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On the relationship between weather and Agricultural Commodity Index in India: a study with reference to Dhaanya of NCDEX

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Abstract
This paper proposes to investigate the Co Movement and Causal Relationship, among the three weather factors (temperature, humidity, and wind speed) and the returns of the Agriculture Commodity Index called Dhaanya, in India. The study employed the secondary daily data of weather in five sample cities (Chennai, Mumbai, Delhi, Kolkata and Hyderabad), and Agriculture Commodity Index called Dhaanya, in India. Statistical tools like Descriptive Statistics, Unit Root, Correlation Matrix, and Granger Causality Test were employed. This study found that the temperature and wind speed influenced the investors' mood in Chennai and Mumbai, in respect of Agriculture Commodity Index, namely Dhaanya. The findings of this study would help the investors in making investment decisions rationally, on the basis of weather condition.

Keywords Weather factors · NCDEX · Descriptive statistics · Unit root test · Correlation matrix · Granger causality test

JEL Classification F65 · G02 · C1 · C58 · N2

1 Introduction

The global agricultural commodities market always faces sudden ups and downs, due to weather effect in the past and the climate changes, during Twenty-First Century. All aspects of commodity price are mainly affected by weather changes, commodity access, commodity utilization, and commodity price stability (Porter et al. 2014).

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Weather effect has been considered as the important sources for changes of agricultural commodity prices (Gilbert and Morgan 2010). Weather effects, among many factors, played a major role in the food price (Headey and Fan 2008). Climate change is likely to influence weather variability and incidence of extreme events has the potential to generate weather shocks on agricultural and food price (Torero and Von Braun 2010). The climate may have considerable influence on poverty levels, with the economic performance of developing countries, the depending on agricultural and agro food sectors. Many existing researchers studied the impact of weather shocks on agricultural prices (Solomou and Wu 1999; and Jolejole-Foreman and Mallory 2011). The attention of researchers is perhaps influenced by the fact that the modern farm management techniques and more globalized agricultural markets have noticeably reduced the impact of weather shocks on agricultural prices (Park 2014, 2018; Shapiro and Park 2015, 2018; Xu et al. 2016; Wang et al. 2012), especially in developed countries. But in developing countries, the agricultural sector has been generally more vulnerable to weather shocks. Hence a many researcher's concern has been focused on market integration price transmission effect and weather impact. It is to be noted that Climate change has increased in the frequencies and the magnitude of weather shocks and they have necessitated a paradigm shift in the focus of researchers, on the effects of weather shocks on agriculture commodities, their prices, especially in developing countries.

1.1 Agricultural Commodity Index

This study proposes to analyse the Agricultural Commodity Index in India, for the reasons listed below. First, Indian agricultural commodity production has improved gradually after independence. In the Indian economy, agricultural sector is the most important and influential component. According to the Department of Economics and Statics (DES) of India, Indian agriculture sector provides for 18 per cent of India's gross domestic product (GDP) and accounts for employment to 50% of the country's workforce. India ranks within top two global producers of traded agricultural commodities like rice, wheat, spices and spice products [Ministry of Agriculture annual report (2013–2014)]. Since only a few studies have focused on agricultural commodity segments, the present study was attempted.

From the above figure, it is understood that weather shocks (temperature, humidity, and wind speed) could influence agricultural (crop) yields and their prices, through influencing expectations of players about the future prices, which would get reflected through investors' decisions on agricultural commodity (Fig. 1). In this paper, four sections are structured as follows. Section 1 Introduction and Conceptual Framework. Section 2 outlines the review of literature, AGRI Index and research design. Section 3 illustrates the samples and summarizes the preliminary analysis results. Section 4 concludes the paper with future directions.

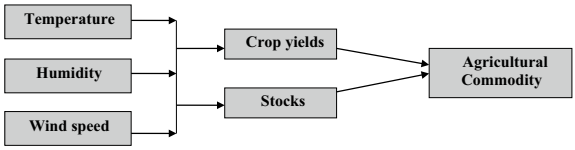

Fig. 1 The conceptual framework for the effects of weather shocks on agricultural commodity. *Source*: developed by authors from the model of Mirzabaev and Tsegai (2012)

