Use of OMP for accurate crop forecasts

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Summary

A short-term crop forecast for the next four months based on black bunch counts (BBC) provides the means to plan field operations, check for crop losses and possible theft, and estimate oil available for future sales. The OMP suite includes two add-in tools (OMP Field Survey and OMP-BBC) that provide the means for verifiable BBC data collection and data processing. Crop forecasts can be easily prepared based on historical bunch weights and customizable calculation settings, while retrospective analysis allows the user to monitor and assess the accuracy of past forecasts. In this way, a disciplined approach to crop forecasting can be implemented that provides accuracy of ±10% with low labour requirements for field work.

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1. Introduction

The oil palm produces fruit bunches throughout the year. Where there are no water deficits, and good agronomic practices are maintained continuously, crop production is rather evenly-distributed through the year. Where there are significant and seasonal water deficits and changes to agronomic management, however, fluctuations in bunch number (bunches/ha/month) and bunch weight (kg/bunch) during the year can be expected. Pollinated flowers develop into black bunches about one month after anthesis and black bunches ripen over the period 1–4 months after anthesis. Thus, at any one time, palms carry a number of black bunches that will be harvested over the following four months. This fact can be used for short-term crop forecasting using the so-called 'Ulu Bernam' method first described by Loh and Sharma (1999).

A crop forecast based on black bunch counts provides useful information on expected crop that can be used to plan field and mill operations and, by retrospective analysis, to identify bunch loss by comparing the number of bunches forecasted with actual bunch production. Despite these potential advantages, BBC crop forecasts remain a contentious topic among oil palm managers due to the labour required and problems with forecast accuracy.

In OMP Field Survey and OMP-BBC, the OMP suite includes two modules that can help to minimize these problems and support the implementation of an efficient, accurate and verifiable black bunch count forecasting scheme. In this article, we provide a description of the software, illustrated with actual data from a large plantation of 10,000 ha. In particular, we explain in detail how the different assumptions and inputs that can be controlled in the OMP-BBC module can be used to produce the crop forecast.

2. Theory of BBC forecasting

The basic principle of the 'Ulu Bernam' BBC forecasting method is very simple and can be summarized by the following formula:

$$t_1 = \frac{b \times w_n \times p \times f_n \times l}{1000}$$

where

t_n is the output in tonnes in month n after the black bunch count.

$n = 1,\ldots,4$ specifies the number of months after the black bunch count was carried out.

b is the black bunch count in black bunches per palm.

w_n is the expected bunch weight in month n after the count.

p is the number of palms in the block under consideration.

f_n is the fraction of the black bunches that are expected to be ripe n months after the count.

l is a bunch loss factor to account for possible losses between field and mill.

Clearly, to achieve a high forecast accuracy we must strive to minimize errors in each of the five factors in the formula, which will be individually discussed below.

The quest for high accuracy must be balanced against the cost of creating the forecast. With OMP-BBC the calculation process and the evaluation of historical data for the majority of the factors in the forecast formula is very simple. This leaves the labour cost associated with carrying out the actual black bunch counts in the field as the only significant cost factor. To optimize the relationship between accuracy and cost, a sampling system is typically used whereby the count is not carried out at every palm in every block. Instead, typically a representative subset of blocks is selected as survey blocks and within these blocks the count is carried out in a subset of the rows. As we will see below, a system of sampling every 20th row in one fifth of the blocks for an overall sampling rate of 1% can be sufficient to achieve satisfactory accuracy.

3. Materials and methods

We will now explain how OMP-BBC add-in can be used in the BBC process. The field practices for black bunch counting (BBC) are described and illustrated in detail in the TCCL Oil Palm Handbooks (Fairhurst et al., 2019).

3.1. Selection of survey blocks

The first step is to organize all blocks in groups of five that are sufficiently homogeneous that a single survey block can be nominated to represent the other four blocks. The OMP-BBC add-in provides the means to do this in a systematic and controlled way and based on data contained in OMP (e.g. soil type, planting material, topography, palm age) (Figure 1).

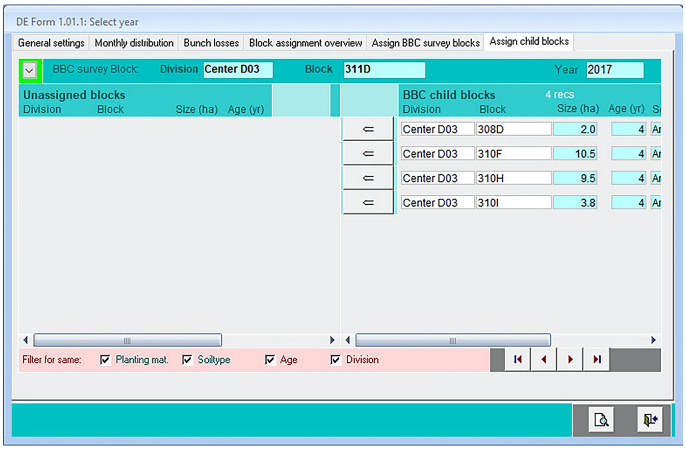

Figure 1. OMP-BBC add-in provides a tool to assist the user to select survey blocks and then allocate child blocks similar in palm age, soil type and planting material to produce BBC block families each comprising a survey block and four child blocks. In this example four blocks, all the same age as the survey block, have been allocated as child blocks of the survey block 311D.

