Mid West & Gascoyne Coastal

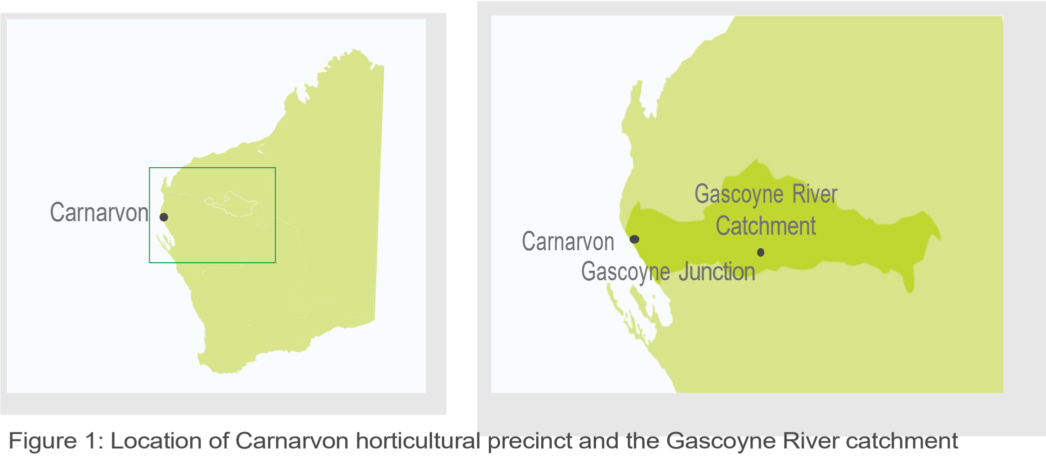

Figure 1: Location of Carnarvon horticultural precinct and the Gascoyne River catchment that supplies the aquifer recharge for irrigation

Key messages

- By 2050, the Carnarvon horticultural precinct is expected to be hotter with about 23% more days above 35°C (medium emissions scenario) than the 30-year average 1991– 2020.
- By 2050, annual rainfall at Carnarvon is likely to be similar to the present day (200mm) with summer rain projected to increase and winter rain projected to decrease (but summer rainfall projections less confident than winter projections).
- Cyclone and flood intensity likely to increase
- New crops and genetically superior varieties will be needed to match the new climate.
- Growing practices will need to be adapted to account for increased temperatures.
- Protected cropping systems will probably become more common to meet the challenges of a hotter, potentially more extreme climate.
- Efficient irrigation and scheduling systems and extension of these to industry will be critical for optimising water use efficiency.

Location and industry demographics

The Carnarvon horticultural district extends 20 kilometres eastward from the town of Carnarvon along the fertile delta of the Gascoyne River. Soils of the horticultural district have developed from alluvial sediments deposited on terraces that extend about one kilometre on either side of the river.

Irrigated agriculture has been undertaken in the area since the early 1900s. Originally based on bananas and vegetables, production has now expanded to many different tropical and temperate crops and the irrigated horticultural area is one of the most productive in Western Australia (Table 1).

In 2020, horticultural production was valued at nearly $110m – with about two thirds of this coming from vegetable crops and a third from fruit crops. Mining ($600m), tourism ($200m) and agriculture and fisheries ($150m) also generate significant revenue for the region.

Figure 2: Aerial photo of the horticultural precinct along the Gascoyne River at Carnarvon

Irrigation water resources

Growers in the Carnarvon horticultural precinct obtain irrigation water from two sources – self supply from the shallow aquifer and the irrigation scheme run by the Gascoyne Water Cooperative.

Self-supply from Basin A

Growers with properties next to the river have a Basin A licence that allows them to pump from the shallow aquifer beneath the riverbed and adjacent land. Individual blocks receive a water allocation of up to 10,000kL each month. This amount can decrease during prolonged periods of no river flow to conserve fresh water and prevent intrusion of saline water from surrounding aquifers. Pumping from Basin A is stopped when the water salinity reaches 1000mg/L total dissolved salts. Maximum annual allocation for all horticultural blocks is 72,000kL but, when the river is flowing growers can pump freely from their river frontage bores.

In most years, the aquifer is recharged when the Gascoyne River flows (typically) in the first half of the year as tropical rain coming from the North West falls on the Gascoyne and Lyons River catchments.

