Final report

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Macadamia Crop Forecasting 2023 - 2025

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Disclaimer:

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Public summary

The ‘Macadamia Crop Forecasting’ project delivered –

- a climate-adjusted macadamia crop forecast for the 2023, 2024 and 2025 seasons, and
- longer-term forecasts (out to 10 years) for the expected production of the Australian macadamia industry.

This information is important to inform processors and producers, and to assist in decision-making regarding industry logistics, export contracts, and future industry expansion.

Each year, targeted data were successfully sourced and analysed to create the annual and long-term crop forecasts. The Australian Macadamia Society (AMS) collated historical production on a regional basis. The relevant meteorological variables were obtained from the Australian Bureau of Meteorology, and other important data (including price history and satellite imagery) were collated. Production patterns were fitted by cross-matching actual production for each region against tree numbers. These models form the basis of the expected production for the long-term forecasts. Adjustments for climate and other proven effects were then made for each year’s final forecast in February. These forecasts were developed using both ‘more traditional’ statistical models along with some of the more promising machine-learning algorithms. In parallel, an industry-wide survey of flower ratings was collated by the Macadamia Benchmarking Project team, to identify any potential problems. The results and crop forecasts were drawn together in a full report that was forwarded to Hort Innovation and AMS each year. This report constitutes the key outcome of this project. The project’s Reference Group, including key AMS and industry personnel, met annually.

Whilst past results have been quite acceptable, in the future forecasting accuracy could well be improved by adopting some of the more-promising developing methodologies.

Keywords

Macadamia; crop forecast; climate effects; statistical models; machine learning

Introduction

The Australian macadamia industry is an exciting, proactive and open industry that continues to grow in size and value. Forecasts of the national macadamia crop provide valuable information for industry and export planning and logistics.

This information is important to inform processors and producers, and to assist in decision-making regarding future expansion in exports and industry logistics. The project outputs support Outcomes 1 (Demand creation – 'to expand into … international markets'), 3 (Extension and capability – 'Build capability … across the supply chain'), and in particular 4 ('Business insights') in the Macadamia Strategic Investment Plan 2022 – 2026.

This project incorporated a variety of data sources, and utilized statistical and machine-learning models to formulate the forecasts. Technical and industry experts, along with Australian Macadamia Society (AMS) liaison personnel, were involved via the project's Reference Group.

Crop forecasts have been delivered to Hort Innovation and the industry via the AMS by DPI since 2000. The 25-year median absolute error for these years is 7.3%, within the nominated target of 10%. These forecasts have proven to be a core requirement for industry planning and price stability.

Methodology

The following steps were adopted for each year of the project –

- Production data (from the Australian Macadamia Handlers Association) from the previous year were obtained and collated to a regional level, by AMS.
- Climate and modelled tree-crop data (up to 31 January) was provided by the Department of Environment and Science (Qld), in the first week of February.
- Forecasting models were formulated, reviewed and compared; and the initial forecast amounts communicated to AMS, Hort Innovation and the project Reference Group, by the second week in February.
- Feedback was collated and incorporated via the project reference group, and a final report delivered to AMS and Hort Innovation by the end of February. This report details the past year's climate for each production region, the base data and assumptions, details of the forecasting models, the climate-adjusted forecasts and the revised long-term forecasts, for each defined region and overall.
- The project reference group met in April, discussing the methodologies behind and results of the forecast.
- In September, collaborators were consulted, and updated data were analysed for trends or changes. An updated forecast was then delivered to industry via the AMS.

Each year, AMS collated the past year's production on a regional basis. These were matched with planted areas by tree-ages, provided from the Applied Agricultural Remote Sensing Centre. This covers 'productive' areas only (*i.e.*, excluding roads and headlands), and now totals over 44,000 ha as at the end of 2023. Future new plantings were assumed, based on past patterns and with industry input from AMS. New plantings have little impact in the near future, and only become important for the forecasts from 2030 onwards when these orchards approach maturity (>10 years old). The integration of tree numbers with expected production patterns (based on AMS data) forms the basis of the census-model, which is used to forecast the 'expected' production for the current and future years.

