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Does climate impact vary across time horizons? A time-frequency analysis of climate-crop yields in India

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Abstract:

Climate change is a major concern the world over; more for a predominantly agrarian country like India. In this paper we analyze the time horizon dynamics of crop and climate variables at the regional level in India. We also analyze the co-movements between crop yields and temperature and rainfall to observe the coherence across heterogenous time horizons. We employ Bai-Perron structural break and Continuous wavelet transform methods on yearly data of seven crop yields and climate variables. Observed variables are analyzed over a period of 55 years from 1956-2011 for the un-divided state of Andhra Pradesh, India. The study shows that there is a steady and constant increase of around 1.0° in annual average, maximum and minimum temperatures in the state, with two observed break points at 1978 and 2002. Rainfall depicts no systematic change with fluctuations being largely random. Wavelet based coherence analysis that map time-horizon specific dynamics of climate and crops with time periods exhibited significant co-movement between climatic and crop variable. Given shifts in climate patterns and subsequent shifts in co-movements across time horizons at the regional level, policy makers and crop scientists should design time specific and locally viable adaption and mitigation policies to tackle the impact of climate on crops and livelihoods.

Key words: Climate Change, Structural break, Crop yields, Bai-Perron, Wavelets, Time horizon, coherence, co-movements

JEL Classification: C13, Q10, Q15, Q50, Q54
1.0 Introduction

Climate change; attributed largely to the anthropogenic increase in greenhouse gas emissions, is no longer a distant scientific prognosis but is a hard reality. The concentration of global atmospheric carbon dioxide, a greenhouse gas (GHG) largely responsible for global warming, has increased from a pre-industrial value of about 280 ppm to 391 ppm in 2011. Similarly, the global atmospheric concentration of methane ($\text{CH}_4$), nitrous oxides ($\text{N}_2\text{O}$) and other important GHGs has also increased considerably (IPCC 2013). There is clear evidence in change in climatic parameters as can be observed in increased global average temperatures and change in rainfall rates during the 20th century. Eleven of the twelve years between 1995 and 2006 rank among the twelve warmest recorded since 1870 (IPCC, 2007).

Climate change and India

Climate variability is a major concern for India given its size and demographic dependence. Studies show a marked rise in temperature over the last century in India (GOI, 2010, Kothawale, Munot, & Krishna Kumar, 2010). The annual mean temperature during 1901-2019 showed an increasing trend of $0.61^\circ\text{C}/100$ years, with significant increasing trend in maximum temperature at around $1.0^\circ\text{C}$ per 100 years (GOI, 2020). This is found to be mainly contributed by the post-monsoon and winter seasons, even as the monsoon temperatures do not show a significant trend (Kumar, Kumar and Pant, 1994; Mondal, Khare and Kundu, 2015). However, rainfall fluctuations in India has been largely random over a century with no systematic change detected in summer monsoon season (Prasad & Kochher, 2009). Yet at regional level rainfall has exhibited changes in the last century, with areas around West coast, North Andhra Pradesh, and North West India found to exhibit increasing trend and East Madhya Pradesh, Orissa and North East exhibiting declining trend (GOI, 2008; Kumar, Pant, Parthasarathy, & Sontakke, 1992)

Estimates show India’s climate to become warmer, with a predicted increase in annual mean maximum and minimum temperature of $0.7^\circ\text{C}$ and $1.0^\circ\text{C}$ over land in the 2040s with respect to the 1980s and increase of 1-1.4$^\circ\text{C}$ and 2.23 to 2.87$^\circ\text{C}$ area average annual mean warming by 2020 and 2050 respectively (Lal et al., 1995,2001). The temperature rise is likely to be much higher during the winter (rabi) rather than in the rainy season
(kharif). The warming is more pronounced over land areas with a maximum increase over Northern India. These changes are likely to increase the pressure on developing countries like India (Mendelsohn, 2008; Rosenzweig & Parry, 1994); given their greater dependence on agriculture, in addition to the ongoing stresses of yield stagnation, competition for land, water and other resources and globalization (Paroda and Kumar, 2000).

