Key words: *crop yield, drought, farmer suicide, Maharashtra.*

INTRODUCTION

Ensuring agricultural risks in developing countries is a relatively new phenomenon that has not spread its roots due to various reasons, for example:

- (i) farmers are not well educated and not adequately aware of the credit options available to them;
- (ii) the average farm size is very small and the farmers income is hardly sufficient to support the basic needs and as a result farmer may not have disposable income to pay for the insurance premiums.

When crops fail due to droughts that occur in most countries (Boken et al., 2005), farmers are unable to return the money they borrow for buying farming inputs.

If the natural calamities strike for successive years, an average farmer's financial condition deteriorates so much that some of the farmers who are unable to cope with the stress even commit suicides although there are several factors responsible for suicide occurrence (Dongre & Deshmukh, 2012; Kale et al., 2015)

Due to liberalization or globalization of agriculture trade, there has been significant fluctuation in the market prices of commercial crops and in the input costs of cultivating these crops thus increasing the risk levels for farmers. Small farmers with the lack of education and access to credit are unable to manage risks and end up even committing suicides.

The goal of this study is to mitigate the sufferings the poor farmers face due to natural hazards in India, so that their financial conditions don't reach a dismal level due to agricultural risks. One of the solutions to address this paramount issue is to provide crop insurance to farmers. While insurance in other sectors (such as, life, business, health etc.) in India is rather common, albeit mostly in urban areas, the insurance in the agricultural sector is lagging far behind. The assessment of crop damages that may be claimed by farmers is also difficult to verify and may be disputable, which may discourage an insurance company from venturing into the agricultural sector successfully.

In recent years, researchers have come up with an idea of a more objective and an index-based insurance (Berhani et al., 2013; Arshad et al., 2015; Black et al., 2015) insuring weather or other variables that affect crop yields and for which the reliable data are available.

Support systems and decision making innovative approached are required to withstand drought conditions and ensure food security (Enenkel et al., 2015).

In this study, a weather-based index (WI) is developed by examining the relationship between weather variables and crop yields.

a. Map of India showing Maharashtra state (shaded)

b. Map of Maharashtra showing Yavatmal district (shaded)

Figure 1. The location of the study area

Study Area

The study was conducted for Yavatmal district, Maharashtra, India, where the number of farmers-suicides was higher than in any other district of the state in recent years. Maharashtra is the state with maximum number of farmer-suicides in India accounting for almost half the number of farmer-suicides occurred in the entire country in 2014 as per the report by the National Crime Records Bureau (2019)

The boundaries of Yavatmal district (Figure 1) lie between 19.26° and 20.42° north latitudes and between 77.18° and 79.90° east longitudes covering about 13.6 thousand km^2. The average annual temperature for the district is about 25°C with the average maximum temperature of 45°C and the minimum temperature of 5.6°C. Dryland agriculture dominates the district as the irrigated area accounts for less than 8% of the total cropped area (http://kvkyavatmal.pdkv.ac.in/districtprofile/). Farmers plant various crops but cotton, sorghum, soybean, and pigeon pea are the main crops accounting for more than 80% of the total cropped area.

MATERIALS AND METHODS

The following data were collected from different sources for developing a weather-based index.

Weather data

The monthly precipitation data were collected from the VDSA database maintained at the International Crops Research Institute for the Semi-Arid Tropics (vdsa.icrisat.ac.in) for the 2000-2011 period; the data for the remaining 2012-2015 period were purchased from the India Meteorological Department (imd.gov.in).

Agricultural data

The harvested area, yield, and production of different crops planted in the district were collected from the VDSA database as well though the original source of the data was the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India (https://eands.dacnet.nic.in).

The above data were used for developing the weather-based index by first examining their relationships with crop yields.

Yield versus weather relationship

A correlation analysis was conducted between the yield (production per unit area) of a crop and the variables relating to monthly temperature and precipitation during the main cropping season, the *Kharif* season (June/July to September/October). The variables included the temperature averaged for June and July (T_{jj}), the total precipitation for June and July (P_{jj}), the temperature averaged for August and September (T_{as}), the total precipitation for August and September (P_{as}), and the number of the rainy days during June through September (NR_{js}).

Table 1 presents the coefficients of correlations between crop yields and these weather variables, which were considered for developing a weather-based index capable of indicating if the crop yield in a year was lower or higher than the multi-year average yield.

Table 1. The correlation coefficients between weather-based variables and the yields of the main crops for Yavatmal district, Maharashtra, India

Crops	Weather-based variables					Multiple regression, R^2
	T_{jj} (^{0}C)	P_{jj} (mm)	T_{as} (^{0}C)	P_{as} (mm)	NR_{js}	
Pigeon pea	0.19	0.21	0.49	0.36	0.20	0.75
Sorghum	0.34	-0.19	-0.08	0.00	0.03	0.37
Soybean	0.20	0.45	-0.19	0.59	0.55	0.84
Cotton	-0.38	-0.36	-0.39	-0.47	-0.11	

T_{jj}= the temperature averaged for June and July, T_{as}= the temperature averaged for August and September,
P_{jj} = the total precipitation in June and July, P_{as} = the total precipitation in August and September,
NR_{js} = the number of the rainy days in June through September.