Each year, the climate-adjusted forecast is then based on estimating 'dev%', which is the deviation from the census-model forecast. Full methods and results are detailed in Mayer *et al*. (2019). Dev% is affected by climate terms - temperatures, rainfall, evaporation, solar radiation, vapor-pressure deficit, and modelled soil-water indices, averaged across key macadamia physiological periods during the year preceding the crop. These are 'previous summer', '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 of the current year). Additional predictors of dev% include CPI-adjusted nut prices (direct, plus lagged by one, two and three years), the biennial-bearing effect, 'late-Summer cyclones' (yes or no), and three remotely-sensed indices of tree health. Results from 'Intelligence-guided' statistical prediction models are integrated with machine-learning algorithms. The relative weightings used for each depend on the observed degree of variability, past performance, and literature studies (Lateh *et al*. 2017, Mayer *et al*. 2019 and Xu *et al*. 2023). These suggest that 'effectively-blind' machine-learning algorithms struggle to give accurate forecasts for systems with smaller numbers of observations (e.g. less than 30; we have 25), and for data-sets with a notable degree of variation amongst the data - both of which are features of the macadamia forecasting project.

Results and discussion

The Australian Macadamia Society sourced, on a regional basis, confidential crop intake data (tonnes at 10% moisture; Figure 1) from the processors (the Australian Macadamia Handlers Association). 2024 was the first year that the crop from Maryborough was listed separately, so for consistency with previous years it has been included with the Bundaberg region. Driven by large areas of recent plantings, this region continues to surge upwards, and now provides 55% of the national crop. In comparison, production in the other regions appears fairly steady or in slow decline due to declining production from aging trees.

