Considerations of Long Term Enterprise Selection for the Water Scarce Little Karoo area

by

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Declaration

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Date: April 2022

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Abstract

With the current drought and predicted drier future climate conditions for the Little Karoo, it is imperative to find crops that have a high water use efficiency while providing sufficient income. Understanding the future climate and its influences on agriculture production in the Little Karoo area is an important factor to consider when discussing alternative water use efficient crops. According to models, historical and current data on climate change and excessive greenhouse gasses it is predicted that rainfall in the Little Karoo will decrease in the coming decades. This decrease in rainfall is paired with an increase in extreme weather patterns leading to more frequent droughts with higher intensity and longer duration.

The different crop industries and morphologies was analysed to determine their responses to a more arid and hotter growing environment. The crops used in the study is best suited for a Mediterranean climate, dry summers and mild/wet winters, as these types of crops will be best suitable for the Little Karoo. The crops used are apricots, almonds, peaches, olives, plums and wine grapes.

The morphological aspects concluded that apricots and peaches can handle water deficits for a prolonged period the best, only requiring two thirds of full irrigation water and still delivering an almost full crop load. Whereas olives can cope the best with excessive heat.

To determine the best suitable crop in terms of income generation to water use ratio, enterprise budgets were set up to determine the net income generated and paired with the individual water usage of each. Enterprise budget was used to determine the net profit, income minus cost (direct and indirect), of each crop used. The different crops have aspects that either promote or hinder the suitability. These aspects include labour requirement, season length, export or local usage, fresh or processed, density planted and mechanised or not. Income was determined by the Rand per kilogram of fruit. Processed fruits received a great deal less per kilogram than that of fresh and export fruits.

Almonds was the most profitable crop with that of wine grapes the least profitable. However, almonds needed the most water to produce a suitable crop load with olives requiring the least amount of irrigation. Therefore, different aspects needed to be taken into consideration when choosing the ideal crop. However not one single crop could fulfil all the aspects need to produce without any hindrance. Thus, diversification was the solution to mitigate or reduce any shortcomings of crops. Therefore this study was conducted to have a better understanding of the existing and pending problem of droughts and how certain crop combinations can be used to successfully produce in the future.

Opsomming

Met die droogte wat tans heers en voorspelde droër toekomstige klimaat toestande vir die Klein Karoo, is dit noodsaaklik om gewasse te vind met hoë water doeltreffendheid wat ook genoegsaam winsgewend is. Die begrip van die toekomstige klimaatsomstandighede en die gepaardgaande effek op landbouproduksie in die Klein Karoo is 'n belangrike oorweging met die oorweging van alternatiewe gewasse. Bestaande modellevoorspel, op grand van historiese en hedendaagse klimaatsverandering en kweekhuisgas, dat reënval in die Klein Karoo na verwagting sal afneem oor die volgende dekades. Die afname in reënval gaan gepaard met 'n verwagte toename in ekstreme klimaat insidente wat aanleiding kan gee tot meer langdurige en meer intense droogtes.

Die verskillende gewasse en gepaardgaande morfologie was geanaliseer om verwagte reaksie te toets op warmer en droëer omstandighede. Die gewasse wat in die studie ingesluit is, is die beste aangepas my Mediterreense klimaat met droë somers en koel, natter winters, wat beter aangepas is vir die Klein Karoo. Gewasse ingesluit is: appelkose, amandels, perskes, olywe, pruime en wyndruiwe.

Die morfologiese aspek wys dat appelkose en perskes water en vog beperkinge oor langer periodes die beste kan hanteer, teen twee derdes van die normale water voorsiening kan bykans vol-oes steeds afgehaal word. Olywe kan ekstreme hitte die beste hanteer.

Ten einde die beste gewas te identifiseer in terme van inkomste potensiaal teenoor water behoefte is vertakkingsbegrotings opgestel om die winsgewendheid te paar met water behoefte. Vertakkingsbegrotings is gebruik om inkomste, toedeelbare koste en marges te bereken. Die gewasse het unieke eienskappe wat volhoubare produksie bevorder of beperk. Die eienskappe sluit in: arbeidsbehoefte, duur van die groeiseisoen, uitvoer doelwitte, vars teenoor inmaak of droog, plantdigtheid, en meganisasie opsies. Inkomste is bepaal in R/kg vrugte. Geprosesseerde vrugte se realiseerde prys was betekenisvol laer as die van uitvoer produkte.

Amandels wys die hoogste winsgewendheid terwyl olywe en wyndruiwe die mins winsgewende gewasse is. Nietemin is amandels se water behoefte die hoogste en olywe we waterbehoeftes die laagste. Dit wys dat verskeie faktore in ag geneem behoort te word met vestigings besluite. Geen gewas kon identifiseer word wat in alle oorwegings die beste vaar nie. Diversifikasie bleik 'n moontlike sterk oorweging te wees om tekorte van gewasse te verlig. Die studie bied 'n beter begrip van die huidige en verwagte toekomste effek van droogte toestande en hoe gewas kombinasies wel oorweeg kan word in die toekoms.

Table of contents

List of Figures

List of Tables

List of Annexures

List of Abbreviations

WUE: Water use efficiency

MLD: Million litres per day

NOAA: National Oceanic and Atmospheric Administration

CSAG: Climate System Analysis Group

GCM: General circulation model

CCRW: Computing Centre for Water Research

SPEAR: Seamless System for Prediction and Earth System Research

Chapter 1: Introduction

1.1 Orientation and general background

South-Africa is a country which is rich and diverse in fauna and flora. It has a wide range of animal and plant biodiversity, climates, and soil types. The country can be divided into distinct farming districts, ranging from intensive crop production in winter and high summer rainfall areas, to cattle ranching in the Bushveld, and sheep farming in the more arid regions. The different climate and soil combinations leave only 12% of the country suitable for the production of rain-fed crops (Goldblatt, 2010). Only 3% is considered truly fertile land. South Africa is relatively poorly endowed with fertile land in comparison to other countries. India for example has arable land cover of 53% of the country. A steady decline in farming profitability coupled with water scarcity causes changing of the land to other uses. Farm mergers reduced the number of farms in South Africa to less than 60% of the number of farms in the early 1990s (Goldblatt, 2010). Although the number of farms has decreased the productivity remained the same. This was mainly due to fully utilizing limited space, technology improvisation, an increasing of globalisation, and improvements in cultivation practices. Modern farmers produce more intensively and focus more on higher income crops to maximise profits and obtain the highest income per hectare.

The reason for the shift in farming strategies is due to a steady rate of economic development in recent decades. It is accompanied by many secondary responses in human behaviour such as the change in the human diets. One response is the shift from a primary diet of cereal crops to more diverse diets especially in terms of animal products. In many countries, health related concerns have led to a renewed interest and increased consumption of fruits and vegetables (Gerbens-Leenes, et al., 2010). The increase in consumption resulted in strong consumer demand for high-quality horticultural products. It is expected that the increase in demand for fruit will continue and presents an incentive for growers to further develop the horticultural industry of South-Africa, which in nearly all areas will be dependent on irrigation (Fereres et al., 2012). The primary goal of any business, corporate and/or agribusiness is to maximise its profits for its owners or stakeholders. Agribusinesses face a more complex environment than that of other companies in other industries. Factors such as market size, market composition, market proximity, product quality, and ever-changing prices are paired with the added impact of the environment, climate, and live products. Especially in South Africa, one of the most important factors in producing a successful crop is to understand and manage the interaction between the environment and the crop being produced.

The interaction between the environment and the type of crop can be broken down into three broad categories. Although these broad categories entail many other variables and influence upon it, these remain the three most important factors to consider. These three factors contributing to successful production is climate, soil, crop choice, and the interaction between them. Of these, climate and soil are solely or semi dependent on where production takes place. Climate, which is solely dependent on where production takes place and how the local weather patterns affect production with variation in precipitation, temperatures, light quality, and adverse weather events. Producers can mitigate or to a lesser extent control these fixed climate attributes by using nets for hail or mist sprayers for heat waves, but would not be able to manipulate it completely. Soil properties such as depth, soil composition, water retention, and nutrient content play an important role in the ability to produce crops. Unlike climate, producers are able to alter soil conditions, though very costly and time-consuming. Thus, the factor that can most easily be managed is the type of product. Poor performing, low-income crops can be substituted for better performing higher income crops, taking into consideration the other two main factors.

Since South Africa is a water-scarce country and climate change affects local climate, producers may well convert from higher profit crops to maximum water utilisation crops. Water scarcity is not new in South Africa as Southern Africa was the second region in the world to be confronted by a debilitating water deficit (Turton, 2000). Within the Southern African region South Africa is clearly one of the most water-scarce countries. South Africa is also characterised as having variable rainfall, both geographically and historically. According to climate change predictions rainfall will be more infrequent with higher chances of extreme weather events. Producers will have little choice but to find the balance of the crop's ability to utilise water as well as produce an income.

1.2 Scope of the study

The focus area of this study is the Little Karoo in the Western Cape. The Western Cape has a typical mediterranean climate associated with dry summers and mild wet winters. An important consideration for these dry summers is the need to store water for summer irrigation, as it does not rain during summer when water requirements are at its peak. The Western Cape is climatologically diverse, with a large number of distinct micro- and macro-climates created by the topography and influence of surrounding ocean currents. These currents lead to climate statistics that can vary significantly over relatively short distances. The Little Karoo is located within the interior of the Western Cape, consisting of a 290 km long valley with a width of only 40-60 km. The Little Karoo is a semi-arid climate region with low annual rainfall. The northern part of this valley is the least dry with average rain and streams cascading down the mountains or gorges in the Swartberg flowing from the Great Karoo. The main towns located along this northern strip are Montagu, Bonnievale, Robertson and Ashton. Roughly 80-90% of production, orchards and vineyards, in the Little Karoo is situated in this northern strip. The aridity and need to use water optimally is the reason why the study mainly focuses on this area.

1.3 Problem statement and research question

Historically land in the Little Karoo is primarily used for wine grapes and other horticultural fruit crops. Over the past decade farmers have been substituting traditionally grown crops with higher income, yet more water dependant crops to maximise their profits. The main goal for implementing this change is based on the producer's need to maximise profit. Water availability is the single most limiting factor for successful crop production in this area. More pressure is expected on water availability, a continuous problem for producers. However, currently new irrigation techniques and crops are available to be considered. It is important to carefully evaluate these alternatives within a wider scope of factors to be considered.

Inadequate rainfall in the region makes it difficult for any producer to successfully cultivate crops. The recent drought of 2015-2018, has severely strained water availability in the Western-Cape and crippled the area. According to Pascale et al. (2020) the cause of this drought and lack of rain in recent years can be attributed to a number of meteorological impacts due to climate change. With the looming threat of decreasing rainfall and an increase in the occurrence of extreme weather events, such as droughts, producers face a problem when it comes to crop selection, especially when trying to replace traditional crops with more profitable crops. Experienced producers view water management as the most critical factor for financial survival especially now that newer crops and tougher growing conditions are presenting itself. A lack of knowledge on the financial implications of balancing income potential with water requirements for conditions in this area exists. The main research question is thus: What are the managerial and financial implications when selecting crops aimed to balance water requirements and income potential?

1.4 Research Objectives

The main aim of the study is to evaluate the financial implications of different crops when trying to balance both income and water requirements. Therefore, this study was done to determine the suitability of crops for the dryer Little Karoo area. The focus is not only profitability but water usage and general adaptability of various crops is also taken into consideration. As there is a decline in water availability producers should be able to maintain or at least manage sources and have some setback absorption ability in terms of profitability. The following specific goals were established:

- To identify and evaluate the perennial crops commonly farmed in the area,
- To determine water use, quality and production risks associated with each crop,
- To assess the expected profitability of each crop, and
- To evaluate the characteristics and profitability of crops in relation to seasonal farm activities, enabling the development of a framework in which crop and cultivars could be explored.

1.5 Proposed method

Each of the selected crops has suitable characteristics, explained from both a horticultural and practical perspective. Crop characteristics are important as some factors like water use have a direct impact on the suitability of alternative crops. This will be evaluated through a literature study.

Secondly the crop characteristics need to be taken into consideration regarding the specific area, including growing requirements, seasonal activities, resource requirements, and profitability. The systems approach is ideal for such an evaluation and will be applied by gathering information and incorporating it in budget models on farm level. Each crop will then be pitted and compared with one another to establish how crop characteristics, resource requirements, profitability and water usage can be integrated to choose the best suitable crop.

1.6 Thesis layout

Chapter 2 provides background on the area being studied, including climate and current (2021) water status. Climate change and its impact on water availability and agriculture in future will be discussed.

Chapter 3 provides an overview of the possible alternative crops selected. Information on the industries, crop characteristics and climactic requirements are discussed. Literature was used to determine how each crop will respond to dry conditions as well as effective irrigation.

Chapter 4 outlines the research techniques, orientation and design thereof. It contains the data and how enterprise budgets were constructed and figures determined.

Chapter 5 provides the results of the selected budgets and how the crop cultivation practices influence crop choice. Discussion on each crop production factor is done to provide information about crop suitability.

In chapter 6 the conclusion, summary and recommendations are given.

Chapter 2: Local water status and climate change

2.1 Introduction

The main goal of this research project is establishing the factors to consider when selecting the best crop combinations to grow in the Little Karoo area. The aim is not only driven by income but also by water usage efficiency (WUE). To justify a change to more water efficient crops, evidence should be presented to explain and clarify the current as well as future water availability of this region. Agricultural background and history of the area will provide insight into how the past and current situation affects planting decisions within the Little Karoo. For producers climate is the most influential factor to crop selection, therefore; the effect of climate change must be prioritised. According to studies (Midgley et al., 2005; Goldblatt, 2010; Pasquini et al., 2013; Pascale et. al., 2020) global climate change is one of the primary drivers in the recent shift in weather patterns and extreme weather events experienced by the Western Cape province.

In this chapter the Little Karoo area is assessed according to climatology and soil. This is necessary to provide an overview of the current growing conditions where crops are presently grown and will be grown in future. Future climate predictions for the Little Karoo need to be considered as it would influence water availability, crop growth, crop development, yield potential, and ultimately fruit quality. The expected effect of climate change will be examined to provide insight into the expected shift in weather and rainfall patterns in the coming 20-30 years in the Western-Cape, especially in the Little Karoo area. Climate will in principle determine the selection of crops. Crops have varied climactic requirements, phenology, WUE, responses to extreme climate, and responses to different stress alleviation techniques.

2.2 Area overview

The focus area is a region in the south-western part of South Africa located inland within the Western Cape Province called the Karoo. The Karoo is divided by the Swartberg Mountain range into two regions namely the Great Karoo and the Little Karoo. This mountain range runs from east to west, parallel to the south coast of South Africa. It is separated from the ocean by the Outeniqua–Langeberg Mountain range. The Great Karoo is located to the north of the Swartberg and the Little Karoo to the south. This corridor between the two mountain ranges (Swartberg and Outeniqua–Langeberg) which forms the Little Karoo is a 290 km valley with a width of 40-60km (Klein Karoo - The Karoo, South Africa, 2021). The northern part of the valley, within 10-20 km from the foot of the Swartberg Mountain, is the least Karoo-like, in that it receives higher than average rainfall in comparison to the rest of the Karoo. The main towns in this northern area are Montagu and Barrydale. The study will mainly focus on the deciduous crop farming areas in and around Montagu, Robertson, Ashton and Bonnievale.

Figure 2.1: Map of the Western Cape displaying the area of study (in red).

Source: Vinum Vine, 2021

According to Beck et al. (2018) the Köppen climate classification, which is the one of the most widely used climate classification systems, classifies the Little Karoo as having a BSk climate. BSk climates tend to occur in elevated areas of temperate zones, typically bordering a humid continental climate or in this case a mediterranean climate. These areas are typically located in continental interiors some distance from large bodies of water. BSk climates usually feature warm to hot dry summers, although not as hot as those with a hot semi-arid climate (BSh). Unlike BSh climates, areas with a BSk climate tend to have cool-cold winters. These areas occasionally encounter snowfall during winter months which can provide essential water resources within these regions when the snow melts. Areas with BSk climates tend to have major differences in day and night temperature, sometimes as much as 20°C. BSk climates at higher altitudes tend to have dry winters with wetter summers. Lower altitude BSk's, like that of the Little Karoo, tend to have precipitation patterns more known to subtropical climates with dry summers, reasonably wet winters and wet springs and autumns (Beck et al., 2018).

This climactic environment is perfectly suited for a number of mediterranean crops, especially stone fruit. According to Hortgro's (2019) industry overview the Little Karoo is South-Africa's largest producer of apricots, cling peaches, and plums having a production value of R1.18 billion. This is followed by a large scale production of pears, citrus, olives, nuts, and a well-developed wine industry. The stone fruit industry is primarily located within this northern part of the Little Karoo.

2.2.1. Area water availability

The Little Karoo has a low annual rainfall within the valley but is fed by streams from the Swartberg mountain range which has a higher annual rainfall than that of the valley. The Little Karoo is characterised by all-year rainfall with a slight variation throughout the year. The most rain usually falls within the 31 days centred on June 26, but this area is also reliant on good summer rains that provide good rainfall to alleviate dry conditions. According to Climate-Data.org (2021), Joubert (2021) and Notnagel (2021) the average rainfall for this region varies greatly, depending on the nature of the area, as valleys and mountains have higher averages than that of plains. Thus, average rainfall can vary from 180 mm to 405 mm, which is far below the average of other wine grape producing areas such as Stellenbosch with an annual rainfall of 697 mm (Weather Stats Rainfall, 2021).

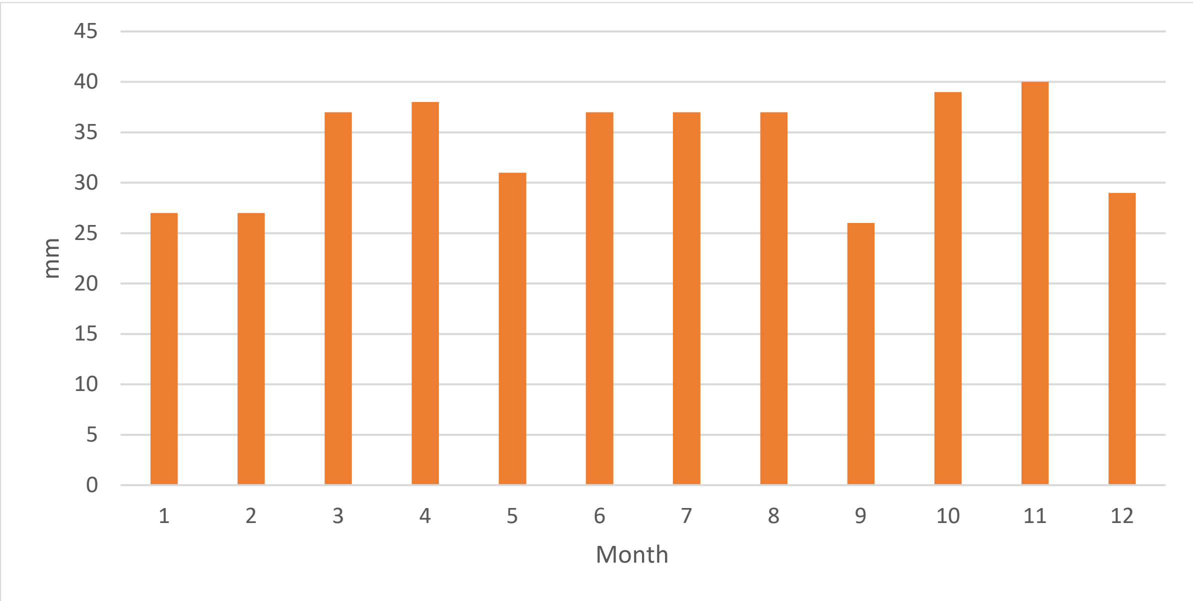


Figure 2.2: Montagu and Robertson monthly average annual precipitation (mm)

Source: Climate-data.org, 2021

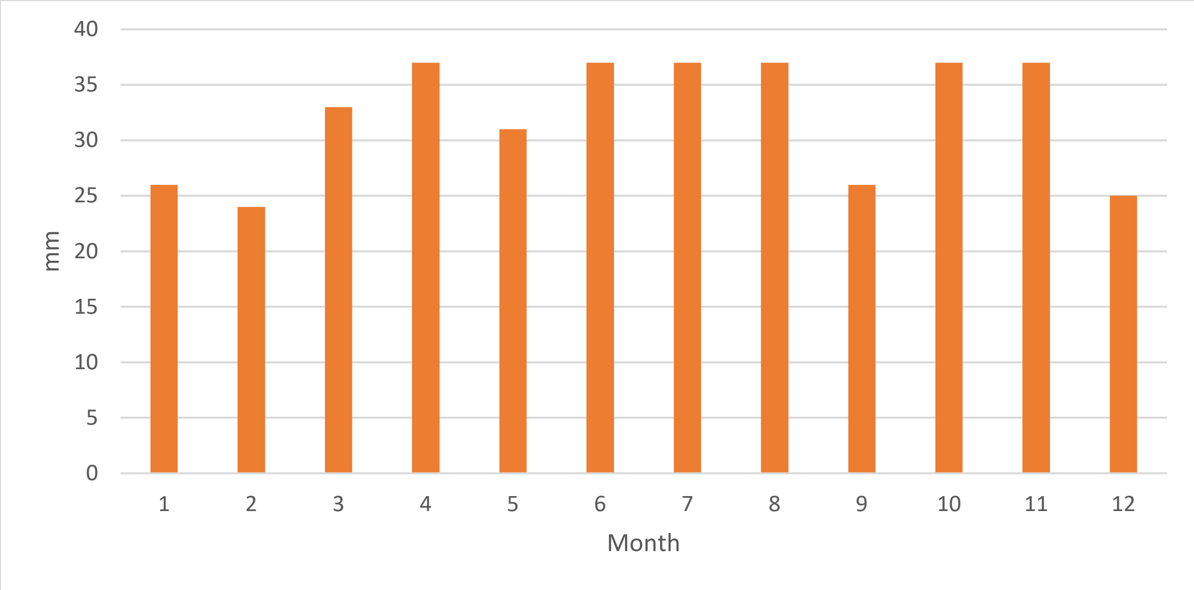


Figure 2.3: Bonnievale monthly average annual precipitation (mm)

Source: Climate-data.org, 2021

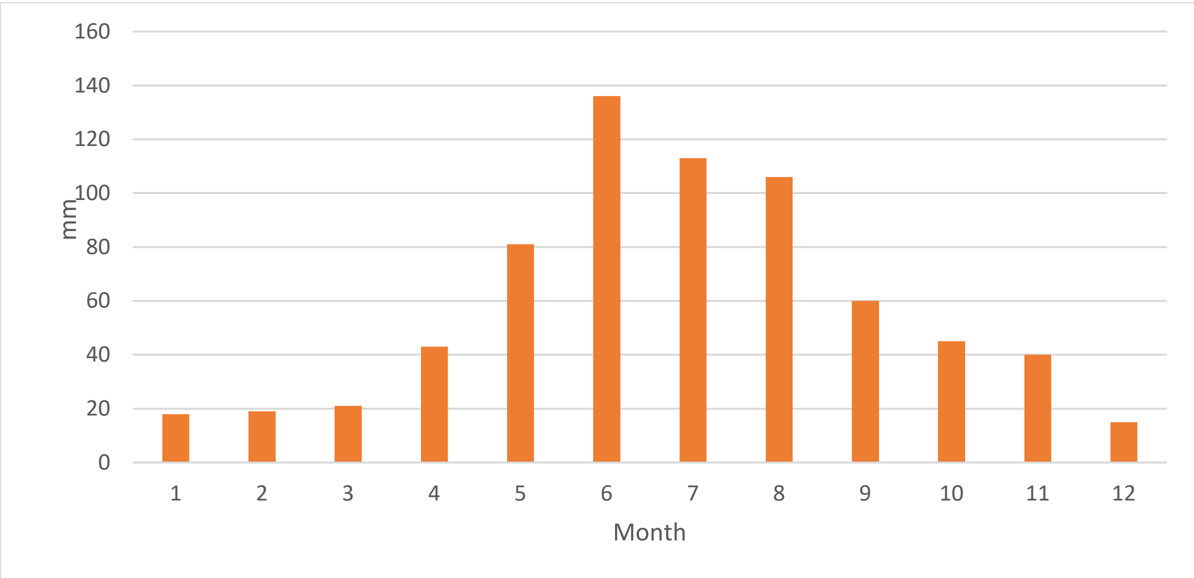


Figure 2.4: Stellenbosch monthly average annual precipitation (mm)

Source: Weather Stats Rainfall - La Colline Observatory, Stellenbosch Weather Station, LCAO, 2021

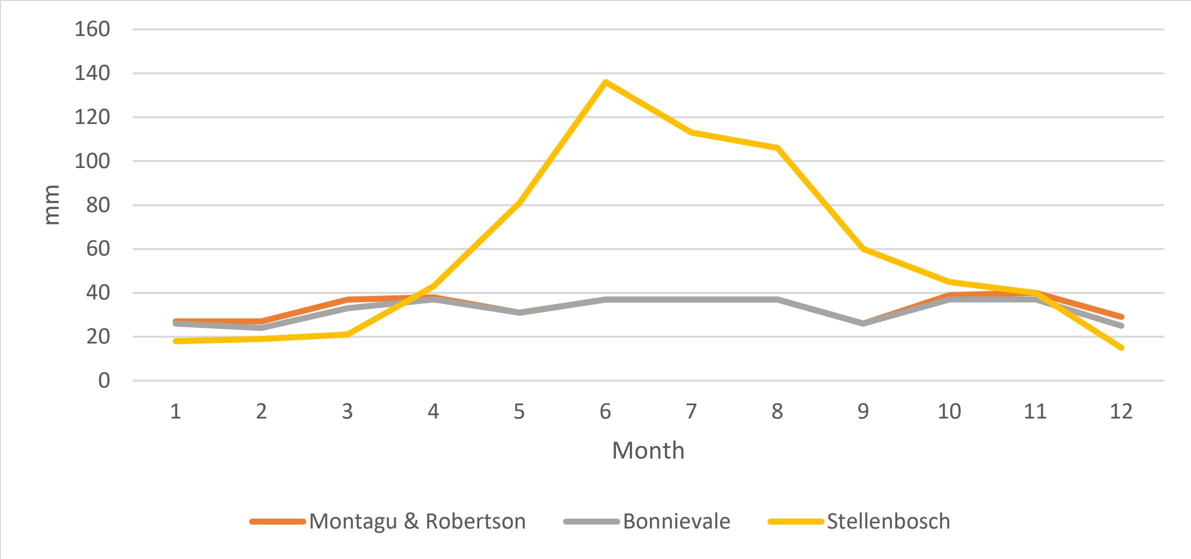


Figure 2.5: Monthly average annual rainfall for Montagu & Robertson, Bonnievale and Stellenbosch (source: Climate-data.org, 2021; Weather Stats Rainfall - La Colline Observatory, Stellenbosch Weather Station, LCAO, 2021)

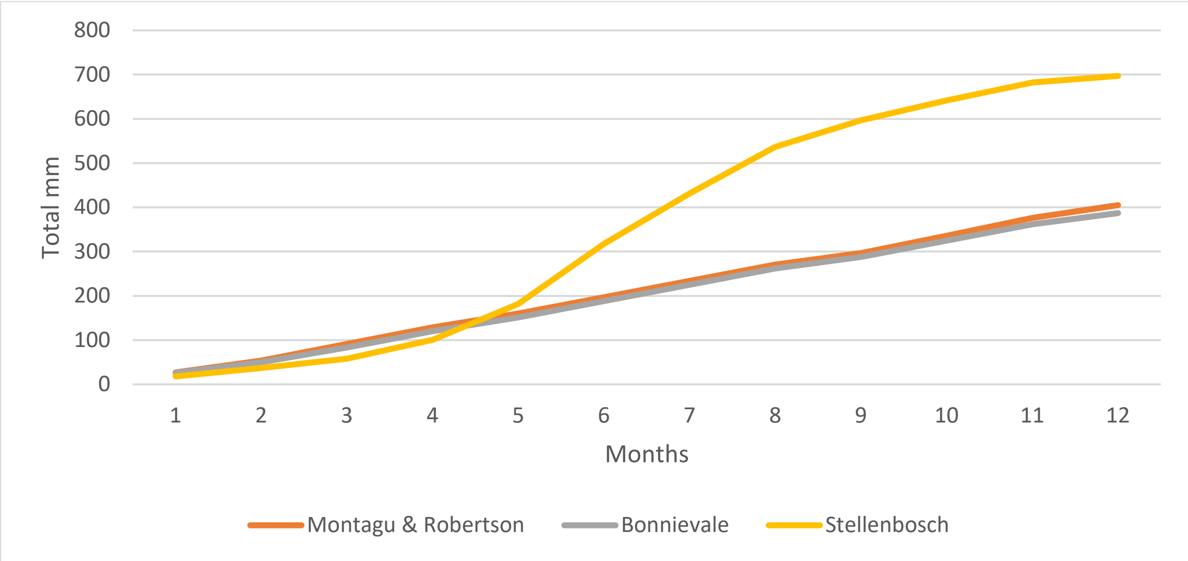


Figure 2.6: Total cumulative average annual rainfall for Montagu & Robertson, Bonnievale and Stellenbosch (source: Climate-data.org, 2021; Weather Stats Rainfall - La Colline Observatory, Stellenbosch Weather Station, LCAO, 2021).

