Research Article

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Climate based coconut yield model for Arsikere taluk of Hassan district in Karnataka

Shripad Vishweshwar*, Shankar Meti, B.V. Champa and M. Nagaraja

University of Horticultural Sciences, Bagalkot-587104, Karnataka, India

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Abstract

Coconut has a prolonged reproductive phase of 44 months from the initiation of the inflorescence primordium to full maturity of the nuts. Weather affects all stages of the long development cycle, and thus there is likely to be extended predictability based on climate variability. Arasikere taluk of Hassan district, which has a major share of coconut area of Karnataka state, is frequently experiencing deficit rainfall coupled with a decline in groundwater level. Hence, an attempt was made to relate the coconut sample survey data of Coconut Development Board with climate data of Arsikere taluk of Hassan district. Mean nut yield per palm, per year in the Arasikere taluk was 49.2. Among the villages, Gijihalli recorded significantly lower nut yield (42.2) followed by Jajur (48.8) and Aggunda (55.3). Mean maximum, and minimum temperature during 2010-2017 was 32.4^{0}C and 19.5^{0}C respectively, with an average annual rainfall of 840 mm. Annual rainfall during 2011, 2012 and 2016 was below normal compared to other years. Correlation of monthly nut yield per palm with rainfall showed a significant positive correlation with the previous three to four years rainfall. Long dry spell during primordial initiations to nut maturity during consecutive two years 2011 and 2012 has resulted in significantly low nut yield during 2014. Rainfall during 2013 and 2014 was comparatively better, resulting in significantly higher nut yield during 2016 compared to 2014. Among the different stages, the primordium initiation stage and the ovary development stages were more strongly and significantly influenced by the weather parameters during all the years. Rainfall during button development stage followed by T_{max} and rainfall during the spadix emergence stage showed a significant contribution to the weather-based regression model. Future climate of Arasikere showed an increase in annual rainfall mainly during September and October but declined during November/December period. Maximum and minimum temperature showed an increase by 1-1.5^{0}C which may increase the evaporative demand and dry spell duration resulting in moisture stress thus highlighting the importance of rainwater harvesting to take advantage of increased rainfall under future climatic condition. The future climate scenario may also favour the attack of pests like eriophyid mite.

Keywords: Coconut, future climate, nut stages, yield model

Introduction

The coconut palm (*Cocos nucifera)* is a benevolent tree and nature's gift to humankind. It is an essential source of earning livelihood to the people of coconut growing states in the country. India ranks third in world coconut production and recently became the largest producer of coconut with the production of 22.17 billion nuts from about 2.09 M. ha plantations. Coconut is the second-largest and important horticultural crop of the Karnataka state, occupying 31 per cent of the total area under horticultural crop. The total area under coconut in the state is around 4.33 lakh hectares, and the annual production of coconut is 303.6 million nuts. Tumkur followed by Hassan are the largest coconut producing districts in Karnataka. Coconut is a perennial crop, and it has a prolonged reproductive phase of 44 months from the initiation of the inflorescence primordium to full maturity of the nuts. The pre-fertilization phase from the initiation of the flower primordium to emergence accounts for 32 months. Weather affects all stages of the long development cycle extending to 44 months, and thus there is likely to be extended predictability based on climate variability. Hence Coconut Development Board is undertaking an

**Corresponding Author: shripadpv@gmail.com*

annual production estimation survey in 31 major coconut growing districts of Kerala and Karnataka since 2013 to get an advance estimate of coconut production. For a given farm, when other external factors are non-limiting; rainfall, temperature and relative humidity (RH) during the months February, June, July, September and December in the year prior to the harvest are the significant factors that influence the yield (Peiris and Thattil, 1998). Location-specific predictive models to predict annual coconut yield have been developed using climatic variables alone (Nambiar *et al.*, 1969; Reynolds, 1979; Peiris *et al.*, 1995; Peiris and Thattil, 1998). Rainfall is the principal climatic variable that affects nut production (Peiris and Thattil, 1998). Karnataka state is experiencing drought consecutively from 2014. Arasikere taluk of Hassan district is frequently experiencing deficit rainfall, coupled with a decline in groundwater level. Advance knowledge of coconut production at national and regional scales is useful for planning within the industry and in this direction, attempts were being made earlier to predict coconut production using climate data such as rainfall (Abeyawardena, 1968) and later by Peiris *et al.* (2008) in Sri Lanka. Similarly, in India, attempts were made using climatic parameters (Krishnakumar, 2011). Weather-based coconut forecast model for Kerala was developed, and there is a need to develop such a model for coconut growing areas of Karnataka. Hence, an attempt was made to relate the sample survey data of Coconut Development Board with climate data of Arsikere taluk of Hassan district.

