Can Tree-crop Horticulture survive the next ‘big blow’?

Joshua Maunder, 2021 Scholar
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Scholar Contact Details

Joshua Maunder
Bellenden Ker, Far North Queensland

Phone: 0431 407 050
Email: joshua.maunder@gmail.com
Address: Telecom Road, Bellenden Ker, QLD 4871

In submitting this Report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

Nuffield Australia Contact Details

Nuffield Australia

Telephone: 0456 916 506
Email: enquiries@nuffield.com.au
Address: 38 Walker Drive, Worongary, QLD 4213

Executive Summary

Australia’s tree crop industries are in a precarious position, constantly aware that the occurrence of the next Tropical Cyclone - colloquially known amongst those who have endured one as a ‘big blow’ - is inevitable. The uncertainty is not whether a Tropical Cyclone will occur; rather, it’s a question of when.

Each year, from November through to April, the threat of Tropical Cyclones looms, presenting a significant risk to the stability and resilience of Australian agriculture. This six-month period is particularly fraught for growers in Northern Australia, as cyclones have the potential to cause widespread devastation at a time when crops are typically in peak production.

The effects of Tropical Cyclones are evident and severe. A single event can be catastrophic enough to financially cripple growers. Beyond the immediate destruction, the aftermath may lead to the collapse of entire industries, the loss of export markets, disruption to food supply chains, and decreased food security across the region.

Whilst Tropical Cyclones are not a new phenomenon to growers, our understanding of the nature and intensity of these events is evolving, with the current system of detection, classification, tracking and reporting having been refined in the mid-1980s. Long-term climatic modelling indicates that whilst the frequency of events is decreasing year-on-year, the severity of each event will continue to increase with a higher probability of more extreme events occurring.

A rise in ocean temperatures means that ideal climatic conditions needed to generate and sustain Tropical Cyclones will be more prevalent. As such, an increased likelihood of impacts on tree crop orchards associated with more severe events crossing the coastline is anticipated.

In December 1974, severe Tropical Cyclone Tracy crossed the Northern Territory coast, resulting in significant destruction of buildings, crop damage and the loss of 66 lives. Within five years of this event, the Building Council of Australia would instigate the largest expansion of building standards for structures in Cyclone regions ever recorded.

While broader society has implemented a range of strategies to prepare for and manage the impacts of Tropical Cyclones, such measures have not been widely adopted within the agricultural sector. This gap in readiness is particularly concerning given the significant risks these events pose to tree crop industries and the wider agricultural community.

Research undertaken through this Nuffield Scholarship has revealed a notable lack of preparedness amongst growers. The findings highlight that most growers have not adequately addressed the evolving threat of Tropical Cyclones, leaving the sector vulnerable to the immediate and long-term consequences when events occur.

The risk to Australia’s agriculture sector, whilst severe, is significantly lower than that of other countries which are closer in proximity to the equator. In countries like Japan, Singapore and parts of India, Tropical Cyclones are an annual risk, making this a truly global challenge to the long-term sustainability of the agricultural sector.

Whilst Australia is generally underprepared for the future of a changed climate and the impacts from Tropical Cyclones, there are several current research and extension

projects which are looking at ways to future-proof tree crop industries. In this space, it was found that whilst Australia is a leader in adopting systematic change, uptake of transformative practices is slow.

Offering management and mitigation strategies to growers is challenging, especially when the risk is not immediately apparent. Key findings from this report highlight that management measures do not require a drastic re-think of cropping methodologies or growing practices. Rather, the required change involves a transition from focusing solely on a production methodology targeting market-based characteristics only to one that creates stronger, more resilient orchards.

Other horticultural industries, particularly those in the temperate climates such as berries and medicinal cannabis, are already trialling and utilising a broad range of production methodologies which have the potential to be adjusted and utilised for tree cropping. Globally, the use of growing hothouses and greenhouses, particularly in the vegetable space, has allowed growers to overcome climatic conditions and achieve enhanced production outcomes.

Notable management and mitigation measures were found to primarily sit within the remit of growers; however, support and collaboration with government will create a more streamlined and timely transition to resilient orchards. High-density plantings coupled with supporting systems such as trellising were identified as the most obvious and easily implemented solution for in-field plantings, however, the understanding and practicality of this approach for tree cropping in Tropical Cyclone regions is yet to be fully understood.

Increasing the quality of planting material provided by commercial nurseries will also play a long-term key role in developing resilient orchards. The current focus of developing planting material which maximises a focus on production must be reduced in favour of a balance with stronger trees that exhibit improved climate resistance traits.

Adoption of these production methodologies typically includes an increase in production yields and a reduction in inputs on a per hectare (ha) basis. This outcome is required to cover the up-front capital investment necessary to adopt this transition. Growers must be prepared to focus on developing orchard resilience through growing strong trees over market-focused qualities in isolation for this approach to be truly effective.

The adaption and adoption of alternative growing methods through hothouses and greenhouses provides a potential opportunity to decouple production from the peak Tropical Cyclone timeframes. Whilst this methodology will require further research and extension prior to adoption, it provides a mechanism for growers to utilise technological advancements and crop science to stagger production across a broader portion of the year. This approach will also allow for a more desirable cash flow.

The tree crop industry faces a new challenge and one it must be prepared to overcome if it is to prosper into the next decades. Resilience, which is largely applied to a business thinking process must be the focus of the design, implementation and management of orchards to ensure sustainable production into the future.

Keywords: Tropical Cyclones, Resilience, Resilient Orchards, Tree Crops, Australian Agriculture, Climate Change, High-density, Trellis, Greenhouse, Hothouse.

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Foreword

I didn’t grow up in agriculture, nor do I farm full-time. However, I do call myself a farmer as I married into a farming family and I’m willing to have a go. We will become the third generation of our family to grow tropical fruit (rambutan, mangosteen, jackfruit and durian) as well as sugarcane on 160ha in Bellenden Ker, far-north Queensland and to ensure prosperity for the business and the industry, Tropical Cyclone management has long been a passion of mine.

Tropical Cyclones are an ever-present risk to tree-crop horticulture growers in Northern Australia. The impacts from Tropical Cyclones is not limited to simply high winds; they extend into prolonged periods of rainfall, severe rainfall intensity and an ongoing loss in annual production. The impacts of a changing climate mean that now, more than ever, we as growers have the most to lose.

There has never been a scenario where margins are as tight as they currently are (when factoring in input and labour costs) and the increasing risk of production losses. You’d have to be crazy to try and grow tree-crop horticulture in Northern Australia, the epicentre of Tropical Cyclones work - right?

