ON FARM WATER DEMAND IN THE SW WA (Warren-Donnelly catchment) Final Report (2026)

By Julia Easton, Leidy Luna, Simon Koric, Arnold Salvacion, Stan Mastrantonis and Mark Gibberd June 2026

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Cover: An avocado orchard with rows of trees on either side of the photo and grass growing in between the row. The sun is setting near the end of the row.

IMPORTANT INFORMATION

Author contact details
Name: Julia Easton
Email: Julia.Easton@curtin.edu.au
Web: ccdm.com.au/c4ap

Food Agility CRC contact details
Level 14 / 5 Martin Place
Sydney NSW 2000

hello@foodagility.com
www.foodagility.com

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The On-Farm Water Demand project is the second project developed as part of the WA Node of Food Agility Cooperative Research Centre. The project would not have been possible without the financial support from the Food Agility CRC, Curtin University, the State Government of Western Australia through the Department of Jobs, Tourism, Innovation and Science and the Department of Primary Industries and Regional Development WA, and SWAN Systems. We also acknowledge the linkages between the project and the South-West WA Drought Resilience Adoption and Innovation Hub and the opportunities to extend the outcomes of the project to a wider audience.

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PROJECT DESCRIPTION

The On-Farm Water Demand (OFWD) project was designed to address the gap in defensible data on the demand side of water allocation for food production in the Warren-Donnelly catchment in south-west WA. The project was developed to provide farm businesses, community, industry and government with credible information on crop water demand, and an independent authoritative data set representing the demand side of water allocation in the Warren-Donnelly catchment, WA. The Warren and Donnelly river basins, an area of almost 6,100 km², are located in the south-west of Western Australia. Water allocation planning in this region is managed through the Warren-Donnelly Surface Water Plan, details on the plan are available on the Water Resources webpage (search WA water resources Warren Donnelly in your internet browser). More than 80% of the catchment is covered by State forest, National park and nature reserve (Figure 1). The towns of Manjimup and Pemberton are located within the plan area.

The Southwest of Western Australia faces major, immediate issues relating to water access for irrigation. The area is impacted by climate change with increasing extreme heat events and decreasing rainfall, particularly during the months from April to October[1]. Forecasts indicate further impact of climate change on vapour pressure deficits and evaporation. Traditionally, water planning has focused on the supply of water. In contrast, this project focuses on the demand side—quantifying how much water is used in food production and the value generated from that use. This approach supports a more balanced understanding of water use, recognising the need to maximise the value of available water while considering crop systems, farm businesses and community expectations.

This industry-led project enables agrifood producers to link water use with key business drivers, including yield, cost of production and profitability. By providing access to consistent, high-quality data, the project outputs will support improved decision-making at both farm and catchment scales, contributing to the long-term sustainability and resilience of the regional economy. The project has provided seasonal water use data for agrifood production (5 crops: avocados, apples, truffles, wine grapes and potatoes) in the Warren-Donnelly catchment in the southwest region of WA near Manjimup and Pemberton. The data has been aggregated with sub-catchment scale land use, landform data and weather observations to estimate actual water use at a scale equivalent to water supply calculations. Cost of production were also collected as part of the project, to assess net profit per megalitre applied. This in turn provides data on the net benefit of irrigation to farmers, the Western Australian economy and the flow-on benefits to the community.

PROJECT PARTNERS

This project is led by Curtin University with co-investment from Curtin, the Western Australian government from the Departments of Jobs, Tourism, Science and Innovation (DJTSI) and Department of Primary Industries and Regional Development, Western Australia (DPIRD - WA), Food Agility CRC and SWAN Systems and in collaboration with Southern Forests Food Council and 27 farm businesses from the Warren-Donnelly catchment in south-west WA. Equipment was sourced through WildEye and made available to the project at a discount rate. The project team informed the Department of Water and Environmental Regulation (DWER) on progress annually.

[1] CSIRO state of the climate report 2024 https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate

EXECUTIVE SUMMARY

Overview of the Report

The On-Farm Water Demand (OFWD) project provides the first independent, industry-owned assessment of water use for food production in the Warren–Donnelly catchment in south-west Western Australia. The report focuses on the demand side of water use, quantifying how much water crops require, how much is applied on farm, and the value generated from that water use.

Led by Curtin University's Centre for Crop and Disease Management (CCDM) in partnership with the Southern Forests Food Council (SFFC), Food Agility CRC, DPIRD, DWER, and technology providers SWAN Systems and WildEye. Working directly with 27 farm businesses across five key horticultural commodities—avocados, apples, truffles, potatoes and wine grapes. These crops represent the majority of irrigated production in the region and underpin a significant contribution to the Western Australian economy and regional communities.

At the core of the project is an industry-owned, independent on-farm data set, capturing irrigation volumes, soil moisture, weather data, yields and costs of production across multiple seasons. These data underpin a series of research outputs that collectively move water assessment beyond supply-side metrics. Key outputs include standardised data governance and sharing frameworks; automated data pipelines and repeatable seasonal reporting; benchmarking of water productivity (t/ML) and water profitability ($/ML); and the integration of on-farm data with publicly available weather, remote sensing and spatial data.

The report presents results from multi-year monitoring of irrigation practices, crop water demand and seasonal conditions, together with a scalable framework for assessing water demand at both farm and catchment scales.

Why the Research Is Important

Water availability is a critical constraint on agricultural productivity and regional resilience in south-west Western Australia. Declining rainfall, increasing evaporative demand and growing competition between agricultural, environmental and community water needs have highlighted the limitations of water planning approaches that focus primarily on supply. This research addresses a major gap by quantifying demand-side water use, linking irrigation volumes to crop performance, costs of production and profitability.

Historically, water planning has focused on the supply side—how much water is available in rivers and storages. This project addresses a critical gap by quantifying **how much water is required to produce food**, linking water use to crop performance, economic outcomes and regional value. This demand-side perspective is essential to:

- Support balanced decision-making between agricultural, environmental and community water use
- Improve irrigation efficiency and farm business resilience
- Provide a defensible evidence base for water allocation

Use by technology partners:
The research directly informed the development and refinement of digital decision-support tools. Insights and data generated through the project were used by technology partners to enhance reporting structures, integrate water productivity and profitability metrics, and support seasonal review and benchmarking functionality for growers.

Who Will Benefit and How

Producers: Improved understanding of crop water demand and irrigation performance, access to benchmarking and seasonal review data to support decision-making, and increased confidence in irrigation planning, risk management and business expansion

Industry organisations: A defensible, industry-owned dataset to strengthen representation in water allocation discussions with evidence to support industry development and long-term resilience.

Policy makers and regulators: Independent, catchment-scale data to inform water allocation and planning decisions and improved understanding of the value of water for food production and regional economies.

Technology providers: Access to real-world data and workflows to improve digital tools and accelerate adoption as well as opportunities to integrate water-use analytics into commercial platforms.

Regional communities and consumers: Strengthened resilience of food production systems in a key horticultural region and improved long-term sustainability of regional economies reliant on irrigated agriculture

KEY RESULTS AND SUMMARY

Background
The project was initiated in response to industry demand for credible data to quantify water use and its value in agricultural production. Increasing pressure on water resources and

community concerns around water allocation highlighted the need to better understand how water contributes to food production and regional economic value.

Aims and Objectives

The project aimed to:

- Generate independent measurements of on-farm water use across key horticultural crops
- Link water use to crop performance, productivity and profitability
- Develop a scalable framework for estimating crop water demand at catchment scale
- Provide a defensible evidence base to support farm, industry and policy decision-making

Methodology

Data were collected from 27 farm businesses across avocados, apples, truffles, potatoes and wine grapes over four growing seasons.

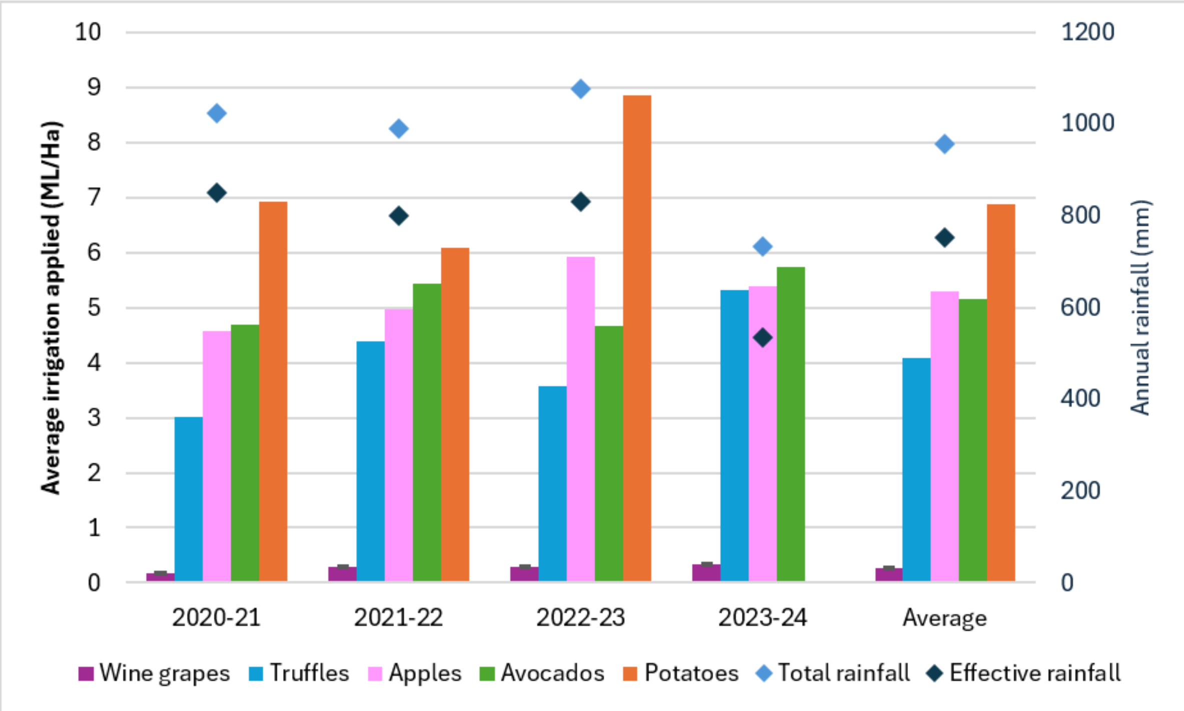
The methodology integrated:

- On-farm measurements of irrigation applied, soil moisture and crop performance
- Publicly available weather data (rainfall, temperature and evapotranspiration)
- Crop factors and water balance calculations based on FAO-56 methods
- Remote sensing and machine learning for crop classification
- GIS-based analysis to scale results to the catchment level

A structured seasonal review process enabled growers to interpret results, benchmark performance and adjust irrigation practices annually.

RESULTS, KEY FINDINGS AND INSIGHTS

Key results:



Average irrigation (ML/ha) to grow an annual crop of avocados, apples, potatoes, truffles and wine grapes and total annual rainfall (DPIRD weather stations), by financial year, across 27 sites in the Warren-Donnelly catchment, south-west Western Australia.

Seasonal drivers of water demand

- Crop water demand is highly seasonal, increasing from spring, peaking in summer, and declining through autumn
- Summer demand is driven by high temperatures and evapotranspiration, with minimal contribution from rainfall

Crop water requirements

Significant differences exist between crops, reflecting production systems and growth patterns

- Apples and avocados have relatively high water demand, while wine grapes require substantially less under current management
- Potatoes, grown in summer, have the highest short-term water demand during peak conditions.

Irrigation applied vs demand

- Across all crops, irrigation is generally aligned with demand at an annual scale
- However, monthly analysis reveals consistent irrigation gaps during peak demand periods (December–February)
- Many farms are not meeting crop water requirements during periods of highest demand

Importance of irrigation timing

Irrigation gaps are driven more by the timing of water application than total annual water use:

- Short periods of under-irrigation during critical growth stages can impact yield, quality and profitability.
- Impact of seasonal variability (e.g. 2023–24)
- Dry and hot seasons significantly increase crop water demand and extend irrigation requirements.
- Reduced rainfall and increased heat events lead to prolonged periods of water deficit
- System stress increases rapidly under these conditions, placing pressure on water storage and irrigation capacity

Farm business outcomes

- Growers improved irrigation practices through better alignment with crop demand
- Benchmarking and seasonal review enabled comparison with peers and identification of performance gaps
- Increased confidence in decision-making and adoption of digital tools were widely reported

RECOMMENDATIONS

The findings from this project highlight key opportunities to improve water use efficiency, farm performance and long-term resilience in the Warren–Donnelly catchment:

1. Strengthen the collection and collation of industry data
   Continue building and maintaining industry-wide datasets to support decision-making, benchmarking and policy discussion.
2. Treat water as a key business input
   Integrate water into business planning by linking irrigation to productivity, profitability and long-term farm viability.
3. Implement benchmarking to drive performance
   Use metrics such as ML/ha, t/ML and $/ML to compare performance and identify opportunities for improvement.
4. Leverage seasonal review for planning and risk management
   Use multi-year data to understand variability, plan for dry seasons and improve irrigation strategies over time.
5. Increase adoption of data, sensors and digital platforms
   Support data-driven irrigation management through monitoring technologies and decision-support tools.
6. Plan for dry years and extended demand periods
   Ensure water storage and irrigation systems can respond to increasingly variable and drier conditions.

Overall recommendation:

Improving irrigation outcomes in the region is less about increasing total water use and more about improving how and when water is applied, supported by data-driven decision-making and improved system performance.

Summary Statement

The OFWD project demonstrates that data-driven, demand-side understanding of water use is essential for improving irrigation performance, supporting farm profitability, and enabling more balanced and transparent water planning in the Warren Donnelly catchment. The framework developed provides a scalable model for application across other agricultural regions facing similar challenges under a drying climate.

IMPACT STATEMENTS

INDUSTRY PARTNER – Kieran Kinsella, Independent Chair, Southern Forests Food Council

The Southern Forests Food Council (SFFC) represents growers of over 50 types of fresh produce in the Southern Forests and Valleys region and works to raise the profile of one of WA's premier food bowls. DPIRD's Situation analysis of horticulture in Western Australia report (2022) highlights the Manjimup local government area as producing 16% of WA's horticulture production by dollar value, the highest horticulture production region in the state.

The SFFC are proud to be industry partners of the On-Farm Water Demand project that was developed in response to industry demand and increases producer understanding of the value of water, benchmarked usage and risk management. The SFFC have been involved since the formation of the project, hosting industry workshops, co-design meetings, attending field sites, developing field days and attending project showcase meetings. The agile and collaborative approach to the project by the research team has built trust between producers and researchers, consistently demonstrating value to participants.

Involvement in the On-Farm Water Demand project has demonstrated great value to producers in gathering a defensible dataset on projected water value by commodity and upskilling producers regarding the current technology options to monitor an increasingly scarce water resource. Local tensions around the allocation of water resources between agriculture and environment have only been increasing, with producers disadvantaged in the discussion phase by a lack of catchment-scale demand information to inform the value of water resources to the industry. The results of the project will enable calculation of the financial value of irrigation water to the region and associated economic benefits that agriculture provides in the face of a declining timber industry and ongoing reduction in rainfall.

TECHNOLOGY PARTNER – Dr John Bussell, Technical Manager, SWAN Systems

SWAN Systems was proud to be associated with the Food Agility On-Farm Water Demand (OFWD) project in two roles. Firstly, SWAN served as a central repository for automatically collected irrigation, soil moisture and weather data. Secondly, SWAN was automatically updated daily with all data relevant to irrigating the fields and was made available to all growers in the project as a daily decision support tool for irrigation scheduling.

We feel that involvement in the project has been mutually beneficial for growers, SWAN, CCDM and Food Agility. The OFWD findings will form critical baseline data for catchment-scale water requirements for key crops grown in the region. Growers will increasingly be advantaged if they can demonstrate environmental stewardship via use of best practice scheduling and reporting tools. SWAN is a well-recognised player in this space and since its origins has been designed to include a full range of data capture, analysis and reporting capabilities. Following the recent release of SWAN's "Impact module" (September 2023), the software can now accept grower yield and revenue data for use in reporting on irrigation effectiveness, water productivity and water profitability, including reporting against crop-specific quality benchmarks. Discussion with OFWD principal researchers and analysis of data produced during the project played a key role in shaping the reporting structures of this new module.

TECHNOLOGY PARTNER – Kieran Coupe, WildEye Monitoring

WildEye has played a pivotal role in the "On-farm Water Demand" project, which has reshaped community understanding of the value of water to food production in the important food producing southwest region of Western Australia.

WildEye's innovative products, centred on precision water management, equip farmers with real-time insights into on-farm water demand. Our simple and rugged IoT devices and sensors, easy to use software, and ready-made tools for integrating client data with platforms from industry partners such as SWAN, has allowed the project team to rapidly deploy sensors and collect the data that has underpinned the benchmarking generated in the project.

Beyond contributing to the overall project outcomes, it's been extremely pleasing to observe the farmers involved embracing data specific to their operation and working with them to generate deeper understandings of soil-water interactions and the impact of their irrigation practices.

We're confident that the project has made a significant impact on future decision making around water allocation in the region and beyond, something for which we believe the project team can be extremely proud.

PROJECT PARTNER, Dr Richard George, Senior Research Scientist, DPIRD

The Manjimup area comprises 7,268 ha of irrigated fruits, vegetables and other produce, representing 16% of the total Western Australian production with a value of $300m annually. It is a critical area for food production due to its high reliability and underpins core agricultural industries, markets and communities.

