Implications of climate change on the water requirements of horticulture in the Victorian Mallee – Phase III

June 2024

mallee
catchment management authority

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ACKNOWLEDGEMENT OF COUNTRY

The Traditional Owner groups of the region include, but are not limited to: Latji Latji; Wadi Wadi; Wamba Wamba;Tati Tati; Jari Jari; Nyeri Nyeri; Ngintait; Ngarkat; and Barengi Gadjin, Wotjobaluk, Jaadwa, Jadawadjali, Yupagalk, and Wergaia. These are represented by the Barengi Gadjin Land Council Aboriginal Corporation and the First People of the Millewa-Mallee Aboriginal Corporation.

We acknowledge the Traditional Owner people as the Traditional Owners of the Country on which this project will be conducted. We recognise their continuing connection to land, waters and culture and pay our respects to their Elders past and present, and we acknowledge emerging leaders. Moreover, we express gratitude for the knowledge and insight that Traditional Owners and other Aboriginal and Torres Strait Islander people contribute to our shared work in Australia.

We pay respects to all Aboriginal and Torres Strait Islander communities. We recognise that Australia was founded on the genocide and dispossession of First Nations people and acknowledge that sovereignty was not ceded in this country. We embrace the spirit of reconciliation, working towards self-determination, equity of outcomes, and an equal voice for Australia's First People.

1 Introduction

1.1 THIS PROJECT

Climate change is changing irrigation crop water requirements as higher temperatures lead to higher evapotranspiration and longer irrigation seasons.

The aims of the project are to:

- Develop, with industry experts, an appropriate methodology for determining future crop water requirements of horticultural crops
- Estimate annual crop water requirements for a range of horticultural crops grown in the Mallee under a changing climate
- Determine future water requirements in consideration with current irrigation management practices to protect horticultural crops under a changing climate
- Assess likely future cooling requirements for table grape and avocado.

The Mallee CMA have overseen the production of Phases 1 and 2 of the project 'Implications of climate change on horticulture in the Victorian Mallee'. In these projects, nine commonly grown horticultural crops were modelled to estimate future production impacts of a warming climate. The modelling also determined growing season length and commodity-specific impacts such as the effect of chill requirements on nut crops, and fruit colour and sugar development on table grapes.

An attempt to predict future crop water requirements was also made in Phase 2 and this proved to be more problematic than first envisaged. Industry consultation determined that this issue is of particular interest and importance to all horticultural industries. Therefore, it was proposed that this report concentrate on future crop water requirements for horticulture in the Mallee.

1.2 PREVIOUS WORK

1.2.1 BACKGROUND

This section summarises the key documents and previous work relating to the implications of climate change on horticulture in the Victorian Mallee. The summarised reports are:

- Phase 1 – Implications of Climate Change for Horticulture In The Victorian Mallee, Mallee CMA (Natural Decisions, 2020)
- Phase 2 – Implications of climate change for horticulture in the Victorian Mallee Phase 2, (Natural Decisions, 2022).

Table 1-1 below shows key aspects.

Table 1-1: Summary of key aspects of Phase I and Phase II.

ASPECT	PHASE 1	PHASE 2
Crops	Almonds - nonpariel Citrus – Washington navel orange Table grapes – Crimson seedless Wine grapes – Shiraz and Pinot Gris Grapes for drying – Sunmuscat	Almonds – nonpareil Avocados – Hass Citrus – Washington navel orange and afourer mandarin Grapes for drying – Sunmuscat Table grapes – Crimson seedless Wine grapes – Shiraz and Pinot Gris Pistachios - Sirora
Climate model	5 x 5 km scale climate models and projections developed by CSIRO RCP 8.5	CESM1-CAM5 Global Climate Model (GCM) rendered to 5×5 km grids by the Victorian Climate Projections 2019 (VCP19) RCP 4.5 – 8.5
Horticultural model	Catchment Analysis Tool (CAT)	Catchment Analysis Tool (CAT)

Key findings are reported for each phase below.

1.2.2 PHASE 1 – IMPLICATIONS OF CLIMATE CHANGE FOR HORTICULTURE IN THE VICTORIAN MALLEE

Phase 1 (Natural Decisions, 2020) of the project investigated yield impacts, growing season length and irrigation requirements for citrus, grapes and almonds across the Victorian Mallee region. These (Natural Decisions, 2022) were estimated using a generic heat unit modelling approach and applied to historic, baseline, 2030, 2050 and 2070 climate scenarios. The modelling was conducted by superimposing Catchment Analysis Tool (CAT) developed by Agriculture Victoria and the 5 x 5 km scale climate models and projections developed by CSIRO.

Phase 1 of the project used the RCP[2] 8.5 scenario and crop responses based on average management. The projected irrigation water requirements were predicted to decline. The crop types/cultivars selected and results are provided in the table below:

Table 1-2: Crop irrigation requirement results from Phase 1

CROP	TYPES/CULTIVARS	LOCATION	IRRIGATION REQUIREMENT (ML/HA)				
			BASELINE	2030	2050	2070	% CHANGE
Citrus	Washington navel orange	Red Cliffs (BoM8 site 76052)	11.7	11.9	11.6	11.3	-3%
Table grapes	Crimson seedless	Merbein (BoM site 76026)	12.0	11.0	10.2	9.7	-19%

2 Note on RCP - The Representative Concentration Pathway scenarios define the concentration of CO_2 in the atmosphere over time. For example, RCP 8.5 refers to the concentration of CO_2 that delivers global warming at an average of 8.5 watts per square meter across the planet. The RCP 8.5 pathway is projected to deliver a temperature increase of about 4.3 degrees C by 2100 relative to pre-industrial temperatures.

CROP	TYPES/CULTIVARS	LOCATION	IRRIGATION REQUIREMENT (ML/HA)				
			BASELINE	2030	2050	2070	% CHANGE
Wine grapes	Shiraz	Mildura (BoM site 76031)	8.1	7.6	7.2	6.8	-16%
	Pinot Gris	Mildura (BoM site 76031)	6.9	7.0	6.7	6.4	-7%
Grapes for drying	Sunmuscat	Merbein (BoM site 76026)	9.0	8.6	8.1	7.6	-16%
Almonds	Nonpariel	Robinvale (BoM site 76053)	13.0	12.8	12.8	12.7	-2%

For all crops studied the irrigation requirements were projected to decline. This result was attributable to a earlier harvest dates and a decline in yield. This was somewhat unexpected as a hotter climate suggests irrigation demand will increase, however, that will only be the case if the yields and growing season length are maintained.

Irrigation demands were estimated based on plant water needs (including post-harvest maintenance requirements) and not what irrigators may choose to apply. Based on these assumptions, water inputs were predicted to remain at similar volumes as under current conditions. The report suggested that because climate models do not account well for extremes, plus a natural tendency for irrigators to make sure water is not limiting, then in practice more water would be likely to be applied than the model predicted was needed.

Rainfall variability and extreme weather events were considered, but were not accounted for in the irrigation demand calculations. Extreme rainfall events are expected to become more intense on average through the century (high confidence) but remain very variable in space and time. Studies focused on the north-west region of Victoria suggest that more frequent summer extreme rainfall events will occur and if this occurs, it will pose additional disease, fruit quality and harvesting issues for horticultural crops. Additionally, extreme weather events will also affect crop yields.

1.2.3 PHASE 2 –IMPLICATIONS OF CLIMATE CHANGE FOR HORTICULTURE IN THE VICTORIAN MALLEE

In Phase 2 (Natural Decisions, 2022) the project expanded the number of crops and cultivars studied and used two approaches to estimate irrigation requirement:

- A modelled one and
- A projected non-dynamic method based on ETo x Kc.

Phase 2 used the average between RCP 4.5 and 8.5 for the climate scenario and the top 20% of best management practices. The results of yield, growing season days (GSD) and GSD shortening were provided for all crops. Estimating future water requirements for horticultural crops was challenging as the shortened growing season had a significant effect on the anticipated increase in annual water requirements.

For the wintergreen crops (avocado, orange and mandarin), irrigation requirements were predicted to increase over time, whereas for the deciduous crops (almond, grapes and pistachio), irrigation requirements were predicted to increase more marginally. More work was recommended to establish whether these increases are real or an artefact of the modelling approach.

Table 1-3: Summary of Phase 2 findings on irrigation demand ML/ha/y by 2050

CROP	MODELLED BASELINE CLIMATE	MODELLED RCP 4.5 2050	MODELLED RCP8.5 2050	KC X ETO BASELINE CLIMATE	KCX ETO 2050
Almonds	13.0	13.0	13.1	13.4	14.1
Avocados	12.0	12.8	13.0	13.0	13.9
Washington navel	9.0	10.6	10.8	11.1	11.9
Sunmuscat (dried grapes)	9.0[3]	9.0	9.1	9.7	10.2
Crimson seedless (Table grapes)	10.1	10.1	10.1	11.9	12.6
Shiraz (wine grapes)	7.0	6.8	7.0	9.3 (combined with Pinot gris)	9.7 (combined with Pinot gris)
Pinot gris (wine grapes)	9.0	9.0	9.0	9.3	9.7
Pistachio	12.0	12.0	12.0	13.5	14.1

Phase 2 also provided a detailed analysis of the change in crop phenology that has been used to derive climate-affected Kc values later in this report. These are listed in Appendix 1. It also considered misting cooling requirements for avocados and table grapes.

3 Reported as 13 ML/ha but this is likely to be an error as it included 4 ML/ha of winter water requirements when dormant. Removing winter requirements gives a value of 9 ML/ha

2 Method

2.1 RATIONALE

The Mallee CMA have overseen the production of Phases 1 and 2 of the project 'Implications of climate change on horticulture in the Victorian Mallee'. In these projects, nine commonly grown horticultural crops were modelled to estimate future production impacts of a warming climate. The modelling also determined growing season length and commodity-specific impacts such as the effect of chill requirements on nut crops, and fruit colour and sugar development on table grapes.

An attempt to predict future water requirements was also made in Phase 2 and this proved to be more problematic than first envisaged. Industry consultation determined that this issue is of particular interest and importance to all horticultural industries. Therefore, it was proposed that this report focus on future water resource use implications for horticulture in the Mallee.

The method used in this report considers the change in water requirements as a result of climate change. The climate affects:

- ETo through temperature, wind, cloud cover and other inputs that determine ETo,
- the timing of crop phenology (e.g. bud burst and harvest dates) which in turn affects Kc values through the season; and also
- the change in effective rainfall (ER).

Therefore, the method has been to examine:

- Change in ETo (using CSIRO projected changes in ETo and pan evaporation projections)
- Change in Kc (considering crop phenology)
- Change in ER.

The irrigation requirement assumes an 85% efficiency is applied to the crop water requirement. This is shown in the schematic diagram provided in Figure 2-1.

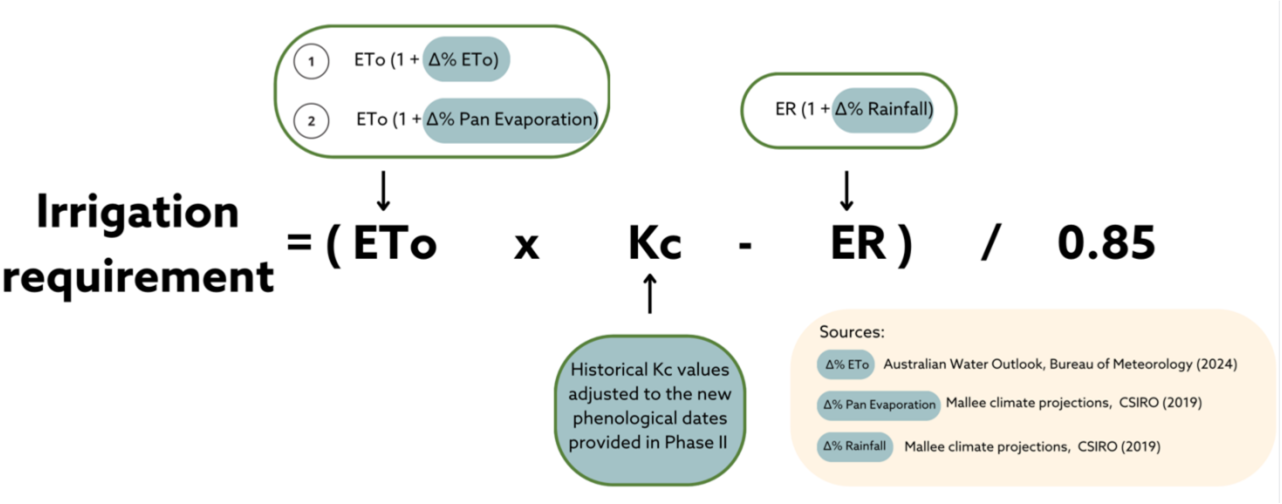

Figure 2-1: Irrigation requirement calculation

The above calculation was considered for each of the following crops:

- Almond
- Avocado
- Citrus
- Wine grapes
- Table grapes
- Dried vine fruit
- Pistachio.

2.2 CLIMATE PROJECTIONS

Climate change is changing irrigation crop water requirements as higher temperatures lead to higher evapotranspiration and longer irrigation seasons.

According to the Victorian Climate Projections 2019[4] (Clarke JM, 2019 (Updated 19th February 2020)) indicates that when compared to the 1986–2005 sequence, the climate of Swan Hill could be more like the current climate of Balranald, NSW, and the climate of Mildura could be more like the current climate of Menindee, NSW by the 2050s. The report indicates:

- Maximum and minimum daily temperatures will continue to increase over this century (very high confidence)
- By the 2030s, increases in daily maximum temperature of 0.8 to 1.6°C (since the 1990s) are expected
- Rainfall will continue to be very variable over time, but over the long term it is expected to continue to decline in winter and spring (medium to high confidence), and autumn (low to medium confidence), but with some chance of little change
- Extreme rainfall events are expected to become more intense on average through the century (high confidence) but remain very variable in space and time.

The impacts on crops in the Mallee Region are expected are tabulated below.

Table 2-1: Climate change scenarios[5] (Clarke JM, 2019 (Updated 19th February 2020))

CLIMATE PARAMETER	PROJECTION FOR THE MALLEE REGION	IMPACT ON INDUSTRY
Daily temperature	Maximum and minimum daily temperatures will continue to increase over this century (very high confidence) Under the high emissions scenario, maximum temperatures in the Mallee region are expected to show a median increase of 1.3°C by the 2030s (2020– 2039), compared to 1986–2005. By mid-century, the increase is likely to be greater, with a median of 2.2°C. Under medium emissions, the mid-century maximum temperatures increase by a median of 1.7°C. Increases in minimum temperatures are expected to be smaller, with a median of 0.8°C by the 2030s and 1.6°C by the 2050s (2040–2059) under high emissions. On average between 1981 and 2010, Mildura experienced 7.8 days per year when the temperature exceeded 40°C. By the 2050s under high emissions, this is expected to increase to between 15 and 23 days. The increase is slightly less under medium emissions, reaching 11 to 17 days on average. Minimum (usually overnight) temperatures are also expected to increase. Frosts are expected to become less frequent over time. However, it is possible for there to be an increased risk of frost in some regions and seasons when cold clear nights persist longer than is suggested by the projected change in minimum temperature. Over time the effect of increasing minimum temperatures is expected to gradually overpower the other effects and lead to a decrease in frost risk. Between 1981 and 2010 Mildura experienced 3.8 days/y with below zero degrees C. This is expected to change to 1.8 with high emissions scenario and 2.4 days with medium emissions scenario.	▪ Heat stress to depress some plant growth in summer ▪ Reduce cold stress in winter, possibly earlier bud burst and later leaf drop for deciduous crops and annuals ▪ Increased growth and water demands for non-deciduous e.g. citrus in cooler months ▪ Possible reduced frost risk for a given date, but not by crop if bud burst is earlier.
Rainfall	Rainfall in Victoria has declined in most seasons over recent decades, with the greatest decreases in the cooler seasons. The Mallee region's rainfall is naturally highly variable and this natural variability will dominate the rainfall over the next decade or so. Over time, annual rainfall totals are likely to decline, particularly under high emissions, with the greatest drying in spring. By late-century under high emissions, the climate change trend becomes obvious compared to natural variability with a median of 21% decrease in annual totals, larger (35%) in spring.	▪ More extreme rainfall events increases waterlogging risks ▪ More flooding loss in summer ▪ Higher irrigation demands in winter and spring
Potential Evapotranspiration (ET)	ET drives irrigation demand. By the 2030's this is expected to increase by 22% in summer and 14% to 18% across the year based on modelled change in pan evaporation. Higher increases (>100% were predicted for summer by 2080-99 using RCP8.5) See Figure 2-2 below. Potential evapotranspiration will increase under higher temperatures because of the higher amount of energy available for evapotranspiration. In potential evapotranspiration formulations, the increase in potential evapotranspiration largely comes from the increase in vapour pressure deficit driven by higher temperature.	▪ Increase irrigation demand in ML/ha for a given crop area

Pan evaporation is well correlated with ETo and was used for many years with pan factors (Kp) to estimate crop water use before ETo was widely available. Therefore the pan evaporation projections (percentage increase from historic) in the above report have been used to estimate potential changes in ETo. The projections are tabulated in Figure 2-2: below using (Clarke JM, 2019 (Updated 19th February 2020)).

5 https://www.climatechange.vic.gov.au/__data/assets/pdf_file/0033/429882/Mallee-Climate-Projections-2019_20200219.pdf (accessed 15 January 2024)

The BoM have also published an Australian Water Outlook (Bureau of Meteorology, 2024) for the impacts of climate change on ETo in the Murray Basin. This data has been used to provide an estimate of the percentage change in baseline ETo established in the period 1975 to 2005. However, this is not ideal as the calculation of ETo in the Australian Water Outlook is based on changes to the baseline of the Australian-developed 'tall crop' ETo. While the method is technically correct, it is not the same as the FAO 56 ETo (short crop) method that has been used to derive commercially used Kc levels in the Mallee Region for decades (shown in Appendix 2).

This study uses the FAO 56 method to determine the baseline ETo, as it is the long-established method, that has been used to determine Kc values for commercial Mallee crops. It is understood from discussions held with CSIRO, that projections for FAO56 short crop are in the process of being produced and will be made available. We have accommodated this to be included in the future within the spreadsheet accompanying this report.

In this study, the future climate scenarios included within the spreadsheet model are:

- Australian Water Outlook projected percentage changes in ETo (tall crop) for 2030, 2050, 2070 with RCP 4.5 and RCP8.5 using the median values of 16 models for each season
- Modelled pan evaporation pan percentage changes as tabulated (Clarke JM, 2019 (Updated 19th February 2020)) for 2030 (2020-2039) and 2050 (2040-2059)
- For user scenario testing a manual input of percentage change to baseline ETo and ER for each month
- Provision for CSIRO projections (2024) for ETo derived with FAO56 short crop. At the time of writing, this is not yet available.

These percentage change projections are tabulated in the following section 0.

Mallee Climate Projections 2019

Table 4. Summary of changes (compared to 1986-2005) for selected climate variables (median, 10th and 90th percentile) from new 5 km downscaled results for greenhouse gas emissions scenarios RCP 4.5 (blue, 1st row) and RCP 8.5 (red, 2nd row).