2 Review of literature

In behavioral finance, there are many studies, focusing on the relationship between prices of agricultural commodity and variables relating to the mood of people. This section reviews the previous research, in the area of weather effect, on the agricultural commodity index price. It is a well-known fact that the daily activities of human being are affected by several environmental factors and weather factors that naturally influence the individual's mood. Apart from the physical impact, a series of researches have been conducted, to find out, the connection between weather factors and individual's mood. Romer (2000) and Mehra and Sah (2002) demonstrated the important role of mood in decision-making of the individual. Besides, Schwarz (1990) and Loewenstein et al. (2001) found that emotions and feelings of individual played an important role in decision-making. According to Isen (1993), when people are in a good mood, the cognitive processes would be simplified, accelerating the process of decision making. Kamstra et al. (2003) found that weather could generate unexpected impact on human beings. Haward and Hoffman (1984) studied the effect of mood, that was correlated with the weather and the study found that humidity, temperature and day time length could have extreme effects on mood. Cunningham (1979) identified that clear and sunny days could produce a good mood. The temperature level has a positive correlation with mood in summer. Lu and Chou (2012) found that changes in weather condition could lead to opposite physiological response and that would lead to different human behavioral manifestations like violent behavior and performance. According to Kals (1982), one-third of people are weather sensitive and their physical health and mental health are affected by weather. Howarth and Hoffman (1984) revealed that the weather variables are related to various mood dimensions. Significantly, humidity played an important role in decision making. Viswanathan and Krishnamurti (1989) pointed out that humidity affected human bodies (moods and attitude) in many ways. Hirshleifer and Shumway (2003) suggested that the investors could be benefited by being aware of their mood, because they could avoid mood based mistakes in their judgement in financial investment. Lingaraja et al. (2014) in their study were focused on eight Asian emerging markets and one developed market like Singapore was used. It is to be noted that inter linkages and co-movements were tested by using 12 years data (01/01/2002 to 31/12/2013). This study was suggested and help to the investors making efficient decisions for investment in the indices of emerging stock markets in Asia. Gilbert and Morgan (2010) studied the impact of weather effect on price policy and found that weather effect was considered a major source of variable in agricultural commodity price. Headey and Fan (2008) found that there was no evidence for the fact that weather effect alone played a major role in agricultural commodity price.

The above literature provides an overview of some empirical studies already undertaken on the same lines of the present Research. But only few studies focused on relationship between Weather and commodity Index. But, no such studies were investigated in India. Therefore, the present study is an attempt to investigate the Relationship between Weather and Agricultural Commodity Index in India. This is the first article that investigate the relationship between weather and Agricultural Commodity Index namely Dhaanya of NCDEX.

2.1 Objectives of the study

This study examines the linkages and relationship among movement of Agriculture Commodity Index (Dhaanya) and weather factors (temperature, humidity, and wind speed)) in five sample cities (Chennai, Mumbai, Delhi, Kolkata and Hyderabad), over the sample period in India.

2.2 Hypotheses of the study

NH1 There is no normal distribution among the Agriculture Commodity Index and weather factors in five sample cities.

NH2 There is no stationarity among the Agriculture Commodity Index and weather factors in five sample cities.

NH3 There is no co-relation between the Agriculture Commodity Index and weather factors in five sample cities.

NH4 There is no causal relationship among the Agriculture Commodity Index and weather factors in five sample cities.

2.3 Methodology of the study

2.3.1 Period of study

For the purpose of examining the linkages and relationship among the Agriculture Commodity Index (Dhaanya) and weather factors (Temperature, Humidity, and Wind speed), the present study covered a period of 10 years from January 1, 2007 through December 31, 2016.

2.3.2 Sample design

In order to examine the linkages and relationship among the Agriculture Commodity Index and weather factors, the study focused on traded Agriculture Commodity Index—NCDEX (Dhaanya) and three weather variables, namely, Temperature, Humidity, and Wind speed. The temperature value was measured in Celsius. The humidity value was taken as the percentage, relative to humidity and the wind speed was measured in miles per hour (mph) (Etzioni 2010; Jung and Park 2014; Meza and Park 2016; Park and Leydesdorff 2013).

2.3.3 Sources of data

For the purpose of analysis, the study used daily data of traded Agriculture Commodity Index (Namely Dhaanya), collected from https://www.ncdex.com/Dhaanya. Similarly, the data relating to weather factors, in five metro cities of India (Bangalore, Chennai, Delhi,

Mumbai, and Kolkata), were collected from Indian Metrological Department-www.imd.gov.in.

2.3.4 Tools used for analysis

For the analysis of this study, the following tools were used.

