Final Report

Macadamia Crop Forecasting 2020-2022

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Delivery partner:

Queensland Department of Agriculture and Fisheries

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MC18003

Project:

Macadamia Crop Forecasting 2020-2022 MC18003

Disclaimer:

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Public summary

The objective of the Macadamia Crop Forecasting project is to deliver (in February) a climate-adjusted forecast for the coming year's macadamia crop, and longer-term forecasts (out to about 10 years) for future expected production volumes.

Early each year, targeted data sources are updated and analysed. The data collected includes regional macadamia production for the past season, spatial meteorological data and tree-crop modelling, orchard areas and tree ages from satellite imagery, on-farm production data and flowering surveys from the Macadamia Benchmarking project, and early-season regional nut-sampling measurements.

These data sources are integrated into statistical and artificial-intelligence crop-forecasting models for each of the seven production regions in Australia, and then combined into an overall crop forecast. The methods and results are discussed at the annual industry-planning meeting of the Australian Macadamia Handlers Association, following which the Australian Macadamia Society issues a press release for the overall industry forecast. Updated press releases are issued as required – for example in 2022 the effects of the extreme rainfall and flooding event across most of the macadamia production regions were evaluated, and revised crop estimates were formulated. These are expected to be released in the near future.

This information is important to processors and producers as it allows them to plan logistics for the coming season, reduce uncertainty through price-stabilisation, and assists in decision-making regarding future industry expansion.

Forecasts for the national crop have thus far been very encouraging. In 2020, the forecast was 49,750 tonnes (nut-in-shell at 10% moisture), and the crop came in at 50,300 tonnes, a 1.1% error. In 2021, the forecast was 53,000 tonnes, with an actual tonnage of 55,200 (4.0% error). These error rates easily meet the nominated project criteria of 'within 10% of actual production'. Separate forecasts for the individual production regions have been more variable but have met the nominated criteria for the major production regions.

Longer-term forecasts indicate that production will approximately double in the next eight years, driven mainly by increased plantings and production in the Bundaberg region.

Keywords

Macadamia; crop forecast; orchard census; statistics; prediction models; remote sensing

Introduction

Australia is the recognized global market leader for its high-quality macadamia. It is estimated that 70% of Australian macadamia are being exported overseas. Macadamia production forecasting information is important to processors and producers as it allows them to plan logistics for the coming season, reduce uncertainty through price-stabilisation, and assists in decision-making regarding future industry expansion.

Australia has one of the most variable climates in the world, being affected by a complex and interacting set of climate drivers including El Nino-Southern Oscillation, Indian Ocean Dipole, Madden-Julien Oscillation, and Southern Annular Mode. Due to the sheer size of the country, weather and climate vary substantially between regions – floods and droughts are known to occur simultaneously in different parts of the country. Consequently, agricultural production and revenues in Australia experience high climate-related volatility. Faced with such volatility, primary producers often refer to weather and climate monitoring and forecasting service portals to help make more informed decisions.

The objective of the Macadamia Crop Forecasting project is two-fold; each year it is to deliver –

- A climate-adjusted macadamia crop forecast for the coming season (the nominated target is to be within 10% of the actual crop), and
- Longer-term forecasts (out to about 10 years) for the expected production amounts.

The current project (2020-2022) is a continuation of the previous macadamia forecasting projects, which have been conducted by the Queensland Department of Agriculture and Fisheries (and earlier versions of this department) since 2000. Figure 1 shows the overall performance of this series of forecasting projects. It shows generally-increasing crops, with a notable degree of variation – which for some years has been somewhat difficult to predict. The underlying data sources and forecasting methods have seen continuous improvement over this period, as outlined in Mayer *et al.* (2019).