Variable	Season	Emissions scenario	Projected changes 2020–2039	2040–2059	2080–2099
Relative humidity (%)	Annual	RCP4.5	-1.9 (-3.2 to -0.2)	-2.6 (-4.5 to -0.3)	-3.1 (-7.5 to -1.3)
		RCP8.5	-2.4 (-4.5 to -0.3)	-3.7 (-5.3 to -0.8)	-7.3 (-8.5 to 1.0)
	Summer	RCP4.5	-1.0 (-3.3 to -0.3)	-1.3 (-2.9 to 0.1)	-2.7 (-6.1 to 0.8)
		RCP8.5	-1.9 (-3.8 to 0.4)	-3.0 (-3.6 to -0.2)	-4.0 (-5.3 to 3.2)
	Autumn	RCP4.5	-2.0 (-3.9 to 2.4)	-1.7 (-4.8 to 1.5)	-2.6 (-5.9 to 0.2)
		RCP8.5	-1.6 (-5.2 to -0.5)	-3.2 (-4.9 to -0.5)	-7.3 (-8.1 to 2.1)
	Winter	RCP4.5	-1.4 (-2.1 to 0.0)	-1.5 (-3.2 to 1.0)	-2.0 (-6.8 to -1.0)
		RCP8.5	-1.2 (-4.1 to 0.1)	-2.2 (-4.6 to -1.4)	-6.4 (-8.6 to -0.7)
	Spring	RCP4.5	-3.5 (-5.4 to -0.4)	-4.5 (-9.2 to -1.5)	-6.0 (-11.8 to -4.1)
		RCP8.5	-4.6 (-5.5 to -0.9)	-7.1 (-8.3 to -0.5)	-11.9 (-14.0 to -0.7)
Pan evaporation (%)	Annual	RCP4.5	14.4 (9.9 to 22.1)	24.5 (10.3 to 29.3)	31.5 (27.8 to 58.0)
		RCP8.5	17.7 (8.6 to 23.4)	32.5 (16.5 to 41.6)	66.4 (23.7 to 86.9)
	Summer	RCP4.5	22.6 (9.3 to 42.4)	31.4 (20.4 to 54.2)	48.5 (39.7 to 90.7)
		RCP8.5	21.9 (13.8 to 42.6)	47.8 (29.9 to 74.1)	103.7 (38.9 to 144.3)
	Autumn	RCP4.5	12.1 (-5.0 to 16.7)	13.7 (2.6 to 25.8)	21.2 (11.3 to 40.3)
		RCP8.5	10.8 (3.9 to 21.1)	22.3 (10.7 to 26.8)	48.0 (14.6 to 56.9)
	Winter	RCP4.5	3.5 (0.8 to 5.3)	4.3 (-1.9 to 11.3)	9.8 (4.9 to 21.6)
		RCP8.5	4.1 (-0.3 to 7.7)	8.2 (3.7 to 11.5)	19.2 (5.9 to 30.8)
	Spring	RCP4.5	23.3 (14.0 to 31.9)	36.0 (18.5 to 49.8)	49.3 (39.8 to 82.0)
		RCP8.5	25.7 (14.9 to 31.2)	48.9 (19.9 to 60.6)	92.1 (36.4 to 119.4)
Solar radiation (%)	Annual	RCP4.5	1.6 (0.4 to 2.1)	1.5 (0.3 to 2.3)	2.2 (1.2 to 4.5)
		RCP8.5	1.3 (0.3 to 2.3)	2.0 (0.2 to 2.5)	3.4 (-0.6 to 4.6)
	Summer	RCP4.5	0.2 (-0.2 to 1.9)	-0.2 (-1.4 to 0.8)	0.1 (-1.5 to 2.2)
		RCP8.5	0.3 (-1.5 to 1.3)	0.3 (-0.8 to 1.3)	0.2 (-3.1 to 1.2)
	Autumn	RCP4.5	1.1 (-0.3 to 3.2)	1.2 (-1.1 to 2.6)	0.9 (0.4 to 2.5)
		RCP8.5	1.5 (-0.8 to 4.5)	1.9 (-0.9 to 3.9)	4.2 (-1.9 to 6.0)
	Winter	RCP4.5	2.6 (1.9 to 3.6)	3.6 (0.4 to 4.8)	4.8 (2.6 to 10.2)
		RCP8.5	3.5 (0.4 to 4.4)	5.2 (3.2 to 7.3)	9.4 (4.7 to 12.0)
	Spring	RCP4.5	2.4 (0.1 to 3.2)	2.3 (1.3 to 4.5)	3.6 (2.8 to 6.7)
		RCP8.5	1.6 (0.7 to 2.8)	2.4 (0.7 to 3.6)	4.9 (1.3 to 6.4)
Surface wind speed (%)	Annual	RCP4.5	-1.3 (-1.9 to 0.1)	-0.8 (-2.0 to 0.5)	-1.2 (-1.6 to 0.4)
		RCP8.5	-1.5 (-2.6 to 0.2)	-1.0 (-2.2 to -0.3)	-1.7 (-4.0 to 0.4)
	Summer	RCP4.5	-0.5 (-2.2 to 0.3)	-0.9 (-2.1 to 0.7)	-1.0 (-1.6 to 0.5)
		RCP8.5	-1.0 (-1.3 to 0.4)	-0.2 (-2.9 to 0.6)	-0.1 (-4.0 to 1.4)
	Autumn	RCP4.5	-1.1 (-2.7 to 0.4)	-1.3 (-2.3 to 0.4)	-1.5 (-4.0 to 0.0)
		RCP8.5	-1.6 (-3.7 to -0.9)	-2.0 (-2.3 to 0.5)	-2.6 (-4.4 to -1.2)
	Winter	RCP4.5	-3.5 (-4.9 to -1.1)	-2.3 (-4.2 to -0.7)	-1.9 (-3.6 to -0.3)
		RCP8.5	-3.1 (-4.7 to 0.5)	-3.3 (-5.9 to -1.5)	-4.7 (-8.0 to -0.8)
	Spring	RCP4.5	0.6 (-1.5 to 2.0)	0.5 (-1.4 to 3.3)	0.5 (-0.2 to 3.1)
		RCP8.5	0.5 (-2.7 to 1.8)	-0.3 (-1.0 to 2.2)	(-1.6 to 4.2)

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Figure 2-2: Mallee Climate Projections 2019. The source for pan evaporation percentage increases

2.3 CHANGE IN EVAPOTRANSPIRATION

ETo specifically refers to evapotranspiration from a reference stand of actively growing, well-watered grass, 120 mm in height. For practical purposes, ETo provides a workable representation of the water requirements of good productive pasture on an irrigated farm[6]. The process of using ETo data for irrigation scheduling on crops other than pasture is to multiply ETo by a crop coefficient Kc. The crop coefficient (Kc) varies through the season depending on canopy cover and the crop's phenological stage. Common FAO 56 crop coefficients used in the Mallee are tabulated in Appendix 2.

Australian research scientists prefer to use the ETr (ETo tall crop) calculation, which is different to the FAO 56 ETo (short crop) reported by BoM at Mildura. But is difficult to use ETr as it does not have widely reported Kc values. Therefore, in this study, FAO 56 ETo (short crop) has been used.

It should be noted that demands (ETo x Kc) to calculate water requirements have no allowance for irrigation system non-uniformity, system losses or leaching requirement. In this study, an irrigation efficiency of 85% has been assumed for all climate scenarios. This percentage is a well established method of estimating irrigation requirements in the Mallee.

Future climate ETo has been derived by multiplying a percentage change to the 1975–2005 baseline for SILO ETo (FAO56 short crop) at Mildura BoM weather station. The Mildura baseline values are shown below.

Table 2-2: Baseline historic ETo (FAO 56 short crop) for Mildura 1975-2005 source SILO database

	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	ANNUAL
ETo	46	66	93	137	171	202	209	175	147	95	60	41	1443

The future climate is modelled by multiplying the baseline ETo above with the following percentage increase associated with each projection shown in Table 2-3. These percentage increases were sourced from the BoM's Australian Water Outlook (which uses ETo tall crop, also known as ETr) and the change in pan evaporation published by the Mallee Climate projections. A key assumption is that the percentage increase will be the same for ETo short crop as ETo tall crop projections or for pan evaporation projections. But due to the uncertainty of this assumption these results should be considered interim and be updated when CSIRO's ETo short crop projections are made available.

It should also be noted that the modelled pan evaporation projections are based on a 1986–2005 baseline, fortunately for Mildura, there is little difference between this and the 1975–2005 baseline used by the Australian Water Outlook so the baseline differences in both evaporation pan and ETo are very small and can be ignored.

CSIRO are currently developing projections for ETo short crop. Provision for including this has been built into the spreadsheet model – ETo short crop (2024).

Table 2-3: Climate change scenarios for ETo

Indicator	Climate scenarion an	july	august	september	october	november	december	january	february	march	april	may	june	Source
ETo (tall crop)	RCP4.5-2030	4.5%	4.5%	4.1%	4.1%	4.1%	1.7%	1.7%	1.7%	3.8%	3.8%	3.8%	4.5%	# Australian Bureau of Meteorology
ETo (tall crop)	RCP4.5-2050	6.2%	6.2%	5.5%	5.5%	5.5%	2.8%	2.8%	2.8%	4.1%	4.1%	4.1%	6.2%	# Australian Bureau of Meteorology
ETo (tall crop)	RCP4.5-2070	7.1%	7.1%	7.8%	7.8%	7.8%	3.4%	3.4%	3.4%	6.0%	6.0%	6.0%	7.1%	# Australian Bureau of Meteorology
ETo (tall crop)	RCP8.5-2030	4.2%	4.2%	5.4%	5.4%	5.4%	1.8%	1.8%	1.8%	3.9%	3.9%	3.9%	4.2%	# Australian Bureau of Meteorology
ETo (tall crop)	RCP8.5-2050	7.1%	7.1%	7.8%	7.8%	7.8%	3.3%	3.3%	3.3%	5.7%	5.7%	5.7%	7.1%	# Australian Bureau of Meteorology
ETo (tall crop)	RCP8.5-2070	9.9%	9.9%	11.7%	11.7%	11.7%	5.3%	3.4%	5.3%	8.0%	8.0%	8.0%	9.9%	# Australian Bureau of Meteorology
PanEvap	RCP4.5-2030	3.5%	23.3%	23.3%	23.3%	23.3%	22.6%	22.6%	22.6%	12.1%	12.1%	3.5%	3.5%	Mallee Climate Projections 2019
PanEvap	RCP4.5-2050	4.3%	36.0%	36.0%	36.0%	36.0%	31.4%	31.4%	31.4%	13.7%	13.7%	4.3%	4.3%	Mallee Climate Projections 2019
PanEvap	RCP8.5-2030	4.1%	25.7%	25.7%	25.7%	25.7%	21.9%	21.9%	21.9%	10.8%	10.8%	4.1%	4.1%	Mallee Climate Projections 2019
PanEvap	RCP8.5-2050	8.2%	48.9%	48.9%	48.9%	48.9%	47.8%	47.8%	47.8%	22.3%	22.3%	8.2%	8.2%	Mallee Climate Projections 2019
ETo short crop CSIRO (2024)	RCP4.5-2030													CSIRO expected research results
ETo short crop CSIRO (2024)	RCP4.5-2050													CSIRO expected research results
ETo short crop CSIRO (2024)	RCP4.5-2070													CSIRO expected research results
ETo short crop CSIRO (2024)	RCP8.5-2030													CSIRO expected research results
ETo short crop CSIRO (2024)	RCP8.5-2050													CSIRO expected research results
ETo short crop CSIRO (2024)	RCP8.5-2070													CSIRO expected research results

6 https://agriculture.vic.gov.au/__data/assets/pdf_file/0008/577025/What-is-evapotranspiration-and-how-do-I-use-it-to-schedule-irrigations-Tech-Note.pdf

Note the pan evaporation percentage change projections are significantly higher and 2070 projections for pan evaporation are not available.

2.4 CHANGE IN CROP COEFFICIENTS (KC)

Crop coefficients (Kc) are crop-specific values that adjust the evapotranspiration of a reference crop to a range of crops. By combining a specific crop Kc with daily reference Evapotranspiration (ETo) observations from a nearby weather station, the crop water usage can be estimated and advice can be provided regarding the amount of irrigation to be applied.

Initial investigations looked at Kc values derived from the same crop at different latitudes using IrriSAT[7], but the variation within crops at the same latitude was too great to be able to pick up any differences due to latitude, so this method was not used. For example, it was found that almonds grown 50 Km north of Wentworth had similar bud burst and leaf drop periods to those near Robinvale.

The adopted baseline Kc values are listed in Appendix 2. These have been well tested in the Mallee Region[8] and have been adopted for the crops to determine baseline /historic demand in this study. However, the crop phenology is expected to change with climate change as shown in Appendix 1, derived from Phase 2. This has been used to inform the Kc for different climate change scenarios/projections as shown in Table 2-4. Kc values were modified following consultation with David Oag, an experienced horticultural agronomist, which confirmed that leaf drop date will remain relatively constant for all crops in a warming climate. Experience has shown that warmer climate areas in Queensland have approximately the same leaf drop date as the same crop in cooler climate areas further south, despite earlier bud burst and harvest times.

[7] IrriSAT v2 is a weather based irrigation scheduling service. The IrriSAT v2 methodology uses satellite images to determine the Normalized Difference Vegetation Index (NDVI) for each field, from which the plant canopy size can be determined and a specific crop coefficient (Kc) can be estimated. IrriSAT was developed by CSIRO and Deakin University with Cotton Research & Development Corporation, NSW DPI and others. See https://www.irrisat.app/

[8] The baseline Kc values used in Appendix 2 were developed by the SA irrigated Crop Management Service in the Riverland and have been found to be equally suitable for the Victorian Mallee due to similar production systems.

Table 2-4: Revised Kc values due to changes in crop phenology (%sa refers to shaded area)

Crop type	Climate scenario	July	August	September	October	November	December	January	February	March	April	May	June
Almonds 90%sa	RCP4.5-2030	0.16	0.32	0.57	0.89	1.04	1.04	1.03	0.99	0.81	0.81	0.00	0.00
Almonds 90%sa	RCP4.5-2050	0.16	0.32	0.57	0.89	1.04	1.04	1.03	0.88	0.81	0.81	0.00	0.00
Almonds 90%sa	RCP4.5-2070	0.32	0.44	0.73	0.96	1.04	1.04	1.03	0.88	0.81	0.81	0.00	0.00
Almonds 90%sa	RCP8.5-2030	0.32	0.32	0.57	0.89	1.04	1.04	1.03	0.99	0.81	0.81	0.00	0.00
Almonds 90%sa	RCP8.5-2050	0.32	0.57	0.89	1.04	1.04	1.04	1.03	0.95	0.81	0.81	0.00	0.00
Almonds 90%sa	RCP8.5-2070	0.44	0.73	0.89	1.04	1.04	1.03	0.99	0.81	0.81	0.81	0.00	0.00
Avocado	RCP4.5-2030	0.61	0.73	0.81	0.85	0.85	0.85	0.85	0.83	0.78	0.67	0.60	0.61
Avocado	RCP4.5-2050	0.61	0.73	0.81	0.85	0.85	0.85	0.85	0.80	0.73	0.64	0.60	0.61
Avocado	RCP4.5-2070	0.69	0.78	0.81	0.85	0.85	0.85	0.83	0.78	0.67	0.64	0.60	0.61
Avocado	RCP8.5-2030	0.65	0.73	0.78	0.84	0.85	0.85	0.85	0.83	0.80	0.67	0.60	0.60
Avocado	RCP8.5-2050	0.69	0.78	0.81	0.85	0.85	0.85	0.85	0.83	0.78	0.67	0.60	0.61
Avocado	RCP8.5-2070	0.73	0.78	0.84	0.85	0.85	0.85	0.80	0.73	0.64	0.60	0.61	0.65
Citrus 90%sa	RCP4.5-2030	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Citrus 90%sa	RCP4.5-2050	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Citrus 90%sa	RCP4.5-2070	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Citrus 90%sa	RCP8.5-2030	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Citrus 90%sa	RCP8.5-2050	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Citrus 90%sa	RCP8.5-2070	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Dried grapes	RCP4.5-2030	0.00	0.16	0.47	0.73	0.83	0.83	0.66	0.64	0.54	0.54	0.00	0.00
Dried grapes	RCP4.5-2050	0.00	0.16	0.47	0.83	0.83	0.75	0.66	0.58	0.54	0.54	0.00	0.00
Dried grapes	RCP4.5-2070	0.00	0.32	0.63	0.83	0.83	0.75	0.66	0.58	0.54	0.54	0.00	0.00
Dried grapes	RCP8.5-2030	0.00	0.16	0.47	0.73	0.83	0.75	0.66	0.64	0.58	0.54	0.00	0.00
Dried grapes	RCP8.5-2050	0.00	0.32	0.63	0.83	0.83	0.66	0.64	0.58	0.54	0.54	0.00	0.00
Dried grapes	RCP8.5-2070	0.16	0.47	0.73	0.83	0.83	0.66	0.64	0.58	0.54	0.54	0.00	0.00
Winegrape 90%sa	RCP4.5-2030	0.00	0.16	0.32	0.73	0.83	0.83	0.83	0.78	0.68	0.68	0.00	0.00
Winegrape 90%sa	RCP4.5-2050	0.00	0.16	0.32	0.73	0.83	0.83	0.80	0.73	0.68	0.68	0.00	0.00
Winegrape 90%sa	RCP4.5-2070	0.00	0.32	0.47	0.73	0.83	0.83	0.80	0.73	0.68	0.68	0.00	0.00
Winegrape 90%sa	RCP8.5-2030	0.00	0.16	0.47	0.73	0.83	0.83	0.83	0.78	0.68	0.68	0.00	0.00
Winegrape 90%sa	RCP8.5-2050	0.00	0.32	0.63	0.73	0.83	0.83	0.80	0.73	0.68	0.68	0.00	0.00
Winegrape 90%sa	RCP8.5-2070	0.16	0.47	0.63	0.83	0.83	0.83	0.78	0.68	0.68	0.68	0.00	0.00
Pistachios	RCP4.5-2030	0.00	0.00	0.21	0.56	0.86	1.06	1.08	0.88	0.69	0.00	0.00	0.00
Pistachios	RCP4.5-2050	0.00	0.00	0.21	0.42	0.86	1.06	1.08	0.69	0.69	0.00	0.00	0.00
Pistachios	RCP4.5-2070	0.00	0.00	0.42	0.56	1.03	1.10	1.07	0.69	0.69	0.00	0.00	0.00
Pistachios	RCP8.5-2030	0.00	0.00	0.21	0.56	0.86	1.06	1.08	0.88	0.69	0.00	0.00	0.00
Pistachios	RCP8.5-2050	0.00	0.00	0.42	0.56	1.03	1.10	1.07	0.69	0.69	0.00	0.00	0.00
Pistachios	RCP8.5-2070	0.00	0.21	0.42	0.70	1.03	1.10	0.88	0.69	0.69	0.00	0.00	0.00
Table Grape 50%sa	RCP4.5-2030	0.14	0.29	0.48	0.93	0.95	0.95	0.94	0.89	0.81	0.78	0.00	0.00
Table Grape 50%sa	RCP4.5-2050	0.14	0.29	0.48	0.93	0.95	0.95	0.94	0.89	0.78	0.78	0.00	0.00
Table Grape 50%sa	RCP4.5-2070	0.29	0.38	0.69	0.95	0.95	0.95	0.93	0.85	0.78	0.78	0.00	0.00
Table Grape 50%sa	RCP8.5-2030	0.29	0.29	0.69	0.93	0.95	0.95	0.94	0.89	0.81	0.78	0.00	0.00
Table Grape 50%sa	RCP8.5-2050	0.29	0.48	0.90	0.95	0.95	0.95	0.93	0.81	0.78	0.78	0.00	0.00
Table Grape 50%sa	RCP8.5-2070	0.38	0.69	0.93	0.95	0.95	0.94	0.89	0.81	0.78	0.78	0.00	0.00

Note:- 90% shaded area Kc values have been adopted from Appendix 2 except for table grapes, which has used 50% shaded area to reflect current commercial practice of using canopy covers.