- Descriptive Statistics (to find out the normal distribution of returns of Agriculture Commodity Index and weather factors in five sample cities).
- Unit Root test (to test the stationarity of returns of Agriculture Commodity Index and weather factors in five sample cities).
- Correlation Matrix (to find the correlation between returns of Agriculture Commodity Index and weather factors in five sample cities) and
- Granger Causality Test (to examine the linkage among Agriculture Commodity Index and weather factors in five sample cities).

2.4 Shortcomings of the study

This present study suffered from the following shortcomings.

- The study was limited to weather factors, only in five metro cities of India.
- The study was based only on secondary data.
- The limitations, associated with various statistical tools, may also apply to this study.

3 Analysis and empirical results

This section describes the deep analysis of effect of weather on AGRI Commodity price by using Descriptive Statistics, Unit Root Test, and Granger Causality test.

1. Normality for the returns of Sample Agricultural Commodity Index and Weather Factors in Sample Cities in India,
2. Stationarity for the returns of Sample Agricultural Commodity Index and Weather Factors in Sample Cities in India,
3. Pearson Correlation for the returns of Sample Agricultural Commodity Index and Weather Factors in Sample Cities in India.
4. Granger Causality for the returns of Sample Agricultural Commodity Index and Weather Factors in Sample Cities in India.

3.1 Normality for the returns of sample Agricultural Commodity Index and weather factors in sample cities in India

To test the normality between the weather factors and Index returns, descriptive analysis has been commonly used in the previous studies (Saunders 1993; Cao and Wei 2005; Dowling and Lucey 2005; Kathiravan et al. 2017, 2018). The results of descriptive statistics, for the returns of Agriculture Commodity Index (namely Dhaanya) and weather factors (temperature, humidity and wind speed), in top cities of India (Bangalore, Chennai,

Table 1 Results of descriptive statistics of sample index and weather factors for the sample metro cities in India from 1st January 2007 to 31st December 2016. *Source*: compiled from www.ncdex.comand IMD/and computed using E-views 6 version

	Dhanya	Humidity	Temperature	Wind_speed
Bangalore				
Mean	0.0002	0.0091	0.0009	0.1279
SD	0.0101	0.1350	0.0417	0.7496
Skewness	−4.0491	1.1570	−0.0777	6.1273
Kurtosis	96.602	8.4736	4.8505	70.812
Jarque–Bera	906,236.8	3625.7	354.0	487,529.4
Probability	0	0	0	0
Observations	2464	2464	2464	2464
Chennai				
Mean	0.00015	0.00367	0.00064	0.06194
SD	0.01011	0.08728	0.03582	0.60062
Skewness	−4.04147	0.73221	0.03620	19.73018
Kurtosis	96.5777	5.972677	7.035179	612.9244
Jarque–Bera	910,516.2	1133.362	1681.048	38,555,004
Probability	0	0	0	0
Observations	2464	2464	2464	2464
Delhi				
Mean	0.00015	0.01911	0.00701	0.10994
SD	0.01011	0.21446	0.13533	0.60555
Skewness	−4.04147	2.52962	10.54653	4.12532
Kurtosis	96.5777	21.40992	298.9247	44.00214
Jarque–Bera	910,516.2	37,621.62	9,084,019	180,537
Probability	0	0	0	0
Observations	2464	2464	2464	2464
Kolkata				
Mean	0.0002	0.0056	0.0015	0.1560
SD	0.0101	0.1067	0.0578	1.2114
Skewness	−4.0399	1.1049	0.0646	24.8074
Kurtosis	96.4422	9.3292	5.1598	914.6538
Jarque–Bera	906,062.30	4629.02	482.19	85,858,141.00
Probability	0.0000	0.0000	0.0000	0.0000
Observations	2464	2464	2464	2464
Mumbai				
Mean	0.0001460	0.0099090	0.0007540	0.0276910
SD	0.0101130	0.1478180	0.0386000	0.2506150
Skewness	−4.0414690	1.7900310	0.3932860	1.7914480
Kurtosis	96.5777	14.03855	7.583864	11.79359
Jarque–Bera	910,516.2	13,898.7	2232.449	9305.711
Probability	0	0	0	0
Observations	2464	2464	2464	2464