The assignment of child blocks to survey blocks can be reviewed regularly by looking at the difference between the forecasted bunches per palm and the actual bunches harvested in the four months after the survey was carried out (see section 5 for more details). In particular, if this difference is small in survey blocks but large in child blocks, then it may be necessary to alter the assignment of child blocks to survey blocks or even to increase the sampling rate and survey in more blocks.

3.2. Black bunch count (*b*)

A monthly black bunch count is carried out on all palms in every 20th palm row (5% of palms) in the survey blocks (20% of blocks), to give an overall sample of 1% of all palms. Survey blocks and survey palm rows should be clearly labelled to avoid any confusion in the field and to ensure that the same palms are counted at each BBC. Proper pruning standards are essential to ensure that the black bunches are clearly visible to the surveyor. One trained surveyor can carry out a BBC in a 30 ha block in one day. Assuming a survey-child block system where one block in five is surveyed each month, this means the effective labour requirement for carrying out a monthly BBC forecast is trivial at about 0.08 md/ha/year.

In order to avoid any confusion between ripe bunches and black bunches (Photo 1), the black bunch count is carried out after the last harvest each month in each surveyed block.

Photo 1. Five fruit bunch development stages can be identified from pre anthesis (a), post anthesis (b), clove bunch (c),coffee bunch (d) and black bunch (e). Only black bunches are counted during a BBC.

The surveyor simply counts the number of black bunches on each survey palm. In a division of 1,000 ha or 30 blocks, it will be necessary to survey six blocks in the last ten days of the month. This work can easily be accomplished by one worker over the ten day period.

Some companies carry out BBC counts once a quarter to produce four crop forecasts but, since BBC is a trivial cost, we recommend carry out a BBC each month in order to monitor closely the dynamics of bunch production and to assess possible losses.

Table 1. *Labour requirements depend on the frequency of BBC and the block and row sampling system.*

Frequency	Sampling		Labour requirement*
	Rows	Blocks	md/ha/year**
Monthly	All	All	0.400
		1 in 5	0.080
	1 in 20	All	0.020
		1 in 5	0.004
Quarterly	All	All	0.133
		1 in 5	0.027
	1 in 20	All	0.007
		1 in 5	0.001

* Assuming one worker can complete counts in 30 ha/day.
** For whole estate.

OMP-BBC and OMP-FS provide the means to check that labelled sampling rows were visited by the surveyor and make it very easy to assess BBC accuracy retrospectively. We recommend marking the BBC palm rows with a QR code label that can be scanned by the OMP-FS app to verify that the surveyor has visited the correct palms and rows. This greatly helps to improve BBC accuracy as surveyors become aware that they can be held accountable for the accuracy of BBC results.

Black bunch count data (i.e. survey date, number of palms surveyed, and the total number of black bunches counted in each survey block) is either imported into OMP from the OMP-FS app or entered manually in OMP. In all subsequent calculations, OMP uses the BBC for survey blocks for the respective child blocks that have been assigned.

3.3. Average bunch weight (w_n)

The second factor required to calculate the crop forecast is the bunch weight factor, w_n. The latest OMP version (10.0) supports three different methods for estimating future bunch weights (Figure 2).

- Option 1: Historical average w_n by palm age.
- Option 2: w_n from previous month by block, with fixed monthly wn increment.
- Option 3: w_n from previous month by block, with growth rate determined by land class, palm age and month.

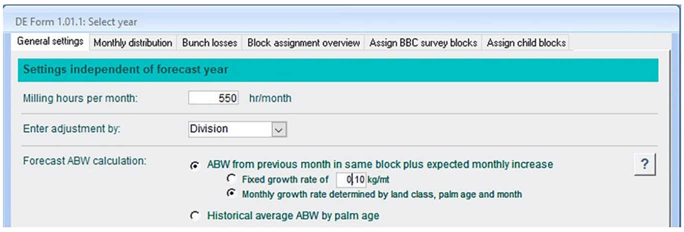

Figure 2. *OMP includes three options for estimating future bunch weights.*

We will now review each of these options and highlight their respective advantages and disadvantages.