**Climate trends in the undivided state of Andhra Pradesh**

The state of Andhra Pradesh; now divided into two separate states; Telangana and Andhra Pradesh, was the fifth largest in the country both in terms of population (84.6 million) and geographical area (27.4 million hectares). The undivided state of Andhra Pradesh has a tropical climate with moderate to subtropical weather and exhibits diverse climatic patterns across different agro-climatic zones (Padakandla, 2020). Humid to semi humid conditions prevail in the Coastal areas while arid to semi-arid situations are prevalent in the interior parts, particularly Rayalaseema and some districts of Telangana (Government of Andhra Pradesh, 2011b). The state receives rainfall from South-West (June-September) and North-East (October- November) monsoons. However, there is large variation in the distribution, as coastal areas generally receive the highest rainfall, while regions of Rayalaseema and Telangana fall in the precarious and modest rainfall category (Government of Andhra Pradesh, 2011a). The undivided state of Andhra Pradesh is primarily agrarian in nature, being the third largest producer of rice and groundnut and second largest producer of cotton and sunflower. The impact of climate on this state is more intense not only because of its dependence on agriculture but also of diverse impact across different climatic regions (Padakandla, 2020).

**2.0 Review of literature**

There is vast literature on the dynamics of climate and crop yields and its impact. Though some experimental and simulation studies demonstrate elevated CO$_2$ in the atmosphere help crops favorably (Baker, Allen, & Boote, 1992; Kimball, Kobayashi, & Bindi, 2002; Krishnan, Swain, Bhaskar, Nayak, & Dash, 2007); related impact of increased temperature, changing patterns of rainfall and extreme weather events is likely to increase risks in crop production (Fofana, 2011; Matthews, Kropff, Horie, & Bachelet, 1997; Parry, Rosenzweig, Iglesias, Livermore, & Fischer, 2004). Apart from
the physical impact of climate on crop yields (Lahari & Roy, 1985; Selvaraju, 2003; Gupta, Sen, & Srinivasan, 2014); there is a fair amount of literature on monetary impact of climate on yields (Kumar & Parikh, 2001; Kumar, 2009; Guiteras, 2009; Fishman, 2012. Studies have also estimated impact of climate change on land value or net revenues (Mendelsohn, Nordhaus, & Shaw, 1994; Massetti & Mendelsohn, 2011).

Breakpoint analysis to test the stationarity and instability in time-series data is employed extensively in financial and economic analysis (Kim et al., 2005; Bajo-Rubio et al., 2008; Chen and Zivot, 2010; Kar et al., 2013). However, studies on crop-climate dynamics is limited, especially in the context of India. Arora et al (2005) and Jhajaria et al., (2011), employed non-parametric test to detect monotonic trends in annual average and seasonal temperature over India and North-East India respectively. Alternatively, Paul et al., (2014) employed CUMSUM and Chow test to discover an observed breakpoint around 1970-1980 both at the country and regional levels. Similarly, Mondal et al., (2015) employed Mann-Kendall test and Sen’s slope to analyze the trend magnitude and Mann-Whitney-Pettitt to test probable break point detection in the series.

Wavelet based analysis of climatic time series is relatively a new area of study where multiresolution analysis is applied to climatic variables at varying time horizons. For example, Zhang et al. (2014), using Haar wavelets, discover regime shift in Arctic oscillation. Similarly, Morlet wavelet is used to study the phenomenon of runoff in Yangtze river at varying time horizon by Qian et al. (2014). In the same vein, Xu et al. (2009) decomposes the time series weather data into multiple time horizons to study the impact of climate change in the Tarim river basin of China.

2.1 Research Motive

Survey of existing literature show majority of studies either analyzed time series dynamics of climate and crop variables either independently or examined their relationship across a time interval. Given that there is increasing variability of climate across time horizons, the present analysis will bridge the gap in the existing literature, by analyzing dynamics of climate and yield patterns of seven principal crops in the undivided state of Andhra Pradesh across time horizons.
3.0 Materials and Methods

3.1: Structural change:

Tests for parameter instability and structural change in regression models have been an important part of applied econometric work dating back to Chow (1960) who tested for regime change at a prior known date using an F-statistic. This was further modified by Quandt (1960), to relax the requirement that the candidate break-date be known and consider the F-statistic with the largest value over all possible break-dates. Later, Andrews (1993) and Andrews and Ploberger (1994) derived the limiting distribution of the Quandt and related test statistics. Bai (1997) and Bai and Perron (1998, 2003) provide theoretical and computational results that further extend the Quandt-Andrews framework by allowing for multiple unknown breakpoints.