The availability of reliable, very low salinity irrigation water is unique in the southwest of WA and vital to crops in the region. Reduced rainfall coupled with increased variability and seasonal conditions is a challenge across South-Western Australia. With comparatively high rainfall and temperate conditions, buffered by the south coast, Manjimup was thought to be a lower risk to climate impacts. However, this has been shown not to be the case and recent IPCC forecasts consider it *very likely* that the region will undergo further reductions in rainfall and increased evaporative demand. Already over 60% of the streamflow in the region has been lost, with flows from forested catchments now unreliable, and excess water primarily generated from cleared landscapes. Water demand from the environment is increasing along with expectations of the community that water be shared.

Licenced, self-supply farm dams provide the cornerstone to harvest and manage water. Previously, supply was in always in excess of demand, and runoff expected to refill farm dams. Since 1987 this expectation has been challenged, with more frequent dry periods since 2000, an especially dry decade (2010-2020) and record dry summer in 2024.

Importantly, reduced runoff coupled with increased local demand has driven the need to conserve water, look for alternative supplies and seek gains in efficiency of use.

This project is both timely and critical to underpin growers understanding of crop demand, seasonality of use and practices to increase water use efficiency – by value and unit of water used. DPIRD congratulates the team, local champions, growers and supporting groups in developing and delivering this important project. Without monitoring, evidence and awareness, farmers cannot increase their efficiency and show the value of water used that supports long term access in a unique environment and challenging period of climate variability.

RESEARCH PARTNER, Prof. Mark Gibberd, Centre Director, CCDM

As a research partner, Curtin University's Centre for Crop and Disease Management (CCDM) led the scientific design and delivery of the project with a clear focus on generating independent, defensible evidence on agricultural water demand and value at both farm and catchment scales. From a research perspective, the project represents a significant advance in how on-farm digital data can be translated into decision-relevant knowledge for the industry as a whole and to inform government policy.

A major impact of the project has been the creation of an industry-owned, independent on-farm data set spanning multiple high-value horticultural commodities and seasons. These data underpin a suite of research outputs, including standardised data governance and sharing frameworks, robust data pipelines, and repeatable seasonal reporting processes that benchmark water use, water productivity and water profitability across farms. Importantly, these outputs move beyond single-farm insights to enable meaningful cross-industry comparison while maintaining grower trust and data integrity.

From a scientific standpoint, the project has also delivered novel methodologies for integrating on-farm measurements with publicly available weather, remotely sensed and spatial data. This has enabled the development of crop classification models, simple farm-scale water balances, and a scalable research framework for estimating crop water demand at catchment scale. Collectively, these outputs establish the foundations for independent assessment of agricultural water demand now and under future climate scenarios.

The broader impact for Curtin lies in demonstrating how applied research, co-designed with food producers and the wider industry can improve decision-making through the adoption of digital agriculture within a facilitated framework. The core data set and research framework developed in the project has the potential to strengthen the long-term sustainability and resilience of regional food production systems.

END-USER PROFILE

Mark Bending, Manjimup WA
Jarnadup Farms
Mixed enterprise cattle and avocados ~ 10ha under avocado
OFWD for seasons 2019, 2020, 2021, 2022, 2023

Mark Bending has been involved with the project since 2019 as part of the avocado grower pilot for the first season of data collection. He farms avocados and beef on a mixed enterprise farm in the high rainfall zone near Manjimup WA.

His problem has been to accurately forecast and record crop demand for water to understand if the current irrigation pattern was suitable for his crop needs and where he sat compared to growers in the local region for irrigation efficiency. The uncertainty on optimum water use for the avocado crop made it difficult to plan for business expansion, should more avocado trees be planted or was the farm already at capacity with existing water storage?

The trial on Mr Bending's property involved installation of WildEye soil monitoring sensors and irrigation pressure transducers to measure crop demand and irrigation volume on avocado trees aged 6 years and older. The data was then fed through the SWAN Systems irrigation dashboard to visualise the information for interpretation by an irrigation consultant.

Mr Bending had used various irrigation and soil monitoring methods in the past but did not have a specialist consultant to interpret the results or diagnose an irrigation deficit. "This project enabled us to get a handle on some changes we needed to make with irrigation. We thought we were in a good position and didn't realise we were actually running pretty close to the wind."

A specialised consultant proved the important ingredient. "We discovered that we weren't covering enough in spring and too much in late autumn. Having the consultant who could demonstrate where they saw shortfalls was crucial, without that we wouldn't have identified areas for change." The irrigation plan has now changed over the season because of the project. Mr Bending pays far closer attention to soil moisture levels in spring and summer, with reduced irrigation in autumn. "Our total water use for the year hasn't changed but it is more targeted which has increased productivity."

A common characteristic of avocados grown in the region is fruit abscission or dropping of fruit in spring which unpredictably reduces overall yield and is difficult to plan for. Mr Bending thought the issue must have been unavoidable as most growers in the region experienced it, but after tailoring the irrigation plan to crop demand over the multi-year course of the project saw no fruit abscission in 2022. “We think we may have it solved now we’ve found it was a water demand issue. It’s hard to put a figure on it but when fruit prices are high a substantial fruit drop can cost you a lot of money.”

The benchmarking feature of the project delivered considerable value for Mr Bending. “It’s been really reassuring to get feedback on how we fit within our product type and region.” The ability to cross reference the business for both water use and profitability against others in the region is a rare experience. “I’ve been involved with beef benchmarking for instance but many of the cohort are on the east coast, so the comparison is not as helpful.”

Mr Bending has already made changes after taking part in the project, doubling the size of the avocado orchard now that he is comfortable the farm water supply can satisfy the crop. “Understanding our total water usage, we could make the decision to increase the orchard with confidence based on what water we have.” Remote sensing has also enabled more orchard management to happen without Mr Bending being present on the farm, allowing for time elsewhere and a farm manager to step in.

Further details of Mark Bending’s involvement in the project are available in the associated Case study booklet for the project.

OBJECTIVES

The project aimed to deliver

- Independent, data-driven water use measurements for key crops grown in the Warren-Donnelly catchment
- Improved industry profitability through data-driven decision-making focussed on ROI for water use (individuals)
- Catchment-scale model for water demand for food production highlighting the value of water for food production and associated the triple bottom line benefits for the region

METHODOLOGY

STUDY SITE

The Warren-Donnelly catchment is approximately 6,100 km^2 and located in the south-west of Western Australia (Figure 1).

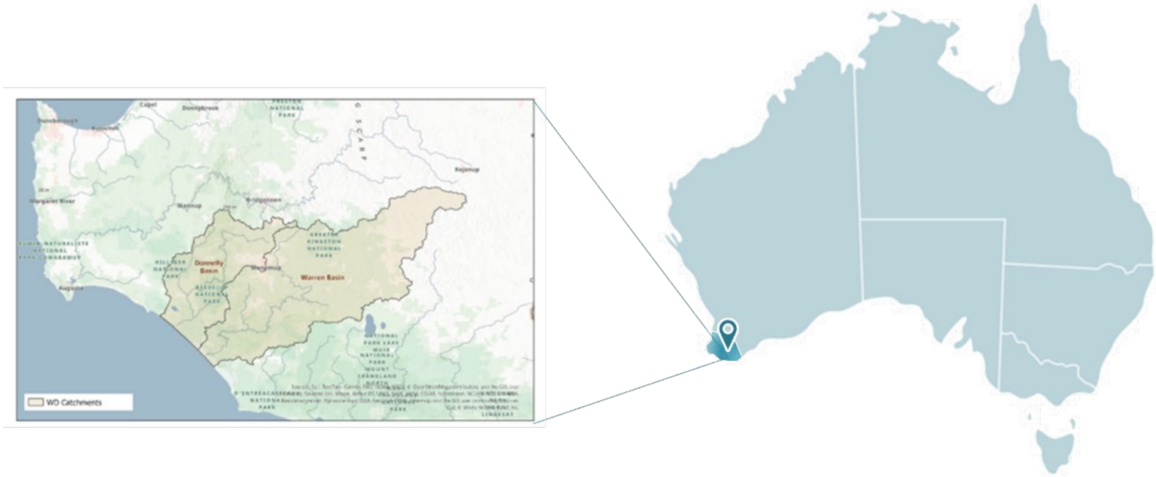


Figure 1 Warren-Donnelly catchment located in the south-west of Western Australia

Around two thirds of the catchment area dominated by State forest, National parks and conservation reserve with multiple land uses including irrigated agriculture, future public water supply and forest/conservation and over 480 on-stream dams[2] (Figure 2).

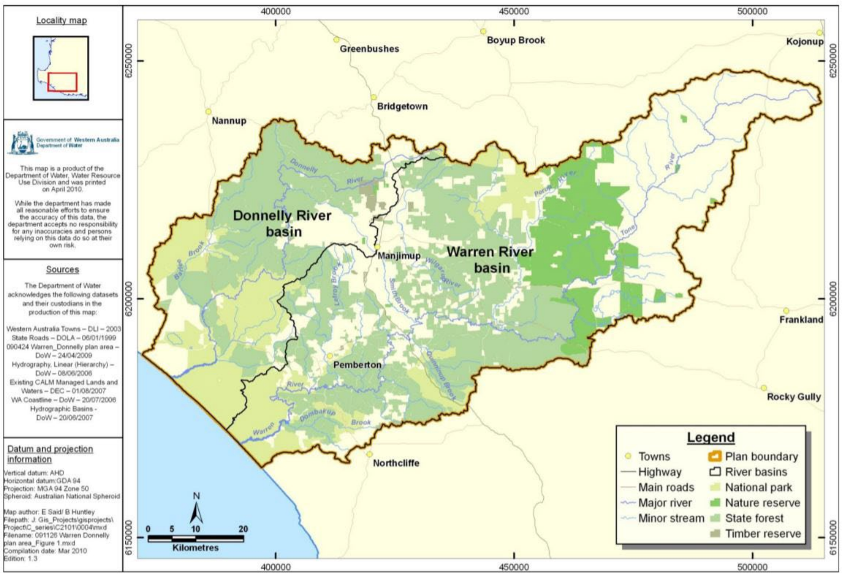


Figure 2 Warren-Donnelly catchment area (Source [Warren-Donnelly Surface Water Allocation Plan Methods Report Figure 2](#))

[2] Warren–Donnelly surface water allocation plan methods report (2012) available at https://www.wa.gov.au/service/natural-resources/water-resources/warren-donnelly-surface-water-allocation-plan

The catchment supports one of the state's most productive irrigated horticultural regions, centred around the communities of Manjimup and Pemberton. The Manjimup region is a major centre of horticultural production in Western Australia, contributing more than 16% of the state's total horticultural value and producing over $300 million annually. Production in the region is strongly dominated by fruit, which accounts for approximately 79% of horticultural value, with key industries including avocados and apples. Avocados are the largest single contributor, representing more than half of the total production value, while apples form the second largest industry. Manjimup also supports a range of vegetable and specialty crops, including fresh and processing potatoes, contributing to a diversified production base. Manjimup is also the heart of truffle production in Australia, generating high-value produce that is exported internationally and overall, the region accounts for a significant share of the state's fruit production and is a major supplier of high-value horticultural produce to both domestic and interstate markets.[3]

The Warren and Donnelly river systems originate inland under moderate rainfall conditions and flow southwest through higher rainfall forested catchments to the coast, with stream flows that are naturally variable from year to year. Irrigated agriculture in the region is largely self-supplied through the capture and storage of surface water in on-farm dams, with more than 5,000 storages estimated across the catchment[3]. Water use is regulated through a licensing system that manages approximately 65 GL of allocatable water across 25 subareas, with many of these areas now fully allocated. This means that additional water is increasingly limited to trading between existing licence holders.[4].

At the same time, long-term climate trends have reduced rainfall by around 20% and stream flows by up to 80% since the 1970s, significantly reducing water availability[5]. These changes, combined with the need to balance agricultural, environmental and community water requirements, are increasing the complexity of water management and placing greater pressure on irrigation systems and farm water planning.

[3] Situation analysis of horticulture in Western Australia available at https://www.dpird.wa.gov.au/businesses/plant-and-crop-farming/horticulture/value-horticulture-industries/
[4] Southern Forest Irrigation Reference Group report (2023) available at https://www.dpird.wa.gov.au/regional-communities/major-projects/SFISS/
[5] Future Climate streamflow estimation in the Donnelly River catchment CSIRO available at https://library.dpird.wa.gov.au/lr_consultrpts/24/

RESEARCH FRAMEWORK

The project was designed to bring on-farm and publicly available data together in a framework that benefited the farm businesses participating in the project, the wider industry and the communities that support them. There were three distinct phases to the project: 1) on-farm data collection and processing 2) public data collection and processing 3) scaling data to the catchment. The research framework (Figure 3) and associated analytics have been developed in such a way that it can be applied to other catchments, provided the necessary raw data elements (i.e. square shapes in on-farm and public data processing) are available.

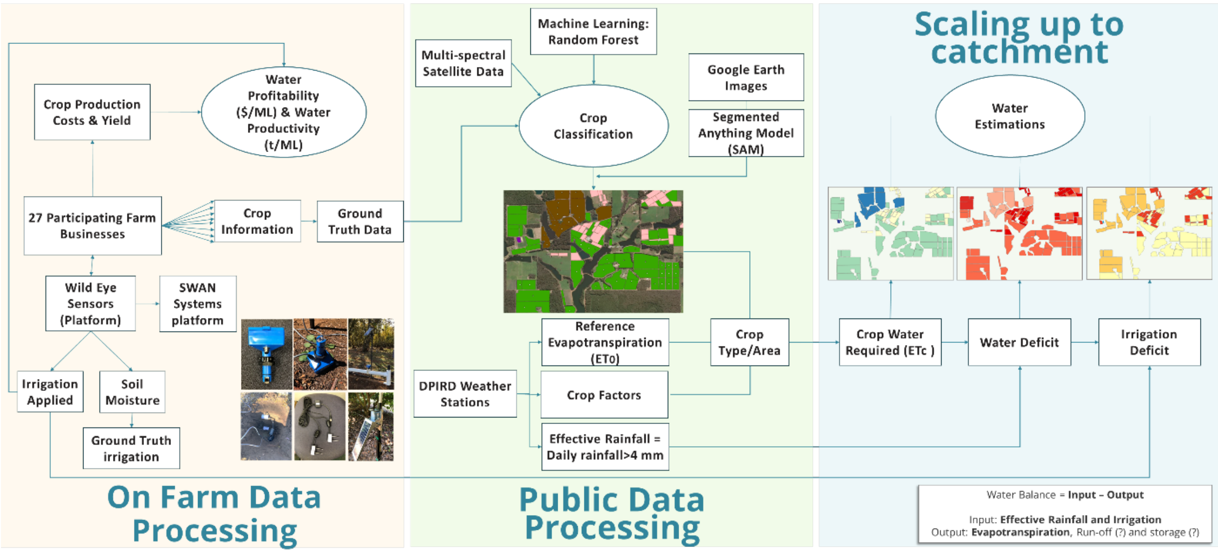


Figure 3 On farm water demand project research framework, incorporating data inputs (i.e. square shapes) and analysis (i.e. oval shapes), developed for the Warren-Donnelly catchment in the south-west of Western Australia.

PROOF OF CONCEPT STUDY

A proof-of-concept study was embarked upon in 2019 to recruit five farm businesses and test the equipment and compare data with irrigation record. Potential candidates for the project were identified by the Southern Forests Food Council members and numerous site visits and conversations. From these conversations, two clear value propositions emerged as to why participants might agree to be involved in the project: 1) individual interest in using data to monitor and support irrigation decisions and 2) the wider industry benefits of an independent, defensible data set for crop water demand in the catchment area.

Data management and security

A key part of the proof-of-concept phase was concerns raised regarding who would have access to data and how would it be used. A data management plan was established for the project (Figure 4) and fieldwork access agreements for each project participant, outlining site access and data sharing arrangements including agreed use and data security. Data was de-identified and stored securely in accordance with the Curtin Research Integrity policy as well as under the Public Sector Management Act 1994 and Freedom of Information Act 1992 to ensure that individual project participant's data cannot be identified. Curtin project staff were granted access to the data by the project leader through a project participation agreement. Publication of project data has been designed to describe the breadth of irrigation practices in the Warren-Donnelly catchment that is independent and robust rather than individual practices.