From the get-go, I saw the photos, heard the stories and observed the impacts Tropical Cyclones had not only on my family farm, but the entire exotic tropical fruit industry. When a single event can wipe out whole orchards, destroy export markets and cause an emerging industry to collapse virtually overnight, you lean forward and listen because deep down you know – the next big blow is coming.

Becoming a Nuffield Scholar is a privilege, one which I can never fully repay either Nuffield Australia (particularly Jodie Redcliffe) or Westpac Agribusiness. When interviewed for my scholarship, I will always remember the question “What benefit does your business get from you being a Nuffield Scholar”. This question threw me, not because I gave an exemplary answer, rather because my pursuit wasn’t just about one business, to me, it was about the future of our industry.

Between the time I became a Nuffield Scholar and finalising this report, a bit happened (actually a lot happened). COVID-19 presented probably the most complex shakeup in Nuffield’s history with global travel (the key component of a Scholarship) virtually extinguished overnight. Nonetheless, to access a range of virtual Global Focus Programs (GFPs) was a incredible advantage and allowed for so many additional conversations to be had.

In my travels, I didn’t solve the problem of Tropical Cyclones. In actuality, I learnt it is bigger than I had given it credit for. However, like any good farmer, perseverance prevails and new-age thinking coupled with a can-do attitude will “save the day”.

Table 1. Travel Itinerary

Travel date	Location	Visits/contacts
Week 1 Travel **1-8 November 2022**	Australia	• Groves Grown • Lush Lychees • Makhoma Farms • Tinaberries • Crook Farm
Virtual GFP (Covid-19) **18-22 November 2020**	Kenya	• Yoani • Kisima • Ausquest • Kakuzi
Virtual GFP (Covid-19) **22-26 March 2021**	Netherlands	• Koppert Cress • Den Eelder • Hamletz • Bio Brass
Virtual GFP (Covid-19) **10-15 May 2021**	Brazil	• Sape Agro • Castrolanda • Malunga Farm
Virtual GFP (Covid-19) **14-18 June 2021**	Ireland	• Karuna Pierce • Mary Delaney • Ailish Moriarty • Ciara O'Halloran • Robert Byrne • Geoff Dooley
Week 2 Travel **3-7 March 2022**	England	• The Bristol Port Company • Myrtle Farm • The White Barn • Lye Cross Farm • Fernhill Farm
CSC England **8-14 March 2022**	England	Contemporary Scholars Conference, England
Week 3 Travel **15-21 March 2022**	England	Various markets, stores and produce outlets in London

Travel date	Location	Visits/contacts
Nuffield Australia National Conference 2022 (Tamworth)	Australia	• Nuffield Australia National Conference and various farm visits • Vinery Stud
Week 4 Travel **17-23 September 2022**	Australia	Various vineyards and fruit farms
Week 5 Travel **22-25 May 2023**	Singapore	• Singapore Markets • Meat and Livestock Australia • Chinatown Markets • ANZ Corporation • La Saffre • Bayer Seed Labs
GFP Week 1 **26 May 2023 - 3 June 2023**	Japan	• Genpachi Honey • Sawaura Farm • Tenaka Rice Farm • Sangotani Dairy • Australian Embassy • Various markets and department stores
GFP Week 2 **4-8 June 2023**	Israel	• Mahaneh Yehuda Market • Kibbutz Neot Semadar • Kibbutz Yotvata • Hazeva Cannabis Farm • Mekorot Water Company • Netafim • Volcani Centre
GFP Week 3 **9-13 June 2023**	Netherlands	• Koppert Cress • Boerinlinda • Royal Flora Holland • Piggy's Palace • Rabobank • Port of Rotterdam
GFP Week 4 **14-22 June 2023**	United States of America (Mainland)	• Cargil Mear Packing • Bowles Farming • Olam Agri • Turloclk Fruit

Travel date	Location	Visits/contacts
		• Meyers Water Bank • HMC Farms • Nuveen
Week 6-7 **8-20 June 2025**	United States of America (Hawaii)	Various farms, street markets and processing facilities
Nuffield Australia National Conference 2025 (Adelaide)	Australia	Nuffield Australia National Conference and various farm visits
Week 8 **11-14 September 2025**	Australia	• Ellimatta Orchards • Thompson Orchards • Agteam Machinery

Acknowledgments

I remember the first time I heard about the Nuffield Community from a previous Nuffield Scholar, Matthew Fealy, who convinced me of the value and benefit of a Nuffield Scholarship. I am extremely grateful for his ongoing guidance and council over these past many years.

Whilst I was prepared for the unknown and uncertainty of what a Nuffield Scholarship would entail; I was in no way ready for just how beneficial the opportunity would be. I could never have envisioned the journey that Nuffield would take me on, particularly considering the previous year, global travel came to a complete standstill under COVID-19.

The support I received from Nuffield Australia, specifically from Jodie Redcliffe and the Nuffield Alumni in Australia and globally, has been exceptional and has helped me achieve a wonderful Nuffield experience.

My Scholarship sponsor, Westpac Agribusiness, has been hugely supportive from the outset, by taking a chance on a study topic asking a big, bold question. Without the generosity of Westpac Agribusiness, I would not have had this opportunity and would not have gained access to a phenomenal network of people.

Thank you to the 2021 and 2022 Nuffield Scholars with whom I was fortunate to share so many unique experiences with. Your support has been exceptional, your guidance and wisdom unreserved and your friendship everlasting.

The next generation of Nuffield Scholars are unlikely to know the joy of having two years of global cohorts meeting in England and navigating the do’s and do-nots of COVID-19 at a time when global travel was marginal at best. A special thanks to fellow COVID Scholar Fritz Bolton whose counsel and friendship has helped me through difficult times and made me a better person.

To my loving wife, Lisa, who let me explore the world whilst holding things down at home. Your faith and belief in me is unlimited and sets a supportive debt I will never be able to fully repay. To my friends and family who did the hard work when I was away and kept things going, my humble appreciation.

Abbreviations

APVMA	Australian Pesticides and Veterinary Medicines Authority
GFP	Global Focus Program
Kph	Kilometres per hour
RDE	Research, Development and Extension

Objectives

The overarching purpose of this Nuffield research and the accompanying report was to investigate what current and future risks Tropical Cyclones present to Australian agriculture, particularly tree-crop horticulture, and to identify potential management and mitigation measures for uptake by growers.

This research focuses on defining the current challenge facing growers, understanding the long-term and evolving nature of the risk, and investigating whether tree-crop horticulture can be self-sustaining into the future.