2.5 CHANGE IN EFFECTIVE RAINFALL

The effective rainfall (ER) is the amount of rainfall retained in the root zone that can be used by the plants. It can be defined as the total rainfall minus:

- Rainfall surface runoff (usually only significant in large storm events in the Mallee)
- Rainfall evaporation (rainfall that evaporates from soil surface and canopy)
- Deep percolation (when the rootzone exceeds field capacity; this occurs after large events or after a small event directly after an irrigation).

Adjusting for these components is part of the FAO 56 methodology (Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. 1998). However, the calculation of effective rainfall is a complex issue, with many different methods. Possible approaches include:

a) Use a daily water balance of soil moisture to calculate effective rainfall
b) Assume 70% of all rainfall is effective (the FAO suggest 80% effectiveness when monthly rainfall exceeds 75 mm/month and 60% when it is less than 75 mm/month; but this is more applicable to surface irrigation than drip when the soil water deficits are much lower and the rootzone is held closer to field capacity)
c) Deduct daily evaporation from daily rainfall to determine effectiveness
d) Assuming all daily rainfall if less than 5 mm in winter and 10 mm in summer is ineffective. With a maximum of 25 mm being effective in one day (to account for deep percolation and/or surface runoff).

Each method has its own strengths and weaknesses. However, the key issue is the variability of rainfall across the Mallee and more complex methods for calculating effectiveness are somewhat academic and do not resolve the variability issue.

Method d) above has been used for many years in irrigation scheduling in Mildura and has been proven to be a reasonable method. This is a simple and easily repeatable method and allows for large rainfall storms, when a large proportion would be surface runoff or be lost to drainage; especially in situations where much of the area is drip irrigated and apart from the centre row held close to field capacity.

Future climate ER has been derived by multiplying a percentage change by the 1975–2005 baseline ER at Mildura BoM weather station. The Mildura baseline values are shown below.

Table 2-5: Baseline historic effective rainfall (ER) for Mildura 1975–2005 - derived from SILO database

	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	ANNUAL
ER	17	17	20	16	11	14	11	10	5	10	16	14	160

The future climate is modelled by multiplying the baseline above with the following percentage decrease associated with each projection shown in Table 2-6.

In this study, the future climate scenarios modelled were:

- Modelled total rainfall changes for the Mallee as tabulated (Clarke JM, 2019 (Updated 19th February 2020)) for each season and RCP scenario
- For user scenario testing a manual input of percentage change to baseline ER for each month.

Table 2-6: Climate change scenarios for ER

Indicator	Climate scenario	july	august	september	october	november	december	january	february	march	april	may	june	Source
ETo (tall crop)	RCP4.5-2030	-9%	-9%	-6%	-6%	-6%	-3%	-3%	-3%	-5%	-5%	-5%	-9%	Mallee Climate Projections 2019
ETo (tall crop)	RCP4.5-2050	-9%	-9%	-4%	-4%	-4%	-4%	-4%	-4%	-7%	-7%	-7%	-9%	Mallee Climate Projections 2019
ETo (tall crop)	RCP4.5-2070	-10%	-10%	-11%	-11%	-11%	-5%	-5%	-5%	-3%	-3%	-3%	-10%	Mallee Climate Projections 2019
ETo (tall crop)	RCP8.5-2030	-7%	-7%	-11%	-11%	-11%	-15%	-15%	-15%	1%	1%	1%	-7%	Mallee Climate Projections 2019
ETo (tall crop)	RCP8.5-2050	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%	Mallee Climate Projections 2019
ETo (tall crop)	RCP8.5-2070	-27%	-27%	-35%	-35%	-35%	-8%	-8%	-8%	-17%	-17%	-17%	-27%	Mallee Climate Projections 2019
PanEvap	RCP4.5-2030	-9%	-9%	-6%	-6%	-6%	-3%	-3%	-3%	-5%	-5%	-5%	-9%	Mallee Climate Projections 2019
PanEvap	RCP4.5-2050	-9%	-9%	-4%	-4%	-4%	-4%	-4%	-4%	-7%	-7%	-7%	-9%	Mallee Climate Projections 2019
PanEvap	RCP8.5-2030	-7%	-7%	-11%	-11%	-11%	-15%	-15%	-15%	1%	1%	1%	-7%	Mallee Climate Projections 2019
PanEvap	RCP8.5-2050	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%	Mallee Climate Projections 2019

(note same projections for both ETo tall crop and PanEvap)

It should be noted that as there are no ER projections provided by climate models so this approach assumes that the change in ER mirrors the same percentage change expected for total rainfall for each season as predicted by the Mallee Climate Projections 2019 (Clarke JM, 2019 (Updated 19th February 2020)).

2.6 CALCULATION OF IRRIGATION DEMAND

Irrigation demand was calculated on a monthly basis by using the following formula:

$$\text{Irrigation requirement} = (\text{ETo} \times \text{Kc} - \text{ER}) / 0.85$$

Where baseline demand is:

- Monthly demand was taken to be zero when ER exceeded ETc (ETc = ETo x Kc)
- ETo baseline = average ETo (baseline[9] month)

[9] 1975 to 2005 taken as baseline from Mildura BoM station as per Table 2-2

- Kc baseline = Kc (baseline month[10])
- ER baseline = average ER (baseline month[11])
- 0.85 allows for 85% efficiency of irrigation
- Annual demand is calculated as the sum of the 12 individual months demand.

Where projected demand is:

- Monthly demand was taken to be zero when ER exceeded ETc
- ETo projection = ETo (baseline month) x model projection percentage ETo change (month[12])
- Kc projection = Kc (projection month[13])
- ER projection = ER (baseline month) x model projection percentage rainfall change (month[14])
- 0.85 allows for 85% efficiency of irrigation
- Annual demand is calculated as the sum of the 12 individual months demand.

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10 As per Appendix 2
11 As per Table 2-5
12 As per Table 2-3
13 As per

Table 2-4
14 As per Table 2-6

3 Results and discussion

3.1 ALL CROPS

The change in ETo and ER are shown in Figure 3-1 for each RCP 4.5 and RCP 8.5 scenarios.

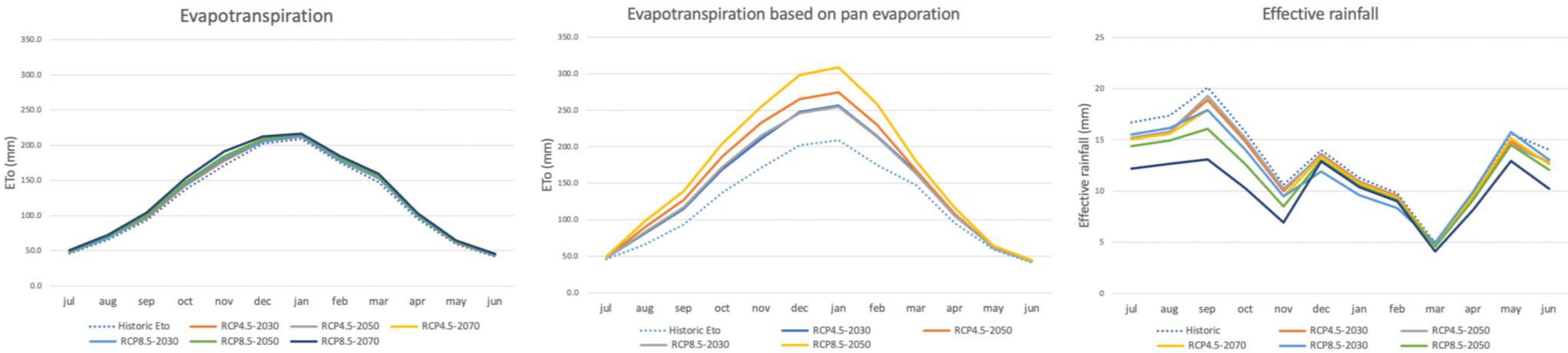


Figure 3-1: (left) Monthly historic and projected evapotranspiration, (centre) Monthly historic and projected evapotranspiration based on pan evaporation increase (right) Monthly historic and projected effective rainfall

The RCP4.5 and RCP8.5 projected evapotranspiration is based on the ETo and pan evaporation percentage change projections. The ETo projection shows a percentage increase ranging from 2–10%. In contrast, the pan evaporation projections are significantly higher ranging from 3–49%. This increase is particularly evident in the summer months when irrigation demand is the highest. Future effective rainfall shows a decrease during winter and a larger decrease for RCP 8.5. Lower winter rain will lead to plants requiring more irrigation during these months, especially for evergreen crops.

Figure 3-2 shows annual irrigation demands for ETo percentage projections and for clarity do not include pan evaporation projections. As would be expected, this shows that RCP 8.5 is in higher demand than RCP 4.5 and 2070 has higher demand than 2050 which has higher demand than 2030.

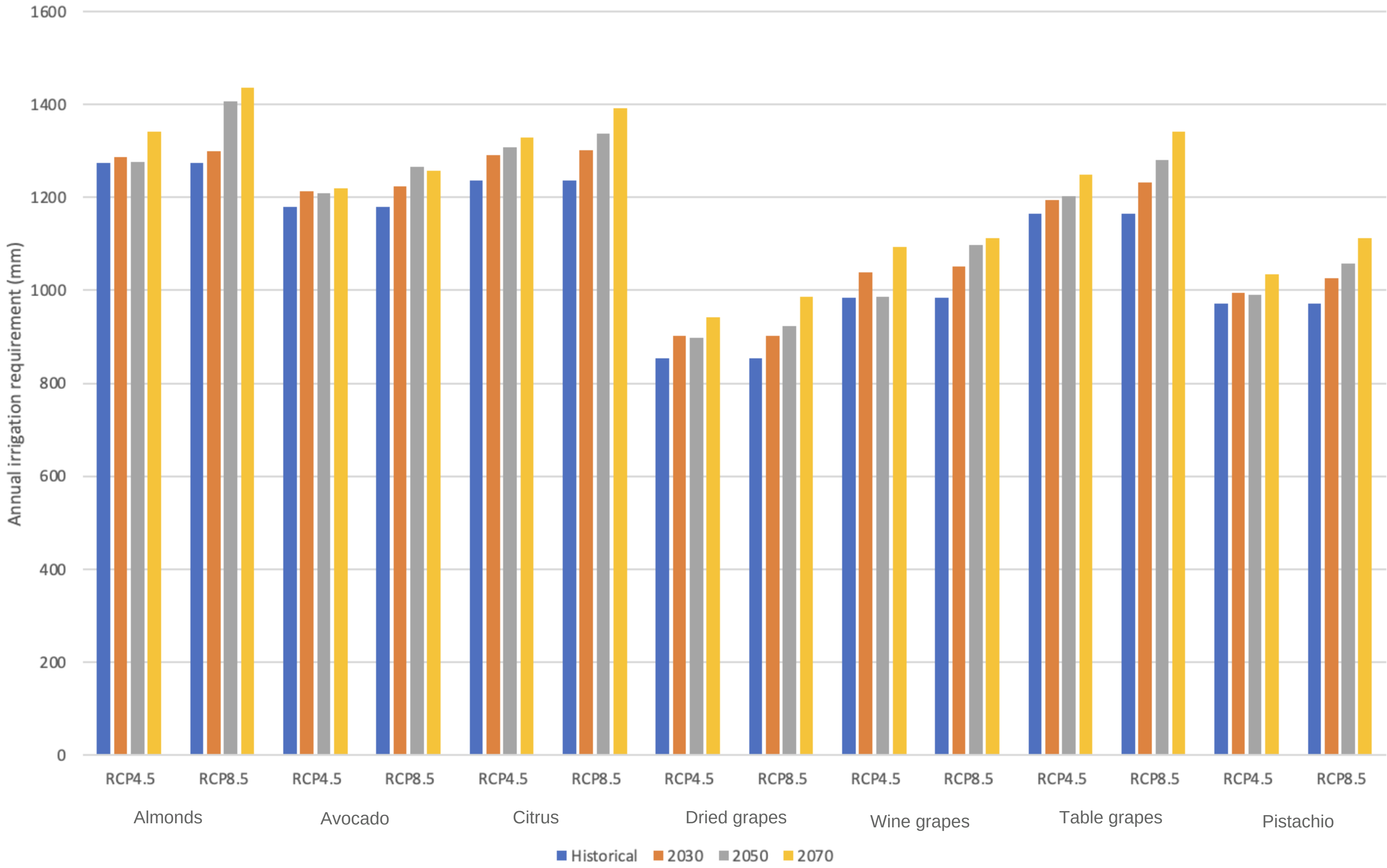


Figure 3-2: Annual irrigation requirement for all crops based on ETo increase (for clarity this excludes evaporation pan projections)

3.2 ALMOND

Figure 3-3 below shows data for 2050 using the RCP8.5 ETo tall crop projections. 2030 and 2070 projections are shown in Appendix 3.

Crop	Almonds 90%sa	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june
manual input of % change to historic ETo	%												
manual input of % change to historic ER	%												

Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160
Almonds 90%sa	Kc	0.00	0.32	0.57	0.89	1.04	1.04	1.04	1.03	0.95	0.81	0.00	0.00	7.67
Water requirement	mm	0	21	53	122	177	209	216	181	140	77	0	0	1196
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160
Irrigation required allowing for no monthly carryover	mm	0.00	3.55	32.82	105.87	166.32	194.94	205.07	171.38	135.39	67.33	0.00	0.00	
Historic irrigation required with 85% efficiency	mm	0.00	4.17	38.61	124.55	195.67	229.34	241.26	201.62	159.29	79.21	0.00	0.00	**1274**

Future Climate		july	august	september	october	november	december	january	february	march	april	may	june	Annual future	Change	change in %
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Almonds 90%sa	Kc	0.32	0.57	0.89	1.04	1.04	1.04	1.03	0.95	0.81	0.81	0.00	0.00	8.48	0.81	10.5%
Future water requirement	mm	16	40	89	153	191	216	223	172	126	82	0	0	1308	111	9.3%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	1.23	25.05	73.22	140.31	182.25	202.81	212.96	162.96	121.51	72.42	0.0	0.0			
Future irrigation required with 85% efficiency	mm	1.45	29.47	86.14	165.08	214.41	238.60	250.54	191.72	142.95	85.20	0.00	0.00	**1406**	**132**	**10.3%**

Figure 3-3: Example output RCP8.5 2050 Almonds 90% shaded area

Figure 3-4 below shows the total irrigation required and the Kc values for almonds. Key findings from the graphs are:

- As seen in the Kc graph, the season is expected to move forward due to earlier bud burst and flowering which brings forward the higher Kc. Earlier bud burst leads to an earlier harvest, which drops the Kc. However, leaf drop is fixed to the first fortnight of May which then drops to zero in May. With increasing climate change projections (RCP 8.5 and beyond 2050) there are earlier harvests, which leads to an evident drop in post harvest Kc in February and in the future irrigation required.
- As seen in the projected irrigation graphs, the summer future irrigation required is higher than the historical values. This is particularly evident with the pan evaporation projection which reaches up to 364 mm in January. This is a product of larger evapotranspiration (especially using the pan evaporation percentage increase) and lower effective rainfall. The higher the RCP and the further the projected year, the lower the winter rain, which leads to higher irrigation demands in winter. This is evident in the projected irrigation of 2070 of 47 mm against a historical average of 4 mm.

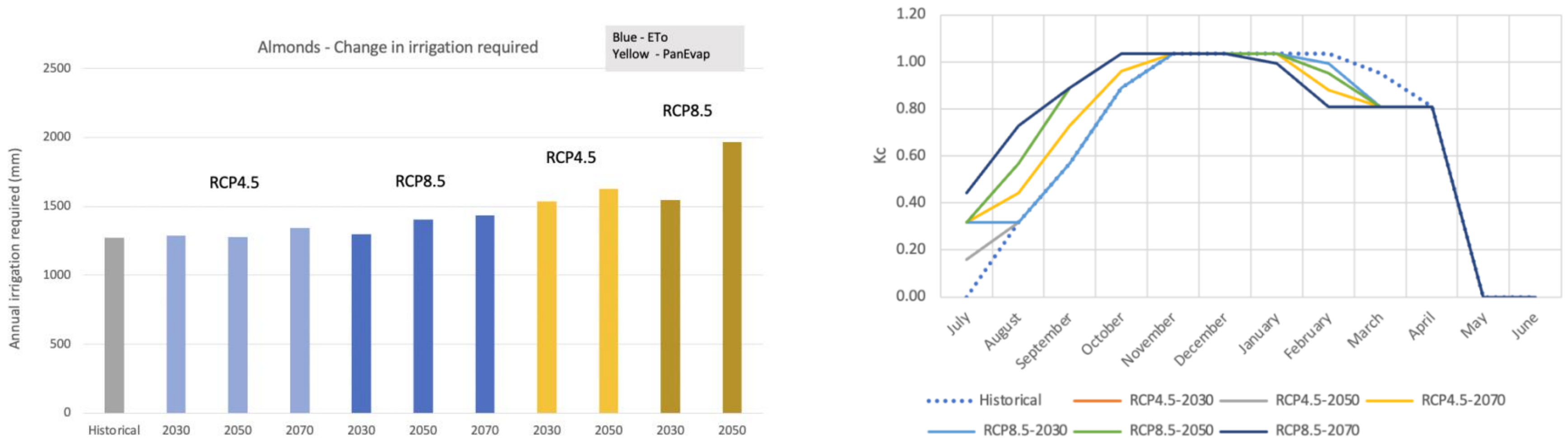


Figure 3-4: (left) Annual historic and projected irrigation required for almonds (right) Historic Kc and projected Kc for almonds

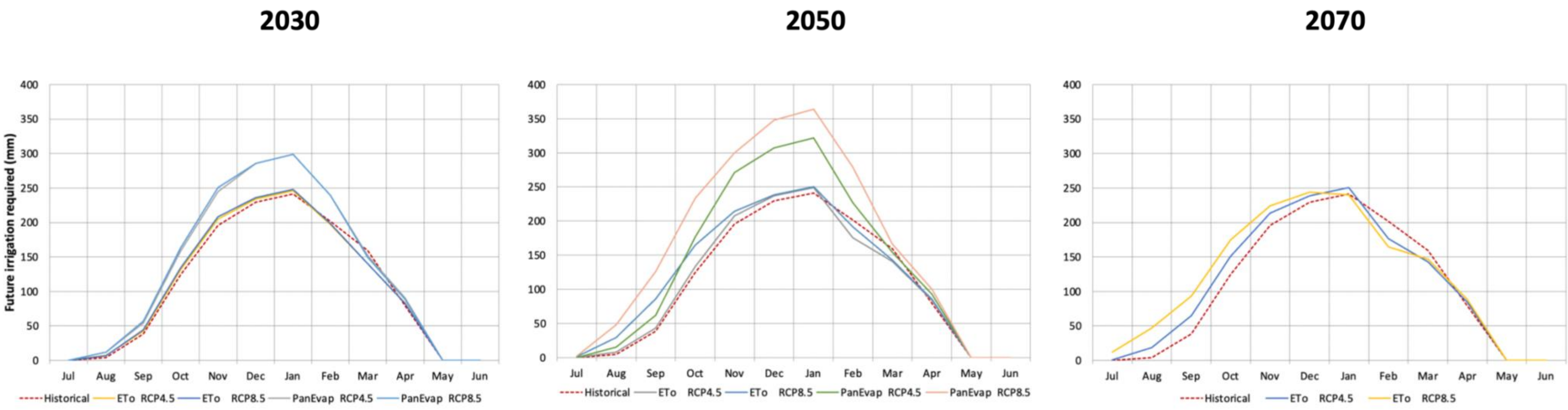


Figure 3-5: Projected irrigation requirement for 2030, 2050 and 2070 Further detail is provided in Appendix 3.