The rainfall received by this region is not enough to successfully produce crops. Additional irrigation is necessary to produce permanent crops. According to The Robertson Wine Valley (2021), growers in the Robertson area are dependent on irrigation water supplied by directly pumping water from the Breede River or from the Brandvlei Dam. These two sources are the main supply for irrigation water to most Robertson producers. Winter water efflux from the adjacent Du Toitskloof Mountain range is stored in the Brandvlei Dam near the town of Worchester. Water is also pumped from the Breede River into the Brandvlei Dam. At the beginning of the main irrigation season for this area (September to the beginning of November) the Breede River usually has sufficient water to supply the network of irrigation canals to supply water to growers. From November onwards the irrigation demand increases beyond capacity and additional water from the Brandvlei Dam is released into the Breede River's system to sufficiently supply the irrigation canals. The growers that have access to the irrigation canals have water allocated to them to store in dams from which they can irrigate their vineyards and orchards. Growers located closer to the mountains and further away from the irrigation canals do not have the luxury of utilising the irrigation canals from the Breede River. They are dependent on stored water and boreholes to supply their irrigation demand. These growers are dependent on the storage of run-off water from the mountains and the groundwater they can extract from their boreholes.

A pipeline system running through Koghmanskloof provides water to the town of Montagu. The dam just outside of Montagu stores water which is pumped to irrigation scheme members and delivered to each farm at a specified cost and allocated amount of water per week or month. The producer is responsible for the storing and dispersion of water from that point. In most cases the producers will supplement their water supply from fountains and or boreholes. Often the water from boreholes is brackish and needs to be diluted in the dams to prevent long term negative effects such as salination.

2.2.2 Water distribution under drought conditions

Even the farmers that use the irrigation canal are still dependant on sufficient rainfall within this region. Farmers without access to the canals have to depend on run-off water from mountains which can be very irregular. If Brandvlei Dam's level falls below a certain threshold, water cannot be supplied to the Breede River for use by producers. This reduces their ability to irrigate crops. When a water shortage occurs, urban use has the highest priority. During the 2015-2017 Cape Town water crises water was reserved for use in the urban sector (Rodina, 2019).

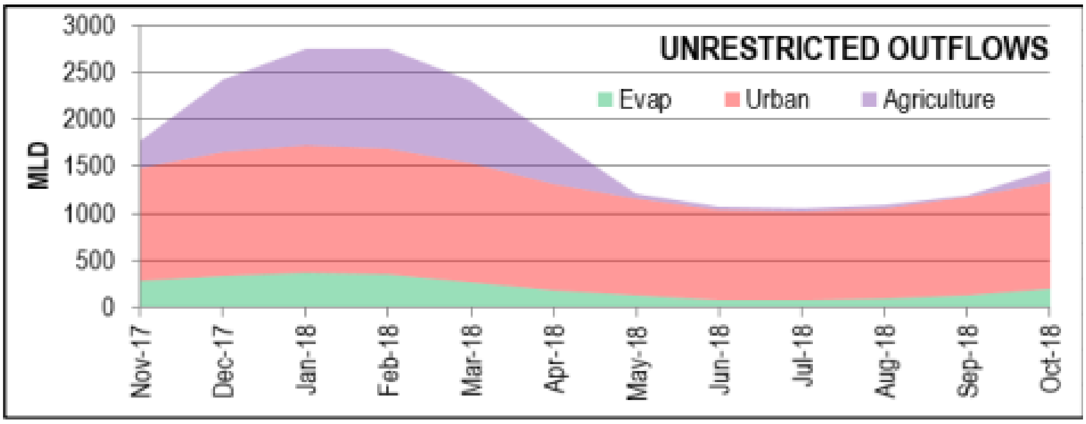


Figure 2.7: Million litres water per day (MLD) released and distributed from Western Cape dams by The National Department of Water and Sanitation without any restrictions on water distribution.

Source: Department of Water & Sanitation, 2018

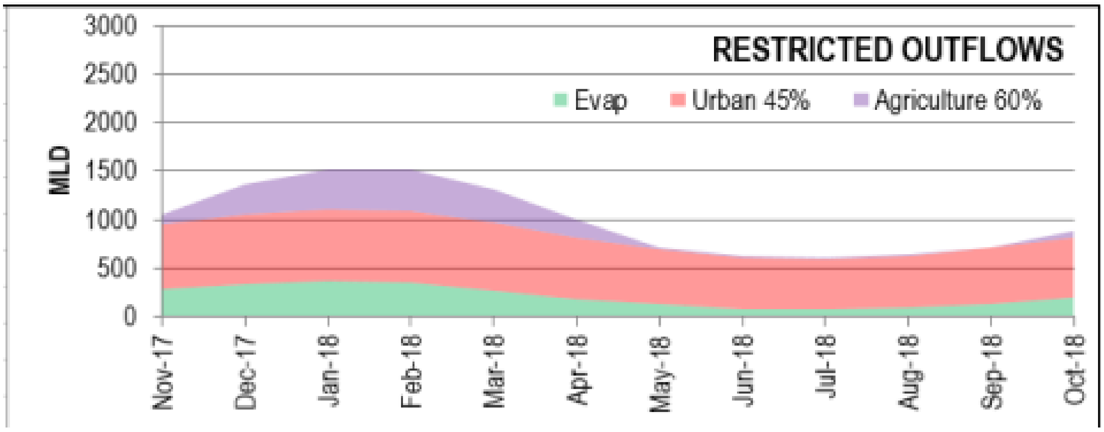


Figure 2.8: Million litres water per day (MLD) released and distributed from Western Cape dams by The National Department of Water and Sanitation during drought conditions.

Source: Department of Water & Sanitation, 2018

Figures 2.7 and 2.8 indicates the restrictions placed on both agricultural and urban water usage during the drought of 2015-2018. Out-flows from the dam systems is based on maximum calculated evaporation, urban and agricultural allocations. If the system is unrestricted as shown in Figure 2.7, the dam water out-flow system for agricultural use in summer peaks at over 2,500 million litres per day (MLD). While the drought was ongoing the dam water system was restricted to approximately 1,500 MLD. This is a restriction of approximately 60% on agricultural water allocation.

These transfers and restrictions on out-flow results in less water supply from major dams for irrigation purposes. Although this restriction during periods of drought would only affect those adjacent to the irrigation canals, producers using collection dams or boreholes would also be subjected to debilitating water supply. During drought conditions producers not reliant on the Breede River irrigation system but on run-off water and/or boreholes would lose the supply provided from run-off, therefore, producers would be solely reliant on borehole water. If drought conditions persist, like the Little Karoo is facing currently, boreholes will run dry and thus has to be either enlarged or moved to a new source. Sinking boreholes are time consuming and expensive, and there is no guarantee of finding water.

2.2.3 Current water status

The drought experienced in the Western-Cape during 2015-2018 had a severe impact on the Little Karoo. Although drought conditions have subsided in many regions of the Western-Cape, the Little Karoo area has had no relief up to 2021. Areas such as Drakenstein, Stellenbosch (Wemmershoek) and Swartland have all reported rainfall at or above the region's historical average but the Little Karoo's rainfall figures indicate that the annual rainfall for the area is still far below the average of 405 mm per annum.

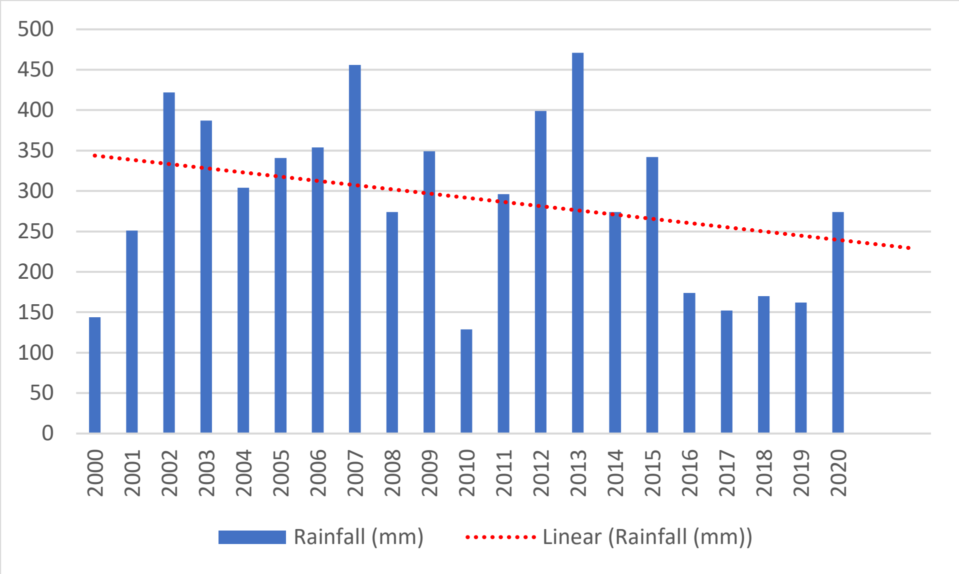


Figure 2.9: Rainfall figures from 2000-2020 in the Robertson/Ashton area (De Wet L , 2021)

Figure 2.9 indicates the lack of rainfall from 2015 to 2020 with a decrease in linear rainfall from the year 2000. There has been years where rainfall has been well below average but then normalise in the following years such as in the years 2000 to 2002 and again in 2010 to 2012. The drought has therefore reduced the region's ability to recover. Since 2013 the area has not yet received its normal or above average rainfall and 2014 saw a decline of -32.4% in the average rainfall. This average rainfall continues to decline apart from 2015 (15% decline) where better rains were reported. From 2015 to 2018 the drought took hold and lead to an immense decrease in rainfall. 2016 indicated a decline of rainfall of 57% and in 2017 a staggering 62.5%. The decline continued up until 2020.

These conditions left dam levels critically low. According to the Western Cape government the Brandvlei Dam, that is used to provide additional water to the Breede River irrigation canals, are currently (2021) at 35.6%. Water extraction from dams are possible up to 10% of the capacity, thereafter it becomes extremely difficult as sediment and sludge needs to be filtered out (Department of Water and Sanitation, 2018). Other dams in this area include the Pietersfontein Dam situated just outside Montagu, with its current level at 25.5% and the Poortjieskloof Dam situated between Montagu and Barrydale, currently empty. These dam levels indicates the desperate water situation this area is facing (Elsenburg- Western Cape Dam Levels, 2021).

2.2.4. Area temperature

Temperature plays a vital part in crop production. Temperature influences almost all plant processes, including photosynthesis, transpiration, respiration, germination, and flowering. Temperature combined with day length also affects the change from vegetative growth to reproductive growth. Temperature does not only influence the plant directly but also indirectly through means of soil and soil water. Soil temperature effects plant growth as it influences the water and nutrient uptake of crops, as well as the water (moisture) retention of soil. Cooler temperature allows for higher moisture retention.

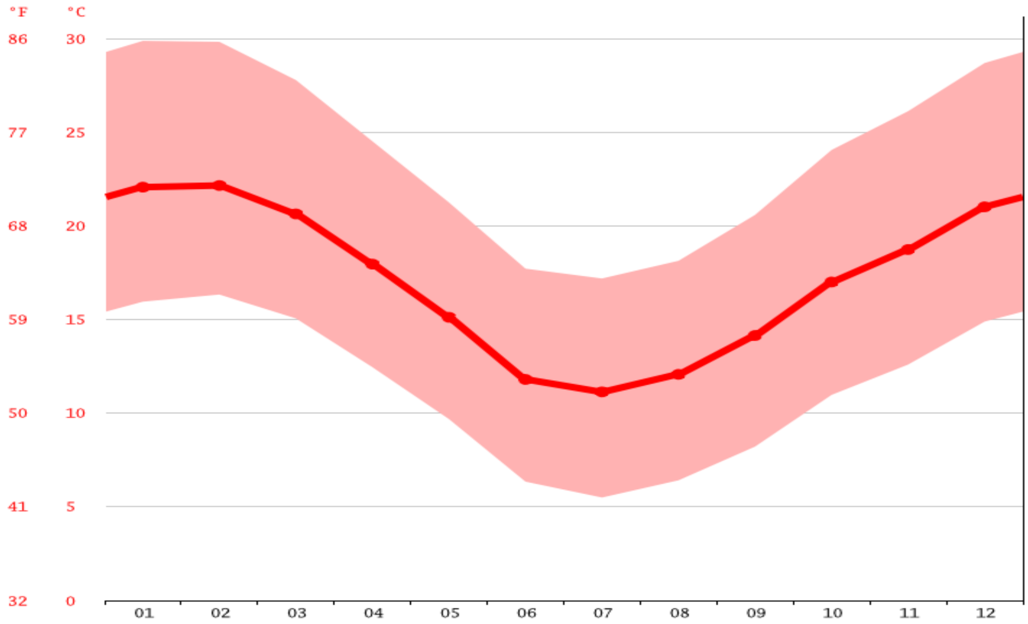


Figure 2.10. Average monthly temperature of Robertson

Source: Climate-Data.org, 2021

According to Figure 2.10 the temperature in Robertson reaches its peak in the months of January and February. During this period the frequency of irrigation has to be increased to provide fruiting crops with adequate water to maintain the photosynthetic rate. Soil temperature also has an effect on crop performance.

During the warm summer months, surface soil's peak temperature may occur early in the evening, which may cause excessive carbon loss from maintenance respiration of plant roots exposed to high temperature. Repeated and prolonged high night temperature stress may compromise plant growth and yield. Irrigation early in the evening may reduce soil temperature and thus improve plant growth (Dong et al., 2016).

Frost can also cause severe damage to both crops and yields. If the predicted increase in variability of the climate occurs, especially in the frequency of extreme weather events such as hot and cold spells, frost is likely to become a more important issue than is currently the case. Frost damage can be mitigated to a certain degree by using sprinklers.

Frost protection depends on the principle of heat fusion to maintain plant temperature at or near 32˚F (0˚C). Essentially, as the air temperature surrounding the plants drops below freezing levels, the water begins to freeze and crystalize, releasing approximately 80 calories of heat for every one gram of water that freezes. As the ice encases the plant it partially insulates it from the harsh exterior temperatures. Sprinklers provide a 2 to 5 ºC temperature difference, which is just enough to protect the crops. As long as the plant is constantly moist it should be successfully protected from severe damage. Although a sound solution, water usage will increase with the occurrence of frost.

The potential economic impact of frost and extreme heat waves are much higher than changes in average temperatures might seem to suggest. Average temperature changes will be gradual and there will be time to change species or varieties, or even move to new regions over time if required. However, a severe frost or heat wave can have a devastating effect on the profitability of a farming operation.

2.3 Climate change effects

Year-on-year weather variations in certain locations are not uncommon; some years might indicate higher levels of rainfall than previous years and vice versa, but the deviations are corrected to maintain the average in the long run. However, analysis of meteorological and other data over large areas and a longer period of time (decades), indicated that there is some evidence of systematic changes in climate and weather patterns over the past century (Erasmus et al., 2000). This change in weather and climate patterns is already influencing the climate in the Little Karoo and will most certainly impact the future patterns. For producers to make an informed choice on future crops and cultivation practices, the type of climate change as well as the degree of change in the future must be studied.

2.3.1 Global climate change

According to the National Oceanic and Atmospheric Administration's (NOAA) Annual Climate Report (2020), the average land and ocean temperatures have increased by an average rate of 0.08˚C per decade since the year 1880. However, since 1981 this rate increased more than twice the previous rate per decade, at a rate of 0.18 ˚C. This confirms that global average temperatures are increasing at an exponential rate heating up oceanic water bodies and leading to changes in weather patterns.

According to the models it was projected that 2020's global surface temperature would be 0.5˚C higher than the 1986-2005 average. The year 2020 was the second warmest in the 141-year record, whereby the global land and ocean surface temperature recorded an increase of 0.98˚C more than the historical average. This value has a 0.02 degrees Celsius deficit from the warmest year recorded in 2016 where a 1.00˚C increase from the average was recorded. The third warmest year on record was 2019, thus, the three warmest years to have been recorded occurred in the last five years. In the 141-year record (1880 - 2020), the seven warmest years have occurred from 2014 and the ten warmest years from 2005. The increase can be tracked by looking at the different decades. The previous decade (2001-2010) has seen an increase in temperature by 0.62˚C from the 20th century's average. This increase however is overshadowed by the current decade's (2011 - 2020) increase of 0.82˚C, making it the warmest decade on record (NOAA, 2020).

A problem caused by these temperature increases is the phenomenon called oceans inertia. Inertia is the tendency of an object to resist a change in its current state. The high heat retention capacity of water means that the oceans and large water bodies does not instantly react to the increase of heat trapped by greenhouse gasses. According to NOAA research, by 2030 the heating imbalance caused by greenhouse gasses will start to overcome the ocean and large bodies of water's thermal inertia. With unchecked carbon dioxide emissions the projected temperature course will diverge and likely lead to an increase of several additional degrees.

The effect that climate change has on the globe spans to the physical environment, ecosystems, and human societies. Human-caused climate change also includes economic and social changes brought on by living on a warmer planet which will have an impact on sustainability.

The physical impact of climate change is already visible and has been observed in a number of locations. These physical changes include extreme weather events, the rising of sea levels, decline in arctic sea ice, glacier retreat, and also changes in natural habitat. Climate variability can lead to negative changes in global food security as it puts pressure on fresh water sources especially in water scarce regions. Climate variability in combination with extreme weather events can lead to negative effects on agriculture and the ability thereof to feed growing populations. These negative effects on agriculture can be in the form of desertification and land degradation in which biological productivity is lost and fertile land becomes more arid.

Rising temperatures, changing weather patterns, changing precipitation patterns, and extreme adverse weather events can threaten agriculture and local economies as crop cycles are disrupted, water availability is influenced, and temperature sensitive crops fail to adapt. These are some of the many challenges faced by farmers with regards to climate change (Hegerl et al., 2007).

2.3.2. Domestic climate change

Environmental factors attributed to climate change played a role in the 2015 - 2017 drought that occurred in south-western South Africa (Cape region). Drought within this region is not uncommon, having occurred in the late 1920s, early 1970s and during 2003-2004. However, the most recent drought occurred over a period of three years (2015 - 2017) and was the most devastating over the last century. According to the Climate System Analysis Group (CSAG) (2021), the city of Cape Town's six major dam's levels dropped from 102% (92 3596 million litres) in 2014 to just around 20% (184 319 million litres) in May 2017 and again to 23% in April 2018. It is important to assess how likely another drought like the one in 2015 - 2017 might be in the coming years.

According to Tyson and Preston-Whyte (2000), the El Niño phenomenon caused a third of the rainfall variation within the Western Cape. El Niño can be described as the warming of ocean currents off the South American coast. This warming of this ocean current has a major disruptive impact on weather patterns across multiple countries leading to a variety of meteorological variations stretching from great floods to extreme droughts. Countries like South Africa will then experience a decrease in rainfall which will therefore, lead to drought conditions. According to Pascale et al. (2020) statistical models [such as the Coupled Model Inter-comparing Project phase three (CMIP3) and five (CMIP5) climate models] indicate that the 2015-2017 drought may have been made 1.4 to 6.4 times more likely due to a +1 K increase in temperature, with the risk expected to upscale linearly with one additional degree of warming.

2.3.3 Overview of future climate predictions

El Niño is not the only factor that can be attributed to the drought and continuing dry conditions in the Western Cape. According to Pascale et al. (2020) an increased aridity of most of southern Africa is expected due to the poleward expansion of the Hadley cell and a shift of the Southern Hemisphere jet stream. The majority of Earth's arid regions are located beneath the 30-degree latitude region of the Hadley cell. It is at the 30-degree latitude where descending movement of air currents from the Hadley cell occurs. This downward movement causes warmer moist air (evaporation) to be pushed down which inhibits condensation to form rain clouds, leading to dry arid conditions (Frierson et al., 2007).

There is evidence to suggest that global warming is causing the expansion of the Hadley cell polewards. The current 30-degree latitude is situated to the northern parts of South Africa and southern Namibia (Namib Desert), but models suggest that the Hadley cell will expand, increasing global temperatures with an estimated 2 degrees of latitude expansion over the 21st century. (Johnson and Fu, 2009). This would lead to changes in precipitations further south, which includes the Western Cape. It is expected that these areas around the expanding 30-degree latitude will become drier at an even higher rate than traditionally expected. This could be devastating for the agricultural sector of the Western Cape.

According to Pascale et al. (2020) their models show that event probability (such as droughts) was stationary from 1980 - 2000, after which it started to increase. For 2015-2017, the occurrence of an extreme weather event probability increased by 3.7%.

This would imply that the risk ratio is 5.5 times that of the 20th century. According to this data an extreme weather event with a recurrence average of 100 years in the early 20th century would have a recurrence average of just 25 years at present. Thus the drought that plagued the Western Cape in 2015-2017 would occur more often further on in the century (Pascale et al., 2020).

Pascale et al. (2020) did a drought risk projection of the Cape Province after the events of the 2015 - 2017 drought. In their model they assumed two continuing emission scenarios: a high-emission scenario and an intermediate emission scenario. According to their model the high-emission scenario will increase the probability of an extreme weather event, such as the 2015-2017 drought, by 20% around 2045 with the intermediate emission scenario increasing the probability by 13% by 2045. If the high-emission scenario continues the probability would increase to 80% by the end of the century. Each of these scenarios predicts drier winter conditions for the Western Cape with a higher probability of extreme droughts occurring. The model also suggests that a 4-year dry period would be even longer. This suggests that the duration of droughts would most likely increase over the coming century.

The increased probability for future rainfall deficits is indicative of a significant shift in the average wintertime (winter rainfall) conditions in the Western Cape. No significant trend is observed in the number of cold fronts making landfall in the Western Cape but it highlights the trend of shorter rainfall periods.

To explain the significance of an extension of high-pressure zones over the wintertime period we must first look at the factors that contribute to the formation of cold fronts leading to winter rainfall in the Western Cape. Cold fronts form in the corridor between two opposing high-pressure zones (one cold and the other hot). These areas form low pressure systems where hot air and cold air meet with the denser cold air forcing hot air to rise thus, forming rain. If a weather anomaly such as the formation of a high-pressure zone further south, caused by El Niño or the shift of the Hadley cell forms, it results in cold fronts being shifted towards the pole, shortening the occurrence of effects (rainfall) from the cold front or it will bypass land mass. Both scenarios will lead to a rainfall deficit especially over the inner Cape (Little-Karoo) area.

A model used by various meteorological offices worldwide known as the General Circulation Model (GCM) was used to predict and monitor climate changes for the Western Cape. Erasmus et al*.* (2000) used the GCM in combination with the Computing Centre for Water Research (CCRW) model for predictions. The results represent a worst-case scenario for South Africa when global temperatures increase in the coming decades. The GMC model as well as the Seamless System for Prediction and Earth System Research (SPEAR), used by Pascale et al*.* (2020) for their predictions, indicates that temperatures in South Africa will rise by an average of 2.5 - 3.0 degrees centigrade when atmospheric CO_2 levels doubled from pre-industrial era levels.

