Assessment of Association Between Observed Weather and Detrended Weather with the Detrended Rice Crop Yield in the Konkan Region of Maharashtra

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ABSTRACT

Maharashtra's total rice production (1961-2014) strongly increases. This is due to the increasing cultivated area and the influence of improved technology. Whereas, year-to-year fluctuation in production is mainly because of fluctuations in the climate. Hence, only the rice crop yield is taken for the detailed study of climate and agriculture in the selected districts from 1981 to 2014 period. Correlation analysis indicates the influence of climate change on detrend yield. A heavy shower of rain and hail can cause immense damage to a standing crop, ready for harvest (Crop weather calendar 2003, IMD). Thus, yield is the summation of conditions in all successive weeks of the crop. Correlation analysis was carried out to see the impact of observed weather with detrend yield and detrended weather with detrend yield. The Research Work explores the importance of additional Climatic variables, other than Temperature and Rainfall, and their impact on Rice crop yield. There is a significant relationship between the Observed Weather Parameter and De-trended Weather Parameter with the De-trend Yield, at different Growth Stages of Crop. The study brought about the Relationship between Rice Crop Yield and Weather Parameters, with and without Climate Change.

INTRODUCTION

Agriculture production aims to produce as much foodstuff from a given area as possible. The climatic aspects of the input-yield relationship essentially concern the determination of the optimum condition that produces the maximum yield. The importance of phenological data is evident from the many aspects that relate to the dates at which planting, germination, and the emergence of the seed occurs or dates at which flowering and ripening take place. The summer or *kharif* growing season (June - September) coincides with the southwest monsoon. Rice is known to be one of the most highly susceptible cereal crops to climate variability because of its high water requirements. Relationships between rice and climate are well documented by past research (e.g., Pattanayak and Kumar *et al.* 2014, Ye *et al.* 2015, Marjuki *et al.* 2016, Biswas *et al.* 2017, Lu *et al.* 2017, Ghose *et al.* 2021).

There are critical growth periods in the life history of a crop from the date of sowing to the date of harvesting. It is well known that the weather at

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sowing time determines even the nature and variety of the crop that the farmer decides to grow in his field. The crop gets a good start if conditions are favorable during the first phase (germination and early vegetative growth). Thus, according to the rice crop weather calendar, rice is a 3 and ½ monthly crop with their meteorological parameter requirement. It differs from place to place and has variety. Only in the vegetative growth stage does rice require more rainfall or need maximum rainfall for a better yield. In other stages, water requirement is low in fact in the flowering and grain formation stage if rainfall is more it may hinder or hamper the growth of the yield of the crop.

Thus, the yield of the crop is the summation of all these atmospheric, genetic, and terrestrial factors that make the successive weeks of the crop. The objective to obtain a direct correlation of observed weather and detrended weather with detrend yield.

MATERIALS AND METHODS

The present study includes the Thane and Raigad districts which come under the Konkan region of the Maharashtra state bounded by the western ghat at the East and the Arabian Sea at the West. The basic climate data on rainfall, maximum and minimum temperature, and morning and evening relative humidity, for the period 1981-2014 for the selected districts of Maharashtra was collected from the Indian Meteorological Department (IMD), Pune.

Detrend analysis

To examine only the direct impact of weather (without the influence of technology intervention) with the help of the detrending method. Detrend Yield has been calculated by using the formula, Detrend Yield = (Actual Yield / Slope* Year + Interception Value) -1 Detrended Weather Parameter = (Actual Weather / Slope *Year + Interception Value) -1 J.W. Hansen and Amor V.M.Ines (2004). The techniques mentioned above remove the influence of non-climatic factors like technology. With the help of the correlation of Detrend yield with actual weather parameters and Detrended weather parameters, Hence, correlation analysis is carried out to examine the impact of ob-

served weather with detrend yield and the detrended weather with detrend yield.

RESULTS AND DISCUSSION

Crop production varies and has year-to-year fluctuations due to weather parameters hence crop climate study plays an important role in finding out the relationship.