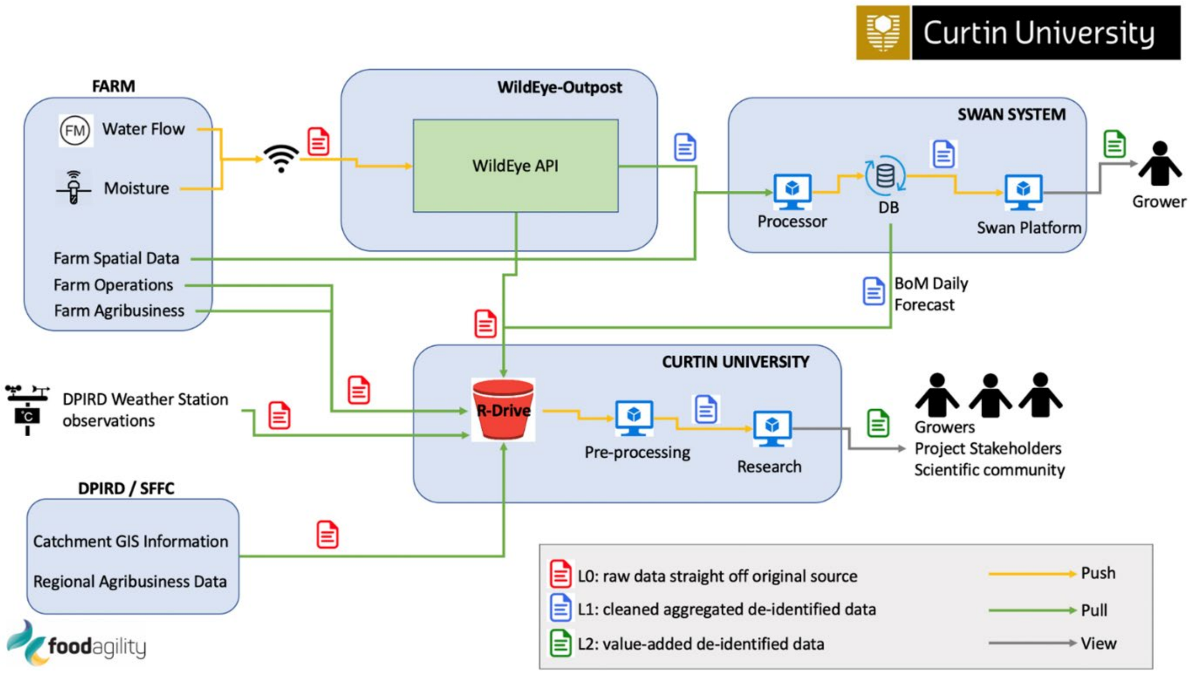


Figure 4 Data flow diagram for the on-farm water demand project

Site selection

Sites selected for the proof-of-concept study were farms that were in the Warren-Blackwood catchment and had avocado orchards or truffieres (i.e. oak and hazelnut plantations inoculated with black truffles (*Tuber melanosporum*)) in full production with an irrigation block of 1 to 4 hectares with an independent main or sub-main for flow meter installation.

Site characterisation – soil type

Soil samples were taken at each site as part of the characterisation process and processed using APAL laboratory services. Apple orchards in the dataset were established across a mix of soil types from loamy sands to silty loams and a few sites with loam at depth (20-30cm). Avocado sites were consistently dominated by loamy sands as were the wine grape sites.

Truffle sites were a mix of loamy sands (most common) and one site that was silty loam. Potato production sites show the widest range of soil types between sites with three sites that were loam to depth, two sites that were loamy sand to depth and one silty loam to depth.

Site characterisation – irrigation

Each site was characterised to define the block planting (i.e. crop type, crop variety, year of planting, planting configuration (number of rows and trees per row, plant spacing, oak/hazel tree arrangement for truffles), soil type, block ID and area. Irrigation details including pipe size, pipe material, sprinkler type (dripper/sprinkler) and location relative to trees, rooting depth, sprinkler radius and flow rate volume. Wetted area calculation and average application rate (mm/hr) were also conducted. These details were used for calculating the water balance for the SWAN system.

Installation of sensor equipment on-farm

For each research block, a soil moisture sensor (GS1 Teros 10; Figure 5) and Manuflo RPFS-LOD irrigation flow meter (Figure 6) were installed and connected to a WildEye internet-connected data logger (Figure 7). The WildEye loggers are managed via the web and collect data from sensors at high temporal resolution, before uploading that data to the client via third party IoT radio networks.

Figure 5 GS1 Teros 10 soil moisture sensor a) prior to installation b) installed

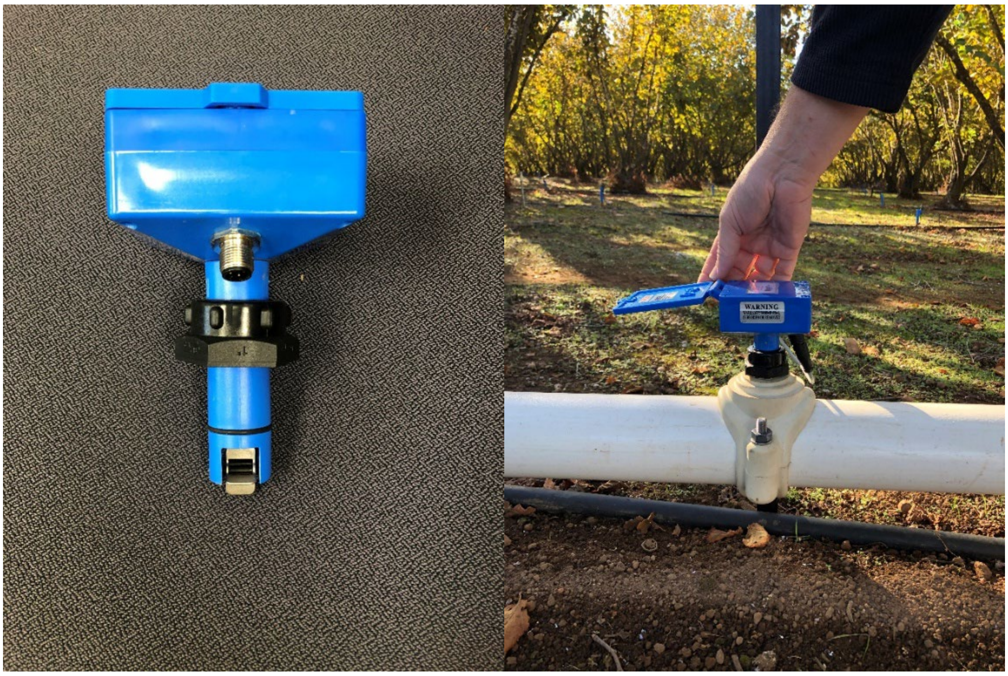


Figure 6 Manuflo RPFS-LOD Irrigation flow meter a) prior to installation and b) installed

Figure 7 WildEye logger a) data logger, solar panel and high gain antenna b) data logger, solar panel and high gain antenna plus flow meter

Data collected from this equipment were visualised in the WildEye portal as well as the SWAN systems portal and participating farm businesses were provided access (Figure 8).

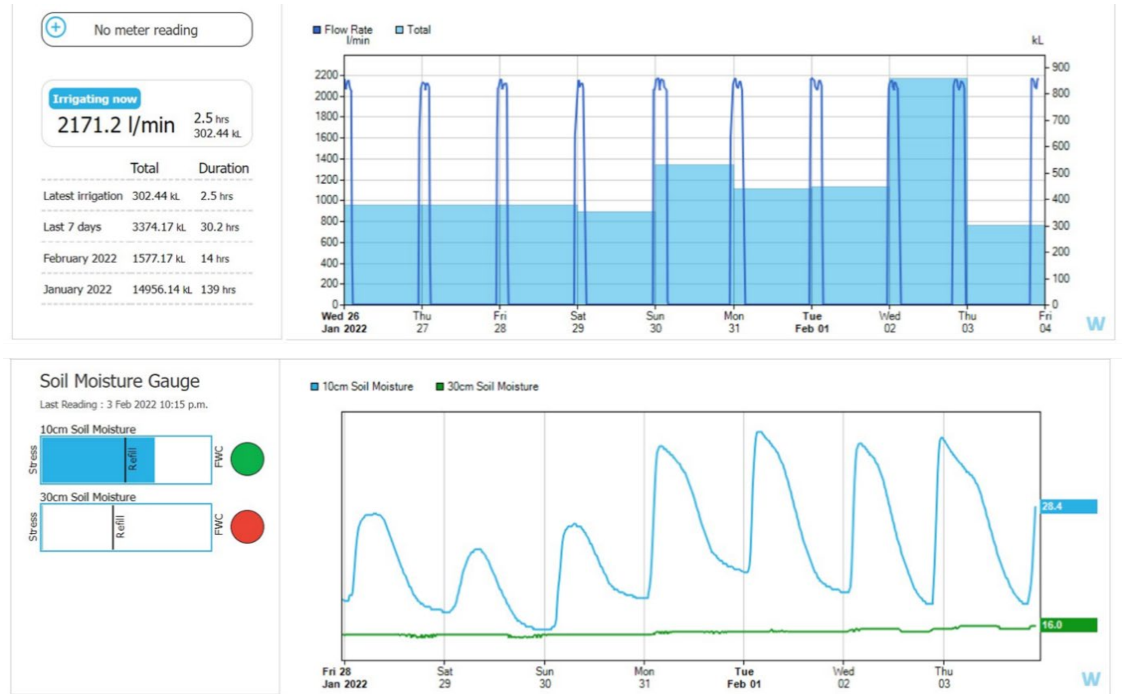


Figure 8 Example data visualisations in the WildEye portal of a) flow meter and b) soil moisture sensor

Monitoring water balance

A SWAN Systems (https://www.swansystems.com/) account was created for each grower. Growers' blocks were configured in their SWAN accounts with soil moisture holding parameters (field capacity, wilting point), crop water use models (crop coefficients, root depths, etc. appropriate for the crop, including growth phase and age adjustments) and irrigation system characteristics (drip vs sprinklers, notional application rates, etc.). SWAN can automatically collect flow, soil moisture probe and weather data from almost any cloud service or irrigation controller. Accordingly, the probe and flow data were collected into SWAN from the WildEye cloud service. Weather observations were collected either from the DPIRD (https://weather.agric.wa.gov.au/) or the Bureau of Meteorology station (e.g. http://www.bom.gov.au/products/IDW60801/IDW60801.94617.shtml) nearest to each farm. Local weather forecasts within 2-3 km of each farm were obtained via SWAN's subscription to the BoM gridded data service (https://weatherwise.swansystems.com.au/). Importantly, the forecasts include ETo to enable forecasts of crop water demand.

The data from these devices and services was analysed daily in SWAN in the context of the crop models, soil parameters, and irrigation system settings to provide a daily summary of irrigation applied, crop water use and soil moisture status. Each grower had access to their own data along with on-demand training and support from SWAN Systems including site location (Figure 9), soil moisture monitoring (Figure 10) and irrigation planning (Figure 11). They were able to follow daily scheduling recommendations if desired. Regardless of user engagement, the crop water use and soil moisture analysis were regularly monitored and reviewed to assess irrigation effectiveness.

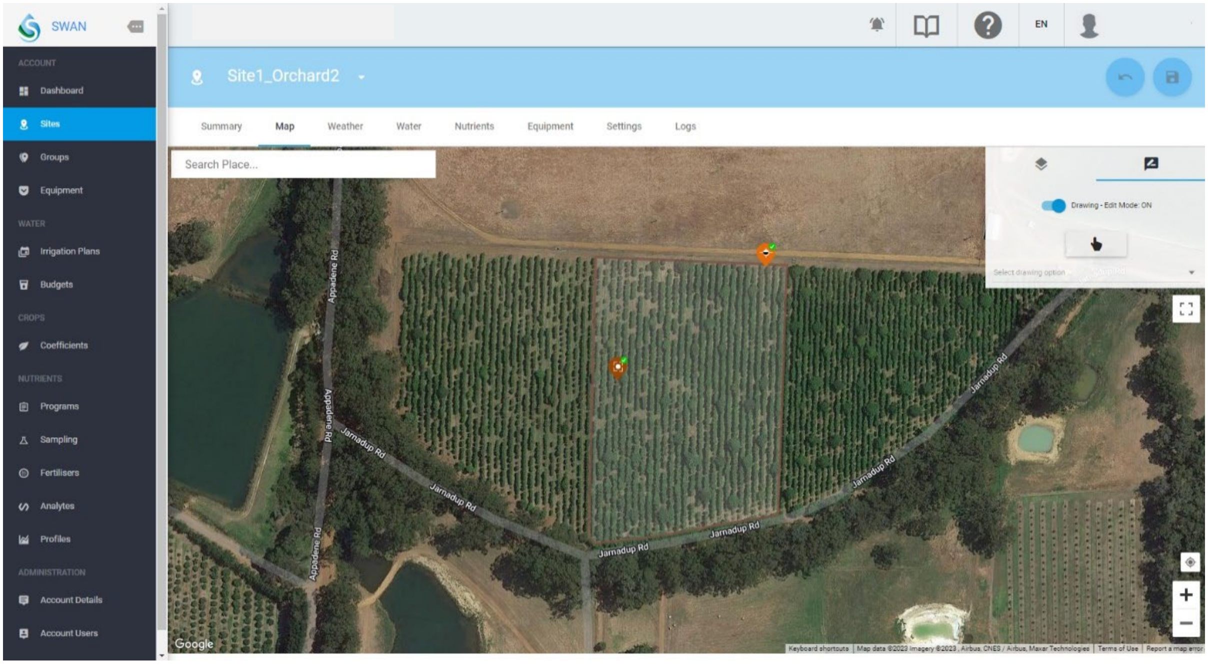


Figure 9 Map in SWAN showing block boundary, probe and flow meter locations overlayed on Google Maps base imagery.

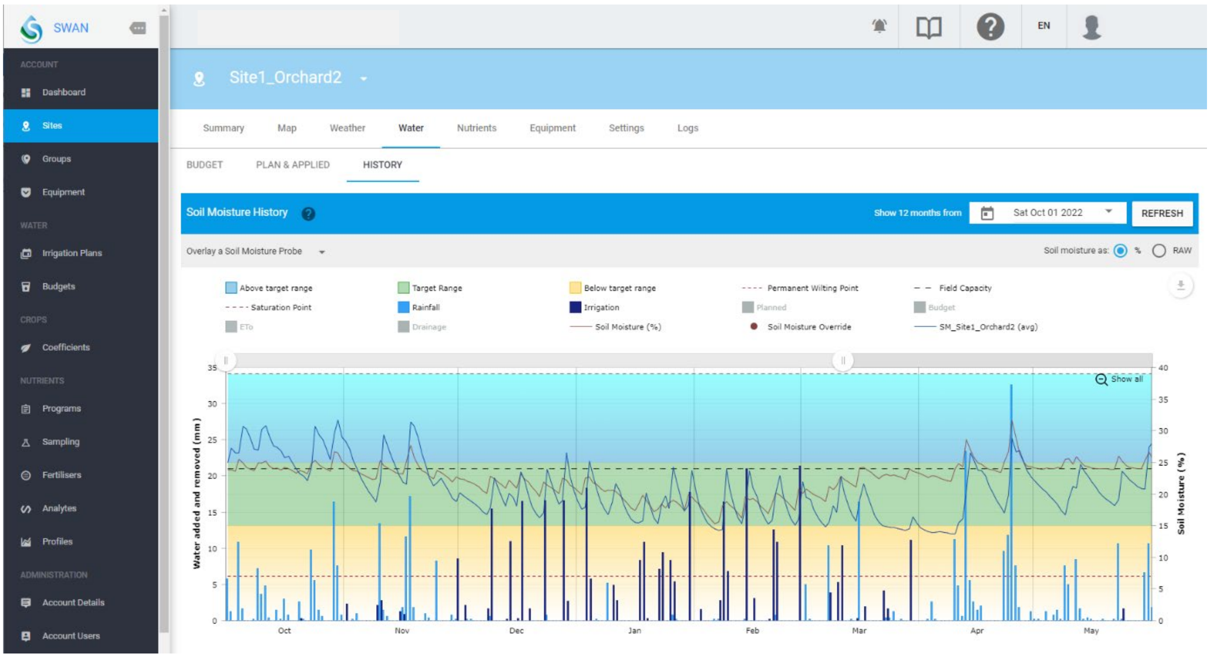


Figure 10 Soil Moisture history for irrigation season 2022-2023 (October 2022 – May 2023). Shown are soil moisture predicted by SWAN, soil moisture measured by the probe, irrigation events, rainfall and soil parameters. Other data overlays that could be shown are ETo and daily drainage predictions (calculated if moisture exceeds field capacity).

Figure 11 Irrigation planning page screenshot captured on 5th October 2023, with inset showing predicted effect on soil moisture of an irrigation event planned for Mon 9th October 2023

Scaling up – expanding sites (27 participating farm businesses)

This phase of the project included a facilitated approach to adoption of data-driven decision making. Participating farm businesses had the opportunity to work with the research team and the technology providers (i.e. WildEye and SWAN systems) to support them in how to use their own data in the data visualisation platforms, to make decisions on a daily/weekly basis.

An additional 22 research sites (blocks) were added to the project. The project recruited a total of six avocado, seven apple, five truffle, five potato and four wine grape sites. These sites were representative of the farm businesses in the region from a geographic and business size point of view. Sites were selected for consistency of variety and block age within commodity and ranged in area from 1 – 10 hectares. While the Southern Forests region of WA produces over 20 different crops, the project focussed avocado, apple, truffle, potatoes and wine grapes. Avocado and apples were selected as they represented more than 90% of the mass and value ($AUD) of food produced in the region. Truffles were included as they are economically important for the region and represent high value ($/kg). Potatoes are an important part of the farming system in the region, often grown as a seasonal crop in a pasture for beef rotation. Wine grapes have been included as they have a low water use requirement in this region under current climate conditions. Future climate projections indicate that wine grapes are likely to switch from supplementary irrigation to obligate irrigation.

ON FARM DATA PROCESSING

Building on the learnings from the proof-of-concept phase, the project switched to collecting and processing the data collected on farm. Figure 12 below provides a detailed overview of the data processing of farm data. Irrigation applied, collected by flow meter sensors, soil moisture meters were used for ground-truth data. Annually, the project team met with the farm participants to collect crop yield data and production costs.