Erasmus et al. (2000) used the GMC model that utilise annual and monthly precipitation data from the past 30 years to make current predictions. The modelling done by Erasmus et al. (2000) resulted in the following: ten regions of the Western Cape varies in their mean annual precipitation ranging from 831.18 to 219.16 mm. The model predicts that by the time global temperatures has increased by 2.5 to 3.0 degrees Celsius, the average decrease in precipitation for the 10 regions would be 9.44%. There is a wide range in predicted decrease from just over 3% to 27% which would have a significant impact on a water scarce province. Their model also predicts that drier areas would be more affected by the predicted decrease, meaning regions such as the Little Karoo will suffer more than regions with a higher rainfall. If one looks at current precipitation data a below average trend can be observed.

2.4 Climate change impacts on agriculture

Climate change can affect fruit crops in two ways: one being the effect of an increase in temperature, the other a reduction in water availability. Two types of studies can be done to determine the impact of global warming on fruit tree production. The first can track historical changes in temperature and precipitation and relate them to actual experimental observations in tree phenology and fruiting size. The second simulates tree behaviour based on the forecast of climate variation and increased future temperatures. With predicted increases in temperatures and an expected decrease in water availability it is essential to study the effects of climate change on agriculture in this agricultural driven region.

2.4.1 Temperature

Increased temperature can affect a multitude of factors contributing to successful crop production. These factors include, chilling requirements, bud break, flower development, and fruit set as well as other non-phenological impacts such as pest distribution.

According to a study done by Guédon and Legave (2008), fruit species that require more chilling units, such as apples, are more affected than those with lower chilling unit requirements, such as pears. Guédon and Legave (2008) also concluded that an increase in temperature is observed more in correspondence with warming periods, after winter chilling. This would imply that cold requirement periods would become shorter leading to earlier bud break and earlier bloom. Future climate predictions indicate that the overall temperature will increase, therefore, significant warming during chilling requirement would reduce the completion of chilling requirements (observed in the Western Cape). If a tree does not receive enough chilling hours, dormancy can occur, leading to delayed flowering. When late bloom occurs flower buds might not bloom at all or result in uneven bloom. This could result in weak fruit set and poor quality fruit (Wilson, 2017).

A study on peach trees done by Lopez and De Jong (2017), linked high spring time temperatures to decreased fruit size and tree productivity. This can be explained by the shortening of early phenological stages of fruit development (Stage I). Since the period for fruit completion is shortened, the fruit growth requirements per day increases more than the tree can provide. This is due to an underdeveloped tree leaf area, due to late bud break, resulting in less assimilated product being transported to the largest sinks (fruits). Other effects of higher temperatures at the start of the winter season have been related to flower bud drop in peaches and apricots (Stöckle et al., 2011). Warm pre-blossom temperatures, results in insufficient chilling which have been reported to decrease fruit set and fruit production in apricots due to abnormal flower development and non-viable flowers (Legave et al., 2006). Like most temperate climate fruit trees, olives require winter chilling to stimulate bud development. Incomplete chilling delays bud break and would result in delayed flowering. If warmer conditions continue the flowering period would be shortened and this would result in the failure of producing fruit normally and a reduction in fruit set (Stöckle et al., 2011).

Air temperature plays a fundamental role in grape maturation, including aroma and colouration. According to Mozell and Thach (2014) negative climate change effects can result in phenological changes i.e. timing of developmental stages such as flowering, fruit formation, veraison, and harvest. A shift in climate can lead to changes in characteristics of the various cultivar's quality and flavours. When the local temperature exceeds varietal specific heat thresholds, the ability to ripen fruit and produce existing styles of wine will be compromised. Warmer temperatures can create overripe fruit with low acid and high sugar contents. The conversion of sugars to alcohol would translate in wine having a high alcohol level with cooked flavours (Santisi, 2011).

The problems mentioned above and the extent thereof, is dependent on:

- the chilling requirement of the individual cultivars,
- the degree of temperature increase, and
- the geographical location of the studied site.

Thus, if warmer temperatures reduce chilling hours, then a cultivar with less to no chilling requirement will be planted instead. Other solutions such as the use of netting can be utilised to reduce the temperature within the orchard. However, cultivar replacement will not entirely compensate for warming effects as other factors may also play a role. Another factor to consider is how temperature can influence pests. For instance, in California it is expected that warming will expand the distribution of *Ceratitis capitata* and make this fruit fly more difficult to control (Stöckle et al., 2011). The interaction between higher temperatures and water requirements should also be taken into consideration. Temperature increases could increase evapotranspiration from the trees and soil, leading to greater need for water.

2.4.2 Water

Coupled with an increase in temperature, reduced water availability is also predicted for the Little Karoo. As stated above, the predicted occurrences of drought have increased considerably in the last couple of decades and will continue to do so in future. Water is essential for agriculture and without it this area will no longer be viable to produce deciduous fruit, stone fruit or even wine grapes. In a daily cycle, water evaporates from the leaves of the tree canopy, internal water deficits develop, and water is taken up through the soil via the root system. Mass flow and bulk flow from the root system to the leaves replace lost water due to evapotranspiration. For this cycle to take place a water deficit must occur within the tree. However, when the soil cannot supply sufficient water to replace the lost water, the tree partially dehydrates and experiences a water deficit. Water deficits can have critical physiological effects that may result in lower yields, reduced flowering, and a weak and deteriorated fruit set.

Water deficits affect the phenological development of fruit trees and vines. It influences flower bud formation, flower development, and fruit set. For deciduous fruit trees, bud formation and differentiation are responsible for fruit formation at the end of the growing season. For this reason water deficit’s effect on bud and flower formation will inherently affect crop yield. For some deciduous trees, water deficit can negatively affect floral viability but some deciduous fruit trees respond differently to water deficits by having an enhanced bloom the following season (Fereres et al., 2012). This response is critical to determine fruit yield/load in relation to water. This response is dependent on the species and should therefore be taken into consideration on individual crop level. The consensus is though, that during periods of bud, floral development, and fruit set fruit trees are most sensitive to water deficits. Damaging water stress should thus be avoided. Water stress does not commonly occur in the early developmental stages as there is a reduced state of evaporative demand early in the season due to a reduced leaf area and day temperatures are generally not that high. The largest impact water deficits will have, is on developing fruit as they act as large sinks for water and assimilates (Fereres et al., 2012)

Fruit size results from cell division and expansion, which are correlated to carbohydrate and water fluxes. These processes and elements are regulated based on the fruit’s ontogeny and the response thereof to environmental conditions (Ripoll et al., 2014). Fruit growth could be limited by two mechanisms:

(1) carbohydrate availability owing to a decrease in photosynthetic rate, and

(2) reduced cell turgor in response to water stress (Lopez et al. 2012).

The growth of a plant cell is primarily driven by the uptake of water into the cytoplasm and vacuole of the plant cell. The vacuole expands rapidly, pressing against the cell wall. In order for the cell to enlarge, the cell wall must yield to the stress produced by cell turgor and an increase in size can be expected. Without sufficient water supply cell enlargement would not take place resulting in smaller fruit.

Water deficit does not only influence fruit development and size but also the fruit's organoleptic (origin and development of a fruit) qualities. These qualities include the fruit's external appearance, size, texture, and taste. Elements that determine a fruit's taste and texture is primarily determined by the dry matter and its sugars, acids, cellulose structure, amino acids, nucleotides and protein concentrations and composition, in addition to the ratios between the acids and sugars (Barrett et al., 2010). Water fluctuations can change the composition and concentration of the fruit's organoleptic qualities. A decrease in water would result in higher sugar and or acid levels that will improve taste but will result in less dry matter formation reducing juiciness and texture.

Many studies have reported that in several species water deficit typically results in a decrease in plant growth, enhanced fruit quality (e.g. increased sugars and acid levels), and an acceleration in fruit maturity. This leads to low marketable yields or fruit that do not meet set standards e.g. size, weight, acid: sugar level (Mirás-Avalos et al., 2013). However, the effects of water deficit on fruit quality are highly variable and at times conflicting. This is due to the number of underlying processes that interact during fruit development, fruit set and the timing and intensity of the water deficit. Species differ in their sensitivity (Ripoll et al., 2014).

2.5 Conclusion

The Little Karoo is defined in terms of climate as being cold and semi-arid. This type of climate makes it well suited for the cultivation of a number of mediterranean crops, especially stone fruit. However, crop production within this area is severely compromised by the low levels of available water. The Little Karoo receives only an average rainfall of between 387 - 405 mm per annum which is lower than most other production regions. The low annual rainfall paired with droughts that are common, negatively impacted water availability in this region. The annual rainfall from 2015-2020 decreased by an average of 54% and has not recovered to previous levels. Lack of rainfall will not only affect producers within the water catchments area or those with boreholes but also those relying on irrigation water from the Breede River irrigation canals. Low water levels will result in prioritising urban population water needs leading to restrictive water outlets to the agricultural sector.

The main causes for the most recent drought of 2015-2017 can mostly be explained by the El Niño phenomenon that caused a third of rainfall variability within the Western Cape. The occurrence of such a phenomenon and other weather shifting occurrences made it 1.4 - 6.4 times more likely due to climate change.

Climate change is expected to negatively impact the future water availability and temperature of this region. Droughts will, expectedly, not only occur more frequently but will increase in duration and possibly severity. This is paired with an increase in temperature by 2.5 - 3 °C when atmospheric CO2 levels have doubled from the pre-industrial era's levels.

These future conditions might impact agriculture in this region. Temperature increases as well as available water decreases will influence a number of phenological processes as well as overall fruiting capacity and composition of fruit trees. This will force producers to seek better suited crops and lead to changes in certain cultivation practices.

Chapter 3: Current industry and crop overview

3.1 Introduction

According to Corsi et al. (2017) crop production is highly sensitive to climate. It is affected by long-term trends in average rainfall, temperature, inter-annual climate variability, disturbances during specific phenological stages, and extreme weather events. Some crops are more tolerant than others to certain stresses, and at each phenological stage, different types of stresses affect each crop differently.

The Little Karoo's semi-arid climate is suitable for several mediterranean crops such as grape vines, olives, almonds, citrus, and a variety of stone fruits. These crops are suitable for production due to the region's soil, and climate characteristics. However, low annual rainfall, limits chilling periods, and high temperatures limit the variety of suitable crops and or cultivars that can be successfully produced.

Mediterranean crops are suitable due to the lack of or little need for winter chilling. Some fruit cultivars require a certain minimum amount of winter chilling hours but this area meets most requirements. The most important limiting factor for agriculture in this region is water availability. With drier conditions predicted it will become more prominent. The limit of abundant fresh water sources makes agriculture difficult within this region, therefore, agriculture in this region is specific to only a number of crops. These crops must be suited for high to cool temperatures with minimal water requirements.

The crops that will be analysed for the study are wine grapes, olives, nuts (Almonds), and a number of stone fruit such as peaches, apricots and plums. This section presents the current production practices of crops in this area as well as the characteristics of these crops. It is important to have a clear understanding of the crops and their characteristics to be able to predict the interaction to future climate. Crop characteristics also have an important role in the planning of cultivation and production practices such as labour, time, machinery, and logistical. If any one of these are not addressed it can lead to delays and or failure of crops. The most important factor to consider is the crop's water usage characteristics, especially since it determines the survivability and success of agriculture in the Little Karoo.

3.2. Industry overview

The Little Karoo accounts for one of the largest fruits producing regions in South Africa. It is one of the largest producers of stone fruit having 6 109 ha under production. This accounts for 44.2% of South Africa's production (Hortgro, 2019). It is not only a large contributor to stone fruit production but it's the third largest wine region in South Africa with a total of 12 801 ha under production, predominantly located in Robertson. The Little Karoo also plays host to the largest production of almonds in South Africa accounting for 62% of the total ha planted. The almond industry is in its infancy and is expected to expand largely in the next decade. These industries contribute large amount of value to the agricultural sector of South Africa. Value is not only added to the producers itself but also to the surrounding area, creating work and supporting local companies. The Little Karoo is known for its fruit processing industry which adds value to fruit and creates jobs for a number of factory workers.

3.2.1. Wine grapes (*Vitis vinifera)*

The wine industry within the Robertson and Little Karoo area is mostly centred on white grape cultivars. White grapes account for 62% of the irrigated land in the Robertson area and 77% are under irrigation within the rest of the Little Karoo (Sawis, 2020). The most common varieties grown in the Robertson and Little Karoo area are Chenin Blanc (28.6%), Colombar (25.1%), and Sauvignon Blanc (16.2%). The Little Karoo is one of the warmest wine grape production areas in South Africa. Therefore, the climate enables it to produce a wide variety of wines, such as dry wines, fortified wines and pot-stilled brandies. Hotter climates enable grapes to ripen quicker but the negative effect is that it generally results in a reduction of natural acidity and in higher sugar levels. The hot climate makes this area ideal for the production of fortified wines as it requires high sugar levels (Balling) to be able to produce the high alcohol levels during fermentation. In terms of brandy distillation, wine grapes are harvested earlier to achieve higher acid to sugar ratios, resulting in good quality 'base wine' which is then distilled. Colombar, which is almost entirely used for distillation and Chenin Blanc are the two grape cultivars mostly used for production in distilled brandies. Thus they are the two most planted cultivars in this hot wine production area.

The number of hectares planted in this area has seen a decline in the last decade, numbering 16 316 ha in 2010 and decreasing to 14 982 ha in 2020. This is a decline of 8.2% in total (Sawis, 2020). This could be indicative of farms that are intensifying their cultivation or that wine grapes are taken out and replaced with other crops.

3.2.2. Stone Fruit

South Africa is the largest stone fruit producer in Africa, but only accounts for 16% of production in the Southern Hemisphere and only 1% of global production. South Africa has gained a reputation for the quality of its fruits which are understandably in high demand, especially in Europe and the United Kingdom (Kriel, 2021). Most of the stone fruit production in South Africa is used for processing with a small percentage being exported globally. The value of the South African stone fruit industry is estimated at over R2 billion (Kriel, 2021).

3.2.2.1. Apricots (*Prunus armeniaca*)

According to Hortgro Tree Census (2019) the Little Karoo has an area of 1 824 hectares planted with apricots and it accounts for 74.5% of the total South African production. Bulida the most popular cultivar, accounts for 49% of the current production. This cultivar is frost and drought tolerant making it a good cultivar for production in the Little Karoo. Around 70% of apricots produced within South Africa are used for processing. This includes canned, frozen, jam, juice, and purée. A further 16% is dried, either halved or pitted. The halved and pitted apricots are then dried in heat chambers or with the sun. The dried fruit is then processed to be cleansed and treated with SO2 to retain colour. Only 9% of apricots produced in South Africa are used fresh for export.

The historical price trend for apricots indicated an increase in the export price (R/ton) with a 121.5% in net export realisation. The local fresh market price increased by 163% over the last decade. Since most apricots are used for processing the price would be considered most crucial. The price for processed apricots has increased by 115.3% over the last decade. Even with an increase in prices the total production has decrease from 56 302 tons in 2010 to 34 104 tons in 2020 (-40%) (Hortgro, 2019). The decreased in total production coincides with the drought of 2015-2017 and continuing drought conditions. Production prior to the drought was at 58 214 tons in 2015. Therefore, the drought had a serious impact on the total production of apricots and will continue to do so until this region is released from the drought.

3.2.2.2. Peaches (*Prunus persica*)

The Little Karoo is the area with the most cling peaches. It has 2 465 hectares under production, accounting for 53% of the total production. Dessert Peaches make up only 16% of the total production (Hortgro Tree Census, 2019). Cultivar distribution is relatively wide with Keisie Cling Peaches accounting for 25% of production, followed by Sandvliet (15%), and Cascade (13%). According to Hortgro the majority of peaches are used for processing, accounting for 65% of South Africa's production. Processed peaches are used for products such as juices, purée, canning, peach halves, sliced or diced and jam. The local fresh market accounts for 21% of the total production with only 7% in exports. Keisie, Sandvliet and Cascade cultivars are grown solely for processing as these cultivars possess good processing qualities.

The historical price trend for peaches indicates that the export price (R/ton) increased by 126% in net export realisation. Local fresh market sales increased by 73% over the last decade. As with apricots, the majority of peaches are used for processing. The price for processing peaches increased by 163.2% in the last decade, which is very good. The total production of peaches were increased from 167 233 tons in 2010 to 211 472 tons in 2015 (+26.5%). As with apricots peach production decreased due to the 2015-2018 drought and continued drought conditions in the Little Karoo and only achieved 152 414 tons in 2019 (Hortgro, 2019).

3.2.2.3. Plums *(Prunus salicina)*

Plum production is mostly centred in the Little Karoo but also produced in the Wolseley/Tulbach, Franschoek, and Wellington areas. The Little Karoo has a total 1 602 ha planted, accounting for 30% of total production.

Plum production in South Africa has a wide range of cultivars, with Angeleno/Suplumsix (10%), Laetitia (9%), and Fortune (8%) being the most planted (Hortgro Tree Census, 2019). A total of 73% of South African plums are exported fresh. The domestic market accounts for 24% of total consumption. Plum processing is fairly low with only 3% being utilised for processing.

Since most plums are exported the price is important to producers. The export price increased by 132% over the last decade and local fresh prices increased by 115.8%. Plum production were not heavily affected by the 2015-2017 drought as most of the other production areas outside the Little Karoo have received relieving rainfall in 2018, such as Franschoek, Wellington, Paarl, and Stellenbosch. Production was at 62 387 tons in 2019 (Hortgro, 2019).

3.2.3. Olives (*Olea europaea*)

According to Hortgro's (2017) tree census, around 2 778 ha of olive trees are grown in South Africa with 95% being in the Western Cape. Olives are traditionally a mediterranean crop. The Little Karoo has 593 ha of olives, accounting for 21.3% of total South Africa's production. The main cultivar planted is Frantoio, which is mostly used for the production of olive oil due to its high oil content. This cultivar accounts for 27.3% of the total hectares, followed by Mission, with 23.8% of total hectares planted. This cultivar is used for both oil extraction and table use. Most olive production is centred on oil production, 64% of the total planted orchards is used for olive oil production, with table olives accounting for 36% (SA Olive, 2018).

According to SA Olive (2018) the total number of olive tree hectares increased from 1 353 in 2008 to 2 778 in 2017. The Little Karoo planted 400 ha in 2012 and this number increased by 48% to 593 ha in 2017. The price of olives is determined by individual buyers within the area that use the olives for oil production. Most olives and olive oils are consumed locally but some are exported. Olive oil exports numbered 1 623 tons in 2020 whereas the fresh olive export was only 23 tons in 2020 (ITC, 2021).

3.2.4. Almonds (*Prunus dulcis*)

The Western Cape with its Mediterranean climate is best suited for growing almonds in South Africa. Almonds thrive in the same regions as stone fruit and wine grapes, therefore, the Little Karoo is ideal for production. The reason the Little Karoo is so well suited for almond production is due to their chilling requirements, which is one of the lowest for tree nuts (Yara Australia, 2021).

According to Louw et al. (2017), Montagu has 130 ha under production with large expansions in the Robertson area. Robertson producers has planted 210 ha and intents on expanding to 250 ha over the following year.

The most popular cultivars are Nonpareil and Independence. Nonpareil accounts for 50 % of the imports. In South Africa, 3 000 tons of almonds have to be imported annually to supply local demand which has been growing by about 5% over the past five years. Local production is currently 200 to 300 tons (Louw et al., 2017). Almond prices are relatively stable due to the maturity of the market and are around R85/kg (Kriel, 2019).

3.3 Crop production

Vineyards and orchards require long-term, costly investments. For the development of any plantation, two critical issues should be avoided:

1) poor soil conditions (e.g. too shallow, poor drainage, high acidity, high salinity), and

2) the uncertainty of supply.

In the Little Karoo the second critical issue is currently the most prominent, due to the Western Cape drought of 2015 - 2017 having a serious impact on water supply as well as looming drought conditions thereafter. Lack of irrigation water would not only reduce yield in the current year but would have a longer-term effect on yield in the subsequent years, promote alternate fruit bearing, and damage or kill trees, either directly or indirectly (Fereres, et al., 2012). In perennial crop production, growers need to keep the risks at a minimum since any developing problems could lead to a loss in yield and profit. Even vineyards and orchards developed under good environmental conditions will suffer.

Many vineyards and orchards have been planted in situations where water may be limited or scarce, such is often the case in the Little Karoo. Therefore, it is important to understand the response of vineyards and orchards to variations in water supply. Experienced producers in the area manage water critically and make the correct crop selection when planting. New crops and new conditions are presenting itself and these considerations need to be evaluated.

Improved irrigation and management techniques in recent years reduced irrigation-related water losses. This decreased the amount of applied water per unit of irrigated land. Limited water availability has led to a shift in higher-value crops to higher application efficiency. This suggests that more water would be available for expansion or to be stored for the next season when drought occurs. Precise information on when and how much irrigation is necessary is essential to ensure sustainable management and enhanced water management. Natural resources like water are increasingly scarce in areas such as the Little Karoo. The projected climate change for the Little Karoo forecasts a reduction in annual precipitation. The availability of irrigation for orchards or vine production would thus decrease further in the coming decades.

3.4 Crop phenology

Phenology is the study of the timing of recurring biological events, the causes of the timing with regard to biotic and abiotic forces, and the interrelation between phases of the same or different species (Ruml and Vulic, 2005).

Knowledge on the time windows of phenological events and their variability can provide valuable information for planning, organising and execution of certain standard and special agricultural activities that require advanced information on the dates of specific stages of crop development. One of phenology’s important factors is to understand how the cycle of growth occurs, vegetative and reproductive, and the specific requirements to successfully complete the phenological cycle. There are three factors that determine the success of phenological stages namely: sunlight, temperature, and precipitation. Variation in one of these key factors can either delay, increase, or halt a certain phenological stage.

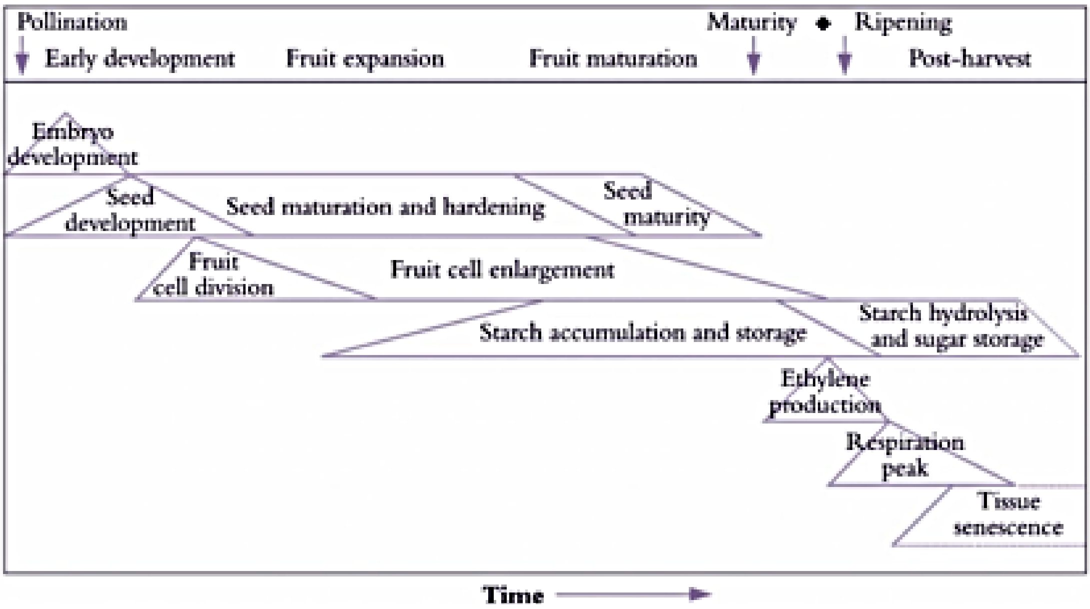


Fig 3.1: Typical growth stages of deciduous crops

(Source: Atkinson et al., 2016)

It is of utmost importance to understand the interaction between the environment and the organism, as it will ultimately lead to deviations in plant cycles. Deviations can result in a loss of vigour, reduced flowering, reduced fruit set, fruit abortion, poor quality fruit, and poor tree health.

Crop phenology is thus a useful tool to determine the specific crop requirements at certain stages. An example of this is the increase of water uptake by the crop when the fruiting period occurs. Cultivation practices can therefore be planned and designed in advance to ensure that orchards' needs are met. Planning must be done to provide the orchard with sufficient resources to avoid any deficiencies. Understanding crop requirements at certain stages, cultivation practices can be altered to compensate for climate and the impact of climate change.

3.4.1 Grapevines

Grapevine phenology includes two developmental cycles namely the vegetative and reproductive (flowering and fruiting) cycles. The vegetative cycle is completed within one growing season. The reproductive cycle runs over two seasons with flower inflorescence formed in year one, followed by flower initiation, bloom, and fruiting in year two (Giese, Velasco-Cruz and Leonardelli, 2020). Simply put, buds formed in the first year gives rise to shoots carrying fruit in the second year. In the first season, flower inflorescence forms within the primary buds. During the second season these buds emerge as flower clusters which are visible on the new shoots. The inflorescence gives rise to flower clusters, which bloom and set grape berries that are harvested when ripe. The timeline for this crop indicates that budburst starts early September to middle October. This period is followed by flowering from middle October to December when berry clusters and development starts. Harvesting takes place from late January to the end of March. The harvest date depends on the type of wine to be produced, therefore, sugar/acid (Balling) concentration and colour development are monitored until the sought after characteristics are achieved.

Both temperature and light play a vital role in grapevine phenology and production. The length of the day is important in the physiology of grapevines. Bud break, flowering, fruit ripening, and leaf drop are set by day length (the amount of light in a given day). However, temperature can cause accentuated deviations to plant metabolic processes and developmental growth.

According to Jones and Alves (2012) temperature is considered to be the most important factor in the overall growth and productivity of wine grapes. In effect, grapevine physiology and fruit metabolism and composition are highly influenced by the mean temperature along the growing season. Once bud break occurs, when temperatures are above 10°C, the accumulation of heat units begins. According to Giese et al. (2020) a "base" temperature of 10°C is used because it is the initial temperature of active growth in most temperate-zone plants. Even though vines are well adapted to environmental stresses, extreme temperatures can damage developing buds and leaves or shoots. Extreme heat or heat waves may permanently affect vine physiology and the associated yield, although some cultivars are more tolerant than others. Grapevines grown under severe heat stress experience a severe decline in productivity. This is due to limitations in the process of photosynthesis, as well as injuries due to other physiological processes.