This report comprises four key objectives, which are to:

1. Identify the risks associated with Tropical Cyclones to tree-crop horticulture.
2. Identify if and how climate change will influence these risks and what new or expanded challenges growers may face.
3. Identify potential mitigation and management measures that growers may employ to combat current and future risks associated with Tropical Cyclones.
4. Identify and highlight areas for further research.

By addressing these objectives, this report aims to prepare growers for the next century of Tropical Cyclones, support the de-risking of Australian agriculture, and advance food production security at a global level.

Introduction

For six months of the year, Northern Australia lives with the knowledge that the next ‘big blow’ is not a matter of if, rather, it’s a matter of when. Like that of sugar, bananas and beef cattle, Tropical Cyclones are a well-known commodity that growers deal with on a yearly basis. Unlike other commodities, which have ups and downs, there are only two types of seasons for this commodity, a ‘bad year’ and a ‘year of survival’.

If agriculture is likened to betting big on a long shot, then establishing tree-crop horticulture in Australia’s Cyclone Regions is to bet purple on the roulette table. The reality is tree-crops are the most susceptible commodity a grower can produce in Northern Australia. Plantings require large capital investments upfront, require ongoing capital to establish and take several years before cropping commences.

The break-even point on most tree-crops is between 5 to 10 years, depending on the commodity. Given Australia, on average, has 13 Tropical Cyclones a year, that is upwards of 130 cyclones that a grower must survive to make an enterprise financially successful. Given that each cyclone has the potential to completely wipe out orchards, the odds are, arguably, unfavourable.

Yet, whilst the risk of Tropical Cyclones remains a constant, it is widely recognised that Northern Australia is the next powerhouse of tree-crop horticulture in Australia. With ample water, favourable growing climates and underutilised farmland, expansion of the horticulture sector, particularly tree-crops, is the next frontier for Australian agriculture. Australia’s plan to achieve a $100 billion agricultural sector by 2030, as driven by the National Farmers Federation, can only be reached if development of Northern Australia occurs.

If Australia is to realise the opportunity for expanding its horticulture sector, particularly for tree-crops, growers must develop and implement new mitigation and management measures to ensure orchard resilience and sustainability of the industry. Whilst there has been piecemeal research done to date, the reality is that a significant increase in financial investment in Research, Development and Extension (RDE) is critical.

Australia is not alone in this journey. In fact, compared with some countries that face the risk of Tropical Cyclones on a yearly basis, Australia has a relatively reduced and well-defined Tropical Cyclone season. Risk identification and mitigation work being done on a global basis must be the foundational stone to which future collaboration between growers and government is built. With the emanating and evolving risks associated with climate change and the potential implications this has on Tropical Cyclone activity, there is simply no avenue in which Australia can start the process of adaptation from scratch.

This report investigates the risks that Tropical Cyclones present to Australia’s horticultural sector with a focus on tree-crops and highlights potential mitigation and management measures that may assist growers to sustain and expand their orchards through the next century.

Chapter 1: The Status Quo

Tropical Cyclones are severe weather systems that form when a tropical low, known as a low-pressure system, encounters favourable conditions over a warm body of water. Tropical Cyclones generally impact Australia between 1 November and 30 April each year, however, earlier and later Tropical Cyclones have been known to occur.

Since the 1970s, the earliest confirmed Tropical Cyclone to directly impact Australia was Severe Tropical Cyclone Ines, which crossed the northern Kimberley on 21 November 1973. One of the latest Tropical Cyclones in a season was Tropical Cyclone Herbie that passed over Shark Bay on 21 May 1988.

1.1 Formation of a Tropical Cyclone

According to BOM, 2025, a Tropical Cyclone is defined as a weather event that:

- is a warm-cored, non-frontal low-pressure system of synoptic scale developing over warm waters.
- has an organised convection.
- has a maximum mean wind speed of 63 kph (10-minute mean) or greater extending more than halfway around near the centre.
- persists in intensity for at least 6 hours.

For a Tropical Cyclone to form and sustain itself, certain meteorological conditions are required. These requirements are:

1. **Warm ocean temperatures:** The ocean temperature is at least 26.5°C.

2. **A low pressure system:** The low pressure system causes warm, moist air to rise from the ocean.

3. **Force and movement:** As the warm, moist air rises, the developing Tropical Cyclone begins to spin. When there is a cluster of thunderstorms over a warm ocean in an area of a low pressure, they can form a band and start rotating, which grows and sustains the Tropical Cyclone.

4. **Additional moisture:** As the Tropical Cyclone begins to rotate, it draws additional warm, moist air. This comes from evaporation from the sea or is pulled in at low levels by the wind. As the air nears the centre, it spins faster. The winds become stronger, drawing in air more quickly.

5. **The eye and eyewall form**: Heavier, cooler air sinks into the low pressure region at the centre of the Tropical Cyclone. This creates a relatively calm area known as ‘the eye’. The eye is usually about 40 km wide but can range from 10 km to more than 100 km.

Once formed, Tropical Cyclones proceed on one of three paths. These are:

1. continual formation and strengthening; or

2. stalled formation and weakening; or
3. landfall and dissipation.

When over water, particularly an ocean, a Tropical Cyclone will generally continue to strengthen and gain intensity where favourable weather conditions persist. In most instances, this is how a Tropical Cyclone gains strength.

In certain circumstances, usually when weather conditions are not favourable, or other weather events are present, a Tropical Cyclone can stall and even weaken. Typically, a Tropical Cyclone will stall and weaken through self-strangulation.

The last scenario, the one to which this report ultimately relates, is when a Tropical Cyclone makes landfall. As the Tropical Cyclone crosses the coastline, it results in heavy rainfall and sustained winds. The combination of rainfall and winds is what ultimately causes damage to the built environment and natural resources.

1.2 Tropical Cyclones, Hurricanes and Typhoons

Tropical Cyclones, Hurricanes and Typhoons are all the same identified weather phenomena in that they have horizontal, rotating and organised systems of clouds and thunderstorms that originate over oceans.

The only difference between these events is the direction that they turn, which depends on the equator that they form within. Systems form anticlockwise in the northern hemisphere and clockwise in the southern hemisphere.

The designation that a system is given (either a Tropical Cyclone, Hurricane or Typhoon) depends on where the system forms. Specific designations are:

1. **Typhoons:** Systems that form in the northern Atlantic Ocean, central North Pacific Ocean and the eastern North Pacific.

2. **Hurricanes:** Systems that form in the northwest Pacific Ocean.