Material and methods

The yield forecasting of coconut assumes importance for framing any policy concerning production, processing, marketing and pricing of coconut. In this connection, a field survey of Arasikere taluk of Hassan district was entrusted by the Coconut Development Board, Ministry of Agriculture, Government of India, to University of Horticultural Sciences (UHS), Bagalkot, Karnataka.

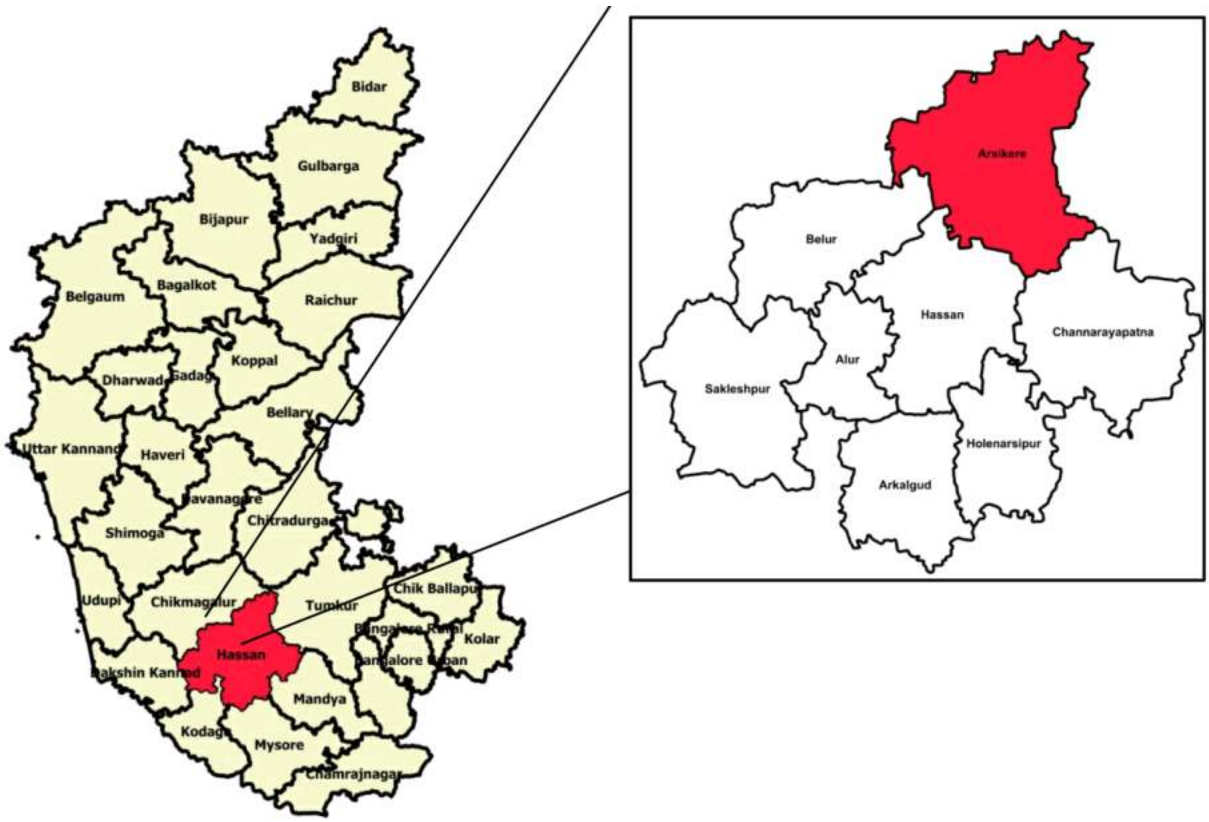

Fig. 1. Location of the study area

Table 1. Details of sampling

Taluk	Grama panchayath	Sample villages	No. of holdings	No. of palms
Arasikere	1.Jajur	Jajur	30	300
	2.Aggunda	Bommenahalli	30	300
	3.Gijihalli	Gijihalli	20	200
		Total	80	800