We employed Bai Perron test to identify the trend and breakpoints across different climate and crop yields. The methodology to detect multiple breakpoints follows the work by Bai and Perron (1998). The data generating process is given by

\[ Y = X\beta^0 + Z\delta^0 + U \] (1.1)

where the true value of the coefficient at time \( t \) is given by the subscript 0. The data is divided into \( m \) partitions and the following global minimum is computed

\[ (T^*_1, \ldots, T^*_2) = \text{argmin}_{T_1, \ldots, T_m} S_T(T_1, \ldots, T_m) \] (1.2)

Where \( S_T \) represents the sum of squared residuals, and is given by

\[ S_T = \sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} [y_t - x_t' \beta - z_t' \delta_i]^2 \] (1.3)

The next procedure in the algorithm is to compute the statistic is derived from the sup F test as detailed in Andrews (1993). The null hypothesis of no breaks is checked against the alternative of \( m=k \) breaks after computing the following statistic.

\[ F(\lambda_1, \ldots, \lambda; q) = \left[ \frac{T-(k+1)q-p}{kq} \right] \left[ \frac{\hat{S}'R'(R(\hat{Z}M_xZ)^{-1}R')^{-1}R \hat{S}}{SSR_k} \right] \] (1.4)

where
\[ T_t = [T\lambda_t] \]
\[(R\delta)' = (\delta'_1 - \delta'_2, ..., \delta'_k - \delta'_{k+1}) \]
\[ M_x = I - X'X^{-1}X' \]

In the above algorithm, an assumption is made at the number of breaks \((m=0,1,...,k)\) in the first stage. Subsequently, the time series is divided into \(m\) segments \((T_1, ..., T_m)\) which minimizes the sum of squared residuals, \(S_t\). The final step in the algorithm involves the computation of an F test which compares the assumption of no breaks with the occurrence of \(k\) breaks. The said number of breaks as assumed in the first step is said to occur if the computed statistic is above the critical value\(^1\). All computations were implemented in R statistical environment using the algorithm developed by Zeileis and and Kleiber, 2005\(^2\).

Alternatively, we employ continuous wavelet transform method to test the robustness in the trends and breakpoints and also observe the co-movements between crop and climate variables across different time horizons. The advantage of wavelet method is that they can decompose the yearly series into different time horizons starting with yearly. For yearly time horizon the wavelet analysis gives results that is also seen in structural break analysis, but the drawback of structural break analysis, is that it cannot give information for higher time horizons i.e. more than two years. Analysis over the time horizon is basically the vantage point of this study. Since climate is a long run phenomena and its impact on crop yields occur over different long-run time horizons, we use wavelets to decompose the trend and also measure the impact. The detailed methodology is explained in the following section.

3.2: Wavelets

Wavelets are small waves\(^3\), with varying oscillations, that vanish after some time interval. Wavelet analysis allows one to decompose the time series data into both time and frequency components simultaneously. This is advantageous as traditional time-
series methods cannot capture frequency information which is related to time-horizon of study. Therefore, wavelets can filter data based on components from varying time-horizon starting with smallest horizon, or short-run, and capturing information from longer time horizons too. Computations are based on the continuous wavelet methodology as described in Grinsted et al. (2004) and Bhandari and Kamaiah (2019).

3.2.1: Continuous wavelet transform

The estimator used to analyze co-movements between two time-domain variables, is given by wavelet coherence which is based on the continuous wavelet transform. A wavelet is a real valued function $\psi(g)$ defined on $\mathbb{R}$ such that

$$\int_{i}^{}\psi(t)\,dt = 0$$  \hspace{1cm} (2.1)

$$\int_{-\infty}^{\infty}|\psi(t)|^2\,dt = 1$$  \hspace{1cm} (2.2)

Wavelet analysis is performed by choosing a reference wavelet known as mother wavelet $\psi_{b,s}(t)$, which is defined as

$$\psi_{b,s}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-b}{s}\right)$$  \hspace{1cm} (2.3)

where $s \neq 0$ and $b$ are real constants. The parameter $s$ is the scaling parameter (used to determine window widths), whereas the parameter $b$ denotes the translation parameter (used to determine the position of the window).