Gascoyne Water Cooperative

The Gascoyne Water Cooperative maintains and administers an irrigation scheme that supplies water to irrigators. Water is sourced from bore fields that extend on both sides of the river from the eastern end of the horticultural area east towards Rocky Pool. The price of water to the grower is 36c/kL, which is moderately expensive by Australian standards. In total, allocated water in the scheme is about 9.6GL with about 8GL per annum being supplied. Current Department of Water and Environmental Regulation modelling predicts that the bore field can supply about three years of water at 9.6 GL/annum (assuming no river flow). Past river flow records show the longest period of no river flow was about 30 months. The reliability of supply of the scheme water is very good.

Gascoyne Food Bowl Initiative

An additional 4GL of water has recently been made available through the Gascoyne Food Bowl project – a WA Government initiative to provide additional land and water for the expansion of irrigated agriculture at Carnarvon. About 400ha of land has so far been released and allocated through the scheme, predominantly for table grapes, mangoes, sweet potatoes, rockmelon and watermelon, as well as zucchini, tomatoes, eggplant and capsicum to supply export and domestic markets.

Table 2: Average annual rainfall (mm) at Carnarvon and inland at Gascoyne Junction between 1960-1990 and 1991-2021

Years	Rainfall	Carnarvon	Gascoyne Junction
1961-1990	Annual average	229	211
	May-Oct	155	113
	Nov-April	74	98
1991-2021	Annual average	216	220
	May-Oct	136 (-12%)	87 (-23%)
	Nov-April	80 (+8%)	133 (+36%)

*Data in brackets indicates change in rainfall over the past 30 years.
Source: BOM data via Dr Meredith Guthrie DPIRD

Average summer rainfall has increased by 36% across the Gascoyne River Catchment in the past 30 years while winter rainfall has fallen by 23%

Carnarvon's annual rainfall has declined by about 6% in the past 30 years compared to the previous few decades. Over the same period, there has been an 8% increase in summer rainfall (Table 2).

Temperature

Over the past 30 years (1991–2021), the Carnarvon horticultural precinct has experienced about 63 days above 32°C each year. This is about four days more, on average, than the previous 30 years (1960–1990) (59 days per year). On average (1991-2021) the Carnarvon horticultural precinct experiences about six days above 40oC each year. This has not changed significantly from the previous 30 years (1960-1990). The average humidity at Carnarvon is between 50 and 60% in all months of the year and can be as low as a 10%.

Wind

Wind speeds in Carnarvon are often strong, particularly in the spring and summer months – ranging from an average of 21.5 km/hour (May–August) through to about 30 km/hour (November to February).

Cyclones

Carnarvon has the highest risk rating for cyclones. Houses must be built to withstand Category 5 cyclones with wind speeds of 317 km/hour and infrastructure and protected cropping structures, such as net houses need to be built to a higher specification, which adds to their cost. On average, about five tropical cyclones occur over the warm ocean waters off the north-west WA coast each cyclone season (Nov-April) and about two cyclones cross the coast, one of which is severe. Cyclone Olwyn in 2015 destroyed the Carnarvon banana season and cyclone Seroja in 2021 took out the town jetty. Since 1980, the frequency of tropical cyclones has not changed significantly in WA but there is some evidence that the frequency of the most intense cyclones has increased.[1]

Floods

Carnarvon has a history of regular flooding (about every decade) (Figure 3). In 2015, the WA Government constructed flood levees to reduce the impacts of large flooding events to the horticultural district. Flooding results in damage to crops and infrastructure and causes sheet and gully erosion.

Flooding in the summer of 2010–2011 caused the loss of an estimated nine million tonnes of soil from erosion, and a damage bill of about $90 million. Soil cultivation and cropping in gullies greatly increases the risk of soil erosion. Historically, government has provided replacement soil to flood-affected farms. The Department of Primary Industries and Regional Development is coordinating a review of Carnarvon flood plain management to mitigate the impact of future flood events.

The 2021 flow at Carnarvon was the largest flow event since 2011, and the first where all the breakouts along the river flowed since the construction of the 2015 levee system.

Climate change

Climate change models for the Carnarvon area show considerable variation. This contrasts with the southwest of WA where the modelling projections are more consistent. Rainfall in the northwest of WA is often driven by tropical moisture and cyclonic events, which by their nature are more variable than the cold fronts that bring rainfall to the southwest. Global climate modelling suggests this high annual variability in Carnarvon's rainfall will continue.