3. **Tropical Cyclones:** Systems that form in the south Pacific and Indian Ocean.

1.3 Australia's History of Tropical Cyclones

Whilst Australia has always been impacted by Tropical Cyclones, accurate records have only been maintained since the 1970s, corresponding with an advancement in satellite technology and the standardisation of definition, tracking and classification systems. Prior to the 1970s, records of Tropical Cyclones are based on ship reports and observations from land, which resulted in significant inconsistencies and inaccuracies with respect to the duration, intensity, location and factuality.

The earliest known record of Tropical Cyclone impacting mainland Australia was an unnamed event which struck Roebourne in the Pilbara of Western Australia in April 1872 (The Herald, 1872). This event is recorded as having destroyed the entire town.

There are limitations in analysing datasets associated with Tropical Cyclones due to changes in observing practices and technology that have occurred over time. With new

and enhanced technologies, the ability to detect and track Tropical Cyclones and to differentiate them from other tropical weather systems has greatly improved.

Changes in detection and tracking, as an example, has resulted in the ability to differentiate Tropical Cyclones from monsoon depressions, which in the past were likely recorded as Tropical Cyclones.

Available datasets from the 1970s onwards show that the total number of Tropical Cyclones making landfall in Australia appears to have decreased. However, there was a change to the definition for Tropical Cyclones in 1978 which led to some systems which would previously have been classified as Tropical Cyclones being considered sub-tropical systems.

On average, Australia experiences 11 Tropical Cyclones each year, with five reaching land and crossing the coast. Tropical Cyclones are influenced by several factors, and in particular variations in the El Niño-Southern Oscillation. In general, more Tropical Cyclones cross the coast during La Niña seasons, and fewer during El Niño years.

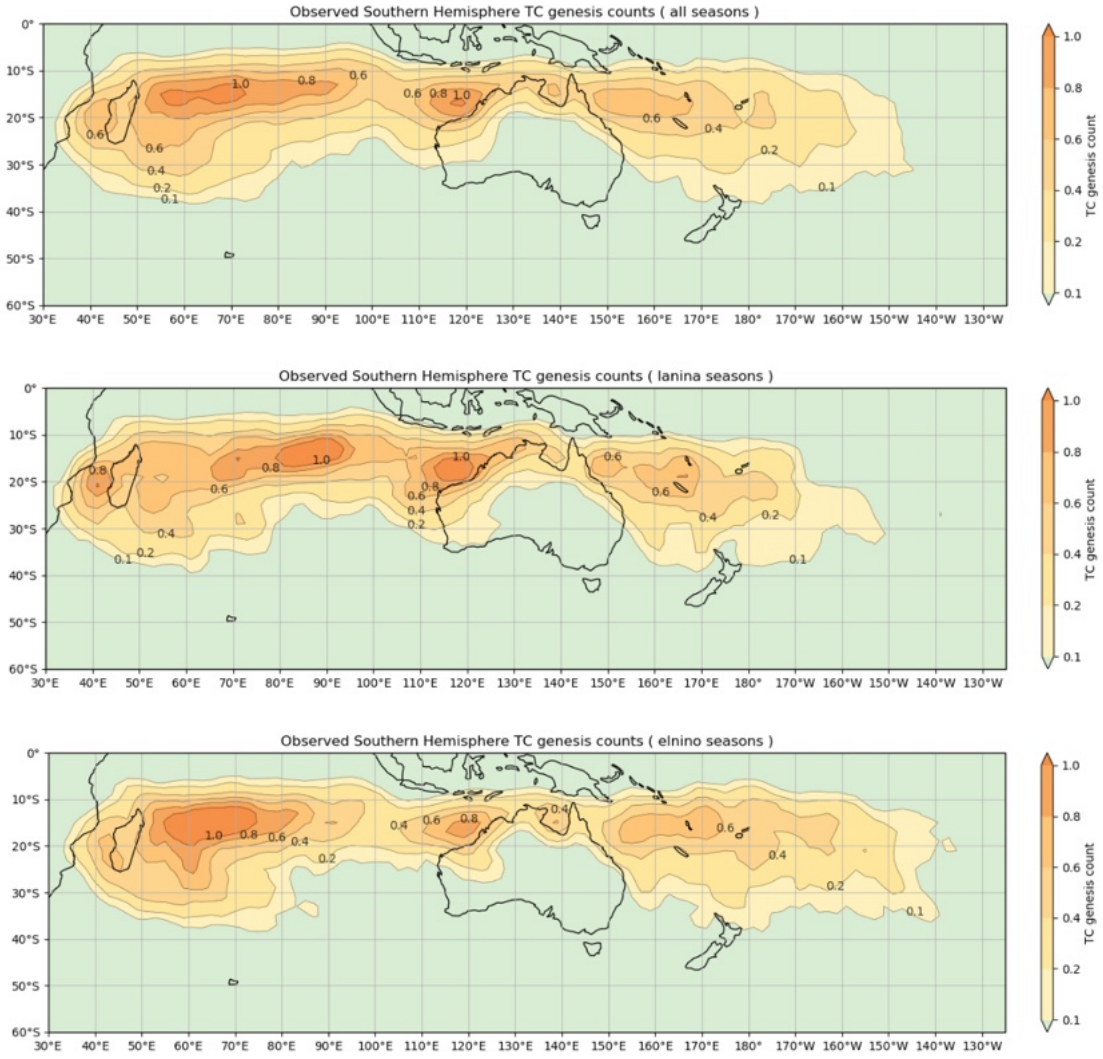

Figure 1: Variation in Tropical Cyclone occurrences (Source: BOM, 2025).

1.4 The Risks Tropical Cyclones Present to Agriculture

Tropical Cyclones are a critical threat to Australian agriculture as they deliver concentrated physical destruction and long-term economic instability to the nation's most productive tropical and subtropical regions. In 2025, events like Cyclone Alfred have highlighted that these storms are not merely weather events, rather massive supply-side shocks that can destabilise local economies and national food security.

The most direct risk is the sheer physical force of the storm. Intense winds exceeding 120 km/h strip leaves, break branches, and topple entire orchards. For example, in March 2025, Cyclone Alfred caused $17 million in reported horticultural damage in New South Wales alone. Conversely, Cyclone Debbie (2017), Cyclone Yasi (2011) and Cyclone Larry (2006) all caused over $1 billion in damage to the agricultural sector.

Beyond direct crop loss, Tropical Cyclones cause significant livestock mortality through drowning and exposure. They also destroy critical infrastructure such as fencing, irrigation systems and sheds. Heavy rainfall often leads to riverine flooding and storm surges that cause severe soil erosion or saltwater intrusion, potentially rendering agricultural land infertile for extended periods.