Delhi, Kolkata, and Mumbai), during the study period from 1st January 2007 to 31st December 2016, are presented in Table 1. For the purpose of the analysis, the daily data, relating to Agriculture Commodity Index (Dhaanya) and daily data of weather factors, in five major cities of India, were compared. The Table clearly shows that there were positive mean returns, earned by sample index, against three weather factors in five metro cities of India. Another weather factor, namely, Wind speed, scored maximum mean value in all five metro cities, i.e., Bangalore earned the value of 0.127877, Chennai with the value of 0.061935, Delhi with the value of 0.109943, Kolkata with the value of 0.15604 and Mumbai with the value of 0.027691, during the study period. But temperature earned minimum mean value in five metro cites i.e., Bangalore recorded the value of 0.0009, Chennai with the value of 0.00064, Delhi with the value of 0.00701, Kolkata with the value of 0.0015 and Mumbai with the value of 0.0007540, during the study period. It is to be noted that the mean value of sample index (Dhaanya) showed positive sign and it indicated that sample Agricultural Commodity Price Index (Dhaanya) and weather factors (temperature, humidity and wind speed), in five major cities of India (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), earned positive return during the study period.

The analysis of standard deviation clearly indicated that Kolkata a sample city earned the highest standard deviation value of 1.211403 for wind speed but the temperature earned a low standard deviation for three sample cities (Bangalore, Chennai and Mumbai), with values of 0.0417 (Bangalore), 0.03582 (Chennai) and 0.0386000 (Mumbai) respectively. According to the analysis of skewness, five sample cities, namely, Bangalore, Chennai, Delhi, Kolkata, and Mumbai and sample Agricultural Commodity Price Index (Dhaanya), were skewed significantly. It is to be noted that the values of skewness, for all sample cities, were found to be between -1 to $+1$. But the level of kurtosis was positive, for all sample cities and for the sample index, during the study period. The overall analysis confirmed the fact that there was a normal distribution of daily return of Agriculture Commodity Index (Dhaanya), against three weather factors (temperature, humidity and wind speed), in five cities, during the study period. Hence the null hypothesis (NH01), "there is no normality in the daily return data of sample index and weather factors in five cities over the sample period", is rejected.

Figure 2 shows that Graphical Expression separately, for the movement of Agricultural Commodity Index (Dhaanya) and three weather variables (Temperature, Humidity, and Wind speed) in five sample cities (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from January 01, 2007 to December 31, 2016. It is found from Fig. 2 that out of five, three cities, namely, Bangalore, Chennai and Kolkata showed more volatility in respect of Temperature. But all the five sample cities gradually recorded ups and downs in respect of Humidity, However, Mumbai registered more volatility in respect of Wind Speed than other cities, during the study period.

3.2 Stationarity for the returns of sample Agriculture Commodity Index and weather factors in sample cities in India

Table 2 reports the results of unit-root test [Augmented Dickey Fuller Test (ADF) and Phillips Perron Test (PP)] for the purpose of examining the stationary of the sample weather variables and sample Agriculture Commodity Index return, during the period from 01st January 2007 to 31st December 2016. The significant value (P value) of unit-root test result, indicated that all the three sample weather variables (Temperature, Humidity, and Wind speed) and sample Agriculture Commodity Index (Dhaanya) were at zero (0), which