Thane and Raigad district comes under the Konkan region of the Maharashtra state. The present research work is an attempt to see the weather parameter effect on the growth stages of rice crops where successive meteorological weeks are considered as per the growth stages which are determined by the onset of the monsoon. The below table shows the growth stages and meteorological weeks as well as the correlation of observed and detrended weather parameters with yield. Table 1 shows the correlation of detrended yield with observed and detrended weather parameters of Thane district.

Thane district

Maximum temperature : During the sowing/ Seed and Germination stage, maximum temperature shows a non-significant correlation between observed and de-trended weather with yield (Table 1). The sowing stage is at the 23rd week of standard meteorological weeks. Seedling includes the Transplanting stage starting from the 24th to the 27th-week maximum temperature showing a non-significant correlation between observed and de-trended weather with yield. It can be concluded that maximum temperature did not affect the yield of rice during the sowing and transplanting stage.

The vegetative growth stage/Tillering stage starts with the 28th to the 32nd week of standard meteorological weeks. Maximum temperature shows non- significant correlation till the 30th week but in the 31st week, it shows a negative correlation at a 90% significant level with observed weather and yield whereas it shows a positive correlation between de-trended weather and yield at a 90% significant level. Panicle development to initiation stage is from the 33rd to 36th

Table 1. Correlation of detrended Rice crop yield with observed weather and detrended weather parameters in the particular meteorological weeks of the different phenological stages at Thane district. Thane district (# 90%, * 95%, ** 99%, level of significance).

Growth stages	MW	T_{max}		T_{min}		RF		RHI		RHII	
		Observed	Detrended	Observed	Detrended	Observed	Detrended	Observed	Detrended	Observed	Detrended
Seed and germination	23	0.2145	-0.2215	0.2821#	-0.2877#	0.1036	0.1738	-0.1218	-0.1244	-0.2348#	0.1831
Seedling include	24	0.0320	-0.0319	-0.0698	0.0723	0.1117	0.1270	0.0725	0.0724	-0.0112	0.0134
	25	0.0233	-0.0249	0.0838	-0.0827	0.0862	0.0578	-0.0140	-0.0138	-0.0101	0.0119
	26	0.1506	-0.1518	0.1664	-0.1667	0.0970	0.1188	-0.1821	-0.1821	-0.1052	0.0697
Transplanting	27	-0.0068	0.0071	-0.1926	0.1926	0.0876	0.0991	0.0925	0.0947	0.1435	-0.1033
Veg growth/ Tillering	28	-0.0084	0.0086	-0.3088*	0.3092*	0.1048	0.1285	0.1094	0.1100	-0.0016	0.0057
	29	0.0448	-0.0562	-0.0091	0.0034	0.1282	0.1559	-0.0040	-0.0048	0.0030	-0.0005
	30	-0.0796	0.0790	-0.0817	0.0820	0.1393	0.1661	0.2841#	0.2844#	0.1766	-0.1514
	31	**-0.2319#**	**0.2336#**	-0.1406	0.1467	0.1702	0.1789	0.1005	0.1006	0.3009*	-0.2933*
	32	0.1117	-0.1117	0.0891	-0.0894	0.1213	0.1739	-0.0700	-0.0704	-0.0571	0.0446
Panicle development to initiation	33	0.1246	-0.1322	0.1465	-0.1567	0.1617	0.1842	-0.1141	-0.1198	-0.0851	0.0585
	34	0.2267	-0.2304#	0.0850	-0.0862	0.1519	0.1546	-0.1026	-0.1025	-0.1762	0.1752
	35	0.1933	-0.1951	0.1237	-0.1267	0.1670	0.1841	-0.0471	-0.0468	0.0972	-0.0773
	36	0.3018*	-0.3038*	-0.0251	0.0249	0.1316	0.1547	-0.0823	-0.0818	-0.0736	0.0733
Flowering	37	0.0700	-0.0725	**0.3732***	-0.3883*	0.1649	0.1487	0.1585	0.1598	0.1141	-0.1055
Milking and dough stage	38	-0.0934	0.0924	-0.0965	0.0967	0.1868	0.1951	0.1489	0.1496	0.3127*	-0.3050*
	39	-0.4944**	0.4978**	-0.2144	0.2144	0.2159	0.2149	0.4414**	0.4429**	0.3100*	-0.2335#
	40	-0.4117**	**0.4209****	-0.1866	0.1928	0.1536	0.0078	0.2239	0.2407#	0.0699	-0.0494
Harvesting/ Phenological maturity	41	-0.1629	0.1681	-0.0426	0.0416	0.1377	0.3699*	-0.0974	-0.1052	-0.0572	0.0493
	42	0.0029		-0.2993*	0.3026*	0.1031	-0.0216	-0.3597*	-0.3615*	-0.3210*	0.2908#