3.3.1 Option 1

With this calculation method (used in OMP 9.3), OMP looks up the palm age in the month of the black bunch count for each block and uses the historical average bunch weight (ABW) for that palm age as the bunch weight for the forecast. All blocks with the same palm age in the survey month therefore use the same bunch weight during the forecast, and the values for w_n are the same for all four months of the forecast period (i.e. n = 1,…,4). The advantage of this method is that it takes into account a large pool of historical data and is thus not sensitive to data entry mistakes or short term fluctuations in data. The disadvantage is that the average being calculated over all blocks and all years in the OMP database may mean that the predictions are distorted by old data. Furthermore, predicted production for the same months can change even without editing any of the BBC data explicitly, as the ABW averages are changed by new production data as time goes on. This can be slightly confusing as printing the same BBC forecast report at different times can lead to different forecast amounts.

3.3.2 Options 2 and 3

These two options, grouped together in Figure 3 under ‘ABW from previous month from same block plus expected monthly increase’, do not rely on averages over many blocks. Instead, for each block OMP looks up the actual ABW for that specific block in the month before the census (month x-1). ABW typically increases over time as palms get older, the forecast ABW for months x+1 to x+4 is then calculated by adding the expected monthly ABW increase on to the previous month’s value.

Options 2 and 3 differ in how the monthly increase in ABW between month x-1 and months x+1 to x+4 is calculated:

With Option 2, a fixed monthly increment is entered directly in the crop forecast settings page. The advantage of this choice is its simplicity, however it does not account for any seasonality or spatial variation in the plantation.

With Option 3, the expected monthly increase is based on the expected ABW profile by palm age, modulated by the expected monthly ABW growth rate entered by land class in the OMP-DBMS picker definitions. This option allows for more detailed modelling if there is strong seasonality in ABW growth rates or large differences between different land classes. It is also possible to account for cases where the bunch weight *decreases* in some months even though an annual increase in ABW is expected.

The main advantage of the new calculation Options 2 and 3 compared to Option 1 is that the ABW is always based on the most recent actual ABW data in each block, so that calculations are not distorted by old data or by other data from blocks in other and completely different parts of the estate. The main disadvantage is that it is susceptible to outliers, so a mistake in calculating the ABW in a single month in one block can distort the respective block's production forecast.

3.4. Palm stand and census (*p*)

In OMP-BBC, the palm stand *p* in Formula 1 is taken from the underlying OMP block data set and thus does not require any additional data entry. Nevertheless, it is obvious that an accurate palm count in each block is a requirement for an accurate BBC crop forecast. Calculations can be performed in two different ways depending on the OMP system settings:

- Based on the number of mature palms in the block, in which case BBC is only performed on mature palms.
- Based on the number of 'normal palms' (i.e. newly planted, immature and mature) in which case BBC is performed on all normal palms.

3.5. Crop distribution (f_n)

The distribution fractions, f_n, are input parameters that have to be specified in OMP-BBC. If the estate already has historical production data in OMP, the distribution fractions can be based on historical monthly distribution data. This distribution can be automatically copied and used in OMP-BBC (Figure 3).

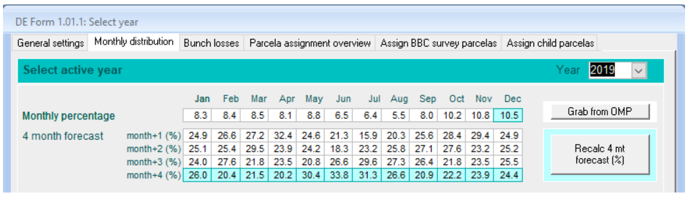

Figure 3. *Form for specifying distribution of 4-month forecast.*

While the distribution calculated from the historical monthly spread is generally a good starting point, it is recommended that the distribution is reviewed regularly in order to achieve greater accuracy. In particular, it might be worthwhile to adjust the distribution to account for changing plantation age profile or specific climatic factors, such as an extended drought in the past.

To avoid errors with the monthly distribution, it may make sense to look at a total forecast for production in the next four months rather than an individual month's forecast. For this reason, OMP-BBC contains a number of forms and reports that show the 4-month forecasted bunches and output.

3.6. Losses (*l*)

The default assumption and the aim of every plantation should be to ensure that all black bunches that are identified in the field will be harvested and brought to the mill in the next four months. However, in some cases losses can occur due to transportation issues, rotting of bunches left for too long at the side of the road etc. If significant bunch losses are expected, the forecast can be adjusted to account for expected losses by using the bunch loss rate setting *l* in Formula 1 to reduce the number of bunches accordingly. As the loss rates might be different in different parts of the estate and may change over time, OMP 10.0 allows you to enter different bunch loss rates by division and year (Figure 4). It should be emphasized however, that entering a non-zero loss rate to get a more accurate current forecast should not imply acceptance of lowered standards and that the goal for field management must still be to lower this loss rate to zero as soon as possible.