Table 2. The derivation of weather-based index for different crops of Yavatmal district, Maharashtra, India; cotton was excluded due to high fluctuations in its yields caused by non-weather-related reasons

Year*	Pigeon pea				Sorghum			Soybean			
	Yield (kg/ha)	Selected weather- based variables		Weather-based Index, WI	Yield (kg/ha)	Selected variable	Weather-based Index, WI	Yield (kg/ha)	Selected weather-based variables		Weather-based Index, WI
		T_{as}	P_{as}			T_{jj}			P_{jj}	P_{as}	
2001	1268.3	26.9	452.7	1.25	1094.2	27.7	0.99	1298.9	404.3	452.7	1.02
2002	1014.1	26.1	414.4	1.11	1180.8	31.4	1.12	1359.4	509.2	414.4	1.17
2003	804.1	24.9	455.6	1.17	1028.7	28.1	1.00	1449.4	534.2	455.6	1.35
2004	651.5	24.9	410.6	1.05	981.8	27.8	0.99	536.6	322.4	410.6	0.74
2005	807.1	25.5	422.1	1.11	768.7	28.9	1.03	1122.8	670.3	422.1	1.57
2008	601.2	25.8	240.0	0.64	967.7	28.2	1.01	332.6	228.6	240.0	0.31
2009	689.8	26.2	216.7	0.58	524.4	28.9	1.03	405.9	253.7	216.7	0.31
2010	743.3	24.6	520.8	1.32	764.4	27.9	1.00	1375.8	472.8	520.8	1.37
2011	864.8	24.1	275.2	0.68	1285.5	26.3	0.94	1346.4	562.2	275.2	0.86
2013	736.3	25.2	418.1	1.08	320.0	25.1	0.90	548.3	737.9	418.1	1.72
Mean	818.1	25.4	382.6	1.00	891.6	28.0	1.00	977.6	469.6	382.6	1.00

*Due to data inconsistency, WI couldn't be developed for 2012 and 2013.

Derivation of weather-based index

In order to develop a weather-based index that has a reasonably strong relationship with the crop yield, the variables that were more significantly related with crop yields were short listed to be used for developing the weather-based index. Based on the coefficients of correlation shown in Table 1, the short-listed variables turned out to be T_{as} and P_{as} for pigeon pea, T_{jj} for sorghum, and P_{jj} and P_{as} for soybean. Cotton was excluded from the analysis because farmers had adopted genetically modified varieties of cotton (Gruere & Sengupta, 2011) that produced very high yields in the first year but were unable to sustain the promised yields in subsequent years thus causing high fluctuation in yields due to non-weather-related reasons (Figure 2).

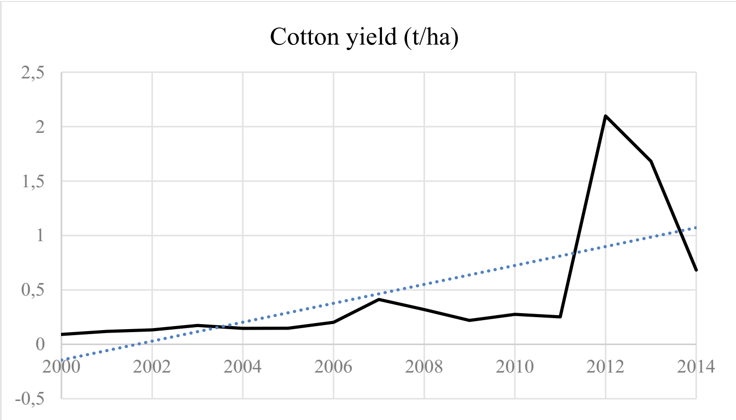

Figure 2. Abnormal fluctuation in cotton yields during 2008-2015

The deviation from the average yield was found a simple and a practical indicator t reflect drought or low crop-yield conditions (Boken, 2009).
For each of the short-listed variables, a new variable was created by dividing the annual value of the variable by the multiyear mean or average value of the variable as shown in Table 2. In case of pigeon pea and soybean, the two new variables were then multiplied to develop the weather-based Index, WI. For example, the WI for soybean was defined as follows:

$$WI=(P_{jj}/P_{jj\_avg})*(P_{as}/P_{as\_avg}) \quad (1)$$

Where:
- P_{jj} and P_{as} are the short-listed variable for soybean;
- *avg* subscript refers to the mean or average value of the variable for the 2001-2013 period considered in this study.

RESULTS AND DISCUSSIONS

The yearly values of WI for main crops (excluding cotton) are shown in Table 2. The average of WI as developed above turned out to be 1.0. A value of WI lower than 1.0 indicated a lower than the average crop yield and a value higher than 1.0 indicated a higher than the average crop yield. A lower than 1.0 value for WI means that the farmers may deserve to receive pay-out as per their insurance plans. WI ranged from 0.64 to 1.32 for pigeon pea, from 0.94 to 1.12 for sorghum, and from 0.31 to 1.72 for soybean. The WI rages could be further divided into qualitative categories of agricultural drought conditions or agrarian crisis, such as mild, moderate and severe crisis. Eventually, the pay-out amount could be determined to make the crop insurance a sustainable venture supporting farmers at a time of agricultural crisis.

CONCLUSIONS

The weather variables showing stronger relationships with crop yields were selected for developing weather-based index to be used in a crop insurance method in order to indicate the level of an agrarian crisis relating to agricultural drought conditions. This will help determine pay-outs to farmers more objectively, in a less disputable way.
The selected variables were the average temperature during August-September and the total precipitation during August-September for pigeon pea, the average temperature for June-July for sorghum, and the total precipitation for June-July and the total precipitation in August-September for soybeans. While the mean value of WI was 1.0, its range was 0.64 to 1.32 for pigeon pea, from 0.94 to 1.12 for sorghum, and from 0.31 to 1.72 for soybean. These ranges could be further divided appropriately into qualitative categories of to define agrarian crisis for the purpose of designing crop insurance plans to support farmers at their hard times thus making agricultural profession more sustainable.

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