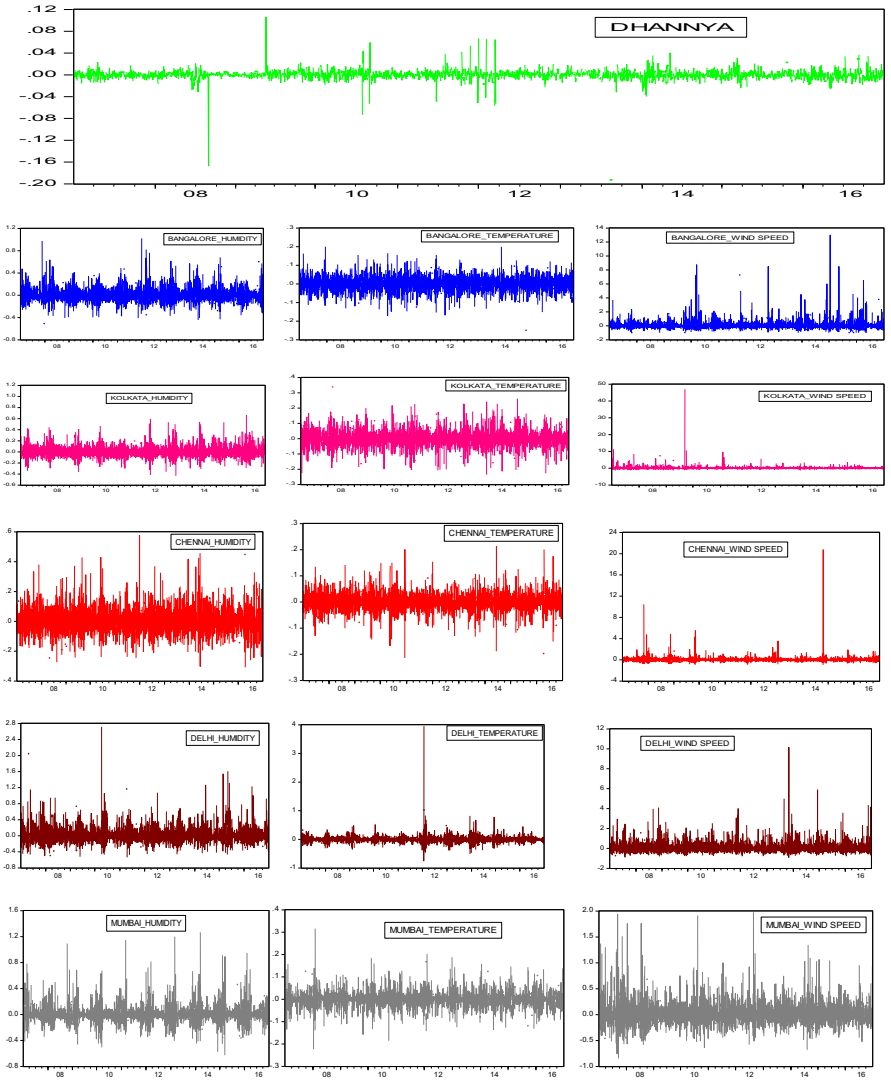

Fig. 2 Graphical expression for Dhaanya and three weather variables in five sample cities during the study period from January 01, 2007 to December 31, 2016

implied that the sample index and weather factors achieved stationarity during the study period. Hence the Null Hypothesis (NH 02), "There is no stationarity in the daily return data of sample index and weather factors in five cities over the sample period", is rejected. In other words, the returns of Agriculture Commodity Index and three weather factors were perfectly fit, for proceeding with further test.

Table 2 The results of ADF for the returns of sample index and weather factors in sample cities in India. *Source*: compiled from www.ncdex.comand IMD/and computed using E-views 6 version

	Dhanya			Humidity			Temperature			Wind_speed		
Critical values	1%	5%	10%	1%	5%	10%	1%	5%	10%	1%	5%	10%
Bangalore												
ADF												
SV*	−47.639	−47.639	−47.639	−24.9839	−24.9839	−24.9839	−27.0517	−27.0517	−27.0517	−39.645	−39.645	−39.645
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP												
SV*	−48.178	−48.178	−48.1781	−77.3783	−77.3783	−77.3783	−82.2584	−82.2584	−82.2584	−58.094	−58.0941	−58.0941
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chennai												
ADF												
SV*	−47.639	−47.639	−47.6393	−23.8111	−23.8111	−23.8111	−23.4211	−23.4211	−23.4211	−56.532	−56.532	−56.532
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP												
SV*	−48.178	−48.178	−48.1781	−124.887	−124.887	−124.887	−84.4262	−84.4262	−84.4262	−56.651	−56.651	−56.651
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi												
ADF												
SV*	−47.639	−47.639	−47.6393	−31.6618	−31.6618	−31.6618	−35.8214	−35.8214	−35.8214	−45.832	−45.832	−45.832
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	-3.43	−2.86	−2.57	−3.43	−2.86	−2.86
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP												

Table 2 (continued)