The “continuous wavelet transform” (CWT) of a time signal $x(t)$ is defined as

$$W^x(b,s) = \int_{-\infty}^{\infty} x(t) \overline{\psi_{b,s}(t)}\,dt$$  \hspace{1cm} (2.4)

provided the following admissibility condition$^4$ is satisfied

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$^4$ The admissibility allows the reconstruction of $x(t)$ from the CWT.
\[ C_{\psi} = \int_{-\infty}^{\infty} \frac{\left| \Psi(\omega) \right|^2}{\left| \omega \right|} d\omega < \infty \] (2.5)

where \( \Psi(\omega) \) is the Fourier transform of the mother wavelet \( \psi_{a,b}(t) \). The square of the absolute value of the CWT is known as the wavelet power and is given by \( \left| W^x(b,s) \right|^2 \), where the complex argument of \( W^x(b,s) \) gives the local phase. Analogous to the boundary problem encountered in discrete wavelet methods, CWT too suffers from edge effects as the transform is incorrectly computed at the initial and end points of the time-series. Edge effects can be taken into consideration by introducing a Cone of Influence (COI). It is the area in wavelet spectrum where wavelet power at the edges generated by some discontinuity has fallen by a magnitude of \( e^{-2} \) of the edge’s value.

Wavelet coherence diagram helps one to distinguish between significant short and long-term correlations. Information from timescales ranging from around 2-16 years is given in the left vertical axis of coherence plot. Morlet wavelet is used as the “mother wavelet” in computing wavelet coherence and the significance is determined by Monte Carlo methods. The cone of influence (COI), where the coherence map is affected by boundary problem, is shown in a lighter shade. Statistically significant areas in the coherence plot, with 5% significance level, are denoted by bold black borders. The color coded coherence map reveals strongest power at regions with red color whereas blue regions reveal low power.

3:3 Data sources:

State level data on temperature (maximum, minimum and average temperature); rainfall (average rainfall, South West monsoon rainfall and North East monsoon rainfall) and yield of seven principal crops (rice, jowar, maize, cotton, groundnut, sugarcane and tobacco) from 1956-2010 is used for the analysis. Crop yield data is collated from various volumes of season and crop reports of Andhra Pradesh. Data on rainfall is collected from a profile of rainfall statistics 1951-2004 and various season and crop

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5 The Fourier transform of the wavelet function \( \psi(t) \) is \( \Psi(\omega) = \int_{-\infty}^{\infty} \psi(t) e^{-i\omega t} dt \)
reports; while data on temperature variables is taken from Indian water portal and different volumes of Statistical abstracts, Government of Andhra Pradesh\(^6\).

4.0: Empirical Results

In this section we discuss the trend and time frequency dynamics of climate and crop yields and the co-movements across time horizons derived from our analysis.

4.1 Crop climate trends in the undivided state of Andhra Pradesh

*Figure 1: Temperature dynamics in the undivided state of Andhra Pradesh*

![Temperature dynamics in the undivided state of Andhra Pradesh](image)

Figure 1. depict the trend and structural breaks of different temperature parameters for the undivided state of Andhra Pradesh during 1956-2010. The break years have been depicted by the dotted vertical on the \(x\) axis. All results are at 95\% significance level. From the results we observe a steady increase of around 1.0\(^0\) in annual average, annual maximum and annual minimum temperatures across break points over the study period. All the three temperature variables depict two similar break points at 1978 and 2002; however annual minimum temperature exhibited a break at 2000. We can observe the uptick in the trend is more visible and pertinent in the latter part of the last decade especially around late 1990s to 2000s. This is in line with the all India trend that depicts

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\(^6\) Though the station level data as captured by the IMD (Indian meteorological department) is available from as early as 1955, the presence of large gaps across the time period, coupled with the absence of stations in many districts during the earlier years has restricted the use of this particular data set.
the greater warming activity observed in the last 40 years (1971–2010), and particularly attributed to the intense warming in the last decade (1998–2007) (Kothawale et al., 2010).