Study area

For the present study, Arsikere taluk of Hassan district was selected (Fig. 1). Hassan is a major coconut growing district in Karnataka state. It is divided into eight taluks, 38 hoblies and 2369 villages.

Sampling frame

Coconut is cultivated in all the taluks of Hassan district. The multistage random sampling technique was used to collect the required data from the required number of sample holdings to estimate the coconut production in the district.

In the first stage, leading taluk *viz.,* Arasikere was selected to elucidate the information on coconut production as the share of this taluk in the district coconut area was 41.9 per cent. In the second stage, three panchayats were selected. The details of the panchayath selected for the study in sample taluks are presented in Table 1. Then a total of 80 holdings were selected randomly from the three Panchayats in Arasikere taluk. Altogether 800 palms from 80 holdings were selected for collection of the nut yield data from 2014 to 2017 using the standardized schedule provided by the Coconut Development Board through personal interview method by the Field Investigators appointed for the survey work with the help of tree climbers. The geographical location of the holdings was recorded using handheld GPS.

Each year, the number of nuts of different ages (3 to 9 months) from all the 10 palms from each holding were collected with the help of trained tree climbers during December. Hobli wise weekly weather data (rainfall, temperature and RH) were collected for 2010-2017 period from Karnataka State Natural Disaster and Management Cell (KSNDMC), Bengaluru (KSNDMC, 2018). Mean nut yield per palm per year was estimated for Arsikere taluk and analyzed the significance of variation among the village and years. Using the temperature and RH data, monthly ET and vapour pressure deficit was estimated by following standard procedure (Allen *et al*., 1998). Every month primordial initiation of inflorescence takes place in the leaf axil, and it takes 16, 25, 29 and 35 months from primordial initiation to reach branch formation, ovary differentiation, spathe emergence and button stage respectively (Krishnakumar, 2011). Monthly nut yield data was correlated with weather data during the five selected nut development stages *viz.,* primordial initiation, formation of branches, ovary differentiation, spathe emergence, and button size stage and developed predictive linear regression model for Arsikere taluk. Downloaded the current (1950-2000) and future monthly climate (2100AD) data of maximum, minimum and rainfall from DIVA-GIS website (http://www.diva-gis.org/climate) and extracted for Arasikere taluk using the GPS readings of sampled holdings. All these holdings were purely rainfed, following standard

Table 2. Village wise nut yield per palm per year for 2014-2017

Taluk	Village	2014	2015	2016	2017	Village mean	SE
Arasikere	Gijihalli	20.7	43.5	69.3	35.2	42.2[a]	2.42
	Jajur	13.2	68.8	80.3	32.9	48.8[b]	2.13
	Aggunda	41.7	36.6	106.8	36.1	55.3[c]	2.17
	Mean	**25.4[a]**	**50.3[b]**	**86.5[c]**	**34.7[d]**	**49.2**	**1.73**

Values with different alphabets are significantly different

Table 3. Correlation between nut yield and rainfall

Rainfall/year	Nut yield per palm per year			
	2014	2015	2016	2017
RF 2010	-0.52	**-0.81***	-0.52	**-0.77**
RF 2011	**0.66**	**0.78**	**0.81**	0.59
RF 2012	-0.36	-0.63	-0.39	-0.62
RF 2013	**0.67**	**0.92**	0.61	**0.84**
RF 2014	-0.10	-0.52	0.16	**-0.72**
RF 2015	0.00	0.32	-0.50	0.58
RF 2016	0.12	0.51	-0.37	**0.75**

* significant at p= 0.05

cultural practices. During 2007, there was a severe incidence of eriophyid mite (*Aceria guerreronis*). Future climate projection was based on WC_CCM3 model.