3.3 AVOCADO

3.3.1 AVOCADOS WITHOUT MISTING/COOLING

Crop	Avocado	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

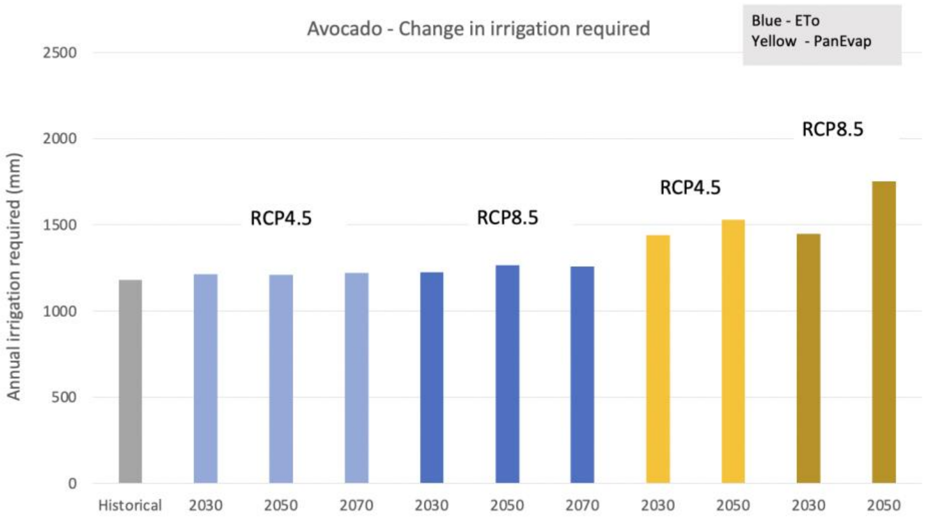
Manual entries		july	august	september	october	november	december	january	february	march	april	may	june
manual input of % change to historic ETo	%												
manual input of % change to historic ER	%												

Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual		
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443		
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160		
Avocado	Kc	0.61	0.69	0.78	0.84	0.85	0.85	0.85	0.84	0.81	0.78	0.67	0.60	9.18		
Water requirement	mm	28	46	72	116	145	172	178	148	120	75	40	25	1163		
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160		
Irrigation required allowing for no monthly carryover	mm	11.44	28.16	52.36	99.93	134.69	157.59	166.40	137.77	115.00	64.68	24.38	10.75			
Historic irrigation required with 85% efficiency	mm	13.46	33.13	61.60	117.56	158.45	185.40	195.76	162.08	135.30	76.09	28.68	12.65	**1180**		
Future Climate														**Annual future**	**Change**	**change in %**
Percentage increase in ETo	**%**	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Avocado	Kc	0.69	0.78	0.81	0.85	0.85	0.85	0.85	0.83	0.78	0.67	0.60	0.61	9.16	-0.03	-0.3%
Future water requirement	mm	34	55	82	125	157	177	183	150	122	68	38	27	1216	53	4.5%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	19.61	39.80	65.44	112.54	148.15	164.23	172.28	140.64	117.18	58.55	23.3	14.8			
Future irrigation required with 85% efficiency	mm	23.08	46.82	76.99	132.40	174.29	193.21	202.68	165.46	137.86	68.88	27.36	17.39	**1266**	**86**	**7.3%**

Figure 3-6: Example output RCP8.5 2050 Avocados

Figure 3-7 below shows the total irrigation required and the Kc values for avocados. Key findings from the graphs being:

- As seen in the Kc graph the irrigation season is expected to move forward and with it the end of the season moves forward. In projection RCP 8.5, by 2070 it is expected that the start of fruiting will move from start of May to end of February
- As seen in the projected irrigation graphs, the summer future irrigation required is higher than the historical values. This is particularly evident with the pan evaporation projection which reaches up to 295 mm in January compared to the 196 historical average
- The evapotranspiration based on ETo percentage change by CSIRO is similar to the historical average except for the 2070 projection.



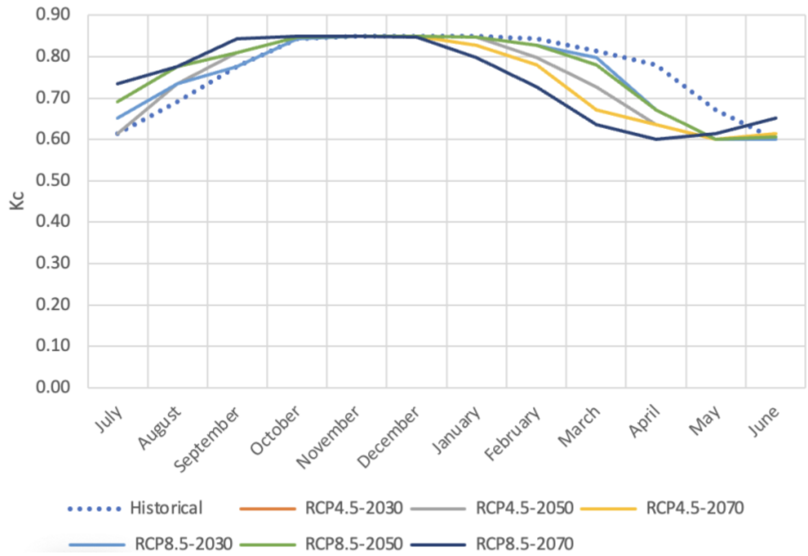
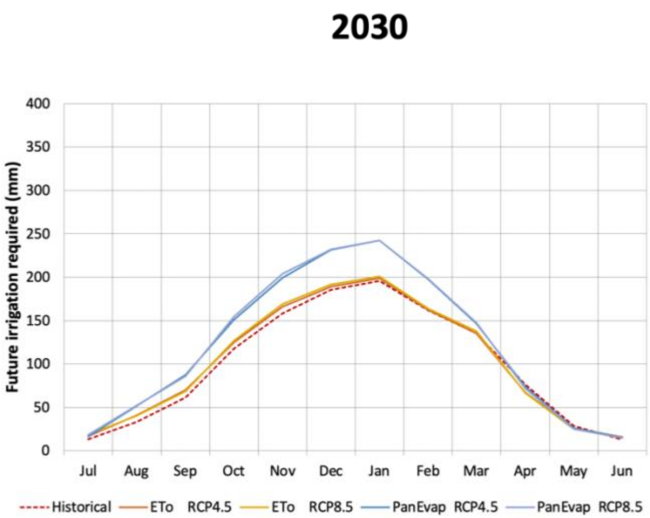
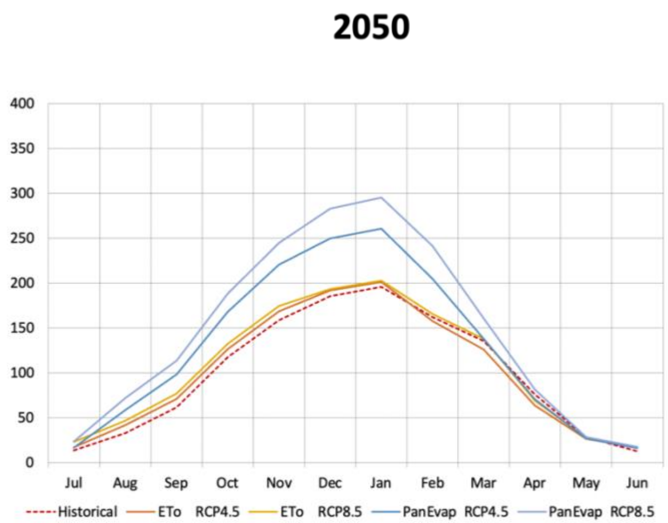


Figure 3-7: (left) Annual historic and projected irrigation required for avocados (right) Historic Kc and projected Kc for avocados





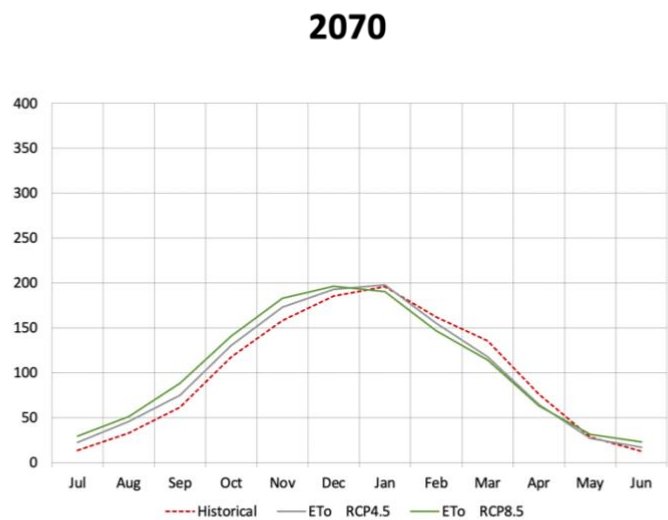


Figure 3-8: Projected irrigation requirement for 2030, 2050 and 2070

3.3.2 AVOCADOS WITH MISTING/COOLING

The Phase 2 (Natural Decisions, 2022) approach was to assume:

- A threshold of 36^{o}C triggers the operation of cooling misters
- The number of days per month that this trigger is currently, and predicted to be reached during the growing season, was used to estimate the likely cooling application requirements
- Assuming 1.5mm/h applied for 6 hours on each day that 36^{o}C is reached. (9mm/d additional water)
- A baseline climate had 30 days cooling at 9 mm/d or 270 mm/y is applied for cooling
- 2030 climate had an additional 5 days cooling or an additional 45 mm/y (numbers rounded)
- 2050 climate had additional 13.5 days cooling or an additional 121 mm/y (numbers rounded)
- 2070 climate had additional 20 days cooling or an additional 180 mm/y (numbers rounded).

The amount of water that can be evaporated is limited by the energy balance so values of ETc are energy-limited and in irrigation districts Kc cannot exceed 1.3 (Allen and Pereira, 2009). Cited by (Ian Goodwin, RMCG, 2013). This means that the maximum water that can be applied before creating water pooling or deep drainage is 1.3 x ETo. SILO baseline peak ETo short crop is approximately 10mm/d (the FO 56 ETo short crop 99th percentile is 8.7 mm/d), which would limit applications to a maximum of 13 mm/d.

This is significantly less than 9 mm/d plus usual crop water use of ETc assumed in Phase 2. Phase 2 appears to ignore the reduction in ETc that would occurs due to the impact of cooling and increased humidity.

Therefore, considering the above, it is estimated that on average, an additional 3 mm/d to 5 mm/d would be used for cooling days to meet cooling use and allowing for the offsetting reduced ETc. This reduces the estimates used in Phase 2 above to:

- 2030 climate -an additional 5 days cooling or an additional 20 -25 mm/y (numbers rounded)
- 2050 climate - an additional 13.5 days cooling or an additional 54 -68 mm/y (numbers rounded)
- 2070 climate - an additional 20 days cooling or an additional 80 -100 mm/y (numbers rounded).

These estimates should be added to the above ‘without cooling’ estimated water demand projections.

3.4 CITRUS

Crop	Citrus 90%sa	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june
manual input of % change to historic ETo	%												
manual input of % change to historic ER	%												

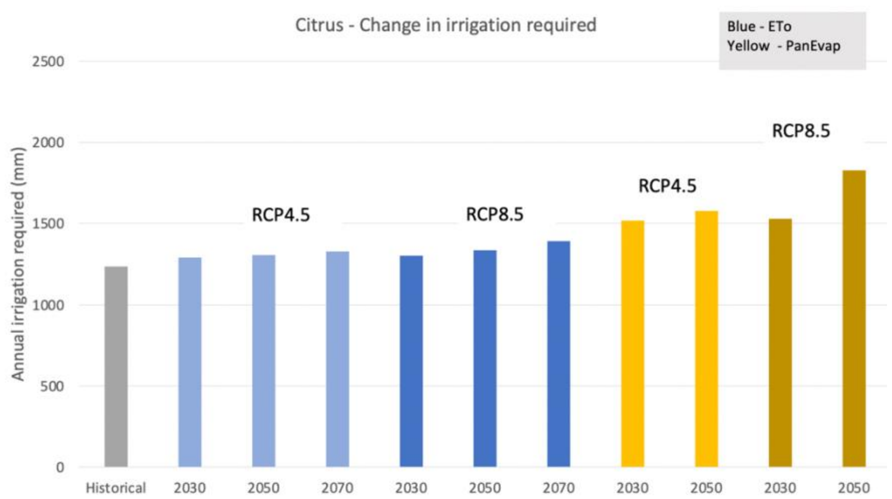
Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160
Citrus 90%sa	Kc	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	10.07
Water requirement	mm	38	55	78	115	143	169	175	147	124	80	50	35	1211
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160
Irrigation required allowing for no monthly carryover	mm	21.78	37.86	58.20	99.23	132.81	155.37	164.10	137.09	118.81	70.21	34.36	20.62	
Historic irrigation required with 85% efficiency	mm	25.62	44.54	68.48	116.74	156.24	182.79	193.06	161.28	139.78	82.60	40.43	24.26	**1236**

Future Climate		july	august	september	october	november	december	january	february	march	april	may	june	Annual future	Change	change in %
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Citrus 90%sa	Kc	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	10.07	0.00	0.0%
Future water requirement	mm	41	59	84	124	155	175	181	152	131	85	53	37	1277	66	5.5%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	26.85	44.21	68.34	111.35	146.12	161.94	170.67	142.63	126.21	75.46	38.3	25.0			
Future irrigation required with 85% efficiency	mm	31.59	52.01	80.40	131.00	171.91	190.52	200.79	167.79	148.48	88.78	45.06	29.47	**1338**	**102**	**8.3%**

Figure 3-9: Example output RCP8.5 2050 Citrus – 90% shaded area

Figure 3-10 below shows the total irrigation required and the Kc values for citrus. Key findings from the graphs are presented below:

- Kc remains stable as the Kc does not change with phenoligical stages in citrus (constant canopy area)
- The future irrigation matches the historical values with an increase due to the increase in evapotranspiration and lower effective rainfall with higher RCP and later years.



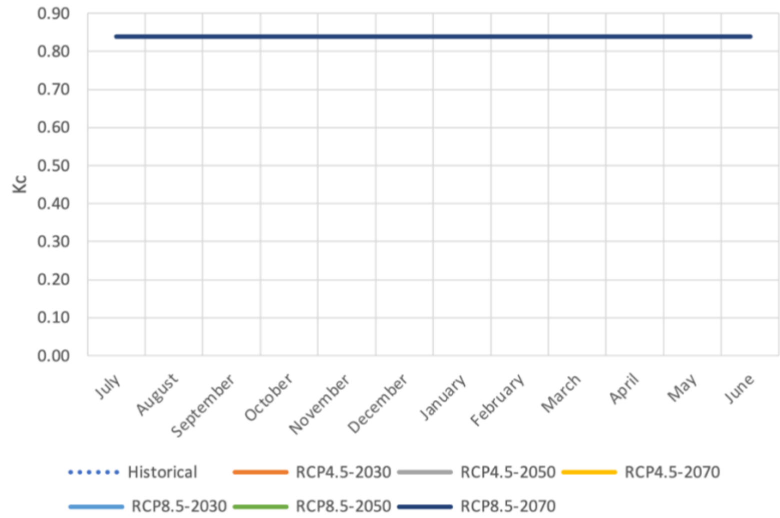


Figure 3-10: (left) Annual historic irrigation required for citrus (right) Historic Kc and projected Kc for citrus.

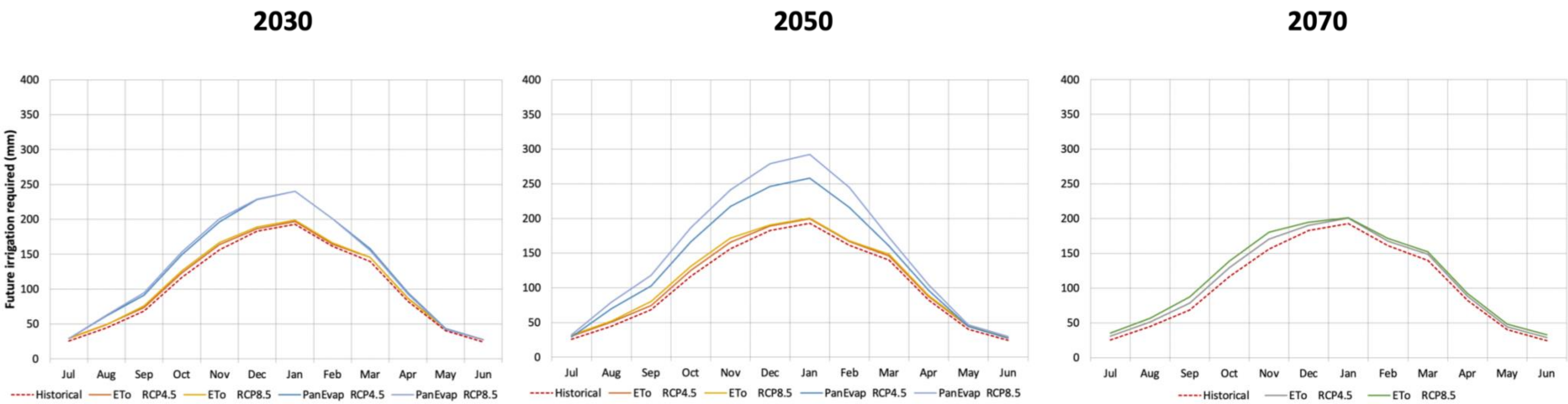


Figure 3-11: Projected irrigation requirement for 2030, 2050 and 2070

3.5 DRIED GRAPES

Crop	Dried grapes	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june			
manual input of % change to historic ETo	%															
manual input of % change to historic ER	%															
Historic		july	august	september	october	november	december	january	february	march	april	may	june	**Annual**		
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443		
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160		
Dried grapes	Kc	0.00	0.00	0.32	0.63	0.83	0.83	0.66	0.66	0.62	0.54	0.00	0.00	5.09		
Water requirement	mm	0	0	30	86	142	167	138	116	92	52	0	0	823		
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160		
Irrigation required allowing for no monthly carryover	mm	0.00	0.00	9.55	70.48	130.93	153.15	127.18	106.17	86.66	42.13	0.00	0.00			
Historic irrigation required with 85% efficiency	mm	0.00	0.00	11.24	82.91	154.03	180.17	149.62	124.90	101.96	49.56	0.00	0.00	**854**		
Future Climate														**Annual future**	**Change**	**change in %**
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Dried grapes	Kc	0.00	0.32	0.63	0.83	0.83	0.66	0.64	0.58	0.54	0.54	0.00	0.00	5.58	0.49	9.5%
Future water requirement	mm	0	22	63	122	153	138	139	105	85	55	0	0	883	60	7.3%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	0.00	7.48	47.23	109.73	144.09	125.11	128.07	96.30	80.33	45.78	0.0	0.0			
Future irrigation required with 85% efficiency	mm	0.00	8.80	55.56	129.09	169.52	147.19	150.67	113.29	94.51	53.86	0.00	0.00	**922**	**68**	**8.0%**

Figure 3-12: Example output RCP8.5 2050 Dried grapes

Figure 3-13 below shows the total irrigation required and the Kc values for dried grapes. Key findings from the graphs are presented below:

- As seen in the Kc graph, the season is expected to move forward due to earlier bud burst and flowering which brings forward the higher Kc for the crop in July and August. Earlier bud burst leads to an earlier harvest, starting in January for the most extreme RCP8.5-2070 compared to a historical March. This make the peak Kc which previously was in December to be earlier and not in the peak of summer. However, leaf drop is fixed to the first fortnight of May which stabilises the Kc between 0.5 and 0.7. For all years and climate scenarios the Kc drops to zero in May as it is the assumed leaf drop time
- The future irrigation requirement shows for 2050 and 2070 a skew and peak from the historic December peak to November. This is due to the shift in Kc values as well as high projected ETo, low projected ER.