week of standard meteorological weeks maximum temperature shows a non-significant correlation between observed and de-trended weather with yield except in the 34th week it shows a 90% significant level negative correlation between de-trended weather and yield. Maximum temperature shows a positive correlation between observed weather and yield at a 95% significance level. Vice versa it shows a negative correlation between de-trended weather and yield at a 95% significance level in the 36th week. The flowering stage starts with the 37th week of standard meteorological weeks. The 37th- week maximum temperature shows a non-significant correlation between observed and de-trended weather with yield.

The milking and dough stage starts with the 3startso the 40th week of standard meteorological weeks. In the 38th week, maximum temperature shows a non-significant correlation between observed and de-trended weather with yield. But in the 39th and 40th-week maximum temperature shows a negative correlation at a 99% significant level between observed weather and yield as well as in de-trended whether it shows a positive correlation with yield, which means

with increasing temperature yield is decreasing in the observed scenario, in this case, found perfect opposite relation in observed and de-trended weather. The harvesting and phonological maturity stage begin with the 41st to 42nd week, there is a non-significant correlation between observed and de-trended weather of maximum temperature with the yield at the 41st and 42nd week of this stage. Maximum temperature adversely affects the rice yield in the Thane district during the Tillering stage and in the milking and dough stages.

Minimum temperature : Seedling includes the Transplanting stage starting with the 24th to 27th week, there is no significant correlation between observed and detrended minimum temperature weather with yield. The vegetative growth or Tillering stage begins with the 28th to the 32nd week of the standard meteorological week. In this stage only in 28th-week result shows a negative correlation with observed minimum temperature weather with yield and vice versa positive correlation in detrended minimum temperature weather with yield. There is no significant correlation between observed and detrended minimum temperature weather with yield in other weeks. Panicle development to the initiation stage begins with the 33rd to 36th week of standard meteorological weeks. There is no significant correlation between observed and detrended minimum temperature weather with yield. The flowering and fertilization stage, begin with the 37th week of standard meteorological weeks. It shows a positive correlation with observed minimum temperature weather with yield vis a vis negative correlation with detrended minimum temperature weather with a yield at a 95% significant level.

The grain formation or milking and dough stage starts with the 38th to the 40th week of standard meteorological weeks. All weeks of this stage show a non-significant correlation between observed and detrended minimum temperature weather with yield. The harvesting or Phenological maturity stage begins with the 41st and 42nd where 41st-week results show a non-significant correlation between observed and detrended minimum temperature weather with yield and the 42nd week shows a negative correlation between observed minimum temperature weather with the yield at a 95% significance level.

An increase in minimum temperature had a harmful effect during the vegetative growth stage and there is a significant negative correlation in the phenological maturity stage with observed weather and yield. A positive correlation was found at the flowering stage with observed weather and yield.