Results and discussion

Nut yield variation

Mean nut yield per palm, per year in the Arasikere taluk was 49.2 with inter-annual mean nut yield among different villages showed variation with significantly lowest in 2014 (25.4 nuts per palm) followed by 2017 (34.7) and 2015 (50.3) and significantly higher in 2016 (86.5 nuts per palm) (Table 2). Among the villages, Gijihalli recorded significantly lower nut yield (42.2) followed by Jajur (48.8) and Aggunda (55.3).

The coconut palm produces mature bunch which grows through a cycle of development lasting for 44 months before it is ready for harvest. These periods are highly sensitive to major climatic factors such as rainfall, solar radiation, atmospheric relative humidity *etc*., (Rajagopal *et al*., 1996; Louis and Annappan, 1980). The effect of weather is usually reflected on the yields. The yield fluctuation between years is very complicated. When nutrients are non-limiting, the yield variation is controlled mainly by the distribution of climatic variables. The yield of the coconut can vary within the district, due to variation in the climatic factors (Vijayakumar *et al*., 1988; Nair and Unnithan, 1988). Mean maximum, and minimum temperature during 2010-2017 was 32.4 and 19.5^{0}C respectively, with an average annual rainfall of 840 mm. Annual rainfall during 2011, 2012 and 2016 was below normal compared to other years (Fig. 2). Correlation of monthly nut yield per palm with rainfall showed a significant positive correlation with the previous three to four years of rainfall (Table 3).

Because of the long duration (44 months) between the primordium initiations to nut maturity, the occurrence of a dry spell or wet spell in any