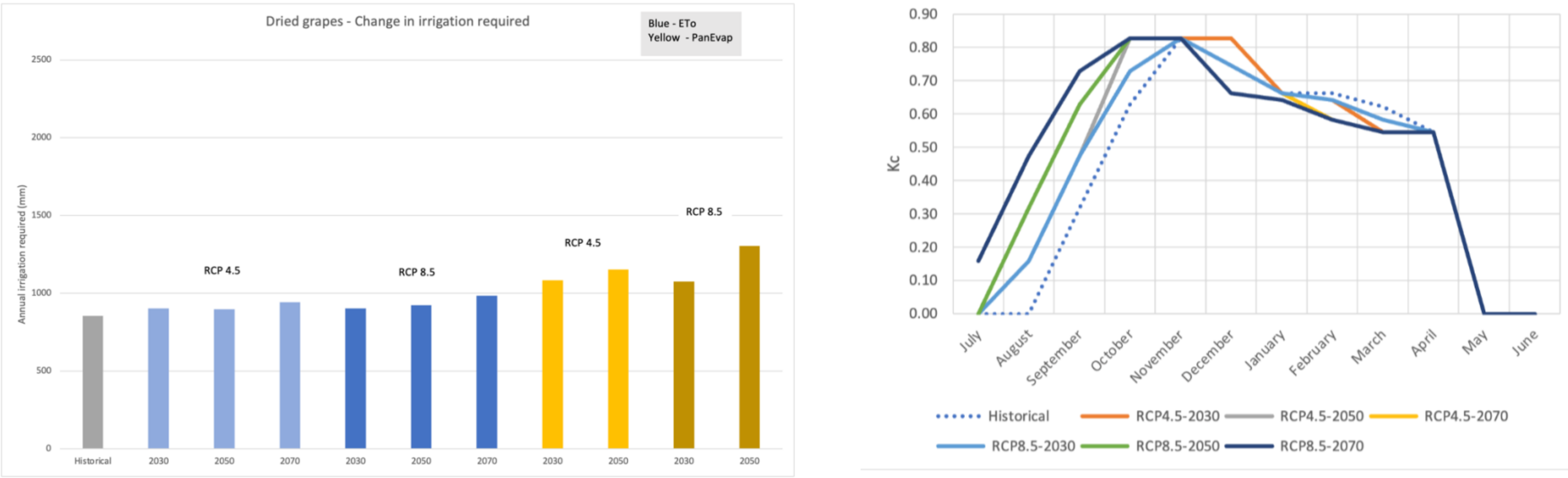


Figure 3-13: (left) annual historic and projected irrigation required for dried grapes (right) Historic Kc and projected Kc for dried grapes

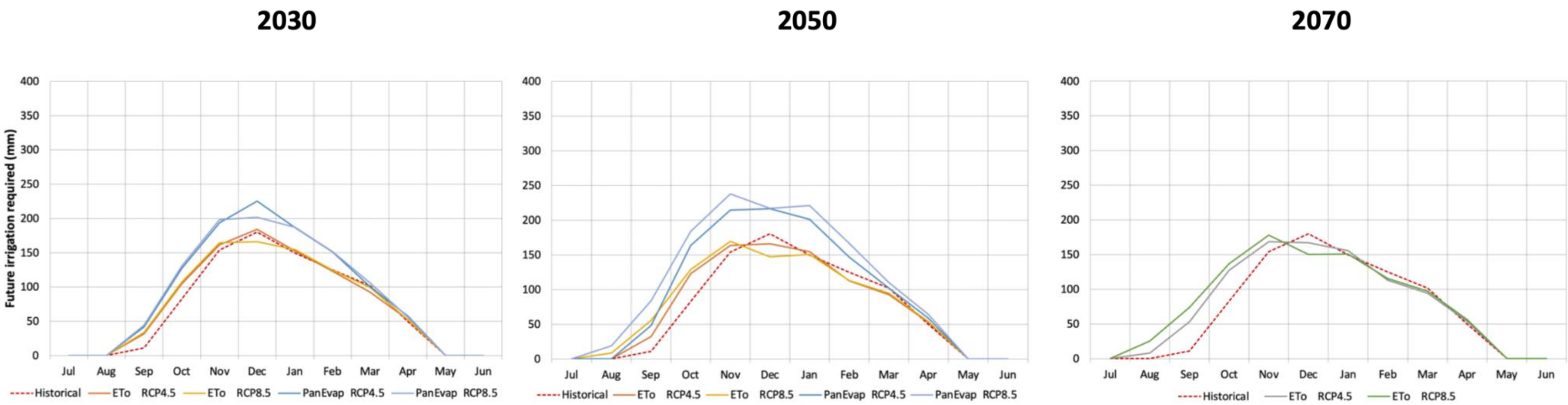


Figure 3-14: Projected irrigation requirement for 2030, 2050, 2070

3.6 WINE GRAPES

Crop	Winegrape 90%sa	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june			
manual input of % change to historic ETo	%															
manual input of % change to historic ER	%															
Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual		
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443		
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160		
Winegrape 90%sa	Kc	0.00	0.00	0.32	0.63	0.83	0.83	0.83	0.83	0.78	0.68	0.00	0.00	5.72		
Water requirement	mm	0	0	30	86	142	167	173	145	114	65	0	0	922		
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160		
Irrigation required allowing for no monthly carryover	mm	0.00	0.00	9.55	70.48	130.93	153.15	161.80	135.16	109.56	55.12	0.00	0.00			
Historic irrigation required with 85% efficiency	mm	0.00	0.00	11.24	82.91	154.03	180.17	190.35	159.02	128.90	64.85	0.00	0.00	**971**		
Future Climate														Annual future	Change	change in %
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Winegrape 90%sa	Kc	0.00	0.32	0.63	0.73	0.83	0.83	0.80	0.73	0.68	0.68	0.00	0.00	6.22	0.51	8.9%
Future water requirement	mm	0	22	63	108	153	173	173	132	106	69	0	0	998	76	8.3%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	0.00	7.48	47.23	95.04	144.09	159.64	162.71	122.65	101.56	59.51	0.0	0.0			
Future irrigation required with 85% efficiency	mm	0.00	8.80	55.56	111.82	169.52	187.82	191.43	144.30	119.49	70.02	0.00	0.00	**1059**	**87**	**9.0%**

Figure 3-15: Example output RCP8.5 2050 Wine grapes 90% shaded area

Key findings from the graphs are presented below:

- As seen in the Kc graph, the season is expected to move forward due to earlier bud burst and flowering which brings forward the higher Kc for the crop. Earlier bud burst leads to an earlier harvest, which drops the Kc. However, leaf drop is fixed to the first fortnight of May which stabilises the Kc which then drops to zero in May. Beyond 2050 and as the RCP increases there is a more evident bend in February in the future irrigation required graphs product of the combination of Kc, ETo and ER
- As seen in the projected irrigation graphs, the summer future irrigation required is higher than the historical values. This is particularly evident with the pan evaporation projection which reaches in 2050 – RCP8.5 up to 279 mm in January compared to 190 mm average. This is a product of larger evapotranspiration (especially using the pan evaporation percentage increase) and lower effective rainfall
- RCP 8.5 with the furtherest projected years give lower winter rain, which leads to irrigation demands in winter in periods when the historical average demand was nil.

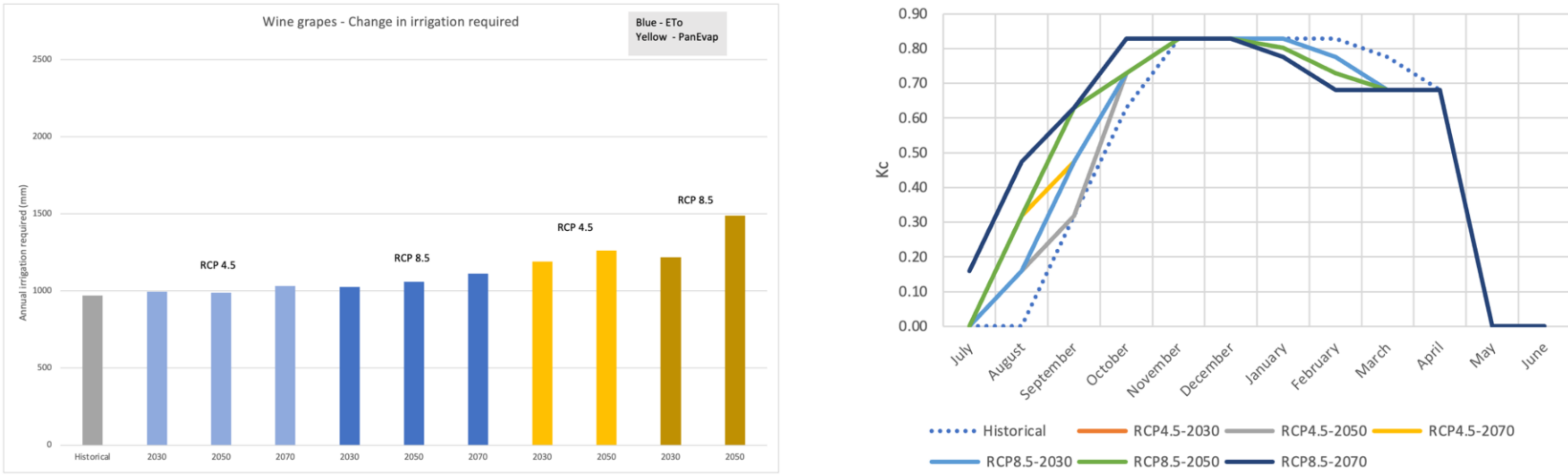


Figure 3-16: (left) Annual historic and projected irrigation required for wine grapes (right) Historic and projected Kc for wine grapes

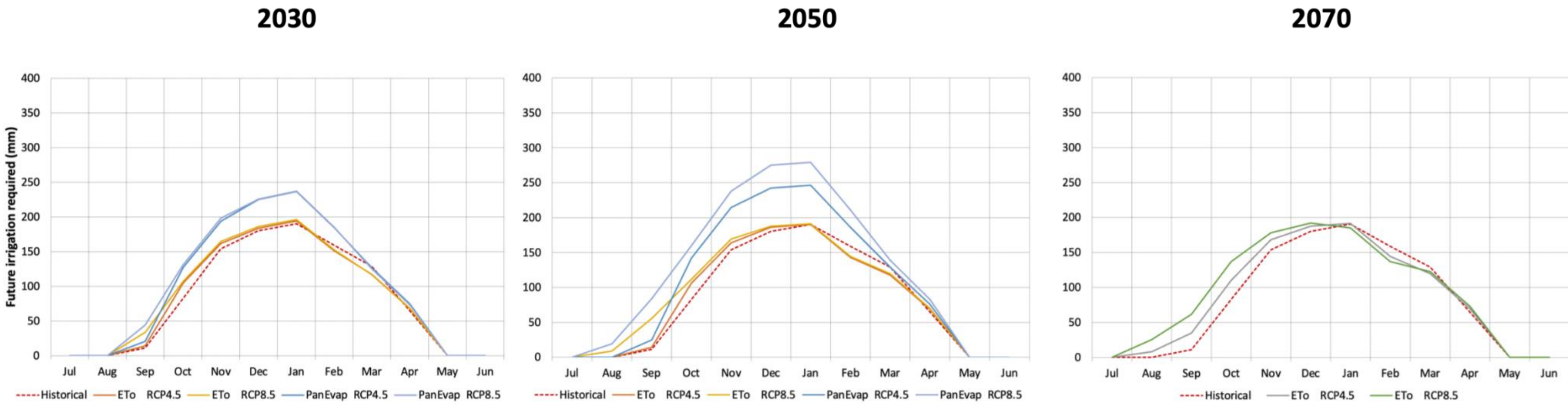


Figure 3-17: Projected irrigation requirement for 2030, 2050 and 2070

3.7 TABLE GRAPES

3.7.1 TABLE GRAPES WITHOUT MISTING/COOLING

Crop	Table Grape 50%sa
Historic ET data source	Mildura SILO short crop
Future climate scenario	RCP8.5-2050
Data source for ET increases	ETo (long crop)

determines Kc adopted and ETo % change and ER % change

Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available and shows 0% increase

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june
manual input of % change to historic ETo	%												
manual input of % change to historic ER	%												

Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160
Table Grape 50%sa	Kc	0.00	0.29	0.48	0.90	0.95	0.95	0.95	0.93	0.85	0.78	0.00	0.00	7.08
Water requirement	mm	0	19	45	124	162	192	199	163	125	75	0	0	1103
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160
Irrigation required allowing for no monthly carryover	mm	0.00	1.59	24.84	107.78	151.78	177.78	187.30	153.54	120.02	64.74	0.00	0.00	
Historic irrigation required with 85% efficiency	mm	0.00	1.88	29.23	126.80	178.57	209.15	220.35	180.64	141.19	76.16	0.00	0.00	**1164**

Future Climate		july	august	september	october	november	december	january	february	march	april	may	june	Annual future	Change	change in %
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Table Grape 50%sa	Kc	0.29	0.48	0.90	0.95	0.95	0.95	0.93	0.81	0.78	0.78	0.00	0.00	7.83	0.75	10.6%
Future water requirement	mm	14.2	34.0	90.7	140.4	175.1	198.1	201.5	147.3	121.9	78.8	0.0	0.0	1202	99	8.9%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	0.00	19.02	74.62	127.76	166.58	185.09	190.97	138.18	117.28	69.68	0.0	0.0			
Future irrigation required with 85% efficiency	mm	0.00	22.38	87.79	150.30	195.98	217.75	224.67	162.57	137.98	81.98	0.00	0.00	**1281**	**117**	**10.1%**

Figure 3-18: Example output RCP8.5 2050 Table grapes 90% shaded area

Figure 3-19 below shows the total irrigation required and the Kc values for table grapes. Key findings from the graphs below:

- As seen in the Kc graph, the season is expected to move forward due to earlier bud burst and flowering which brings forward the higher Kc for the crop in July and August. Earlier bud burst leads to an earlier harvest, starting in January for the most extreme RCP8.5-2070 compared to a historical February. This makes the peak Kc which previously was in December and January to be as early as September. However, leaf drop is fixed to the first fortnight of May which stabilises the Kc between 0.8 and 1. For all years and climate scenarios, the Kc drops to zero in May as it is the assumed leaf drop time
- As seen in the Kc graph, between December and April there is a dip in projected Kc compared to the historical
- The future irrigation requirement shows for 2050 a peak in January of between 225 to 327mm compared to 220 mm historical average.

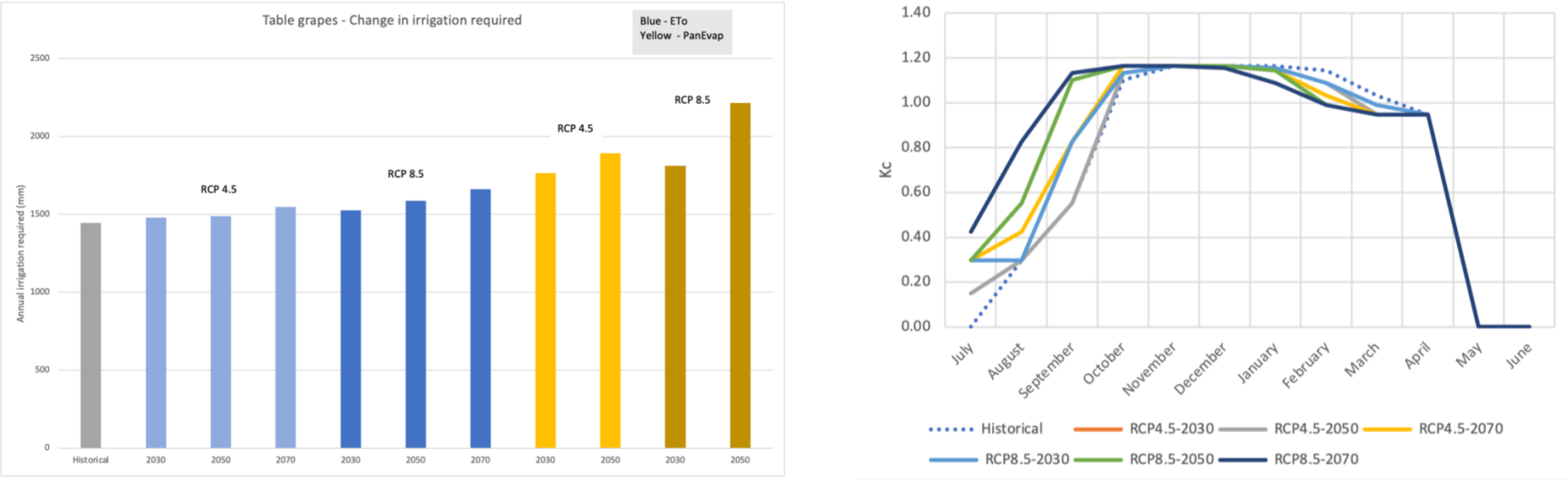


Figure 3-19: (left) Annual historic and projected irrigation required for table grapes (right) Historic Kc and projected Kc for table grapes

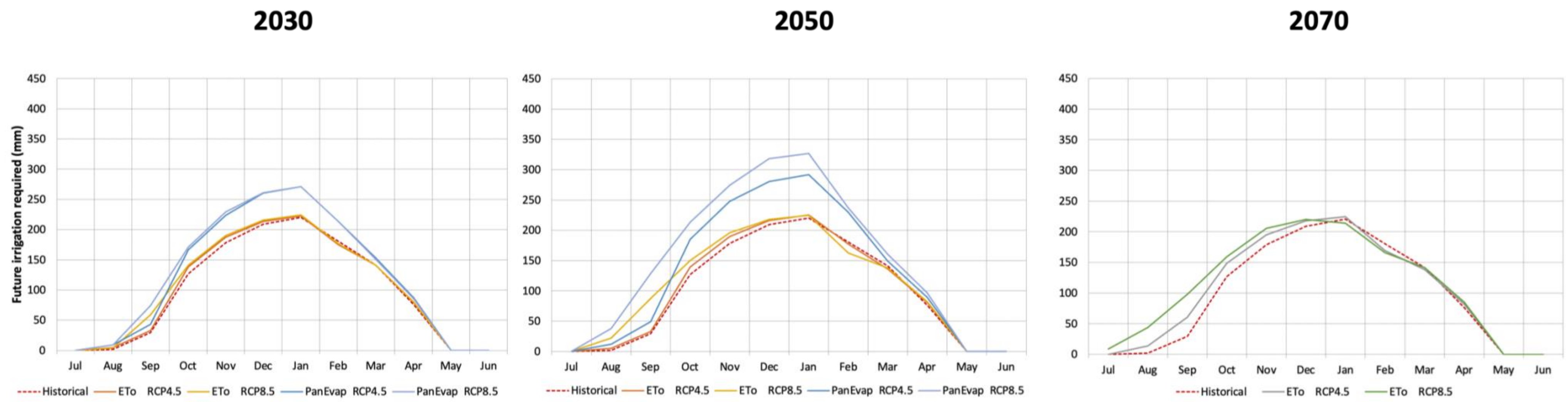


Figure 3-20: Projected irrigation requirement for 2030, 2050 and 2070

3.7.2 TABLE GRAPES WITH MISTING/COOLING

The Phase 2 (Natural Decisions, 2022) approach was to assume:

- A threshold of 38ºC triggers the operation of cooling misters
- 1.5mm/h applied for 6 hours on each day that 36ºC is reached. (9mm/d additional water)
- Baseline climate had 16 days with 99 mm/y applied for cooling
- 2030 climate had 20-21 days with 108 mm/y applied for cooling
- 2050 climate had 24-30 days with 139.5 mm/y applied for cooling
- 2070 climate had 30-37 days with 153 mm/y applied for cooling.