	Dhanya			Humidity			Temperature			Wind_speed		
Critical values	1%	5%	10%	1%	5%	10%	1%	5%	10%	1%	5%	10%
SV*	−48.178	−48.178	−48.1781	−62.1785	−62.1785	−62.1785	−62.8492	−62.8492	−62.8492	−65.901	−65.901	−65.901
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kolkata												
ADF												
SV*	−47.639	−47.639	−47.639	−26.9574	−26.9574	−26.9574	−25.2529	−25.2529	−25.2529	−53.735	−53.735	−53.735
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP												
SV*	−48.178	−48.178	−48.1781	−90.4541	−90.4541	−90.4541	−60.2295	−60.2295	−60.2295	−53.851	−53.851	−53.851
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mumbai												
ADF												
SV*	−47.639	−47.639	−47.6393	−25.495	−25.495	−25.495	−28.3602	−28.3602	−28.3602	−38.057	−38.057	−38.057
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PP												
SV*	−48.178	−48.178	−48.1781	−66.3937	−66.3937	−66.3937	−85.4038	−85.4038	−85.4038	−74.114	−74.1143	−74.1143
t-Statistic	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57	−3.43	−2.86	−2.57
P value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Critical value at 1, 5 and 10% level of significance: *SV** statistical value

Table 3 Results of Pearson correlation statistics for the returns of sample index and weather factors in metro cities in India from 1st January 2007 to 31st December 2016. *Source*: compiled from www.ncdex.comand IMD/and computed using SPSS

Correlations		Dhanya
Bangalore		
Humidity	Pearson correlation	−0.0329
	Sig. (2-tailed)	0.1020
Temperature	Pearson correlation	0.0232
	Sig. (2-tailed)	0.2480
Wind speed	Pearson correlation	−0.0132
	Sig. (2-tailed)	0.5128
Chennai		
Humidity	Pearson correlation	−0.0186
	Sig. (2-tailed)	0.3549
Temperature	Pearson correlation	−0.0033
	Sig. (2-tailed)	0.8700
Wind speed	Pearson correlation	0.0007
	Sig. (2-tailed)	0.9733
Delhi		
Humidity	Pearson correlation	0.0260
	Sig. (2-tailed)	0.1953
Temperature	Pearson correlation	−0.0146
	Sig. (2-tailed)	0.4674
Wind speed	Pearson correlation	0.0090
	Sig. (2-tailed)	0.6547
Kolkata		
Humidity	Pearson correlation	−0.0146
	Sig. (2-tailed)	0.4674
Temperature	Pearson correlation	0.0260
	Sig. (2-tailed)	0.1953
Wind speed	Pearson correlation	0.0090
	Sig. (2-tailed)	0.6547
Mumbai		
Humidity	Pearson correlation	0.0070
	Sig. (2-tailed)	0.7291
Temperature	Pearson correlation	−0.0124
	Sig. (2-tailed)	0.5389
Wind speed	Pearson correlation	0.0086
	Sig. (2-tailed)	0.6671

*Significant at the 0.05 level (2-tailed)

**Significant at the 0.01 level (2-tailed)

3.3 Pearson correlation for the returns of sample Agricultural Index and weather factors in sample cities in India

Table 3 shows the results of correlation, among the returns of Agriculture Commodity Index in respect of weather factors, in sample cities in India, during the study period from 1st January, 2007 to 31st December, 2016. According to the results of the Table 3, the values of correlation for weather factors, ranged from −0.0329 (Bangalore Humidity) to 0.0260 (Delhi Humidity and Kolkata Temperature), in respect of Agriculture Commodity Index (Dhaanya). The Table brings out the fact that the values of correlation, for all sample variables, were lesser than one, during the study period. The analysis of weather factors, in five sample cities, in respect of Agriculture Commodity Index (Dhaanya) revealed that there was no correlation between the returns of weather factors, in five sample cities, during the study period. Hence the Null Hypothesis (NH03), "There is no Correlation in the daily return data of sample index and weather factor in five cities over the sample period", is accepted. According to the results of Pearson correlation, the three weather factors did not influence significantly the returns of sample index, during the study period. Hence the returns of sample indices were further analysed, by using the Granger Causality Test and each weather factor was analysed, separately, against each sample city.

3.4 Granger causality for the returns of sample Agricultural Commodity Index and weather factors in sample cities in India

3.4.1 Granger causality between the returns of sample index and weather factors in Bangalore city

An attempt has been made, to study the Co Movements and Bidirectional Causal relationship, among the Agriculture Commodity Index (Dhaanya) and weather factors (temperature, humidity and wind speed), in top cities of India (Bangalore, Chennai, Delhi, Kolkata, and Mumbai), during the study period from 1st January 2007 to 31st December 2016. Table 4 shows the results of Granger Causality, for testing the inter linkages of weather factors (temperature, humidity and wind speed) in Bangalore City, with the sample index (Dhaanya), during the study period from 1st January 2007 to 31st December 2016. It is understood that among the three sample weather variables, no one weather variable in Bangalore City was perfectly fit with the sample Agriculture Commodity Index (Dhaanya). Hence the Null Hypothesis (NH04), "There is no causal relationship among the stock market indices with weather variable in Bangalore City", is not rejected.