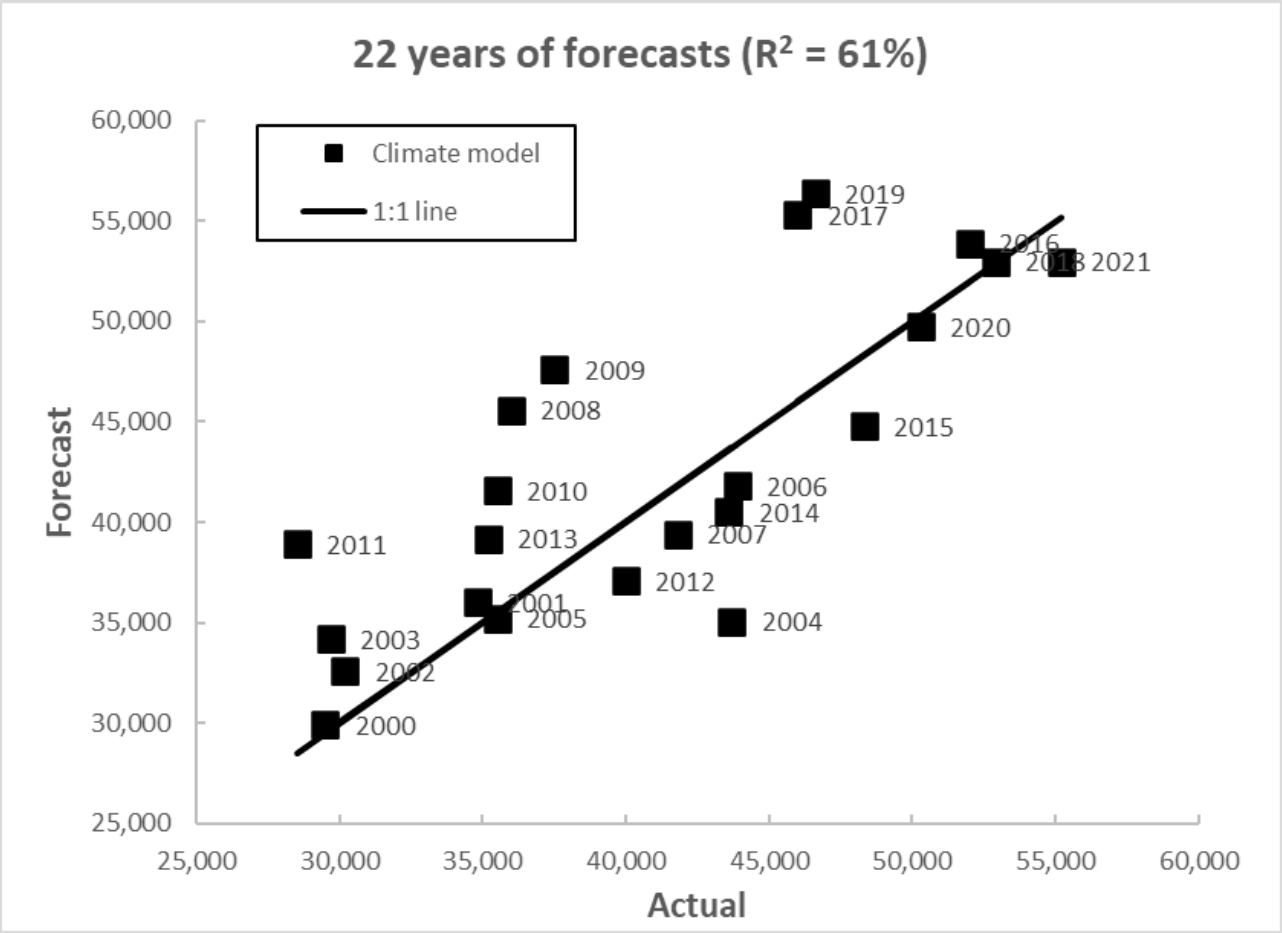

Figure 1. Actual and forecast annual macadamia production (tonnes nut in shell, at 10% moisture) from 2000 to 2021, with the 1:1 line.

Methodology

Early each year, targeted data sources are updated and analysed, including –

- Regional macadamia production for the past season, provided by the members of the Australian Macadamia Handlers Association and facilitated by the Australian Macadamia Society
- Spatial meteorological data and tree-crop modelling from the Queensland Department of Environment and Science
- Regional tree-census data (planted areas and tree ages) from the Applied Agricultural Remote Sensing Centre at the University of New England (Brinkhoff and Robson, 2021)
- On-farm production data and flowering surveys from the Macadamia Benchmarking team
- Early-season nut-sampling measurements and analyses coordinated by David Bell

These data sources are integrated into statistical and artificial-intelligence crop-forecasting models for each of the seven production regions in Australia and then combined into an overall crop forecast. These methods and results are discussed at the annual industry-planning meeting of the Australian Macadamia Handlers Association, following which the Australian Macadamia Society issues a press release for the overall industry forecast. Updated press releases are issued as required – for example in 2022 the effects of the extreme rainfall and flooding event across most of the macadamia production regions were evaluated, and revised crop estimates were formulated and are expected to be released in the near future.

In parallel, two 'ground-truthing' surveys are conducted each year in the period leading up to the forecasts –

- ***Flowering.*** In Spring we contact collaborating producers across the region to estimate 'flowering rating' (on a simple five-point scale). This is to check for potentially poor flowering which would have a detrimental effect on the crop. In the three years of this project, flowering ratings have been quite good, so no problems were expected from this aspect.
- ***Nut sizes.*** David Bell coordinates the collection, measurement, and analysis of early-season (January/February) nut sizes from across the production regions. Small nut sizes have (in some past years) been the main cause of lower-than-expected crops. Kernel recovery is also measured, and this forms additional information that is highly-valued by the industry. For this project, nut sizes have been near or above normal each year, so no problems in this regard have been anticipated.