As previously discussed for avocados, the amount of water that can be evaporated is limited by the energy balance so values of ETc are energy-limited and in irrigation districts, Kc cannot exceed 1.3 (Allen and Pereira, 2009). Cited by (Ian Goodwin, RMCG, 2013).

This means that the maximum water that can be applied before creating water pooling or deep drainage is 1.3 x ETo. SILO baseline peak ETo short crop is approximately 10mm/d (the FO 56 ETo short crop 99th percentile is 8.7 mm/d), which would limit applications to a maximum of 13 mm/d.

This is significantly less than 9 mm/d plus the usual crop water use of ETc assumed in Phase 2. Phase 2 appears to have ignored the reduction in ETc that would occurs due to the impact of cooling and increased humidity.

Therefore, considering the above, it is estimated that on average, an additional 3 mm/d to 5 mm/d would be used for cooling days to meet cooling use and allowing for the offsetting reduced ETc. This reduces the estimates used in Phase 2 above to:

- 2030 climate -an additional 5 day cooling or an additional 15–25 mm/y (numbers rounded)
- 2050 climate - an additional 11 days cooling or an additional 33–55 mm/y (numbers rounded)
- 2070 climate - an additional 20 days cooling or an additional 60–100 mm/y (numbers rounded).

These estimates should be added to the above ‘without cooling’ estimated water demand projections.

3.8 PISTACHIO

Crop	Pistachios	
Historic ET data source	Mildura SILO short crop	
Future climate scenario	RCP8.5-2050	determines Kc adopted and ETo % change and ER % change
Data source for ET increases	ETo (tall crop)	Only changes ETo % increase. Note ETo CSIRO short crop (2024) not yet available

Manual entries		july	august	september	october	november	december	january	february	march	april	may	june
manual input of % change to historic ETo	%												
manual input of % change to historic ER	%												

Historic		july	august	september	october	november	december	january	february	march	april	may	june	Annual
ETo 1976 to 2005 Historic Reference Period	mm/month	46	66	93	137	171	202	209	175	147	95	60	41	1443
Effective Rainfall 1976 to 2005 Historic Reference Period	mm/month	17	17	20	16	11	14	11	10	5	10	16	14	160
Pistachios	Kc	0.00	0.00	0.00	0.42	0.70	1.03	1.10	1.07	0.69	0.00	0.00	0.00	5.01
Water requirement	mm	0	0	0	58	119	208	230	187	102	0	0	0	904
ER (Effective rainfall)	mm	17	17	20	16	11	14	11	10	5	10	16	14	160
Irrigation required allowing for no monthly carryover	mm	0.00	0.00	0.00	41.89	108.61	193.62	218.66	177.20	97.39	0.00	0.00	0.00	
Historic irrigation required with 85% efficiency	mm	0.00	0.00	0.00	49.28	127.78	227.79	257.24	208.47	114.58	0.00	0.00	0.00	**985**

Future Climate		july	august	september	october	november	december	january	february	march	april	may	june	Annual future	Change	change in %
Percentage increase in ETo	%	**7.1%**	**7.1%**	**7.8%**	**7.8%**	**7.8%**	**3.3%**	**3.3%**	**3.3%**	**5.7%**	**5.7%**	**5.7%**	**7.1%**			
Future ETo adopted	mm/month	49.1	70.5	100.6	147.8	184.3	208.5	215.9	180.9	155.9	100.9	62.9	44.2	1522	79	5.5%
Pistachios	Kc	0.00	0.00	0.42	0.56	1.03	1.10	1.07	0.69	0.69	0.00	0.00	0.00	5.56	0.56	11.1%
Future water requirement	mm	0	0	42	83	190	229	231	125	108	0	0	0	1008	104	11.5%
% change to historic rainfall	mm	-14%	-14%	-20%	-20%	-20%	-7%	-7%	-7%	-7%	-7%	-7%	-14%			
Future ER	mm	14.4	14.9	16.1	12.6	8.5	13.0	10.5	9.1	4.6	9.2	14.5	12.1	139	-21	-12.9%
Future Irrigation required allowing for no monthly carryover	mm	0.00	0.00	26.24	69.99	181.05	216.37	220.14	116.35	103.57	0.00	0.0	0.0			
Future irrigation required with 85% efficiency	mm	0.00	0.00	30.87	82.35	213.00	254.55	258.99	136.89	121.85	0.00	0.00	0.00	**1098**	**113**	**11.5%**

Figure 3-21: Example output RCP8.5 2050 Pistachios

Key findings from the graphs below:

- As seen in the Kc graph, the season is expected to move forward due to earlier bud burst and flowering which brings forward the higher Kc for the crop from August to October. Earlier bud burst leads to an earlier harvest, starting in January for the most extreme RCP8.5-2070 compared to a historical start in March. This makes the peak Kc which previously was in January to be as early as December. However, leaf drop is fixed to the first fortnight of May which stabilises the Kc between February and March. For all years and climate scenarios the Kc drops to zero in May as it is the assumed leaf drop time
- As seen in the Kc graph, between December and March there is a dip in projected Kc's compared to the historical.

The future irrigation requirement shows for 2050 a peak in January of between 258–376 mm compared to the 257 mm historical average.

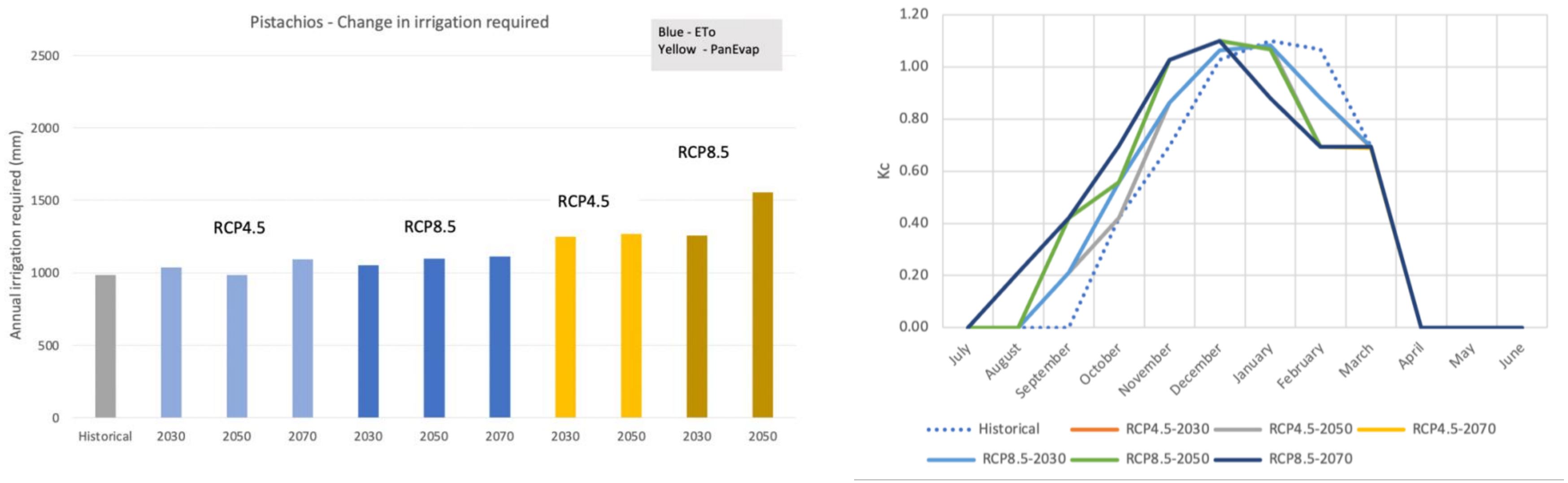


Figure 3-22: (left) Annual historic and projected irrigation required for pistachios (right) Historic Kc and projected Kc for pistachios

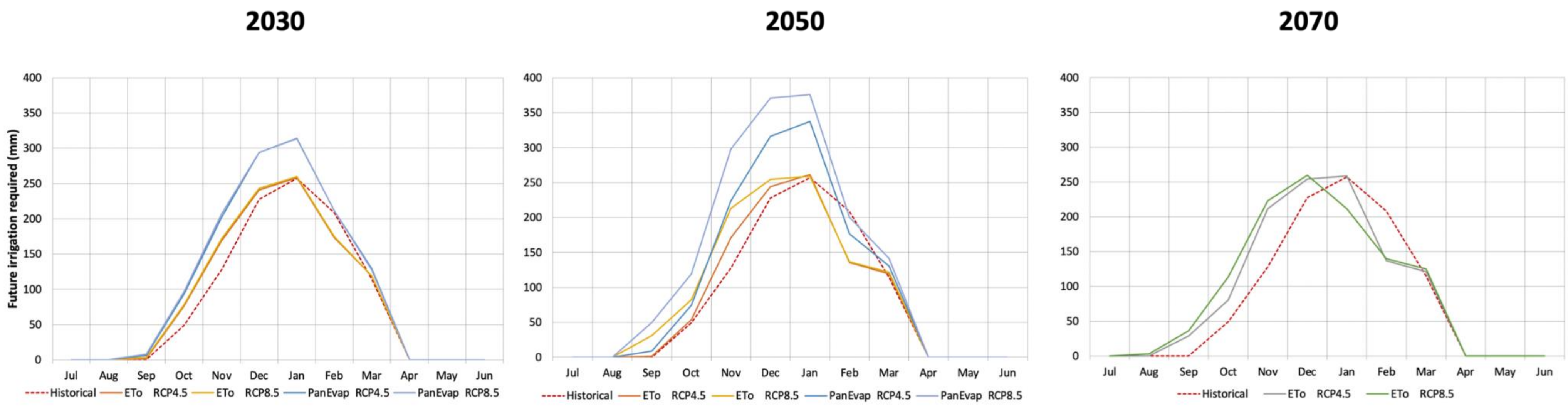


Figure 3-23: Projected irrigation requirement for 2030, 2050 and 2070

4 Conclusion

Future irrigation demand is influenced by the increase in ETo, projected rainfall reductions and the change in crop Kc as a result of the climate affecting phenology, in particular bud burst and harvest date.

The results are different to the research conducted in the previous phases, but it has not been able to identify the specific reasons for this, as it is unclear what Kc values were used and what % changes in ETo or ER were assumed in the previous work.

The average increase in annual demand across the crops studied is tabulated below, note individual crops vary from the averages and are shown in Appendix 3.

Table 4-1: Average increases in projected annual irrigation demand across all crops studied

FUTURE % CHANGE ABOVE HISTORIC BASELINE	RCP4.5 2030	RCP4.5 2050	RCP4.5 2070	RCP8.5 2030	RCP8.5 2050	RCP8.5 2070
Australian Water Outlook projections using ETo % increases	3%	3%	7%	5%	9%	13%
Mallee climate projections using evaporation pan % increases	23%	31%	Not available	25%	52%	Not available

There is a large difference between the ETo projections and evaporation pan projections and it is recommended that this study be updated when data from the CSIRO 2024 short crop ETo projections are available.

5 Works Cited

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Appendix 1: Crop phenology

These were provided by Agriculture Victoria from Phase 2 analysis.

Note there are some highlighted errors in the sequence of some the phenostages. These were corrected for in the calculation of Kc for this report.

CROP	PHENOSTAGE	HIST	BASE	RCP4.5-2030	RCP4.5-2050	RCP4.5-2070	RCP4.5-2090	RCP8.5-2030	RCP8.5-2050	RCP8.5-2070	RCP8.5-2090
Almonds	Bud burst	4-Aug	20-Aug	28-Jul	28-Jul	6-Jul	3-Jul	13-Jul	30-Jun	24-Jun	16-Jun
Almonds	Peak flowering	31-Aug	8-Sep	26-Aug	22-Aug	8-Aug	29-Jul	16-Aug	30-Jul	15-Jul	29-Jun
Almonds	Nut fill start	19-Nov	23-Nov	8-Nov	1-Nov	29-Oct	24-Oct	10-Nov	30-Oct	18-Oct	5-Oct
Almonds	Start of hull split	1-Feb	3-Feb	21-Jan	15-Jan	12-Jan	10-Jan	20-Jan	10-Jan	24-Dec	14-Dec
Almonds	Start nut drying	15-Feb	17-Feb	2-Feb	26-Jan	23-Jan	15-Jan	2-Feb	20-Jan	11-Jan	24-Dec
Almonds	End harvest	17-Mar	19-Mar	25-Feb	15-Feb	12-Feb	30-Dec	26-Feb	8-Feb	31-Dec	31-Dec
Avocados	Flower bud break	9-Aug	21-Aug	5-Aug	5-Aug	12-Jul	9-Jul	22-Jul	8-Jul	29-Jun	21-Jun
Avocados	Start of flowering	8-Sep	9-Sep	29-Aug	26-Aug	15-Aug	8-Aug	25-Aug	9-Aug	27-Jul	7-Jul
Avocados	Peak flowering	12-Oct	13-Oct	29-Sep	24-Sep	22-Sep	16-Sep	2-Oct	22-Sep	12-Sep	26-Aug
Avocados	End of flowering	24-Nov	25-Nov	12-Nov	5-Nov	1-Nov	27-Oct	13-Nov	1-Nov	22-Oct	9-Oct
Avocados	Start of fruit mature	1-May	8-Jun	2-Apr	21-Mar	14-Mar	5-Mar	4-Apr	11-Mar	23-Feb	5-Feb
Avocados	Start of harvest	7-May	27-Jul	4-Apr	23-Mar	17-Mar	7-Mar	8-Apr	12-Mar	25-Feb	6-Feb
Avocados	End harvest	7-Oct	25-Sep	12-May	11-May	26-Apr	8-Apr	21-May	19-Apr	24-Mar	24-Feb
Dried Grapes	Bud burst	19-Sep	18-Sep	8-Sep	4-Sep	28-Aug	22-Aug	5-Sep	24-Aug	8-Aug	23-Jul

CROP	PHENOSTAGE	HIST	BASE	RCP4.5-2030	RCP4.5-2050	RCP4.5-2070	RCP4.5-2090	RCP8.5-2030	RCP8.5-2050	RCP8.5-2070	RCP8.5-2090
Dried Grapes	Start flowering	3-Nov	3-Nov	22-Oct	13-Oct	11-Oct	5-Oct	22-Oct	10-Oct	27-Sep	17-Sep
Dried Grapes	Net fruit set	6-Dec	6-Dec	24-Nov	16-Nov	14-Nov	6-Nov	24-Nov	13-Nov	2-Nov	19-Oct
Dried Grapes	Veraison start	22-Dec	23-Dec	17-Dec	8-Dec	8-Dec	28-Nov	15-Dec	4-Dec	23-Nov	8-Nov
Dried Grapes	Start harvest	5-Mar	5-Mar	18-Feb	9-Feb	5-Feb	29-Jan	18-Feb	31-Jan	21-Jan	8-Jan
Dried Grapes	End harvest	14-Apr	7-Apr	17-Mar	28-Feb	24-Feb	16-Feb	17-Mar	18-Feb	7-Feb	31-Dec
Mandarins	Bud burst	17-Jul	17-Jul	19-Jun	15-Jun	8-Jun	8-Jun	13-Jun	8-Jun	7-Jun	5-Jun
Mandarins	Full bloom	28-Sep	24-Sep	15-Sep	8-Sep	2-Sep	26-Aug	14-Sep	1-Sep	20-Aug	13-Jul
Mandarins	Start of fruit set	21-Oct	18-Oct	2-Oct	27-Sep	26-Sep	20-Sep	6-Oct	26-Sep	16-Sep	2-Sep
Mandarins	Colour change	13-Apr	13-Apr	12-Mar	27-Feb	24-Feb	16-Feb	18-Mar	22-Feb	9-Feb	21-Jan
Mandarins	Start harvest	18-May	28-Apr	19-Mar	3-Mar	1-Mar	21-Feb	27-Mar	26-Feb	13-Feb	23-Jan
Mandarins	End harvest	19-Nov	8-Nov	17-Sep	25-Apr	11-Apr	28-Mar	25-Sep	6-Apr	12-Mar	13-Feb
Oranges	Bud burst	10-Aug	14-Aug	27-Jun	18-Jun	9-Jun	9-Jun	15-Jun	9-Jun	7-Jun	6-Jun
Oranges	Full bloom	11-Oct	5-Oct	26-Sep	20-Sep	17-Sep	14-Sep	27-Sep	17-Sep	5-Sep	22-Aug
Oranges	Start of fruit set	24-Oct	24-Oct	7-Oct	29-Sep	29-Sep	24-Sep	10-Oct	29-Sep	18-Sep	5-Sep
Oranges	Colour change	9-Apr	5-Apr	9-Mar	25-Feb	23-Feb	14-Feb	15-Mar	20-Feb	6-Feb	19-Jan
Oranges	Start harvest	18-May	28-Apr	18-Mar	24-Mar	11-Feb	21-Feb	27-Mar	26-Feb	19-Feb	29-Jan
Oranges	End harvest	15-Nov	24-Oct	25-Jul	24-Mar	11-Feb	17-Mar	15-Aug	27-Mar	22-Feb	3-Feb

