Hort Innovation

Final Report

Macadamia Crop Forecasting 2015-2018

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Delivery partner:

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Macadamia Crop Forecasting 2015-2018 – MC15009

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Content

Summary

Since the year 2001, this project and its predecessors have produced annual macadamia crop forecasts for the industry. To produce these forecasts, the predicted effects of the past year's climate and other influences are incorporated with expected yields based on an industry census. Additionally, longer-term forecasts (10 to 15 years out) based on this census and estimated new plantings, assuming average climate conditions, are also produced each year.

Over the three testable forecasts of this particular project (2016, 2017 and 2018), the overall average error rate for the crop forecasts was 8.0%. This value was heavily influenced by the 20.2% over-prediction for the 2017 crop, which was severely affected by the destructive winds and flooding from Cyclone Debbie. The error rate for the other two years averaged 1.9%. Still, the overall mean error is quite comparable to similar regional or national forecasting projects around the globe.

These crop forecasts are used in the industry for logistics, future planning and export scheduling. They also assist in lowering the perceived lack of uncertainty in supply that can cause price discounting, and hence help stabilize prices.

Keywords

Macadamia, crop forecast, climate influences, ensemble models, industry planning

Introduction

The Australian macadamia industry continues to expand as new plantings of trees come into bearing ages. To strategically plan for expansion in the domestic and export markets, both annual and longer-term crop forecasts are required. The annual forecasts are required by the industry in mid-February each year. They assist with market stability, by reducing the degree of price discounting that is associated with uncertainty about supply amounts.

These crop forecasts have now been provided to the key industry body (the Australian Macadamia Society) since 2001, from this project and its predecessors. During this period, the underlying databases of tree numbers and historical production amounts, and the statistical forecasting methods, have been continually revised and improved. Overall, this project's crop forecasts (2016 to 2019[1]) have returned to the levels of accuracy required by the industry, allowing the necessary planning to proceed accordingly.

[1] Note that a project variation approved by Hort Innovation extended the forecasting term of this project to deliver a fourth and final crop forecast for the 2019 year.

Methodology

The crop forecasting process is based on combining two main components, namely the census-based forecasting model (for the longer-term forecasts) and the climate-adjustment statistical models (for each year's specific forecast).

The census-based model integrates tree numbers with expected yields-per-tree. The tree numbers are based on data from the AMS survey of 2010 combined with assumed new plantings since. These tree numbers are now becoming too dated to be reliable, and for any future forecasting project would need to be revised using other data, e.g. results from the Remote Sensing Project (ST15009 – Multi-scale monitoring tools for managing Australian Tree Crops: Industry meets innovation). Details of the existing tree numbers, and the resultant long-term crop forecasts for the industry, were all provided in the respective Milestone Reports for this project. These outputs are confidential, so are not listed in this report.

The yield-per-tree model incorporates the effects of region and the interaction between age and density. This model was formulated using producers' data, obtained from the 'Macadamia Benchmarking Project' (MC15005-Benchmarking the macadamia industry 2015-2018). The yield patterns here show that tree-yields in the Bundaberg region are initially 'ahead' of yields from the other regions. Again, full details of these yield patterns by ages, planting densities and regions were provided in an earlier Milestone Report, and remain confidential.

Each year, models are re-estimated to apply a climate adjustment to the annual crop forecast. These models estimate the likely impacts of the previous year's climate on the crop. Meteorological data sets across the defined production regions are accessed, and the necessary soil-water and plant parameters are modelled. The key variables used for the statistical models are maximum and minimum temperatures, rainfall, pan evaporation rate, solar radiation, the number of water-stress days per month, the average soil-water-index from a hydrological 'typical' macadamia-farm model, and the monthly cumulative day-degrees either side of the optimal temperature for photosynthesis (26° C).

The monthly data were integrated into 'defined macadamia physiological periods'. The key periods for the 2019 crop are 'last summer' (January 2018), 'floral initiation' (April and May), 'winter' (June to August), 'flowering and nut set' (September and October), 'premature nut fall' (November), 'nut growth' (December), and 'oil accumulation' (January 2019). For some regions targeted individual monthly data, and 'summer' (November through January), are also used. Important 'non-climatic' effects are also included in the prediction models. These are the biennial-bearing effect, and CPI-adjusted nut prices (direct and lagged by one, two and three years).

During 2018, intensive Monte-Carlo investigations of a wider range of alternate statistical forecasting methods were conducted. This study used cross-validation, which in turn leaves-out one historical year and predicts it using the other years, and then summarises the mean absolute error rate across all years. This method results in the best expectation of selecting models which will produce superior predictions of future crop production. The full methods and results are detailed in Mayer *et al*. (2019). The key finding from these investigations was that LASSO (least absolute shrinkage and selection operator) penalised regression outperformed both general linear models (which we had previously adopted in the forecasting projects) and other supposedly-advantageous statistical methods for forecasting with high-dimensional problems. Model ensembles (which we also previously used to advantage) then gave further improvements. For the historical data, LASSO ensembles gave the lowest mean absolute error rates of 9.0% for the Lismore production region, 8.4% for south-east Queensland and 5.9% for Bundaberg. Hence LASSO ensembles were adopted for the 2019 forecasts.

