Research Article

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Yield estimation in cocoa with partial harvest data

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Abstract

Methodology for estimation of crop production varies depending on the nature and duration of the crop. Perennial crops like cocoa, where the harvest is done throughout the year at different intervals, crop cutting experiments are laborious and time consuming. In this study, a methodology for early estimation of cocoa yield based on a few observations is proposed. A model based on observations on number of pods present on the tree during the beginning of major harvest season and after six months have been proposed to estimate the annual yield of cocoa. The accuracy of the methodology was validated using the test data. Subsequently, yield estimation of cocoa in major cocoa growing districts of Kerala and Karnataka were carried out. The effect of irrigation type, major cropping systems and age of the cocoa garden on the yield were also studied using Hierarchical linear modelling approach. The study revealed that cocoa yield in coconut based cropping system is better than any other systems.

Keywords: Cocoa, harvest data, yield estimation

Introduction

Forecasting of agricultural crops has got a crucial role in planning and policy making whereas the task is always challenging. Various approaches like production forecast based on weather variables (Agarwal *et al.,* 1980) and Bayesian approach using farmer's appraisal (Chandrahas and Rai, 2001) have been used to forecast the annual yield. Matis *et al.,* (1985) and Jain and Ramasubramaniyan (1998) in their studies employed Markov chain approach using plant characters at different growth stages to give the yield forecast before the actual harvest. Finalisation of production figures at state or national level after complete harvest and compilation of the enumerated data may take time and it might be late to make decisions. A practical approach is to estimate the production after partial harvest with a sound sampling technique instead of complete enumeration. The crop production of major crops in India is usually estimated as a product of area under the crop and the average yield per unit area of the crop wherein the estimates of the crop acreage at a district level are obtained through complete enumeration whereas the average yield is obtained through general crop estimation surveys (GCES) based on crop cutting experiments conducted on a number of randomly selected fields in a sample of villages in the district. The yield surveys are fairly extensive with plot yield data collected under a complex sampling design based on a stratified multistage random sampling (Sukhatme and Panse, 1951).

The above method is time consuming and labour intensive and requires constant monitoring in perennial crops like coconut, arecanut and cocoa. In coconut, Abeywardena (1968) and Vijaya Kumar *et al.* (1989) had developed crop forecasting formulae based on rainfall and other weather parameters. Use of these formulae is limited by the paucity of climatic information. Reynolds (1979) had suggested a methodology to get fairly accurate estimate of annual coconut production, by counting larger nuts from sampled 10 per cent of the palms in that area. Arul Raj *et al.* (1979) also tried to estimate the yield in a calendar year using characters like number of nuts above and below fist size and the number of bunches as explanatory variables.

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Jacob Mathew *et al*. (1991) developed a methodology based on the observations recorded for four years, at Kasaragod and Kayangulam in Kerala, India, on palms of ordinary tall variety, grown under rainfed conditions. Appropriate prediction equations have been proposed to estimate the annual yield of coconuts, at selected periods of the year, based on biometrical characters. Identification of suitable biometrical characters for this purpose and the best period for recording observations is also proposed in the study. In the similar line, an extensive survey for coconut production forecast was conducted during 2006 to 2008 (Muralidharan *et al*., 2013). Stratified multistage random sampling approach was employed in major coconut producing states of the country based on observations on nut at different stages of development.

Similar to coconut, cocoa (*Theobroma cacao* L.), a perennial crop, requires multiple harvests throughout the year. Cocoa, a potential commercial crop, is mostly grown as a mixed crop in arecanut, coconut and oil palm, which contributes about 2000 million rupees annually to the GDP. It is mainly cultivated in four southern states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The cocoa sector in India is in the initial stage of development, showing promise of rapid growth. At present India produces 12,954 tonnes of cocoa which is only about 40 per cent of the current demand of 30,000 tonnes (DES, 2013). Considering the market growth in the chocolate segment in India, which is about 20 per cent per annum, cocoa has a great potential to develop in future years. Kerala was the leading state in promoting cocoa cultivation and in recent years cocoa cultivation has expanded to non-traditional tracts of Karnataka and other states like Andhra Pradesh and Tamil Nadu. Considering the growing importance and commercial nature of the product, precise and quick estimates of the yield and production of cocoa and its performance in various regions are necessary for the future research and developmental activities. Moreover, it is important to evaluate the performance of the crop in different intercropping systems and agro-ecological zones so as to plan the area expansion programmes. The objectives of this study were to develop a methodology for yield estimation of cocoa well in advance with minimum observations on plant characteristics and to estimate the yield of major cocoa growing districts of Kerala and Karnataka.