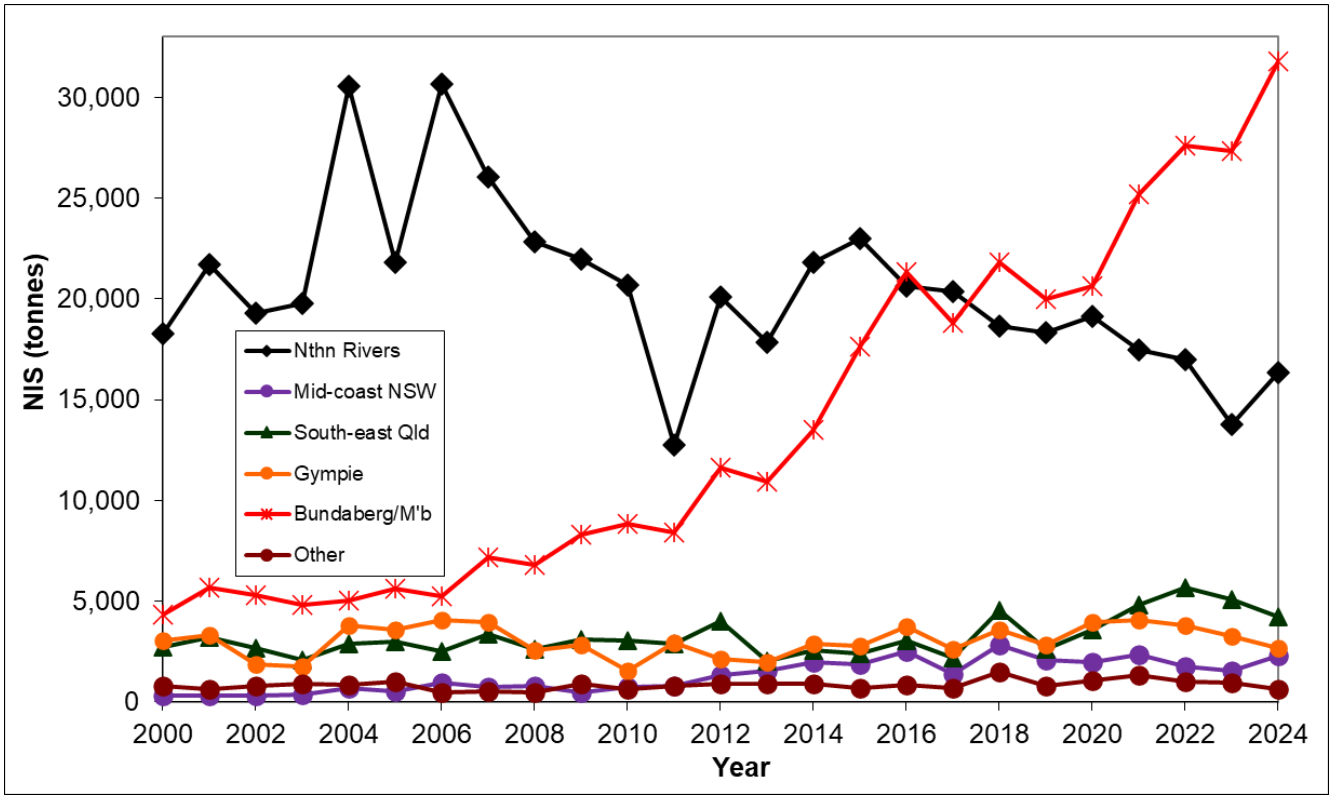

Figure 1. Historical macadamia production by regions.

For this short-term project (three years, covering the 2022 to 2024 crops) the mean absolute errors for the climate-adjusted forecasts were 3.7%, 24.1% and 9.5% respectively. The poor 2023 result was due to the crop being much lower than expected, due to historically-low prices – averaging $1.88 for that year; down from the high of $6.65 a mere three years previously.

Figure 2 shows the overall performance for this series of forecasting projects (back to 2000). The 25-year median for the absolute error of the climate-adjusted forecasts is 7.3%, well within the nominated target of 10%. In comparison, the median error rate for the census-model forecasts is 9.3%. This shows that the adjustment process is warranted, as the census-model forecasts are 27% worse than the climate-adjusted forecasts. As outlined this project's annual forecast reports, and discussed by experts at the Reference Group meetings, these adjustments are largely driven by prices. The climatic effects have only had relatively minor contributions.