Outputs

For each year of this project, the climate-adjusted crop forecast for the coming year was delivered to the AMS, which formed the basis for their press release on their 'official' crop forecast.

The comprehensive forecasting reports were around 40 pages in length, giving an overview and then detailed data and discussion for each production region. These reports also include assumed numbers of new plantings each year, and the resultant revised long-term crop forecasts (out to 2030). As such, these reports remain confidential.

The actual crop and overall crop forecasts for each year of this project were -

Year	Actual crop (t)	Climate-adjusted forecast	% error
2016	52,000	53,900	3.7
2017	46,000	55,300	20.2
2018	52,900	53,000	0.2
2019[2]	TBC		

The harvested crop of 2017 was notably low, being severely affected by the destructive winds and flooding caused by Cyclone Debbie. This wide-spread weather event affected the major production regions of Bundaberg, Gympie, south-east Queensland, and coastal and inland NSW. Despite this, the overall average error rate for these three years was 8.0%. This is comparable to similar (regional or national) forecasting projects around the globe. Crop forecasts for USA almonds are based on the annual crop-sampling of over 800 orchards by the USDA, with a two-month lead-time. Since 2001 these have averaged 7.1% error, with the worst being 13.8% (in both 2002 and 2011). Similarly, the USDA sample 180 orchards each year for their hazelnut crop forecasts, which over 34 years resulted in an averaged error rate of 8.1% (Olsen and Goodwin 2005). Peiris et al. (2008) predicted coconut production in Sri Lanka using seasonal climate information (primarily rainfall), with an average error rate of 6.8% (for two years only).

[2] At the time of publication, the 2019 forecast remains confidential until the actual crop is confirmed at the end of the season.

Outcomes

The delivered crop forecasts have been used by the industry for logistical planning and marketing, including the scheduling of exports. It is impossible to quantify the effect that the crop forecasts had on the degree of price discounting and market stability. However from the AMS database, in 2015 to 2018 the average annual price varied between $4.50 and $5.80 per kg nut-in-shell, which was notably higher than in the preceding four years ($3.10 to $3.80).

Monitoring and evaluation

This project delivered a final, or an interim, crop forecast in mid-February each year. These forecasts were required for the annual early-season meeting between the executive of the Australian Macadamia Society and the Australian Macadamia Handlers Association (AMHA). Subsequent to this meeting, in each year the project reference group met to review the project's findings and to discuss potential methodological improvements or alternatives for the coming year.

All of the project's milestones were met on time, and all outcomes delivered on schedule.

Recommendations

The outputs from this project are of direct relevance to, and are used by, the macadamia industry. It is hence recommended that annual crop forecasting be continued.

Should this eventuate, a number of potential improvements have been identified –

- The base data of tree numbers (or planted areas) needs to be updated, as the AMS census of 2010 is now too dated. The new data should be specified by postcodes, to define revised production regions if needed.
- Finer definitions of the production regions should be considered. For example, the current 'coastal NSW' region incorporates the more northern areas in with the industry expansion in the Clarence Valley, and these environments are potentially different.
- Within each region, approximate age structures of the trees will need to be defined. The Australian Macadamia Society would appear the best source for these estimates.
- The yield-per-tree (or, alternately, yield-per-area) models should be checked and updated if necessary. The crucial data for this process would be needed from the Macadamia Benchmarking Project, or other sources if this project is not to be renewed.
- The timing and extent of flowering was not adequately addressed in this project, as it varies between regions and years. As this is believed to have a key influence on crop amounts, direct methods such as in-orchard cameras or observer-surveys could be used to quantify these events for future forecasts.

Refereed scientific publications

Journal articles

Mayer, D.G., Stephenson, R.A., 2016. Statistical forecasting of the Australian macadamia crop. *Acta Horticulturae* **1109**, 265-270. doi: 10.17660/ActaHortic.2016.1109.43

Mayer, D.G., Chandra, K.A., Burnett, J.A., 2019. Improved crop forecasts for the Australian macadamia industry from ensemble models. *Agricultural Systems* **173**, 519–523. https://doi.org/10.1016/j.agsy.2019.03.018

Conference proceedings

Mayer, D.G., Stephenson, R.A., 2015. Statistical ensemble models to forecast the Australian macadamia crop. In: 21st International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, Gold Coast, Queensland, Australia. pp. 455–461. www.mssanz.org.au/modsim2015/B4/mayer.pdf

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Olsen, J., Goodwin, J., 2005. The methods and results of the Oregon Agricultural Statistics Service: annual objective yield survey of Oregon hazelnut production. *Acta Horticulturae* **686**, 533-537.

Pieris, T.S.G., Hansen, J.W., Zubair, L., 2008. Use of seasonal climate information to predict coconut production in Sri Lanka. *International Journal of Climatology* **28**, 103–110. doi: 10.1002/joc.1517

Intellectual property, commercialisation and confidentiality

The long-term forecasts for the Australian macadamia industry, reported separately, remain confidential. Additionally, the 2019 forecast remains confidential until the actual crop volume is confirmed at the end of the season. Apart from these, this project has no IP, project outputs, commercialisation or confidentiality issues to report.

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