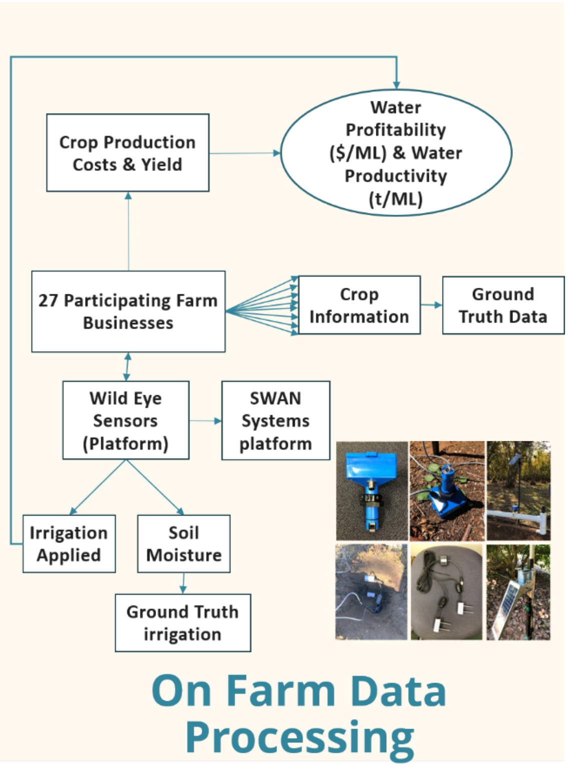


Figure 12 Detailed overview of the on-farm data processing component of the project methodology

Farm data processing - Irrigation applied

Water use (irrigation) volume data was collected on a range of crops including avocados (6), apples (7), truffles (5), wine grapes (4) and potatoes for the growing seasons (and financial years) of 2021, 2022, 2023 and 2024. Irrigation applied and soil moisture data were collated through the WildEye database hosted through Outpost Central. This database records measurements from the IoT sensors at 15-minute intervals, and these measurements were streamed as text into the OFWD research drive at Curtin University. Data ingestion pipelines were developed to extract and clean irrigation flow and soil moisture measurements from Outpost Central for each farm and then aggregated (cumulative for irrigation flow and average for soil moisture) at daily intervals for each site. Daily, monthly and annual water use (irrigation) data sets created for each of the project sites. Where irrigation data was missing (sensor/connectivity failure), gaps were filled using a model developed based on weather observations and previous irrigation strategies.

Farm data processing – Crop yield and cost of production

Crop yield (tonnes per hectare) data was collected for the site (block) annually, along with production costs (2021 and 2022 only). Crop production costs were collected using a similar methodology to Planfarm benchmarking[6], considering operating costs only (does not include farm overhead expenses), to ensure that each farm measured operating costs in the same way. Operating profit/loss was calculated as crop income minus variable expenses (e.g. crates, chemicals, fertiliser, packaging, freight, fuel, levies and pumping costs) and wages.

Farm data processing – Crop identification reference data

As part of the first seasonal review, participating farms reviewed maps provided by the project team and added details about the crop type and when it was planted. In total, 321 blocks were collected for apple (115), avocado (85), truffle (40), and wine grape blocks (81). Potatoes were not included in this part of the study as, unlike tree crops, they are planted in different parts of the farm each year making it difficult to identify them from satellite imagery. Publicly available reference datasets were collected for land cover classes, including cleared (51), pasture (66), native (69), structure (49), and water (48). Overall, the final dataset contains 604 samples across nine classes.

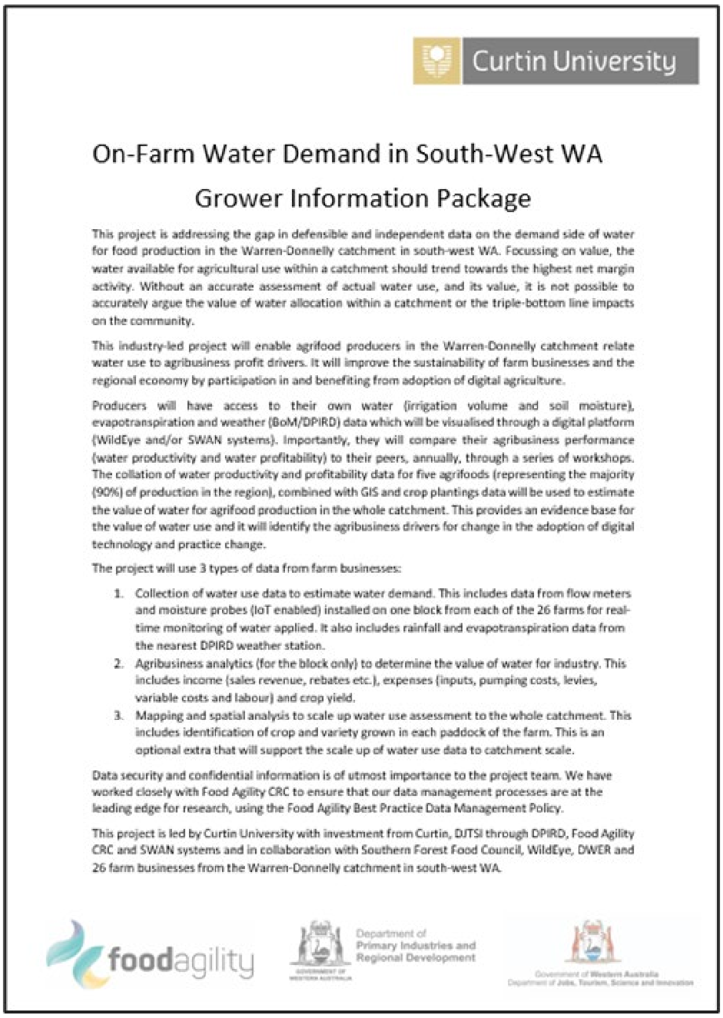
SEASONAL REVIEW – facilitated adoption of data-driven decision-making

At the end of each growing season, the research team met with the participating farm businesses to review the data from the previous season (Figure 13). The discussion was conducted prior to the start of the following season to allow time to reflect on the past season and consider changes in the following season. Reports were auto generated for each farm using research code that

- aligned irrigation data with publicly available data to understand the crop water demand compared with the irrigation applied
- compared monthly irrigation (ML/ha) applied on farm with each of the project sites in the same commodity
- aligned irrigation data with operating profit ($/ha) and yield (t/ha) data to compared farm performance in terms of total water productivity (t/ML) and profitability ($/ML) for the growing season with that of the other farms in the cohort growing the same crop.

Annual water productivity (tonnes/megalitre/hectare) was calculated for each site using crop yield and irrigation as applied. Annual water profitability ($ profit/ML/ha) was calculated for each site using crop yield and operating profit and irrigation as applied.

[6] Details on Planfarm benchmarking methodology and results are available online here: https://planfarm.com.au/resources/#benchmark



Curtin University

On-Farm Water Demand in South-West WA

Grower Information Package

This project is addressing the gap in defensible and independent data on the demand side of water for food production in the Warren-Donnelly catchment in south-west WA. Focussing on value, the water available for agricultural use within a catchment should trend towards the highest net margin activity. Without an accurate assessment of actual water use, and its value, it is not possible to accurately argue the value of water allocation within a catchment or the triple-bottom line impacts on the community.

This industry-led project will enable agrifood producers in the Warren-Donnelly catchment relate water use to agribusiness profit drivers. It will improve the sustainability of farm businesses and the regional economy by participation in and benefiting from adoption of digital agriculture.

Producers will have access to their own water (irrigation volume and soil moisture), evapotranspiration and weather (BoM/DPIRD) data which will be visualised through a digital platform (WildEye and/or SWAN systems). Importantly, they will compare their agribusiness performance (water productivity and water profitability) to their peers, annually, through a series of workshops. The collation of water productivity and profitability data for five agrifoods (representing the majority (90%) of production in the region), combined with GIS and crop plantings data will be used to estimate the value of water for agrifood production in the whole catchment. This provides an evidence base for the value of water use and it will identify the agribusiness drivers for change in the adoption of digital technology and practice change.

The project will use 3 types of data from farm businesses:

1. Collection of water use data to estimate water demand. This includes data from flow meters and moisture probes (IoT enabled) installed on one block from each of the 26 farms for real-time monitoring of water applied. It also includes rainfall and evapotranspiration data from the nearest DPIRD weather station.
2. Agribusiness analytics (for the block only) to determine the value of water for industry. This includes income (sales revenue, rebates etc.), expenses (inputs, pumping costs, levies, variable costs and labour) and crop yield.
3. Mapping and spatial analysis to scale up water use assessment to the whole catchment. This includes identification of crop and variety grown in each paddock of the farm. This is an optional extra that will support the scale up of water use data to catchment scale.

Data security and confidential information is of utmost importance to the project team. We have worked closely with Food Agility CRC to ensure that our data management processes are at the leading edge for research, using the Food Agility Best Practice Data Management Policy.

This project is led by Curtin University with investment from Curtin, DJTSI through DPIRD, Food Agility CRC and SWAN systems and in collaboration with Southern Forest Food Council, WildEye, DWER and 26 farm businesses from the Warren-Donnelly catchment in south-west WA.

foodagility

Department of Primary Industries and Regional Development

Government of Western Australia Department of Jobs, Tourism, Science and Innovation

Figure 13 Overview of the seasonal review process (left) and cover page of the seasonal review report (right)

PUBLIC DATA PROCESSING

A core element of this project was collecting and processing publicly available data. Weather conditions play a major role in determining how much water crops need. In order to estimate the crop type and their area within the catchment, a crop classification model was developed. Figure 14 below is a detailed view of the research framework for this part of the project. Crops were classified using satellite imagery, Google Earth imagery, a machine learning random forest model. Segment Anything Model (SAM) was used as a post-processing tool. Weather observations (rainfall and crop evapotranspiration) were collated with crop factors and calculations of reference evapotranspiration (ETo) and effective rainfall. By integrating this weather information with on-farm irrigation data, the study was able to assess how climate conditions influence water demand and irrigation practices.

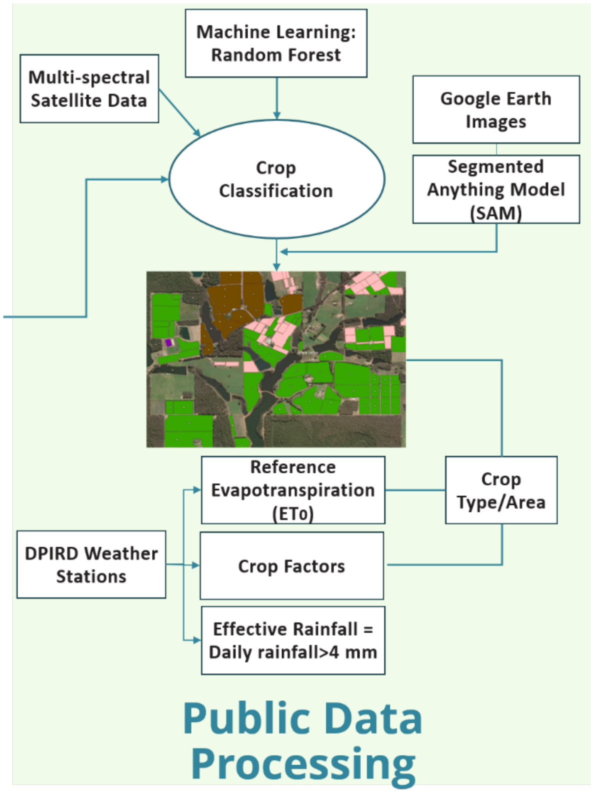


Figure 14 Detailed view of research framework for the public data processing phase of the project

Public Data Processing - Weather observations

Daily weather data were sourced from the Department of Primary Industries and Regional Development (DPIRD)[7]. The data included rainfall, reference evapotranspiration (ETo: a measure of how much water is lost from soil and plants), and minimum and maximum temperatures. Information was drawn from five weather stations located in the Warren–Donnelly catchment (Manjimup, Yanmah, Pemberton, Quinninup, and Tonebridge) and two in the surrounding area (Nannup and Northcliffe). These data were then combined and summarised into monthly and annual values to support analysis.

Public Data Processing - Effective rainfall

Not all rainfall contributes to crop water supply. Some rainfall events are too small to be useful, as the water may evaporate before it reaches the soil or becomes available to plants. To account for this, the study used an approach that estimates effective rainfall i.e. the portion of rainfall that contributes to meeting crop water needs. Minimum thresholds were applied to daily rainfall values, based on guidance from the Department of Primary Industries and Regional Development (DPIRD) irrigation calculator[2]. Rainfall amounts below these thresholds were not counted, as they are unlikely to benefit crops. For rainfall events above the threshold, only the usable portion was included in the final calculation.

Table 1 Effective rainfall for each month, sourced from DPIRD: Crop factors for perennial crops – Irrigation calculators

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	4	4	4	3	3	2	2	2	3	3	4	4

[7] Weather data sourced from DPIRD via the weather v2 API available online here: https://weather.agric.wa.gov.au/developer-api

Public Data Processing - Crop factors

Crop factors (Kc) for each of the crops were sourced from DPIRD's irrigation calculators and are reproduced in Table 2 below.

Table 2 Crop factors for each month of the year for the corresponding crop type. Crop factors were sourced from DPIRD (Crop factors for perennial crops – Table 4 Irrigation calculators[2])

Month	Avocados	Apples	Wine Grapes	Truffles	Potatoes
Jan	0.7	1	0.25	0.45	1.1
Feb	0.8	1	0.3	0.45	1.1
Mar	0.8	0.9	0.3	0.4	0.9
Apr	0.7	0.8	0.25	0.4	0.9
May	0.4	0.5	0	0.1	0.7
June	0.4	0.1	0	0.1	0.7
July	0.4	0.1	0	0.1	0.7
Aug	0.4	0.1	0	0.1	0.7
Sept	0.7	0.3	0	0.3	0.9
Oct	0.8	0.7	0	0.3	0.9
Nov	0.8	0.9	0.25	0.3	0.9
Dec	0.7	1	0.25	0.45	1.1

Public Data Processing – Multispectral satellite imagery

Satellite imagery from the European Space Agency's Sentinel-2 program was collected for the Warren–Donnelly catchment and pre-processed for inclusion in the project. The Sentinel-2 satellites provide high-resolution images of the land surface and capture information across multiple spectral bands, allowing differences in vegetation to be detected. In this study, a selection of key bands was used to identify crop characteristics, including those sensitive to plant colour, structure and water content. These data were sourced from an online processing platform and prepared so that they could be compared consistently across the region.

Images were collected across the 2020 and 2021 seasons to capture how crops change throughout the year, which is critical for distinguishing between crop types such as evergreen (e.g. avocado) orchards and deciduous systems (i.e. oak and hazelnuts planted as hosts for truffle production). However, cloud cover (particularly during the wetter winter months) limits the availability of suitable imagery. To address this, only low-cloud images were used and additional processing steps were applied to remove cloud effects, standardise the data, and combine multiple images where needed. The analysis also incorporated vegetation indices, which are commonly used measures derived from satellite data that highlight plant growth and condition. Together, these approaches ensured that the satellite data provided a reliable and consistent basis for identifying crop types and understanding land use across the catchment.

Public Data Processing – sub-basin/catchment maps

Delineation of the Warren River Basin, the Donnelly River Basin, and the 25 sub-basins, was sourced from the HydroSHEDS webpage[8] and recreated in Figure 15 below.

Figure 15 Warren and Donnelly basins and 25 subcatchment areas of the Warren-Donnelly catchment in the southwest of Western Australia. Map recreated from data sourced from the HydroSHEDS website for hydrobasins.

[8] HydroSHEDS website: https://www.hydrosheds.org/products/hydrobasins

CROP CLASSIFICATION

A core part of the research framework is establishing the planted area of each of the commodities. To do this, farm and public data was collected and collated including satellite data, farm and paddock boundaries and crop type (see details in previous sections). These core data sets were used to train a machine learning model using the random forest algorithm to identify cropped areas.

The Segment Anything Model (SAM), a machine learning tool designed to automatically identify and delineate objects within imagery, was applied to aerial imagery to generate paddock boundaries across the agricultural areas of the catchment. This approach provided an efficient and consistent way to map field boundaries over a large and complex landscape, reducing the need for manual digitisation. The resulting boundaries were then reviewed and refined where required and used alongside the satellite classification outputs to assign a dominant crop type to each paddock. This integration ensures that crop areas are represented at a farm-relevant scale, rather than as individual pixels, improving the practical value of the outputs for both industry and policy applications. By combining automated boundary detection with targeted quality control, the approach provides a reliable and scalable method for mapping agricultural land use and supporting analysis of water demand across the region.

The accuracy of the approach was tested using a percentage of the ground truth data provided by farmers. In total, the dataset included 604 blocks representing avocado, truffle, apple, and wine grapes. Potato crops were not included in this section of the project as it is too difficult to identify these crops due to their seasonal nature and movement around the farm. Further details on the research methodology developed as part of the project are contained within a journal manuscript. Please contact the author for details of the paper.

SCALING UP TO CATCHMENT

In order to assess the water estimation requirements for the catchment area, a series of calculations were required to be conducted. An overview of the research framework for this phase of the project is in Figure 16.

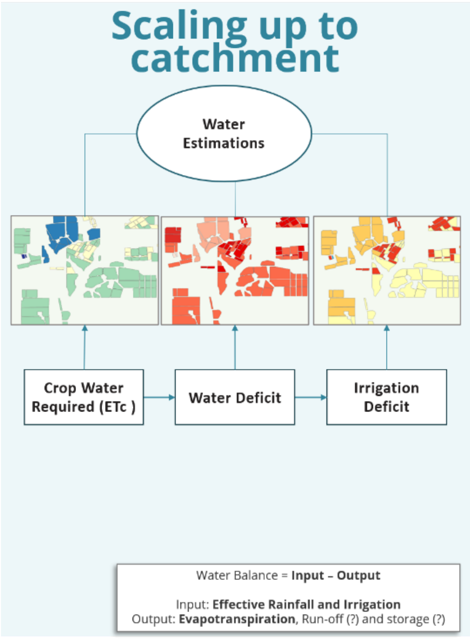


Figure 16 Detailed view of research framework for the scaling up to catchment phase of the project

Calculations for the catchment included crop water requirements, water deficit and irrigation deficit were developed as research code with the ability to project the results into map format. Using the methodology outlined in the Crop evapotranspiration – guidelines for computing crop water requirements - FAO56 irrigation and drainage paper 56[9], estimates of crop water requirement (ETc) and crop water deficits were calculated. These calculations relied on processed data from farms (i.e. irrigation applied), public datasets (i.e. reference evapotranspiration, effective rainfall, Warren and Donnelly basin and sub-basin/catchment boundaries) and model outputs (i.e. crop type/area).