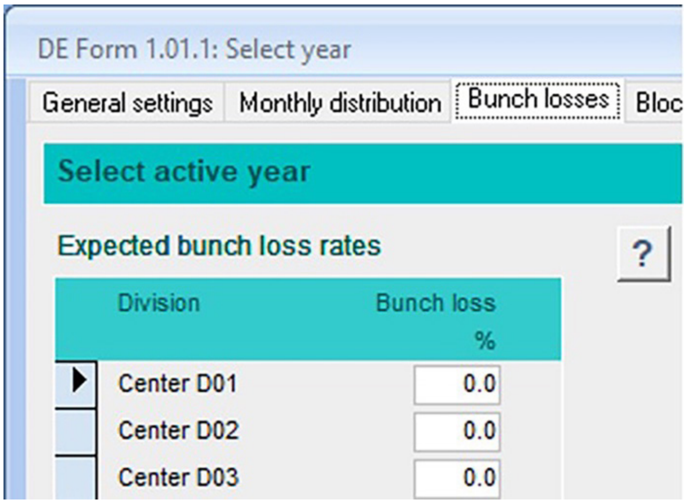

Figure 4. *Bunch loss rate entry form in OMP-BBC 10.0, in this case no losses are expected.*

4. Adjusted production forecast

As we will see, the production forecast calculated by OMP-BBC using the various settings described above can reach a high level of accuracy. Despite this, it is strongly recommended that field managers regularly review and adjust the forecast to account for other factors that they may expect to impact the upcoming production. For example, this might include availability of harvesters, current weather conditions and weather forecasts, and pest or disease outbreaks. To account for this, OMP-BBC allows managers to enter an *adjusted* forecast output value at division or field level, together with explanations on the reasons for the adjustment. We recommend that a review of the calculated forecast and suggested adjustments become part of the crop forecast routine. This helps to minimize the potential for unrealistic forecasts due to outliers or data entry mistakes, but also means that the field management cannot blame OMP for an unrealistic forecast.

5. Results of the crop forecast

To illustrate the effects of different forecast options, we look at real forecast data from a plantation that uses OMP-BBC. The plantation in question has an area of about 10,000 ha and predominantly young palms between 4 and 7 years after planting in the time period under consideration. This real-life data shows that it is indeed possible to achieve a high level of accuracy when a black bunch count forecasting system is correctly carried out.

The most basic forecast quantity we can consider is the 4-month bunch forecast (Figure 6a). This quantity depends on the fewest assumptions as does not rely on either the monthly fractions f_n nor the bunch weights wn in Formula 1. Indeed, Figure 6a shows a very close relationship between forecast and actual.

Next let us consider the monthly bunch forecast (Figure 6b). Whilst the discrepancy between forecast and actual value is much larger, the graph suggests that this may be more due to high month-on-month fluctuations in the actual bunch harvest rather than the forecast.

The four-month production forecast (Figure 6c), depends on the bunch weight as well as bunch counts but does not take into account monthly distribution fractions. To show the effects of the different calculation settings, we have included the raw production forecast with two of possible settings for the average bunch weight calculation outlined above (Options 1 and 2). We also include the adjusted forecast prepared by the field manager. In general, all three forecast values are quite close to actual production, but each forecast calculation method has time periods where it is relatively more or less accurate than the others.

To assess the different forecast methods in more detail, we can calculate the average of the difference between forecast and actual as a percentage (Table 2). As a more stringent measure of the forecast accuracy we also consider the average of the absolute value of this difference. In this instance, the manager's adjusted forecast indeed achieved the overall greatest accuracy, whereas both raw forecast calculation methods were relatively similar in their overall accuracy (Table 1).

Table 2. *Forecast versus actual for 4-month output.*

Forecast method	Average difference (%)	Average absolute difference (%)
Raw, ABW by palm age	- 9.2	11.4
Raw, ABW by block	- 8.0	13.7
Adjusted	5.2	9.4

Finally, we consider the highest level of detail, namely the monthly production forecast. Again we compare raw forecasts with both ABW calculation methods, the adjusted forecast, and the actual production. There is a very good general forecast accuracy for all forecast methods, with only the adjusted forecast for months 9 and 10 appearing significantly too high (Figure 6d).

The averaged difference and absolute difference for each forecast method is shown in Table 3. While the raw forecast with the ABW by block calculation method provides the greatest accuracy in this instance, all three forecast methods were again broadly similar in terms of their overall accuracy. However, the larger positive value of the average difference shows that the manager's adjustment tended to systematically overestimate the output whereas the raw forecasts fluctuated more randomly, being above or below the actual output in different months.