Full details on the data sources and statistical forecasting methodologies, and the resultant forecasts for each production region, are covered in the project's annual milestone reports. These have previously been submitted to Hort Innovation.

Results and discussion

This project's overall forecasting accuracy has proven to be quite good. In 2020, the forecast was 49,750 tonnes (nut-in-shell at 10% moisture), and the crop came in at 50,300 tonnes, a 1.1% error in the forecast. In 2021, the forecast was 53,000 tonnes, with the actual tonnage of 55,200, a 4.0% error. Validation of the 2022 forecast is not possible at the time of writing and can only be checked in December, when the final crop figures become available. Figure 2 shows the actual region and year forecasts. Production is predominantly driven by production in Bundaberg, Lismore and coastal NSW (to some extent), with the 'bottom cluster' of minor regions not important to the overall forecasts. The mean absolute errors for these three regions are 8.8%, 9.6% and 2.0% – all well within the targeted 'less than 10%'.

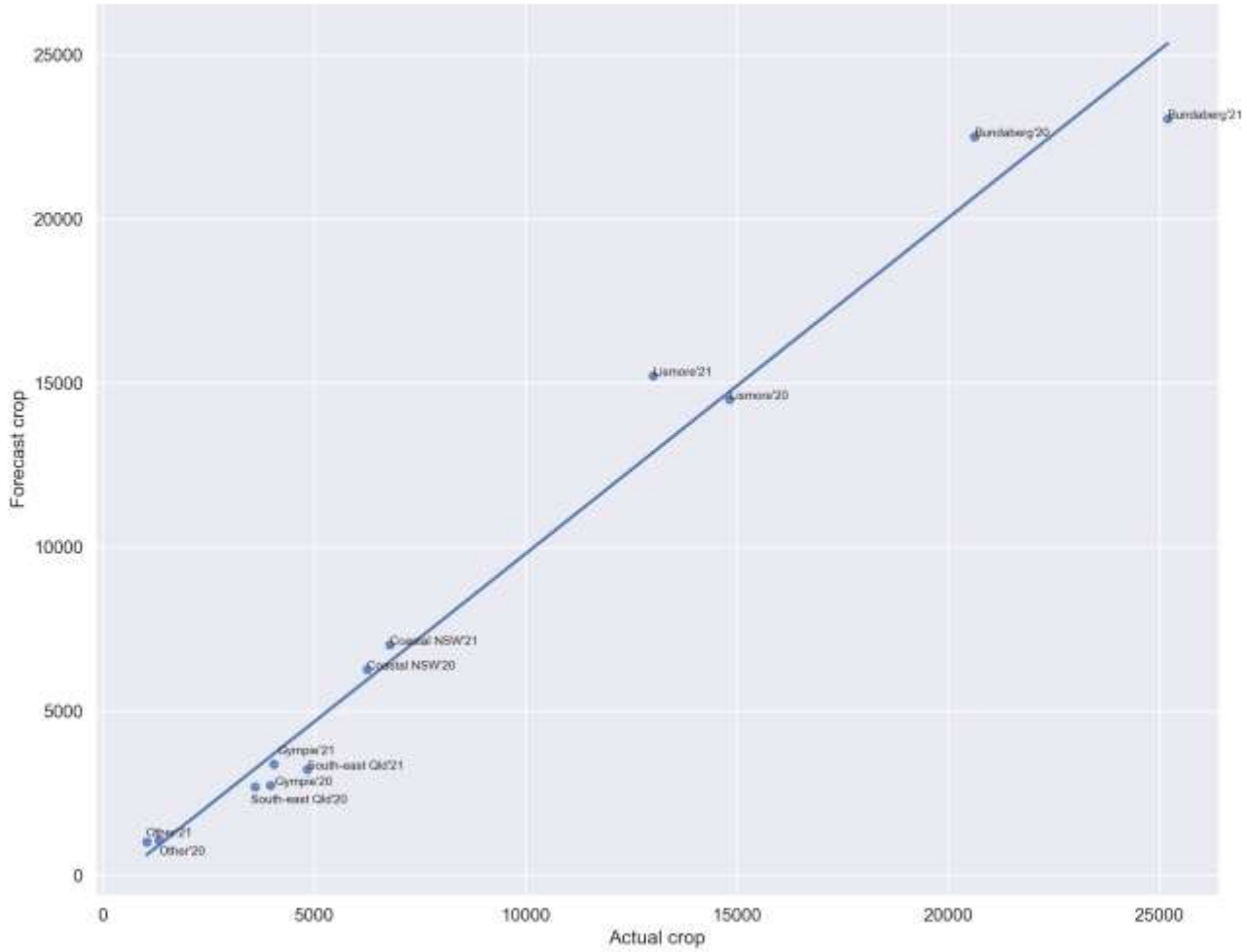

Figure 2. Forecast *vs*. actual production for each region and year, with a plotted 1:1 line.