The WA Department of Water and Environmental Regulation is currently (2022) working with the

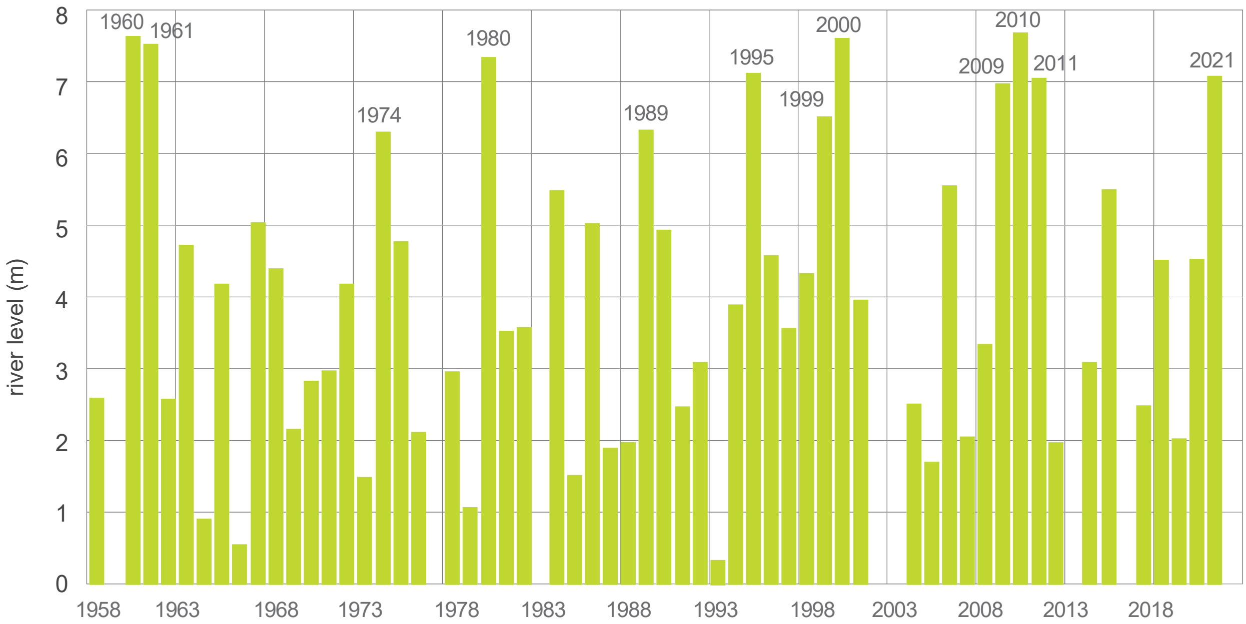

Figure 3: Peak annual water level for the Gascoyne River at Nine Mile Bridge, Carnarvon, between 1958 and 2021

Bureau of Meteorology to generate more accurate climate change models for the Gascoyne region.

It is likely that Carnarvon's future climate:

- will be hotter (Tables 3 and 4)
- will probably have less winter rain (higher confidence) and more summer rain (lower confidence) and overall, a similar annual rainfall to today (Table 3)
- may have fewer cyclones, but these are more likely to be intense and extend further south into the Gascoyne and possibly the Mid-West regions.

A warmer atmosphere and ocean are likely to promote higher rainfall rates, so while there may be large gaps between events, the rain may be heavier and flood risk could increase.

Streamflow in the Gascoyne River will remain episodic and highly dependent of tropical disturbances (low-pressure systems or fully developed cyclones).

Climate model projections of summer rainfall in the Gascoyne region have less confidence than those for winter rainfall because the cold front drivers underpinning a decline in winter rain are well established. However, the drivers of summer rainfall are less well understood and are therefore model projections are not as consistent.

The number of days that Carnarvon crops are exposed to heat stress is predicted to increase

The confidence of future rainfall projections for the Carnarvon region is low relative to those for the South West of WA. While annual rainfall levels are predicted to change by 2050, the direction of this change is unclear. For example, the annual rainfall projections for Gascoyne Junction by 2050 under a high emissions scenario range from as low as 70mm to as high as 368mm.