Materials and methods

Cocoa crop has got two harvest seasons; a major season starting in April and second in the month of October. The fact that duration from flowering to pod maturity in cocoa is six months has also been utilised in deciding the time points for taking observation on plant and pod characters. Thus, observations on number of pods present at different growth stages were recorded twice from 120 cocoa trees, one before the beginning of the major harvest season (April) and other during the month of October. Harvest data of individual trees were also recorded to obtain the total harvest as well as partial harvest data to work out a suitable model to predict the yield tree^{-1}year^{-1}. A linear regression model was developed taking yield as the dependent variable and number of pods observed at two seasons as explanatory variables. The model developed has shown that 97 per cent of the variations in the data have been explained by the two variables and it was validated with an out of sample test data. The model was used to estimate the yield in field level survey conducted in Kerala and Karnataka.

A stratified random sampling technique was employed taking three villages each from selected districts, *viz*., Kozhikode and Kasaragod in Kerala and Dakshina Kannada in Karnataka state. Ten gardens were selected at random from each villages and randomly selected 15 trees per garden for taking observation on yield parameters. Observations on number of pods, size of mature pods and the number of cherelles present on the tree were also recorded. Proportion of bearing/non-bearing trees was also recorded from the selected garden in addition to farmers' perception on expected yield and previous year's data on total number/weight of pods. Information on pod size and data on pest and disease incidence were collected which reflect in future yield of the tree. In addition to the plant and pod characters, data on nature of irrigation followed and the extent of pruning practised in the garden were also collected.

Influence of the various factors, both operational and demographic, on the average yield from a garden was assessed employing Hierarchical

Linear modelling approach (Bryk and Raudenbush, 1992). Hierarchical models are appropriate for research designs where data is generated at more than one level. These models are alternatives to analysis of repeated measures. An essential step in estimating multilevel models is the estimation of variance components. Full and restricted maximum likelihood (REML) estimation have become the preferred method than ANOVA approaches due to their advantage of handling unbalanced data without the issues like lack of uniqueness, negative variance estimates. Since it is unbiased, REML is preferred to multiple linear regression (MLR) in small samples with balanced data.

In the present study, since the gardens were nested within the village, linear regression approach would not be appropriate. Thus, the model considered was as follows:

$$Y_{ij}=\gamma_{00}+\gamma_{01}Main + \gamma_{02}Irrig+\gamma_{03}Pruning+\gamma_{04}Age +u_{oj}+u_{ij}$$

Here, Y_{ij} is the yield corresponding to i^{th} garden in j^{th} village and the γs are the coefficients corresponding to the independent variables and u_{0j} and u_{ij} are the village specific and garden specific errors. Hierarchical model analysis was carried out using procedure mixed in SAS 9.3 (SAS, 2011).

Results and discussion

Yield estimation with partial harvest data

The farm level cocoa yield, as obtained in regular harvest throughout the year, was related with the pod numbers and number of cherelles observed on tree at two occasions (in April and October). Two years pooled data on yield characters at different growth stages are given in Table 1. Yield data on different harvests were recorded in addition to the two point observations. It was observed that about 80 percentage of the pods were harvested during May to October and only the remaining 20 percentage were harvested during November to April (Fig. 1).

Table 1. Summary of yield characters observed on two seasons (N=100)

Variables	Min	Max	Mean	SE
X_1: Pods on the tree (April)	1	141	51.2	3.0
X_2: Pods on the tree (Oct)	0	55	7.4	0.9
X_3: Cherelles on the tree (April)	0	68	9.7	1.2
X_4: Cherelles on the tree (Oct)	0	15	1.7	0.3
Y : Total Production	5	142	58.2	3.2

It was found that the annual yield data of cocoa can be predicted based on one time observation on the number of pods available on the tree during the month of April with a coefficient of determination as high as 0.84. The fitted model using the two years pooled data is as follows.

$$Y = 7.20 + 1.02\ X_1\ (R^2=0.84)$$

As the next step, the annual yield of cocoa was predicted based on the number of pods available on the tree during the month of April (before the