An increase in the frequency of + 35°C days within the growing season could affect wine production, as previously stated, but can be managed through vineyard canopy and water management practices (Louw, 2015). This water management practices would lead to an increase in water demand by the plant. This increase is not a long-term feasible solution as the Little Karoo already experiences water shortages and cannot meet the demand for excess water usage. Water stress during budburst and shoot development would cause small shoot growth, poor flower cluster formation, and poor berry set development. Severe water stress during the developmental stage from flowering to berry formation and ripening will result in a low leaf area. This would limit photosynthesis, flower abortion and cluster abscission (Fraga et al., 2012). Decreased water availability during berry development would result in smaller berries.

The predicted drier conditions and expected increase in drought occurrences, could lead to a shift of wine grape cultivation to cooler regions with more available water. This reason, paired with the prospects of higher income, would encourage producers to remove already established vineyards to plant alternative crops.

3.4.2 Stone fruit

Stone fruit grows well in the Little Karoo and flourishes in warm and drier climates. Stone fruit has a lower to medium winter chill requirement, depending on the cultivar. Certain stone fruit, such as apricots, thrive in areas with cold, dry winters and dry, hot summers. This makes apricots ideal for production in the Little Karoo (Kriel, 2021).

Unlike grapes, stone fruit completes its reproductive cycle within one growing season. In the southern hemisphere, after the stone fruit acquired enough chilling units to be released from dormancy, bud break, flower initiation, and differentiation starts. The bloom period starts in spring. In this period fruit set is determined. During fruit growth stage I (early development), cell differentiation and growth occur. This stage consists of embryo development, seed development, and fruit cell division. Stage II (fruit expansion and endocarp hardening) consist of an increase of water and assimilates uptake for cell expansion to take place. This stage is critical for the final fruit size. If water stress occurs during this phase there would not be enough turgor pressure (hydrostatic pressure) to promote cell growth. Stage III is characterised by colour development, sugar synthesis, phenolic development, and starch accumulation. Stage III continues till harvest time (Atkinson et al., 2016).

The length of these stages is dependent on the type of crop and cultivar, as some cultivars differ significantly in their growth periods. Fruit crop phenology can also be influenced by other external factors such as day length, temperature, water availability, rest breaking agents, pruning, and a variety of chemicals.

3.4.2.1. Apricots

Apricot trees possess a moderate ability to tolerate high pH soils and salinity but are intolerant to water logged conditions. Apricots, when not pruned, get fairly heavy as they tend to bear too much fruit. In general, most new growth and interfering wood is removed each year, exposing spurs to maximum sun interception (Siddiq et al., 2012). According to Perez-Gonzales (1992) the most important morphological traits of the apricot tree that correlates with fruit weight is tree growth habits, apical and basal diameter of fruiting spurs, and bud and leaf size. Therefore, yields can be controlled through cultivation practices to some extent.

Apricots require 700-1000 (dependent on cultivar) accumulated hours of temperatures under 7^{o}C for dormancy to break and the start of growth to occur (Theron, 2018). Bud break occurs from middle August to middle September. After bud break, reproductive growth starts and the formation of flower clusters follow. Flowering starts in late August to September, followed by fruit set and the beginning of ovary growth. In middle October fruits achieve 50% of their final size and full size reached in late October or early November. Colour development starts November followed by harvest in early December when fruit displays full organoleptic characteristics. Apricots have a relatively short growth period compared to other stone fruit such as peaches, since the final fruit size is relatively small.

Maturity and the harvest date of apricots depend on the change of colour from green to yellow and is cultivar dependent. Important qualities other than colour, includes fruit size, shape, and lack of defects such as pit burn or gel breakdown and decay. A soluble solid content (predominantly sugars) of over 10% and a moderate level of total acidity of 0.7-1.0% are critical for consumer acceptance.

According to a study done by Caprio and Quamme (2006) apricot production is favoured by high temperatures, 26^{o}C - 34^{o}C, but if temperatures increase beyond 37 ^{o}C, production is restrained. Therefore, it is expected that apricots will cope well with the predicted increase in temperature due to global warming. The response of apricot trees to high temperatures and water deficit depends on several factors but is mostly influenced by the cultivar and rootstock combination, with each cultivar having its own tolerance to stresses.

3.4.2.2. Peaches

Peach production is fairly limited to dry, continental or temperate climates. The reason for this limitation is peach trees requirement for winter chilling, thus excluding any tropical or subtropical regions. Chilling requirements for peaches are between 1 100 - 1 200 hours under 7°C (Theron, 2018). As with apricots, peaches require maximum sun interception and are therefore extensively pruned. Sun interception refers to the amount of sunlight that penetrates the leaf canopy and fruit bearing area.

The phenology of a peach tree occurs over a one-year cycle. After reaching the necessary chilling hours and an increase in day length and temperature, bud break starts. Flower formation and full bloom is reached in early to middle September which determines fruit set for the growing season. Fruit growth occurs from October till maturity is achieved and harvest starts in late January to middle March, depending on the cultivar.

Maturity and harvest are generally determined by fruit size and the peel background colour. In addition to these parameters, firmness, and soluble solids may also be added as additional parameters (Lurie et al., 2013). Peaches for processing are harvested near the tree-ripe stage to maximise fruit size, yield, quality and sugar content measured in Brix (Gradziel and McCaa, 2008). A major difference between cultivars for processing and those for the fresh market, is that processing peach cultivars are largely handled as a bulk commodity, requiring greater fruit durability and uniformity for bulk handling. A higher yield is required to compensate for the generally lower price for the raw product (Gradziel and McCaa, 2008). A small portion of cling peaches are used for drying. The market for dried fruit is relatively small but also quite stable. It is quite labour intensive with different labour requirements than usual, but makes for greater farm diversification.

As with apricots, temperature exceeding the cultivar's threshold will result in decreased production. Therefore, the response of peach trees to stresses is dependent on the cultivar and the selected rootstock.

3.4.2.3. Plums

The two main commercial types are Japanese plums (*Prunus salicina* L. and hybrids) and European plums (*Prunus domestica* L.). Both species are medium-sized stone fruit trees but differ notably in climactic requirements. European plums are cultivated in temperate climates as they require winter chilling to progress out of endodormancy and are relatively late flowering trees. Japanese plums grow better in warmer regions as they require less winter chilling temperatures and usually flower earlier (Torrecillas et al., 2018).

The cultivars mostly planted are Angeleno/Suplumsix and Laetitia, both Japanese type plums. The morphological difference between Japanese and European plums is that Japanese plums are cling stone fruits, the flesh "clings" to the pit and European plums has freestone pits. European plums are more frequently used in drying as it is typically sweeter than the Japanese counterpart but they are much more delicate. Japanese plums are more suitable for warmer climates and exporting. South African producers predominantly plant Japanese cultivars because imported varieties did not do well under South Africa's production conditions. Over the years, the Agricultural Research Centre (ARC) and other agricultural companies developed production standards and new varieties, some of which are still in high demand today, better suited to South Africa's climactic and production conditions (Byrne, 2005).

Plums require a winter chilling period of 700-1000 hours under 7^{o}C, depending on the variety planted (Theron, 2018). After sufficient winter chilling has been achieved and an increase in temperatures occur bud break starts, followed by the flowering period. The flowering period occurs from beginning September to end of September and lasts for 11 - 15 days, depending on the cultivar. Fruit set and fruit development follows the initial flower period and occurs until maturity is achieved. According to Sundouri et al., (2017) there is a relatively wide gap between the dates of maturity for the different cultivars. Some achieve maturity as early as the end of November to the end of February.

The inherent problem with early blooming and the vulnerability of flowers to early spring frost restricts plum adaptation. The lack of mid-winter tree hardiness results in damage and increased susceptibility to diseases and insects (Ramming and Cociu, 1991). The plum's flowers are not only susceptible to early spring frost but excessive wind can also lead to flower abortion. With the predicted heat increase for the Little Karoo, physiological disorders such as heat spot can occur. It is usually a consequence of high temperatures during fruit maturity, shown as concentric rings and sunken areas on Japanese plums (Ramming and Cociu, 1991).

3.4.2.4. Summary stone fruit

Problems with stone fruit production, such as reduced availability of water (rainfall and irrigation), reduced winter chilling and a shift in phenology (late or early blooming) are common amongst all fruits produced (Stöckle et al., 2011). Flowering occurs during early spring in many cultivars, therefore, external climactic conditions could also affect flowering such as frost or wind during pollination. The above-mentioned negative effects on production could be mitigated through cultivation practices. A positive aspect of the drier climactic conditions of the Little Karoo is that stone fruit are highly sensitive to waterlogged condition. Stone fruit such as plums and peached would suffer from root rot and fungal diseases.

3.4.3 Olives

Olive trees are alternate bearing trees. Thus, shoot growth and fruit development are cyclical and repeated on an annual basis. Vegetative growth is completed in the same year, while the formation of fruit needs two consecutive years. During the first year of the cycle, flower buds form and their floral induction takes place. In the following year, flower development and differentiation takes place followed by flowering, fruit set, growth, and oil accumulation (Torres et al*.,* 2017). The occurrence and development of alternate bearing is formidable in intensive orchards with controlled irrigation, nutrition, and training techniques. Without specific intervention, the gap between 'off' and 'on' years may very between 5 and 30 tons/ha, therefore, alternative bearing is of high economic importance. (Crop Guide: Growing Olives, 2021).

The southern hemisphere's flowering period starts September and lasts until the end of October. After flowering, fruit growth starts which can be divided into three phases. During phase I, cell division and cell expansion contributes to a large increase in fruit size, reaching 80% of its volume. In phase II, the endocarp progressively hardens and both the embryo and the endocarp reach its final size. Lastly in phase III, parenchyma cells of the mesocarp increases in size due to cell expansion and oil synthesis also begins. Harvest season usually begins in late February or early March with the picking of green table olives and it continues until the middle of August when the last of the late oil cultivars are picked (SA Olive, 2021).

Olive uses are separated into two categories namely oil and table olives. Cultivars have specific qualities aligning itself with either oil production, table usage or both. Oil cultivars, such as Frantoio, usually has an oil content of 18-20%, whereas dual olive cultivars such as Mission, has an oil content of only 12 - 16%. Table olives can be separated into two distinctive groups, namely black and green olives. Green olives are harvested unripe with black olives fully ripened (SA Olive, 2021).

Olive production thrives under cool winters and hot summer conditions. Olives require a short winter chilling period of only 200 - 300 hours under 7^{o}C (Theron, 2018). Olive trees are highly adapted to high temperatures with most olive production regions in the world averaging a maximum daily temperature above 30 °C in the hottest summer months. These trees are adapted to be resilient and withstand afternoon temperatures of up to 45°C. Although olives are relatively drought tolerant, they do require adequate water to enable them to produce on a commercial level. It would seem unlikely that climate warming will have a major impact, compared to other fruit trees, on production in the Little Karoo. A decrease in available water would negatively impact the production of this crop on commercial scale.

3.4.5. Almonds

The fruit of the almond tree is a drupe, with an outer hull and hard shell around the seed or 'nut'. Almonds require low winter chilling, only 200 - 300 hours under 7^{o}C (Theron, 2018). From early September bud break and flower development starts, continuing till the end of November where full bloom is achieved. In early December early fruit development can be observed, followed by pit hardening. Kernel filling is achieved by the end of January to early February, with hull split observed in February. Hull split is where the fruit's exocarp and mesocarp splits to reveal the almond nut on the inside, this stage is followed by harvest of the fruit and seeds in March (Yara Australia, 2021). Harvest consists of either hitting the tree to enable nut drop or to utilise machinery such as a shaker to "shake" the nuts loose. Harvested nuts are then left to dry or taken to a dryer to speed up the drying process in a more controlled environment.

Almonds are prone to alternative bearing. This is where a large crop load is expected one year with a small crop load the next. Researchers suggest that where high levels of a tree's energy and nutrient resources are used in one year, there are fewer reserves available for the spring flush in the following crop. This would be problematic for growers relying on yields to produce a profit.

3.5 Irrigation responses and management

Managing irrigation water is the act of timing and regulating applied water in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. It means applying water according to crop needs in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site (USDA, 2006)

According to Fernandes-Silva et al. (2019) research conducted over the past decade has shown some fruit crops respond positively to conditions of mild (less than 20%) water deficit imposed by deficit irrigation strategies. In this propagation practice, the amount of water applied is reduced to the value below maximal crop irrigation requirements, allowing for mild water deficit to occur with minimal effects on yield. This irrigation strategy is applicable to areas with limited water resources, such as the Little Karoo. Scheduling deficit irrigation for commercial orchards requires extensive knowledge of the soil water retention capacity, the specific plant's water requirements, plant water relations, and plant stress sensitivity according to their phenological stages (Fernandes-Silva et al., 2019). One must be aware of the response orchards and vineyards will have on deficit irrigation. The Little Karoo is currently facing water shortages and a decrease in precipitation due to climate change is predicted. Farmers should know how their crops will react to the deficit as certain crops might be more suitable or adaptable to these conditions. In this section the responses of different crops such as olives, peaches, grapevines, apricots and plums will be addressed as well as its specific response to deficit irrigation practices.

3.5.1 Response to deficit irrigation

3.5.1.1 Olives

Shoot growth of olive trees in the southern hemisphere takes place towards the end of winter. Some late growth is to be expected when fully irrigated. When deficit irrigation is in place, shoot growth will be reduced, negatively affecting the potential yield during the following year (Pierantozzi et al., 2014). Flowering is delayed when olive trees are under moderate water stress. This delay and a reduced flowering intensity, mostly leads to poor fruit set and a decrease in oil accumulation in the fruit (Torres et al., 2017 and Fernandes-Silva et al., 2019).

As mentioned, the growing phase of olives are comprised of three phases. During phase I, cell division and cell expansion contributes to a large increase in fruit size, reaching 80% of its volume. A mild water deficit during this phase will typically result in a small endocarp. Heavy water stress reduces the viability of the fruit itself. Phase II, with its slow growth rate, is less sensitive to water stress. During this process the endocarp progressively hardens and both the embryo and the endocarp reach its final size. Phase III, parenchyma cells of the mesocarp increases in size, due to cell expansion and oil synthesis begins. Water availability in this phase determines size and oil accumulation (Torres *et al*., 2017 and Fernandes-Silva et al., 2019). With cultivars such as Frantoio oil accumulation is necessary as the olives are not suitable, or desirable, for fresh consumption. Dual olive cultivars, such as Mission, can be used for fresh consumption although oil accumulation is low and size is small. Therefore, excessive water deficits can negatively impact producers who rely on olives for oil production.

3.5.1.2 Peach

Peach trees' response to water deficit irrigation differs between genotypes due to the length of some growth phases that differ from early-maturing and late varieties. The effect of deficit irrigation differs according to when it is applied. If applied during the vegetative growth phase it could lead to a decrease in vigour and vegetative growth leading to favourable fruit growth. According to Johnson, Hadley and De Jong (1992) deficit irrigation reduces pruning requirements due to a loss of vigour and increases flowering in the next season. Application of deficit irrigation at this stage cannot be applied in multiple consecutive seasons as vegetative growth would decrease, causing lower photosynthetic rates and assimilates production and storage. This leads to weaker fruiting in the following seasons. It should also not be applied during young tree stages as it will result in small trees with weak growth and small canopies thereby compromising orchard production.

Girona et al*.* (1993) concluded that a reduction of up to 30% deficit irrigation during fruit development only had a slight effect on production and fruit size. There is a slight decrease in fruit size but not a significant reduction under deficit irrigation. Fruit quality can be compromised under deficit irrigation.

Several authors, Fernandes-Silva et al. (2019) and Naor et al. (2005) contributed water stress to the formation of double fruits and fruit cracking which will result in lower yields of export quality fruit. A study done by Noar et al*.* (2005) attributed fruit cracking and double fruits to stem water potential lower than -2.0 MPa. This would mean that there is a certain limit to where deficit irrigation can be applied before size and quality is compromised. Water deficit irrigation during the final stage of fruit growth can increase the concentration of total soluble sugars (TSS) and flesh firmness. This; however, paired with smaller fruit sizes and a decrease in fruit juiciness (Lopez et al*.*, 2012).

For peaches, applying deficit irrigation, production is not significantly reduced as long as it is applied during a suitable phase. It should also be kept in mind that the varieties response and fruit maturation phases could well differ in response.

3.5.1.3. Grapevines

Grapevine phenology is strongly influenced by the climate and weather. The duration of each stage, bud break, flowering, and *veraison* (colour change of berries) is largely determined by temperature. Temperature influences the plant physiology, impacts the berry composition and therefore, the wine quality (Bonada and Sadras, 2014).

The cultivation of grapevines for wine, is a climate sensitive agricultural system. The predicted higher temperatures and less precipitation due to climate change might render some regions over the optimum range for the growing season. The expected decrease in precipitation in the Little Karoo will result in increased water stress conditions during critical stages such as bud break and *veraison*, for grapevines. Given the trend in climactic conditions, the grapevines will have an advance in phenological stages, shortening the growing season with maturation occurring much earlier than before.

Intense and persistent water deficits can reduce bud fertility via the fall in the number of inflorescences. Water deficits does not only affect the amount of inflorescence but also hinders flowering. Water deficits near the time of flowering may limit ovary growth, leading to a smaller berry size. The effect on pollen formation, germination, and pollen tube growth are more severe (Baeza et al., 2019).

Shortly after budburst, reproductive growth is relatively unaffected by water deficit. In the early stages of berry growth water deficits can restrict cell enlargement which leads to smaller berry sizes. Berries become increasingly resistant to stress from *veraison* onwards, therefore, water deficit plays a much larger role in yield formation before the onset of *veraison* (Baeza et al., 2019).

It is well documented that grapevine yields increase the more water is available. An increase in yield from excessive water is due to larger berry size that dilutes colour, aroma, and soluble solids leading to a drop in the quality of wine being produced. Water stress levels that are too high will result in declining vine capacity and productivity, eventually becoming economically unsustainable (Keller et al., 2016).

In viticulture production regions where water stress can decrease production, deficit irrigation can be used to balance vegetative and reproductive development. A fine balance must be maintained to ensure adequate berry size for yield targets to ensure economic viability. The prediction of higher temperatures for the Little Karoo, paired with lower precipitation would ultimately lead to a drop in net income due to a decrease in yield.

3.5.1.4 Apricot

Apricots responds similar to peaches to deficit irrigation. The duration of water deficit and the current physiological stage of the plant largely determine the response thereof. From a yield point of view the apricot tree has two phenological phases that are sensitive to water deficit. The first phenological phase is that of rapid fruit growth and the second is postharvest to the fruit tree. Smaller fruit is the result of water deficit during the rapid fruit growth stage. This is due to the lack of available water when cell elongation and division occurs and causes early ripening of fruit (Torrecillas et al., 2018). Water deficit postharvest reduces yield the following year due to an increase in young fruit drop, which will reduce final fruit set.

One of the apricot tree's characteristics is being able to handle deficit irrigation quite well. These characteristics are firstly related to the separation between shoot growth and fruit growth, secondly its ability to compensate for growth when full irrigation is restored and thirdly the fact that there are several phenological periods in which deficit irrigation does not influence the yield or fruit quality (Torrecillas et al., 2000 and Torrecillas et al., 2018)

According to Pérez-Pastor et al. (2014), regulated irrigation deficit provides similar yields to that of fully irrigated trees with moderate water deficits (-22% than that of fully irrigated). The period when water deficit irrigation was applied in the study of Pérez-Pastor et al. (2014) was before the beginning of the second rapid fruit growth stage and two months after harvest. As with peaches, the response of water deficit irrigation during the final growth phase can increase the concentration of total soluble sugars (TSS) and flesh firmness. This is paired with smaller fruit sizes. For the above-mentioned reasons apricots can be propagated with an effective regulated deficit irrigation strategy, since it can obtain similar yield and quality to that of fully irrigated trees.

3.5.1.5 Plums

A plum tree's response to water deficit irrigation varies depending on the fruit type as well as cultivar. The two main commercial species are Japanese plums and European plums.

In South Africa Japanese plums are mostly planted as most areas require trees that can tolerate higher temperatures. Intrigliolo and Castel (2012) concluded that the best deficit irrigation strategy would be during phase II of fruit growth, that short period of slow growth during pit hardening and embryo development and postharvest. This is to avoid a severe reduction in fruit size at harvest. During postharvest, different cultivars have a different tolerance to water stress. Thus, a model should be used to determine the amount of water stress that different cultivars can handle. According to Torrecillas et al., (2018) deficit irrigation should be applied with caution in young orchards where deficit irrigation could drastically reduce the canopy size.

In terms of fruit quality, Maatallah et al. (2015) concluded that deficit irrigation applied during fruit growth results in increased fruit firmness, soluble solids, total phenolics, and flavonoids. However, this improvement is paired with smaller plum sizes. Smaller plums have a considerable impact on this industry as it mostly focuses on export. According to Maatallah et al. (2015) deficit irrigation resulted in a weight loss of fruit by 18-24g and an average diameter loss of 1.7mm. Juice content percentage decreased from 54% to 45%, therefore, increasing firmness by an average of 19%. All the above-mentioned parameters are important for export quality of plums.

3.5.1.6 Almonds

A study done by Goldhamer et al. (2005) concluded that both preharvest and postharvest water stress levels are important for crop production. When deficit irrigation is applied at preharvest stage the cell differentiation and growth will be limited to the amount of water available. Water stress during postharvest and fruit development would lead to a negative impact on kernel weight and thus, production. It should be noted that smaller kernels not only reduce yields for a given fruit load, but processors pay less for smaller fruit (nuts). According to their study, deficit irrigation resulted in an average kernel dry weight loss of 14.4 %.

Deficit irrigation during postharvest negatively impacted crop load but would mean that kernel weight will remain the same as conventional irrigation. With the cultivar Nonpareil, the bulk of floral differentiation occurs during postharvest. It is thus critical to avoid postharvest stress during the stages of floral development as stress would reduce the following season's crop load.

Almond growers with limited water supply must balance potential yield reductions due to preharvest stress that leads to a reduction in kernel size and postharvest stress that lowers fruit load in the following season. Irrigation levels are cultivar-dependent, which determines the need to characterise each cultivar growth under deficit irrigation conditions (García-Tejero et al., 2020).

3.5.2 Conclusion of deficit irrigation effects

With the expected impact of climate change on the agricultural industry in the Little Karoo, producers will need to respond accordingly ensuring profitable crops in the future. According to Pascale et al. (2020) the average precipitation as well as the chances of extreme weather events occurring is set to increase if greenhouse gas levels continue to increase. Even with reduced greenhouse gasses an increase in global temperatures and shift in weather patterns is to be expected. The expectation for the Little Karoo is a decrease in precipitation and/or droughts will occur more frequently. It is expected that these changes will be paired with higher temperature, making production of crops more difficult.

A possible solution would be to apply deficit irrigation to limit the amount of water applied to land without significantly reducing the yield. Farmers can choose a crop based on the optimal water requirement and response to prolonged periods of deficit irrigation to ensure profitably. Some crops, such as apricots and peaches, respond more positively to deficit irrigation than other crops and will therefore be preferential when a drought occurs.

Deficit irrigation should not be viewed as a perfect solution to drier conditions. There are some negative effects on all the crops mentioned. It should only be used to reduce water when necessary or when regulated deficit irrigation scheduling can be optimised to maintain crop loads, quality, and tree health. Factors such as soil type, soil depth, soil water holding capacity, yield, tree age, orchard characteristics, environmental conditions, evapotranspiration, and cultivar influence the outcome of regulated deficit irrigation. Experiments should be done on individual farms to determine the best practices for regulated deficit irrigation. Based on the successful use of regulated deficit irrigation, the adoption of regulated deficit irrigation strategies in water-limited areas could be encouraged.

3.6 Conclusion

The Little Karoo is a region well suited for numerous mediterranean crops and is one of the largest producing areas of stone fruit in South Africa. This chapter evaluated six different perennial crops, commonly grown in this region. These include almonds, peaches, apricots, plums, wine grapes, and olives. These vary in their utility, used for wine, canned fruit, frozen fruit, fruit juice, jam, purée, and oil. Alternatively it is utilised as fresh products aimed at the export or domestic market.

Understanding crop phenology and plant reaction to certain soil and climate events is a vital part of production management. Understanding crops allow a producer to adapt and alter certain propagation strategies to either alleviate stress conditions or to improve current growing conditions. One such stress condition includes drought, where deficit irrigation can be applied to reduce stress within the orchard/vineyard. As irrigation and seasonal planning are key factors to be taken into account for decisions on an array of crops, a thorough understanding of these issues and options are required.

Chapter 4: Research technique

4.1 Introduction

The main aim of this research project is to identify and evaluate the various managerial and financial considerations for decisions on cultivar type in the Little Karoo. As indicated, the Little Karoo's climate is ideally suited for stone fruit, olive, and wine grape production. Almonds are also starting to gain popularity in the area. There are three factors that have to be considered when evaluating the different fruit types. First there are the physical/biological properties of matching fruit trees and vines with climate and soil. This was discussed in Chapters 2 and 3. The second important factor is profitability. Thirdly is the preference of the producer, but this falls outside of the scope of this research project.

To assess the expected performance of various fruits and vines a producer could include his basket of crops, requires a standardised method. The aim is to apply a method that can accommodate and include all the income and cost concepts of the different enterprises. One should also be able to make comparisons. The method should be user friendly and producers consulted to gain information, should be able to easily interpret the results. To adhere to all these requirements, budgeting is introduced as an applicable method.

4.2 Research orientation

Exploratory research principles were followed in this study. Although different farming practices are rather well established and well known, most producers do not include all the options available into their farming mix. To assess different fruit and vines options, require a generalisation of results into a more "typical" format, rather than site specific results. The aim is to identify and quantify different considerations, their relative importance and impact. The idea was thus to generate financial considerations that producers can relate to, but will need to be adjusted to exactly fit into a specific farm environment. A further challenge was that producers do not typically include all the possible options and varieties. Constructing a whole-farm model, which is the ideal tool to make provision for replacements etc., is thus not ideal, as it will not generate general considerations. Explorative research was thus conducted to ensure a better understanding of the general problems associated with the effect of climate change on selected crops. The study can be used as a basis for the future research of specific problems.

4.3 Research design

Budgets were constructed to determine the balance between potential income and crop water usage within the plant processes and stages that determine yield and fruit quality. These budgets allow for structure to determine income between different crops and different crop uses.