[9] Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56 (FAO56) report is available online here: https://www.fao.org/4/x0490e/x0490e00.htm re

Crop water requirements

Crop water requirements (ETc) throughout the year, for each year (i.e. 2020-21 to 2023-24) were estimated using reference evapotranspiration (ETo), which reflects the atmospheric demand for water, and crop factors (Kc) for each month (see Table 2) with the following equation:

Crop water requirement (ETc) = Crop factor (Kc) x Reference evapotranspiration (ETo)

Net irrigation requirements

For the net irrigation requirement to be calculated for each crop, the effective rainfall was subtracted from the crop water requirement (ETc) using the following equation:

Net Irrigation Requirement (NIR) = Crop water requirements (ETc) – Effective rainfall.

Water deficit

For each crop, the gap between net irrigation requirement and irrigation applied was calculated for each month over the study period using the following calculation:

Water deficit = Net Irrigation – Irrigation applied

These calculations were conducted monthly for the duration of the project (July 2020 to June 2024).

RESULTS

SEASONAL REVIEW FOR PROJECT PARTICIPANTS

The project team wrote research code to collate and visualise farm data and publicly available data to convert complex datasets (e.g. Figure 17) into useful graphs for reviewing farm performance and support decision making (e.g. Figures 18-24). At each research site irrigation data (mm), rainfall (ML), evapotranspiration (mm) and soil moisture (%) was collected at each site for each year (FY 2021 to 2024). An example of a season's (financial year) worth of data is in Figure 17 below. While there is interest in the daily details as presented below, the WildEye portal and SWAN System portal are designed for irrigation planning.

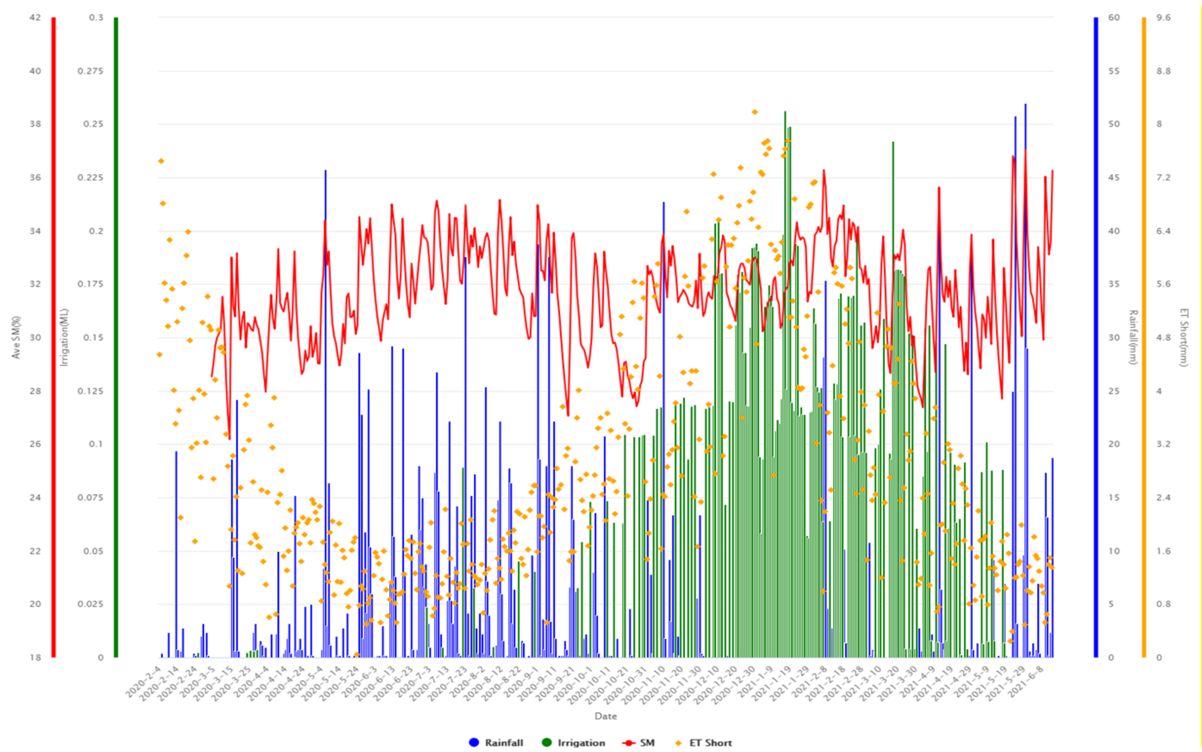


Figure 17 Example visualisation of processed data collected each year (FY2020 – 2023) from farm study sites, i.e. irrigation applied in ML/ha (green) and soil moisture % (red), and publicly available rainfall observations (mm)and calculated evapotranspiration short in mm (yellow) from the nearest DPIRD weather station (blue).

A monthly summary of rainfall, irrigation and evapotranspiration was plotted against the water demand for each site and each year. Rainfall and evapotranspiration data were collected from the nearest DPIRD weather station. Water demand was calculated using the crop coefficient as published by DPIRD. The monthly summary was a key part of the seasonal review and was useful for discussions about the crop production and water use for the season. An example of the monthly summary data is in Figure 18.

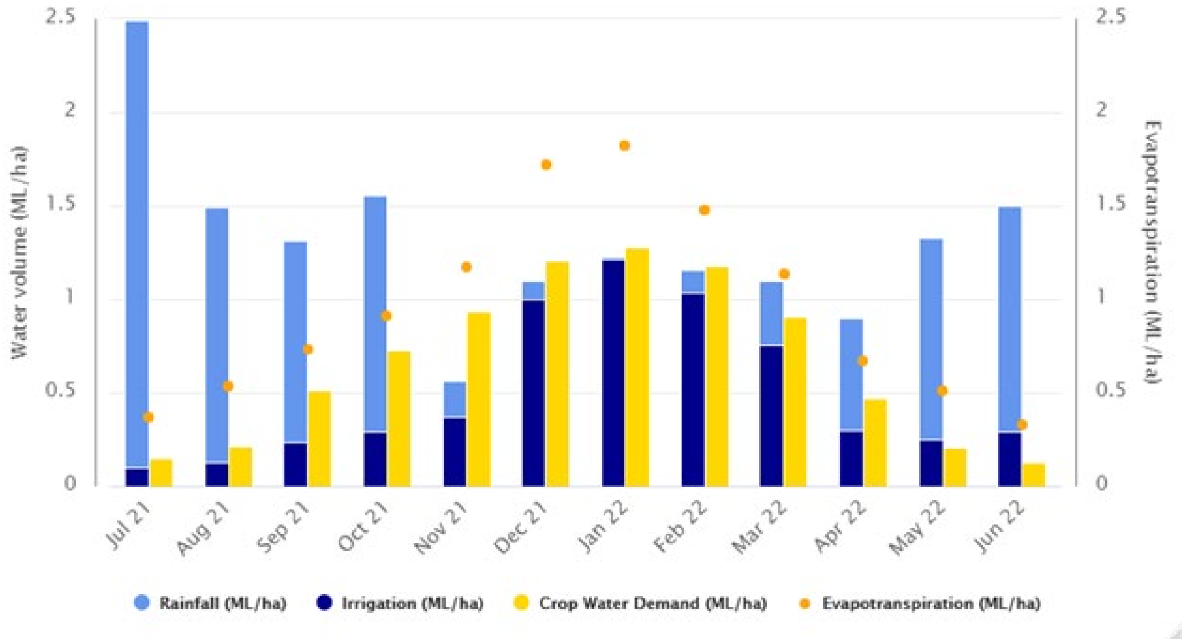


Figure 18 An example visualisation of processed farm processed data collected each year (FY2020 – 2023) crop water demand (yellow) compared with evapotranspiration (orange spots) and total water applied i.e. stacked rainfall (light blue) and irrigation (dark blue). Each data set has been converted to megalitres per hectare (ML/ha).

Comparison of monthly applied irrigation (ML/ha) during financial year 21/22 for the avocado cohort (Figure 19), were provided to each farm business within the cohort (i.e. by crop), on an annual basis. Data was collected and presented in the same format, for each of the crops and of the four growing seasons.

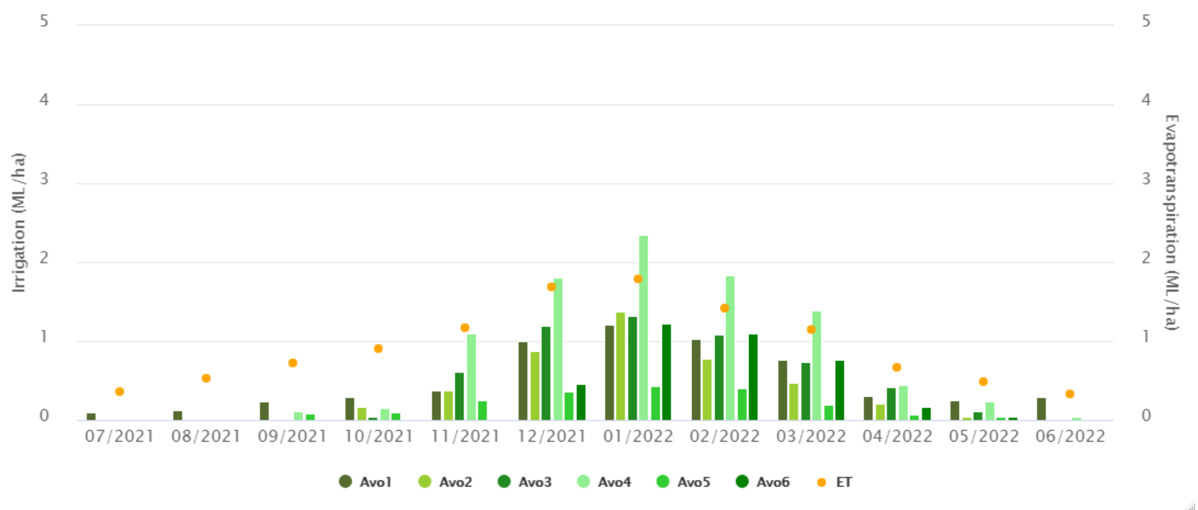


Figure 19 Comparison of monthly irrigation (ML/ha) applied at each of the avocado sites in the Warren-Donnelly catchment (2021-22)

Comparison of monthly applied irrigation (ML/ha) during financial year 21/22 for the apple cohort (Figure 20), were provided to each farm business within the cohort (i.e. by crop), on an annual basis.

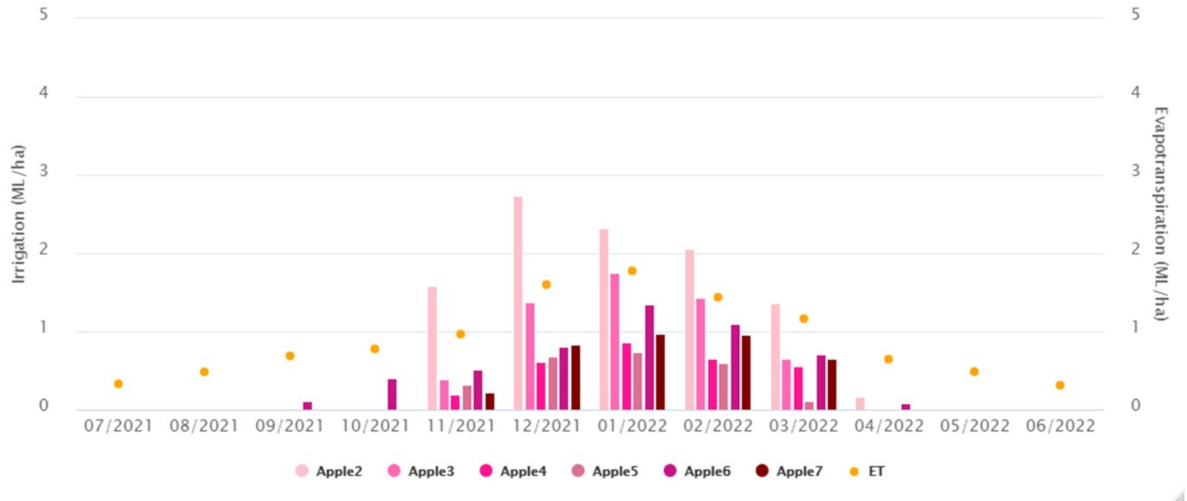


Figure 20 Comparison of monthly irrigation (ML/ha) applied at each of the apple sites in the Warren-Donnelly catchment (2020-21)

Comparison of monthly applied irrigation (ML/ha) during financial year 21/22 for the truffle cohort (Figure 21), were provided to each farm business within the cohort (i.e. by crop), on an annual basis.

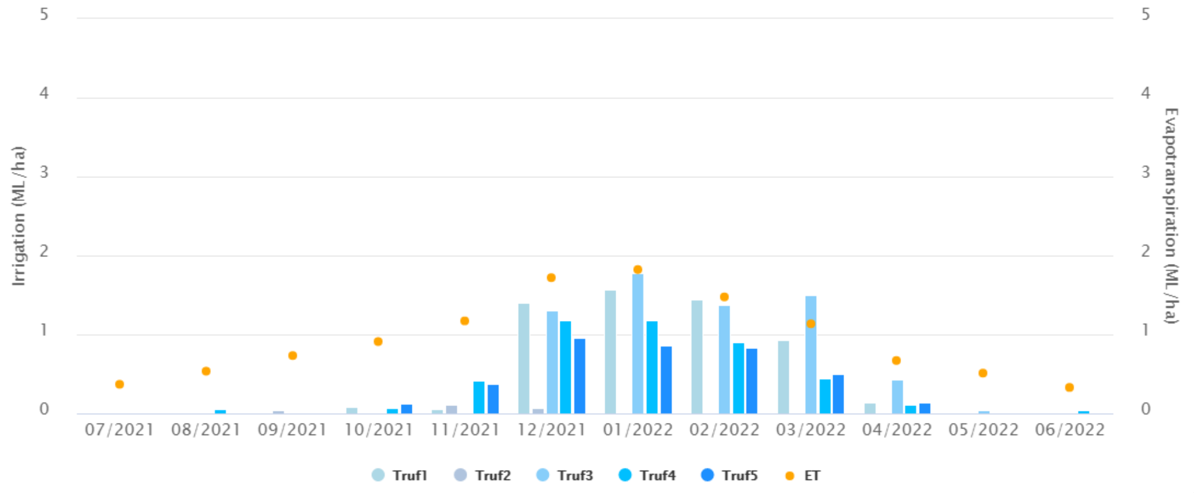


Figure 21 Comparison of monthly irrigation (ML/ha) applied at each of the truffle sites in the Warren-Donnelly catchment (2021-22)

Comparison of monthly applied irrigation (ML/ha) during financial year 21/22 for the wine grapes cohort (Figure 22), were provided to each farm business within the cohort (i.e. by crop), on an annual basis.

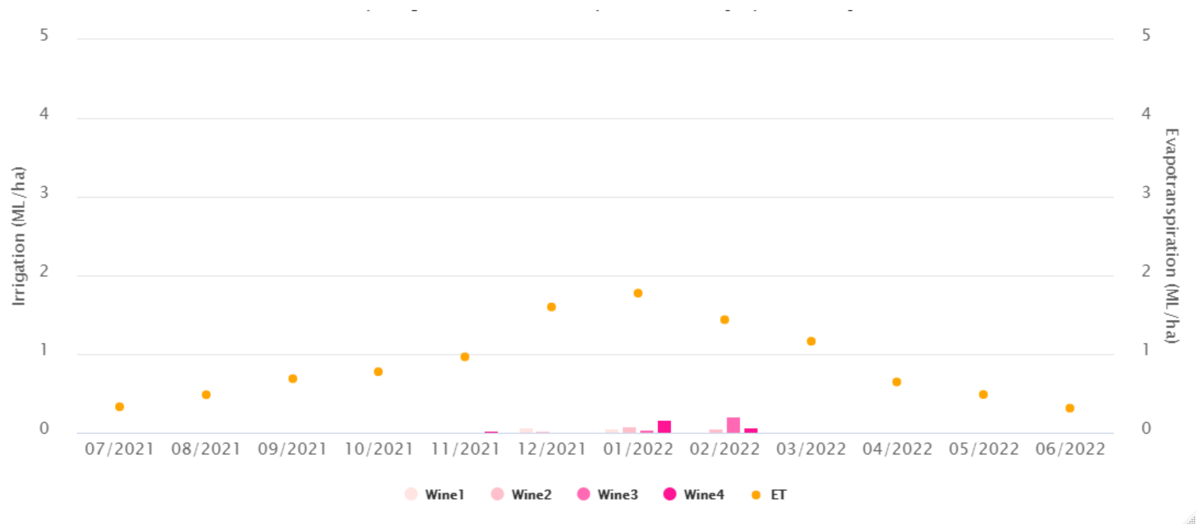


Figure 22 Comparison of monthly irrigation (ML/ha) applied at each of the wine grape sites in the Warren-Donnelly catchment (2021-22)

Comparison of monthly applied irrigation (ML/ha) during financial year 21/22 for the potato cohort (Figure 23), were provided to each farm business within the cohort (i.e. by crop), on an annual basis.