Tropical Cyclones matter for farming because they paralyse the logistics required to get produce to market. Flooding and debris frequently isolate farms, cutting off power to essential facilities like dairy refrigeration or climate-controlled fruit storage. These disruptions contribute to immediate nationwide price spikes for commodities like bananas, tomatoes and capsicums.

Economic impacts to Australian agriculture associated with Tropical Cyclones are projected to cost between AUD $300 million and AUD $1.2 billion each year. The cumulative cost associated with Tropical Cyclones is estimated to be approximately AUD $23 billion since 1967, with cost implications having tripled since the 1990s.

Chapter 2: The Evolving Risk

The purpose of this chapter is to explore whether the risks associated with Tropical Cyclones are consistent or changing, particularly with consideration of climate change.

For this report, it is assumed that the impacts of Climate change, as projected through modelling, are accurate. Importantly, this chapter does not provide an opinion on climate change, or the influence of anthropogenic factors on climatology.

2.1 Tropical Cyclone Patterns and Trends

To understand the potential for evolving risks, it is important to firstly explore and highlight what, if any, patterns and trends exist in the impacts associated with Tropical Cyclones. Caution must be expressed when considering and interpreting historical trends due to changes in detection and tracking methodologies, variances in records and the general lack of qualification and accuracy of datasets (CSIRO, 2025).

Due to limitations in reliable long-term data, especially prior to the introduction of satellite technologies in the 1970s, it is difficult to accurately identify and discern the long-term characteristics of Tropical Cyclones. Since the use of satellite technologies commenced, there has been a downward trend in the number of Tropical Cyclones observed in the Australian region on a year-to-year basis. Non-satellite records and observations suggest there has also been a longer-term reduction in the total number of Tropical Cyclones since the 1900s.

Intensity is much harder to quantify than frequency due to uncertainties in estimating the intensity of individual Tropical Cyclones, and the relatively small number of more intense Tropical Cyclones which have occurred since the 1970s. There is, however, evidence of changes in other aspects of extreme weather patterns, particularly the intensity of rainfall events and longevity of drought, which suggest that there is a change in the level of intensity associated with Tropical Cyclones.

According to CSIRO (2025), there have been fewer cold days and nights, and more hot days and nights, as well as heatwaves globally in the past 50 years. The number of heavy rainfall events has increased in frequency over most areas of the globe, along with the length of dry spells. Changes in the level of precipitation has also been noted with levels increasing in the Americas, northern Europe, parts of Asia and north-west Australia whilst reducing in central and southern Africa, the Mediterranean and southern Asia.

These long-term global climate trends are occurring alongside normal weather variations that happen naturally over seasons or decades. Without a more broad-scale dataset, it is simply not yet possible to draw accurate conclusions around trends and patterns associated with Tropical Cyclones. However, whilst conclusions cannot be drawn, it is possible to note a correlation of factors which suggest that, on average, there is a tendency for Tropical Cyclones to be more destructive than historically recorded.

2.2 The Influence of Climate Change

The impacts of climate change are likely to continue affecting the meteorological conditions associated with Tropical Cyclones. Climate change has been linked to influencing the formation and behaviour, particularly intensification and sustainment of Tropical Cyclones (Abbs, 2010).

Impacts associated with climate change are likely to include:

- How often Tropical Cyclones form;
- The maximum wind speed of Tropical Cyclones;
- The amount and intensity of rainfall associated with Tropical Cyclones;
- The speed at which Tropical Cyclones move;
- The strength Tropical Cyclones retain after making landfall; and
- The geographical range of impacts associated with Tropical Cyclones.

The Australian Climate Council (2025) notes that Tropical Cyclones form most readily when there are very warm ocean surfaces and strong temperature gradients through the atmosphere. The primary outcome of climate change is most notably reported as a warming climate (a warming planet), which means the temperature gradient is likely to decrease. As a result of the temperature gradient decrease, the formation of a Tropical Cyclone is less likely to occur and therefore the total number of Tropical Cyclones that form each year will decrease.

Conversely to the frequency of formation, however, climate change is also noted as resulting in rising ocean temperatures and a warmer, wetter ocean atmosphere. This is important as these meteorological considerations are considered as the critical variables which form and sustain Tropical Cyclones. It could therefore be deduced that whilst the total number of Tropical Cyclones that form each year may decrease; the intensity of these events is anticipated to increase. Patricola and Wehner (2018) identified that two destructive Hurricanes (Irma and Maria) had a 6% and 9% respective increase in total rainfall compared with a pre-climate change scenario.

While there may be differences in the state of knowledge about these various trends and their links to climate change, there is little doubt that overall, climate change is increasing the destructive power of Tropical Cyclones. This is especially true when considering other impacts of climate change that, while not directly affecting Tropical Cyclone behaviour, are nonetheless increasing the dangers.

The increase in sea levels means that storm surges associated with Tropical Cyclones and often a notable risk, are higher and penetrate further inland than previous experiences. Climate change is also damaging many natural coastal defences, including coral reefs and mangroves, leaving communities and infrastructure more exposed. Furthermore, the intensity and duration of rainfall events associated with Tropical Cyclones is likely to increase resulting in significant impacts from flooding.

Chapter 3: Managing Risk

The purpose of this chapter is to explore what measures growers can implement to increase preparedness for and manage risks associated with Tropical Cyclones.

In a conventional risk management hierarchy, management actions present as a low-level control measure compared with that of avoidance or mitigation. Strategically, any business that aims to avoid the impacts associated with Tropical Cyclones is highly likely to falter, similarly to those that look purely to mitigate.

Unlike traditional industries, agriculture cannot generally avoid weather-related risk as the risk itself is a given part of farming. This holds true for the types of tree-crop horticulture typically grown in Northern Australia, which is geographically limited and as such, management actions are regarded as the better risk management option.

At this juncture, crop insurance would be a logical consideration. However, at the time of authoring this report, this option is not available in Australia. Globally, crop insurance is an option in several countries, including the United States, however, it is subject to its own challenges. Risk management considerations have therefore focused on on-ground (grower-led) solutions, noting that the adaptation of crop insurance is likely to require a significant change in policy relation to agriculture.

3.1 High-density Plantings

High-density orchard plantings, whilst not a new concept in agriculture, is a relatively new notion for the tree-crop industries, particularly those in the tropical climate associated with Northern Australia. The concept, whilst self-evident in its namesake, is quite complex and there is no set definition as to what 'high-density' is.