A budget is a financial plan for a defined period of time, usually a year. It may include planned sales volumes and revenues, resource quantities, costs and expenses, assets, liabilities and cash flows. Budget modelling is used in research to represent a real-world scenario that can indicate how different inputs affect outputs. Models allow for the evaluation of possible future outcomes (Hoffmann, 2010). Budget outcomes can then be compared to data and possible changes can be made.

Budgets embody several characteristics that allow for the successful implementation thereof. Some of these include;

- Providing structure to the user where it follows standard accounting principle, this allows for replicability of budgets.
- It entails easy use where inputs can be added or removed to manipulate and make predictions of outcomes.
- Budgeting is user friendly and logical, allowing producers to be part of the research project and to enable the use of outcomes as guidelines for future planning.

Budgets allow for systems analysis where physical/biological aspects can be integrated with an economic overview. Physical/biological parameters and inputs can be manipulated and will impact on the predicted economic outcome. Food prices and yield could for example be manipulated. When yield is decreased due to drought a physical change occurs and will have an impact on the total income generated, thus, physical changes will lead to economical change. It is therefore important for producers and researches to understand the financial impact of technical changes to the farm systems.

The type of budget used in this research is the enterprise budget. Enterprise budgets form the basis for constructing whole-farm, partial, and cash-flow budgets. An enterprise budget includes all the costs and returns associated with producing one enterprise in a particular manner. Enterprise budgets are constructed on a per unit basis, such as per hectare, to facilitate comparisons among alternative enterprises. An enterprise is any activity which results in a product used on the farm or sold at the market. Examples of enterprises include a hectare of pasture with cows producing calves, and a hectare of oats. A farm is made up of one or more enterprises, each requiring a certain combination of resources (Curtis et al., 2005)

Enterprise budgets are useful for estimating costs and returns on enterprises currently part of the farm plan, as well as new enterprises under consideration. Most enterprise budgets also list physical resources needed for production which is useful information for prospective new producers or producer switching to new enterprises.

An enterprise budget represents the expected costs and returns associated with a particular farm system. This means an enterprise budget constructed for one area may not be entirely applicable for another area, yet it could be used as baseline data or for comparison purposes. It is important to stress that these budgets are not averages but represent typical parameters to a common area. The enterprise budget provides the best means to evaluate the potential profitability for a given enterprise or farm income source. Developing an enterprise budgets allows for the identification of costs, both variable and fixed, and returns associated with the production and marketing of a product (Doye and Sahs, 2005).

By understanding the basic concepts and format of an enterprise budget, the producer will be better able to analyse the short and long term fiscal impacts and evaluate profitability.

This approach is used to determine the differences in characteristics of alternative crops to that of more tradition crops. Three main criteria: Rand per hectare, Rand per ton, and Rand per square meter of water, were integrated within the budgets of each of these crops.

The study is specific to the Little Karoo in the Western Cape, focusing on the northern part of the valley, within 10-20 km from the foot of the Swartberg Mountain. The main towns within this region is Montagu, Bonnievale, Ashton, and Robertson.

4.4 Assumptions

The crops used within this study include olives (oil and fresh), apricots (processing and fresh), peaches (processing and fresh), plums (fresh), almonds, and grapevines (wine grapes). Each of these fruit types consist of different cultivars with distinguishing characteristics. For wine grapes the three cultivars mostly grown in the region will be used for comparison. The financial performance for each of the other five crops (olives, plums, peaches, apricots, almond nuts) was calculated using the most common cultivar planted and/or available to producers. The crops used in the budgets are assumed to be in full production.

To obtain a meaningful comparison between selected crops, certain factors will be non-limiting and/or fixed. The basis for comparing these cash-flow budgets is one hectare in size, with a fixed layout. Industry norms are assumed for the row orientation (east-west to north-south degree), spacing, trellising, tree height, pruning methods, and harvesting methods (mechanical or labour). Site specific aspects of the production process will be assumed to remain fixed for all crops and include: soil composition, soil depth, slope, sunlight interception, meso-climate, temperature, natural precipitation, and day length. These factors are assumed to remain fixed across all budgets so that there are no limiting factors from one crop to the next.

For the model construction an area of one hectare (1 ha) is used. This is done so that it can be multiplied by any number larger than one. One hectare is also universal in expressing cost, application rates, yields, etc. when crops are compared or comparisons between areas or even countries are done. The model will span over one production year. For specific crop production, the industry norms were applied for the initial budget construction. These norms take into consideration pesticides, herbicides, fungicides, fertiliser, rest breaking agents, irrigation type, and seasonal labour. These budgets were then presented and discussed with local producers in the area to adjust the specific rates and practices of the area. The type of cultivar used for each crop will be that which is currently (2020) most prominent within this region or freely available to producers.

4.5 Data

Data from multiple sources was collected to construct an initial budget that was relatively accurate, to engage with producers on the model calibrations. The following data was obtained and used in the budgets. To determine the crop loads (kg/ha, ton/ha, or L/ha) of each crop, different sources were used to determine an average yield per crop (Sjöholm et al., 1989; SA Olive, 2018; Louw et al., 2017; Hortgro, 2019; Sawis, 2020; Vinpro, 2021; De Wet, 2021; Du Plessis, 2021; Thalwitzer, 2021; Joubert, AJJ, 2021; Joubert, F, 2021 and Steyn, 2021). Averages were obtained from multiple sources including articles, personal communications, and reports. The average was the most accurate way of deriving the central tendencies of the group of values, as certain yields was influenced by climate, soil, cultivation practices, and pests.

Table 4.1 is a summary of the aspects of the different crops.

Table 4.1 Orchard/vineyard dimensions information of selected crops

Crop	Cultivar	Tree (or vine) Spacing (m)	Tree/vine number /ha	Yield (ton/ha)
Wine Grapes	Chenin Blanc	2.5 x 1.6	2500	22.5
	Colombar	2.5 x 1.6	2500	17.5
	Sauvignon Blanc	2.5 x 1.6	2500	11
Plums (Fresh)	Angeleno/Suplumsix	3.5 x 2	1428	35
Peaches (Processed)	Keisie	4 x 2	1250	40
Peaches (Fresh)	Tiffany	4.5 x 2	1100	30
Olives (Fresh)	Mission	4 x 6	416	7
Olives (Oil)	Frantoio	4 x 6	416	8
Apricots (Fresh)	Bebeco	4 x 2.5	1000	27
Apricots (Processed)	Saldonne	5 x 3	666	42
Nuts (Almonds)	Nonpareil	6 x 4	420	3

Source: (Sjöholm et al., 1989), (Louw et al. 2017), (Hortgro, 2019), , (Sawis, 2020), (Vinpro, 2021), (De Wet L, 2021), (Du Plessis S, 2021), (Thalwitzer JM, 2021; Joubert AJJ, 2021; Joubert F, 2021 and Steyn, J-H, 2021)

4.6 Pricing and income assumptions

Income from fruit is not only determined by the number of harvestable fruits but also the use thereof. Prices for different fruit utility classes, such as export, local consumption, dried and processed, are determined by fruit quality. Quality is to some extent a subjective attribute which is determined by the intended target market. Different consumers have varying expectations when evaluating the quality of the product. An organically produced peach with numerous superficial lesions may be deemed high quality by one consumer while another may prefer the blemish-free appearance of a chemically treated fruit.

Several methods are used to determine a fruit's quality such as:

- Appearance - determined by size, shape, colour, sheen, defects (morphological, physical, physiological, pathological, entomological)
- Texture - firmness, softness, crispness, juiciness, toughness, mealiness
- Flavour - sweet, sour, bitter, astringent, aroma, salty
- Food safety – natural toxins, contaminations

All these attributes determine a fruit's quality. If fruit falls into the fresh export quality range the price obtained will expectedly be higher than that of processed (canned) exported. Fruit used for juice will generally be of the lowest quality.

To construct the model it was assumed that the "typical" producer already determined a target market. Fruit will be produced according to that standard. It is presumed that the producer will aim to grow the best quality fruit to ensure the highest income per hectare. The spread of each crop in fruit quality, classes, pools and/or usage, was obtained from local sources, literature, government sources, and personal communications. Prices fluctuate according to the global and local market. These fluctuations are caused mainly by inflation, demand, supply, policy, and the exchange rate. The specific prices captured in the model are for the year 2020 as the covid-19 pandemic has caused severe fluctuation prices. These fluctuations do not represent the real market as lockdowns and bans on certain types of trade caused artificial shortages, stock overflow, food spikes, and an extensive increase in exchange rate. Therefore, when the pandemic's shock subsides, prices should in theory return to pre-pandemic levels.

4.7 Cost assumptions

Some costs that have an impact on a producer's income can be controlled, while other cannot. For example, producers cannot always control the price or the yield they receive for their products, so the best possible option is to reduce the costs of production. They have the ability to reduce costs as it is relatively certain; however, input prices may carry risk factors.

Production costs for farming can be classified into two categories, namely variably costs and fixed costs. Variable costs consists of short term expenditures such as, fuel, fertiliser, hired labour, electricity, irrigation water, herbicides and insecticides, and packaging material. Fixed costs are costs that stay constant regardless of farm size. Examples would be capital costs of buying farm machinery, permanent labour and land rent. The enterprise profit of a farm is the gross income received minus the costs of producing (Louw, 2021).

Enterprise budgets provide a perfect platform to calculate how costs would impact the gross margin of a farm enterprise.

4.7.1 Direct allocated costs

Directly allocated costs are the costs of a resource used by a project, where the same resource is also used by other activities. It involves costs directly attached to a resource that can influence resource output. For example fertiliser, where the application has a direct impact on output, yield.

4.7.1.1 Pesticides, Fungicides and Herbicide

Pesticides, fungicides and herbicides are chemicals used to manage or kill pests that would cause harm or disrupt the fruit production cycle. There are different types of chemicals and powders available to kill or manage unwanted plants and insects. The benefits of pesticides include an increase in food production, profits and the prevention of diseases. Although pests cause harm to large portions of agricultural crops, without the use of pesticides, the damage done would have increased dramatically. Therefore, the use of pesticides, fungicides and herbicides have increased fourfold over the past half-century. Pests, such as mealybugs, fall armyworms, Xiphinema nematodes are some of the insects that can cause damage to crops.

Diseases such as fanleaf, phytophtera, leaf brown spot and vine trunk disease are some of the diseases that can plague an orchard. If insects and diseases are left untreated it can lead to loss of yield and even a loss of an orchard. They can have a large impact on the distribution of crops, for example crops damaged due to pests will be used for processing whereas undamaged crops are prime candidates for export, which would earn the farmer more income.

Each crop has a different requirement for pesticides, fungicides and herbicides according to the characteristics of the crops. Therefore, in the budget the different needs of each crop with regards to pesticides, fungicides and herbicides needs to be taken into consideration. The selected products have an impact on the production success of farming. One such product is glyphosate which targets a broad range of weeds and is important in the production of fruits, vegetables and nuts. It is effective at managing invasive and noxious weeds. In addition, glyphosate breaks down in the environment. It can be used for no-till and low-till farming which can reduce soil erosion and is useful for integrated pest management (EPA, 2021). Products used in pest and disease control can be used in conjunction or in an alternating pattern with other products to improve its efficiency and also to avoid disease resistance.

The specific cost requirements of each crop were obtained from varying sources to determine the average amount needed. If specific costs were not available, the application program was used to determine the amounts of each chemical or powder needed. The amount of chemicals and powders was then used to determine the costs by multiplying it by the price obtained from suppliers.

4.7.1.2 Fertilisers

Fertilizer is used to replace the nutrients crops remove from the soil to successfully complete their production cycle. Without the addition of fertilizers, crop yields and agricultural productivity would be significantly reduced. Mineral fertilisers are used to supplement the soil's nutrient stocks with minerals the crop can quickly absorb. Fertilisers can also improve soil quality and reduce internal mineral deficits. Each crop has different requirements for nutrients, depending on the crop load, tree density, type of fruit, fruit size, fruit colour, and fruit growth.

Each crop's fertiliser requirements are calculated in the budget by using the average costs from a number of sources. If the specific costs were not available, the application program was used to determine the amounts needed for each component. The amount of fertilisers was then used to determine the costs by multiplying it with the price thereof, obtained from suppliers.

The main fertilisers used are Nitrogen, Phosphorus and Potassium, but for specific fruit trees a group of micro elements are often also required. Fertilisers are mostly applied through the irrigation systems but in some instances also by physical spreading. Micro elements are often applied through leaf spray methods. Thus the cost of application may differ. Monitoring is an essential management requirement. Soil samples at various depths, especially before planting, are important. Leaf sampling may also be required during the lifespan of the trees. Corrective actions are too costly in terms of potential losses and the associated time window for corrections to have an effect. If plant resilience is lost it will be more exposed to disease and pests and it will be more easily affected by drought and heatwaves.

4.7.1.3 Pollination

The cost of pollination was determined by cultivar characteristics. Some cultivars are self-pollinating. If cultivars are not self-pollinating, tree pollinators need to be used to promote cross pollination of the orchard trees. Contracting honey bee pollination services is commonly used and the cost well documented.

4.7.1.4 Water and electricity

The cost of water was determined by using the current government prices of agricultural water supply for the area and multiplying it by the amount of water given per hectare per year (m^3/ha/yr). It is important to note that in the Little Karoo the water scheme cost differs depending on distance and elevation from the central CBR dam outside Montagu.

4.7.1.5 Labour

Seasonal labour costs were determined by the number of workers needed as per cultivation practice such as thinning, harvesting, pruning, pest control, and sometimes mechanical deweeding. The number of labourers were multiplied by the amount of time it would take to complete a certain cultivation practice, for example harvesting. When the number of months worked had been calculated, the national minimum wage per month (R4 229.22) was used to determine cost per annum. The time of activities are based on industry norms and verified through various sources such as Hortgro, Vinpro, and personal communications.

4.7.1.6 Packaging

Packaging is only applicable to fresh fruit as it needs to be packed in cartons, and/or wrapped in plastic to be sold on various export market destinations or the domestic market. Packaging protects the contents from external sources such as heat, moisture, odours, and in some cases light. It keeps fruit from rubbing, moving, colliding, and jolting which causes damage and render the fruit undesirable. Processed fruit is transported directly to the processing plant without the need of any packaging. The packaging cost used in the budgets also accounts for any process in relation to packaging which includes washing fruit, sorting, and/or dipping in a wax layer. Costs were obtained from Hortgro's (2019) stone fruit budgets. Specific packaging costs will be determined by the requirements of the different market destinations.

4.7.2 Non-directly allocated variable costs

Indirect costs are costs that can't be directly assigned to the end product or process. These costs are not directly applied to the physical products, but are linked to the product through other channels. An example would be diesel used in tractors enabling harvesting and the transport of fruit.

These costs can also be divided into fixed and variable costs. Variable costs include machinery maintenance and repairs, which is dependent on the use of machinery. Fixed costs include licences and depreciation which are not captured here but forms part of fixed and overhead costs.

4.7.2.1 Fuel

Fuel costs include all petroleum products, diesel or petrol, used in equipment to perform tasks within or around the orchard. This includes tractors used for a myriad of tasks such as, spray application, fruit transport, worker transport, machinery transport, mulching, and orchard floor management. Fuel costs can also include any transport via truck, pick-up trucks or cars used to perform tasks related to the orchard and the management thereof. These costs are associated with a specific enterprise and/or can be allocated to such an enterprise. Oil and lubricants are also included under fuel cost.

4.7.2.2 Repairs and maintenance

These costs are associated with normal wear of machines and implements. Repair and maintenance cost is applied to a vast array of equipment and machinery. Any mechanised equipment needs to have scheduled maintenance done to function properly during future use. Manual equipment, such as hand tools, is used extensively for harvesting, pruning, topping, and thinning. Degradation takes place thus constant repairs like the sharpening of pruning shears must be done in order to work efficiently. If any equipment hand or mechanised, is used without proper maintenance it can cause damage of orchard trees and even harm labourers. The most costly effect is inefficient labour, which is expensive. These costs vary among producers as equipment and usage scale differs, thus these figures were obtained from Hortgro's (2019) stone fruit budgets and Vinpro's Cost guide 2021/2022 (2021).

4.7.2.3 Transport

Transport cost is calculated by using the total running cost of transportation from one location to another. The cost was calculated by using the costs of a single truck load per km. This was then divided by the tonnage to correlate with one hectare yield to obtain a formula of R/km/ton. Processed fruit's transport cost is considerably less than that of export fruit, as the processing factories is located within the Little Karoo district. Ashton is host to one of the biggest processing facilities, located within the centre of the area between Montagu, Robertson and Bonnievale. Processed fruit is only has to be moved between 15km to 30km. Export fruit needs to be transported to the harbour located in Cape Town, which is between 157km and 187km from the Little Karoo area. The cost was calculated by using the fixed costs per km and adding the total rate charged by transport companies (Goldfields Logistics, personal communication, 2021). This figure was then divided by the amount of fruit one truck can carry at a given time to determine the farmer's cost (R/km/ton). Tonnage obtain from fruit per hectare was multiplied by this number and the total distance to travel, plus the charges of renting the required number of trucks.

4.7.3 Overhead Costs

Overhead costs are assumed to remain the same for each crop. These costs are applied to the area of land, which is one hectare. Since every crop uses the exact same land with the exact same layout and only planting distances differing, the costs remain consistent. These costs include electricity (factor of irrigation quantity), water (for worker consumption), fixed labour, general costs, and other overhead costs.

4.8 Water Usage

Specific irrigation requirements are determined by numerous physical factors. These include slope, soil depth, soil composition, soil water holding capacity, soil evaporation, root depth, plant transpiration, and plant water requirements. Since the area studied is widespread with various combinations of physical factors, specific irrigation requirements will differ. A number of sources were used to determine the average water application by various producers for conventional cultivation practices.

Climate factors such as rainfall patterns, temperatures, and wind were also kept constant for each crop. The reason was to eliminate variables that will lead to a change in results that was not directly related to the crop.

Table 4.2: Irrigation application of selected crops

Crop	Irrigation (m^3 water/ha/yr)
Almonds	7 300
Apricots	5 000
Peaches	6 700
Plums	6 200
Olives	5 000
Grapes	5 500

Sources: (Kriel, G. 2019), (Vinpro, 2021), (Kriel, G. 2021), (De Wet, 2021), (du Plessis, 2021), (Thalwitzer,2021)

Irrigation application as presented in in Table 4.2 was determined by the average irrigation water (m^3) applied per hectare (ha) over a period of a single year.

4.9 Establishment costs

Establishment costs include expenses and asset purchases associated with initial planting activities. These costs were calculated including planting material, land clearing and soil mapping, land preparation and ridging, irrigation, drainage, and trellising.

Plant material was calculated using cost per tree multiplied by the total amount of trees per hectare. Olives and almonds require the least number of trees per hectare at 416 and 420, reducing the total cost of planting.

Land clearing and soil mapping, as well as drainage, was kept constant as one of the assumptions is that the soil location and properties remain constant.

Land preparation and ridging as well as irrigation differ from crop to crop due to row spacing. Higher density planting requires more ridges and irrigation networks per hectare, thus increasing costs. Trellising is only needed for those crops that require it, thus also increasing costs considerably as the material is expensive and a large amount is required.

Table 4.3: Establishment costs of different crop types

	Almonds	Apricots (Processed)	Apricots (Fresh)	Peaches (Processed)	Peaches (Fresh)	Plums	Olives	Vine grapes
R/ha								
Plant Material	16 800	30 637	46 001	72 963	64 028	85 005	26 624	45 884
Land clearing & soil mapping	42 267	42 267	42 267	42 267	42 267	42 267	42 267	39 370
Land preparation & ridging	23 689	37 902.4	37 902.4	47 378	47 378	47 378	23 689	38 980
Irrigation: design & material	27 500	30 382	34 328.8	37 911	37 911	37 911	27 500	38 918
Drainage	29 053	29 053	29 053	29 053	29 053	29 053	29 053	29 053
Trellising	0	0	0	0	0	69 492	0	53 060
Total	139 309.00	170 241.40	189 552.20	229 572.00	220 637.00	311 106.00	149 133.00	245 265.00

Sources: (Hortgro, 2019); (Louw et. al. , 2017) (Western Cape Government, 2015)

According to Table 4.3 the least expensive crops in terms of establishment is almonds and olives since they are spaced further apart requiring less planting material and fewer ridges. Plums are the most expensive due to the large number of trees per hectare as well as large costs towards trellising. Shade nets were not included as it is not seen as typical but it is gaining popularity. The use of shade nets is also seen as possibly improving water management. Currently the benefit is associated with fruit quality due to limiting sunburn and other defects. It is expensive and the benefit for stone fruit is not as obvious as is the case for pome fruit in colder areas (De Beer, 2021).

4.10 Conclusion

The information required includes factors that influence income, production cost, and establishment cost. This information was used to construct budgets for the selected crops. For a meaningful comparison all external factors were kept fixed and excluded in calculations. Industry norms were applied for the selected crops with cultivars mostly used or freely available to producers. Costs were calculated by including activities and costs applied to cultivate a certain crop. These include, fertiliser, pesticides, herbicides, fungicides, labour, pollination, and packaging. These costs are seen as directly allocated costs. Additional costs such as average fuel, maintenance, transport are seen as non-direct costs. Other costs such as overhead costs remain the same for each crop. These costs are applied to the physical land, with the assumption that every crop is cultivated on the same piece of land therefore, remaining the same for each crop.

The gross margin is calculated for each crop to allow comparison between one another in terms of income generated in a single production year. The income is then compared to water usage by each crop to establish the ratio between income and water usage.

Chapter 5: Results

5.1 Introduction

This chapter provides the results of the enterprise budgets. The results are broken down into different categories, allowing comparison between different crop types. It also serves to show how each aspect contributes to the overall suitability of the crop as used in production. The discussion includes multiple factors such as, water usage, labour, capital requirements, practical considerations, and profitability.

The generated information paired with practical and theoretical information should conceptually contribute to crop selection by producers and other industry role players. Different decision-making options are presented to show how each will affect overall production and outcomes.

5.2 Gross margin and water requirement

The results for the different crop budgets are summarised and specified. This is to compare different crops and their specific criteria.

Table 5.1: Budget example

Almonds		
	Item	**Yearly Total**
Almond production (kg/ha)	Whole kernal	2 850
	Sliced	150
	Production yield	3 000
Production income	Whole kernal	242 250
	Sliced	6 000
	Total income	248 250
Production expenses	**Direct allocated costs**	
	Fertiliser	20 687
	Pesticides	6 280
	Herbecides	4 100
	Fungicides	8 781
	Seasonal labour*	21 146.10
	Pollination	3 000
	Water	462.82
	Non-Direct allocated costs	
	Fuel	10 274
	Repaires and maintenance	12 689
	Transport	662.27
	Total Costs	87 419.92
Buto margin		160 830.08
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Gross Margin		130 320.08

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Harvest	12 687.66
	Pest control	4 229.22
	Pruning	8 458.44
Total		21 146.10

The above budget example is the format used for the budgets in the research study.

Table 5.2: Results obtained from budgets

Crops	Yield (Ton/ha)	Gross margin(R/ha)	Water requirement (m^3/ha/yr)
Almonds	3	R 130 320.08	7 300
Apricots (Processed)	42	R 110 149.60	5 000
Apricots (Fresh)	30	R 119 676.37	5 000
Peaches (Processed)	45	R 106 091.62	6 700
Peaches (Fresh)	30	R 130 043.89	6 700
Plums (Fresh)	27	R 119 787.77	6 200
Olives (Fresh)	7	R 31 609.36	4 700
Olives (Oil)	8	R 91 609.36	4 700
Grapes (Chenin Blanc)	22.5	R 33 559.84	5 500
Grapes (Colombar)	17.5	R 14 615.11	5 500
Grapes (Sauvignon Blanc)	11	R 30 949.47	5 500

Table 5.2 shows the two most prominent factors, net income and irrigation requirement. Gross margin generated by price per ton per hectare minus the costs of producing the crop. Irrigation requirements were derived from personal communications and literature.

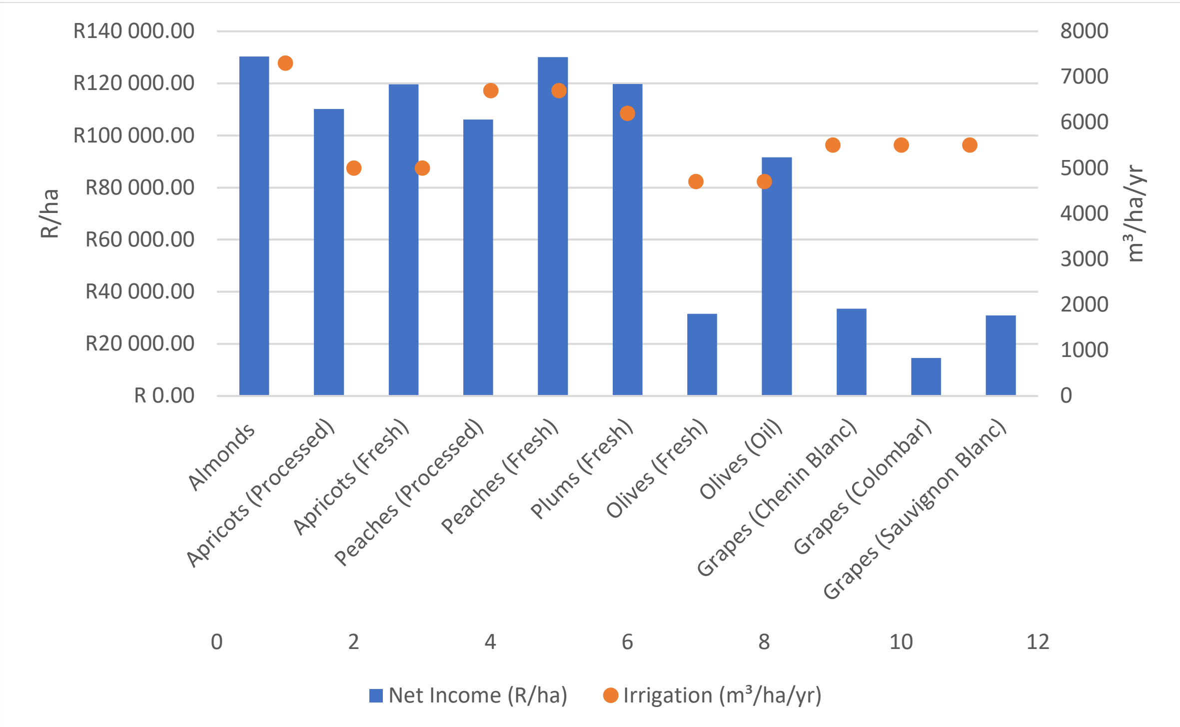


Figure 5.1: Graphical relation of water to income generated.