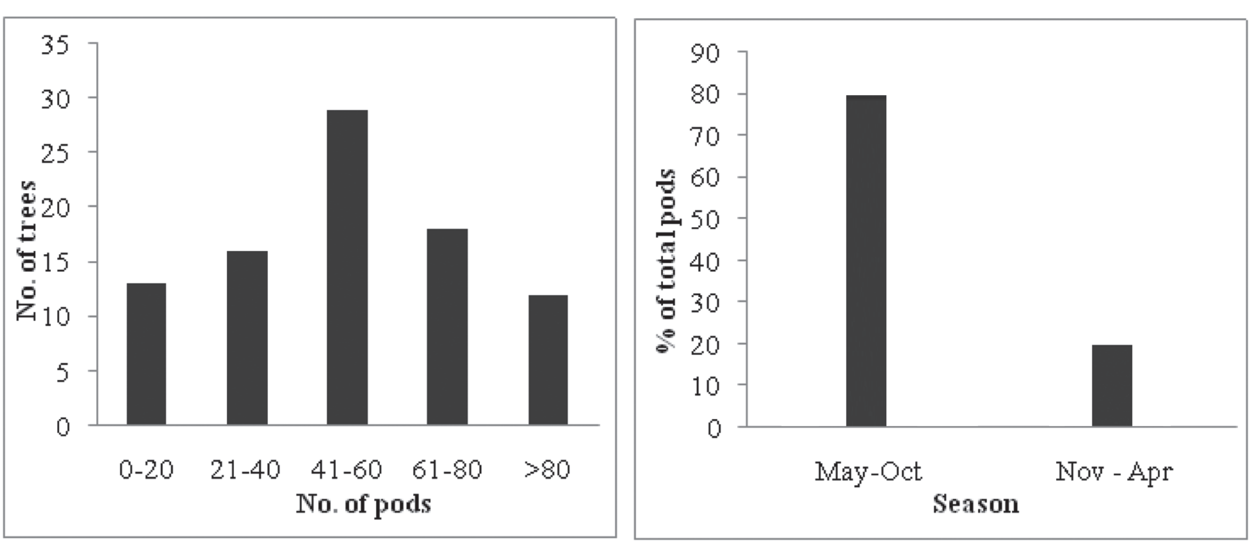

Fig. 1. Tree-wise and season-wise cocoa yield distribution in experimental field

peak harvest season) and during the month of October and found that 97 percentage variability in cocoa yield could be explained by the multiple regression model. The fitted model for predicting the annual yield of cocoa using the two year pooled data is given as:

$$Y = -0.83 + 0.95X_1 + 1.066\ X_2\ (R^2=0.97)$$

Where, Y is the number of pods per tree, X_1 and X_2 are the number of pods present in the tree during April and October respectively. The observed and predicted yield of 100 cocoa trees based on the above model is shown in the Fig. 2.

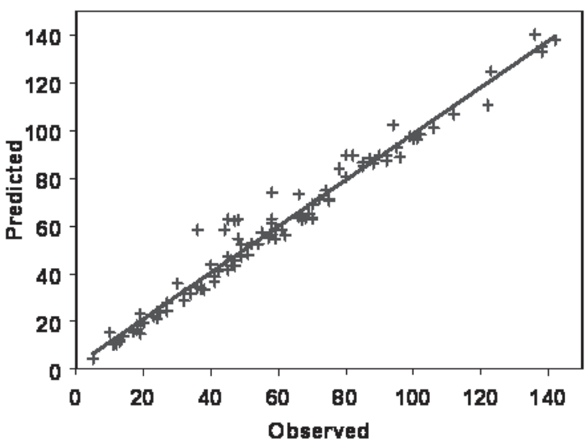

Fig. 2. Goodness of fit of multiple regression model in predicting annual cocoa yield

Validation of the model with the test data set showed that the model predicts the yield with an accuracy of 95 per cent.

Yield estimation with sample surveys in Kerala and Karnataka

Cocoa yield estimation survey was conducted in Kasaragod and Kozhikode districts of Kerala and Dakshina Kannada (DK) district of Karnataka in two phases. First round survey was conducted in April and the next in October 2012. Three villages from each district were selected randomly and 10 cocoa farmers were interviewed per village. Number of pods available on the tree were observed from 15 trees per plot thus totalling 1350 trees in three districts. A summary of cocoa production pattern in the gardens in each district is provided in Table 2. It is clear that in majority of the gardens in Kasaragod and Dakshina Kannada districts, cocoa was grown as an intercrop in arecanut whereas, in Kozhikode it was coconut based. Pruning was not practised in majority of the gardens in Kasaragod district whereas in Kozhikode, this practice was highest. Dakshina Kannada had less non-bearing gardens indicating low area expansion in the recent past.

