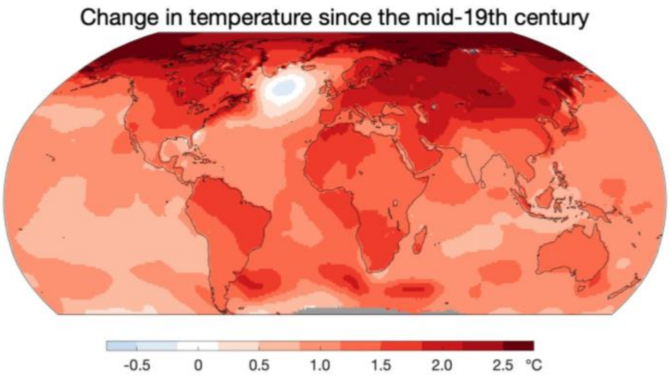
HORTGRO
Growing Fruit IQ

Scientific and Practical Guide to Climate Change and Pome/Stone Fruit Production in South Africa

Extended Executive Summary

April 2021


Change in temperature since the mid-19th century

Isikhungusethu Environmental Services (Pty) Ltd

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Objectives & Rationale

The future sustainability of the pome and stone fruit industries in South Africa, in view of climate change, is threatened regarding yield as well as fruit quality and irrigation water requirements. Across all the production areas, temperatures are rising and daily maximum temperatures are already in places reaching record levels. This exacerbates the already serious problems of sunburn in sensitive pome and stone fruit cultivars, and poor red colour development in red and bicolour pome fruit cultivars. Increasing autumn and winter temperatures reduce the accumulated chill units, with implications for dormancy development and spring bud break. The geographic areas climatically suitable for commercial pome and stone fruit cultivation are likely to shift. Warming brought about by climate change will also cause changes in the population dynamics of key pests, and this will differ from area to area. Furthermore, climate change projections for rainfall indicate greater rainfall variability and altered total annual rainfall, which will change surface water runoff, groundwater recharge and irrigation water demand. Simultaneous warming will lead to faster drying of soils and will further alter the irrigation demand of crops. Agriculture is already experiencing the impacts of climate change, and long-term adaptation planning is vital for perennial fruit crops with an expected economic lifetime of 25-30 years. Growers need a reliable science-based source of information to guide their decision making, and this should differentiate between different production regions with different climate characteristics. The overall project objective was to compile a science-based, relevant and practical guide (practitioners' handbook) to pome and stone fruit farmers in South Africa on climate change risks, impacts and adaptation responses.

Methods

Industry experts guided the choice of key climate-related parameters to be included in the Guide. The modelling and mapping of these parameters (soil, water, climate, pests) was based on existing databases and knowledge, with additional modelling of fruit quality parameters such as sunburn and red colour development. The climate variables used are based primarily on temperature and rainfall and some of their derivative variables. Maps were prepared at a spatial resolution of so-called Quinary Catchments (QCs, or Quinaries), which are relatively homogeneous agricultural and hydrological spatial units regarding climate, topography and soils.

The historical climate for the 50-year period 1950-1999 provides the reference, or baseline, against which projected impacts of climate change can be evaluated. A comprehensive database of quality-controlled rainfall data in southern Africa was used (Lynch, 2004). The procedures used resulted in a unique 50-year daily rainfall record for each of the Quinaries covering the region.

Daily maximum and minimum air temperature values facilitate estimations to be made, either directly or indirectly, of solar radiation, vapour pressure deficit and potential evaporation (Schulze, 2008). Procedures outlined by Schulze and Maharaj (2004) enabled the generation of a 50-year quality-controlled historical time series (1950-1999) of daily maximum and minimum temperatures at any unmeasured location in the region at a spatial resolution of one arc minute of latitude / longitude (~1.7 x 1.7 km). Representative grid points were determined for each of the Quinaries using techniques outlined in Schulze et al. (2010). The resulting 50-year series of daily maximum and minimum temperatures for each Quinary was then used to generate daily estimates of solar radiation and vapour pressure deficit and from these, daily values of reference potential evaporation were computed.

Future climate *projections* (which are NOT forecasts nor predictions) are scenario descriptions of possible future conditions based on the current understanding of the physics of the atmosphere, on assumptions about changing greenhouse gas emissions and their atmospheric concentrations, as well as on assumptions of future technological, economic and demographic trends. The skill of the projections (i.e. their accuracy) depends strongly on how far into the future they are made, which of a number of possible future greenhouse gas emissions pathways is considered, and on the climate variable considered (e.g. temperature projections are generally more skilful than rainfall projections). Deriving key regional messages about future potential change thus requires assessing multiple lines of evidence. Climate projections are therefore assessed in this Guide from a range of climate models generically termed GCMs, i.e. General Circulation Models, as it is not possible to identify a 'best' model for all relevant climate variables for South Africa.

Some of the climate projections used in the impact studies in this Guide have been based on certain case studies of the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios (SRES) so-called A2 emission scenario. This is essentially a 'business as usual' scenario representing CO_2 equivalent levels of above 500 ppm by 2050. Other climate projections have used outputs from GCMs driven by a so-called RCP, or Representative Concentration Pathway, used in more recent IPCC assessments.

Irrespective of the suite of GCMs used, future rainfall projections remain challenging. This is because:

- First, rainfall is a derived rather than a direct output from GCMs.
- Second, complex rainfall-generating processes such as cloud formation and land surface-atmosphere interactions are not yet fully understood and resolved in climate models.
- Third, rainfall is an event based variable, and not continuous, as is temperature.

The suite of multiple GCMs which were used in a specific analysis are referred to on all the relevant maps. The two sets of GCMs that were used in various sections of this Guide were:

- Five CMIP3 GCMs which were downscaled / distributed by the Climate Systems Analysis Group (CSAG) of the University of Cape Town. These GCMs were statistically downscaled to over 2 000 climate stations in South Africa and then further bias corrected for the Quinary Catchments using techniques described in Schulze et al. (2010). The future scenario A2 was used with these models. Daily values of climatic parameters were generated for two 20-year time periods: the present (1971-1990) and the intermediate future (2046-2065).

- Ten CMIP5 GCMs from the World Climate Research Programme sponsored Coordinated Regional Climate Downscaling Experiment (CORDEX). The GCMs were downscaled to the Quinary Catchments and then bias corrected for local topography using methods described in Schulze et al. (2014). The RCP8.5 future scenario was used with these models. Daily values of climatic parameters were generated for two 30-year time periods: historical or present (1976-2005) and the immediate future

(2016-2045). In the case of mean annual accumulated streamflow, this was simulated with the ACRU model using daily climate inputs from present (mid-1990s) and projected immediate future (mid-2030s) climatic conditions derived from six bias-corrected CMIP5 GCMs used in a current (as yet unpublished) Water Research Commission project at the Centre for Water Resources Research at the University of KwaZulu-Natal.

All results were mapped using ArcGIS (Environmental Systems Research Institute or ESRI). In most cases maps were presented for the historical situation (present), the future (either immediate [2030s] or intermediate [2050s]) and the change between the two time periods. In some cases the coefficient of variability for the parameter was also presented.

High resolution maps were generated for key parameters for eleven fruit production regions of the Western Cape and Langkloof (Fig. 1) using a recent fly-over database (WCDoA, 2018) and Google Earth (eastern Langkloof valley):

1. South-western coastal regions: Elgin-Grabouw-Vyeboom-Villiersdorp, Somerset West, Riviersonderend
2. North-western high-lying regions: Ceres (cold and warm Bokkeveld), Wolseley-Tulbagh, Piketberg
3. Eastern interior regions: Klein Karoo West, Klein Karoo East, Langkloof
4. South-western river valleys regions: Stellenbosch-Berg, Breede Valley

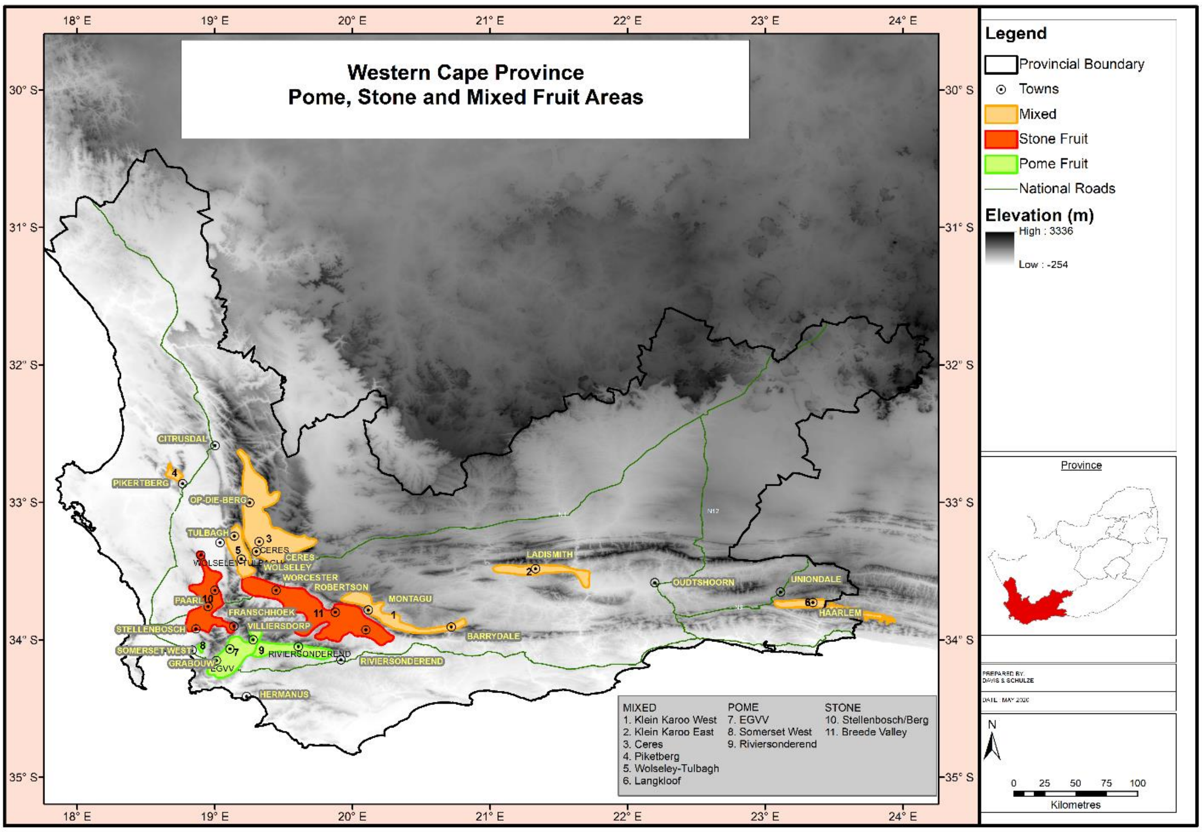


Figure 1. Pome and stone production regions of the Western Cape and Langkloof.