Table 3: Projected average rainfall and maximum temperatures at Carnarvon and Gascoyne Junction by 2050 under medium and high emissions scenarios compared with recent climate (1991–2020)

	Annual rainfall (mm)*		Summer rainfall (mm)*		Maximum temperature °C	
Emissions scenario	Medium	High	Medium	High	Medium	High
Carnarvon	248 (+20%)	212 (+2%)	66 (+53%)	57 (+32%)	28.9 (+0.9)	29.4 (+1.4)
Gascoyne Junction	214 (+0.9%)	187 (-12%)	66 (-20%)	60 (-26%)	33.8 (+1.4)	34.6 (+2.2)

Source: Climate Services for Agriculture

*Climate models for future rainfall at Carnarvon and Gascoyne Junction not as confident as those for the southwest of WA. Rainfall will change but degree and direction of summer rainfall are not yet clear. Please note values in Table 3 are based on predicted averages but range in predicted values is large. Medium emissions = greenhouse gas emissions reduced substantially by end of the century, but not enough to stop continued warming. Adaptation continues to become increasingly harder over time. High emissions = rapid increases in greenhouse gases continue towards the end of the century. Some systems are unlikely to be able to adapt to the large changes in climate.

Table 4: Projected number of heat risk days (days >35°C) at Carnarvon and Gascoyne Junction by 2050 under medium and high emissions scenarios compared with recent climate (1991–2020)

		Carnarvon		Gascoyne Junction	
Heat risk: (days >35°C)	Recent average (1991-2020)	30		137	
	2050 – medium emissions	37	(+23%)	165	(+20%)
	2050 – high emissions	42	(+40%)	175	(+28%)

Source: Climate Services for Agriculture

Medium emissions = greenhouse gas emissions reduced substantially by end of the century, but not enough to stop continued warming. Adaptation continues to become increasingly harder over time. High emissions = rapid increases in greenhouse gases continue towards the end of the century. Some systems are unlikely to be able to adapt to the large changes in climate.

significantly by 2050 - from a recent (1991-2020) average of 30 days per year to a projected average of 37–42 days per year depending on emissions scenario (Table 4).

Table 5 outlines the possible impact of predicted climate change in the Carnarvon area on crop production and infrastructure.

In summary:

- As the climate models are not consistent enough to categorically predict future rainfall in the Gascoyne, management of year-to-year rainfall variability will become increasingly important.
- Streamflow and aquifer recharge will remain episodic.
- When rainfall does occur it could be heavy, raising the flood risk.
- Cyclones could be fewer but more intense and damaging.
- There is high confidence in the climate model projections of higher temperatures, and this will impact crop yield and quality, water use efficiency and human wellbeing.

Rob Kuzmicich, Carnarvon vegetable grower

Industry perspective — adapting to climate change

- Protected cropping will play a significant role in adapting Carnarvon's horticultural industry to climate change. Retractable roof greenhouses allow temperature, wind and humidity to be adjusted according to seasonal conditions and crop needs. Net houses need to be built strongly so they can withstand cyclones.
- High temperatures and low humidity result in flower abortion for early planted capsicum crops, which may necessitate delaying planting for a week or two.
- Higher temperatures at the end of the season cause crop stress and damage and could crop water requirements increasing by 10 to 20%.
- Summer rain is a major problem for capsicum and cucurbit growers as weed growth creates a 'green bridge' that allows pests to over-summer and affect the following years crops.
- Areawide weed management is needed - including the removal of passion vine infestations from the riverbank and common areas.
- Development of native bush sites that allow the build-up of beneficial and predator insects should be trialled.
- The role of cover crops to cool soil temperatures and prevent heat radiating onto crops causing heat stress and sun burn damage requires further investigation.
- We need to work out how to protect areas without levees from floods.

Rob Kuzmicich
Carnarvon vegetable grower

Table 5. Possible impact of predicted climate change on Carnarvon's horticultural productivity and infrastructure