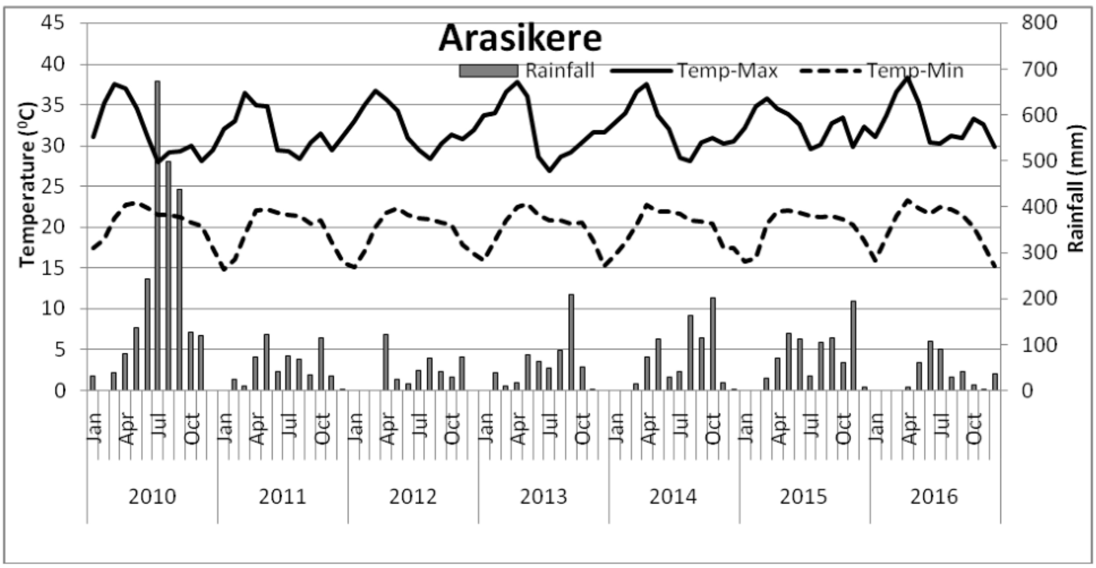

Fig. 2. Weather at Arsikere and Chanrayapatna taluk during 2010-2016

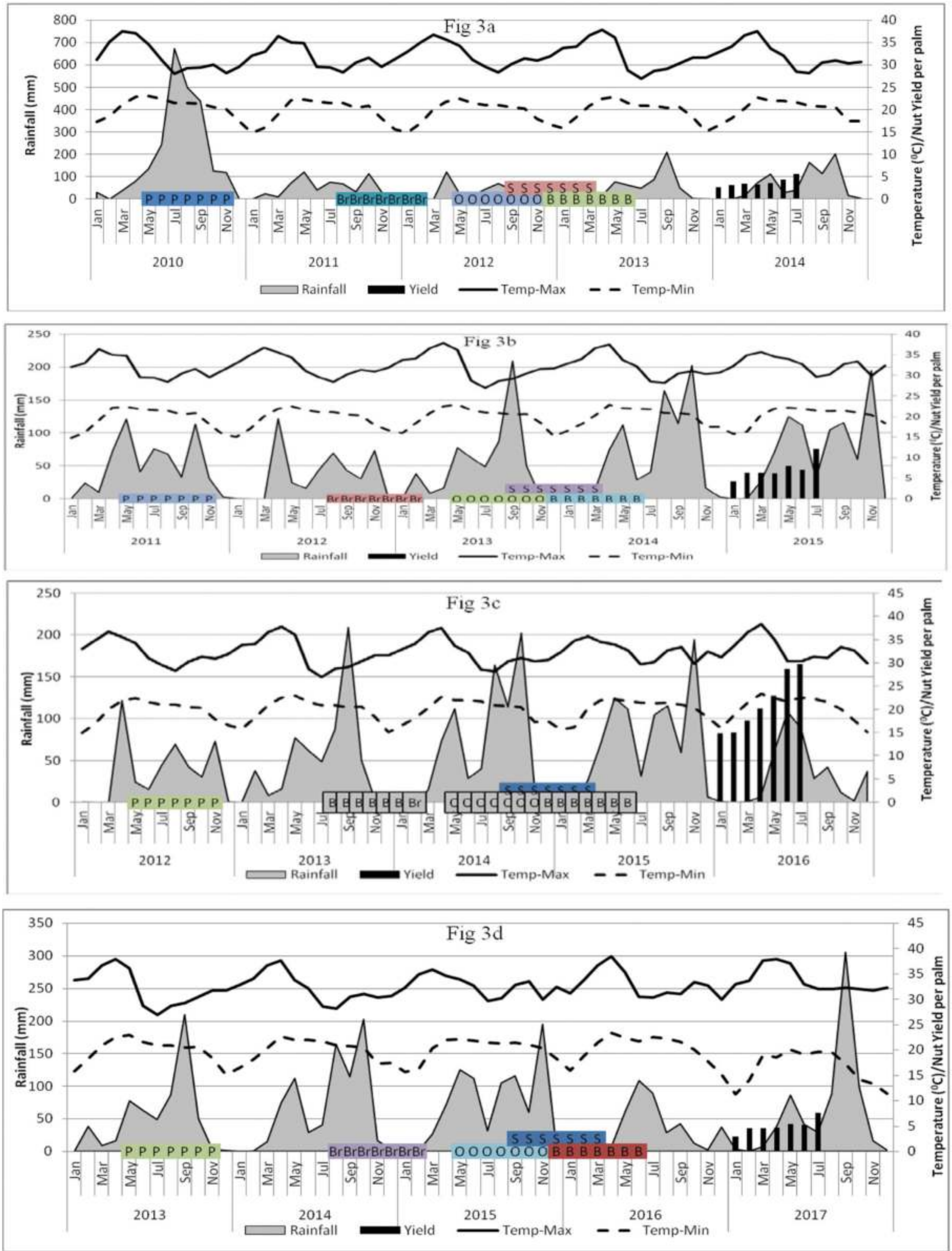

Fig. 3. Previous four years monthly rainfall, minimum and maximum temperature for 2014 (3a), 2015 (3b), 2016 (3c) and 2017(3d) nut yield per palm

Table 4. Correlation of nut yield per palm with weather parameters at different stages