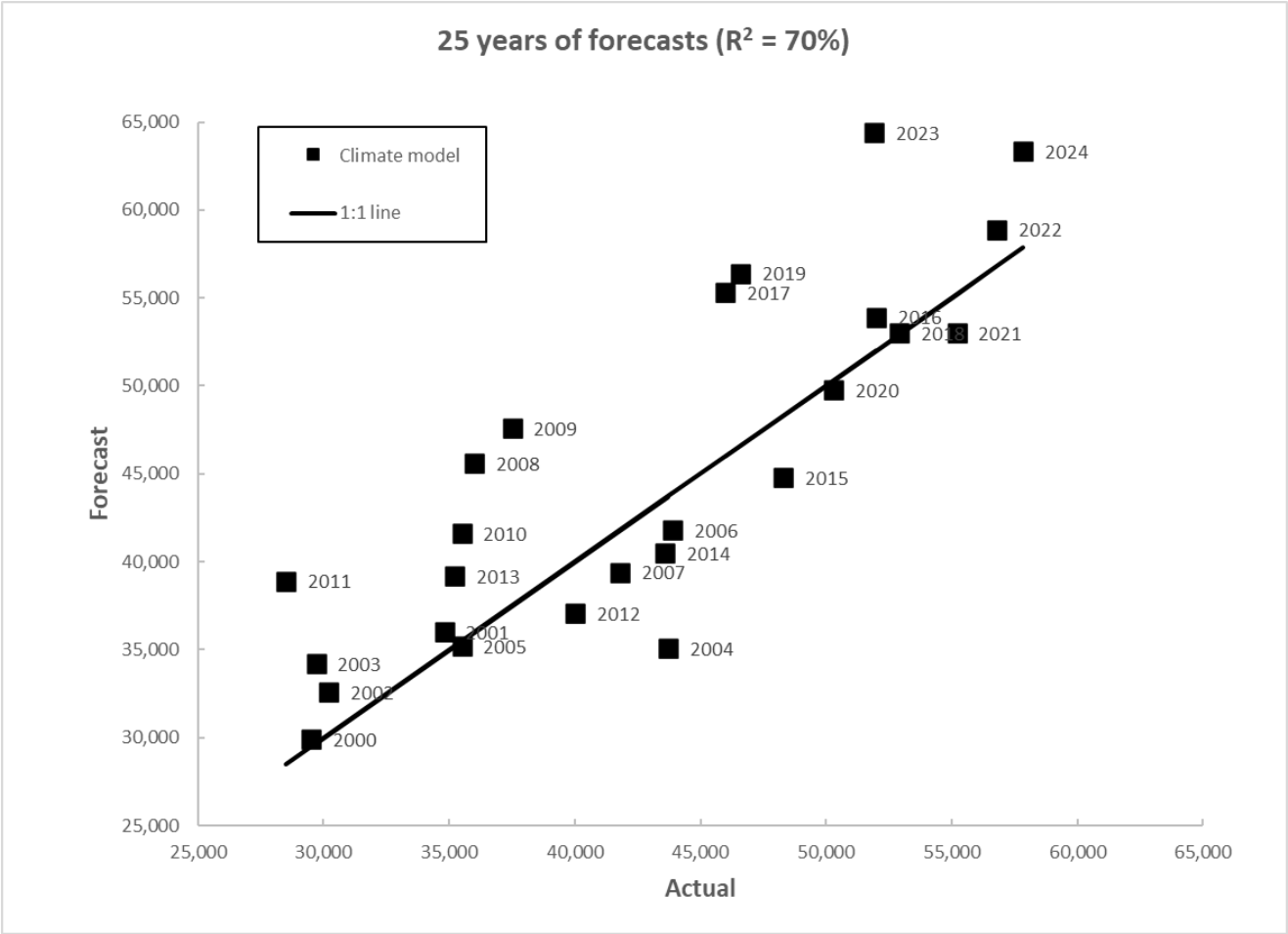

Figure 2. Actual vs. forecast annual macadamia production by years.

An additional key performance indicator (KPI) for this project was maintaining price stability. Australian prices are 'commercial in confidence', so we obtained the Japanese Yen monthly price history (back to 2011) from the AMS. Variability (or 'within-year volatility') is best measured as the coefficient of variation (CV%) for the monthly prices within each year, being the ratio of the standard deviation to the mean.

Figure 3 shows the historically-high degree of instability in 2023 when prices plummeted. The three years preceding this had very low forecast errors (1.1%, 4.0% and 3.7% respectively). Hence accurate forecasts did not have a stabilizing effect on prices, and the high variability of 2023 (also flowing into 2024) was obviously due to other market factors.

It is thus recommended that this 'price stability' key performance indicator be discontinued for any future crop-forecasting project.