Key Results

Mean annual temperature (*MAT*)

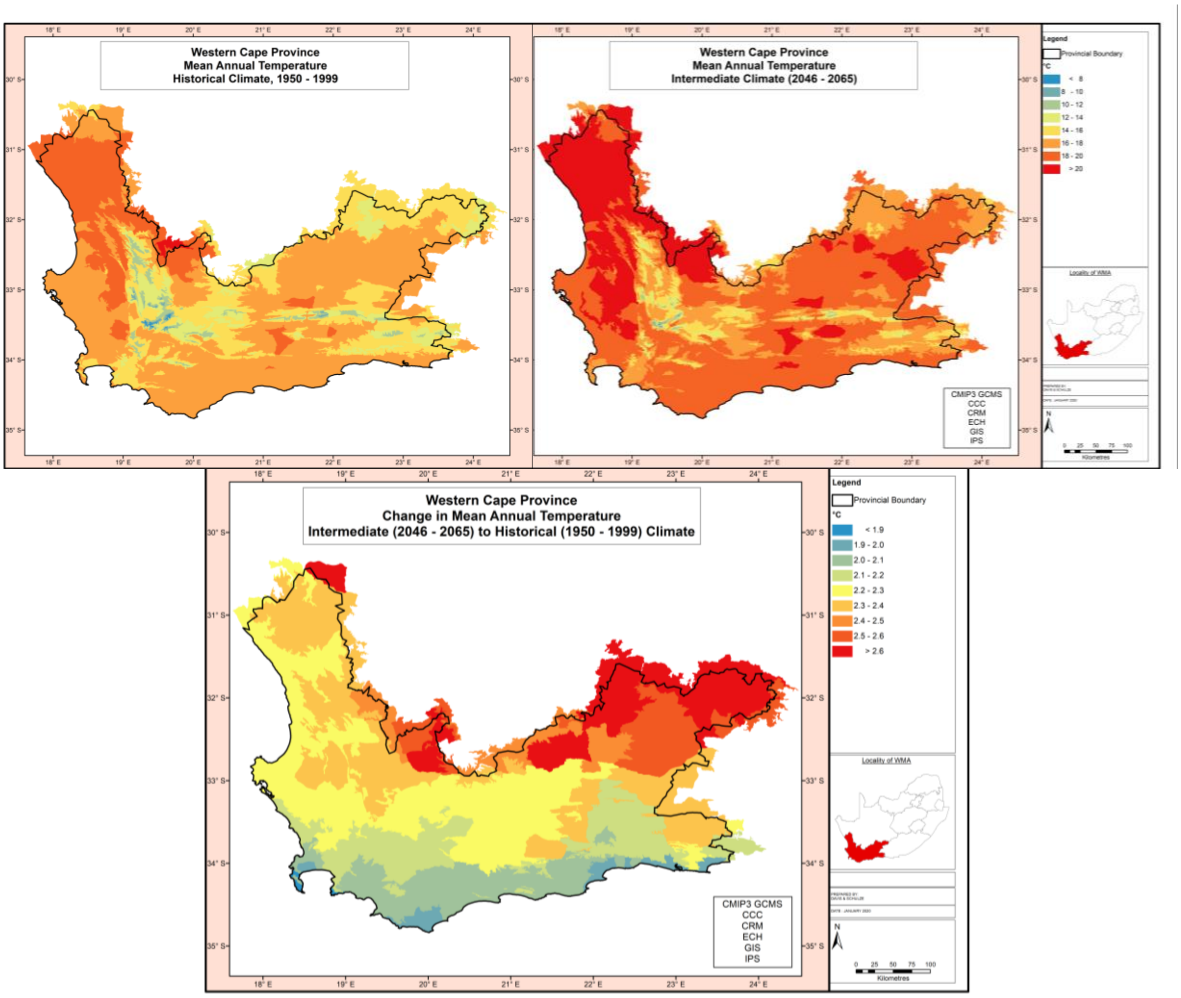


Figure 2. Mean annual temperature (°C) under historical climatic conditions (top left) and projected intermediate future climatic conditions (top right), and (bottom) projected changes (in °C) from the historical climatic conditions to the intermediate future of mean annual temperatures. The latter two are derived from multiple CMIP3 GCMs. (Original research: Schulze, 2011)

Under historical climatic conditions, *MAT* in the Western Cape and Langkloof ranges from <8°C in the mountain peaks to 18-20°C in the arid north-west, with most of the region experiencing a *MAT* of 14-18°C (Fig. 2, top left). Model projections from multiple CMIP3 GCMs for the intermediate future (mid-century) display marked increases in *MAT* (Fig. 2, top right). The changes from historical to intermediate future (Fig. 2, bottom) are of the order up to 2.0°C along the southern coast (under the modifying influence of the warm Mozambique current) to approximately 2.6°C in the northern interior and north-east.

Annual temperatures are the integrator of both diurnal and seasonal temperature differences and serve as a very broad indicator of agricultural potential and crop suitability. Thus the anticipated increase in *MAT* becomes a major concern for pome and stone fruit growers. It will likely lead to spatial shifts in production areas and shifts in the fruit types and cultivars that are suited to specific regions. In broad terms, such shifts could see the warmer parts of EGVV and Piketberg becoming unsuited to pome fruit production, and core cooler apple regions becoming like present day core pear regions. Pear production in the Klein Karoo is likely to become more marginal, if not unsuited. Stone fruit production should not become limited by *MAT* in the north-western high-lying regions or the Stellenbosch-southern Berg region, but could become marginal in the presently warmest parts of the Klein Karoo production regions, the northern Berg and the Breede Valley.

Mean daily maximum air temperature in January and mean daily minimum air temperature in July

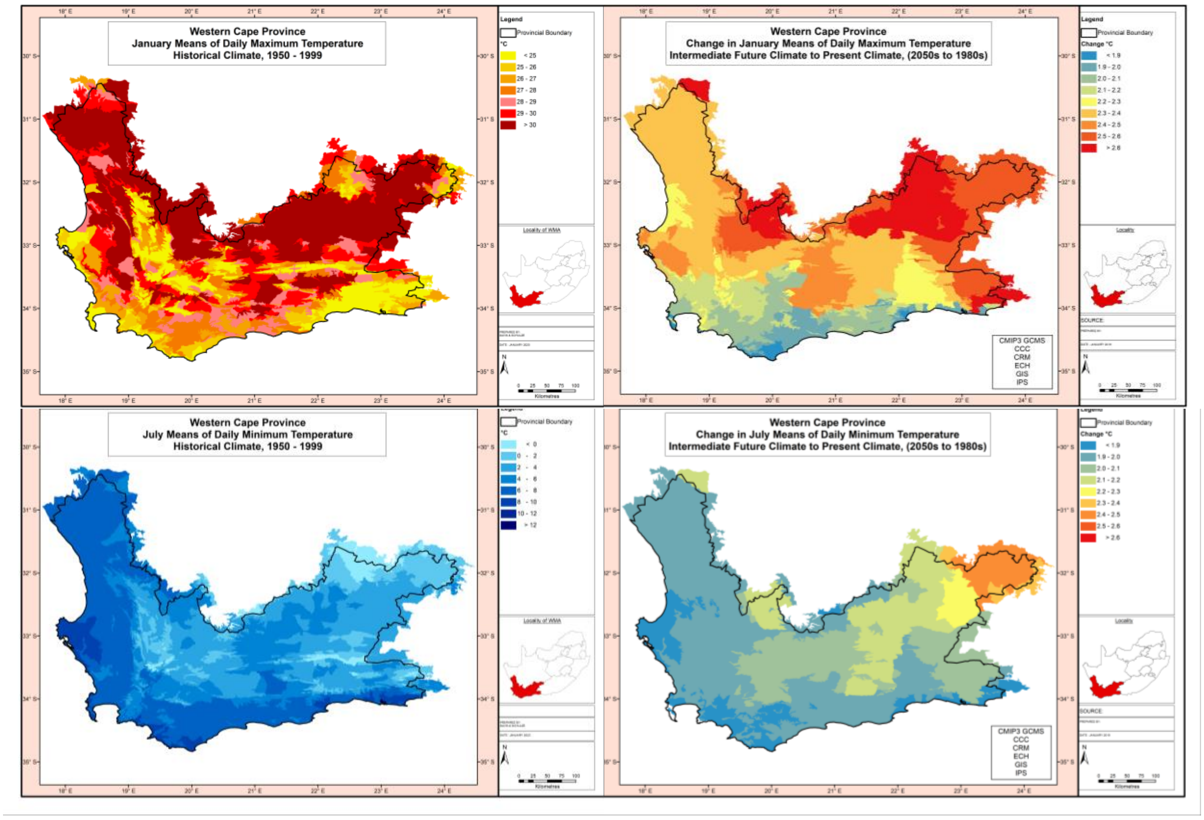


Figure 3. January means of daily maximum temperatures (top left) and July means of daily minimum temperatures (bottom left) under historical climatic conditions, and respective projected changes (in °C, top and bottom right) between present and intermediate future climates. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs. (Original research: Schulze, 2011)

Under historical climatic conditions, high mid-summer temperature maxima are a feature of the semi-arid north-east interior, the inter-montane areas, and the arid north-west (Fig. 3, top left), with mean monthly maxima averaging > 30°C in January. In the higher-lying mountainous areas and the coastal zone, mean monthly maxima are < 28°C (Fig. 3, top left). With projected climate change into the intermediate future (mid-century) it is particularly the east and north-east that display the highest increases at > 2.5°C, with maxima in the southern areas projected to generally increase at < 2.2°C (Fig. 3, top right).