Stage	Weather parameter	Years 2014	2015	2016	2017
Primordium	T_{min}	-0.31	0.21	-0.16	-0.18
	T_{max}	**0.93 ****	**0.88 ****	**0.98 ****	**0.86 ***
	VPD	**0.90 ****	**0.79 ***	**0.99 ****	**0.80 ***
	ET	**0.92 ****	**0.89 ****	**0.96 ****	**0.85 ***
	RF	-0.62	-0.51	-0.70	-0.50
Branch initiation	T_{min}	0.74	0.63	**0.89 ****	**0.77 ***
	T_{max}	-0.59	-0.59	-0.46	-0.23
	VPD	**0.81 ***	**0.77 ***	**0.97 ****	**0.82 ***
	ET	-0.44	-0.44	-0.25	-0.04
	RF	0.62	**0.78 ***	**0.95 ****	**0.79 ***
Ovary development	T_{min}	0.57	0.37	0.11	0.21
	T_{max}	**0.92 ****	**0.80 ***	**0.98 ****	**0.84 ***
	VPD	**0.81 ***	**0.77 ***	**0.97 ****	**0.82 ***
	ET	**0.94 ****	**0.82 ***	**0.99 ****	**0.80 ***
	RF	-0.32	-0.15	-0.55	-0.73
Spadix emergence	T_{min}	0.51	0.59	**0.82 ***	0.67
	T_{max}	**-0.81 ***	-0.63	-0.68	-0.40
	VPD	**-0.86 ***	-0.64	**-0.87 ***	-0.52
	ET	-0.73	-0.53	-0.53	-0.24
	RF	**0.86 ***	0.71	**0.84 ***	0.72
Button development	T_{min}	**0.98 ****	**0.89 ****	**0.95 ****	-0.46
	T_{max}	0.29	0.66	0.25	0.75
	VPD	0.49	0.75	0.49	**0.78 ***
	ET	0.45	0.75	0.51	**0.87 ***
	RF	0.54	-0.06	**-0.92 ****	**0.85 ***

season per year would affect the yield for the subsequent three to four years. In Arasikere also rainfall during consecutive two years 2010 and 2011 was low, as a result, nut yield during the year 2014 was significantly low (Fig. 1). Rainfall during 2013 and 2014 was comparatively better, resulting in significantly higher nut yield during 2016 compared to 2014. Similarly, Kumar *et al*. (2007) reported that longer dry spell affects the nut yield for the next four years to follow with stronger impact on the fourth year, irrespective of the total rainfall. Rajagopal *et al.* (1996) also observed that the nut production under rainfed condition is influenced significantly by the length of dry spells at critical stages and the dry spell during the primordium initiation, ovary development and button size is crucial for the production of nut yield.

Weather *vs.* nut development stage

Monthly nut yield per palm in different years showed significant correlation with weather data in corresponding nut development stages (Table 4). Among the different stages, the primordium initiation stage and ovary development stages were more strongly and significantly influenced by the weather parameters during all the years. The primordium of the inflorescence is reported to develop in the leaf axils about 32 months before the opening of the inflorescence and seasonal conditions during these development stages spanning 32 months do affect the nut yield (Krishnakumar, 2011). Rainfall and temperature during different nut development stages of each year and monthly nut yield is depicted in Figure 3. Primordium (P) of the nuts which came to harvest during Jan-July in 2014 were initiated during May-Nov 2010 and coincided with good rainfall, but branch initiation (Br), ovary development (O), spathe emergence (S) and button (B) stages experienced low rainfall (Fig. 3a). Because of successive low rainfall year of 2011-2013, nut development stages experienced stress resulting in low nut yield. This is reflected in nut yield showing

Table 5. Linear regression model of nut yield for Arasikere

Model	Unstandardized coefficients B	Std. Error	Standardized coefficients Beta	t	Sig.
Constant	108.98	22.24		4.90	0.000
RF_button	0.10	0.01	1.60	7.35	0.000
T_{Max}_spadix	-3.73	0.74	-0.99	-5.07	0.000
RF_spadix	0.04	0.01	0.55	4.10	0.000