The long-term forecasts are reformulated each year from the updated data-sources and models. The latest (2022) expectations are listed in Table 1. Production increases are expected for all regions, however the majority of the future increases will come from the Bundaberg region.

Year	**Overall**	Lismore	Nth-coast NSW	Mid-coast NSW	South-east Qld	Gympie	Bundaberg	Other
2022	**57,634**	14,497	4,431	3,184	4,053	3,459	26,759	1,251
2023	**63,038**	14,530	4,478	3,909	4,205	3,707	30,913	1,296
2024	**69,215**	14,547	4,522	4,778	4,204	3,995	35,826	1,342
2025	**76,218**	14,662	4,596	5,701	4,391	4,314	41,160	1,395
2026	**83,364**	14,780	4,674	6,469	4,586	4,635	46,749	1,471
2027	**90,630**	14,928	4,757	7,117	4,799	4,964	52,500	1,566
2028	**97,880**	15,072	4,836	7,664	5,025	5,289	58,322	1,673
2029	**105,062**	15,205	4,910	8,131	5,264	5,610	64,156	1,786
2030	**112,156**	15,365	4,982	8,517	5,519	5,900	69,981	1,891

Table 1. Long-term crop forecasts (tonnes) by region and overall.

Outputs

Table 2. Output summary

Outputs	Description	Detail
1. Crop Forecasting Reports – 2020, 2021 and 2022.	These detailed annual reports outline the steps of data acquisition, refinement, analyses and forecasting developments, and list the resultant long-term and climate-adjusted crop forecasts.	The Crop Forecasting Reports were emailed to Hort Innovation (Adam Briggs) and the Australian Macadamia Society (Jolyon Burnett), by mid-February each year - prior to the industry-planning meeting of the Australian Macadamia Handlers Association. These reports contain some commercial-in-confidence data from these handlers. Only the overall (industry-wide) forecasts are given in AMS's press releases and grower newsletters.
2. Press releases each year.	The crop forecasts and updated versions are issued by the Australian Macadamia Society.	The 2022 press releases are – https://australianmacadamias.org/industry/news/australian-macadamia-crop-predicted-to-increase https://australianmacadamias.org/industry/news/australian-macadamia-crop-forecast-reduced-due-to-severe-weather-and-flooding

Outcomes

Table 3. Outcome summary

Outcome	Alignment to fund outcome, strategy and KPI	Description	Evidence
Improved decision-making capacity in the Australian macadamia industry.	Outcome 4 *Business Insights*. Strategy 3, KPI 2 Evidence of data used to support industry-level decision-making.	The crop forecasts are a key input for the annual industry-wide planning meeting of the Australian Macadamia Handlers Association. This meeting plans out export contracts and harvesting, and processing logistics for the coming year. Additionally, the longer-term forecasts are factored into planning for future industry infrastructure and expansion.	Accurate forecasts lead to greater industry confidence, resulting in less price instability. Jolyon Burnett (CEO, Australian Macadamia Society) has publicly stated that 'this has saved the industry in the order of tens or hundreds of thousands of dollars each year'.

Monitoring and evaluation

Table 4. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
The Australian macadamia industry continually requires accurate short and long-term crop forecasts, for planning, resource coordination and maintaining price stability.	This project delivered these required forecasts annually at the start of each season (in February 2020, 2021, and 2022), and also provided updated data and trend analyses later in each season (September).	The data sources and forecasting methodologies were continuously improved during the project, as outlined in previous sections.

Recommendations

- That annual crop forecasts for the macadamia industry be continued. All feedback we received from growers, processors, consultants, and industry facilitators was very positive regarding the value of these forecasts to the industry.
- That a feedback mechanism be established to collect evidence of the project's positive impact.
- That the satellite-imaged areas planted to macadamia be updated at least every two years. Having up-to-date data is crucial for the accuracy of the forecasts.
- That the auxiliary ('ground-truthing') data surveys, namely the flowering ratings and early-season nut size measurements, be continued.
- That innovative forecasting methodologies are continually investigated. These may include (but are not limited to) seeking alternate 'driving factors' to include in the modelling, new and novel statistical models, and machine-learning and artificial intelligence methods.

Refereed scientific publications

None.

References

Brinkhoff, J. and Robson, A.J. (2021). Block-level macadamia yield forecasting using spatio-temporal datasets. *Agricultural and Forest Meteorology* **303**, https://doi.org/10.1016/j.agrformet.2021.108369.

Mayer D.G., K.A. Chandra and J.A. Burnett (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

Intellectual property

No project IP or commercialisation to report.

Acknowledgements

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