Table 3. *Forecast versus actual for monthly output.*

Forecast method	Average difference (%)	Average absolute difference (%)
Raw, ABW by palm age	-2.3	14.9
Raw, ABW by block	- 1.8	12.0
Adjusted	11.1	15.6

A key feature of OMP BBC are the tools for retrospective analysis. First, it is easy to check the accuracy of individual BBC counts by comparing actual with forecast BBC at block level (Figure 6, Figure 7). In this example, the accuracy of survey blocks is good but there are significant errors in the child blocks, which may indicate that the survey block groups are insufficiently homogeneous. Second, each completed crop forecast can be compared with actual production at estate level (Figure 8). Such comparisons both at block and estate level would be extremely tedious to calculate with spreadsheets.

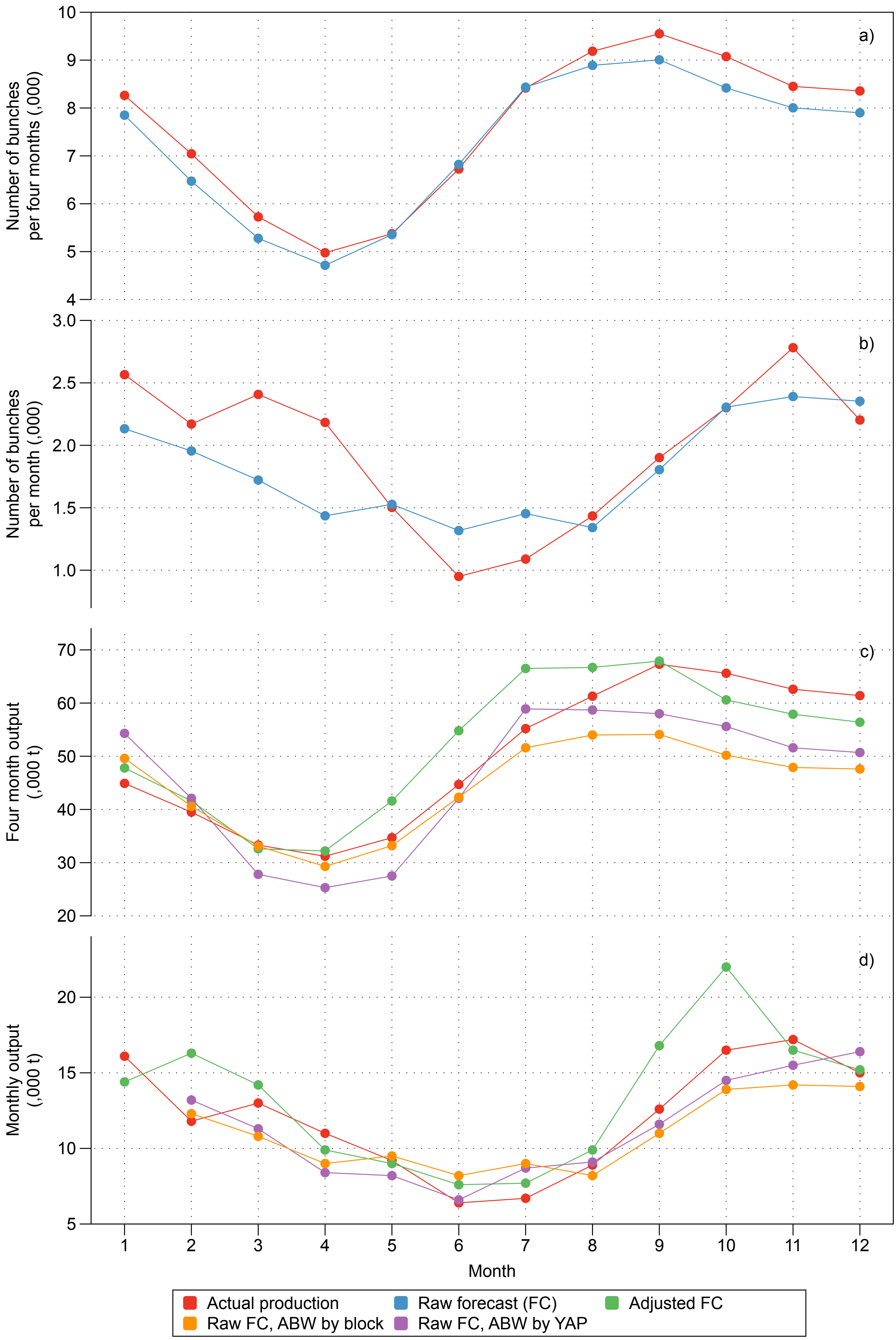

Figure 5. *Four month bunch forecast (a), one month bunch forecast (b), four month production forecast (c) and one month production forecast (d).*