Average pod number per tree was computed separately for each district under different cropping systems, irrigation practices and under different age groups among the observed gardens (Table 3). It was observed that pod number per tree was higher in coconut based cropping systems. Number of trees per hectare varied depending on the cropping systems and taking an average crop stand of 550, 400 and 500 for arecanut, coconut and others, respectively, yield per hectare was estimated for each district. Average dry bean yield was estimated

Table 2. District-wise summary of production pattern of cocoa (No. of households)

Production parameters		Kasaragod	Kozhikode	Dakshina Kannada
Cropping system	Arecanut	26	2	26
	Coconut	2	14	3
	Others	2	14	1
Irrigation	Drip	3	2	3
	Sprinkler	26	7	26
	Hose	1	6	1
	No	0	15	0
Age of tree	>20	14	10	3
	10-20	5	4	9
	5 -10	5	9	13
	<5	6	7	5

Table 3. Districtwise cocoa yield (number of pods tree^{-1}) in different cropping systems

	Kasaragod				Kozhikode				Dakshina Kannada			
	A	C	O	Overall	A	C	O	Overall	A	C	O	Overall
Age												
<5	31	–	32	31	36	34	36	35	29	–	–	29
5-10	26	35	–	27	34	59	48	53	31	76	39	35
10-20	39	–	40	39	–	58	62	60	38	53	–	41
>20	52	77	–	55	–	55	59	58	65	–	–	65
Irrigation												
Drip	33	35	–	33	–	–	54	54	33	77	–	47
Sprinkler	37	77	36	39	–	56	56	56	36	52	39	37
Hose	43	–	–	43	–	47	48	47	57	–	–	57
Rainfed	–	–	–	–	35	46	55	49	–	–	–	–
Pruning												
Pruned	41	35	–	40	34	38	51	45	30	76	–	36
No pruning	36	77	36	38	36	58	64	58	43	29	39	42
Yield												
Pod number tree^{-1}	37	56	36	38	35	49	54	50	36	61	39	39
Yield ha^{-1}*	617	679	545	616	583	594	818	698	600	739	591	614

*Crop stand for different cropping systems: Arecanut(A) – 550, coconut (C)– 400 and others (O) – 500.

Table 4. Estimated parameters of HLM on cocoa yield

Effect	Coefficient	SE	df	Probability
γ_{00}	26.4509	6.4773	41.6	0.0002
γ_{01}	-12.2060	4.2101	62.1	0.0052
γ_{02}	8.5054	4.7443	74.1	0.0471
γ_{03}	4.0463	3.1079	83.0	0.1965
γ_{04}	1.1628	0.1779	78.3	<.0001

as 616,698 and 614 kg ha^{-1} for Kasaragod, Kozhikode and Dakshina Kannada districts, respectively.

As the pairwise cross tabulation has got the influence of other factors, simultaneous estimation of individual effect was attempted. Variation in pod yield at village level were analysed and the between village variance was modelled using hierarchical linear model (HLM).The variables main crop, age of the tree and sprinkler irrigation were found out to be significantly influencing the yield of cocoa gardens. The coefficients indicate that gardens with coconut as main crop had on an average 12 pods more than arecanut based gardens. Similarly, sprinkler irrigated plots had 9 pods more than the plots without irrigation.

Conclusion

The proposed method suggests undertaking field surveys for observations on number of pods per tree on two occasions, one at the beginning of major season and the other after six months. This certainly reduces the laborious task of observing the tagged trees on various time points and completely enumerating the tree, wherein the magnitude of non-sampling error could be very high. Moreover, the survey work conducted in different districts of two major states of cocoa production shows that the cropping systems, age of the garden and irrigation system followed have got impact on the yield, which also has to be accommodated while giving estimates at district level. Impact of disease and pests on yield and size of the pod also were utilised in estimating the dry bean yield in addition to the crop stand in the garden. An accurate information on proportion of harvested yield in the first season to the total would help to even reduce the number of observations to be made to one in case of limited resources for an extensive survey.

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