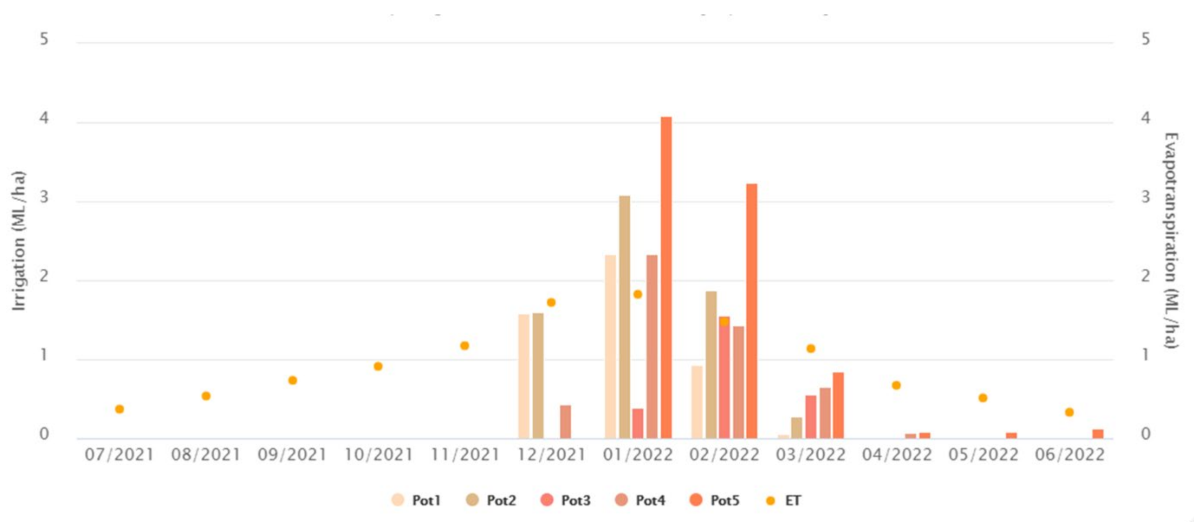


Figure 23 Comparison of monthly irrigation (ML/ha) applied at each of the potato sites in the Warren-Donnelly catchment (2021-22)

For each farm, water productivity i.e. tonnes of produce per megalitre of water applied was calculated each season for the duration of the project. Water profitability i.e. $ operating profit per megalitre of water was calculated for the 2020-21 and 2021-22 financial years. Data was aggregated to include all farms in a commodity cohort (Figure 24).

Figure 24 Example of water productivity (t/ML) and water profitability ($/ML) for the avocado cohort in the 2020/21 financial year

SEASONAL CONDITIONS DRIVING WATER DEMAND

The following sections summarises the processed, publicly available data that has been processed for the Warren-Donnelly catchment. While all seven DPIRD weather sites were collected, the following sections show data from the Manjimup site. Generally, the region has a Mediterranean-type climate, with cool, wet winters and warm to hot, dry summers. The catchment falls in the very high rainfall zone according to DPIRD rainfall zones[10], with an annual rainfall relatively higher that much of Western Australia. Rainfall is highly seasonal in this catchment, with most occurring between April and September.

Over recent decades there has been a significant decline in winter rainfall and streamflow, combined with increasing temperatures and more frequent extreme heat events[11]. While the region typically receives most of its rainfall during the winter months, this water is not always available when crops need it most, particularly during spring and summer.

Recent seasons highlight how variable these conditions can be. Lower rainfall and higher temperatures, particularly in 2023–24, resulted in reduced effective rainfall and increased crop water demand. Extended periods of hot weather further increased evaporation and crop water use, placing additional pressure on irrigation systems. In these conditions, crops rely more heavily on stored and applied irrigation water, with less contribution from rainfall. The combination of a hot summer with multiple extreme temperatures in Feb 2024 following significantly less rainfall (732 mm in 2023-24 compared with 991 – 1075 mm for the three years prior) put significant pressure on dam levels and farm businesses across the catchment.

[10] DPIRD crop variety testing zones of WA (DPIRD-028) https://catalogue.data.wa.gov.au/en/dataset/crop-variety-testing-zones-of-wa-dpird-028
[11] CSIRO state of the climate report 2024 https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate

Daily maximum temperatures (Spring and Summer)

The impact of temperature on crop water requirements is well understood. Over the study period, extreme heat events were recorded (Figure 25) and two of the four years had several consecutive days of extreme heat events (Figure 26), particularly in January and February.

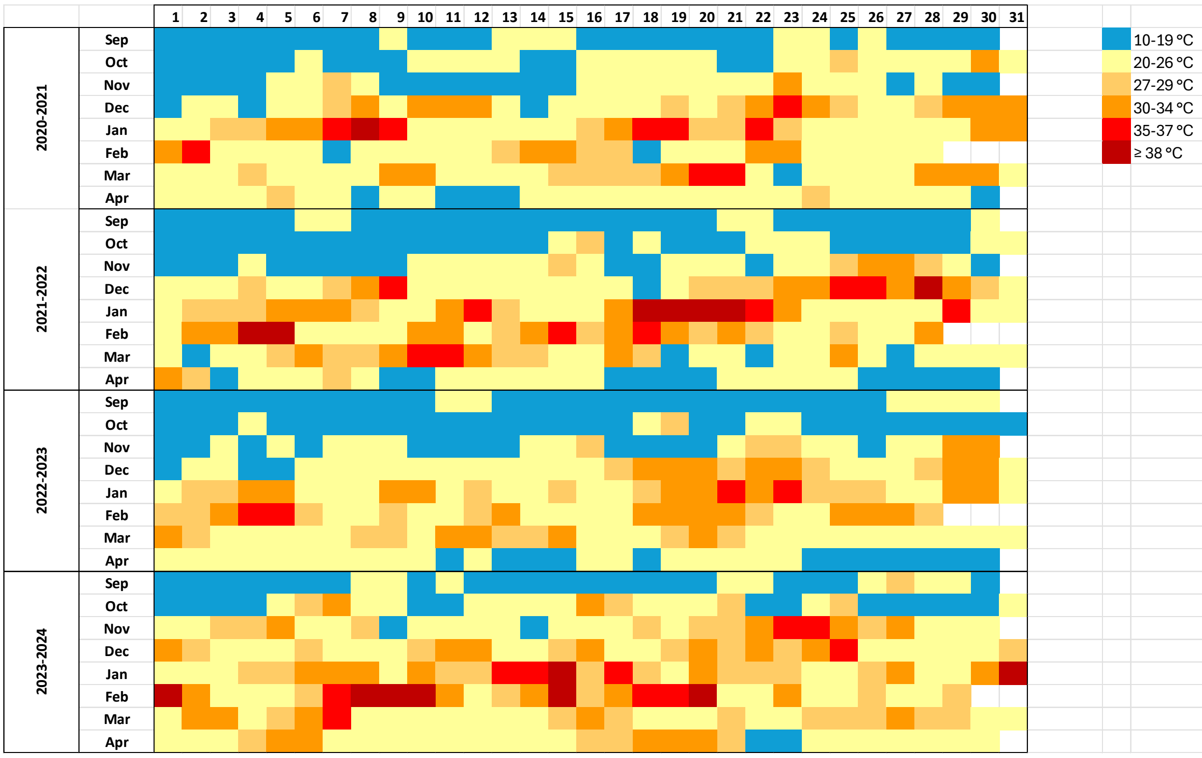


Figure 25 Daily maximum temperature heatmap (°C) across the study period (September to April), classified into six temperature ranges. The figure highlights clustered extreme heat events (>35 °C and ≥38 °C) during the summer in dark red.

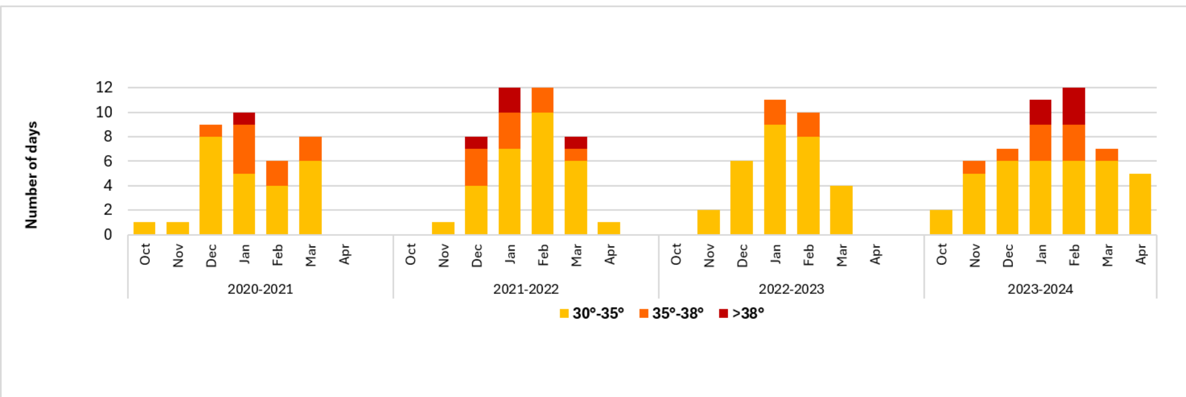


Figure 26 Number of days exceeding 35 °C for DPIRD weather station – Manjimup, based on daily maximum temperature (°C) across the study period (September to April). The figure highlights clustered extreme heat events (>35 °C and ≥38 °C) during the summer months (January and February) in dark red.

Evapotranspiration

Evapotranspiration (ETo), which represents the amount of water lost from soil and plants due to environmental conditions, is a key index of crop water demand across the Warren–Donnelly catchment. As temperatures increase and periods of high ETo become more frequent, farm businesses can expect higher and more prolonged irrigation requirements. The results show strong seasonal patterns, with lower ETo during the cooler, wetter winter months and significantly higher values during spring and summer. Increases in ETo during spring (November) and early autumn (April) indicate an extension of the period of high water demand beyond the traditional summer peak. Peak levels occurred in December and January, extended into February in the 2023–24 season which followed a period of below average rainfall (Figure 27).

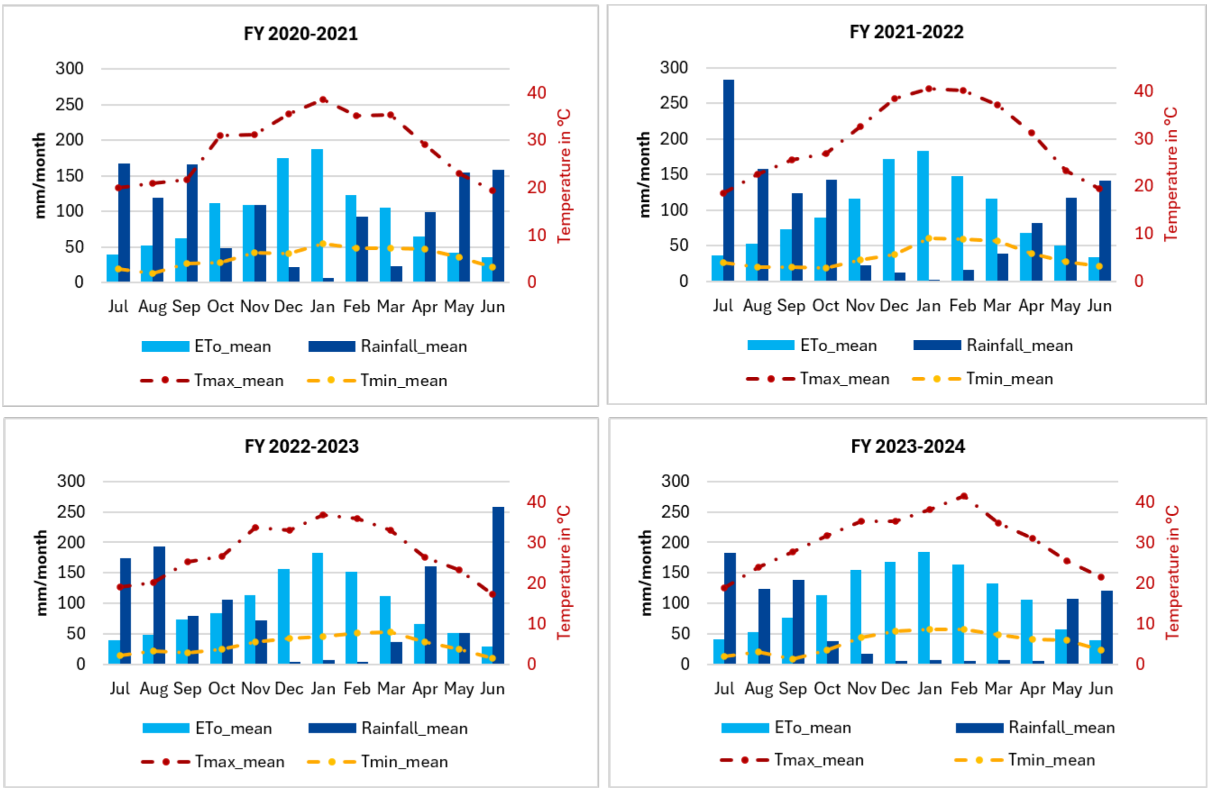


Figure 27 Monthly evapotranspiration (reference ETo) plotted against monthly rainfall, maximum and minimum temperature observations from the DPIRD Manjimup weather station.

Effective Rainfall

Effective rainfall, which represents the portion of rainfall available for crop use, also followed a strong seasonal pattern. Daily effective rainfall were calculated from observations from the DPIRD Manjimup weather station. Higher values were observed in the winter months (June to August), typically ranging from around 90 mm to over 230 mm per month (Figure 28), and provided a significant contribution to crop water needs. This declined through spring, with values generally falling to between approximately 20 mm and 100 mm per month, depending on seasonal conditions. In contrast, effective rainfall during the peak growing season (December to February) was negligible across all years, frequently close to zero despite occasional rainfall events.

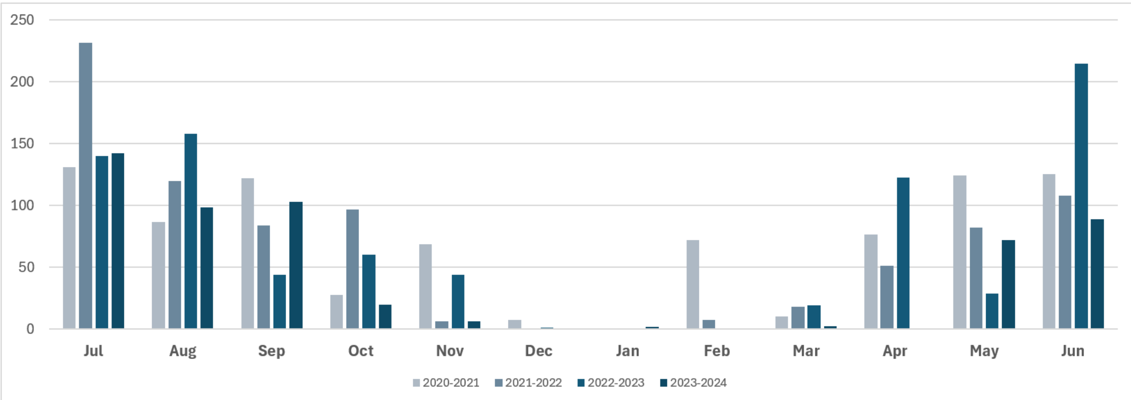


Figure 28 Monthly effective rainfall (mm) by season from DPIRD weather station, Manjimup for the 2020-21 to 2023-24 seasons

HOW MUCH WATER DO CROPS REQUIRE?

Understanding how much water crops need is critical for planning irrigation, managing risk, and making informed business decisions. Unlike many other Australian catchments that support horticultural production, the Warren-Donnelly catchment is supplemented by rainfall in winter, this contribution is limited during the growing season when demand is highest.

Across all crops assessed, water demand increases from spring (October), peaks during summer (December to February), and then declines toward autumn (Figure 29). These peak summer months represent the highest risk period for water stress, when irrigation systems must work hardest to meet crop requirements. In contrast, water demand during winter is relatively low, and rainfall typically meets or exceeds crop needs during this period.

Differences in crop water demand between seasons is also evident in Figures 29 and 30. In particularly the effect of the extreme heat weather events in January and February 2024, followed by no effective rainfall until May is evident in higher than average crop water demand between January and May 2024.