The projected changes in summer mean monthly maxima will affect the pome and stone fruit sector throughout the region. However, parts of the region e.g. northern Berg River valley, Wolseley-Tulbagh and Klein Karoo, will likely experience the ‘double whammy’ in already being hot and then having the highest projected increases in temperatures in mid-summer. Impacts will be wide-ranging, from sunburn to increased irrigation water demand resulting from high evapotranspiration rates.

July mean minima are, historically, highest along the south and west coast areas at 6-12°C. In the interior, July mean minima are often in the range 0-4°C, with the lowest minima in the mountainous regions (Fig. 3, bottom left). Overall, projected July minimum temperature by mid-century increases by around 2°C, but in the north-east by up to 2.5°C (Fig. 3, bottom right). Note that, overall, the CMIP3 GCMs used in this analysis display lower, more benign, mid-winter minimum temperature increases than the projected increases of mid-summer maxima.

The increase in winter mean monthly minima holds both positives and negatives. Less frost damage could be one outcome. However, dormancy could be disrupted, with trees beginning to flower earlier, which may even increase the risk of frost during the early season. Insufficient accumulated chilling would have significant impacts on pome (and some stone) fruit production in already warmer production regions. Many pests and diseases would be able to over-winter in the warmer conditions, thus changing the timing and severity of early season impacts on orchards.

Annual number of days >35°C

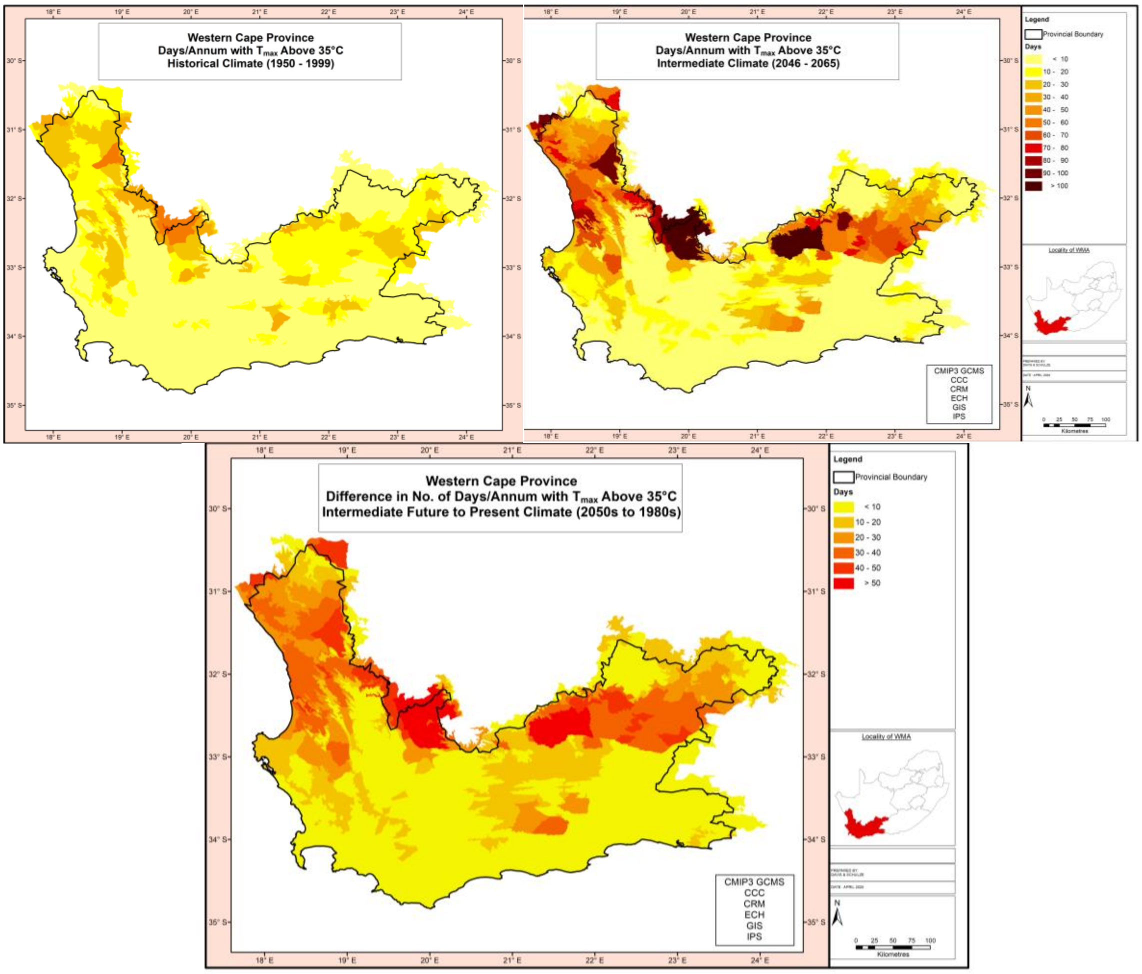


Figure 4. Average days per annum on which daily maximum temperatures exceed 35°C under historical climatic conditions (top left) and projected intermediate future (top right) climates. The figure at the bottom shows the changes (in days per annum) between present and intermediate future climates. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

The average number of days per annum with a maximum temperature exceeding 35°C is, for the most part, less than 20 over most of the region (Fig. 4, top left). Along the north-west border this can be 30-40 days, and in places even up to 50 days per annum under historical climate conditions. Under the projections for the 2050s (Fig. 4, top right), much of the region will experience up to 20 additional days exceeding 35°C (Fig. 4, bottom). In the worst affected regions of the north-west coast, the northern border and the north-east (Karoo), 30 to 50 additional hot days could be experienced per annum.

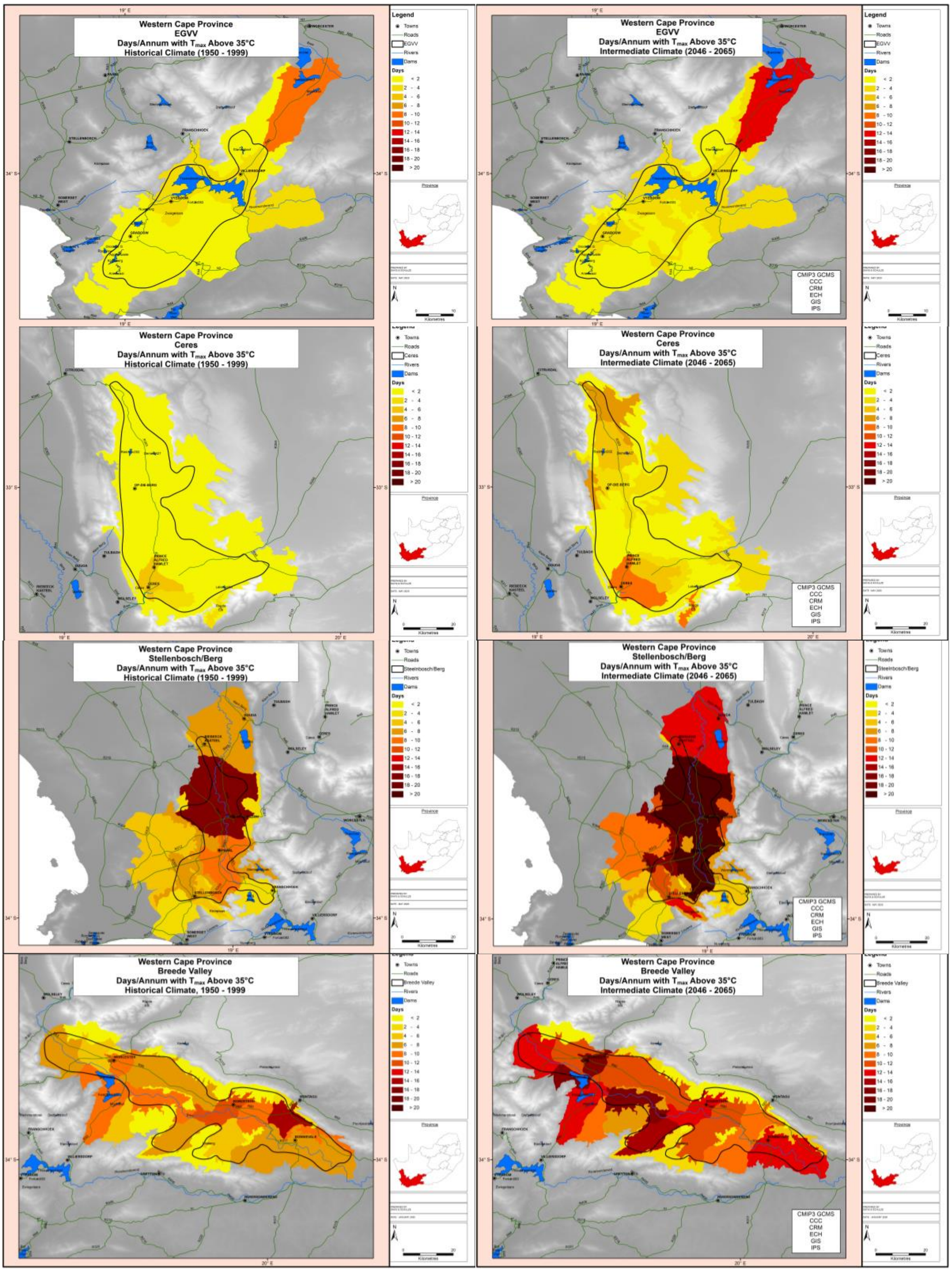


Figure 5 (cont. next page). Average days per annum on which daily maximum temperatures exceed 35°C under historical climatic conditions (left column) and projected intermediate future (right column) climates. From top to bottom: EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo West, Klein Karoo East. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