Source: Own calculations

Table 5.3: Income to water ratio for different crops

Crops	Income: water ratio (R/m³)
Almonds	R 17.85
Apricots (Processed)	R 22.03
Apricots (Fresh)	R 23.94
Peaches (Processed)	R 15.83
Peaches (Fresh)	R 19.41
Plums (Fresh)	R 19.32
Olives (Fresh)	R 6.73
Olives (Oil)	R 19.49
Grapes (Chenin Blanc)	R 6.10
Grapes (Colombar)	R 2.66
Grapes (Sauvignon Blanc)	R 5.63

Table 5.3 and Figure 5.2 illustrates the ratio of income generated per single unit of water (m^3) applied. In this table emphasis was given to both income and water application.

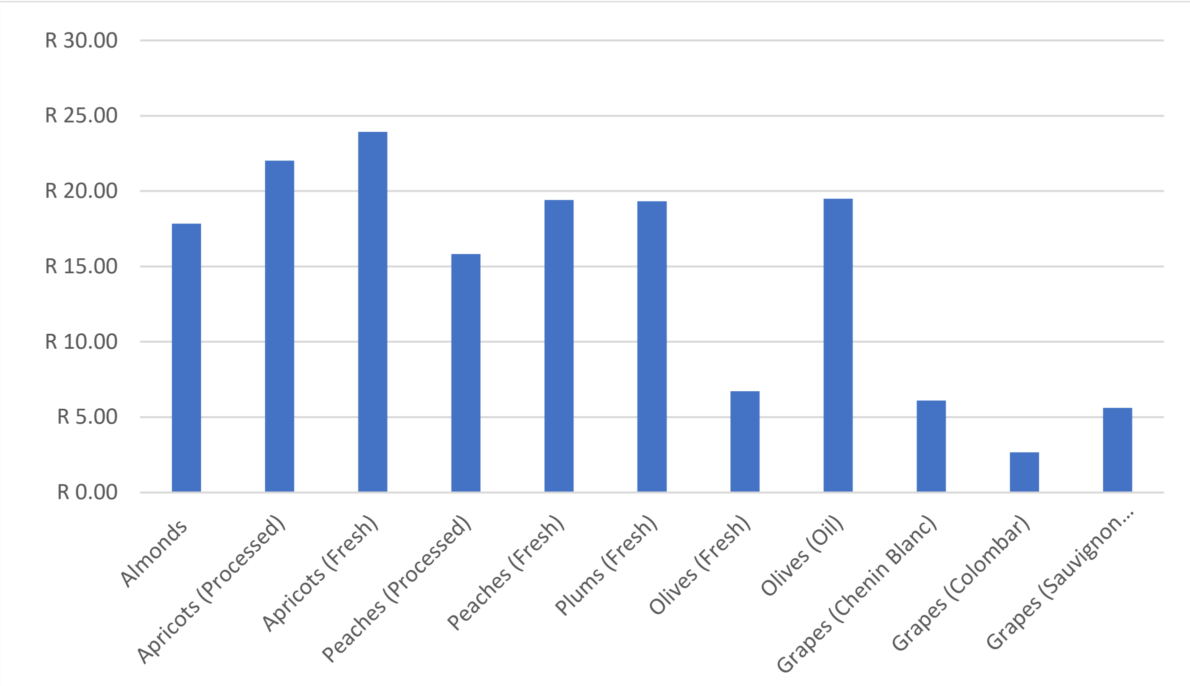


Figure 5.2. Income to water ratio for different selected crops

Income is determined by two factors, yield and price. The price to yield ratio is critical for profitability. If any of these two factors decreases, the overall profitability will decrease.

Table 5.4: Prices of different crops classes and styles.

Crops	Class and style	R/kg (R/L)
Almonds	Whole	R 85.00
	Dicing	R 40.00
Apricots (Processed)	Processed Class 1	R 5.50
	Processed Class 2	R 3.00
Apricots (Fresh)	Class 1 (Export)	R 21.30
	Class 2 (Local sales)	R 11.22
	Class 3 (Juice)	R 3.00
Peaches (Processed)	Class 1	R 5.20
	Class 2	R 3.02
	Class 3	R 1.10
Peaches (Fresh)	Class 1 (Export)	R 28.70
	Class 2 (local sales)	R 11.03
	Class 3 (Juice)	R 1.20
Plums (Fresh)	Class 1 (Export)	R 17.86
	Class 2 (Local sales)	R 6.32
	Class 3 (Juice)	R 1.00
Olives (Fresh)	Local fresh market	R 15.00
Olives (Oil)	Local fresh market	R 55.00
Grapes (Chenin Blanc)	Cultivar	R 4.24
Grapes (Colombar)	Cultivar	R 4.31
Grapes (Sauvignon Blanc)	Cultivar	R 8.22

5.3 Considerations on fruit and cultivar choice

The main purpose of this research project was to identify the factors that need to be considered for crop selection in the Little Karoo in terms of WUE and income generated. Budgets provide an indication of the potential profit that can be generated per cultivated hectare. Literature provided evidence on crop growth characteristics and WUE.

5.3.1 Climate

The drought that occurred in the Western Cape from 2015-2017 has by 2021 not fully subsided in the Little Karoo. Areas such as Drakenstein, Stellenbosch (Wemmershoek) and the Swartland have all reported recovering rainfall at or above the regions historical average. The Little Karoo (Robertson, Montagu, Bonnievale and Ashton) has not yet received that relieve. According to Figure 2.9 the annual rainfall for the area is still far below the average. If this decrease in rainfall continues, producers who rely on irrigation will also suffer. As shown by Figures. 2.7 & 2.8, when dam levels are below a certain agreed upon threshold, water from large dams that was usually used for irrigation will be diverted for urban use, leaving producers without adequate irrigation water. Even when receiving adequate rainfall, available irrigation will have a delayed effect as catchment dam levels need to be increased before water can be used again.

Climate change accentuated the severity of the drought of 2015-2017. Increases in global surface temperatures resulted in disturbances in climate patterns leading to adverse weather events. El Niño is one such event and is considered to be the main cause for the drought, although it cannot be the only factor to consider. Due to higher global surface temperatures the poleward expansion of the Hadley cell is to be expected. The shift will cause aridification of the more southerly parts of South Africa leading to drier conditions and rainfall deficits, especially in the Karoo and Little Karoo. According to Pascale et al. (2020) climate change effects will become more severe in the Western Cape with the chances of droughts increasing by 5.5 times in the coming century. According to their model the high-emission scenario will increase the probability of an extreme weather event such as the drought of 2015-2017 by 20% around 2045 with the intermediate emission scenario increasing the probability by 13% by 2045. If the high-emission scenario continues the probability would increase to 80% by the end of the century. If a decrease in rainfall persists paired with another drought in the future, it will result in devastation for the area's agricultural production capabilities.

With a predicted decrease in rainfall and increased probability for droughts, irrigation will be the limiting factor for crop production in this region. Water stress adversely impacts many dimensions of the physiology of plants, especially their photosynthetic capacity. If the stress is prolonged plant growth and productivity are severely diminished (Osakabe et al., 2014). Producers will have no other choice than to adapt to the changes. This could be done by planting better suited crops and improved water saving production techniques. WUE, a parameter of crop quality and performance under water deficit is an important selection trait. Producers cannot adapt to water scarcity at the cost of ensuring sufficient income, as this would be uneconomical and would devastate the region's agricultural prominence.

5.3.2. Chilling requirements

The mechanism in which the crops will cope physiologically with these potential temperature increases needs to be taken into consideration. Fruit that grows in a temperate climate requires winter chilling. Insufficient chilling hours can adversely affect many types of plants. Fruit trees may leaf out and flower late, set less fruit and become weak and vulnerable to pest and disease infestation. Knowledge of the typical chill accumulation for the region and fruit should be one of the primary decision criteria in choosing suitable cultivars. Peaches require the highest number of chilling hours at 1 100-1 200 hours under 7°C, followed by apricots and plums at 700-1 000 hours. Olives and almonds only require 200-300 hours, making them more suitable for the predicted temperature increases. However, rest breaking agents (RBA) can be used to reduce the negative effects of insufficient winter chilling. Their effectiveness depends on application date, concentration, chemistry, and cultivar.

5.3.3. Water requirements

Income potential is key to the agricultural business and mostly the producer's primary goal. The drought of 2015-2017, predicted future droughts and generally drier conditions, water management and water use efficiency must be the predominant factor to consider for future crop production. Several factors need to be taken into consideration related to water management. The main factor is the amount of water that the crop needs to successfully complete its production cycle and produce good quality fruit. The crop that uses the least amount of water is olive trees. It requires only 4 700 (m^3/ha/yr) to produce fruit without incurring water stress. Then it is apricots with 5 000 (m^3/ha/yr), followed by grape vines at 5 500 (m^3/ha/yr). The crop that requires the highest amount of water is almonds, requiring around 7 300 (m^3/ha/yr) making it 64.4 % more water dependent that olives.

Even though olives require the least amount of water, other physiological factors make it less water efficient. Olives are prone to alternate bearing resulting in one year of high yields following by a year of low yields. Throughout the low yield cycle water is still required to promote tree health and vegetative growth.

Apricots are the best choice when only considering water use. Apricots produce adequate yields within each season. Another factor that favours apricots as the most water efficient is the length of the growing season. Apricots have the shortest and earliest season of all the other fruits, nuts, and grapes according to annexure A. During the flowering and fruit forming period water application requirement is the highest, stone fruits are especially sensitive to water stress during the last two weeks prior to harvest. Therefore, irrigation for apricots is critical from September to early December when harvest takes place. The other fruit types, almonds and grapes require irrigation until January, February, and March when their respective harvests takes place. Irrigation during January and February is critical for plant health as these months are the hottest throughout the calendar year, as shown by Figure 2.10. During this period irrigation is influenced by the increase in crop water requirements due to excess heat. The need for irrigation also increases due to a loss of water through means of soil evaporation. Irrigating the optimal amount of time to bring the soil back to saturation will maximise evapotranspiration during hot days, and should prevent or limit heat damage to crops. Water application efficiency for apricots is higher compared to other crops as the high water demand period is shorter and irrigation demand is lower during high evaporative times.

Frost contributes to the amount of water applied. With a predicted increase in variability of weather patterns, frost can become more frequent. Frost can cause severe damage to crops and yields. Mitigating measures should be in place to allow for a quick response. Mitigation measures involve sprinkler systems to distribute water. The water freezes and encases the tree in ice. As the ice encases the plant it partially insulates it from the harsh exterior temperatures mitigating frost damage. However, this measure increases water consumption.

With the probability of more and longer droughts, adaptation to these harsh conditions is required. Therefore, the crops response to deficit irrigation could become crucial. Fruit grown for export markets will expectedly not respond well to deficit irrigation as there is a decrease in fruit size and quality to an extent. These parameters are important when looking to comply to export requirements and regulations. For example, if fruit does not comply with a certain size and weight it might not be approved for export, leading to a loss of income. Processed fruit used in jams, juices, and purée can be irregular in shape or have a decrease in size without being demoted to a lower class. Grapes and olives (oil) exclusively used for juice/oil extraction will also be negatively influenced by deficit irrigation as juice/oil content decrease under water stress conditions. Stone fruit such as peaches and apricots are better suited for deficit irrigation and can cope with a decrease of 20% to 30% and still produce adequate crop yields. Deficit irrigation is better suited for apricots and peaches. All fruit can be propagated with deficit irrigation as long as the right scheduling is applied with regard to irrigation and phenological timing.

5.3.4. Labour and production activities

Labour requirement is an important factor to consider as it can account for 20 to 50 % of the total cost of production. The cost of labour is not the only factor to consider but also the time window of certain activities such as harvest, pruning, and thinning, as well as the availability of labour within these time windows.

The most important window is that of harvesting. The physiological stage at which the fruit is harvested is important for quality indicators, such as taste, texture, size, colour, and aromas. Fruit can only be harvested during a certain window of opportunity, where after the fruit is overripe and not be suitable for utilisation or exporting. This is referred to as the harvesting window.

Fruit should be harvested at the optimum stage of maturity in order to be utilised according to its potential. Fruit, during its lifetime goes through a pre-climacteric, climacteric, and post climacteric phases, which includes senescence. When the onset, duration, and termination of these phases are known, fruit can be managed accordingly. These changes in fruit physiology are referred to as changes in maturity.

The start of the harvest window is defined as the fruit reaching physiological maturity. Export fruit must maintain its characteristics despite travelling long distances to international destinations. Such fruit needs to be harvested at the correct stage to allow it to ripen to good eating quality after a period of storage. It is thus the absolute minimum maturity for harvest and the fruit should not be presented for immediate consumption. These fruits are picked soon after the harvest release date and will ripen normally but will only develop an acceptable taste after storage and ripening. Processed fruits are harvested riper but within a strict time frame as fruit will soften and not be eligible for certain processing activities resulting in the degrading of fruit. Overripe fruit is not ideal for canning purposes.

Both export and processed fruit needs to be harvested within a certain harvest window. Failure to do so will lead to a loss of income due to the degrading of fruit. Export fruit carries the most risk as the price of good quality (Class 1) and lower quality (Class 2 and 3) differs by as much as R 17.00 per kg, resulting in a potential higher forfeit of income than that of processed fruit which only differs by R 2.00/kg.

If the time window of the harvest period is taken into consideration, as presented in Annexure A, apricots have the smallest harvest window. Harvesting an average of 42t/ha for processed and 30t/ha for fresh fruit in such a limited window will increase the number of workers needed as well as the cost of employing the workers. Any delays in this period will lead to large quantities of fruit loss and lower fruit quality. Therefore, the longer the harvest period the fewer labourers are needed and with less associated risk. Crops such as vine grapes, almonds, and olives can be mechanically harvested. Equipment such as a “shaker” and grape harvester reduces the seasonal labour requirement. This type of equipment initially requires a high level of investment and will need to be paid off after a few seasons. The equipment is also prone to depreciate and thus replacement needs to be provided for.

Thinning is the practise of removing selected fruits from trees to allow the remainder of the fruits to increase in size and/or to promote overall fruit set. Thinning is a method used to improve the following year’s harvest. Heavy yields in one year can lead to a depletion of tree carbohydrates and result in poor yields the following year. The thinning time window depends on the type of fruit, for example apricots with a shorter growth period will have a smaller window. Only selected fruits are removed based on practical experience and or knowledge, thus it is less labour intensive than harvest and can differ slightly from one season to the next. Crops such as olives and almonds require minimal to no thinning as these crops are cultivated in a manner that requires higher yields. This inherently results in less labour needed to cultivate. Trees such as plums are prone to over-cropping, resulting in thinning being vital for successful production.

Pruning is the activity of removing shoots and/or buds to achieve a certain fruit set and or to improve tree architecture, such as light interception. Pruning is a standard practice with crops such as grape vines and some deciduous fruits. Pruning is determined by the desired outcome of the producer. Some producers do not prune crops at all, therefore, it is up to producers to decide if and how intense they want to prune. Certain crops have characteristics paired with minimal pruning such as olives and almonds. The time window is fairly long for most crops as it is done during winter when most trees and vines are dormant. The intensity of pruning determines the amount of labour needed for a season.

5.3.5. Capital requirements

Capital requirements are determined by a number of factors as shown in Table 4.3. An important cost is that of plant material which incorporates a large percentage of the total costs. The tree density of the orchard is also important in determining the costs of establishing the orchard. Orchards with large number of trees per hectare (higher density) will inflate the total costs.

Table 5.5 Comparison of conventional planting and high-density planting (HDP)

Crops	Price per unit (R/crop)	Conventional Trees /ha	High density (HDP) trees/ ha	Conventional (R/ha)	HDP (R/ha)
Almonds	R 40.38	416	1666	R 16 800	R 67 280.77
Apricots (Processed)	R 46.00	666	2000	R 30 637	R 92 003.00
Apricots (Fresh)	R 46.00	1000	2000	R 46 001	R 92 002.00
Peaches (Processed)	R 58.37	1250	2222	R 72 963	R 129 699.03
Peaches (Fresh)	R 58.21	1100	2222	R 64 028	R 129 336.56
Plums (Fresh)	R 55.78	1524	2500	R 85 005	R 139 443.90
Olives (Fresh)	R 64.00	416	1666	R 26 624	R 106 624.00
Olives (Oil)	R 64.00	416	1666	R 26 624	R 106 624.00
Grapes (Chenin Blanc)	R 17.20	2667	5556	R 45 884	R 95 587.37
Grapes (Colombar)	R 17.20	2667	5556	R 45 884	R 95 587.37
Grapes (Sauvignon Blanc)	R 17.20	2667	5556	R 45 884	R 95 587.37

As seen in Table 5.5 the total number of trees has a huge impact on the establishment costs of an orchard. High density planting will result in more yield/ha but will be offset by the high costs.

Crop density has an impact on the amount of irrigation and ridging required. A denser orchard will have more rows per hectare and therefore more irrigation material and ridges will be needed. Orchard planning is important to fully utilise space for crops and to calculate the total costs attached to the orchard. Land clearing, land preparation, and drainage costs are inherent of the farm location and the characteristics of the land and soil. Therefore, these costs will differ from farm to farm as some factors wouldn’t need to be addressed.

Table 4.3 shows that almonds need the least amount of establishment costs followed by olives. This is due to the low amount of plant material needed paired with fewer irrigation pipelines and ridges. However, the low cost of almonds and olives can be drastically increased by the purchase of a mechanical harvester, which can be as much as R1 million to R1,8 million depending on the type and level of equipment (Sperandio et al., 2017). The purchase and use of mechanical equipment is the producer’s choice.

Table 5.6 Manual labour vs machine labour

	Almonds (1ha)	Olives (1ha)	Almonds (10ha)	Olives (10ha)	Almonds (30ha)	Olives (30ha)
	Seasonal labour	Seasonal labour	Seasonal labour	Seasonal labour	Seasonal labour	Seasonal labour
year 1	R 21 146.10	R 18 677.66	R 211 461.00	R 186 776.60	R 634 383.00	R 560 329.80
year 2	R 42 292.20	R 37 355.32	R 422 922.00	R 373 553.20	R 1 268 766.00	R 1 120 659.60
year 3	R 63 438.30	R 56 032.98	R 634 383.00	R 560 329.80	R 1 903 149.00	R 1 680 989.40
year 4	R 84 584.40	R 74 710.64	R 845 844.00	R 747 106.40		
year 5	R 105 730.50	R93 388.30	R 1 057 305.00	R 933 883.00		
year 6	R 126 876.60	R 112 065.96	R 1 268 766.00	R 1 120 659.60		
year 7	R 148 022.70	R 130 743.62	R 1 480 227.00	R 1 307 436.20		
year 8	R 169 168.80	R 149 421.28	R 1 691 688.00	R 1 494 212.80		
year 9	R 190 314.90	R 168 098.94		R 1 680 989.40		
year 10	R 211 461.00	R 186 776.6				
year 11	R 232 607.10	R 205 454.26				

Mechanisation is dependent on the farm size. As seen in Figure 5.6, seasonal labour in a 10 hectare orchard will nullify the purchase of a machine harvester by year eight for almonds and year 9 for olives. Therefore, the larger the farm size the more priority needs to be given to mechanised labour.

The crop that requires the highest amount of initial capital investment is plums. Plums are propagated with higher density, therefore, requiring a large amount of planting material. The higher density with increases in costs is paired with the cost of trellising. Trellising is a structure of open latticework, especially used as support for trees or branches. Trellising require wires, poles and labour to set up thereby accounting for 22 % of the total costs.

Depending on the type of crop, production methods, soil characteristics, and mechanisation, costs can vary greatly between selected crops. One fact that is worth mentioning is that newly established trees and vines cannot be put under water stress. This should not be a problem as producers should have a good indication of water availability for the first two years. Water stress at these stages can negatively impact the newly planted tree for its entire expected lifespan. Thus, a producer needs to consider all the above-mentioned factors and formulate an establishment plan to know the costs used to start producing.

5.3.6. Transport

Export fruit is transported to the Cape Town harbour which is between 157 and 181 km. This increases the cost and the risk of mechanical damage to fruit, such as bruising. According to Van Zeebroeck et al. (2007), mechanical injuries are the most common defect on fruit. Mechanical injuries can lead to the fungal infection, grey mould (*Botrytis*) or blue mould (*Penicillium*) which infects through dead tissue. Transport can cause vibrations and shock of fruit, the motion of the vehicle-loading tray is dependent on the road profile, vehicle characteristics; speed, vehicle axle and wheel type, suspension characteristics, tyre characteristics and viscous damper position on the vehicle, as well as the load (Van Zeebroeck et al., 2007). Violent movement of the truck bed, i.e. going over a pothole or bump, can cause a sequence of collisions between various packaging layers and within each individual package. The movement can lead to bruising and subsequently infection in the damaged tissue.

Processed fruit is transported a distance of between 15 and 30 km. Less time is spent on the road, therefore, reducing the risk of mechanical damage. Mechanical damage leads to the degradation of fruit and as stated above export fruit have a much larger income loss than that of processed fruit if damage occurs.

Ports can also act as a hurdle to export fruit. Fruit is delivered to the port by road, where after it is transported either directly to the quayside for immediate loading on the ship or to the stacks (containers) or terminal cold stores (pallets), for temporary storage until loading. According to Van Dyk and Maspero (2004) the Cape Town container terminals are operating at a high utilisation rate, which results in bottlenecks and delays. Cold sterilisation requirements for fruit exported to the Far East and the USA place cold-store facilities under pressure. During the peak season some of the cold stores face delays due to not being able to load the vehicles within the time frame resulting in delays in vessel loading. Another risk factor is strikes by the port labour force. During the 2010 Transnet strike the fruit industry lost R 150 million in exports (DAFF, 2010).

Delays can result in reduced fruit quality as it would not reach the destination in a certain timeframe resulting in the rejection or degrading of the fruit. Delays result in increased costs of keeping fruit in cold storage until trade can continue. These factors are not constant but do carry the risk of probability and producers must take these risks into consideration when deciding on specific crops.

5.3.7. Income and costs

According to the calculations, almonds are the highest income crop, followed by fresh peaches, plums and fresh apricots. The higher income is generated due to higher prices for export and local fresh fruit and nuts. Foreign currency inflows are generally positive due to the weakening exchange rates. Exports will lead to higher income generated by producers. However, this influx of foreign exchange is somewhat negated by a large increase in costs, excluding that of almonds. Almonds do not require high cost as it is produced for local consumption, resulting in the higher income not being negated by high costs. Almonds obtain high income due to South Africa being a net importer resulting in producers asking just shy of import parity prices.

The cost of export or local fresh fruit is exceedingly higher than that of processed fruit. To keep export fruit fresh and presentable for international export, it needs to be packaged. Packaging serves as protection against contamination, damage, and most importantly, against excess moisture loss, enabling fruit to travel large distances. However, packaging is expensive and income generated by fresh peaches, plums, and apricots need to carry that cost. Export fruit travel vast distances to the Cape Town harbour. This journey of about 157 to 181 km to the harbour contributes to the overall costs of producing export quality fruit. Fruit needs to be transported in cooling trucks where temperature can be maintained and regulated to a certain degree, increasing costs further.

On the other hand, processed fruit (apricots, peaches, olives (oil), and wine grapes) earns much less money per kg/ton. Generally larger yields are targeted and the gap of income generated less, especially that of apricots and peaches. The cost of processed fruit is also significantly lower than that of export or local fresh fruit, leading to a smaller deficit between gross and net income.

Table 5.7 Costs variation between crops

Crops	Total costs
Grapes (Sauvignon Blanc)	R 28 960.53
Grapes (Colombar)	R 30 299.89
Grapes (Chenin Blanc)	R 30 510.00
Olives (Fresh)	R 42 880.64
Olives (Oil)	R 42 880.64
Apricots (Processed)	R 81 494.16
Almonds	R 87 419.92
Peaches (Processed)	R 91 573.58
Apricots (Fresh)	R 181 283.63
Peaches (Fresh)	R 211 470.11
Plums (Fresh)	R 239 663.23

The reason for the lower costs occurs because fruit for processing only needs to be transported to the nearest processing facility. Such facilities are located within the region itself, limiting costs spent on transport. Packaging costs for processed fruit is not applicable, as fruit is transported in mass bins from the farm to the facilities itself without the need of packaging. Processed fruit generally have a lower cost requirement in terms of fertiliser, pesticides, herbicides, and fungicides as there is not such a big emphasis on perfect quality. From all the fruits produced for processing, apricots achieved the highest income per hectare, followed by peaches and olives for oil. Wine grapes received the lowest average net income by crop as the low price paired with lower yields impacts income generated.

Table 5.8 Ranking of selected crops

Crop	Establishment cost	Hardiness	Water use	Yield	Cost	Profitability
Apricots fresh	4th	Well	2nd	4th	6th	4th
Apricots Processed	3rd	Well	2nd	2nd	3rd	5th
Wine grapes	7th	Average	3rd	6th	1st	8th, 10th & 11th
Peaches Fresh	5th	Average	5th	3rd	7th	2nd
Peaches Processed	6th	Average	5th	1st	5th	6th
Plums	8th	Poor	4th	5th	8th	3rd
Olives	2nd	Excellent	1st	7th	2nd	7th & 9th
Almonds	1st	Excellent	6th	8th	4th	1st

5.4 Discussion

The idiosyncratic nature of farms makes it difficult to allow for all possible options of crop choice within a specific modelling exercise. The Little Karoo area is unique in that the climate is ideal for fruit production, especially stone fruit and wine grapes, but that the relative dry and warm conditions make it absolutely dependent on irrigation. Water management and planning is central to farming in this area. All considerations are thus ultimately dependent on water availability.

From a farming perspective it is important for producers to make informed choices regarding long term crop establishment. Once a fruit enterprise is established the enterprise is locked into the farm system for a considerable period. These periods are at least 20 years, for olives and might be much longer still. Ultimately the producer needs to make profit to remain in business. The potential profitability is thus important.