Rainfall : During the sowing or seed germination stage i.e. in the 23rd week there is no significant correlation between observed and detrended rainfall weather with yield. Seedling includes the Transplanting stage begins from the 24th to the 27th week results show that there is no significant correlation between observed and detrended weather of rainfall with the yield at this stage. The vegetative growth or Tillering stage starts with the 28th to the 32nd week of standard meteorological weeks. This stage also results show that there is no significant correlation between observed and detrended weather with yield. Panicle development to the initiation stage begins with the 33rd to 36th week of standard meteorological weeks. This stage also results show that there is no significant correlation between observed and detrended weather with yield. The flowering and fertilization stage begins with the 37th week of standard meteorological weeks. This stage also results show that there is no significant correlation between observed and detrended weather with yield. The grain formation or milking and dough stage starts on the 38th to the 40th week. During this stage also results found that there is no significant correlation between observed and detrended weather with yield. Harvesting or the phenological maturity stage starts at the 41st week, here rainfall shows a non-significant correlation between observed weather with yield and a positive but non-significant correlation between detrended rainfall weather with the yield at a 90% significant level. The effect of rainfall is beneficial during the vegetative stage and detrimental during the seedling and maturity stage.

Relative humidity (Morning) : During the sowing or seed germination stage i.e. on the 23rd week result shows a negative but non-significant correlation between observed and detrended weather of morning relative humidity with yield. Seedling includes the Transplanting stage and also shows a non-significant correlation between observed and detrended

Table 2. Correlation of detrended Rice crop yield with observed weather and detrended weather parameters in the particular meteorological weeks of the different phenological stages at Raigad district. Raigad district (# 90% ,* 95%, ** 99%, level of significance).

Phenological stages	MW	T_{max} Observed	Detrended	T_{min} Observed	Detrended	RF Observed	Detrended	RHI Observed	Detrended	RHII Observed	Detrended
Sowing	23	**0.3172***	-0.3559	0.3172	-0.3183	-0.2129	-0.0134	0.0025	-0.0036	0.0397	0.0511
	24	-0.1194	0.1194	-0.1194	0.1194	-0.2285	0.1294	-0.1958	0.1945	0.1409	0.1680
Seedling	25	-0.0763	0.0807	0.0235	-0.0243	-0.2210	0.1107	0.1314	0.1327	0.2207	0.2510#
include	26	0.1281	-0.1278	0.0722	-0.0705	-0.2250	0.0607	0.0029	0.0254	0.1522	0.1877
Trans-	27	-0.2628#	0.2596#	**-0.3307***	**0.3290***	-0.1839	-0.0446	-0.1548	0.2272	**0.4933****	**0.5216****
planting	28	-0.0725	0.0752	-0.1195	0.1237	-0.1980	0.1824	-0.0118	0.0536	**0.5260****	**0.5794****
Veg gro-	29	0.3030*	**-0.3156***	0.2583#	-0.2801#	-0.2271	0.0927	0.0671	-0.1895	0.0878	0.1133
wth/Till-	30	0.1768	0.0740	0.0368	-0.0271	-0.2055	0.1895	0.0541	-0.0493	0.1772	0.2083
ering	31	0.0293	-0.0297	0.1452	-0.1492	-0.2273	-0.2118	0.0590	-0.0536	0.0355	0.0434
	32	0.3715*	-0.3706*	0.4258**	**-0.4247****	**-0.2563#**	0.0881	0.3022*	-0.2995*	-0.1011	-0.0949
Panicle	33	**0.3877***	**-0.4034****	0.1401	-0.1384	-0.2517#	-0.0318	0.19500	-0.2683#	0.05492	0.08535
develop-	34	**0.2671#**	-0.2646#	0.01977	-0.0127#	-0.2149	-0.0605	0.03986	-0.0504	0.3387*	0.3751*
ment to	35	0.2616#	-0.2598#	0.17752	-0.1775	-0.2381#	-0.1841	0.03393	-0.0343	0.08453	0.10997
initia-	36	**0.3219***	**-0.3200***	0.16444	-0.1614	**-0.2776#**	-0.0709	0.2372#	**-0.3062***	0.11088	0.12688
tion Flower- ing and fertili- zation	37	0.04925	-0.0487	0.06062	-0.0527	-0.2262	-0.1914	-0.0136	0.02579	**0.3004***	**0.3445***
Milking	38	-0.0375	0.03492	0.08447	-0.0776	-0.2305#	0.10802	-0.0133	0.04901	**0.2525#**	**0.2993***
and do-	39	-0.1441	0.14560	-0.0922	0.09768	**-0.2382#**	-0.0163	0.05059	-0.0475	**0.2646#**	**0.3446***
ugh stage	40	-0.0170	0.02411	-0.0296	0.02969	-0.1221	0.20038	0.21193	-0.2098	0.03633	0.05767
Harves- ting/ Phe- nologi- cal matu- rity	41	0.15544	-0.1519	0.2452#	-0.2433#	-0.1613	-0.1306	0.12194	-0.1104	-0.0251	-0.0046