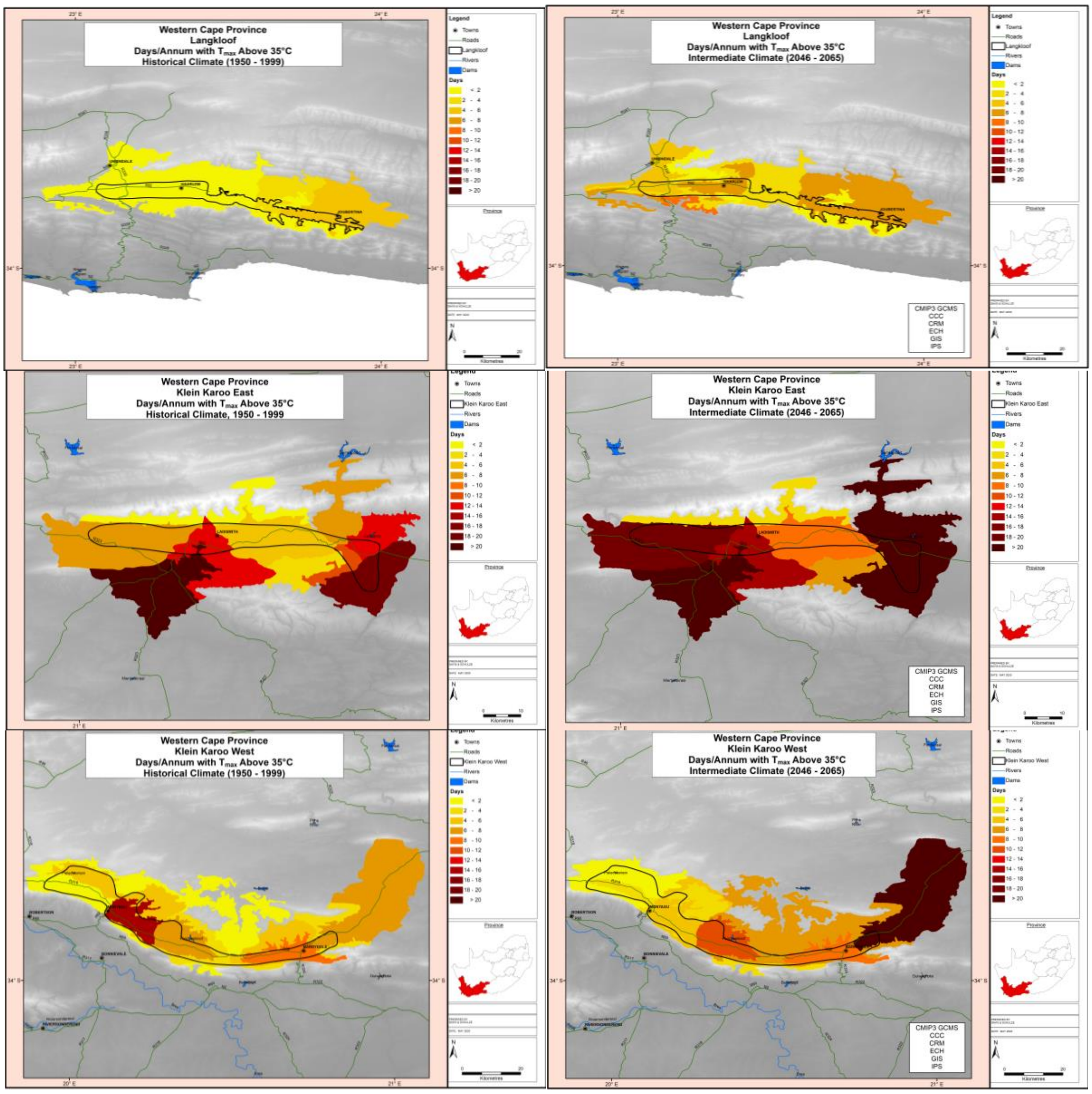


Figure 5 (cont.). Average days per annum on which daily maximum temperatures exceed 35°C under historical climatic conditions (left column) and projected intermediate future (right column) climates. From top to bottom: EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo West, Klein Karoo East. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

Fig. 5 presents the results for days per annum of daily maximum temperatures exceeding 35°C for seven key pome and stone fruit regions. For the historical period (left column), the values range from fewer than 4 days (EGVV, most of Ceres, western Langkloof) to more than 12 days (Wellington, Ashton, Montagu, south of Calitzdorp). Under the projections for the 2050s (Fig. 5, right column), an additional 2-6 days above 35°C is seen for most of the EGVV region, Koue Bokkeveld and Koo/Montagu. At the other end of the spectrum, 16-18 additional hot days are projected for the area around Wellington, and more than 18 additional hot days are projected for Calitzdorp, so that by mid-century the areas around these towns could experience between 34 and 42 such hot days annually.

The significant projected increases in hot and very hot days in the intermediate future (~ 30 years hence) does not bode well for pome and stone fruit growers in regions that today are already hot. Heat stress will affect fruit trees and humans working outside in many ways. Such conditions also result in high evaporative water losses from soil and water bodies and through transpiration. There will be an increased water demand to meet the higher irrigation requirements.

Annual reference potential evaporation

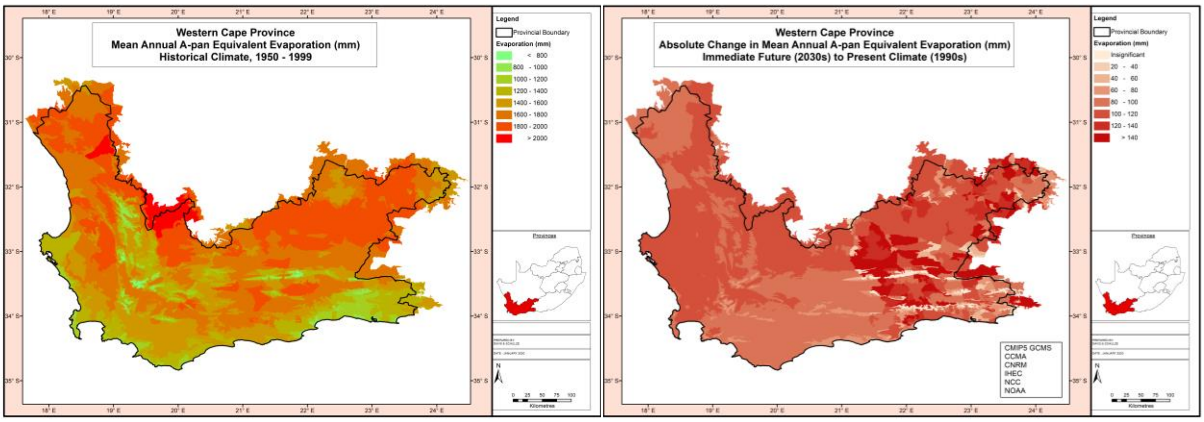


Figure 6. Mean annual A-pan equivalent reference potential evaporation under historical climatic conditions (left) and projected increases (mm) from the present to immediate future climates (right). The latter is derived from multiple CMIP5 GCMs.

Under historical conditions (1950-1999), mean annual A-pan equivalent reference potential evaporation ranges from ~ 800 mm along the cool moist mountain ranges to > 2 000 mm in the arid and hot north-west to north-east (Fig. 6, left). Climate projections from the present into the immediate future of the 2030s show annual increases from as little as 20 mm in the eastern mountains to > 140 mm in the eastern Karoo (Fig. 6, right). Over the pome and stone fruit production regions the historical annual values are in the range 1200-1900 mm, and the projected annual increases into the immediate future are in the range 70-120 mm.

Historical annual reference potential evaporation is already high in the region at up to around 2000 mm, and projected increases into the 2030s of up to 120 mm, mostly in spring and summer, will impact on water availability. Higher potential evaporation from dams, wetlands and riparian zones will constitute an unavoidable loss to the region’s water, ecology, and agriculture sectors. Additionally, all else remaining the same, soils are anticipated to dry out more rapidly in future, leading to potential negative implications for runoff production. Irrigation water demands will be higher than at present, leading to both increased abstractions from dams and reduction in river flows where irrigation is from run-of-river.

Months to reach 250, 500 and 700 chill units (Infruitec model)

This analysis was performed at national scale, and the full report presents maps for three provinces in addition to the Western Cape: Free State, KwaZulu-Natal and Mpumalanga.

For deciduous fruit cultivars with a given chill requirement, a key question is when (i.e. in which month) certain levels of chill accumulation are met at a specific location. For the purposes of this study, a low chill requirement is represented by 250 PCUs, a medium chill requirement is represented by 500 PCUs, and a high chill requirement is represented by700 PCUs. Results are illustrated by way of maps in Fig. 7, with the left column showing the historical climate and the right column showing the intermediate future climate.