One would be inclined to lean towards a shift to the most profitable crops and use all resources towards that goal. In an area with a risk profile of droughts and heatwaves such as the Little Karoo, the potential risk of losing a harvest, given the high investment requirement and operational cost of export fruit, is simply too high. A further consideration towards water and drought risk is the peak time differences in terms of water requirements. Apricots are early into harvest, late November early December. Once the fruit is harvested irrigation can be drastically reduced towards maintenance levels and thus allow for buffering water to other crops that are harvested later in the season.

Mostly planting early seasonal crops such as apricots is not the solution. This will require labour and machinery for a short two to three week period. Such a high peak could be simply unpractical and then leave machinery unused for a long period of time, significantly pushing up the cost per time unit.

The low risk option is surely to plant combinations of crops with low water requirements and a relative resilience towards droughts. These crops however have a relatively low profit return. With the high land values and the opportunity cost involved it would thus not make business sense to focus solely on such combinations.

Based on the evidence it could be well worth the effort for producers to do an exact analysis of profits to water consumption ratios for their specific farm. Soil quality, depth, and tree age will certainly impact on it and the results of this project will only serve as a guideline. It would also be necessary to project the combinations into seasonal labour, irrigation, and mechanisation requirements, matching it with availability. The idea of this research project was not to define an optimal combination, as the specific farm characteristics will determine that. The focus was to provide substance to the considerations and define and relate these considerations to scientific principles. The main factors for consideration is the growth phases of trees, general suitability to the area, seasonality, water requirements, and profitability. Profitability is a factor of investment requirement, income potential, and expected cost structure.

According to the results of the model in Annexure I, an example for farm layout should be the following. A part of the land needs to be allocated to the production of apricots for processing. This would allow a producer to achieve fairly high income without a high water requirement being needed. Processed apricots would reduce the cost and risk of travel and export therefore, risk can be somewhat negated. Another positive of using only a section of farm land for apricots is that it would reduce the impact of high labour requirements during its small harvest window. This small and early harvest window, occurring in December, would result in the releasing of water to other higher income crops during January and February, the hottest period of the southern African summer.

In combination with processed apricots, fresh peaches can be produced. It can produce high income but the higher water requirement can be somewhat negated by the low water requirement for apricots and its early harvest window. The shorter harvest window of apricots will free up labour and water resources for the production of the fresh peaches. Both of these crops have the ability to cope fairly well with deficit irrigation, both being able to produce close to full production with a reduction of 25% of water with the right irrigation strategy.

Another combination that could be feasible would be planting almonds and olives for oil. The high water requirement for almonds would be negated by the low requirement for olives. Almonds produce the highest income per hectare, with olives producing a fair amount of income. The problem with olives is that it is prone to alternative bearing, producing high yields in one year and lower yields in the next. This can be overcome by the higher income of almonds. The biggest positive of this combination is that the machine (“shaker”) used for harvesting can be used on both of these crops reducing the amount of overall labour. The establishment costs for both of these crops are low, almonds being the lowest, therefore, investment in the harvest equipment, like that of the “shaker”, would be feasible.

Combinations of any magnitude can be made and is up to the producer to decide how their land should be distributed keeping in mind that water requirement is the most limiting factor in the Little Karoo. If they want to produce successfully in the future they need to plan accordingly.

5.5 Conclusion

When all the above factors are taken into consideration there is not one single crop that is ideal in every aspect. Therefore, the best option would be to combine diverse types of crops over the allotted space. Diversification primarily involves an increase in the number of enterprises, or activities carried out by a particular farm. Diversification would mean resources would be allocated and distributed between different crop types. It offers the benefit of variation in crop responses to droughts and frost, but also market price fluctuations. Through diversification producers would be able to extract multiple benefits from different types of crops. In short, it is a technique that reduces risk by allocating investment among various financial instruments, in this case agricultural products, industries or other categories. It aims to maximise returns by investing in a number of different crops, each of which would react differently to the same event.

Chapter 6: Conclusions, summary and recommendations

6.1 Conclusions

Current data and models predict that climate change will increasingly cause adverse climate variations that will impact the Western Cape in the near future. Extreme weather events such as droughts paired with continually drier and arid conditions is to be expected. Thus, agriculture in the Little Karoo region will become more challenging, if these factors are not addressed as soon as possible. With the current threat of climate change and the predicted negative impacts it can have on the Western Cape and especially the Little Karoo region it is imperative that the region's main agricultural production focus is on WUE of its crops. Switching the focus from being purely profit driven to more water and conservation efficient is important for the region's prosperity in the production of agricultural products in the near future. In the research project the aim is to provide context to information and factors that can affect production capabilities. Further the aim was to include practices, water requirements, and profitability to allow a fuller understanding for decision making aimed at successful production.

The agricultural industry is one of the main contributors to the economy of this area with multiple other industries relying on the effectiveness of the agricultural sector. Businesses such as packing plants, processing plants, distributors, and supporting companies (input supplying and consulting entities) rely on farming output in this region. The majority of jobs are created throughout this industry along with supporting industries. The effectiveness of this industry is of key importance for this region. If this industry suffers producers must be able to adapt and continue to produce to sustain the economy in the region. If adaptation is not given priority agricultural sustainability can fail. This would be devastating to South Africa's stone fruit industry since the majority of its production is situated around the Little Karoo.

Enabling adaptability, a strategy is required to balance the profitable production and effective water usage. Water is the most limiting factor for production in South Africa and more so in the Little Karoo. It is important to plant crops that are less water reliant while ensuring sufficient income for the producer. Income is generated by multiple factors such yield, quality, value, and cost. WUE is determined by the crop physiology, fruit growth period, and climactic conditions. Successful production in the future will depend on the ability of producers to balance all of these factors.

The aim of this project was to identify and evaluate factors to consider during enterprise decision making. Budgets were used to provide a financial overview of selected crops. Budgets are in essence simulation type models based on standard accounting principles.

This information provided on the expected income and costs were paired with a specific commodity. The budgets provide only the financial perspective. This is paired with theoretical and practical considerations. Such considerations include fruit type and suitability, yield and quality, resilience to drought and frost, water requirements and adaptability to deficit irrigation. Deficit irrigation is identified as one possible strategy for areas with limited water availability, but is not risk free. The main consideration is that of the crops itself, crop development, water use, harvest period, and other factors that can contribute to efficient water usage. Therefore, WUE must be taken as the predominant factor for choosing a certain crop and production method.

With all the information obtained throughout the research project there is no clear, best suited crop for future propagation. All the crops that are well suited for the area have both benefits and challenges. Certain conclusion and solutions could be made when considering the best suitable crop. When considering Table 5.2, it is made clear that almonds and peaches are the two crops with the highest income but with a high water demand. Olives and apricots use the least amount of water per hectare. It is thus imperative that a balance between the ratio of water use and income is reached. Table 5.8 makes this balance easier by selecting a crop with the highest overall ranking received. Processed apricots have the highest overall ranking making it a favourite to consider for planting in the near future. Apricots is also more water efficient as the water application period is the shortest and concludes before the hottest part of the South African summer.

All these factors, water usage, planning, income, cultivation practices, labour costs, and practicality need to be considered before making a decision. Quantifying these factors allows producers to plan and gain knowledge to make informative decisions for future crop production. However not one crop proves to be the ultimate answer for all categories which means the optimal solution would be that of diversification.

Diversification is probably the best way to mitigate some of these negative attributes. By combining different crop types negative traits can be addressed to provide the producer with an adequate production layout in terms of water efficiency and income generation. This could reduce risk of droughts or drier conditions while maintaining income.

The aim of this paper was not to identify the best enterprise or even an optimal combination of enterprises. The nature of the area is such that soil, access to capital, and even climate differ too much among farms. The valleys and mountains causes certain areas to be dryer than others, even if relatively close in proximity. The aim was to identify and evaluate the considerations producers need to take into account when making production choices. Multiple factors will each have a different impact on the net result. A producer can only take the information as a guideline to design a layout suitable for their available resources. Through means of adapting and diversification of agriculture in this region, climate change and its effects can be mitigated and agricultural prowess in this region can continue in the foreseeable future.

6.2 Summary

The current drought and climate variability were highlighted as the main concern for finding alternative crops for production in the Little Karoo area. Fruit and vine type selections have previously been made primarily based on income potential, with other factors as secondary concerns. The drought of 2015-2017 caused a greater awareness in perspective to be more water use and conservation orientated.

The chosen geographical area of study is the Little Karoo in the Western Cape Province. The main focus area is the northern part of the valley and parts of the Breede River Valley with similar climate, rainfall, soil, and water characteristics. This area includes the towns of Montagu, Robertson, Bonnievale, and Ashton. The climate of this area is defined as a cold semi-arid climate (Bsk) that tends to be in elevated areas of temperate zones. Bsk climates means warm to hot dry summers with cool to cold winters. This climate is ideal for the propagation of a number of mediterranean perennial crops. The area has a fairly low annual rainfall average of just 220 mm meaning that producers depend on irrigation water sources such as boreholes, dams, and the Breede River. When the drought of 2015-2017 occurred water from the river was diverted frorm agricultural use to urban use leading to a disruption in irrigation water availability. The current water status is relatively pessimistic for the area.

Future climate change predictions indicate that the climate in the Western Cape will become characterised by more frequent and severe droughts. A poleward shift of the Hadley cell will expectedly lead to the aridification of more parts of the Western Cape, threatening the Little Karoo's agricultural production. With such models it is predicted that the climate in the Little Karoo will become even hotter and drier. The impact on plants will be disruptive on their production cycles, leading to reduced yields and quality.

Selected crops; almonds, wine grapes, apricots, peaches, plums, and olives that are well established. The Little Karoo is South Africa's biggest stone fruit producing area. It produces the largest amount of apricots, peaches, and almonds. Industries such as almonds are fairly new and have seen fairly large expansion over the past decade. Other Industries such as apricots, peaches, and olives have shown steady growth over the past decade, but was negatively influenced by the drought of 2015-2018.

Understanding crop production and phenology is required to determine individual crop growth patterns and development. These attributes impact on other factors of crop production such as the amount of labour needed or the yield within a given year. Understanding the cropping cycle is crucial in determining the amount and duration of irrigation given to crops. The cropping period is the most important in terms of water usage. These attributes and factors and how they react to mitigating measures such as deficit irrigation, must be taken into consideration when fruits are placed in hotter drier conditions.

To provide a financial overview budgets were constructed for one hectare of each crop. Enterprise budgets are classified under the broader term of budgeting, which is a form of simulation modelling. Simulation is basically the mimicking of a real world system, but allows for evaluation and comparison that is much cheaper and time efficient. The total evaluation is carried out under the broader term of systems analysis. Systems thinking adhere to the idea of irreducibility and suggest that factors would not be considered in isolation. In this instance various climatological, plant characteristic, soil characteristics, water requirements and availability, and profitability is considered. Budgeting also allows for the integration of physical/biological and financial dimensions of production.

Income and costs were evaluated for each crop and its method of production, processed or fresh, to determine gross margins. The gross margin was the highest for almonds, peaches (fresh), plums, and apricots (fresh). This is due to the large amount of income generated through means of exports, fetching higher prices per ton. Export fruit incur higher costs as they require transport, packaging, higher amounts fertilisers, pesticides, fungicides, and herbicide. Processed fruits such as apricots, peaches, and olives (oil) achieved high income due to average income paired with lower costs. Factors such as water usage and establishment costs were included as these would ultimately affect crop choice. Almonds and olives have fairly low establishment costs as it require lower amounts of trees. Plums require trellising and high numbers of planting material, making it twice as expensive to establish, as almonds. Other crops such as apricots, peaches and wine grapes require lower establishment costs.

The final results indicate that the crop with the most income potential is almonds. Almonds use the most water though. Olives used the least amount of water but produces an average income with the added impact of alternate bearing. Apricots showed promise in terms of both income and water usage but was hindered by a small harvest window and the massive amount of labour needed within that window.

Thus, different aspects of each crops such as climate, WUE, transport, harvest window, deficit irrigation, labour, capital requirements, and income was evaluated to determine the most important qualities of each. The net result was that not one crop suits every consideration and that different crop combinations are needed to enable successful production in. The identification of the importance of considering profitability as a factor of water and land use is important. Also the ranking of the ability of each crop to adhere to the various considerations might be useful for producers when matched with personal preferences and skills.

6.3 Recommendations

This study aimed to highlight considerations, in terms of income and WUE, when making crop selection for production. There is room for future studies on this topic, both in horticultural and economical dimensions. Firstly field studies can be initiated to determine the best combinations of crops and income generation. Such a study would take a number of years but could provide good indicators to plant developers and irrigation system design.

The factors and considerations could be used in an optimisation exercise to determine a trade-off curve for each crop between saving and profitability. This can be done since the constraints and resources are the same for which alternating objective functions are run through a linear programming exercise.

A study that would greatly benefit crop production in this area would be experimenting with different cultivars paired with different rootstock combinations. Individual cultivars and rootstocks have different environmental requirements and attributes that could lead to a much better suited cultivar to the drier expected conditions.

The influence of different production practices can also be examined such as the effects of netting and high-density planting on the amount of evaporation and irrigation water when applied. This measure would also influence costs by means of increasing establishment costs, however, seeing that water is the main threat to this region it would take priority. Higher-density planting theoretically increases WUE and income generated. A study can be done by using each crop and determining its high-density capabilities and the resulting WUE of each paired with the increase in income generated.

It could also be suggested that annual crops such as vegetables, vegetable seed or other single season crops be investigated. These crops would allow for the utilisation of irrigation water available during wetter seasons and could provide cash flow options. Soil burn disease and soil nutrient depletion will have to be carefully evaluated.

References

Atkinson, R., Brummell, D., Burdon, J., Patterson, K., Patterson, R. and Schaffer, R., 2016. Fruit growth, ripening and post-harvest physiology. Plant & Food Research, 1.Baeza, P., Junquera, P., Peiro, E., Ramón Lissarrague, J., Uriarte, D. and Vilanova, M. 2019. Effects of vine water status on yield components, vegetative response and must and wine composition. *Advances in Grape and Wine Biotechnology*.

Barrett, D., Beaulieu, J. and Shewfelt, R. 2010. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: Desirable levels, instrumental and sensory measurement, and the effects of processing. *Critical Reviews in Food Science and Nutrition*, 50(5), pp. 369-389.

Beck, H., Zimmermann, N., McVicar, T., Vergopolan, N., Berg, A. and Wood, E. 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Scientific Data*, 5(1).

Bonada, M. and Sadras, V. 2014. Review: critical appraisal of methods to investigate the effect of temperature on grapevine berry composition. *Australian Journal of Grape and Wine Research*, 21(1), pp. 1-17.

Byrne, D. (2005). Trends in stone fruit cultivar development. *Hort Technology.* Vol 15(3), pp. 494–500.Caprio, J. and Quamme, H. 2006. Influence of weather on apricot, peach and sweet cherry production in the Okanagan Valley of British Columbia. *Canadian Journal of Plant Science*, 86(1), pp. 259-267.

Climate-Data.org, 2021. Climate Montagu [online] Available at: <https://en.climate-data.org/africa/south-africa/western-cape/montagu-14401/> [Accessed 30 August 2021].

Climate-data.org, 2021. Robertson climate: Average Temperature, weather by month, Robertson weather averages - *Climate-Data.org*. [online] Available at: <https://en.climate-data.org/africa/south-africa/western-cape/robertson-13552/> [Accessed 21 September 2021].

Corsi, S., Hugo, W., Kienzle, J. and Mba, C. 2017. Crop production and climate change. *FAO: climate smart agriculture sourcebook*, 2.

CSAG, 2021. [online] Csag.uct.ac.za. Available at: <https://www.csag.uct.ac.za/current-seasons-rainfall-in-cape-town/> [Accessed 4 October 2021].

Curtis, K., Harris, T., and Riggs, W. 2005. Importance & use of enterprise budgets in agricultural operations. University of Nevada.

Department of Agriculture, Forestry and Fisheries, 2010. *Estimated impact of the Transnet strike action on traders of agricultural products and seafood.*

Department of Water and Sanitation, 2018. *Water Outlook 2018 Report*. City of Cape Town.

Dong, X., Xu, W., Zhang, Y. and Leskovar, D., 2016. Effect of irrigation timing on root zone soil temperature, root growth and grain yield and chemical composition in corn. *Agronomy*, 6(2), pp.34.

Doye, D. and Sahs, R., 2005. Importance & Use of Enterprise Budgets in Agricultural Operations | Extension | University of Nevada, Reno. [online] Extension | University of Nevada, Reno. Available at: <https://extension.unr.edu/publication.aspx?PubID=2383> [Accessed 15 December 2021].

Elsenburg.com. 2021. Western Cape dam levels. *Agriculture*. [online] Available at: <https://www.elsenburg.com/agri-tools/western-cape-dam-levels> [Accessed 4 October 2021].

EPA, 2021. Glyphosate. [online] Available at: <https://www.epa.gov/ingredients-used-pesticide-products/glyphosate> [Accessed 21 November 2021].

Fereres, E., Goldhamer, D. and Sadras, V. 2012. Yield response to water of fruit trees and vines: guidelines. *FAO Irrigation and Drainage*, (66), pp. 246-497.

Fernandes-Silva, A., Oliveira, M., Paço, T. and Ferreira, I. 2019. Deficit irrigation in mediterranean fruit trees and grapevines: Water stress indicators and crop responses. *Irrigation in Agroecosystems*.

Fraga, H., Malheiro, A., Moutinho-Pereira, J. and Santos, J., 2012. An overview of climate change impacts on European viticulture. *Food and Energy Security*, 1(2), pp.94-110.

Frierson, D., Lu, J. and Chen, G. 2007. Width of the Hadley cell in simple and comprehensive general circulation models. *Geophysical Research Letters*, 34(18).

García-Tejero, I., Lipan, L., Gutiérrez-Gordillo, S., Durán Zuazo, V., Jančo, I., Hernández, F., Cárceles Rodríguez, B. and Carbonell-Barrachina, Á. 2020. Deficit irrigation and its implications for Hydro sustainable imond production. *Agronomy*, 10(11), pp. 1 632.

Gerbens-Leenes, P., Nonhebel, S. and Krol, M. 2010. Food consumption patterns and economic growth. Increasing affluence and the use of natural resources. *Appetite*, 55(3), pp. 597-608.

Giese, G., Velasco-Cruz, C. and Leonardelli, M. 2020. Grapevine phenology: Annual growth and development. *New Mexico State University, Consumer and Environmental Sciences*, for HydroSOStainable Almond Production. *Agronomy*, 10(11).

Girona, J., Mata, M., Goldhamer, D., Johnson, R. and De Jong, T. 1993. Patterns of soil and tree water status and leaf functioning during regulated deficit irrigation scheduling in peach. *Journal of the American Society for Horticultural Science*, 118(5), pp. 580-586.

Goldblatt, A. 2010. *Agriculture: Facts and Trends South Africa*. WWF.

Goldhamer, D., Viveros, M. and Salinas, M. 2005. Regulated deficit irrigation in almonds: effects of variations in applied water and stress timing on yield and yield components. *Irrigation Science*, 24(2), pp. 101-114.

Gradziel, T. and McCaa, J. 2008. Processing peach cultivar development. *The peach: botany, production and uses*, pp. 175-192.

Guédon, Y. and Legave, J. 2008. Analyzing the time-course variation of apple and pear tree dates of flowering stages in the global warming context. *Ecological Modelling*, 219(1-2), pp. 189-199.

Haifa Group. 2021. *Crop Guide: Growing Olives*. [online] Available at: <https://www.haifa-group.com/olives-fertilizer/crop-guide-growing-olives> [Accessed 27 August 2021].

Hegerl, G., Zwiers, F., Braconnot, P., Gillett, N., Luo, Y., Marengo Orsini, J., Nicholls, N., Penner, J. and Stott, P. 2007. Understanding and attributing climate change. Climate Change 2007: the physical science basis contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change, pp. 663-746.

HORTGRO, 2019. *Key Deciduous Fruit Statistics*.

Intrigliolo, D.S., Castel, J.R., 2012. Plum. In: Steduto, P., Hsiao, T.C., Fereres, E., Raes, D. (Eds.), Crop Yield Response to Water. FAO Irrigation and Drainage Paper No 66. FAO, Roma, pp. 348-355.

ITC, 2021. *Trade Map - List of importing markets for the product exported by South Africa in 2020*. [online] Trademap.org. Available at: <https://www.trademap.org/Country_SelProductCountry.aspx?nvpm=1%7c710%7c%7c%7c%7c1509%7c%7c%7c4%7c1%7c1%7c2%7c1%7c1%7c2%7c1%7c1%7c1> [Accessed 30 August 2021].

Johanson, C. and Fu, Q. 2009. Hadley Cell Widening: Model Simulations versus Observations. *Journal of Climate*, 22(10), pp. 2713-2725.

Johnson, R., Handley, D. and De Jong, T. 1992. Long-term response of early maturing peach trees to postharvest water deficits. *Journal of the American Society for Horticultural Science*, 117(6), pp. 881-886.

Jones, G. and Alves, F. 2012. Impact of climate change on wine production: a global overview and regional assessment in the Douro Valley of Portugal. *International Journal of Global Warming,* 4(3/4), p.383.

Keller, M., Romero, P., Gohil, H., Smithyman, R., Riley, W., Casassa, L. and Harbertson, J. 2016. Deficit irrigation alters grapevine growth, physiology, and fruit microclimate. *American Journal of Enology and Viticulture*, 67(4), pp. 426-435.

The Karoo, South Africa. 2021. Klein Karoo - The Karoo, South Africa. [online] Available at: <https://www.karoo-southafrica.com/klein-karoo/> [Accessed 12 December 2021].

Kriel, G. 2021. Stone Fruit - Fruit Farming in South Africa. [online] Southafrica.co.za. Available at: <https://southafrica.co.za/stone-fruit.html> [Accessed 25 August 2021].

Kriel, G., 2021. Carmingo apricots breathe new life into Koo Valley. [online] Farmer's Weekly. Available at: <https://www.farmersweekly.co.za/crops/fruit-nuts/carmingo-apricots-breathe-new-life-into-koo-valley/> [Accessed 17 December 2021].

Kriel, G., 2019. Almonds: High value, huge potential. [online] Farmer's Weekly. Available at: <https://www.farmersweekly.co.za/crops/fruit-nuts/almonds-high-value-huge-potential/> [Accessed 17 December 2021].

Legave, J., Richard, J. and Viti, R. 2006. Inheritance of floral abortion in progenies of ‘stark early orange´ apricot. *Acta Horticulturae*, (701), pp. 127-130.

Lopez, G., Girona, J., Marsal, J., 2012. Fruit quality responses to severe water stress during stage III of peach fruit development. *Acta Horticulturae,* (962), pp. 355-362.

Lopez, G., Hossein Behboudian, M., Girona, J. and Marsal, J., 2012. Drought in deciduous fruittTrees: Implications for yield and fruit quality. *Plant Responses to Drought Stress*, pp. 441-459.

Lopez, G. and Dejong, T. 2007. Spring temperatures have a major effect on early stages of peach fruit growth. *The Journal of Horticultural Science and Biotechnology*, 82(4), pp.507-512.

Louw, M. 2021. Income, costs and profitability of farming. [online] Southafrica.co.za. Available at: <https://southafrica.co.za/income-costs-profitability-farming.html> [Accessed 21 November 2021].

Louw, D., Oosthuizen, H. and Flandorp, C. 2017. *Study on the market potential for the commercial viability of almond production in South Africa*. OABS.

Louw, VDW. 2015. Finansiële implikasies van besproeiing, geïntegreer met bestuur, vir rooi wyndruiwe in die Robertson-wynvallei [Financial implications of irrigation, integrated with canopy management, for red wine grapes in the Robertson wine valley]. MSc.Agric

Lurie, S., Friedman, H., Weksler, A., Dagar, A. and Eccher Zerbini, P. 2013. Maturity assessment at harvest and prediction of softening in an early and late season melting peach. *Postharvest Biology and Technology*, 76, pp. 10-16.

Maatallah, S., Guizani, M., Hjlaoui, H., Boughattas, N.E.H., Lopez-Lauri, F., Ennajeh, M. 2015. Improvement of fruit quality by moderate water deficit in three plum cultivars (Prunus salicina L.) cultivated in a semi-arid region. *Fruits,* (70), pp. 325-332

Mekonnen, D., Moges, M., Mulat, A. and Shumitter, P. 2019. The impact of climate change on mean and extreme state of hydrological variables in Megech watershed, Upper Blue Nile Basin, Ethiopia. *Extreme Hydrology and Climate Variability*, pp.123-135.

Midgley, G., Chapman, R., Hewitson, B., Johnston, P., de Wit, M., Ziervogel, G., Mukheibir, P., Van Niekerk, L., Tadross, M., Van Wilgen, B., Kgope, B., Morant, P., Theron, A., Scholes, R. and Forsyth, G. 2005. *A status quo, vulnerability and adaptation assessment of the physical and socio-economic effects of climate change in the Western Cape.* Report to the Western Cape Government, Cape Town, South Africa.

Mirás-Avalos, J.M., Alcobendas, R., Alarcón, J.J., Valsesia, P., Génard, M., Nicolás, E. 2013. Assessment of the water stress effects on peach fruit quality and size using a fruit tree model, QualiTree. *Agricultural Water Management*, pp. 128, vol. 1.

Mozell, M. and Thach, L. 2014. The impact of climate change on the global wine industry: Challenges & solutions. *Wine Economics and Policy*, 3(2), pp. 81-89.

Naor, A., Stern, R., Peres, M., Greenblat, Y., Gal, Y. and Flaishman, M. 2005. Timing and severity of postharvest water stress affect following-year productivity and fruit quality of field-grown `Snow Queen' nectarine. *Journal of the American Society for Horticultural Science*, 130(6), pp. 806-812.

National Oceanic and Atmospheric Administration, 2020. State of the Climate: Global Climate Report for Annual 2020. [online] Available at: <https://www.ncdc.noaa.gov/sotc/global/202013> [Accessed 4 October 2021].

Osakabe, Y., Osakabe, K., Shinozaki, K. and Tran, L. 2014. Response of plants to water stress. *Frontiers in Plant Science*, vol. 5.