Climate Change	Production Impact
Increased temperature	Increased number of heat stress days may necessitate delayed planting, which could reduce harvest volume and impact on profitability. High temperatures and low humidity cause flower abortion in early planted capsicum crops. High temperatures at the end of the season cause crop stress and damage. Area suited to temperate crops could decline but area suited to growing tropical and subtropical crops could increase. Energy costs could increase with greater need to chill produce Irrigation water requirements likely to increase with increasing temperature, radiation, humidity and wind speed. Current irrigation allocations might be insufficient forcing growers to buy additional water or reduce the area planted. Some fruit crops may need to be planted inside shade houses, which will affect profitability. Reduced difference between day- and night-time temperatures and warmer night-time temperatures could affect colour development in table grapes.
	Achieving acceptable skin colour in oranges and mandarins will be difficult to achieve under higher temperatures and could reduce profitability of production in Carnarvon. Avocados may become unprofitable at Carnarvon under future climate change scenarios. Sunburn of mangoes currently results in up to 20% of fruit being rejected and predicted rise in heat stress days will increase this damage. Any increase in temperature over the winter months will probably make stone fruit growing unviable due to insufficient number of chilling hours.
Reduced and variable rainfall	Groundwater recharge and run-off could decrease. If the Gascoyne River does not flow for two years, irrigation allocations could be reduced. Reduced irrigation supply would particularly affect perennial crop growers as the area planted cannot be easily reduced in response to irrigation supply. Summer rain is a major problem for capsicum and cucurbit growers as weed growth creates a 'green bridge' that allows pests to over-summer and affect the following year's crops. The increased likelihood of late spring and summer rain may increase crop disease risk.
More intense floods	Predicted increase in storm and tropical cyclone intensity will increase flooding and erosion risk and infrastructure damage. To put this in context: flooding in the summer of 2010–2011 caused the loss of an estimated 9 million tonnes of soil from erosion, and a damage bill of about $90 million. The 2021 flood caused an estimated $2.6 million in damage to infrastructure, crops and soil. Perennial crop growers often suffer more financial damage as these crops take many years to reach production age. Annual crop growers can also suffer major losses if cyclones occur after planting has commenced in February/March.
More intense cyclones and increased wind speeds	Wind is a major constraint to horticultural production in Carnarvon as it reduces plant growth and causes produce to be downgraded to second grade due to wind blemish. Predicted climate change will likely result in more damaging wind events. Increased tropical cyclone intensity could increase risk of infrastructure damage. To put this in context: the total value of lost production from Cyclone Olwyn in 2015 was $35.2 million and many growers did not reinstall net houses and windbreaks due to the high cost.
Seawater surge	Coastal aquifers are vulnerable to seawater intrusion — the landward encroachment of sea water into coastal aquifer, which can significantly degrade water quality and reduce freshwater availability. The unconfined superficial aquifer along the Gascoyne River from which horticulturalists abstract irrigation water has been rated as moderately vulnerable to saltwater intrusion.

Drought adaptation – past successes and RD&E gaps

While there has been no focused climate change R&D program in Carnarvon, in the past few years DPIRD has been investigating the capacity of protected cropping systems to mitigate the impacts of seasonal variability and future climate change on crop production and quality. A draft publication *The potential for protected cropping in Carnarvon* has been produced to underpin future research efforts in this area. To support the research, a Cravo retractable-roof greenhouse and a 1.3-hectare net house with four shade factors have been built at the DPIRD Carnarvon Research Facility, which covers 65 hectares close to the Gascoyne River in the plantation district. The greenhouse has a fogging system and the net house a misting system for humidity and temperature control. A digital data network has been installed and connected to soil moisture sensors, water flow meters and weather stations.

Table 6 outlines the drought/climate change adaptation levers that Carnarvon horticultural producers currently use to alleviate the impacts of drought and seasonal variation. Also outlined, is the RD&E needed to better equip producers to meet future climate change challenges.

Table 6: Summary of drought adaptation levers available to the Carnarvon horticultural industry and the RD&E gaps needing attention to better equip the industry in the face of projected climate change

Drought adaptation lever	What's worked?	What's needed?
Best practice agronomy	DPIRD is a participant in a CRC for Developing Northern Australia project investigating the use of trellis and fruit tree architecture to mitigate against cyclone damage. A trial has been established at the Carnarvon Research Facility investigating high density, small tree plantings of jackfruit on trellis.	Time of planting x variety trials to assess the impact of climate change on productivity. Further investigate the use of small trees and trellising to reduce cyclone damage of fruit crops. Investigate the role of cover crops to cool soil temperatures and prevent heat from radiating onto crops to cause heat stress and sunburn. Broadscale management of summer weeds to reduce spread of pests and diseases into crops the following season.
Protected cropping	Research at the Carnarvon Research Facility is investigating the capacity of net houses to mitigate against extreme weather events and reduce irrigation requirements for mangoes, persimmons and lychees. An eggplant trial is comparing three different shade levels under a net house to determine how shading affects growth, water use efficiency, yield and quality. Results from the trial will be transferrable to many other crops grown in the area. A small partial netted structure was built over a section of a commercial mango orchard to investigate an option to prevent sunburn of fruit. A small fully enclosed net house was built over nine grapefruit trees on a commercial growers' property to investigate the effect on tree growth and wind blemish.	Determine the best performing crops and management methods for each type of protected structure and the return on investment for each crop/structure combination. Develop agronomic packages for protected cropping systems in Carnarvon. Investigations into the use of insect exclusion netting to protect crops from disease-carrying insects. The longevity of exclusion netting under Carnarvon's incessant winds is unknown and reduced ventilation may make conditions excessively hot and compromise plant growth. Investigate retractable and partial netting systems.
Crop genetics	A demonstration trial is underway at the Carnarvon Research Facility to showcase new and emerging genetic material suitable for the Carnarvon environment.	Carry out a detailed review of existing and new crop varieties suited to Carnarvon's projected climate change scenarios and investigate suitable crops for their production potential.