Table 4 Results of granger causality for the returns of sample index and weather factors in Bangalore city from 1st January 2007 to 31st December 2016. *Sources*: compiled from www.ncdex.com and IMD/using E-views 6 version

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not granger cause Dhanya	2473	0.7965	0.5521	Accepted
Dhanya does not granger cause humidity	2473	0.4153	0.8384	Accepted
Temperature does not granger cause Dhanya	2473	0.3060	0.9095	Accepted
Dhanya does not granger cause temperature	2473	0.7064	0.6186	Accepted
Wind_speed does not granger cause Dhanya	2473	1.9676	0.0804	Accepted
Dhanya does not granger cause Wind_speed	2473	0.2399	0.9449	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

Table 5 Results of granger causality for the returns of sample index and weather factors in Chennai city from 1st January 2007 to 31st December 2016. *Sources*: compiled from www.ncdex.com and IMD/using E-views 6 version

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not granger cause Dhanya	2473	3.0629	0.0157	Accepted
Dhanya does not granger cause humidity	2473	3.04482	0.0162	Accepted
Temperature does not granger cause Dhanya	2473	4.71931	0.0009	Rejected
Dhanya does not granger cause temperature	2473	1.76532	0.1331	Accepted
Wind_speed does not granger cause dhanya	2473	1.12256	0.3441	Accepted
Dhanya does not granger cause wind_speed	2473	0.85926	0.4877	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

3.4.2 Granger causality between the returns of sample index and weather factors in Chennai city

Table 5 shows the results of Granger Causality, for testing the inter linkages of weather factors (temperature, humidity and wind speed), in CHENNAI CITY with the Agriculture Commodity Index (Dhaanya), during the study period from 1st January 2007 to 31st December 2016. It is understood that only one variable (Temperature), out of three sample weather variables in Chennai City, was perfectly fit with the sample index (Dhaanya). It is interesting to find that temperature recorded one way—bidirectional causality relation (as per F-Statistics with the value of 4.71931 and *P* Value with the value of 0.0009). Further, the remaining two weather factors (humidity and wind speed), in Chennai City, had no causal relation with the sample index (Dhaanya). Hence the Null Hypothesis (NH04), "There is no causal relationship sample indices and weather factors in Chennai City", is partially accepted.

3.4.3 Granger causality between the returns of sample index and weather factors in Delhi city

The results of Granger Causality, for testing the inter linkages of weather factors (temperature, humidity and wind speed) in DELHI CITY, with Agriculture Commodity Index

Table 6 Results of granger causality for the returns of sample index and weather factors in Delhi city from 1st January 2007 to 31st December 2016. *Sources*: compiled from www.ncdex.com and IMD/using E-views 6 version

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not granger cause Dhanya	2473	0.59482	0.6664	Accepted
Dhanya does not granger cause humidity	2473	0.90338	0.4610	Accepted
Temperature does not granger cause Dhanya	2473	0.79608	0.5276	Accepted
Dhanya does not granger cause temperature	2473	0.72086	0.5776	Accepted
Wind_speed does not granger cause Dhanya	2473	0.57531	0.6806	Accepted
Dhanya does not granger cause wind_speed	2473	0.43444	0.7838	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

Table 7 Results of granger causality for the returns of sample index and weather factors in Kolkata city from 1st January 2007 to 31st December 2016. *Sources*: compiled from www.ncdex.com and IMD/using E-views 6 version

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not granger cause Dhanya	2473	0.3146	0.8684	Accepted
Dhanya does not granger cause humidity	2473	0.4977	0.7375	Accepted
Temperature does not granger cause Dhanya	2473	0.5099	0.7285	Accepted
Dhanya does not granger cause temperature	2473	1.1471	0.3325	Accepted
Wind_speed does not granger cause Dhanya	2473	0.2892	0.8851	Accepted
Dhanya does not granger cause wind_speed	2473	0.0309	0.9982	Accepted

Rejection of null hypothesis when the probability value is less than or equal to 0.05

(Dhaanya), during the study period from 1st January 2007 to 31st December 2016, are displayed in Table 6. It is understood that among the three sample weather variables in Delhi City, no one weather variable was perfectly fit with the Agriculture Commodity Index (Dhaanya). Hence, the Null Hypothesis (NH04), "There is no causal relationship among the stock market indices with weather variable in Delhi City", is accepted.