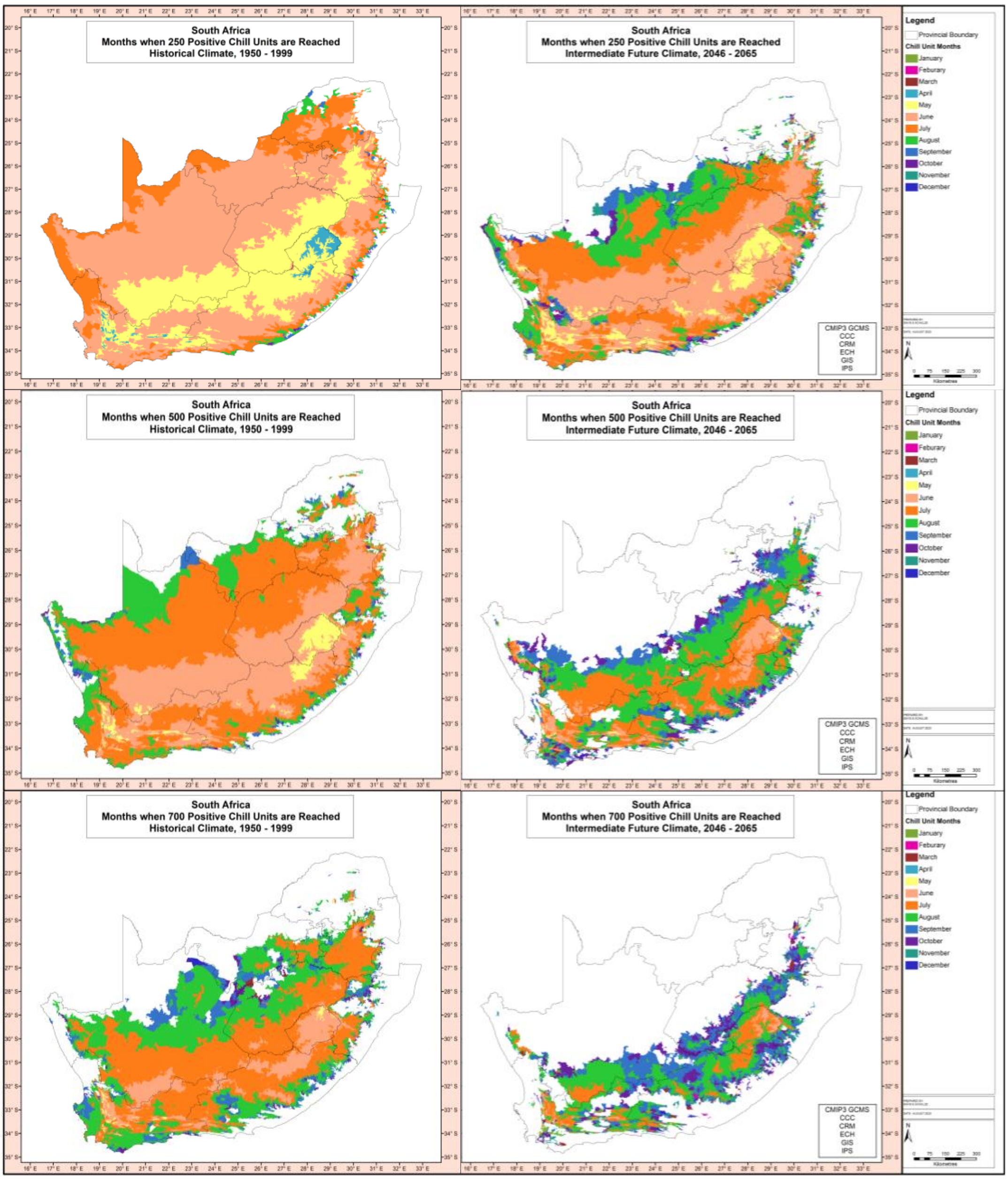


Figure 7. Month by which 250 (top left), 500 (middle left) and 700 (bottom left) PCUs are reached in South Africa under historical climatic conditions, as well as under intermediate future climatic conditions in the corresponding right-hand maps. (Original research: Schulze and Schütte, 2016).

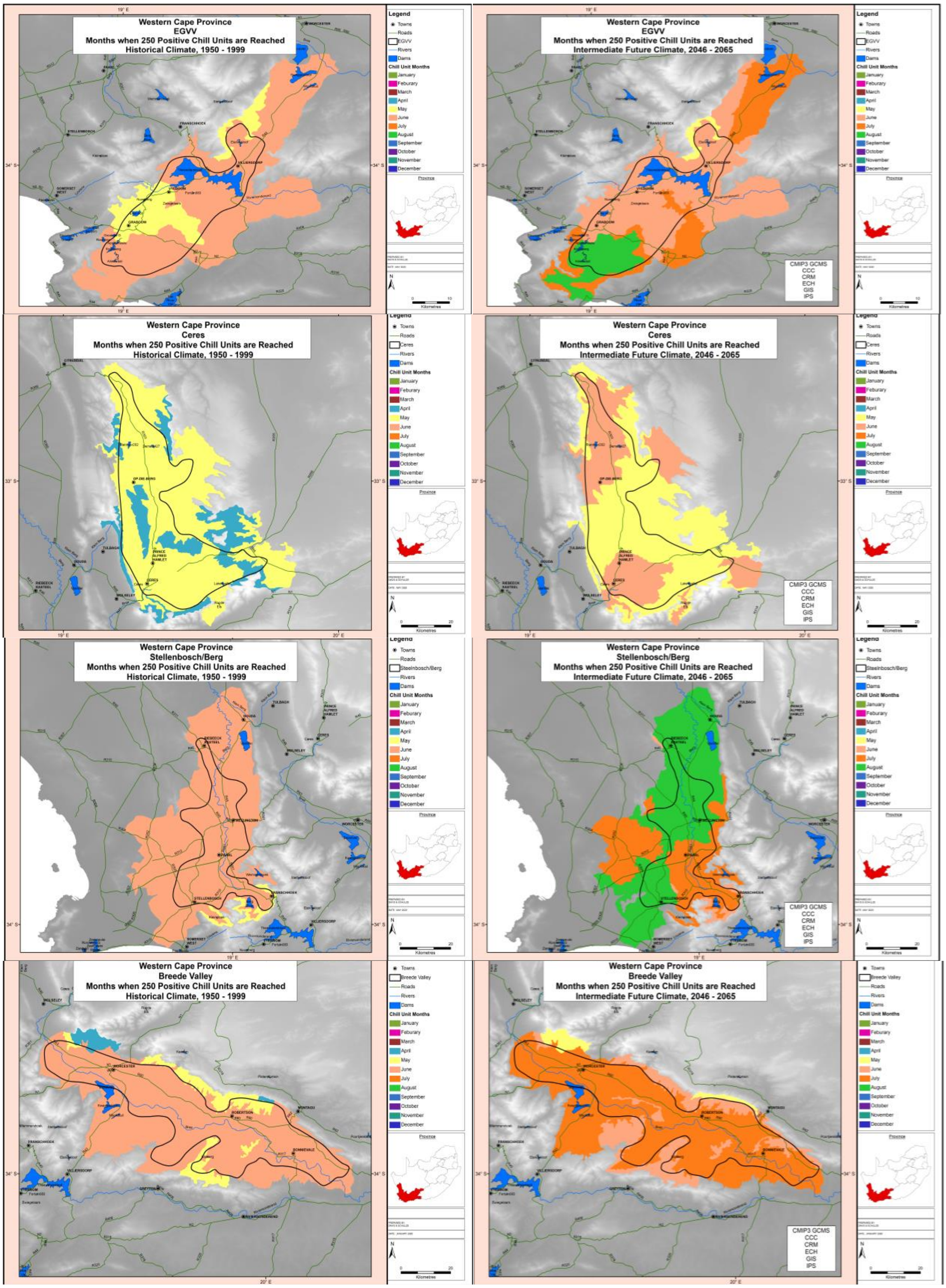
Historically, low PCUs (250) are reached by May in the cooler parts of South Africa, including the Cape Fold mountains, the eastern escarpment, The Drakensberg and its foothills, and parts of the Karoo and Highveld. Across the remainder of the areas where deciduous fruit can be grown, 250 PCUs are generally reached in June (Fig. 7, top left). By the intermediate future of the 2050s, 250 PCUs are projected to be reached generally one month later (June to July), but in some areas up to two months later (Fig. 7, top right). Only the highest elevation mountains and foothills still reach this threshold in May.

On the other hand, 500 PCUs are achieved historically in May (coldest mountainous areas), June (other high-lying cooler areas) or July (warmer areas where deciduous fruit is produced) (Fig. 7, middle left). By the intermediate future of the 2050s (Fig. 7, middle right) the area still achieving this threshold is projected to be greatly reduced. The south-western parts of the fruit production areas (Western Cape) will only achieve 500 PCUs by August or September or even later, whereas the cooler north-western high-lying areas of the Western Cape, parts of the Klein Karoo, the Langkloof, eastern Free State, and patches of high-lying areas of Mpumalanga and the KwaZulu-Natal Midlands mostly still achieve 500 PCUs by June or July.

Under historical climatic conditions, high PCUs (700) are reached by June (highest and coldest areas), July (other fruit production regions, and the high-lying southern and eastern interior and KwaZulu-Natal Midlands) or August (warmer south-western fruit production regions, parts of the Klein Karoo) (Fig. 7, bottom left). Into the intermediate future (Fig. 7, bottom right), the models project a shift to July in the coldest areas, August (e.g. eastern Free State), or September-October (south-western Cape, KwaZulu-Natal Midlands, Mpumalanga). Some fruit production regions may not each 700 PCUs at all (e.g. Berg and Breede River Valleys).

More detailed results for seven key pome and stone production regions (Western Cape – Langkloof) are shown in Fig. 8 (250 PCUs), Fig. 9 (500 PCUs) and Fig. 10 (700 PCUs). In each case, the results for the historical climate are shown in the left column, and those for the intermediate future (mid-century) are shown in the right column.

Historically, low PCUs (250) are reached by May in the cooler regions (Grabouw-Vyeboom, Ceres, western Langkloof), and by June in the other regions shown (Fig. 8). By the intermediate future, 250 PCUs are generally reached one month later, but in some areas (warmer parts of the Berg region) up to two months later (August). The colder parts of the Bokkeveld and the Koo valley still reach 250 PCUs in May. The core stone fruit regions of Stellenbosch-Berg, Breede Valley and most of the Klein Karoo reach the threshold by June or July.



Western Cape Province
EGVV
Months when 250 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
EGVV
Months when 250 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Western Cape Province
Ceres
Months when 250 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Ceres
Months when 250 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Western Cape Province
Stellenbosch/Berg
Months when 250 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Stellenbosch/Berg
Months when 250 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Western Cape Province
Breede Valley
Months when 250 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Breede Valley
Months when 250 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Figure 8 (cont. next page). Month by which 250 PCUs are reached under historical climatic conditions (left column), and projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