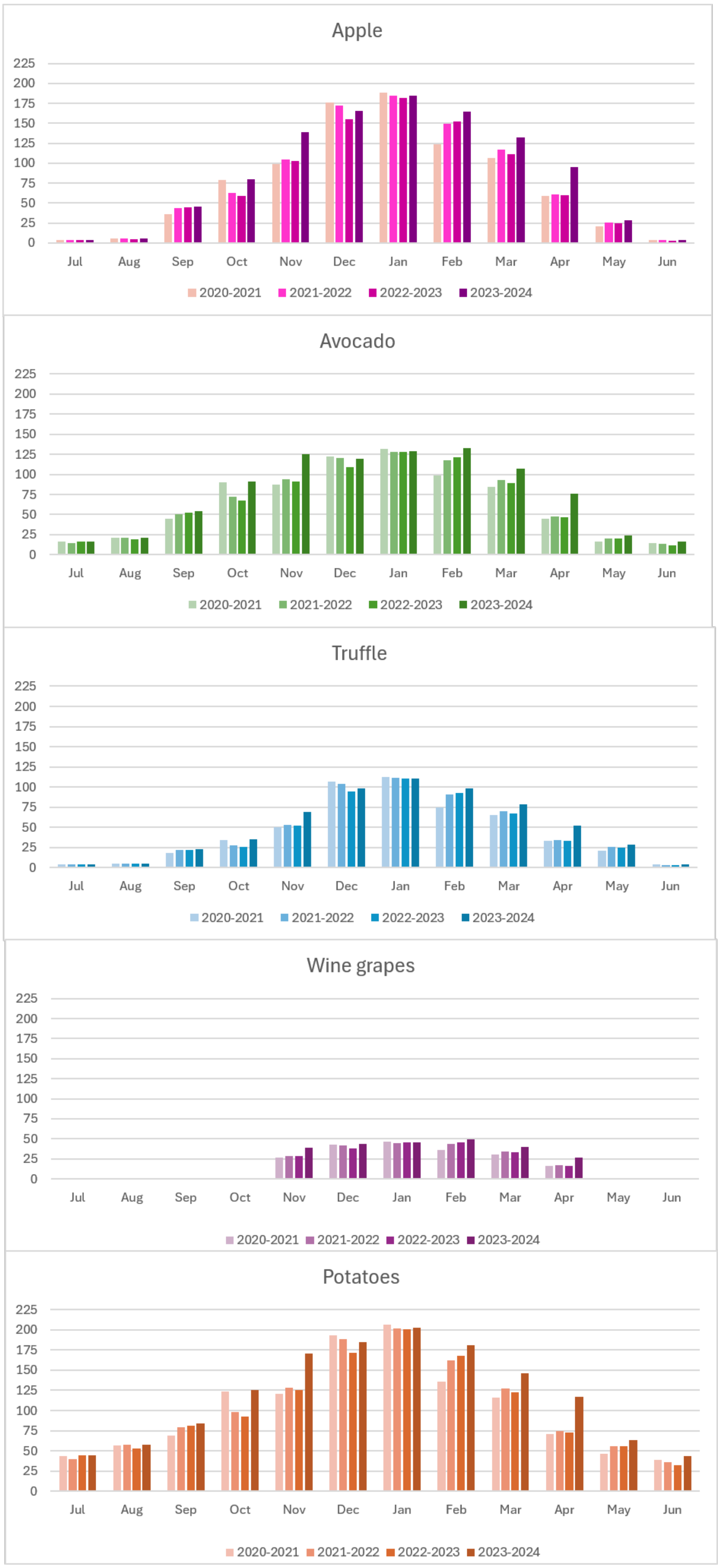


Figure 29 Average crop water demand (mm/day) for apples, avocados, truffles, wine grapes and potatoes when grown in the Warren-Donnelly catchment over the study period. Crop water demand (ETc) was calculated by multiplying a monthly crop factor to the reference evapotranspiration (ETo). *NB. Potatoes usually grow for 12 weeks before harvesting so time of planting affects the crop water demand.*

There are clear differences in water requirements between crops in monthly and annual crop water demand. Potatoes, grown over summer, had the highest water demand with an average annual crop water demand (1,277 mm). Of the tree crops, apples consistently had the highest water demand (946 mm), followed by avocados (811 mm) and truffles (555 mm), while wine grapes (215 mm) require significantly less water under current management systems. These differences reflect crop type, growth patterns and production systems, and have important implications for both farm-level decision-making and broader water planning.

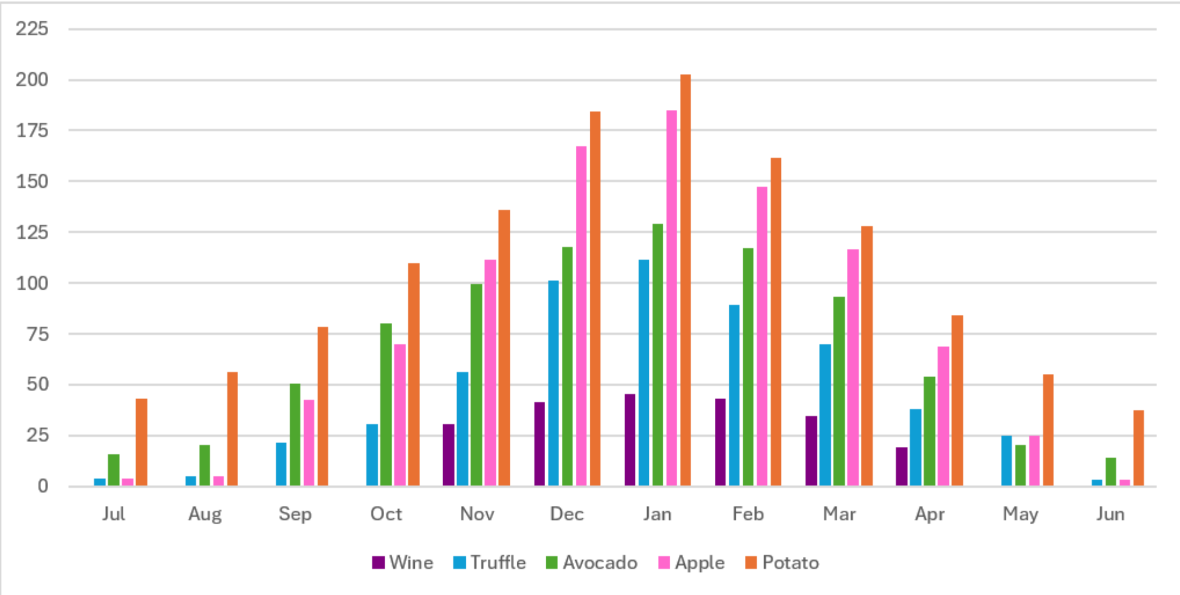


Figure 30 Average crop water demand by month for the study period (2020-21 to 2023-24) for apples, avocados, truffles and wine grapes when grown in the Warren-Donnelly catchment

HOW MUCH WATER WAS APPLIED ON FARM?

Irrigation volumes were annualised for each of the sites for each of the growing seasons (i.e. 2020-21, 2021-22, 2022-23 and 2023-24). Average irrigation volumes (megalitres per hectare) for each of the crops is represented in Figure 31. As anticipated, the wine grapes had the least amount of irrigation, and mostly consistent between years with an average of 0.28 megalitres per hectare.

Truffle production was assessed as part of the project, as Manjimup is where the industry began and the value of farm gate value for truffles is orders of magnitude higher than any other commodity produced in the catchment. Average irrigation for truffle production in the region was 4.07 megalitres per hectare. At the beginning of the project, irrigation was lower in the truffle sites than avocados and apples however it increased to a similar value in the last year of the project.

Avocados and apple production accounts for more than 90% of the tonnes produced in the catchment. A similar amount of irrigation was applied to avocados and apples, except for the 2022-23 season where apples received more than 1 megalitre per hectare more. An average of 5.14 megalitres per hectare was applied to avocados and 5.30 megalitres for apples over the study period.

Irrigation for potato production was included in the project as the catchment is a primary production area in WA and they are a key part of the farming system in the region. Potatoes are generally grown over summer for chips and seed production. They are irrigated for less than three months, generally over the hottest period of the year. Average irrigation for summer potatoes was 6.88 megalitres per hectare (2020-21 to 2022-23 only) and was particularly high in 2022-23 due to a high number of days over 35 in January and February 2023.

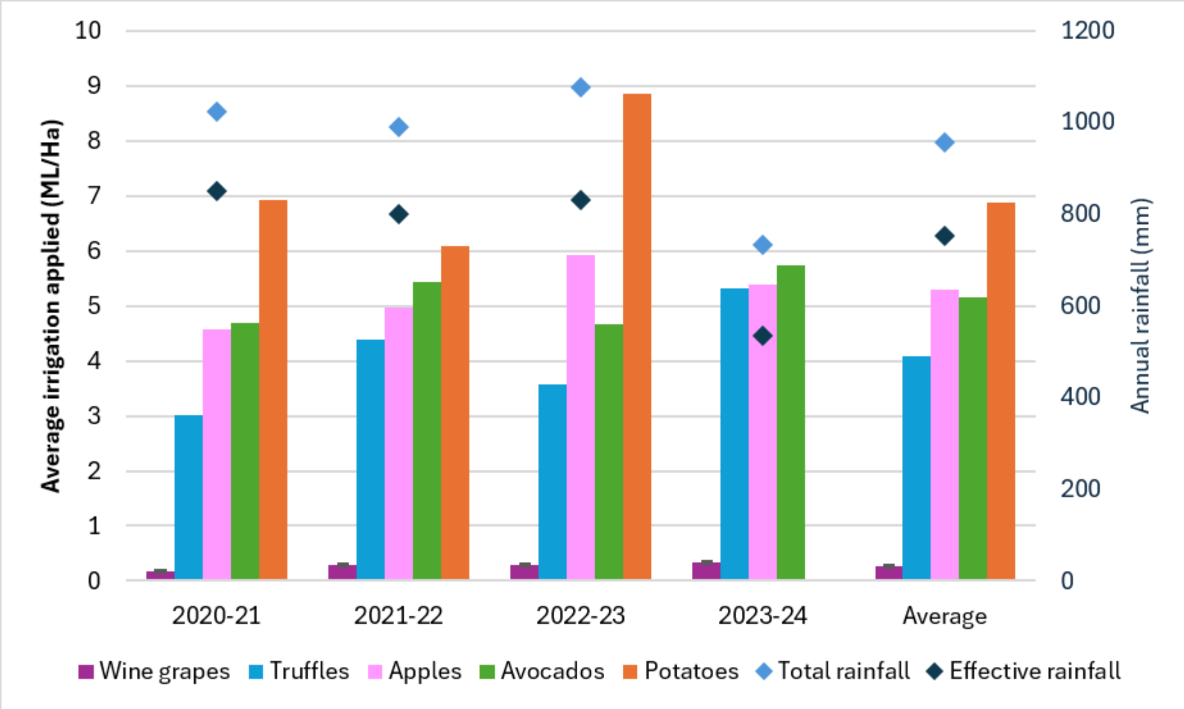


Figure 31 Average irrigation (ML/ha) to grow an annual crop of avocados, apples, potatoes, truffles and wine grapes and total annual rainfall (DPIRD weather stations), by financial year, across 27 sites in the Warren-Donnelly catchment, south-west Western Australia.

ARE CROPS GETTING ENOUGH WATER

To determine whether crops are getting enough water, the net irrigation requirements were calculated by assessing the gap between water applied (i.e. irrigation and effective rainfall) and crop water demand. Comparing crop water demand with irrigation (plus rainfall) applied shows that, in many cases, crops are not receiving sufficient water to meet their requirements during peak demand periods. While total annual irrigation often appears adequate, a closer examination at a monthly scale highlights consistent shortfalls during the spring and summer months when water demand is highest (Figure 32). These gaps are particularly evident during December to February, when evapotranspiration and crop water requirements peak but effective rainfall is minimal.

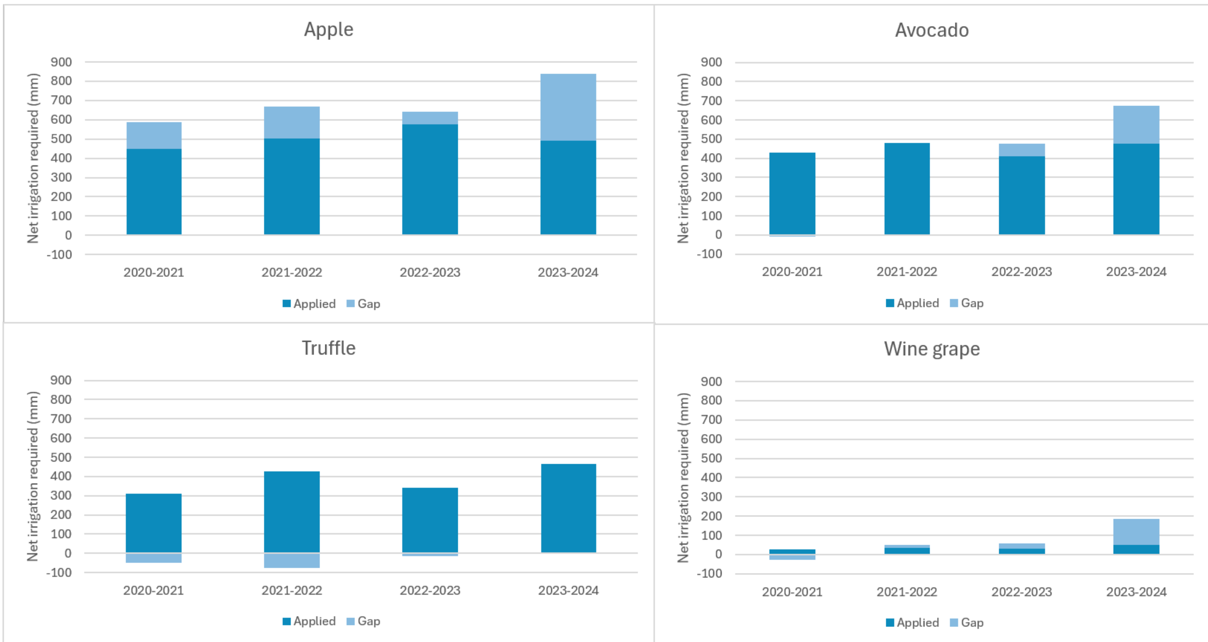


Figure 32 Annual (Oct-Mar) net irrigation requirements (i.e. Crop water requirements (ETc) – Effective rainfall) plotted against irrigation applied to apples, avocados, truffles and wine grapes for the study period (i.e. 2020-21 to 2023-24)

The size and timing of these irrigation gaps vary between crops (Figure 33). Apples had the largest and most consistent deficits, with irrigation frequently falling short of demand during peak summer months. Avocados also experience shortfalls, although these are generally smaller and more variable between sites. Truffle systems tend to be closer to meeting water requirements, reflecting more stable irrigation practices, while wine grapes often operate with lower water inputs under managed deficit irrigation strategies. Across all crops, the greatest risk of under-irrigation occurs during consecutive periods of hot weather, where demand increases rapidly and irrigation systems are unable to fully respond.

Figure 33 Monthly (Oct-Mar) net irrigation requirements (i.e. Crop water requirements (ETc) – Effective rainfall) plotted against irrigation applied to apples, avocados, truffles and wine grapes for the study period (i.e. 2020-21 to 2023-24)

These results highlight that irrigation performance is not only about total volume applied, but also the timing of water delivery relative to crop demand. Even where annual irrigation matches or exceeds crop water requirements, short periods of deficit during critical growth stages can impact yield, quality and profitability. Likewise, farms may deliberately use short periods of water deficit or a long-term deficit strategy to manage crop characteristics – for example for the management of excess canopy vigour. However, strategies that include deficits either deliberately or through limitations in design create additional risk. This is particularly relevant for perennial crops such as apples and avocados, where water stress during flowering and fruit development can have significant consequences.

Overall, the findings indicate that irrigation gaps (deficit irrigation) are a common feature across the catchment, particularly during peak summer conditions. This reinforces the importance of aligning irrigation scheduling more closely with crop water demand at a seasonal and monthly scale, rather than relying on total annual water use. Improving the timing and responsiveness of irrigation—supported by monitoring tools and seasonal data—represents a key opportunity to increase water use efficiency and reduce production risk under increasingly variable climate conditions.

WHAT HAPPENS IN DRY YEARS (e.g. 2023-24)

Seasonal conditions observed during the 2023–24 growing season provide a clear example of how dry and hot years influence crop water demand and irrigation requirements across the Warren–Donnelly catchment. Reduced rainfall throughout the year, particularly during winter and spring, resulted in lower total rainfall (732 mm compared with 991–1075 mm in previous years) and limited recharge of on-farm water storages. At the same time, an increased number of hot days during summer (Figure 26) and elevated evapotranspiration (Figure 27) significantly increased atmospheric demand for water.

These conditions had a direct impact on crop water requirements. Crop demand remained elevated for longer than in previous seasons, with values in the 2023–24 season extending beyond the typical summer peak. In particular, water demand remained high from February through to May (Figure 29), reflecting the combined effects of sustained heat and increased evapotranspiration. During this period, effective rainfall was minimal (Figure 28), providing little contribution to crop water needs despite occasional rainfall events. As a result, crops experienced a prolonged period of high demand with limited natural water supply, increasing reliance on irrigation.

The combination of reduced rainfall, high temperatures and extended periods of elevated evapotranspiration effectively lengthened the irrigation season and increased the total volume of water required to maintain crop growth. It also amplified irrigation gaps during critical periods, as irrigation systems were required to meet higher demand over a longer duration. These results demonstrate that system stress increases rapidly under dry conditions, highlighting the importance of planning for variability between seasons and ensuring that irrigation systems and water storage capacity can respond to extended periods of high water demand.