In actuality, the mathematical equations behind high-density plantings vary location to location, industry to industry, and grower to grower. In speaking with growers, it can be inferred that high-density means to increase planting densities by at least 100% over that of a traditional approach for any tree-crop.

Extending beyond this thinking, there are a broad range of terms that have gathered momentum in tree-crop horticulture over recent years. Numerous growers and researchers used terminology such as high-density, ultra-high density, low-density and even borrowed terminology from other industries when referring to planting densities.

A typical example, which demonstrates the differences between traditional density, high-density and ultra-high density in North Queensland is provided below. It is noted that the example given here is a generalised approach and the author acknowledges a broad range of planting densities exist in north Queensland.

<u>Traditional density</u>

- Tree Spacing: 6m
- Row Spacing: 10m
- Tree planting: 1 tree per 60m^2
- Planting Density = 166 trees per ha

High-density

- Tree Spacing: 3m
- Row Spacing: 6m
- Tree planting: 1 tree per 18m^2
- Planting Density = 555 trees per ha

Ultra-high density

- Tree Spacing: 2.5m
- Row Spacing: 4m
- Tree planting: 1 tree per 10m^2
- Planting Density = 1000 trees per ha

Figure 2: High-density mango plantings in Mareeba north Queensland (Source: DAF, 2024).

High-density plantings provide an approach to tree-crop horticulture which improves resource utilisation, reduces input costs, and generally provides for an increased financial return on a per ha basis. Several industry representative bodies and RDE organisations have published papers on the benefits of high-density plantings and examine, in detail, the variances in inputs and outputs which varies crop to crop. Increasing planting density does not directly create a mechanism for managing risks associated with Tropical Cyclones. Rather, the potential benefit is achieved via a co-benefit outcome.

Traditional density orchards, as shown above, are typically planted at or around 166 trees per ha on a wide tree-to-tree and row-to-row spacing. This allows trees to grow to significant heights, upwards of 5m in many instances, creating a tree with significant vegetative mass. Comparatively, a high-density orchard works on the basis that trees are grown closer together and are pruned on a more regular basis to ensure

interconnection of tree branches does not occur, and so that tree height can be managed, generally to 2-3m above ground.

Height management, which is created as a result of growers seeking efficiency in the production cycle, reduces exposure of the orchard to winds from Tropical Cyclones, which then, in turn, reduces the potential for orchard damage. Reducing damage to an orchard as a result of trees being less likely to be damaged or blown over is a desirable outcome, and an outcome that has the potential to manage impacts associated with Tropical Cyclones.

As noted, high-density orchards are typically associated with a higher financial return on a per ha basis which is largely driven by a reduction of costs (including both input quantities and labour requirements) and increased yields. If a grower can crop high-density orchards, the financial return over a given time period can be considered a management measure for Tropical Cyclones, as net returns can be used to buffer economic losses in the event of a Tropical Cyclone occurring.

From conversations with growers, yield to density considerations vary from crop to crop and location to location and are further seasonally influenced. For the purpose of this report, a notional 10% yield was adopted. Assuming that a grower can achieve a marginal increase of 10% net return per ha using a high-density planting regime, then, and a Tropical Cyclone occurs with a frequency of impact (to that orchard) of 1 in 5 years, then the grower will be well positioned to cover these losses, as shown below using a hypothetical calculation.

Traditional Return

- Yearly Net Return: $20,000
- Net Return over 5 years: $80,000 (Year 5 = 0% return)
- Recovery Costs: $10,000
- Financial Position (at year 5): $70,000

High-density Return

- Yearly Net Return: $22,000
- Net Return over 5 years: $88,000 (Year 5 = 0% return)
- Recovery Costs: $15,000
- Financial Position (at year 5): $73,000

In this scenario, whilst the grower still loses the crop in the fifth year, financially, the transition to high-density plantings provides for a management measure that results in the grower being financially (albeit only slightly in this example) better off.

Higher density plantings require a change in grower mindset and a more thorough consideration of production cycles and schedules. With this criticality, there comes an increased reliance on skilled labour. As many growers will attest, access to labour is challenging, access to skilled labour is even more so. In high-density plantings, it is imperative that crop production triggers, especially pruning is managed on time and completed to a high standard. Where these requirements are missed, or not executed properly, the grower risks a potential decline in yield per ha meaning that whilst input costs remain, the increase in production yields may not be achieved, thus jeopardising the financial benefit in adopting this approach.

This would result in the projected net return advantage being lost, potentially resulting in the grower being financially worse off, as shown below.

Traditional Return

- Yearly Net Return: $20,000
- Net Return over 5 years: $80,000 (Year 5 = 0% return)
- Recovery Costs: $10,000
- Financial Position (at year 5): $70,000

High-density Return (less 5% yield increase)

- Yearly Net Return: $20,000
- Net Return over 5 years: $80,000 (Year 5 = 0% return)
- Recovery Costs: $15,000
- Financial Position (at year 5): $65,000

3.2 Trellising and Supported Plantings

Like high-density plantings, the concept of trellising and/or supporting plantings is not new, and in reality, is commonly applied across a multitude of crops already. Crops grown in temperate climates, particularly stone fruit, were early adopters of trellising systems. Similarly, grapes, passionfruit and hops are routinely grown with a degree of supporting infrastructure. What differs between supported plantings and non-supported plantings is that trellising has the potential to manage Tropical Cyclone risks irrespective of any potential benefit in cropping.

Trellising can be effectively likened to that of structural engineering. Whilst it is possible to build a house without considering structural engineering, the potential for a catastrophic failure becomes elevated, almost to the point of being guaranteed, particularly when wind becomes a contributing factor. When applied correctly, however, houses can withstand winds and are much less likely to fail (to collapse).

A trellised orchard is a noteworthy concept in the tropical climate and one which has been trialled with mixed results across a range of crops. Trellising is considered to be most effective when combined with a high-density planting regime as benefits in yield can be used to offset increased costs, particularly during orchard establishment.

Depending on a broad range of factors including density, trellis type, material selection, geographical location and labour, actual costs for Trellising may vary from a few thousand to tens-of-thousand per ha. The premise of trellising or supporting tree crop orchards focuses on the provision of a reinforced structure which provides a physical support to plantings in the event of high winds resulting in a reduction of tree damage and uprooting.

The concept of trellising for Tropical Cyclone resilience works on the basis that a grower may lose a crop in a given year, however, does not incur substantial damage to the orchard meaning that production will occur in the following year. In a conventional planting situation, the grower without trellising would not only lose the crop, would be required to repair the orchard and would require a period of 3-5 years before cropping can re-commence.