morning relative humidity weather with yield. The vegetative growth or Tillering stage starts with the 28th to the 32nd week of standard meteorological weeks. Only the 30th week shows a positive correlation between observed and detrended weather with the yield at a 90% significant level. Other weeks show a non-significant correlation between observed and detrended weather with yield. Panicle development to the initiation stage starts with the 33rd to 36th week where morning relative humidity shows a negative but non-significant correlation in both observed and detrended weather with yield. The flowering stage starts with the 37th week and results show a negative but non-significant correlation between observed and detrended weather with yield.

The milking and dough or grain formation stage begins in the 38th to the 40th week. In the 39th week, results show a positive correlation at a 99% significance level between observed and detrended weather

with yield. In the 40th week, it shows a positive but non-significant correlation between observed weather with yield and a positive correlation but significant at a 90% confidence level in detrended weather with yield. The phenological maturity or harvesting stage starts in the 41st week to the 42nd week. In the 42nd week results a negative correlation at a 95% significance level in both detrended and observed weather with yield.

***Relative humidity (Evening)* :** In detrended weather, it shows a non-significant correlation with yield. Seedling includes the Transplanting stage begins from the 24th to the 27th week, there is no significant correlation between observed and detrended weather and the yield at this stage. The vegetative growth or Tillering stage starts with the 28th to the 32nd week of standard meteorological weeks. Other weeks show a non-significant correlation between observed and detrended weather with yield. Panicle development

to the initiation stage starts with the 33rd to 36th week result shows a negative but non-significant correlation between observed and detrended weather with yield. During the flowering stage, i.e. on the 37th week results show a non-significant correlation between observed and detrended weather with yield. The milking and dough or grain formation stage begins from 38th to 40th weeks. The 38th and 39th week's results show a positive correlation at a 95% significance level between observed weather and yield. In detrended weather, results found a negative correlation at a 95% significance level in the 38th week. The other week shows a non-significant correlation between observed and detrended weather with yield. Phenological maturity or harvesting stage starts with the 41st to the 42nd week, results show a non-significant correlation in the 41st week but the 42nd week shows a negative correlation at a 95% significant level between detrended weather with yield. Table 2 depicts the correlation of detrend yield with observed and detrended weather surface parameters at Raigad district.

Raigad district

Maximum temperature : The seed and germination or sowing stage starts on the 23rd week of standard meteorological weeks (Table 2). Maximum temperature shows a positive correlation at a 95% significance level for observed weather with yield. It also found a negative correlation at a 95% significance level for detrended maximum temperature weather with yield. Seedling includes the transplanting stage starting with the 24th to the 27th week of standard meteorological weeks. In the 24th and 25th weeks, the result shows a non-significant negative correlation and the 27th-week result shows a negative correlation at a 90% significant level with observed weather with yield. In detrended weather, it shows a non-significant correlation except in the 27th week shows a positive correlation at a 90% significance level.