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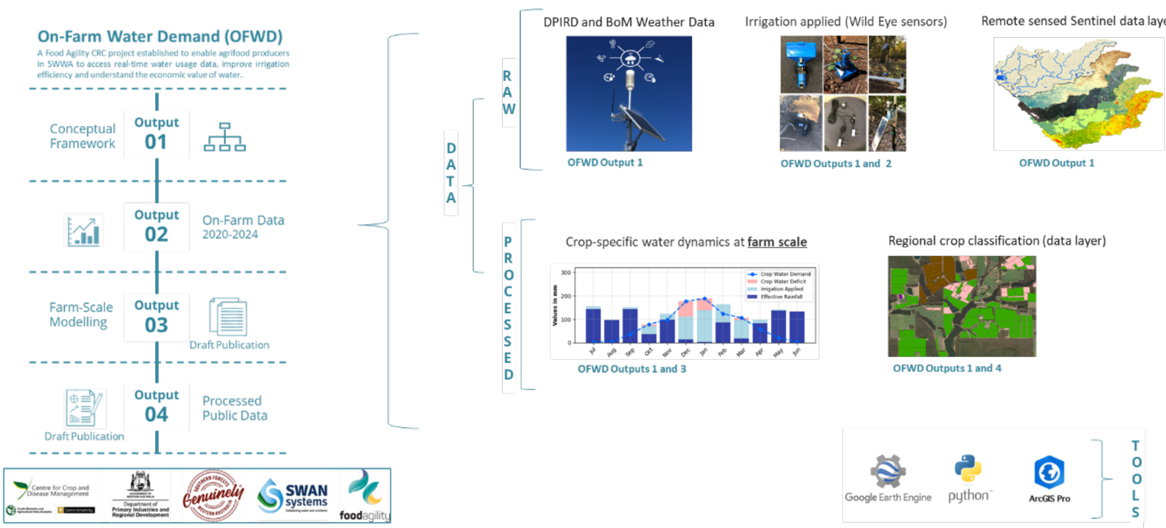
HIGHER DEGREE BY RESEARCH STUDENTS

Understanding Water Resource Dynamics for Food Production in Southwest Western Australia Under Future Drying Climate Scenarios

PhD Research Summary developed by Leidy Luna Cabeza, Julia Easton and Mark Gibberd:

This PhD project aimed to build directly on the Food Agility CRC On Farm Water Demand (OFWD) project by extending its industry owned datasets and modelling framework to assess future irrigation water requirements and water availability under a drying climate in southwest Western Australia (SWWA). It draws on the core industry-derived data set developed as part of the OFWD project as well as the processed data, crop classification model and digital tools developed in Google Earth Engine, ArcGIS and python.



Background and Rationale

SWWA has experienced a sustained decline in rainfall since the 1960s combined with rising temperatures, resulting in reduced streamflow and increasing pressure on irrigation water resources. These trends pose a growing risk to high-value irrigated horticulture, particularly in the Warren–Donnelly catchment, one of Western Australia's most important food-producing regions. While the OFWD project delivered robust, independent evidence of on-farm water use and crop water demand under current climatic conditions, there remains limited understanding of how future climate change will affect irrigation requirements, water availability and drought resilience at farm and catchment scales.

Warren-Donnelly catchment

Approximate area 6,090 km²

- More than 80% is forested,
- Less than 20%: dryland, and
- Less than 5%: Irrigated agricultural areas

Research Aim and Approach
The aim of the PhD was to evaluate how climate variability and projected climate change will impact water availability and irrigation requirements for key horticultural crops in SWWA. The research integrates:

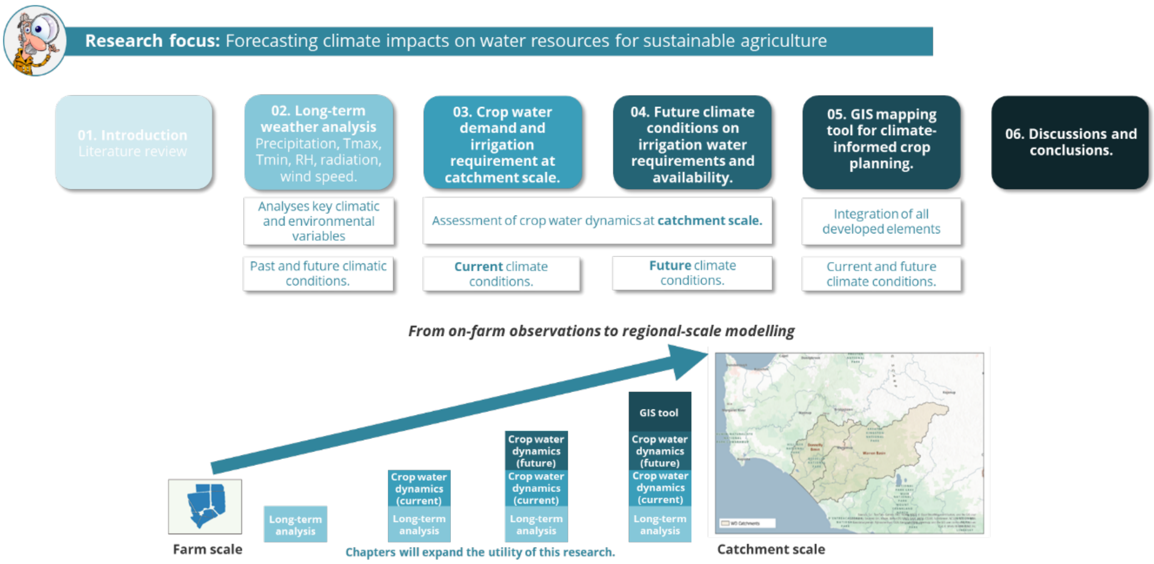
- Long-term historical climate analysis (1980–2024) and future climate projections (2025–2100) using CMIP6 scenarios.
- Crop-specific modelling of water requirements, effective rainfall and net irrigation requirements using established FAO-56 and DPIRD methods.
- Spatial assessment of drought using multiple drought indices to identify areas and periods of heightened water stress.

Crucially, the study reuses and amplifies OFWD outputs, including the regional crop classification, on-farm irrigation datasets, and GIS framework, ensuring continued engagement between the industry and research project.

Key Outputs and Industry Value
The PhD will deliver:

1. Research code to ingest and create a long-term analysis of climate variability and environmental drought across space and time
2. Assessment of crop water requirements and modelled net irrigation requirements at catchment scale under current climatic conditions (Apple, avocado, truffle and wine grapes)

3. Catchment-scale maps of **current** and **future** crop water demand and irrigation deficits (Apple, avocado, truffle and wine grapes plus 6 additional crops), exploring “what-if” scenarios assessing changes in horticultural water demand and crop suitability.
4. Development of a GIS mapping tool for climate-informed crop planning at catchment scale.



Significance

This research substantially extends the impact of OFWD by moving from observational, multi-season farm data to forward-looking, climate-informed planning tools. It provides industry, technology providers and policy makers with defensible evidence to support long-term water allocation decisions, crop planning and regional adaptation strategies, strengthening the resilience of food production systems in SWWA under future drying climates.

CONCLUSIONS AND RECOMMENDATIONS

The On-Farm Water Demand project has delivered a range of measurable and practical outcomes for participating farm businesses, particularly in improving decision-making, benchmarking performance, and increasing confidence in water use under increasingly variable seasonal conditions. These outcomes extend beyond data collection, supporting changes in irrigation practice, strengthening business resilience, and enabling more informed long-term planning. Further details on the learnings from the project are available in the aligned Case study booklet, available on the CCDM website:
https://www.ccdm.com.au/research/c4ap/

CONCLUSIONS

Improved irrigation decision-making

A key outcome of the project has been improved alignment between irrigation practices and crop water demand. Participating farm businesses gained access to integrated datasets combining irrigation applied, soil moisture, evapotranspiration, and rainfall, enabling more informed, timely decisions at both daily and seasonal scales. Case study evidence demonstrated that this translated directly into practice change. For example, avocado growers identified mismatches in irrigation timing—under-watering during spring and over-watering in late autumn—and adjusted their irrigation strategy accordingly to better match crop demand.

Similarly, truffle growers shifted from infrequent, deep irrigation to shorter, more frequent applications after observing how water moved through the soil profile and was lost beyond the root zone. The seasonal review process was important for supporting truffle producers given that they are classified as an emerging industry (by Agrifutures Australia) and little is known about the irrigation requirements. Participants noted that comparisons of irrigation between project participants and understanding the role of crop water demand provided confidence to adjust irrigation strategies. The changes in irrigation practice reflect a transition from intuitive or experience-based irrigation decisions to data-informed management.

Comparing irrigation practices and performance

The project provided farm businesses with the opportunity to compare their performance against peers within the same crop type, as part of the seasonal review process. This process was consistently identified as one of the most valuable aspects of the project by participants. Producers were able to compare water use and productivity within their crop cohort and identify whether they were over- or under-performing. Where financial data was also collected, the participants were also able to quantify the relationship between water use and financial return.

Greater understanding of variability within farms

The project aimed to capture the breadth of irrigation practices across farm size and business complexity in the catchment rather than generating averages. The data captured highlighted the variability in water use and crop performance exists not only between farms, but also within individual farm businesses. Given that that tree crops were selected at similar ages/maturity stages and there are small differences between soil types, the likely differences between farms will be driven by different water demand (i.e. geographical differences) and irrigation practices. Anecdotally, in the avocado cohort irrigation strategies (quantity and timing) for farms targeting quality (and price) was different to those targeting tonnes or have a large number of hectares to cover.

Ability to learn from seasonal conditions

Another important outcome was the ability for farm businesses to reflect on and learn from seasonal patterns over time. By comparing data across multiple seasons, growers were able to:

- Identify how irrigation practices performed under different climate conditions
- Understand the impact of extreme heat and reduced rainfall
- Adjust future management decisions based on past outcomes

In particular, the 2023–24 season highlighted the importance of monitoring and adapting irrigation practices under prolonged periods of high temperature and water demand. Growers reported using historical data to identify where irrigation had not kept pace with demand and to inform improvements for subsequent seasons.

The capacity to pause and review the farm performance at the end of the season and prior to the new season starting helped participants to learn from the past seasons and consider how to manage risk, particularly under a drying and more variable climate.

Increased confidence and decision certainty

Project participants reported increased confidence in their decision-making. Access to real-time and historical data reduced reliance on subjective judgement and improved certainty around irrigation timing and volume. This was particularly valuable during challenging seasons, where growers needed to make rapid decisions under uncertain conditions. The ability to validate decisions with data reduced risk and improved operational confidence.

Adoption of digital tools and practices

The project supported the uptake of digital agriculture tools, including IoT-enabled flow meters, soil moisture probes, and decision-support platforms such as SWAN Systems and WildEye. While engagement with real-time monitoring varied between businesses, most participants recognised value in:

- Seasonal reporting
- Data visualisation
- Benchmarked outputs

The project therefore contributed to building digital capability within the industry, supporting longer-term adoption of data-driven farm management practices.

Improved understanding of water as a business input

The intent of the project was to support more informed decisions around crop selection and expansion, irrigation investment and long-term farm planning. Importantly, growers noted that having access to this data enables decisions to be based on business performance rather than intuition or external pressure. A central outcome of the project was shifting the perception of water from a fixed input to a measurable and valuable economic resource. Farm businesses developed a clearer understanding of water use efficiency, water productivity and profitability and the relationship between water, yield, and economic return.

Contribution to industry and community value

Beyond individual farm outcomes, participants recognised the broader value of contributing to a defensible, industry-wide dataset on water use. Growers expressed strong support for using this information to:

- Demonstrate the value of water for food production
- Inform policy and water allocation decisions
- Strengthen the case for agriculture at a regional and state level

This reflects a shared understanding that improved data not only benefits farm businesses and supports the long-term sustainability of the industry and regional communities.

RECOMMENDATIONS

The outcomes observed at the farm level through this project demonstrate the practical value of integrating water use data into decision-making. These findings provide a clear evidence base for improving irrigation management, supporting farm profitability, and informing broader industry and policy responses, reflecting the outcomes observed across participating farm businesses.

1. Use data to inform policy and water allocation decisions

A key objective of the project was to improve understanding of the value of water for agriculture and support balanced decision-making between production and environmental outcomes.

Recommendations*:*

1. Use project data to inform water allocation and licensing decisions.
2. Recognise the role of irrigation in supporting regional economies and food production.
3. Ensure policy decisions consider both water availability and the value of water use in agriculture

Expected outcome: More balanced and transparent policy decisions that support both environmental sustainability and agricultural productivity.

2. Strengthen industry data and collaboration

The development of a defensible, industry-wide dataset was identified as a critical outcome for supporting both farm and regional decision-making. Core data sets of processed farm data and publicly available data and associated research code have been developed.

Recommendations:

4. Continue to build and maintain shared industry datasets on water use and crop performance for the Warren-Donnelly catchment.
5. Application of research framework to other catchments to benchmark the Warren-Donnelly's contribution to water for food production.
6. Facilitate ongoing data collection and knowledge sharing through industry workshops and extension activities

Expected outcome: Stronger evidence base to support industry development, innovation and informed decision-making.

3. Implement benchmarking to drive farm business performance improvement

Benchmarking across farms and commodities was identified as one of the most valuable outcomes of the project, enabling growers to assess their performance relative to peers.

Recommendations:

7. Adopt a seasonal review process in between scheduled irrigation seasons, incorporating benchmarking to compare water use, productivity and profitability. Use benchmarking metrics such as ML/ha, t/ML and $/ML to evaluate irrigation strategies. Incorporate benchmarking into annual business planning.
8. Treat water as a key business input - Incorporate water into whole-of-business decision-making, alongside inputs such as fertiliser and labour.

Expected outcome: Improved farm performance through evidence-based decision-making and identification of opportunities to optimise water use.

4. Increase the use of data, sensors and digital platforms

Alignment of irrigation timing with crop water demand has been highlighted by the project. Across all crops, the project identified that irrigation gaps are primarily driven by misalignment between irrigation timing and periods of peak crop water demand, rather than total annual water use.

Recommendation:

9. Adopt soil moisture monitoring, flow metering and decision-support tools to guide irrigation scheduling, integrating real-time and historical data into routine farm management decisions
10. Consider irrigation efficiency and water losses in planning, using irrigation calculation tools developed by DPIRD for the region.

Expected outcome: Improved alignment between irrigation and demand will reduce periods of water stress, supporting more consistent yield and crop quality. Increased irrigation efficiency, reduced water loss, and more responsive management under changing environmental conditions.

5. Plan for dry years and extended peak demand

Dry and hot seasons, such as 2023–24, were shown to significantly increase water demand and extend the irrigation period, placing additional pressure on water resources.

Recommendation:

11. Plan for extended periods of high water demand, particularly in late summer and early autumn
12. Maintain sufficient on-farm water storage to buffer against low rainfall and high demand years
13. Use historical data to inform irrigation strategies under similar climatic conditions

Expected outcome: Improved resilience to climate variability and reduced risk of water shortages during critical growth periods.

PROJECT TEAM

Centre for Crop and Disease Management (CCDM), Curtin University

- Julia Easton, Project Leader
- Mark Gibberd, Director
- Simon Koric, Research Assistant
- Leidy Luna, Data Scientist
- Arnold Salvacion, Research Fellow
- Stan Mastrantonis, Research Fellow
- Danielle Gale and Roberto Fornarelli, Research Fellows
- Tom Heenan and Chris Watts, Research Assistant

Southern Forests Food Council

- Laura Bolitho
- Jennifer Riseley
- Arthur Wilson
- Kieran Kinsella

Department of Primary Industries and Regional Development WA (DPIRD)

- Rohan Prince, Director Horticulture
- Richard George, Senior Research Scientist
- Eugene Carew
- Ian Guthridge
- Neil Guise

SWAN Systems

- Tim Hyde, CEO
- Ivor Gaylard, Director
- John Bussell, Scientists
- Alejandra Santos Rubiano

WildEye

- Kieran Coupe
- John Kammann
- Ben Taylor

Industry Advisory Committee

- Bevan Eatts
- Steve Gill
- Michael Lowe
- Mark Bending
- Monica Radomiljak
- Jennifer Riseley

Finally, and most importantly, the many farm businesses that we have collaborated with as part of this project.

REFERENCES

1. CSIRO state of the climate report 2024 https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate
2. Warren–Donnelly surface water allocation plan methods report (2012) available at https://www.wa.gov.au/service/natural-resources/water-resources/warren-donnelly-surface-water-allocation-plan
3. Situation analysis of horticulture in Western Australia: area, volume and value of horticultural crop production by local government area within Western Australia available at https://library.dpird.wa.gov.au/hc_researchrpts/2/
4. Southern Forest Irrigation Reference Group report (2023) available at https://www.dpird.wa.gov.au/regional-communities/major-projects/SFISS/
5. Future Climate streamflow estimation in the Donnelly river catchment CSIRO available at https://library.dpird.wa.gov.au/lr_consultrpts/24/
6. Details on Planfarm benchmarking methodology and results are available online here: https://planfarm.com.au/resources/#benchmark
7. Weather data sourced from DPIRD via the weather v2 API available online here: https://weather.agric.wa.gov.au/developer-api
8. DPIRD online tools - irrigation calculator and associated data tables available online: https://www.dpird.wa.gov.au/online-tools/rain-and-irrigation-calculators/irrigation-calculator .
9. HydroSHEDS website: https://www.hydrosheds.org/products/hydrobasins
10. [1] Crop evapotranspiration - Guidelines for computing crop water requirements - FAO Irrigation and drainage paper 56 (FAO56) report is available online here: https://www.fao.org/4/x0490e/x0490e00.htm
11. DPIRD crop variety testing zones of WA (DPIRD-028) https://catalogue.data.wa.gov.au/en/dataset/crop-variety-testing-zones-of-wa-dpird-028
12. CSIRO state of the climate report 2024 https://www.csiro.au/en/research/environmental-impacts/climate-change/state-of-the-climate

On Farm Water Demand

Julia Easton, Simon Koric, Leidy Luna, Stan Mastrantonis and Mark Gibberd.
2025

Project No. FA022 (Curtin RES-61416)

hello@foodagility.com
@FoodAgility
foodagility.com