OMP *OCHO SUR* *Report 0.0* *printed:* *12-Oct-20*

BBC vs actual bunches/palm

Year: 2019

Filtered by: Survey parcela only

Plantacion	Parcela		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			Bunches/palm in next 4 months											
OSP_I	E05c	Forecast	4.6	4.7	3.8	4.1	5.0	5.7	5.8	4.4	3.9	3.6	4.1	4.1
BBC status: survey parcela		Actual	4.4	4.7	3.5	3.8	4.8	5.8	5.9	4.2	4.0	3.4	4.0	4.2
		Different	0.2	0.1	0.3	0.3	0.2	-	-0.1	0.1	-0.1	0.2	0.1	-0.1
	F03c	Forecast	3.8	2.9	1.9	1.5	2.1	3.8	4.7	5.2	4.6	3.2	3.6	4.0
BBC status: survey parcela		Actual	3.6	2.9	1.7	1.3	1.8	3.6	4.4	5.0	4.5	3.2	3.5	3.9
		Different	0.3	-	0.2	0.2	0.2	0.2	0.2	0.2	0.1	-	0.1	0.2
	F04b	Forecast	3.8	3.2	2.3	3.3	5.6	8.1	8.8	7.8	5.4	3.1	2.9	3.6
BBC status: survey parcela		Actual	3.5	3.1	2.3	3.0	5.4	8.3	8.9	8.0	5.6	3.2	2.7	3.9
		Different	0.2	0.1	-	0.3	0.2	-0.2	-0.1	-0.2	-0.2	-	0.2	-0.3
	F05b	Forecast	4.5	2.6	2.0	1.4	1.5	2.0	3.2	4.6	5.8	5.8	6.4	7.3
BBC status: survey parcela		Actual	4.3	2.5	1.7	1.4	1.3	1.8	3.4	4.7	6.0	5.6	6.3	7.5
		Different	0.2	0.1	0.3	-	0.2	0.2	-0.2	-0.1	-0.2	0.2	0.1	-0.1
	F06b	Forecast	8.2	6.0	3.6	2.2	1.7	1.9	2.1	2.4	3.3	3.8	5.5	4.8
BBC status: survey parcela		Actual	8.4	6.1	3.8	1.9	1.5	1.8	2.1	2.4	3.5	3.8	5.5	4.9
		Different	-0.3	-0.1	-0.2	0.3	0.2	0.1	-	-0.1	-0.2	-	-0.1	-0.1
	G03b	Forecast	2.3	1.3	1.4	2.1	4.3	6.5	7.7	7.6	5.0	2.6	1.4	1.1
BBC status: survey parcela		Actual	2.1	1.4	1.1	1.8	4.3	6.7	7.9	7.7	5.2	2.8	1.4	0.9
		Different	0.2	-0.1	0.2	0.3	-	-0.1	-0.1	-	-0.1	-0.2	-	0.1
	G03c	Forecast	2.8	1.9	1.6	2.2	4.2	7.0	7.8	7.4	5.3	2.5	1.5	1.6
BBC status: survey parcela		Actual	2.6	1.9	1.4	2.0	4.0	7.1	8.0	7.6	5.5	2.5	1.6	1.8
		Different	0.3	-	0.1	0.2	0.2	-0.1	-0.2	-0.1	-0.2	-	-	-0.2

Figure 6. *Comparison between actual and BBC forecast for 4-month bunches at block level can be made as soon as the crop forecast period has elapsed. In this example, the level of accuracy in survey blocks is very good suggesting that counting and crop recovery are satisfactory.*