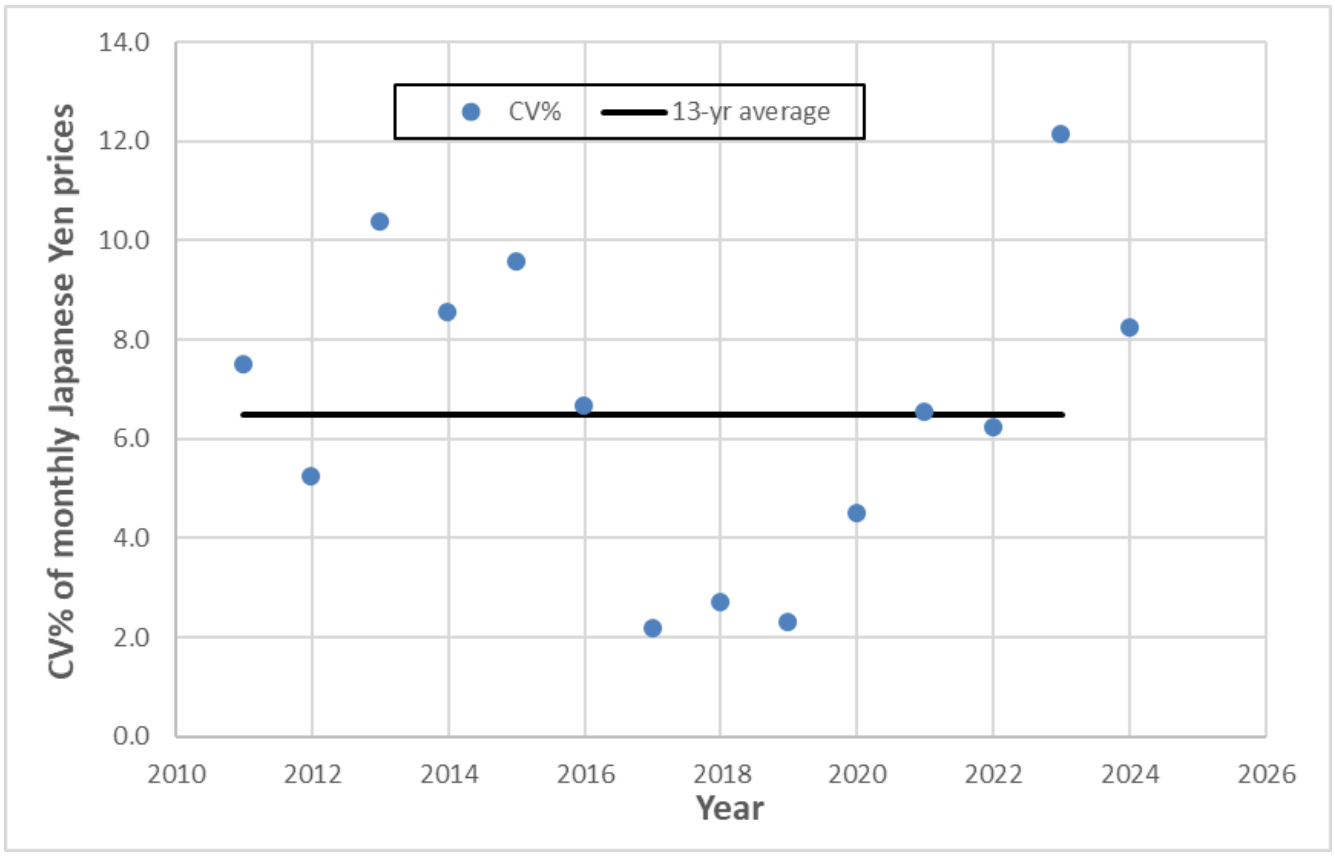

Figure 3. Relative variability of Japanese prices over years.

Outputs

The project's Monitoring and Evaluation Plan specified three key outputs for each year, namely –

- A climate-adjusted crop forecast, by the end of February in each year.
- Updated longer-term crop forecasts for the Australian industry, out to ten years.
- Mid-season forecast updates, by the end of September each year.

The first two outputs were met via this project's annual forecasting reports, which covered project performance, revised methodologies, climate analyses for each region, and the required forecasts. These have been delivered to industry, via the Australian Macadamia Society.

The final output of the mid-season forecast updates was delivered each year to Hort Innovation and the Australian Macadamia Society, via this project's scheduled milestone reports. With no problems being identified in these three years, AMS did not release any updated crop forecasts.

Outcomes

The key project outcome was 'Industry accepts and uses the annual crop forecasts, for export and infrastructure planning and logistics.' For each year of this project (and, in fact, for preceding years also), the Australian Macadamia Society has issued a press-release listing the crop forecast and outlining contributing factors. The links for previous years have been taken down by AMS; the latest (2025) forecast is outlined in - Australian Macadamia Society

These outcomes support the following SIP targets –

1. Demand creation – 'to expand into … international markets.'
3. Extension and capability – 'Build capability … across the supply chain.'
4. Business insights – 'to inform decision-making.'