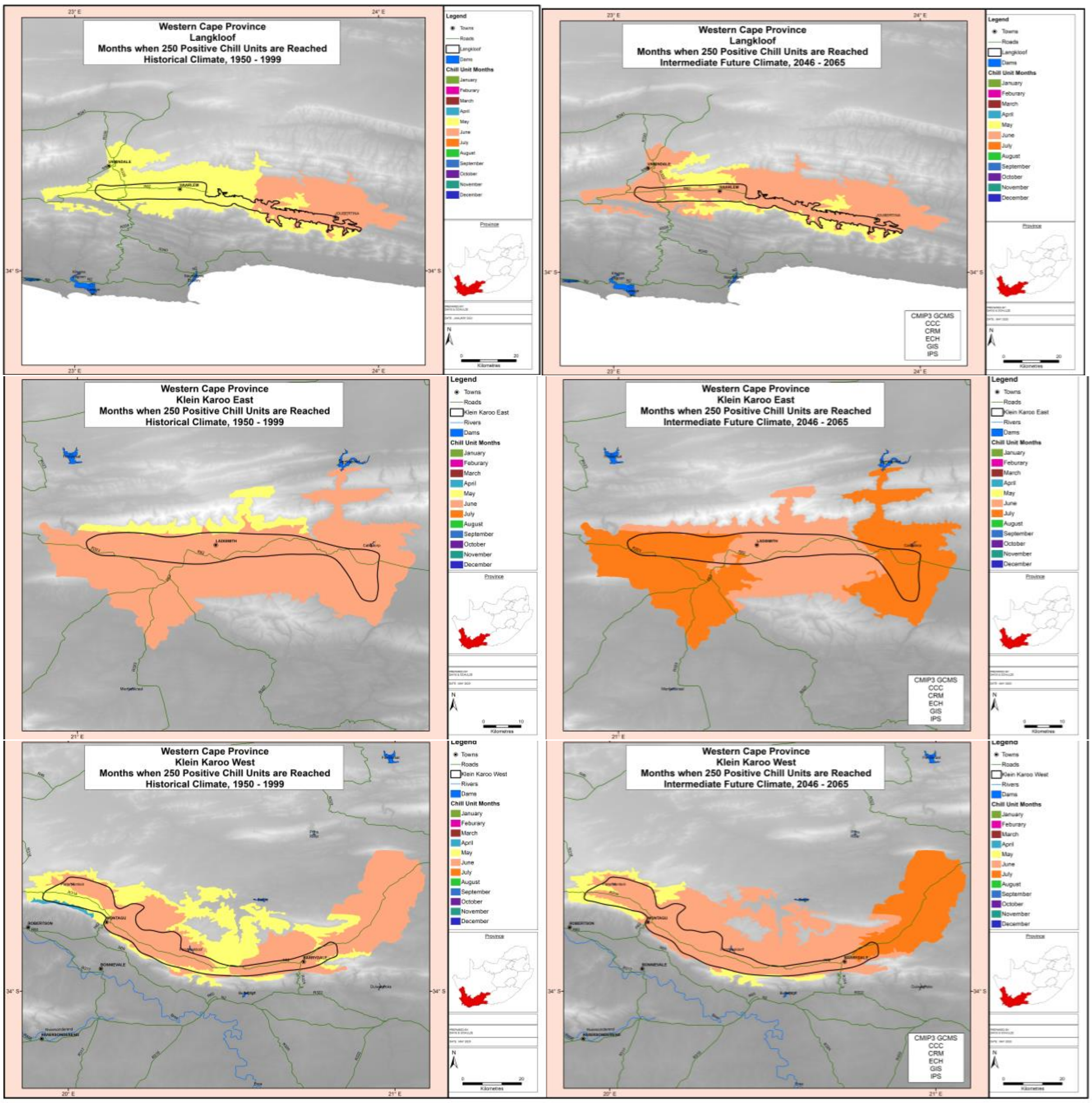


Figure 8 (cont.). Month by which 250 PCUs are reached under historical climatic conditions (left column), and projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

On the other hand, 500 PCUs are achieved historically largely by May-June (cooler areas) or July (warmer areas) in the fruit growing areas (Fig. 9). By the intermediate future, the EGVV region only achieves 500 PCUs by August, whereas the cooler Ceres region still achieves 500 PCUs by June or July. The cooler parts of the Stellenbosch-Berg region achieve 500 PCUs by September, and a range from August to October is seen across the Breede Valley. The threshold is reached generally in August in the Klein Karoo, although earlier (June) in the Koo Valley west of Montagu.

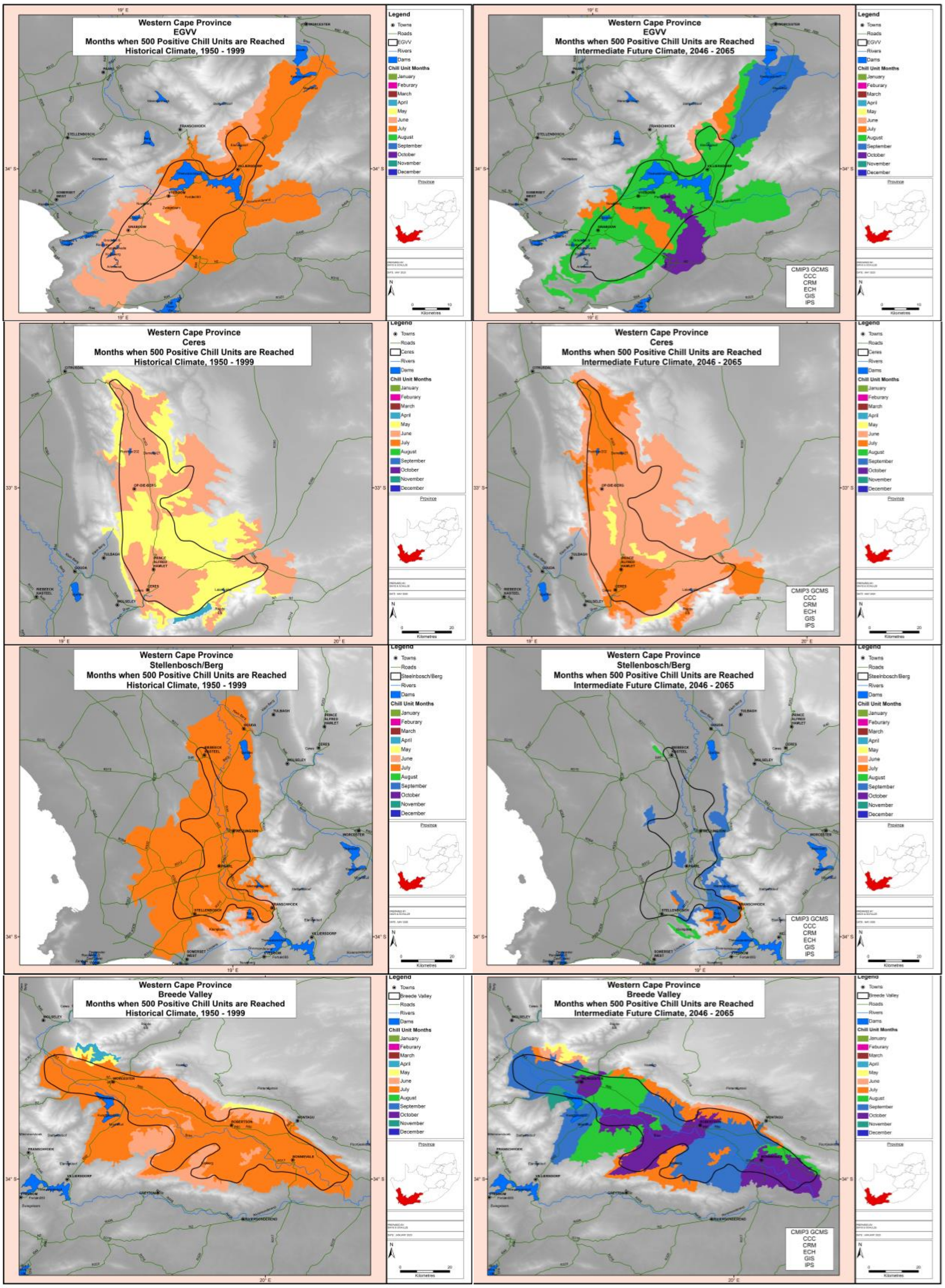


Figure 9 (cont. next page). Month by which 500 PCUs are reached under historical climatic conditions (left column), and under projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