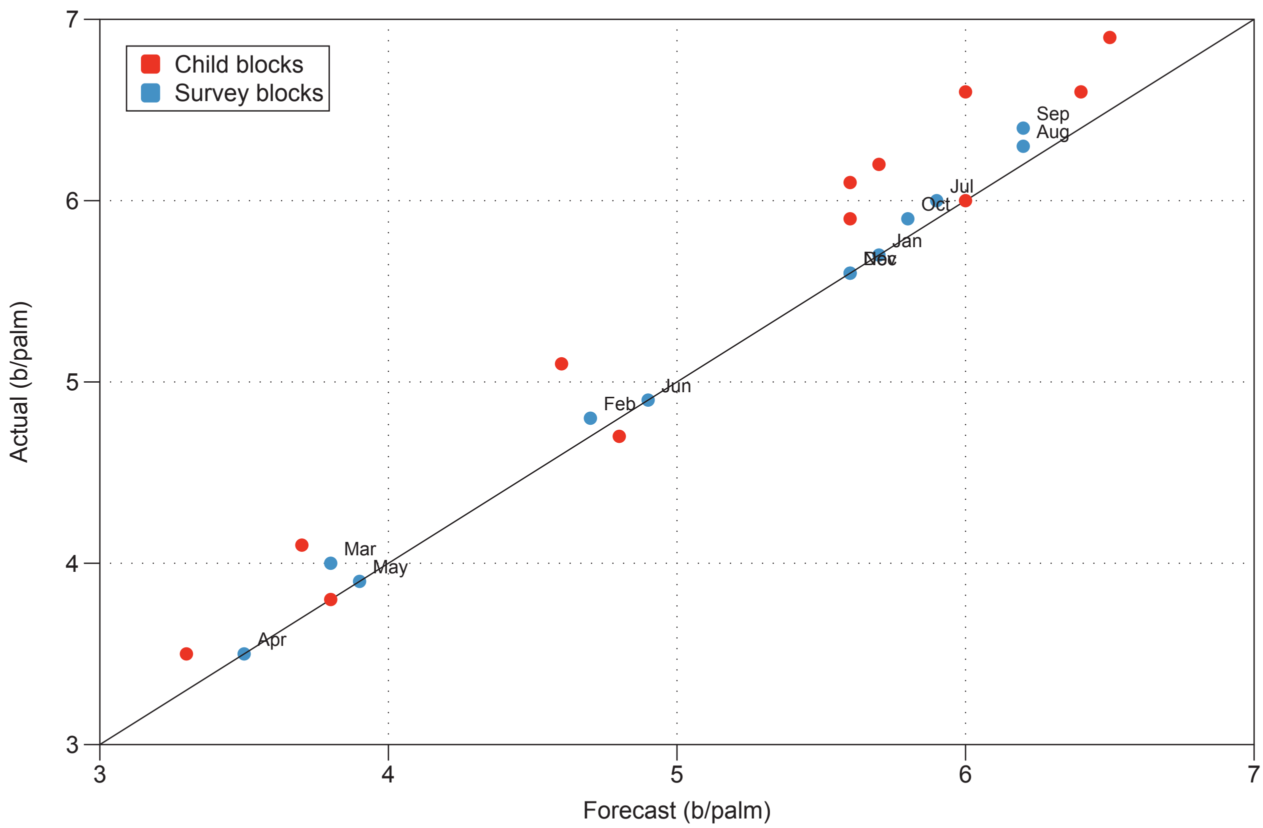

Figure 7. *Comparison of 4-month forecast and actual bunch number for survey and child blocks over 12 months in 2019.*

OMP Ocho Sur — Report 4.07 printed: 12-Oct-20

Crop forecast variance report

Year: 2019

No filter active.

		Output [t]				
		Feb	Mar	Apr	May	4-month total
January	Adjusted forecast	16,337	14,286	8,252	8,938	47,814
	Actual	11,785	12,954	10,958	9,186	44,883
	Budget	12,492	12,654	6,489	4,867	36,503
	Potential	15,553	15,738	14,972	16,294	62,557
	Forecast vs actual [%]	139	110	75	97	107
	Forecast vs budget [%]	131	113	127	184	131
		Mar	Apr	May	Jun	4-month total
February	Adjusted forecast	14,234	10,426	8,886	8,014	41,560
	Actual	12,954	10,958	9,186	6,425	39,522
	Budget	12,654	6,489	4,867	4,867	28,878
	Potential	15,738	14,972	16,294	12,035	59,039
	Forecast vs actual [%]	110	95	97	125	105
	Forecast vs budget [%]	112	161	183	165	144
		Apr	May	Jun	Jul	4-month total
March	Adjusted forecast	9,859	9,116	6,942	6,689	32,606
	Actual	10,958	9,186	6,425	6,717	33,285
	Budget	6,489	4,867	4,867	9,734	25,958
	Potential	14,972	16,294	12,035	11,850	55,150
	Forecast vs actual [%]	90	99	108	100	98
	Forecast vs budget [%]	152	187	143	69	126

Figure 8. *Variance report for an estate provides analysis of each crop forecast period. In this example, variance is less than 7% in all months.*