CROP	PHENOSTAGE	HIST	BASE	RCP4.5-2030	RCP4.5-2050	RCP4.5-2070	RCP4.5-2090	RCP8.5-2030	RCP8.5-2050	RCP8.5-2070	RCP8.5-2090
Pinot	Bud burst	10-Sep	8-Sep	26-Aug	22-Aug	7-Aug	30-Jul	22-Aug	4-Aug	19-Jul	2-Jul
Pinot	Start flowering	31-Oct	28-Oct	13-Oct	7-Oct	4-Oct	28-Sep	15-Oct	4-Oct	23-Sep	13-Sep
Pinot	Net fruit set	27-Nov	25-Nov	10-Nov	2-Nov	31-Oct	25-Oct	13-Nov	1-Nov	22-Oct	7-Oct
Pinot	Veraison start	17-Dec	15-Dec	2-Dec	25-Nov	23-Nov	14-Nov	3-Dec	23-Nov	12-Nov	29-Oct
Pinot	Start harvest	6-Feb	3-Feb	21-Jan	14-Jan	12-Jan	10-Jan	20-Jan	11-Jan	23-Dec	14-Dec
Pinot	End harvest	3-Mar	24-Feb	9-Feb	28-Dec	25-Dec	31-Dec	9-Feb	31-Dec	30-Dec	27-Dec
Pistachios	Bud swell	18-Sep	19-Sep	9-Sep	4-Sep	31-Aug	22-Aug	8-Sep	27-Aug	11-Aug	23-Jul
Pistachios	Start of fruit set	21-Oct	25-Oct	12-Oct	5-Oct	2-Oct	27-Sep	12-Oct	2-Oct	20-Sep	9-Sep
Pistachios	Shell hardening comm	2-Dec	4-Dec	24-Nov	16-Nov	13-Nov	6-Nov	24-Nov	13-Nov	2-Nov	19-Oct
Pistachios	Start harvest	4-Mar	8-Mar	19-Feb	11-Feb	7-Feb	29-Jan	21-Feb	3-Feb	23-Jan	8-Jan
Pistachios	End harvest	13-Apr	19-Apr	24-Mar	6-Mar	1-Mar	18-Feb	26-Mar	24-Feb	10-Feb	31-Dec
Shiraz	Bud burst	10-Sep	8-Sep	25-Aug	21-Aug	6-Aug	30-Jul	21-Aug	3-Aug	19-Jul	2-Jul
Shiraz	Start flowering	6-Nov	4-Nov	22-Oct	13-Oct	11-Oct	5-Oct	24-Oct	11-Oct	29-Sep	19-Sep
Shiraz	Net fruit set	3-Dec	1-Dec	18-Nov	9-Nov	7-Nov	31-Oct	19-Nov	8-Nov	28-Oct	14-Oct
Shiraz	Veraison start	20-Dec	21-Dec	9-Dec	1-Dec	29-Nov	21-Nov	9-Dec	29-Nov	18-Nov	4-Nov
Shiraz	Start harvest	3-Mar	28-Feb	12-Feb	3-Feb	31-Jan	22-Jan	14-Feb	29-Jan	18-Jan	10-Jan
Shiraz	End harvest	10-Apr	3-Apr	7-Mar	20-Feb	18-Feb	10-Feb	11-Mar	14-Feb	31-Dec	31-Dec
Table Grapes	Bud burst	18-Sep	19-Sep	9-Sep	3-Sep	30-Aug	21-Aug	7-Sep	27-Aug	10-Aug	16-Jul

CROP	PHENOSTAGE	HIST	BASE	RCP4.5-2030	RCP4.5-2050	RCP4.5-2070	RCP4.5-2090	RCP8.5-2030	RCP8.5-2050	RCP8.5-2070	RCP8.5-2090
Table Grapes	Start flowering	4-Nov	5-Nov	24-Oct	16-Oct	14-Oct	9-Oct	25-Oct	14-Oct	2-Oct	20-Sep
Table Grapes	Net fruit set	29-Nov	2-Dec	20-Nov	12-Nov	9-Nov	2-Nov	21-Nov	10-Nov	29-Oct	16-Oct
Table Grapes	Veraison start	4-Feb	7-Feb	24-Jan	17-Jan	15-Jan	12-Jan	24-Jan	12-Jan	24-Dec	16-Dec
Table Grapes	Start harvest	22-Feb	24-Feb	8-Feb	31-Jan	28-Jan	20-Jan	8-Feb	25-Jan	14-Jan	24-Dec
Table Grapes	End harvest	27-Mar	1-Apr	6-Mar	19-Feb	17-Feb	9-Feb	9-Mar	14-Feb	29-Dec	31-Dec

Appendix 2: Baseline Crop coefficients

The table below has been prepared by the Irrigated Crop Management Service of Rural Solutions South Australia. It is used with permission.

Crop Kc values (FAO56)

RURAL SOLUTIONS SA

CROP TYPE	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Sum
Bare Soil													0.00
Bare Soil Loxton	0.36	0.26	0.29	0.18	0.08	0.10	0.07	0.14	0.09	0.19	0.24	0.36	2.35
Almonds (FAO56)		0.41	0.58	0.80	0.90	0.90	0.90	0.90	0.83	0.71			6.93
Almonds 10%sa		0.26	0.30	0.35	0.37	0.37	0.37	0.37	0.35	0.32			3.07
Almonds 30%sa		0.29	0.44	0.62	0.71	0.71	0.71	0.71	0.66	0.57			5.42
Almonds 40%sa		0.30	0.50	0.76	0.88	0.88	0.88	0.88	0.81	0.70			6.60
Almonds 50%sa		0.31	0.54	0.82	0.96	0.96	0.96	0.96	0.88	0.75			7.13
Almonds 70%sa		0.31	0.55	0.86	1.00	1.00	1.00	1.00	0.92	0.78			7.44
Almonds 90%sa		0.32	0.57	0.89	1.04	1.04	1.04	1.03	0.95	0.81			7.67
Apple (FAO56)			0.61	0.73	0.89	0.95	0.95	0.95	0.95	0.91	0.76		7.69
Apple 10%sa			0.28	0.32	0.38	0.40	0.40	0.40	0.40	0.38	0.35		3.31
Apple 30%sa			0.35	0.50	0.70	0.80	0.80	0.80	0.80	0.74	0.64		6.14
Apple 40%sa			0.38	0.60	0.87	1.00	1.00	1.00	1.00	0.92	0.79		7.56
Apple 50%sa			0.40	0.64	0.94	1.09	1.09	1.09	1.09	1.01	0.85		8.20
Apple 70%sa			0.41	0.66	0.99	1.14	1.14	1.14	1.14	1.05	0.89		8.56
Apple 90%sa			0.41	0.68	1.02	1.18	1.18	1.18	1.18	1.09	0.92		8.85
Artichoke 1stYR	1.00	1.00	0.97	0.50	0.59	0.92	1.00	1.00	1.00	1.00	1.00	1.00	10.98
Artichoke 2ndYR	1.00	0.97		0.54	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	10.43
Asparagus	0.53	0.50	0.50	0.50	0.75	0.95	0.95	0.95	0.95	0.95	0.95	0.91	9.38
Avocado	0.61	0.69	0.78	0.84	0.85	0.85	0.85	0.84	0.81	0.78	0.67	0.60	9.18
Banana	1.00	1.00	1.02	1.11	1.19	1.20	1.20	1.20	1.20	1.20	1.09	1.00	13.41
Banksia	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.73	0.74	0.72	8.48
Beans Dry						0.40	0.76	1.15	0.73				3.04
Beans Green			0.50	0.82	1.02								2.34
Beetroot							0.50	0.62	1.02	1.03			3.17
Blueberries			0.32	0.57	0.89	1.05	1.05	1.05	1.05	0.90	0.63		7.51
Boronia	1.04	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.10	1.11	1.08	12.80
Broad Bean	1.01	0.36								0.50	0.66	1.12	3.65
Broccoli	1.02								0.70	0.74	0.95	1.05	4.45
Brussel Sprout						0.70	0.70	0.77	0.94	1.05	1.04	0.97	6.17
Cabbage	0.99								0.70	0.78	1.00	1.05	4.53
Canola Irrigated	1.07	1.15	1.09	0.61						0.35	0.36	0.66	5.29
Canola Rainfed	0.93	1.00	0.95	0.56						0.35	0.36	0.60	4.76
Cantaloupe					0.50	0.62	0.82	0.80					2.74
Capsicum				0.60	0.77	1.03	1.05	1.05	1.05	0.97			6.53
Carrot Summer				0.72	0.98	1.05	1.01						3.76
Carrot Winter	1.05	1.01								0.70	0.83	1.04	4.63
Cauliflower	1.01								0.70	0.78	0.98	1.05	4.52
Celery								0.70	0.73	0.96	1.05	1.04	4.47
Cherry			0.61	0.73	0.88	0.95	0.95	0.95	0.95	0.90	0.80		7.70
Cherry RL Early cc		0.78	1.05	1.04	0.96	0.86	0.75	0.65	0.55	0.45			7.11
Cherry RL Early nc		0.55	0.80	0.80	0.75	0.68	0.62	0.56	0.50	0.43			5.68
Cherry RL Late cc		0.55	1.00	1.05	1.04	0.95	0.82	0.70	0.58	0.46			7.16
Cherry RL Late nc		0.34	0.76	0.80	0.80	0.74	0.66	0.59	0.51	0.44			5.62
Cherry RL Mid cc		0.55	1.00	1.05	0.99	0.88	0.77	0.67	0.56	0.46			6.93

Cherry RL Mid nc		0.34	0.76	0.80	0.76	0.70	0.63	0.57	0.50	0.43			5.48
Chickpeas	0.98	1.00	0.95	0.56							0.40	0.60	4.49
Chinese Cabbage									0.72	0.98	1.02		2.72
Citrus with cover (FAO56)	0.75	0.75	0.74	0.72	0.71	0.70	0.70	0.70	0.70	0.71	0.73	0.74	8.65
Citrus no cover (FAO56)	0.70	0.70	0.69	0.67	0.66	0.65	0.65	0.65	0.65	0.66	0.68	0.69	8.05
Citrus 10%sa	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	3.58
Citrus 30%sa	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	5.92
Citrus 40%sa	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	7.08
Citrus 50%sa	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	8.26
Citrus 70%sa	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	9.74
Citrus 90%sa	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	10.07
Clover Seed	0.40	0.60	0.98	1.15	1.05	0.67						0.40	5.25
Coffee	1.10	1.10	1.10	1.10	1.10	1.10	1.05	1.05	1.07	1.10	1.10	1.10	13.07
Cotton				0.35	0.60	1.05	1.15	1.11	0.85				5.10
Cowpeas/GreenGram						0.40	0.58	1.03	0.81				2.81
Cucumber					0.60	0.83	1.00	0.98	0.82				4.23
Date Palm	0.90	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.90	0.90	11.24
Egg Plant				0.60	0.76	1.02	1.05	1.02	0.93				5.38
Eucalyptus	1.20	1.20	1.20	1.20	1.20	1.18	0.98	0.98	1.08	1.20	1.20	1.20	13.82
Faba Bean	0.98	1.15	1.15	0.85	0.41						0.50	0.54	5.58
Garlic	1.00	1.00	1.00	1.00	0.86	0.73			0.70	0.81	0.98	1.00	9.08
Geraldton Wax	1.04	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.07	1.10	1.11	1.08	12.80
Jojoba	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	6.00
Lentil	0.92	1.10	1.10	0.82	0.41						0.40	0.44	5.20
Lettuce Spring	0.72	0.94	0.98										2.64
Lettuce Winter	0.98										0.72	0.94	2.64
Leucadendron	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.73	0.74	0.72	8.48
Linseed/Flax	1.00	1.10	1.10	1.09	0.77	0.38					0.35	0.49	6.28
Lucerne AvCutting (Hay)	0.90	0.91	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.93	0.90	0.90	11.18
Lucerne SeedProd(FAO56)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	6.00
Maize Grain			0.30	0.40	0.99	1.20	1.13	0.81	0.62				5.46
Millet			0.30	0.62	1.00	0.77	0.33						3.02
Olive	0.50	0.50	0.65	0.66	0.68	0.69	0.70	0.70	0.70	0.70	0.70	0.58	7.76
Olive RedcedYield	0.50	0.50	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.56	7.41
Onion Dry	1.04	1.05	1.05	1.05	0.92	0.79					0.70	0.82	7.41
Onion Green	0.99	1.00	1.00	1.00							0.70	0.80	5.49
Onion Seed	1.05	1.05	1.05	1.05	0.94	0.83			0.70	0.83	1.03	1.05	9.57
Open Water	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	12.60
Palm Tree	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.95	11.84
Parsnips	1.02								0.50	0.56	0.89	1.05	4.01
Pasture HighInput	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05	12.60
Pasture LowInput	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	9.00
Pasture MedInput	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	10.20
Pea Dry	1.15	0.85									0.50	0.80	3.30
Pea Fresh	0.69	1.14	1.14									0.50	3.48
Pear			0.61	0.73	0.88	0.95	0.95	0.95	0.95	0.90	0.79		7.70
Pecan			0.56	0.68	0.83	0.90	0.90	0.90	0.90	0.83	0.70		7.20
Pimelea	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.73	0.74	0.72	8.48
Pineapples	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	6.00
Pistachios				0.42	0.70	1.03	1.10	1.07	0.69				5.01

Plum			0.56	0.68	0.83	0.90	0.90	0.90	0.90	0.83	0.71		7.20
Potato Summer							0.50	0.65	1.11	1.14	0.92		4.32
Potato Winter	0.50	0.59	1.06	1.15	1.00	0.76							5.06
Protea	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.73	0.74	0.72	8.48
Pumpkin				0.50	0.56	0.92	0.99	0.87					3.84
Radish Autumn Winter										0.70	0.87		1.57
Radish Spring Summer			0.73	0.89									1.61
Rambutan	0.60	0.67	0.79	0.92	1.05	1.10	1.10	1.10	1.10	0.73	0.50	0.50	10.16
Rhubarb	0.99	0.87	0.50	0.50	0.50	0.77	1.00	1.00	1.00	1.00	1.00	1.00	10.12
Rockmelons				0.50	0.68	0.85	0.83	0.67					3.53
Sesame						0.35	0.77	1.10	0.80				3.03
Silverbeet						0.59	1.02	0.99					2.59
Sorghum			0.30	0.45	0.94	0.99	0.72						3.40
Soybeans						0.40	0.88	1.15	1.15	0.98	0.60		5.16
Spinach	0.98									0.72	0.93	1.00	3.62
Spring Onion - Summer			0.70	0.74	0.97								2.41
Spring Onion - Winter	1.00									0.71	0.87	1.00	3.57
Stonefruit Apricot (FAO56)	0.00	0.00	0.56	0.68	0.83	0.90	0.90	0.90	0.90	0.83	0.71		7.20
Stonefruit Apricot 10%sa			0.27	0.30	0.34	0.36	0.36	0.36	0.36	0.34	0.31		3.00
Stonefruit Apricot 30%sa			0.33	0.44	0.60	0.67	0.67	0.67	0.67	0.62	0.54		5.22
Stonefruit Apricot 40%sa			0.35	0.52	0.73	0.83	0.83	0.83	0.83	0.76	0.65		6.33
Stonefruit Apricot 50%sa			0.38	0.59	0.86	0.99	0.99	0.99	0.99	0.91	0.76		7.44
Stonefruit Apricot 70%sa			0.41	0.68	1.02	1.19	1.19	1.19	1.19	1.09	0.90		8.85
Stonefruit Apricot 90%sa			0.41	0.70	1.06	1.23	1.23	1.23	1.23	1.12	0.93		9.15
Stonefruit Peach (FAO56)			0.56	0.68	0.83	0.90	0.90	0.90	0.90	0.83	0.71		7.20
Stonefruit Peach Reduced Yield			0.57	0.47	0.42	0.68	0.90	0.90	0.90	0.83	0.71		6.38
Stonefruit Riverland early			0.37	0.69	1.02	1.17	0.50	0.50	0.43	0.24			4.92
Stonefruit Riverland mid			0.37	0.69	0.86	0.90	1.01	1.25	0.97	0.24			6.29
Stonefruit Riverland late				0.66	0.86	0.89	1.00	1.25	1.09	0.51			6.26
Strawberry	0.85	0.85	0.85	0.79	0.75				0.40	0.44	0.68	0.85	6.45
Sunflower				0.35	0.45	1.02	1.15	0.76					3.74
Sweet Potato				0.54	1.01	1.15	1.12	0.83					4.64
Sweetcorn			0.30	0.62	1.14	1.12							3.18
TableGrape (FAO56)			0.30	0.42	0.75	0.85	0.85	0.84	0.59				4.60
Table Grape 10%sa		0.26	0.28	0.34	0.35	0.35	0.35	0.35	0.33	0.32			2.93
Table Grape 30%sa		0.27	0.38	0.62	0.65	0.65	0.65	0.64	0.59	0.55			5.01
Table Grape 40%sa		0.28	0.43	0.76	0.80	0.80	0.80	0.79	0.72	0.67			6.04
Table Grape 50%sa		0.29	0.48	0.90	0.95	0.95	0.95	0.93	0.85	0.78			7.08
Table Grape 70%sa		0.29	0.53	1.03	1.09	1.09	1.09	1.07	0.97	0.89			8.04
Table Grape 90%sa		0.30	0.55	1.10	1.17	1.17	1.17	1.14	1.03	0.95			8.57
Tea	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.95	11.83
Tomato			0.60	0.63	0.96	1.15	1.12	0.90					5.36
Turf SumActive			0.81	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85		7.61
Turf YrRound Active	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	11.40
Turnip									0.50	0.65	1.08	1.00	3.23
Walnuts			0.50	0.66	0.96	1.10	1.10	1.10	1.10	1.03	0.77		8.32
WaterMelons				0.44	0.87	0.98	0.83						3.12
Wheat/Barley	1.00	1.15	1.11	0.58							0.30	0.50	4.64
Winegrape (FAO56)			0.32	0.55	0.70	0.70	0.70	0.70	0.63	0.51			4.81
Winegrape Reduced Yield (SARDI)				0.29	0.39	0.43	0.43	0.43	0.39	0.24	0.16		2.76