Using the hypothetical calculations from Section 3.1, the following can be adopted to highlight the potential benefit to growers.

Traditional Orchard

- Yearly Net Return: $20,000
- Net Return over 5 years: $80,000 (Year 5 = 0% return)
- Recovery Costs: $10,000
- Financial Position (at year 5): $70,000
- Financial Position (at year 10 assuming 3 years of recovery): $110,000

Trellised Orchard

- Initial trellis setup costs: $10,000
- Yearly Net Return: $20,000
- Net Return over 5 years: $80,000 (Year 5 = 0% return)
- Recovery Costs: $0
- Financial Position (at year 5): $80,000
- Financial Position (at year 10): $180,000

It is important to recognise that the use of trellising and supporting structures has historically been for improving production yields and as such, the use of trellising and supporting structures as management measures for Tropical Cyclones is largely untested. Preliminary research work has been completed by the Queensland Government over the past 10 years, with support from growers; however, this was limited in its scope and did not test actual trellised crops against a Tropical Cyclone. Some growers have independently trellised a variety of crops with mixed results.

There exists ambiguity in trellising type and selection, particularly on a crop-to-crop basis, which makes consideration of its applicability for managing Tropical Cyclones challenging. In the horticultural regions of Tatura and Shepparton in Victoria, Australia, no less than four separate trellis types were observed in use for the same crops with the differentiating factor being the grower's preference.

Figure 3: Espalier Trellis (top) Vs free-standing (bottom) orchards in Tatura Victoria (Source: Author)

Two types of Tatura Trellis, open and closed were observed, as well as two types of Espalier Trellis. Tree spacing was also a common variable with no two orchards being fully identical in setup. Whilst economic drivers such as crop cycle, crop use (e.g. fresh consumption Vs canning/juicing) and machinery selection played a critical role in how a grower ultimately selected the type of trellis to be utilised, their use was consistent with only older orchards maintaining free-standing trees.

Figure 4: Open Tatura Trellis (V Trellis) in Shepperton Victoria (Source: Author).

Whilst there is limited work on the use of trellising to manage impacts from Tropical Cyclones, it is important to note the impacts of Tropical Cyclone Gabrielle (Category 3 event) which impacted the North Island of New Zealand in February 2023. In this instance, tree crops which employed trellising were subjected to winds of circa 165kph, however, were still uprooted causing widespread damage, particularly across the Hawke’s Bay region.

The cause of the damage was not attributed to wind speed, rather, the main consideration and causation of damage was the significant rainfall and subsequent flooding which caused weakness in the soil profile allowing the trellis structure as a whole to be tipped, resulting in a loss of crops and the need to rebuild and replant whole orchards.

Importantly, the trellis selection in the Hawke’s Bay region was neither selected for nor constructed to withstand the impacts from Tropical Cyclones so a direct comparison is not possible, nor should this be used to determine the effectiveness of trellising as a risk management scenario.

3.3 Canopy Management

In traditional orchards, canopy management presents an opportunity to implement management measures where conversion to, or adoption of, high-density or trellis-style plantings is not possible. Without proof of concept, it is a high-risk endeavour for growers to remove productive orchards, despite the risks of being severely impacted by a Tropical Cyclone remaining.

Canopy management is typically associated with orchard management and pruning to encourage crop production each year. Typically, more vegetative branches are pruned and removed from the tree crop, leaving behind branches which are more likely to promote flowering and crop production.

Extending beyond this thinking, however, is the concept that canopy management can be used to manage the impacts of Tropical Cyclones on tree crops. In particular, the shaping of tree crops, particularly from an early age, can help to promote strong orchards which have the ability to withstand higher winds.

Reducing vegetative covering and density allows for more wind penetration through trees, making them less likely to falter under heavy winds, including those associated with Tropical Cyclones. Additionally, trees can be managed to a set height with the concept of height management presenting another option for growers to manage risk.

Figure 5: Pruning high-density jackfruits for canopy management (Source: Author).

3.4 Varietal Genetics and Propagation

Variety selection and propagation has historically been focused on identifying and capturing desirable market characteristics and producing new varieties for orchard planting. Once desirable characteristics are identified, trees are produced to order by commercial propagation nurseries and transported for planting by growers. Typically, growers may wait up to two or even three years to receive their order.

Whilst varietal selection has tended to focus on market characteristics, this has been at the expense of other considerations like tree shape and strength. For example, in avocados, the ‘Velvick’® variety is used almost exclusively for rootstocks given its resistance to disease, particularly phytophthora. In solving one orchard issue, the use of ‘Velvick’® has created orchards which are highly susceptible to waterlogging and trees which have high input requirements for commercial production.

Variety selection must evolve beyond a siloed focus on cropping characteristics and must be broader in its consideration to the creation of resilient trees which have strong roots and produce desirable tree architecture and height. Arguably, it is more productive for a grower to have an orchard that produces more consistently less volume than one that produces more volume less consistently.

Propagation plays a considerable role in developing resilient orchard trees and should be further considered by commercial nurseries. Whilst the use of plastic planter bags and forestry tube pots is ideal from a commercial production perspective due to cost and area considerations, they have a high potential of creating trees with compromised roots through root binding and root spiralling. Comparatively, commercial nurseries in Israel recognise the importance of high-quality trees in extreme desert environments and have commenced the use of improved pots with natural air pruning to address these issues. Whilst this may present as an additional cost in the production cycle, the long-term benefit of this approach presents opportunities for the development of stronger, more resilient tree crop orchards.

Figure 6: Avocados produced using air-pruning pots in Israel (Source: Author).

3.5 Greenhouse and Hothouse Technology

Tree crop orchards, particularly those in the tropical climate, have traditionally been developed with plantings placed into earthen ground. This approach provides a broad range of benefits including soil-based nutritional benefits and rainfall which reduces the manual inputs required by a grower. These orchards are, however, susceptible to the impact of climate variables which can have a notable impact on yield and production.

The use of soil-based plantings has given way to alternative production methods for a range of crops over the past 10-15 years. In particular, the berry industry has adopted the use of hothouses with plants grown in substrate. Similarly, the medicinal marijuana industry adopts a similar approach. This allows the inputs to be carefully managed and reduces (to the point of elimination), the impact of climate on productivity. Climatic impacts are an important factor, particularly for terminal-bearing crops (e.g. mango, rambutan, etc), which require distinct climatic events to trigger flowering, fruit set and fruiting.