The vegetative growth or Tillering stage begins with the 28th to 32nd week of standard meteorological weeks. There is no significant correlation in both observed and detrended weather with yield except in the 29th week which shows a positive correlation at a 95% significance level in observed weather with yield and a negative correlation at a 95% significance level

in detrended weather with yield. There is a positive correlation in the 32nd week at a 95% significant level. Panicle development to the initiation stage begins with the 33rd to 36th week of standard meteorological weeks. There are positive correlations in and 33rd week at a 95% significant level. Vice versa there is a negative correlation at a 95% significance level in the 32nd week, and a 99% significance level in the 33rd week. The 36th week shows a positive correlation at a 95% significance level with observed weather and yield and a negative correlation with detrended weather with yield. There are no significant correlations in other weeks. The flowering and fertilization stage start with the 37th week of standard meteorological weeks. The milking and dough or grain formation stage starts with the 38th to the 40th week of standard meteorological weeks. The phenological maturity or harvesting stage begins with the 41st to 45th week of standard meteorological weeks. In the 45th week, there is a positive correlation at a 99% significant level with observed weather and yield. Vice versa there is a negative correlation at a 99% significant level in detrended weather with yield. There are non-significant correlations in other weeks.

Minimum temperature : During the sowing stage in the 23rd week, there is a non – significant correlation in both observed and de-trended weather with yield. During seedling including the transplanting stage from the 24th to 28th week of the standard meteorological week only in the 27th week. Minimum temperature shows a negative correlation at a 95% significant level in observed weather and yield and a positive correlation with a 95% significant level with de-trended weather with yield. The 32nd week shows a 99% significant level of positive correlation with observed and de-trended weather with yield. The panicle development initiation stage begins with the 33rd to 36th standard meteorological week. The flowering and fertilization stage begin with the 37th week which shows the non – significant correlation in both observed and de-trended weather with yield. The milking and dough stage start with the 38th to the 40th week, and the result shows the non – significant correlation in both observed and de-trended weather with yield.

Rainfall : During the sowing stage in the 23rd week,

there is a non – significant correlation in both observed and de-trended weather with yield. During seedling including the transplanting stage, there is a non – significant correlation in both observed and de-trended weather with yield. Another week shows a non-significant correlation with yield. The flowering and fertilization stage begins in the 37th week and shows the non – significant correlation in both observed and de-trended weather with yield. During harvesting and phenological maturity, a non – significant correlation was found in both observed and de-trended weather with yield.

Relative humidity (Morning) : During the sowing stage in the 23rd week, there is a non-significant correlation found in both observed and de-trended weather with yield. During seedling including the transplanting stage, there is a non – significant correlation in both observed and de-trended weather with yield. A 95% significant level in de-trended weather with yield. The flowering and fertilization stage begins with the 37th week which shows a non – significant correlation in both observed and de-trended weather with yield. In the milking and dough stage where 38th and 39th weeks their a non-significant correlation in both observed and de-trended weather with yield. During the harvesting and phenological maturity stage, a non-significant correlation in both observed and de-trended weather with yield.

Relative humidity (Evening) : During the sowing stage in the 23rd week, there is a non-significant correlation in both observed and de-trended weather with yield. During seedling including the transplanting stage, it shows a non-significant correlation from the 27th to the 28th week shows a positive correlation at a 99% significant level in both observed and de-trended weather with yield. During the vegetative growth / tillering stage there is a non-significant correlation in both observed and de-trended weather with yield. In the panical development initiation stage where 34th week shows a positive correlation at a 95% significant level in both observed and de-trended weather with yield. At the flowering and fertilization stage, the 37th week shows a significant correlation with the yield at a 95% significant level in both observed and de-trended weather. In the milking and dough stage where 38th week shows 95% in de-trended weather with yield.

39th week shows a positive correlation with a yield at 95% in de-trended weather. During harvesting and phenological maturity, a non-significant correlation in both observed and de-trended weather with yield.

CONCLUSION

There is a significant relationship between the Observed Weather Parameter and De-trended Weather Parameter with the De-trend yield, at different growth stages of the rice crop. The study brought about the Relationship between Rice Crop Yield and Weather Parameters, with and without Climate Change.

Many non-climatic factors influence yield like high-yield varieties, improved technology, fertilizers, and so on hence to see only weather impact with the help of the detrending method removes the influence of technology intervention and gets a direct correlation with detrend yield and observed weather parameter and detrend yield with detrended weather parameter.

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