The secondary project outcome was 'Better price stability, from improved industry confidence in the accuracy of the forecasts.' As outlined above, this outcome was not met for this project. Market uncertainty in 2023, unrelated to the very-successful crop forecasts of the preceding three years, led to price volatility in the final two years of this project. Notably, price stability was achieved in our previous two crop-forecasting projects (each of three year's duration).

The end-of-project outcome was 'Continued industry confidence in the accuracy and value of the crop forecasts, with average error rates for the annual crop forecasts of below 10%.'

Error rates of less than the targeted 10% were achieved in two of the three years of this particular project. Given that the median error rate over the 25 years of our crop-forecasting projects is 7.3%, we surmise that industry does have continuing confidence in the accuracy and value of the crop forecasts.

Monitoring and evaluation

Assessments of the project's Key Evaluation Questions are listed in Table 1.

Table 1. Key Evaluation Questions

Key Evaluation Question	Project performance	Continuous improvement opportunities
To what extent has the project achieved its expected outcomes? Have the annual crop forecasts been within 10% of the actual industry production totals?	The crop forecasts were within the nominated 10% error rate for two of the three years of this project. Over the 25 years of crop forecasting, the median error rate was 7.3%, meeting this criterion.	Future crop forecasts can potentially be improved by obtaining updated and more accurate data, and the adoption of prediction methods suited to this type of problem.
How relevant was the project to the needs of intended beneficiaries? Do the primary clients (namely the Australian Macadamia Society and the Australian Macadamia Handlers Association) continue to see value in the project outputs?	The primary clients of this project are the macadamia industry, represented by the Australian Macadamia Society and the Australian Macadamia Handlers Association. These organisations used our forecasts in their annual press-releases, so do continue to see value in the project outputs.	Maintaining open and good relationships with our main clients.
How well have intended beneficiaries been engaged in the project? Were key industry personnel, including a nominee from the Australian Macadamia Society, included in the project's steering committee which meets annually?	Our project reference group, which met annually, included AMS's CEO and marketing officer, government representatives from Qld and NSW, and at least one key industry person from each of the main macadamia production areas.	Continued consultation with a range of industry personnel and experts, as was done in this project, is vital in the future.
What efforts did the project make to improve efficiency? Were remotely-sensed data sets used to full extent? Were the most efficient and appropriate forecasting models investigated and adopted? Were automated data collation and analysis flows developed?	The remotely-sensed data sets were updated annually. Literature and other sources were perused to identify the more-promising forecasting algorithms. Templates were developed for streamlining the climate data analyses.	Accurate base data, and adoption of the most suited prediction methods, are seen as the main drivers for the improvement of future forecasts.

Recommendations

The key recommendation is that crop forecasting be continued, as industry supports the need and sees its value. The following steps will facilitate continuous improvement -

- A thorough review of forecasting methods be conducted, focusing on tree-crops but including other commodities. Where applicable, the more-successful forecasting methodologies should be adopted for future macadamia forecasts.
- Continuous improvement in the remote-sensing data to estimate areas planted to macadamias, by ages.
- Review the more-effective predictors and possible new indices, given that climate terms have not been shown to have as much effect on production as some of the other variables.
- Instigate an early-season nut-size survey, to support the forecasting process and flag any problems due to small nut-size.
- Continue to have the Macadamia Benchmarking Project team survey growers and extension officers regarding flowering, to factor into the forecasting process (should this prove a problem).
- Discontinue 'price stability' as a target, as this project demonstrated that even very-good crop forecasts did not lead to price stability.

Conference Publication

Li, Xingjuan and Mayer, David (2023). Improved National Macadamia Yield Forecasting Using an Ensemble Approach. Australian Statistical Conference, 10-15 December 2023, Wollongong.

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Lateh, Masitah Abdul et al. (2017). Handling a small dataset problem in prediction model by employ artificial data generation approach: A review. Journal of Physics: Conference Series 892 012016

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Intellectual property

No project IP or commercialisation to report.

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