There is the potential that this growing methodology can be applied for tree crops which are grown in areas subjected to Tropical Cyclones. Whilst establishment costs would be significantly higher than that of a traditional orchard, the potential long-term benefits of growing high value horticultural products in an enclosed environment such as a greenhouse or hothouse has the potential to increase production yields and manage impacts from climatic variables, particularly rainfall.

The use of this technology opens up another possibility; that of producing out-of-season production. Where enclosed greenhouses are used (typically referred to as glasshouses), there is a potential that mechanical optionality can be used to trigger floral induction in tree crops out-of-season through the manipulation of drought stressing, temperature and lighting conditions. Under this scenario, a grower could potentially produce out of season products resulting in a market premium and negate the impacts of Tropical Cyclones on production. This approach has been adopted in Japan, where out-of-season production of mangoes occurs using glasshouses.

Figure 7: Peppers grown in climate-controlled greenhouses in the Netherlands (Source: Author).

Figure 8: Medicinal Cannabis grown in climate-controlled greenhouses Israel (Source: Author).

Figure 9: Tomatoes grown in automated glasshouse in the Netherlands (Source: Author).

3.6 Chemistry and Technology

There exists an opportunity for the use of chemistry and technology in tree crop orchards to manage risks associated with Tropical Cyclones. In Australia, tree crop orchards are at their most vulnerable during the defined Tropical Cyclone season, which generally also correlates with floral initiation, fruit set and development. By extension, tree crop orchards are at their most vulnerable to weather during the most critical time of the year for production.

Advances in chemistry have occurred over many years with most crops able to access specific pesticides (particularly fungicides and insecticides) that targets a specific problem pest or achieves a targeted outcome. The use of chemistry can also have positive effects with regards to fruit thinning (reducing total number of fruits to allow fruit size to increase). In other countries, particularly in Malaysia and Thailand, the use of inorganic chemistry options is common practice and allows for floral induction to occur out of season. This results in the grower being able to manage production timeframes, generally through the staggering of production to enable an improved cash flow.

The use of chemistry in Australia is generally limited by the existence of regulations as governed by the Australian Pesticides and Veterinary Medicines Authority (APVMA). A broader allowance under APVMA governance would allow for greater RDE regarding chemistry and may ultimately allow for growers to adopt out-of-season production methods.

Similarly, the rise of technology provides growers with a potential avenue to better manage orchards and time critical application of inputs. In crops like dragon fruit, where light is a major consideration for fruiting, the use of artificial lighting can significantly increase total production on a yearly basis. Technology has the potential to expand and can be used to artificially manipulate the input requirements relevant to floral induction in tree cropping. For example, trees that require a drought-stress triggering for flowering can use technology which reduces water penetration and brings on floral induction regardless of weather patterns.

Conclusions

Tree-crop horticulture in Northern Australia stands on a knife’s edge. The sector is already vulnerable to Tropical Cyclones which are predicted to increase in severity as a result of climate change. The occurrence of the next ‘big blow’ is not an if; it’s a matter of when. There is early adoption of resilient production methodologies, however these are limited, and significantly increased uptake is required.

If long-term weather modelling projections are to be considered as the new reality for tree-crop horticulture, then the severity of future events is unlikely to leave most orchards untouched. Climate change, by its very nature, poses a risk to food security and the resilience and sustainability of Northern Australia’s agricultural commodities.

What this report was unable to do was present a single ‘golden bullet’ solution to the problem of Tropical Cyclones. Rather, a broad range of potential management measures which can be considered and adopted by growers to reduce their exposure to Tropical Cyclones and manage risk has been identified. Whilst the strategies are presented, it is ultimately up to industry to adopt them.

It is the author’s view that the most effective long-term solution to Tropical Cyclones is to develop methods of cropping using engineered greenhouses and hothouses. The pressure that exists on tree-crop horticulture is immense and requires not only the mitigation and management of evolving cyclone risks, rather it also requires the ongoing finding of efficiencies and production values. In reality, the only way that seems likely for this to be achieved for growers, whilst managing risk, is to utilise alternative production mechanisms.

Tree cropping is a difficult business and one which is subject to long-term payback periods and eve- diminishing margins. To ask growers to reduce their pursuit of market quality characteristics in favour of climatic sustainability is a bold position, however, it is one that is necessary from a long-term risk management perspective. Creation of resilient orchards will not occur overnight; it requires generational change.

Figure 10: Engaging with school children learn about agriculture in Japan (Source: Author).

Key Findings and Recommendations

The Australian tree crop industries will continue to see increasing impacts from Tropical Cyclones in the future. As the pressure for growers to find ongoing yield improvements with reduced inputs and on tighter margins intensifies, the impact from a single event could have demonstrable and irreversible effects on food security and industry sustainability. Growers must be prepared to adapt and implement measures to manage ever-present risk.

Long-term climatic modelling indicates the potential for increased severity of Tropical Cyclones leading to the potential creation of a Category 6 event. Increasing ocean temperatures will provide the mechanism for Tropical Cyclones to intensify more quickly and stay active for longer periods prior to crossing the Australian coastline.

The repercussive impacts of these events are not limited to coastal communities, as has been experienced in the past and is likely to have impacts to inland commodities including the broadacre and cattle sectors.

To manage risks associated with Tropical Cyclones, there are three key areas where industry and government must collaborate and execute a single, aligned strategic plan to provide Australia's agriculture sector with the skillsets needed for survival.

1. **Grower-led Change:** These 'on-ground' changes that growers can implement in the short and medium term focus on developing and implementing alternative methodologies for growing tree crops in impacted areas. Leveraging other industries, particularly those in the temperate climates, and adjusting approaches means that growers can focus on resilience over marketability in isolation. Adapting to new production thinking, with a focus on orchard resilience, is a key long-term management measure for mitigating impacts from Tropical Cyclones.

2. **Nursery-led Change:** These changes are critical in providing growers with resilient trees that can be planted and cultivated. The current focus on developing tree stocks with ideal marketable characteristics in production must be reduced with an increased focus on propagating healthy and stronger trees. The long-term benefits to industry are difficult to measure with existing metrics, however, are very likely to make initial upfront capital costs a strategic investment.

3. **Government-led Change:** Whilst growers and nurseries can collaborate to implement measures for developing resilient orchards, it falls to government to ensure the pathway for change is navigable. Governments at all levels must invest in making the adaptation and implementation of new growing mechanisms easier and unlock the potential for growers to use more technology and smarter inputs as standard production techniques. The creation of an industry insurance scheme will provide the potential for de-risking the costly upfront capital requirements enabling a broader range of growers to create change.

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