Winegrape 10%sa			0.26	0.28	0.30	0.30	0.30	0.30	0.29	0.28			2.30
Winegrape 30%sa			0.28	0.41	0.49	0.49	0.49	0.49	0.47	0.42			3.56
Winegrape 40%sa			0.29	0.47	0.59	0.59	0.59	0.59	0.56	0.50			4.18
Winegrape 50%sa			0.30	0.54	0.69	0.69	0.69	0.69	0.65	0.57			4.82
Winegrape 70%sa			0.31	0.60	0.78	0.78	0.78	0.78	0.73	0.64			5.39
Winegrape 90%sa			0.32	0.63	0.83	0.83	0.83	0.83	0.78	0.68			5.72
Zucchini				0.50	0.56	0.88	0.88						2.82
South East Kc Values													0.00
SE CANOLA - ZSEED MULTIPLICATION*			0.35	0.41	0.85	1.10	0.91						3.62
SE CANOLA (S)*	0.48	0.73	0.98	1.05	0.73	0.22					0.35	0.35	4.87
SE CARROT ZSEED	0.70	0.76	0.88	0.99	1.05	1.00			0.70	0.70	0.70	0.70	8.18
SE CEREALS*	0.44	0.72	1.00	1.15	0.78							0.30	4.39
SE CHINESE CABBAGE ZSEED		0.41	0.85	1.10	0.91								3.27
SE CLOVER ZSEED - ANNUAL	0.40	0.59	0.96	1.15	1.08	0.35						0.40	4.93
SE CLOVER ZSEED - PERRENNI	0.90	0.90	0.90	1.10	1.15	1.08	0.35		0.33	0.90	0.90	0.90	9.40
SE CLOVER ZSEED - PERSIAN	0.40	0.53	0.78	1.03	1.15	1.15	1.00					0.40	6.43
SE CLOVER ZSEED - RED	0.40	0.51	0.72	0.94	1.12	1.15	1.15	1.00				0.40	7.39
SE CLOVER ZSEED - SUBTERRA	0.40	0.75	1.10	1.10	1.10	0.41					0.40	0.40	5.66
SE CORIANDER	0.70	0.79	0.96	1.05	1.05	0.50							5.05
SE FRUIT TREES*			0.30	0.62	0.78	0.93	0.95	0.95	0.95	0.93	0.82		7.22
SE GRASS ZSEED	0.75	0.75	0.95	1.15	0.39				0.66	0.75	0.75	0.75	6.90
SE LUCERNE FODDER	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.40	0.40	8.30
SE LUCERNE HAY*	0.40	0.63	0.85	0.85	0.85	0.85	0.85	0.85	0.63	0.40	0.75	0.75	8.65
SE LUCERNE SEED Prod	0.75	0.75	0.91	0.95	0.95	0.86	0.50	0.50	0.47	0.25	0.48	0.75	8.11
SE LUCERNE ZSEED*	0.75	0.75	0.90	0.95	0.95	0.84	0.50	0.50	0.43	0.24	0.46	0.75	8.01
SE LUPINS	0.40	0.55	0.85	1.00	0.84								3.64
SE MAIZE				0.30	0.53	0.98	1.20	1.20	0.99				5.19
SE MUSTARD		0.35	0.44	1.01	1.10								2.90
SE NATIVE FLOWERS*	0.40	0.40	0.40	0.48	0.64	0.63	0.64	0.64	0.56				4.79
SE NATIVE FOLIAGE*	0.57	0.56	0.38	0.20	0.25	0.34	0.43	0.51	0.56	0.57	0.58	0.58	5.53
SE OLIVE - FRESH*	0.65	0.65	0.69	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.69	0.65	8.23
SE OLIVE - OIL*	0.50	0.50	0.61	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.61	0.50	7.27
SE ONION			0.70	0.70	0.79	0.96	1.05	1.05	0.90				6.15
SE ONION ZSEED		0.70	0.70	0.79	0.96	1.05	0.93						5.13
SE PASTURE	0.40	0.63	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85			7.83
SE PASTURE - FINISHER	0.75	0.75	0.75	0.75	0.38								3.38
SE PASTURE - HALF	0.40	0.63	0.85	0.85	0.85	0.85							4.43
SE PASTURE - HIGH INPUT	0.40	0.73	1.05	1.05	1.05	1.05	1.05	1.05	1.05	0.95			9.43
SE PASTURE ROTATION GRAZI	0.40	0.64	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.75	0.75	9.34
SE PASTURE - STARTER								0.30	0.41	0.64			1.35
SE PEAS - FIELD	0.25	0.54	0.83	1.11	0.58								3.30
SE POTATOES - ZSEED					0.50	0.70	0.90	0.90					3.00
SE POTATOES (N)			0.50	0.83	1.15	1.15	1.15	0.48					5.25
SE POTATOES (S)				0.50	0.72	1.10	1.15	1.05					4.52
SE RADISH ZSEED		0.70	0.78	0.85	0.84	0.39							3.55
SE REFERENCE CROP*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	12.00
SE STIRLING LUCERNE CAT. 2*	0.75	0.75	0.90	0.95	0.95								4.30
SE STIRLING LUCERNE CAT. 3*	0.75	0.75	0.90	0.95	0.95				0.75	0.75	0.75	0.75	7.30
SE STIRLING LUCERNE CAT. 4*						0.84	0.50	0.50					1.84
SE STIRLING LUCERNE CAT. 5*					0.71	0.84	0.50	0.50					2.55

SE STIRLING LUCERNE CAT. 6*						0.84	0.50	0.50	0.50	0.27	0.68	0.75	4.04
SE STIRLING LUCERNE CAT. 7*	0.75	0.75	0.90	0.95	0.95	0.84	0.50	0.50	0.13				6.27
SE STIRLING LUCERNE CAT. 8*	0.75	0.75	0.90	0.95	0.95	0.84	0.50	0.50	0.50	0.27	0.68	0.75	8.34
SE SUMMER FODDER (N)					0.30	0.50	0.70	0.70	0.70	0.70	0.50		4.10
SE SUNFLOWER				0.15	0.35	0.53	1.05	1.05	0.38				3.50
SE SWEETCORN					0.30	0.75	1.15	1.05					3.25
SE WINEGRAPE*			0.33	0.50	0.68	0.70	0.50	0.43	0.43	0.39	0.33		4.29

* Specific SE crop calendars

Appendix 3: Irrigation demands by scenario

Figure A-3-1-% Change in irrigation demands for ETo projection and pan evaporation projections

Crop	Future climate sce	Year	Data so	july	august	septembe	october	november	december	january	february	march	april	may	june	Total	% change to historic
Almonds 90%sa	Historical	Historical		0.0	4.2	38.6	124.6	195.7	229.3	241.3	201.6	159.3	79.2	0.0	0.0	1274	0%
Almonds 90%sa	RCP4.5	2030	ETo (lor	0.0	7.1	42.6	131.5	205.0	233.9	245.9	196.8	140.1	83.2	0.0	0.0	1286	1%
Almonds 90%sa	RCP4.5	2050	ETo (lor	0.0	7.5	43.0	133.2	207.6	236.9	248.9	175.3	140.7	83.7	0.0	0.0	1277	0%
Almonds 90%sa	RCP4.5	2070	ETo (lor	0.7	18.3	65.0	150.6	213.3	238.5	250.5	176.5	143.1	85.0	0.0	0.0	1342	5%
Almonds 90%sa	RCP8.5	2030	ETo (lor	0.0	6.6	44.6	134.4	208.3	236.2	247.7	198.4	140.0	82.7	0.0	0.0	1299	2%
Almonds 90%sa	RCP8.5	2050	ETo (lor	1.5	29.5	86.1	165.1	214.4	238.6	250.5	191.7	143.0	85.2	0.0	0.0	1406	10%
Almonds 90%sa	RCP8.5	2070	ETo (lor	11.9	47.0	93.5	174.4	224.4	243.7	240.3	164.8	146.8	88.4	0.0	0.0	1435	13%
Almonds 90%sa	RCP4.5	2030	PanEvap	0.0	11.7	54.5	159.0	244.9	285.4	299.2	239.6	151.8	90.8	0.0	0.0	1537	21%
Almonds 90%sa	RCP4.5	2050	PanEvap	0.0	14.9	62.0	176.8	271.1	307.2	321.7	227.1	154.2	92.5	0.0	0.0	1627	28%
Almonds 90%sa	RCP8.5	2030	PanEvap	0.0	11.9	57.2	163.4	250.5	285.6	299.0	239.6	149.6	88.9	0.0	0.0	1546	21%
Almonds 90%sa	RCP8.5	2050	PanEvap	1.6	47.8	126.2	233.7	300.0	348.0	363.8	278.9	166.2	100.3	0.0	0.0	1967	54%
Avocado	Historical	Historical		13.5	33.1	61.6	117.6	158.5	185.4	195.8	162.1	135.3	76.1	28.7	12.6	1180	0%
Avocado	RCP4.5	2030	ETo (lor	16.7	40.8	70.4	124.8	166.2	189.2	198.7	162.2	135.1	67.2	26.2	15.8	1213	3%
Avocado	RCP4.5	2050	ETo (lor	17.3	41.8	71.2	126.3	168.4	191.7	201.2	157.7	125.8	63.5	26.7	16.6	1208	2%
Avocado	RCP4.5	2070	ETo (lor	22.3	46.0	74.9	130.7	173.2	193.1	197.9	155.4	117.8	64.4	26.8	17.1	1220	3%
Avocado	RCP8.5	2030	ETo (lor	18.4	40.2	68.8	127.0	169.1	191.4	200.6	163.8	137.9	66.6	25.2	15.0	1224	4%
Avocado	RCP8.5	2050	ETo (lor	23.1	46.8	77.0	132.4	174.3	193.2	202.7	165.5	137.9	68.9	27.4	17.4	1266	7%
Avocado	RCP8.5	2070	ETo (lor	29.2	51.2	88.2	141.0	182.8	196.5	190.5	146.9	114.3	63.1	31.2	22.8	1258	7%
Avocado	RCP4.5	2030	PanEvap	16.4	51.5	87.5	151.0	199.0	231.5	242.3	197.9	146.4	73.5	26.1	15.5	1439	22%
Avocado	RCP4.5	2050	PanEvap	16.7	58.7	98.3	168.0	220.5	249.4	260.8	204.7	137.9	70.4	26.8	16.1	1528	29%
Avocado	RCP8.5	2030	PanEvap	18.4	52.5	86.1	154.6	203.8	232.1	242.5	198.1	147.4	71.8	25.2	15.0	1447	23%
Avocado	RCP8.5	2050	PanEvap	23.5	72.0	113.6	188.5	244.6	283.1	295.3	241.4	160.4	81.4	28.4	17.7	1750	48%
Citrus 90%sa	Historical	Historical		25.6	44.5	68.5	116.7	156.2	182.8	193.1	161.3	139.8	82.6	40.4	24.3	1236	0%
Citrus 90%sa	RCP4.5	2030	ETo (lor	29.4	49.3	73.7	123.4	163.9	186.6	196.9	164.5	145.5	86.7	43.6	27.6	1291	4%
Citrus 90%sa	RCP4.5	2050	ETo (lor	30.2	50.4	74.5	124.9	166.0	189.0	199.4	166.6	146.2	87.3	44.1	28.3	1307	6%
Citrus 90%sa	RCP4.5	2070	ETo (lor	30.8	51.2	78.3	129.3	170.8	190.4	200.7	167.7	148.7	88.6	44.5	28.8	1330	7%
Citrus 90%sa	RCP8.5	2030	ETo (lor	28.9	48.7	76.1	126.1	166.8	188.8	198.7	166.1	145.5	86.2	42.6	27.1	1302	5%
Citrus 90%sa	RCP8.5	2050	ETo (lor	31.6	52.0	80.4	131.0	171.9	190.5	200.8	167.8	148.5	88.8	45.1	29.5	1338	8%
Citrus 90%sa	RCP8.5	2070	ETo (lor	35.4	56.5	87.5	139.1	180.4	194.7	201.1	171.4	152.4	92.1	48.3	32.8	1392	12%
Citrus 90%sa	RCP4.5	2030	PanEvap	29.0	61.5	91.4	149.4	196.3	228.3	240.1	200.7	157.7	94.6	43.4	27.2	1519	22%
Citrus 90%sa	RCP4.5	2050	PanEvap	29.3	69.8	102.6	166.2	217.5	246.0	258.4	216.0	160.1	96.3	44.2	27.5	1634	31%
Citrus 90%sa	RCP8.5	2030	PanEvap	28.9	62.7	94.8	153.6	201.0	228.9	240.2	200.9	155.4	92.7	42.7	27.1	1529	23%
Citrus 90%sa	RCP8.5	2050	PanEvap	32.1	79.2	118.3	186.6	241.3	279.2	292.6	244.7	172.6	104.4	46.5	29.9	1827	46%
Dried grapes	Historical	Historical		0.00	0.00	11.24	82.91	154.03	180.17	149.62	124.90	101.96	49.56	0.00	0.00	854	0%
Dried grapes	RCP4.5	2030	ETo (lor	0.0	0.0	31.9	104.9	161.6	183.9	152.7	123.2	92.6	52.4	0.0	0.0	903	6%
Dried grapes	RCP4.5	2050	ETo (lor	0.0	0.0	32.1	123.1	163.7	166.1	154.7	112.3	93.0	52.9	0.0	0.0	898	5%
Dried grapes	RCP4.5	2070	ETo (lor	0.0	8.0	53.4	127.4	168.4	167.3	155.8	113.2	94.6	53.6	0.0	0.0	942	10%
Dried grapes	RCP8.5	2030	ETo (lor	0.0	0.0	33.8	107.4	164.4	166.1	154.5	124.7	99.3	51.9	0.0	0.0	902	6%
Dried grapes	RCP8.5	2050	ETo (lor	0.0	8.8	55.6	129.1	169.5	147.2	150.7	113.3	94.5	53.9	0.0	0.0	922	8%
Dried grapes	RCP8.5	2070	ETo (lor	0.0	25.4	74.0	137.1	177.9	150.5	151.0	115.8	97.3	56.4	0.0	0.0	985	15%
Dried grapes	RCP4.5	2030	PanEvap	0.0	0.0	41.9	127.4	193.6	225.1	186.8	150.9	100.4	57.5	0.0	0.0	1084	27%
Dried grapes	RCP4.5	2050	PanEvap	0.0	0.0	48.0	163.8	214.5	216.7	201.3	146.7	102.1	58.7	0.0	0.0	1152	35%
Dried grapes	RCP8.5	2030	PanEvap	0.0	0.0	44.3	131.2	198.2	201.7	187.3	151.3	106.2	56.0	0.0	0.0	1076	26%
Dried grapes	RCP8.5	2050	PanEvap	0.0	19.1	84.0	184.0	238.0	217.2	220.9	166.7	110.2	64.0	0.0	0.0	1304	53%
Winegrape 90%sa	Historical	Historical		0.0	0.0	11.2	82.9	154.0	180.2	190.4	159.0	128.9	64.8	0.0	0.0	971	0%
Winegrape 90%sa	RCP4.5	2030	ETo (lor	0.0	0.0	14.1	104.9	161.6	183.9	194.1	151.4	117.1	68.3	0.0	0.0	995	2%
Winegrape 90%sa	RCP4.5	2050	ETo (lor	0.0	0.0	14.1	106.1	163.7	186.3	190.0	143.2	117.6	68.8	0.0	0.0	990	2%
Winegrape 90%sa	RCP4.5	2070	ETo (lor	0.0	8.0	35.0	110.1	168.4	187.7	191.4	144.2	119.6	69.8	0.0	0.0	1034	6%
Winegrape 90%sa	RCP8.5	2030	ETo (lor	0.0	0.0	33.8	107.4	164.4	186.1	195.9	152.9	116.9	67.7	0.0	0.0	1025	6%
Winegrape 90%sa	RCP8.5	2050	ETo (lor	0.0	8.8	55.6	111.8	169.5	187.8	191.4	144.3	119.5	70.0	0.0	0.0	1059	9%
Winegrape 90%sa	RCP8.5	2070	ETo (lor	0.0	25.4	61.8	137.1	177.9	191.9	185.2	137.1	122.8	72.9	0.0	0.0	1112	14%
Winegrape 90%sa	RCP4.5	2030	PanEvap	0.0	0.0	20.8	127.4	193.6	225.1	236.8	184.8	126.9	74.7	0.0	0.0	1190	23%
Winegrape 90%sa	RCP4.5	2050	PanEvap	0.0	0.0	24.8	142.0	214.5	242.6	246.5	186.1	128.9	76.1	0.0	0.0	1261	30%
Winegrape 90%sa	RCP8.5	2030	PanEvap	0.0	0.0	44.3	131.2	198.2	225.7	236.9	185.1	125.0	73.0	0.0	0.0	1219	26%
Winegrape 90%sa	RCP8.5	2050	PanEvap	0.0	19.1	84.0	160.1	238.0	275.3	279.2	211.1	139.1	82.7	0.0	0.0	1489	53%
Pistachios	Historical	Historical		0.0	0.0	0.0	49.3	127.8	227.8	257.2	208.5	114.6	0.0	0.0	0.0	985	0%
Pistachios	RCP4.5	2030	ETo (lor	0.0	0.0	1.8	76.4	168.9	241.0	258.1	173.3	119.1	0.0	0.0	0.0	1039	5%
Pistachios	RCP4.5	2050	ETo (lor	0.0	0.0	1.6	53.8	171.1	244.0	261.3	135.8	119.2	0.0	0.0	0.0	987	0%
Pistachios	RCP4.5	2070	ETo (lor	0.0	0.0	28.7	80.7	211.9	254.5	259.0	136.8	121.3	0.0	0.0	0.0	1093	11%
Pistachios	RCP8.5	2030	ETo (lor	0.0	0.0	3.3	78.5	171.9	243.2	260.0	174.9	119.3	0.0	0.0	0.0	1051	7%
Pistachios	RCP8.5	2050	ETo (lor	0.0	0.0	30.9	82.3	213.0	254.6	259.0	136.9	121.8	0.0	0.0	0.0	1098	12%
Pistachios	RCP8.5	2070	ETo (lor	0.0	3.0	36.2	113.6	222.9	259.9	211.8	139.9	125.2	0.0	0.0	0.0	1113	13%
Pistachios	RCP4.5	2030	PanEvap	0.0	0.0	6.2	93.7	202.3	293.9	314.0	211.3	129.1	0.0	0.0	0.0	1250	27%
Pistachios	RCP4.5	2050	PanEvap	0.0	0.0	8.7	74.4	224.1	316.3	337.6	176.7	130.7	0.0	0.0	0.0	1269	29%
Pistachios	RCP8.5	2030	PanEvap	0.0	0.0	8.0	96.8	207.1	294.1	313.7	211.4	127.5	0.0	0.0	0.0	1259	28%
Pistachios	RCP8.5	2050	PanEvap	0.0	0.0	49.9	119.4	298.0	370.8	375.9	200.5	141.8	0.0	0.0	0.0	1556	58%
Table Grape 50%sa	Historical	Historical		0.0	1.9	29.2	126.8	178.6	209.1	220.4	180.6	141.2	76.2	0.0	0.0	1164	0%
Table Grape 50%sa	RCP4.5	2030	ETo (lor	0.0	4.7	32.8	138.0	187.2	213.4	222.5	175.2	141.1	80.0	0.0	0.0	1195	3%
Table Grape 50%sa	RCP4.5	2050	ETo (lor	0.0	5.1	33.1	139.7	189.6	216.1	225.3	177.4	135.8	80.6	0.0	0.0	1203	3%
Table Grape 50%sa	RCP4.5	2070	ETo (lor	0.0	13.5	60.8	148.6	194.9	217.6	224.6	169.5	138.2	81.8	0.0	0.0	1249	7%
Table Grape 50%sa	RCP8.5	2030	ETo (lor	0.0	4.2	59.0	140.9	190.3	215.6	224.3	176.8	141.0	79.5	0.0	0.0	1232	6%
Table Grape 50%sa	RCP8.5	2050	ETo (lor	0.0	22.4	87.8	150.3	196.0	217.7	224.7	162.6	138.0	82.0	0.0	0.0	1281	10%
Table Grape 50%sa	RCP8.5	2070	ETo (lor	8.5	43.9	98.2	159.1	205.3	220.3	214.1	166.0	141.7	85.2	0.0	0.0	1342	15%
Table Grape 50%sa	RCP4.5	2030	PanEvap	0.0	8.9	43.0	166.6	223.8	260.6	271.0	213.6	152.9	87.4	0.0	0.0	1428	23%
Table Grape 50%sa	RCP4.5	2050	PanEvap	0.0	11.7	49.2	185.2	247.9	280.7	291.5	229.8	148.8	89.0	0.0	0.0	1534	32%
Table Grape 50%sa	RCP8.5	2030	PanEvap	0.0	9.0	74.4	171.1	229.1	261.0	271.0	213.7	150.7	85.5	0.0	0.0	1466	26%
Table Grape 50%sa	RCP8.5	2050	PanEvap	0.0	38.0	128.5	213.3	274.5	318.2	326.8	237.2	160.5	96.5	0.0	0.0	1793	54%

Figure 5-% change in irrigation demands averaged across all crops above for ETo projection and pan evaporation projections

Average of % change to historic	Column Labels	
Row Labels	ETo (long crop)	PanEvap
⊟ RCP4.5	4%	27%
2030	3%	23%
2050	3%	31%
2070	7%	
⊟ RCP8.5	9%	38%
2030	5%	25%
2050	9%	52%
2070	13%	

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