Dependent variable: Nut yield

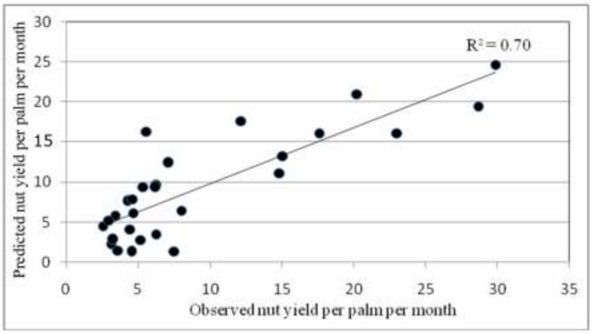

Fig. 4. Scatter plot of observed and predicted nut yield

significant negative correlation with T_{max} (0.81) and VPD (-0.86) and positively with rainfall (0.86) during spadix emergence (Table 4).

However, all the development stages of nuts which came to harvest during 2015 and 2016 experienced better rainfall and other climate parameters compared to 2014. As a result, there was an improvement in nut yield during these two years (Fig. 3b and c). It is interesting to note that even though the 2016 year annual rainfall was low, but the nut yield was better because all the nut development stages experienced better rainfall and temperature. Effect of low rainfall experienced during 2016 was observed on 2017 nut yield (Fig. 3d). Button nut development stages of 2017 nuts coincided with 2016 low summer and monsoon rainfall, and the same thing is reflected in the significant positive correlation of nut yield with rainfall (0.85), VPD (0.78) and ET (0.87) (Table 4).

Similarly, Nambiar *et al.* (1969) identified three distinct stages of nut development with active growth period coinciding with 3-7 months after fertilization and any weather aberration during this period will adversely affect the rate of growth and final size of the nut and copra content. Among the months, nut production from May to July in all the years was high compared to winter months January and February. The result was in agreement with Rao (1988) and Rao *et al*. (1993).

Yield model

Using the climatic variables as an independent factor and nut yield per palm per month as a dependent factor, a simple linear regression model was developed to predict nut yield. Details of the simple weather-based linear regression model are given in Table 5. According to the model, rainfall during button development stage followed by T_{max} and rainfall during the spadix emergence stage showed a significant contribution to the model. Actual and estimated monthly nut yield per palm using the above equations is illustrated in Figure 4. The results indicated that the actual and estimated values were in good agreement (R^2 =0.70).

Climate change

The long term (1950 to 2000) average rainfall of Arasikere taluk of Hassan district is 516.9 mm with peak rainfall during September/October months (Fig. 5). Southwest monsoon rainfall accounts for 40 per cent of annual rainfall whereas northeast monsoon accounts for 36 per cent.

Current average maximum and minimum temperature are 29.4 and 18.7^{0}C, respectively. The maximum temperature was high during March/April months. Annual maximum temperature of Arsikere is likely to be 30.4^{0}C by 2100 as against the current average of 29.4^{0}C indicating the increase by 1.0^{0}C over a century. Increase in maximum temperature was seen mainly during winter and monsoon period only. Minimum temperature also showed an increasing trend and is likely to be 20.2^{0}C by 2100 as against current minimum temperature 18.7^{0}C, indicating an increase by 1.5^{0}C over a century. Coconut palm prefers 20-32^{0}C temperature with less diurnal variation and does not tolerate extremes of temperature (TNAU, 2019). In Arsikere maximum temperature showed increase close to 35^{0}C, particularly during summer months (Fig. 5). According to yield model and Table 5, T_{max} during spadix emergence showed a significant negative correlation with nut yield. So spadix emerged during summer will face extreme weather affecting the nut development and yield. Coupled with this, long dry spell with high temperature favours Eriophyid infestation as evident from severe attack observed during 2017 due to 2016 and 2017 dry spells. Unlike maximum temperature, minimum temperature showed an increase over average in all the months. This narrowing of the difference between the maximum and minimum temperature will increase