**Figure 2: Rainfall dynamics in the undivided state of Andhra Pradesh**

With reference to rainfall in the state (figure 2), we observe that the trend is more or less steady for all the three variables i.e annual average, South West and North East rainfall over the study period. As in the case with all India trend (Kumar et al., 1992, Prasad and Kochher, 2009), rainfall fluctuations in Andhra Pradesh have been largely random with no systematic change over the last century with no identified break point. However, in line with the all India trend (Pant and Kumar, 1997; Kumar et al., 1999 a,b; Gadgil et al., 2002), actual rainfall depicts oscillating pattern over the years, with regional differences and multi-decadal variations

**Figure 3: Yield dynamics of major crops in the undivided state of Andhra Pradesh**
Yields of major principal crops have recorded positive increase as depicted in figure 3. However, yield trends of sugarcane and groundnut show volatility with no significant increasing trend. With regard to break points, all crops except sugarcane and groundnut have recorded three or more break points. While rice exhibited four breaks at 1969, 1977, 1987 and 1999, jowar (1976, 1991, 2002), maize (1971, 1991, 2002), cotton (1972, 1980, 2002) and tobacco (1976, 1987, 1999) exhibited three breaks each. For all crops, except jowar and tobacco, the first observed break point is around early part of 1970s, while the last observed break for all the crops is around 1999-2002. We can observe that the last observed break point of temperature is around the same time period as of yields. Even with regard to rainfall, the last decade shows an increasing oscillating
pattern, implying higher inconsistencies across the years. It has to be mentioned here that, though yields of major crops are increasing, there is however a deceleration in the growth rates over time (Padakandla, 2016). This phenomenon is more visible especially in the last two decades, which coincidentally is the time during which the state has experienced uptick in temperature patterns.

4.2: Wavelet Co-movement

Having analyzed the trends in climate and crop yields, we employed continuous wavelet transform method to validate our results and to understand coherence between crop and climate variables across different time horizons. Figure 4 shows the wavelet coherence between temperature and seven crops. It can be seen from the figure that concentration of power or high coherence of average temperature with tobacco, rice, jowar, groundnut and sugarcane, given in red color code, at yearly time horizon manifests around 1995. Overall, high coherence or co-movement between average temperature and the crops under study seems to be significant at yearly time horizon and time interval between 1995-2000. However, coherence between average temperature and crops changes when the time horizon increases. For example, significant coherence between rice and average temperature can be observed at a time horizon of four years for the time interval 1967-74. The same phenomenon can be observed if we look at the coherence of average temperature with tobacco and sugarcane but not for the other remaining crops under study. This can be attributed to similarity in climatic dependence of rice, sugarcane, and tobacco on crop yield. Furthermore, groundnut and sugarcane seem to exhibit high coherence with average temperature when we consider higher time horizon of six-eight year during the time interval 1990-2000. For these two crops, yield show high co-movement with average temperature during 1990-2000, time interval, but only at much longer time horizon i.e six-eight-year horizon. No immediate impact can be seen from the analysis, but there seems to be a definite high negative impact on the yield patterns of these two crops over the long run. Therefore, except for yearly time scale, coherence tends to change when the time horizon increases. The results obtained in Figure 4 is also in consonance with results obtained from structural break analysis which shows observable breaks in temperature and yields around 1995-2000 and in line with decelerating yield growth observed during the same period (Padakandla, 2016).
Figure 4: Coherence of crop yields with temperature
Figure 5 Wavelet Coherence between crops and rainfall
Figure 5 reports coherence between rainfall and the seven crops under study. One can observe from the figure that there exists high coherence of actual rainfall with rice, jowar, maize and sugarcane during 1975-80 at yearly time horizon. Similarly, significant coherence of actual rainfall with rice, tobacco, and maize can be observed during 1995-2000 at yearly time horizon. Moreover, one can observe significant coherence of actual rainfall with rice, maize, and tobacco during 1995-2000 at two to three-year horizon. However, coherence of actual rainfall and the crops under study changes when we look at higher time horizons. For example, the coherence of actual rainfall with cotton, maize, and rice seems to be significant during 1985-1994 at six-year time horizon. Though rainfall pattern does not observe any specific structural change in our analysis, coherence of rainfall with crop yields is in line with the existing literature in the context of India (Parthasarathy and Pant, 1985; Parthasarathy et al., 1992; Selvaraju, 2003; Kumar et al. (2004).