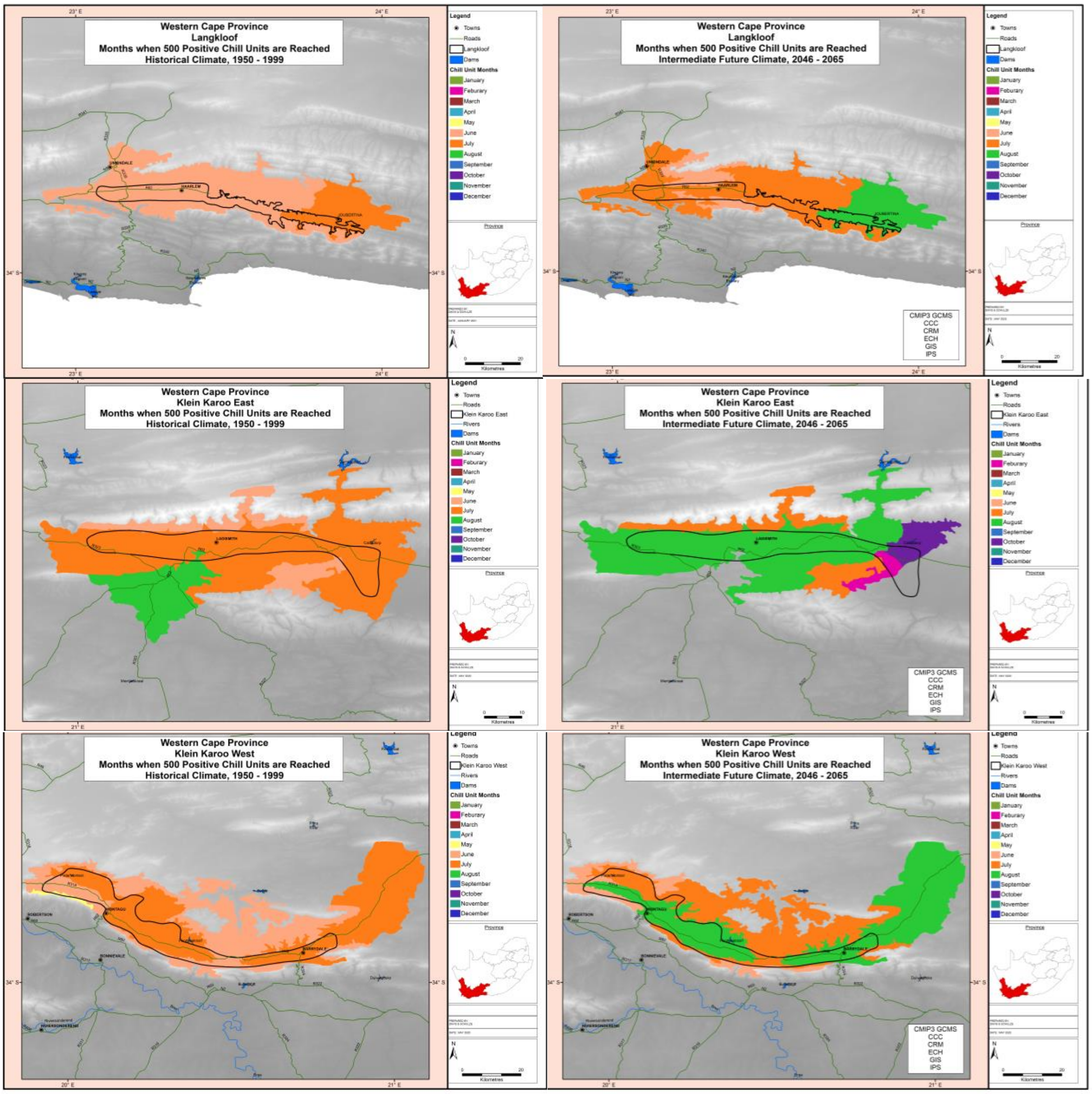
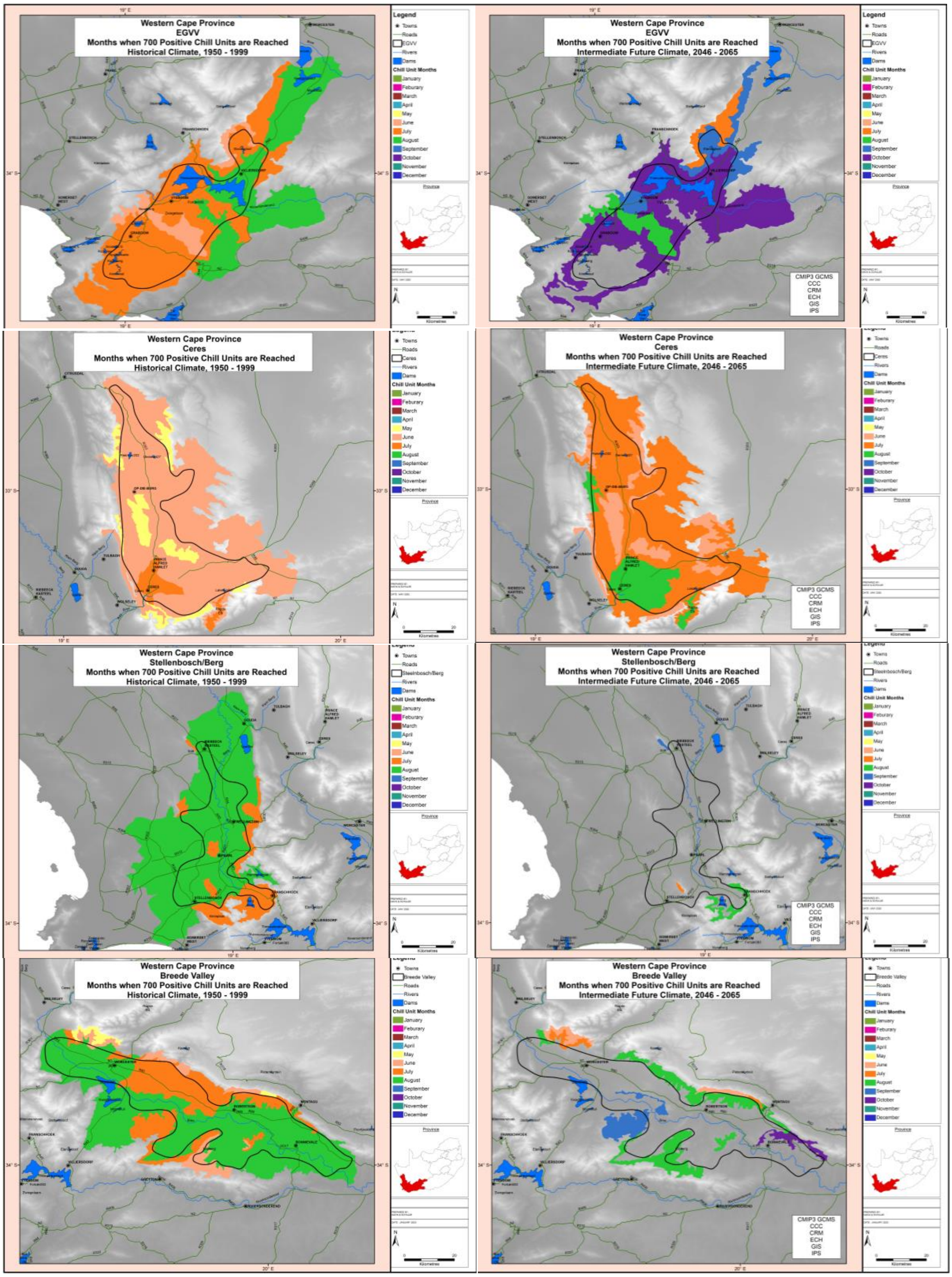


Figure 9 (cont.). Month by which 500 PCUs are reached under historical climatic conditions (left column), and under projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

Under historical climatic conditions, high PCUs (700) are reached by June-July (Ceres, western Langkloof) or July-August (EGVV, Stellenbosch-Berg, Breede Valley, eastern Langkloof, Klein Karoo) (Fig. 10). Into the intermediate future, this shifts to July-August in Ceres, Koo Valley and western Langkloof, and to September and later (or never) in the other regions.

If climate change continues as projected under the emissions scenario used in the modelling (RCP8.5), this will present severe challenges regarding the loss of chill accumulation. The regions at most risk regarding production of high chill requiring pome fruit cultivars (even considering the use of rest-breaking agents) include the whole EGVV and the Ceres – Prince Alfred Hamlet area. There is a wide range of stone fruit cultivars available with differing chill requirements, so the situation for this industry will depend on whether new climates can be matched with suitable cultivars. Challenges could arise in large parts of the Klein Karoo, Stellenbosch-Berg and Breede Valley regions.



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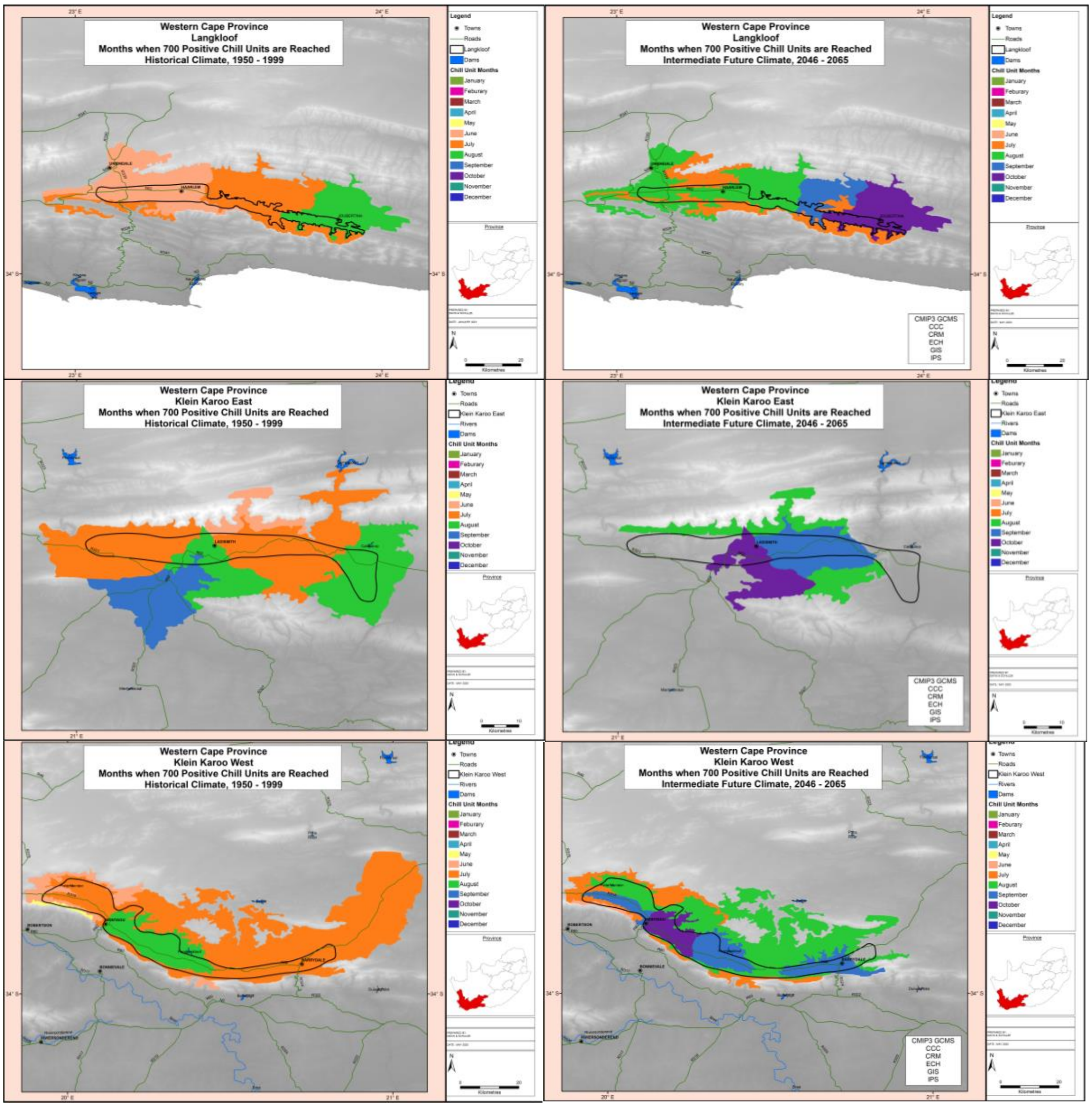
Western Cape Province
Breede Valley
Months when 700 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Figure 10 (cont. next page). Month by which 700 PCUs are reached under historical climatic conditions (left column), and under projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.



Western Cape Province
Langkloof
Months when 700 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Langkloof
Months when 700 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Western Cape Province
Klein Karoo East
Months when 700 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Klein Karoo East
Months when 700 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Western Cape Province
Klein Karoo West
Months when 700 Positive Chill Units are Reached
Historical Climate, 1950 - 1999

Western Cape Province
Klein Karoo West
Months when 700 Positive Chill Units are Reached
Intermediate Future Climate, 2046 - 2065

Figure 10 (cont.). Month by which 700 PCUs are reached under historical climatic conditions (left column), and under projected intermediate future climatic conditions (right column) for (from top to bottom) EGVV, Ceres, Stellenbosch-Berg, Breede Valley, Langkloof, Klein Karoo East and Klein Karoo West. Futures mapping was based on the means of outputs from multiple CMIP3 GCMs.