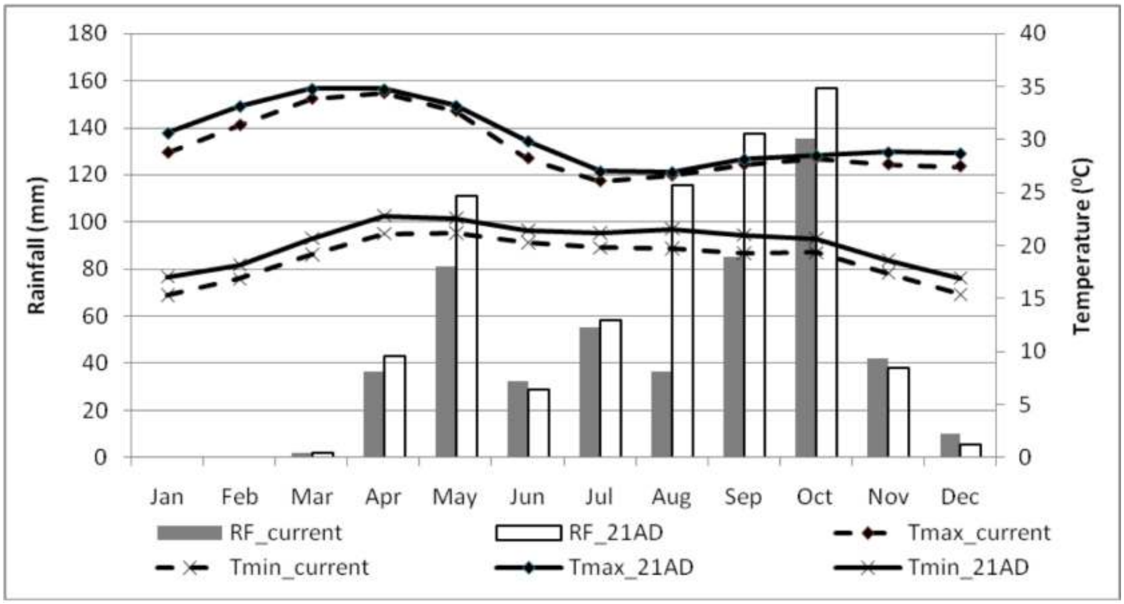

Fig. 5. Current and future climate of Arasikere

the VPD increasing evaporative demand. Annual rainfall of Arsikere is likely to be 696.3 mm by 2100, indicating the increase over average by 179.4 mm. This increase is seen mainly in the post-monsoon period, particularly August to October months and some extent during May. However, rainfall is declining during November and December resulting in the extension of the dry period. Rainfall may increase, but distribution may not be equal, thus necessitating the need for on-site rainwater harvesting and conservation. Maximum temperature, rainfall and VPD are showing significant correlation with different nut development stages, particularly primordium initiation and ovary development stages. Ideal mean annual temperature for coconut is 27^0C. In Arsikere current mean annual maximum temperature is 29.4^0C, and it is going to increase to 30.4^0C by 2100. Similarly minimum also increases from current 18.7 to 20.2^0C by 2100. So the future increase in maximum and minimum temperature is going to affect the nut yield in Arsikere taluk. As per the model, the nut yield under present climate is 27 nuts per palm per month, and same under future climate will be 28 nuts per palm per month indicating no much improvement in yield due to increase in rainfall. This may be because the benefit of increased rainfall projected during future years is nullified through increased evaporative demand, particularly during summer by the increase in maximum and minimum temperature. In future, a slight decline in rainfall during November and December is projected for 2100 (Fig. 5) resulting in a prolonged dry spell. Increased temperature and prolonged dry spell favours pest attack of eriophyid mite.

Conclusion

From the present study, it can be concluded that coconut yield at Arasikere is significantly influenced by weather during the different nut development stages spread over 32 months before the opening of the inflorescence. Year to year variation was mainly due to weather, particularly rainfall during the nut development stages mainly primordium initiation, ovary development and nut development stages. Weather-based simple linear regression model consisting of rainfall during spadix emergence and button stage and T_{max} during spadix emergence was developed and was in good agreement with observed nut yield. Future climate of Arasikere showed an increase in annual rainfall mainly during September and October but declined during November/December increasing dry spell. T_{max} as well T_{min} also showed an increase by 1-1.5^{0}C, which may increase the evaporative demand resulting in moisture stress. This stresses the importance of rainwater harvesting to take advantage of increased rainfall under future climatic condition. Future climate changes may also favour the pest attack, particularly Eriophyid mite.

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