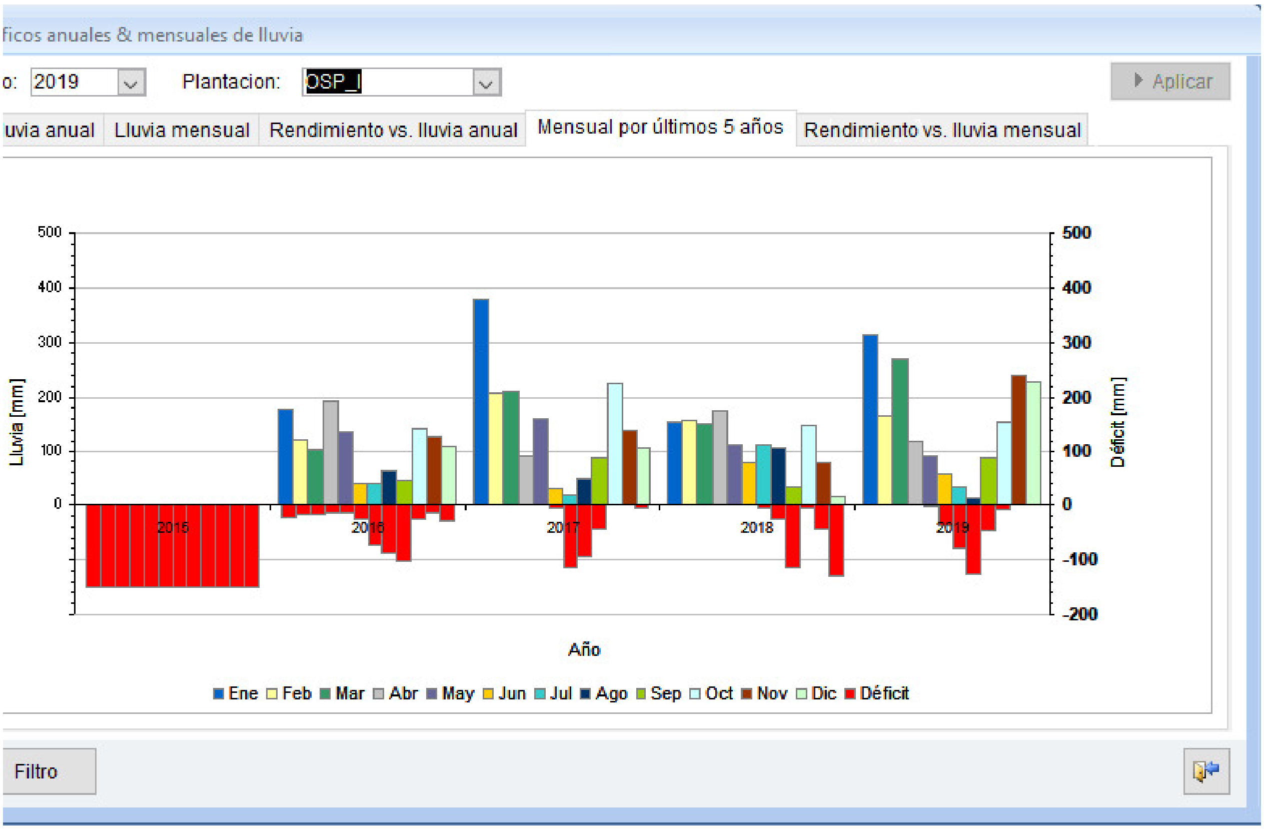

Figure 9. *OMP calculates monthly water deficits (based on the method of Surre, 1968). Monthly fluctuations in bunch number, bunch weight and yield are often related to past droughts with time lags of 12–24 months.*

6. Effect of past water deficits

Periods with a significant water deficit may result in a change in sex ratio (affecting bunch production after 24 months) and abortion (affecting production after 12 months). Regular seasonal patterns of water deficits are automatically taken into account by the distribution fractions where the function to base the monthly distributions on the historical OMP crop distribution has been selected. The historical yield distribution might be distorted, however, if the plantation is mainly in the steep ascent yield phase (SAYP)as is the case in the data set used here.

OMP calculates monthly water deficits based on rainfall data and provides the means to record tensiometer readings (used to assess soil moisture availability). Thus, a relationship between present production and past water deficits may be evident (Figure 9). Once patterns have been identified, it may also be possible to predict future periods of low production.

7. Conclusions

We have shown that by collecting very basic data on black bunch counts from a small sample area within the estate that it is possible to produce accurate four-month and monthly crop forecasts using OMP-BBC. OMP-BBC contains a range of settings and options to help the user customize the way the forecast is calculated. The data set in this article illustrates that neither of the two ABW calculation options used is inherently more accurate than the other – and in fact even the adjusted forecast is not necessarily always more accurate than the raw forecast. We recommend that users evaluate different methods to find the options that work best at each location.

We have shown that a sampling system (i.e., one survey block in each family of five blocks, 1 row in 20 in survey blocks), producing a 1% sample is sufficient to produce an accurate but low-cost crop forecast. A key aspect of the OMP-BBC system is its capability to make field work accountable, to eliminate the calculation errors that tend to creep into spreadsheet calculations, and to provide retrospective analysis of each forecast period so that management are motivated to continuously improve the process.

8. References

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9. Acknowledgements

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