3.4.4 Granger causality between the returns of sample index and weather factors in Kolkata city

Table 7 shows the results of Granger Causality, for testing the inter linkages of weather factors (temperature, humidity and wind speed), in KOLKATA CITY, with Agriculture Commodity Index (Dhaanya), during the study period from 1st January 2007 to 31st December 2016. It is clear that among the three sample weather variables in Kolkata City, no one weather variable was perfectly fit with the traded Agriculture Commodity Index (Dhaanya) Hence, the Null Hypothesis (NH04), "There is no causal relationship among the stock market indices with weather variable in Kolkata City", is not rejected.

Table 8 Results of granger causality for the returns of sample index and weather factors in Mumbai city from 1st January 2007 to 31st December 2016. *Sources*: compiled from www.ncdex.com and IMD/using E-views 6 version

Null hypothesis	Obs	F-statistic	Prob.	Result
Humidity does not granger cause dhanya	2473	1.5370	0.2152	Accepted
Dhanya does not granger cause humidity	2473	0.2295	0.7949	Accepted
Temperature does not granger cause Dhanya	2473	1.0578	0.3474	Accepted
Dhanya does not granger cause temperature	2473	0.3604	0.6974	Accepted
Wind_speed does not granger cause Dhanya	2473	0.1645	0.8483	Accepted
Dhanya does not granger cause wind_speed	2473	4.2414	0.0145	Rejected

Rejection of null hypothesis when the probability value is less than or equal to 0.05

3.4.5 Granger causality between the returns of sample index and weather factors in Mumbai city

Table 8 reveals the results of Granger Causality, for testing the inter linkages of weather factors (temperature, humidity and wind speed), in MUMBAI CITY, with the Agriculture Commodity Index (Dhaanya), during the study period from 1st January 2007 to 31st December 2016. It is understood that only one variable (Wind Speed), out of three sample weather variables in Mumbai City, was perfectly fit with the sample index (Dhaanya) while the study recorded one way—bidirectional causality relation (as per F-Statistics with the value of 4.2414 and *P* Value with the value of 0.0145). Further, the remaining two weather factors (Temperature and humidity) in Mumbai City had no causality relation with the traded Agriculture Commodity Index (Dhaanya). Hence, the Null Hypothesis (NH04), "There is no causal relationship sample indices and weather factors in Chennai City", is partially accepted.

4 Conclusion and future directions

It has been proved that the weather could affect investors' mood and thus may affect investors' behavior in the commodity market. In India, commodity market prices experienced high volatility. It was expected that weather shocks should have had smooth transmission, on the general price levels, in commodity market. In this study, an attempt was made to understand the relationship between the Agriculture Commodity Index (Dhaanya) and weather conditions [Temperature, Humidity, and Wind speed), in sample Cities (Bangalore, Chennai, Delhi, Mumbai, and Kolkata)] in India. It is found that the temperature in Chennai city and Wind Speed in Mumbai City affected the index returns negatively. Other weather variables did not have inter linkages with sample Agriculture Commodity Index (Dhaanya). It is to be noted that increased temperature and Wind Speed played a crucial role in disturbing the investors while taking investment decisions. The results of the study clearly showed that two weather variables induced changes in mood and behavior of people, in two different cities. The study found one way—bidirectional causality relation between Chennai temperature and Agriculture Commodity Index (Dhaanya) and Mumbai Wind Speed and Agriculture Commodity Index (Dhaanya). Overall, this study found that weather variables (temperature and wind speed) did have influence on Indian commodity market index (traded Agriculture Commodity Index, Namely Dhaanya).

However, the results and suggestions of this present study based on the data, samples from different locations of Metro cities and AGRI Index with adopted appropriate statistical tools. It is also a platform for the future research in this area. Similar studies may be conducted by considering Weather on other Commodity Index variables such as Metals (gold, silver, platinum and copper), Energy (crude oil, heating oil, natural gas and gasoline), Livestock and Meat (lean hogs, pork bellies, live cattle and feeder cattle) Agricultural (corn, soybeans, wheat, rice, cocoa, coffee, cotton and sugar) etc. Similar study could be conducted by extending the coverage of all other Asian and European Countries.

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