Drought adaptation lever	What's worked?	What's needed?
Crop genetics cont.	The field demonstration is a collaborative venture between DPIRD and eight seed companies and includes 121 tomato varieties, 78 capsicum varieties and 22 zucchini varieties.	
Carbon footprint	In the future, Carnarvon growers will need to demonstrate their environmental credentials to access certain markets.	With high fertiliser, water, plastic and chemical inputs many Carnarvon growers have a high carbon footprint. Plastic mulch and drip tape are dumped at the end of the cropping cycle and food miles are generally high because of the distance to the Perth market. · Assist Carnarvon growers achieve carbon neutrality and sustainability · Demonstrate this sustainability to consumers to maintain markets
Irrigation use efficiency	Research at the Carnarvon Research Facility is identifying suitable soil moisture sensors and the critical soil moisture contents at which plant stress occurs for a range of crops. Investigations are also underway to evaluate plant sensors for improved irrigation scheduling and volumes in mango. The research results will enable growers to use irrigation water more efficiently.	Monitoring of irrigation practices in Carnarvon indicates growers often poorly schedule both the amount and timing of irrigations. There has been poor uptake of irrigation scheduling techniques, such as soil moisture monitoring and using evapotranspiration data. · A dedicated irrigation expert is required to work with growers to install soil moisture monitoring equipment and demonstrate how to use evapotranspiration and crop coefficients to schedule irrigations. · Robust user-friendly irrigation scheduling systems are required.
Flood plain erosion management	DPIRD flood assessments following the 2021 flood in Carnarvon indicated poor farming practices had exacerbated flood damage in low lying areas with soil cultivation greatly increasing soil loss.	Extend and encourage adoption of soil, crop, and land management practices to mitigate erosion. Carry out a hydrological study to model flood flow behaviour and its impact on public and private infrastructure. Include consideration of future climate change and likelihood of more intense rain events.
Evaporative cooling	Evaporative cooling of crops such as fogging in greenhouses can decrease temperatures by as much as 10°C. Greater cooling can be achieved when humidity is low – which is common in Carnarvon.	Investigate the effectiveness of evaporative cooling systems in protected cropping systems and for outdoor crops. Investigate how to modify the micro-climate in banana plantations and mango orchards and determine if overhead misting systems can reduce sunburn of fruit. Investigate the impact of salinity levels in misting water on leaf burn.
Professional development	Retractable roof greenhouse manufacturer Cravo has a research facility and access to commercial farms in the Culiacan region in Mexico — a major vegetable production region at the same latitude as Carnarvon. The Negev region of Israel has a similar climate to Carnarvon and is known for innovative agricultural practices.	Organise grower tour to Mexico and Israel to investigate climate resilient growing practices.

Industry perspective — adapting to climate change

- Accessing varieties suited to Carnarvon's current and future climate is an important R&D priority for Carnarvon banana growers.
- An increase in the number of extreme weather days will impact on the profitability of Carnarvon banana growers as hot conditions with low humidity cause fruit sunburn and leaf damage and have long term production impacts.
- Bananas leaves are easily damaged by strong winds.
- Bananas are very susceptible to cyclones - if cyclone frequency increases the profitability of the industry will be greatly reduced. Bananas grow slowly in Carnarvon, and it takes 18 months from replanting until picking can commence and three years until full production is reached.
- River flows with elevated salt levels (800mg/L) can impact on the Basin A aquifer and growers may not be able to use this water source until fresh flows recharge the aquifer.
- If the climate becomes more tropical then this will likely increase fungal disease pressure. Carnarvon growers currently use very few if any sprays and this provides us with an advantage over Queensland where conditions are much more humid and fungal diseases are common.

Doriana Mangili, Sweeter Banana Cooperative

- Degraded pastoral land results in more runoff and greater floods. Catchment wide management action is required.
- Net houses may offer protection from climate extremes but the profitability of these structures for the Carnarvon banana industry has not been demonstrated.

Doriana Mangili
Business Manager
Sweeter Banana Cooperative

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