Pascale, S., Kapnick, S., Delworth, T. and Cooke, W. 2020. Increasing risk of another Cape Town "Day Zero" drought in the 21st century. *Proceedings of the National Academy of Sciences*, 117(47), pp. 495-503.

Pasquini, L., Cowling, R. and Ziervogel, G. 2013. Facing the heat: Barriers to mainstreaming climate change adaptation in local government in the Western Cape Province, South Africa. *Habitat International*, 40, pp. 225-232.

Perez-Gonzales, S. 1992. Associations among morphological and phonological characters representing apricot germplasm in Central Mexico. *Journal of the American Society for Horticultural Science*, 117(3), pp. 486-490.

Pérez-Pastor, A., Ruiz-Sánchez, M.C., Domingo, R. 2014. Effects of timing and intensity of deficit irrigation on vegetative and fruit growth of apricot trees. *Agricultural Water Management*, 134, pp. 110- 118.

Pierantozzi, P., Torres, M., Lavee, S. and Maestri, D. 2013. Vegetative and reproductive responses, oil yield and composition from olive trees (Olea europaea) under contrasting water availability during the dry winter-spring period in central Argentina. *Annals of Applied Biology,* 164(1), pp. 116-127.

Ramming, D. and Cociu, V. 1991. Plums (Prunus). *Acta Horticulturae*, (290), pp. 235-290.

Ripoll, J., Urban, L., Staudt, M., Lopez-Lauri, F., Bidel, L. and Bertin, N. 2014. Water shortage and quality of fleshy fruits—making the most of the unavoidable. *Journal of Experimental Botany*, 65(15), pp. 4097-4117.

Robertson Wine Valley, 2021. *Robertson Valley Climate*. [online] Robertsonwinevalley.com. Available at: <https://www.robertsonwinevalley.com/2018/12/> [Accessed 19 August 2021].

Rodina, L. 2019. Water resilience lessons from Cape Town's water crisis. *WIREs Water*, 6(6).

Ruml, M. and Vulic, T. 2005. Importance of phenological observations and predictions in agriculture. *Journal of Agricultural Sciences, Belgrade*, 50(2), pp. 217-225.

Santisi, J., 2011. Warming Up the Wine Industry. *The Environmental Magazine*, 22(6), pp. 15-17.

SA Olive. 2021. Harvesting Olives - SA Olive. [online] Available at: <https://www.saolive.co.za/follow-olive-harvesting/> [Accessed 27 August 2021].

SA Olive, 2018. *The South African Olive Industry – inside info*. SAOlive.

Sawis, 2020. *Vineyard Status Booklet*.

Senninger, 2019. *How to Protect Crops from Frost Damage Using Sprinklers*. AGRICULTURAL IRRIGATION. [online] Available at: <https://www.senninger.com/news/2017/10/2/how-protect-crops-frost-damage-using-sprinklers> [Accessed 21 September 2021].

Siddiq, M., Butt, M. and Greiby, I. 2012. Apricots production, processing, and nutrition. *Handbook of Fruits and Fruit Processing*, pp. 385-398.

Sjöholm, H., Reynders, M. and Folliott, P. 1989. *Arid zone forestry : A guide for field technicians*. Rome: FAO.

Stöckle, C., Marsal, J. and Villar, J., 2011. Impact of climate change on irrigated tree fruit production. *Acta Horticulturae*, (889), pp. 41-52.

Sundouri, A., Verma, S., Sharma, M., Kumar, A., Nazir, N. and Khalil, A. 2017. Characterization of newly introduced exotic plum cultivars for character association and genetic improvement. *Current Journal of Applied Science and Technology*, 24(2), pp. 1-10.

Sperandio, G., Biocca, M., Fedrizzi, M., and Toscano, P. 2017. Economic and technical features of different levels of mechanization in olive harvesting. *Chemical Engineering Transactions,* 58, pp. 853-858.

The Karoo, South Africa. 2021. Little Karoo - The Karoo, South Africa. [online] Available at: <https://www.karoo-southafrica.com/Little-karoo/> [Accessed 14 June 2021].

Theron, K. 2018. Vegetatiewe Ontwikkeling, lecture notes, Hortologie 314, Stellenbosch University, delivered April 2018.

Torrecillas, A., Corell, M., Galindo, A., Pérez-López, D., Memmi, H., Rodríguez, P., Cruz, Z., Centeno, A., Intrigliolo, D. and Moriana, A., 2018. Agronomical effects of deficit irrigation in apricot, peach, and plum trees. *Water Scarcity and Sustainable Agriculture in Semiarid Environment*, pp. 87-109.

Torrecillas, A., Domingo, R., Galego, R., Ruiz-Sánchez, M.C. 2000. Apricot tree response to irrigation withholding at different phenological periods. *Scientia Horticulturae*, 85, pp. 201-215.

Torres, M., Pierantozzi, P., Searles, P., Rousseaux, M., García-Inza, G., Miserere, A., Bodoira, R., Contreras, C. and Maestri, D. 2017. Olive cultivation in the Southern Hemisphere: Flowering, water requirements and oil quality responses to new crop environments. *Frontiers in Plant Science*, vol. 8.

Turton, A. 2000. Water and sustainable development: A Southern perspective. *Water and Development*, 2.

Tyson, P. and Preston-Whyte, R. 2000. *The weather and climate of Southern Africa.* 1st ed.

USDA, 2006. *Irrigation Guide*. [online] United States Department of Agriculture. Available at: <https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs141p2_018371.pdf> [Accessed 20 November 2021].

Van Dyk, F. and Maspero, E. 2004. An analysis of the South African fruit logistics infrastructure. *Orion*, 20(1).

Van Zeebroeck, M., Van linden, V., Ramon, H., De Baerdemaeker, J., Nicolaï, B. and Tijskens, E. 2007. Impact damage of apples during transport and handling. *Postharvest Biology and Technology*, 45(2), pp. 157-167.

Vinpro, 2021. *Cost guide 2021/2022*. Vinpro.

Vinum Vine. 2021. *Vinum Vine*. [online] Available at: <https://vinumvine.wordpress.com/> [Accessed 14 September 2021].

Weather.lcao.co.za. 2021. Weather Stats Rainfall - La Colline Observatory, Stellenbosch Weather Station, LCAO. [online] Available at: <http://www.weather.lcao.co.za/index.php/Special_WeatherStatsRainfall> [Accessed 15 June 2021].

Western Cape Government, 2015. TABLE-OLIVE-BUDGET. Elsenburg.

Wilson, B. 2017. Chill hours for fruit plants & trees. [Blog] *Wilson Bros Gardens*, Available at: <https://www.wilsonbrosgardens.com/what-are-chill-hours-for-fruit-plants-trees.html> [Accessed 23 August 2021].

Xiloyannis, C., Montanaro, G. and Dichio, B. 2016. Sustainable orchard management in semi-arid areas to improve water use efficiency and soil fertility. *Acta Horticulturae*, (1139), pp. 425-430.

Yara Australia. 2021. *Almond Growth Requirements | Yara Australia*. [online] Available at: <https://www.yara.com.au/crop-nutrition/almond/almond-growth-requirements/> [Accessed 15 July 2021].

Personal communications

De Beer, H. 2021. Personal communication. Producer Ceres.

De Wet, L. 2021. Personal communication. Producer Montagu

Du Plessis, S. 2021. Personal communication. Producer Porterville

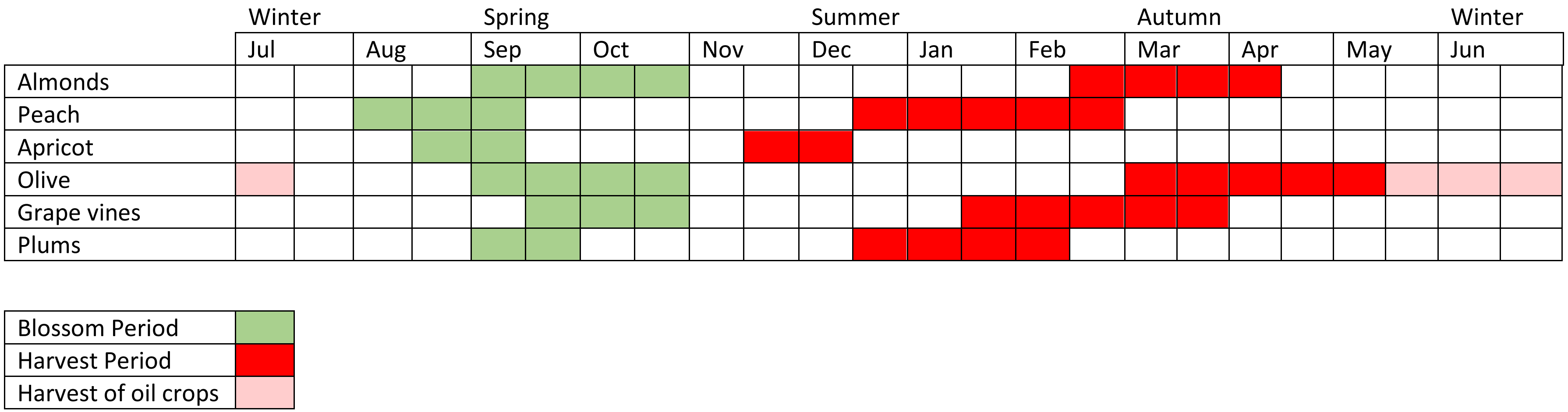
Thalwitzer, J. M. 2021. Personal communication. Producer Citrusdal

Joubert, A. J. J. 2021. Personal communication. Producer Montagu

Joubert, F. 2021. Personal communication. Producer

Steyn, J. H. 2021. Personal communication. Producer

Annexure A: Growth periods of selected fruit


Winter
Spring
Summer
Autumn
Winter
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Almonds
Peach
Apricot
Olive
Grape vines
Plums
Blossom Period
Harvest Period
Harvest of oil crops

Annexure B: Assumptions of annual budgets

Almonds (Nuts)	
Cultivar:	Nonpareil
Trees per hectare	416
Yield per hectare (Tons/ha)	3
m³ water/ha	7 300

Assumptions:		
Farm Almond price*	R 85	/kg kernal
Yield Potential	3 000	kg kernal/ha
Price per style*		
Whole	R 85	
Dicing	R 40	

Percentage per product		Yield per product	
Whole	95%	2 850	kg/ha
Dicing	5%	150	kg/ha

Price per style*	
Whole	R85.00
Dicing	R40.00

Apricots (Fresh)	
Cultivar:	Bebeco
Trees per hectare:	1 000
Yield per hectare (Tons/ha)	30
m³ water/ha	5 000

Assumptions:		
Price per product style		
Class 1 (Export)	R 21.3	R/kg
Class 2 (Local sales)	R 11.22	R/kg
Class 3 (Juice)	R 3	R/kg
Yield Potential	30 000	kg/ha

Percentage per product		Yield per product	
Local fresh market	15%	4 500	kg/ha
Export	70%	21 000	kg/ha
Juice	15%	4 500	kg/ha

Apricots (Processed)	
Cultivar:	Saldonne
Trees per hectare:	666
Yield per hectare (Tons/ha)	42
m³ water/ha	5 000

Assumptions:		
Price per product style		
Processed Class 1	R 5.5	R/kg
Processed Class 2	R 3	R/kg
Yield Potential	42 000	kg/ha

Percentage per product		Yield per product	
Processed Class 1	95%	39 900	kg/ha
Processed Class 2	5%	2 100	kg/ha

Peaches (Fresh)	
Cultivar:	Tifany
Trees per hectare:	1 100
Yield per hectare (Tons/ha)	30
m³ water/ha	6 700

Assumptions:		
Price per product style		
Class 1 (Export)	R 28.7	R/kg
Class 2 (local sales)	R 11.03	R/kg
Class 3 (Juice)	R 1.2	kg/ha
Yield Potential	30 000	

Percentage per product		Yield per product	
Local fresh market	14%	4 200	kg/ha
Export	76%	22 800	kg/ha
Juice	10%	3 000	kg/ha

Peaches (Processed)	
Cultivar:	Keisie/sandvliet
Trees per hectare:	1 250
Yield per hectare (Tons/ha)	45
m³ water/ha	6 700

Assumptions:		
Price per product style		
Class 1	R 5.2	R/kg
Class 2	R 3.02	R/kg
Class 3	R 1.1	R/kg
Yield Potential	45 000	kg/ha

Percentage per product		Yield per product	
Class 1	96%	43 200	kg/ha
Class 2	1.8%	810	kg/ha
Class 3	2.2%	990	kg/ha

Plums	
Cultivar:	N/A
Trees per hectare:	1 524
Yield per hectare (Tons/ha)	27
m³ water/ha	6 200

Assumptions:		
Price per product style		
Class 1 (Export)	R 17.86	R/kg
Class 2 (Local sales)	R 6.32	R/kg
Class 3 (Juice)	R 1	R/kg
Yield Potential	27 000	kg/ha

Percentage per product		Yield per product	
Local fresh market	15%	4 050	kg/ha
Export	75%	20 250	kg/ha
Juice	10%	2 700	kg/ha

Olives (Table)	
Cultivar:	Mission
Trees per hectare:	416
Yield per hectare (Tons/ha)	7
m³ water/ha	4 700

Assumptions:		
Price per product style		
Local fresh market	R 15	R/kg
Yield Potential	7 000	kg/ha

Percentage per product		Yield per product	
Local fresh market	100%	7 000	kg/ha

Olives (Oil)	
Cultivar:	Frantoio
Trees per hectare:	416
Yield per hectare (Tons/ha)	8
m³ water/ha	4 700

Assumptions:		
Price per product style		
Local fresh market	R 55	R/L
Yield Potential	3 000	L/ha

Percentage per product		Yield per product	
Local fresh market	100%	3 000	L/ha

Grapes (Wine)		
Cultivars	Chenin Blanc	
	Colombar	
	Sauvignon Blanc	
Trees per hectare		
Average yield per hectare (Tons/ha)	Chenin Blanc	22.5
	Colombar	17.5
	Sauvignon Blanc	11
m³ water/ha	5 500	

Price per product			
Celler			
Cultivar	Chenin Blanc	R 4.24	R/kg
	Colombar	R 4.31	R/kg
	Sauvignon Blanc	R 8.22	R/kg

Percentage usable		Yield per cultivar	
Celler	Chenin Blanc	22 500	kg/ha
	Colombar	17 500	kg/ha
	Sauvignon Blanc	11 000	kg/ha

Seasonal labour	
Rand/hour	Rand/Month
R 21.69	R 4229.22

Water Price	
c/m³	R/m³
R 6.34	R 0.0634

Annexure C: Almond annual budget

Almonds

	Item	Yearly Total
Almond production (kg/ha)	Whole kernal	2 850
	Sliced	150
	Production yield	3 000
Production income	Whole kernal	242 250
	Sliced	6 000
	Total income	248 250
Production expenses	**Direct allocated costs**	
	Fertiliser	20 687
	Pesticides	6 280
	Herbecides	4 100
	Fungicides	8 781
	Seasonal labour*	21 146.10
	Pollination	3 000
	Water	462.82
	Non-Direct allocated costs	
	Fuel	10 274
	Repaires and maintenance	12 689
	Transport	662.27
	Total Costs	87 419.92
Gross margin		160 830.08
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		130 320.08

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Harvest	12 687.66
	Pest control	4 229.22
	Pruning	8 458.44
Total		21 146.10

Annexure D: Apricot annual budget

Apricots (Fresh)

	Item	Yearly Total
Apricot production (kg/ha)	Local fresh market	4 500
	Export	21 000
	Juice	4 500
	Production yield	25 500
Production income	Local fresh market	95 850
	Export	235 620
	Juice	13 500
	Total income	331 470
Production expenses	**Direct allocated costs**	
	Fertiliser	10 506
	Pesticides	6 175
	Herbecides	2 248
	Fungicides	9 062
	Seasonal labour*	37 077
	Pollination	1 960
	Water	317
	Packaging	81 162
	Non-Direct allocated costs	
	Fuel	10 163
	Repaires and maintenance	12 653
	Transport	9 960.63
	Total costs	181 283.63
Gross margin		150 186.37
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		119 676.37

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Harvest	13 673
	Thinning	11 256
	Pest control	3 265
	Pruning	8 883
Total		37 077

Apricots (Processed)

	Item	Yearly Total
Apricot production (kg/ha)	Processed Class 1	39 900
	Processed Class 2	2 100
	Production yield	42 000
Production income		
	Processed Class 1	219 450
	Processed Class 2	6 300
	Total income	225 750
Production expenses	**Direct allocated costs**	
	Fertiliser	5 754.40
	Pesticides	4 998
	Herbecides	1 960
	Fungicides	10 208
	Seasonal labour*	37 077
	Pollination	1 960
	Water	317
	Non-Direct allocated costs	
	Fuel	10 163
	Repaires and maintenance	12 653
	Transport	2 158.16
	Total Costs	872 48.56
Gross margin		138 501.44
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		107 991.44

***Seasonal labour**	**Activity**	**cost/ annum**
	Harvest	13 673
	Pest Control	3 265
	Thinning	11 256
	Pruning	8 883
Total		37 077

Annexure E: Cling peach annual budget

Cling Peaches (Fresh)

	Item	Yearly Total
Peach production (kg/ha)	Local fresh market	4 200
	Export	22 800
	Juice	3 000
	Production yield	27 000
Production income	Local fresh market	120 540
	Export	251 484
	Juice	3 600
	Total income	372 024
Production expenses	**Direct allocated costs**	
	Fertiliser	11 028
	Pesticides	11 462
	Herbecides	1 960
	Fungicides	13 890
	Seasonal labour*	33 509
	Pollination	0
	Water	424.78
	Packaging	100 890
	Non-Direct allocated costs	
	Fuel	10 274
	Repaires and maintenance	12 689
	Transport	15 343.33
	Total Costs	211 470.11
Gross margin		160 553.89
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		130 043.89

***Seasonal labour**	**Activity**	**cost/ annum**
	Post-harvest	9 640
	Thinning	9 876
	Pest control	3 874
	Harvest	10 119
Total		33 509

Cling Peaches (Processed)

	Item	Yearly Total
Peach production (kg/ha)	Local fresh market	43 200
	Export	810
	Juice	990
	Production yield	45 000
Production income	Local fresh market	224 640
	Export	2 446.20
	Juice	1 089
	Total income	228 175.20
Production expenses	**Direct allocated costs**	
	Fertiliser	7 364.80
	Pesticides	11 462
	Herbecides	1 960
	Fungicides	13 890
	Seasonal labour*	33 509
	Pollination	0
	Water	424.78
	Non-Direct allocated costs	
	Fuel	10 274
	Repaires and maintenance	12 689
	Transport	3 228.18
	Total Costs	91 573.58
Gross margin		136 601.62
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		106 091.62

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Post-harvest	9 640
	Thinning	9 876
	Pest control	3 874
	Harvest	10 119
Total		33 509

Annexure F: Plum annual budget

Plums

	Item	Yearly Totaal
Plum production (kg/ha)	Export	20 250
	Local Sales	4 050
	Juice	2 700
	Production yield	27 000
Production income	Export	361 665
	Local Sales	25 596
	Juice	2 700
	Total income	389 961
Production expenses	**Direct allocated costs**	
	Fertiliser	9 623.89
	Pesticides	16 264.71
	Herbecides	1 946.16
	Fungicides	2 247.06
	Seasonal labour*	43 517
	Pollination	3 176.47
	Water	393.08
	Packaging	130 531
	Non-Direct allocated costs	
	Fuel	10 107
	Repaires and maintenance	13 080
	Transport	8 776.87
	Total Costs	239 663.23
Gross margin		150 297.77
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		119 787.77

***Seasonal labour**	**Activity**	**cost/ annum**
	Harvesting	15 941
	Pruning	10 841
	Thinning	13 294
	Pest control	3 441
Total		43 517

Annexure G: Olive annual budget

Olives (Table)

	Item	Yearly Total
Olive production (kg/ha)	Local fresh market	7 000
	Production yield	7000
Production income	Local fresh market	105 000
	Total income	105 000
Production expenses	**Direct allocated costs**	
	Fertiliser	1 485
	Pesticides	539.71
	Herbecides	138
	Fungicides	1 322.29
	Seasonal labour*	18 677.66
	Pollination	0
	Water	297.98
	Non-Direct allocated costs	
	Fuel	9 850
	Repaires and maintenance	10 570
	Transport	754.89
	Total Costs	428 80.64
Gross margin		62 119.36
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		31 609.36

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Harvest	12 678.66
	Pest Control	1 547
	Pruning	4 452
Total		18 677.66

Olives (Table)

	Item	Yearly Total
Olive production (kg/ha)	Local fresh market	3 000
	Production yield	3 000
Production income	Local fresh market	165 000
	Total income	165 000
Production expenses	**Direct allocated costs**	
	Fertiliser	1 485
	Pesticides	539.71
	Herbecides	138
	Fungicides	1 322.29
	Seasonal labour*	18 677.66
	Pollination	0
	Water	297.98
	Non-Direct allocated costs	
	Fuel	9 850
	Repaires and maintenance	10 570
	Transport	754.89
	Total Costs	428 80.64
Gross margin		122 119.36
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		91 609.36

***Seasonal labour**	**Activity**	**Cost/ Annum**
	Harvest	12 678.66
	Pest Control	1 547
	Pruning	4 452
Total		18 677.66

Annexure H: Wine grape annual budget

Grapes (Chenin Blanc)

	Item	Yearly Total
Vine production (kg/ha)	Chenin Blanc	22 500
	Production yield	22 500
Production income	Local Celler	95 400
	Total income	95 400
Production expenses	**Direct allocated costs**	
	Fertiliser	3 783
	Pesticides	2 150
	Herbecides	1 425
	Fungicides	1 290
	Seasonal labour*	17 704.46
	Pollination	0
	Water	348.7
	Non-Direct allocated costs	
	Fuel	2 828
	Repaires and maintenance	1 801
	Transport	1 113.82
	Total Costs	31 330.16
Gross margin		64 069.84
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		33 559.84

***Seasonal labour**	**Activity**	**Man hours/ha**	**Avg. man hours**	**Cost/ Annum**
	Collective pruning	90-145	117.5	2 548.56
	Top shoots	15-25	20	433.8
	Remove leaves	20-30	25	542.25
	Crop Control	65-80	72.5	1 572.53
	Harvest of trellis*	9.5	213.75	4 636.24
	Pest control	60-75	67.5	1 464.08
	Intensive and extensive offset	45	45	976.05
	leaf removal	20-30	25	542.25
	Summer foliage action	230	230	4 988.70
Total				17 704.46

Note Harvest of trellis is calculated as man hours per tonne (Machine)

Grapes (Colombar)

	Item	Yearly Total
Vine production (kg/ha)	Colombar	17 500
	Production yield	17 500
Production income	Local Celler	75 425
	Total income	75 425
Production expenses	**Direct allocated costs**	
	Fertiliser	3 783
	Pesticides	2 150
	Herbecides	1 425
	Fungicides	1 290
	Seasonal labour*	16 674.19
	Pollination	0
	Water	348.7
	Non-Direct allocated costs	
	Fuel	2 828
	Repaires and maintenance	1 801
	Transport	998.03
	Total Costs	30 299.89
Gross margin		45 125.11
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		14 615.11

***Seasonal labour**	**Activity**	**Man hours/ha**	**Avg. man hours**	**Cost/ Annum**
	Collective pruning	90-145	117.5	2 548.58
	Top shoots	15-25	20	433.8
	Remove leaves	20-30	25	542.25
	Crop Control	65-80	72.5	1 572.53
	Harvest of trellis*	9.5	166.25	3 605.96
	Pest control	60-75	67.5	1 464.10
	Intensive and extensive offset	45	45	976.05
	Leaf removal	20-30	25	542.25
	Summer foliage action	230	230	4 988.70
Total				16 674.19

Note	Harvest of trellis is calculated as man hours per tonne (Machine)	

Grapes (Sauvignon Blanc)

	Item	Yearly Total
Vine production (kg/ha)	Sauvignon Blanc	11 000
	Production yield	11 000
Production income	Local Celler	90 420
	Total income	90 420
Production expenses	**Direct allocated costs**	
	Fertiliser	3 783
	Pesticides	2 150
	Herbecides	1 425
	Fungicides	1 290
	Seasonal labour*	15 334.83
	Pollination	0
	Water	348.7
	Non-Direct allocated costs	
	Fuel	2 828
	Repaires and maintenance	1 801
	Transport	847.52
	Total Costs	28 960.53
Gross margin		61 459.47
Overhead costs	Electricity	3 689
	Water	2 150
	General	500
	Fixed labour	3 336
	Other overheads	20 835
	Total overhead costs	30 510
Nett Margin		30 949.47

***Seasonal labour**	**Activity**	**Man hours/ha**	**Avg. man hours**	**Cost/ Annum**
	Collective pruning	90-145	117.5	2 548.58
	Top shoots	15-25	20	433.8
	Remove leaves	20-30	25	542.25
	Crop Control	65-80	72.5	1 572.53
	Harvest of trellis*	9.5	104.5	2 266.61
	Pest control	60-75	67.5	1 464.08
	Intensive and extensive offset	45	45	976.05
	Leaf removal	20-30	25	542.25
	Summer foliage action	230	230	4 988.70
Total				15 334.83

Note	Harvest of trellis is calculated as man hours per tonne (Machine)

Annexure I: Pros and cons of each crop

Crop	Pros	Cons
Almonds	• Very low establishment costs • High income (1st) • Mechanical harvesting available • Short travel distance	• Highest water requirement
Apricots (Fresh)	• Low water requirement (2nd) • Good income • Shortest growing season • Low establishment costs	• Very High labour requirement • Travel to harbour
Apricots (Processed)	• Low water requirement (2nd) • Good income • Short travel distance • Shortest growing season • Low establishment cost	• Very High labour requirement
Peaches (Fresh)	• High income (2nd)	• Travel to harbour • High water requirement
Peaches (Processed)	• Short travel distance • Average income	• High water requirement
Plums	• Good income	• Travel to harbour • Very high establishment costs (1st) • High water requirement
Olives (Oil)	• Very low establishment costs • Mechanical harvesting available • Average income • Lowest water requirement	• Alternate bearing
Olives (Fresh)	• Very low establishment costs • Mechanical harvesting available • Lowest water requirement	• Low income • Alternate bearing

Grape vines (Wine grapes)	• Average-low water requirement • Mechanical harvesting available	• Lowest income