Coherence analysis of co-movement across time horizons:

The wavelet-based coherence analysis of co-movement between climatic and select crops yields reveal the existence of high coherence of average temperature with crops under study during 1995-2000 at yearly time horizon. However, co-movement among climatic and crop yield tend to vary as we move towards longer time horizon. This is evident when we look at the coherence of average temperature with rice, tobacco, and sugarcane during 1967-74 for four-year time horizon. The coherence further varies, for groundnut and sugarcane, if we look at longer time horizon of six-eight year during the time interval 1990-2000. On the other hand, coherence of rainfall with crops like rice, jowar, maize, and sugarcane is significant during 1975-80 at yearly time horizon. The same is also true for rice, tobacco, and maize during 1995-2000. Similarly, coherence of rainfall with rice, maize, and tobacco is significant during 1995-2000 if we look at the short-run horizon of two-three year. The phenomenon of rising co-movement during long-run time horizons is also evident in the case of rainfall where there exists strong coherence of actual rainfall with cotton, maize, and rice during 1985-1994 at six-year time horizon. The crop-wise climatic coherence for all variables under study is summarized in Table 1.
Table 1: Coherence of Climatic Variables with Crops at Varying Time-Horizon

|                                     | Rice        | Cotton      | Jowar       | Groundnut   | Maize       | Tobacco     | Sugarcane   |
|-------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| One-year Time Horizon               |             |             |             |             |             |             |             |
| Rainfall                            | High Coherence (around 1975-80) and (around 1995-2000) | High Coherence (around 1975-80) | High Coherence (around 1975-80) | High Coherence (around 1975-80 and (around 1995-2000) | High Coherence (around 1975-80) | High Coherence (around 1975-80) |
| Temperature                         | High Coherence (around 1995-2000) | High Coherence (around 1995-2000) | High Coherence (around 1995-2000) | High Coherence (around 1995-2000) | High Coherence (around 1995-2000) | High Coherence (around 1995-2000) |
| Two-Three years’ Time Horizon       |             |             |             |             |             |             |             |
| Rainfall                            | High Coherence (around 1995-2000) |             |             |             |             |             |             |
| Temperature                         |             |             |             |             |             |             |             |
| Four-year Time Horizon              |             |             |             |             |             |             |             |
| Temperature                         |             |             |             |             |             |             |             |
| Six-Eight years’ Time Horizon       |             |             |             |             |             |             |             |
| Rainfall                            | High Coherence (around 1985-94) | High Coherence (around 1985-94) | High Coherence (around 1985-94) | High Coherence (around 1985-94) | High Coherence (around 1985-94) | High Coherence (around 1985-94) |
| Temperature                         |             |             |             |             |             |             |             |

5:0 Conclusions:

Results show that observed variables exhibit multiple structural break points implying significant changes in climatic and crop yield patterns in the undivided state of Andhra Pradesh. Temperature variables observed around 1.0°C increase across structural break periods, with the latest break observed around 2000. Though rainfall doesn’t show any shift in trends, results show increased variability in the last few decades. Results also depict a convergence of break points for most of crop and climate variables. Wavelet based coherence analysis that map the time-horizon specific dynamics of climate and crops with time periods exhibited significant co-movement between climatic and crop
variables. This mapping, however, cannot be explored with traditional time-series methods. The framework of time-frequency analysis employed in the study, allow us to segregate the relationship among climatic variables and crop yields at varying time-horizon beginning with the short-run (1-2 years) and extending up to long-run (6-8 years) horizons. Wavelets allow one to examine climate and crop dynamics at heterogeneous time horizons, allowing one to study the impact of climate and crop yields at longer time-horizon as we have demonstrated in our study. Given shifts in climate patterns and subsequent shifts in co-movements across time horizons, policy makers and crop scientists should design time specific and locally viable adaption and mitigation policies to tackle the impact of climate on crops and livelihoods.

Length of Manuscript: 5706
Declarations:

-Ethical Approval

This article does not contain any studies with human or animal participants performed by any of the authors.

-Consent to Participate

We here-by provide our full consent to participate in the process of the journal

-Consent to Publish

We here-by provide our full consent to publish our article in the journal

-Author Contributions

SR Padakandla: Conceptualization of the idea, data collection and formulation and preparing of manuscript

A Bhandari: Analysis of Wavelet co-movements

AA Atluri: Structural break analysis

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-Competing Interests

Also there is no financial or personal relationships, or conflict of interest that could be perceived as potential source of bias.

-Availability of data and materials

The data has been uploaded
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