Annual number of dry and wet spells

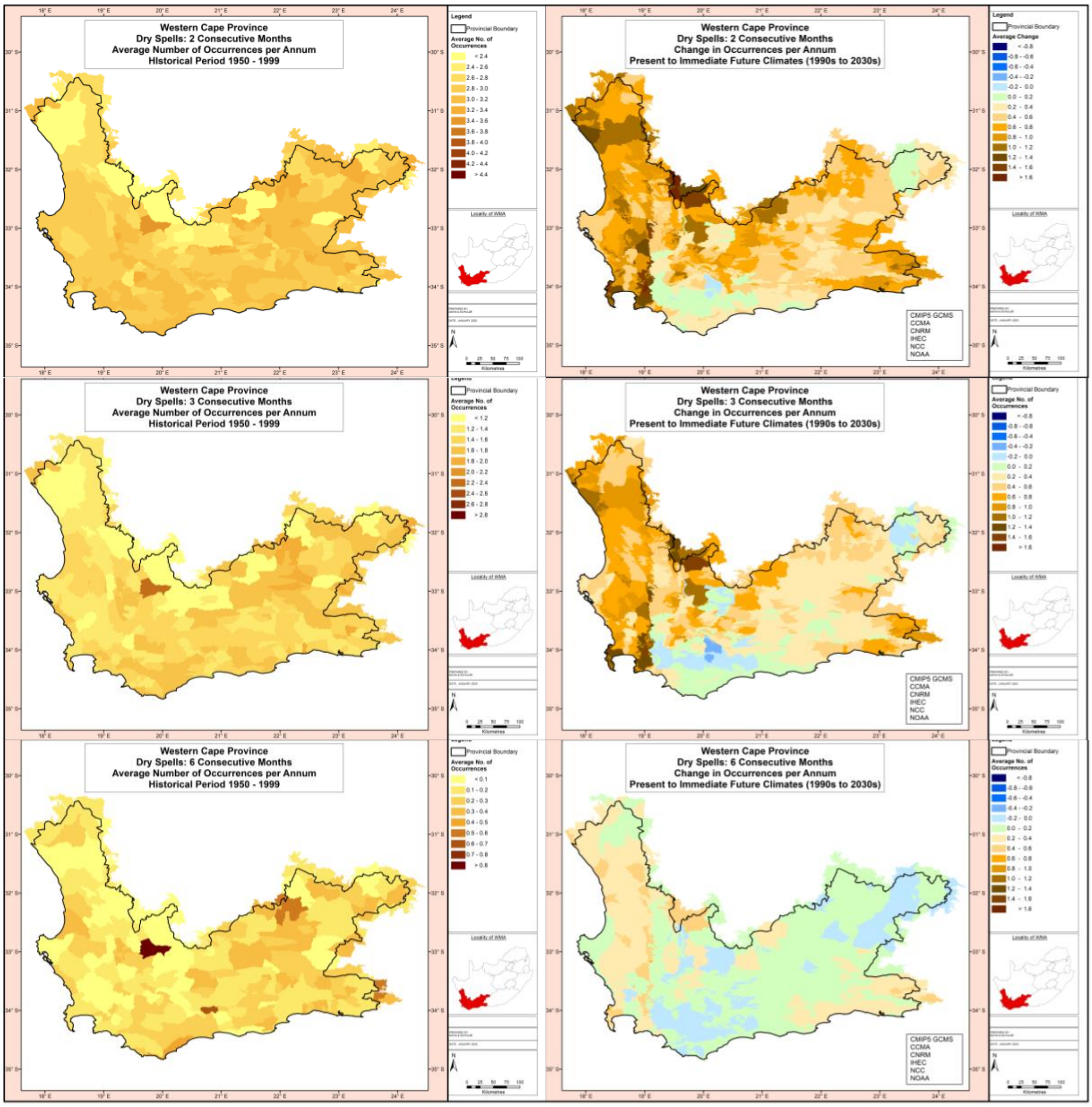


Figure 11. Two, three and six consecutive month dry spells under historical climatic conditions (left column, top to bottom), with corresponding projected changes (in number of occurrences per annum) from present to immediate future climatic conditions (right column, top to bottom). The latter maps were derived from outputs of multiple CMIP5 GCMs.

Average numbers of 2, 3 and 6 consecutive month dry spells per annum shown in Fig. 11 for historical climatic conditions (left column), along with changes in occurrences per annum of dry spells from the present into the intermediate future (right column). Overall, 2 and 3 consecutive month dry spells are projected to increase into the immediate future, especially in the west and along the northern border which show one or more additional occurrences per annum in some parts. For the 6 consecutive month dry spells the results are much more indeterminate.

Dry spells of short and medium duration are a concern to water resource managers as they imply increases in irrigation water requirements and reductions in runoff. The projections of more dry spells per annum of 2 and 3 consecutive months' duration over the next 10-20 years would thus constitute a further concern to region's irrigators and water resource managers.

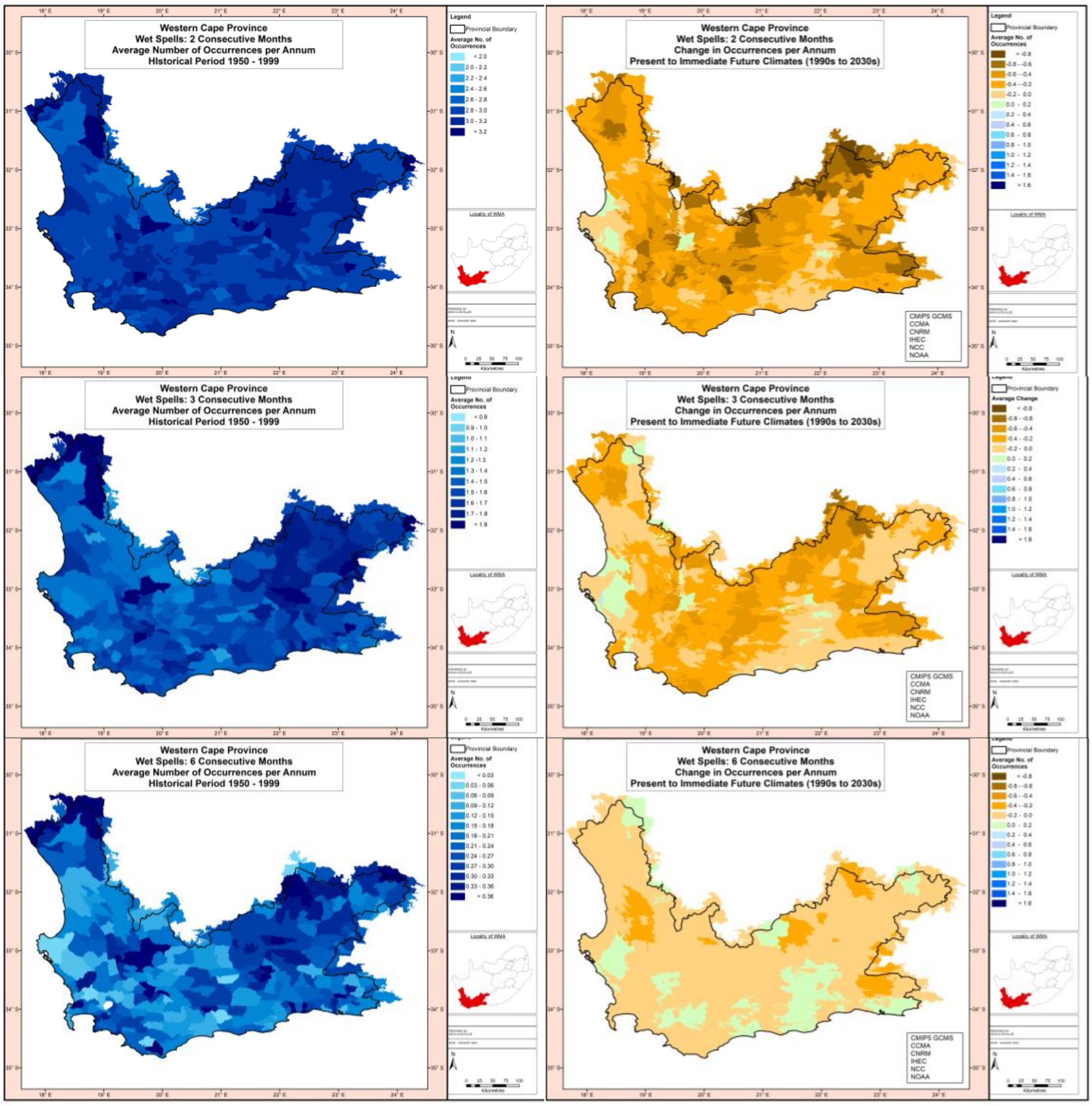


Figure 12. Two, three and six consecutive month wet spells under historical climatic conditions (left column, top to bottom), with corresponding projected changes (in number of occurrences per annum) from present to immediate future (1990s to 2030s) climatic conditions (right column, top to bottom). The latter maps were derived from outputs of multiple CMIP5 GCMs.

The number of wet spells of the three selected durations are shown for historical climatic conditions in the left column of Fig. 12. Of significance to the pome and stone fruit sectors are the projected changes into the immediate future (Fig. 12, right column). Projections point to generally fewer wet spells of 2- and 3-month duration, but the results for changes in 6-month wet spells are essentially inconclusive.

When considering both dry spells and wet spells, arguably the most significant finding is the ‘double whammy’ effect of simultaneous projections for increases in dry spells of 2 and 3 consecutive month durations and of decreases in wet spells of the same durations. This analysis clearly illustrates that one needs to go well beyond merely assessing impacts of climate change on an annual or even a seasonal basis. This “double whammy”, while not showing when the dry or wet spells occur over a year, could signify important impacts such as reduced irrigation water availability in dams.

Please note that wet and dry spell maps should be updated as soon as the latest CMIP5 GCM outputs have been released.

Annual streamflow

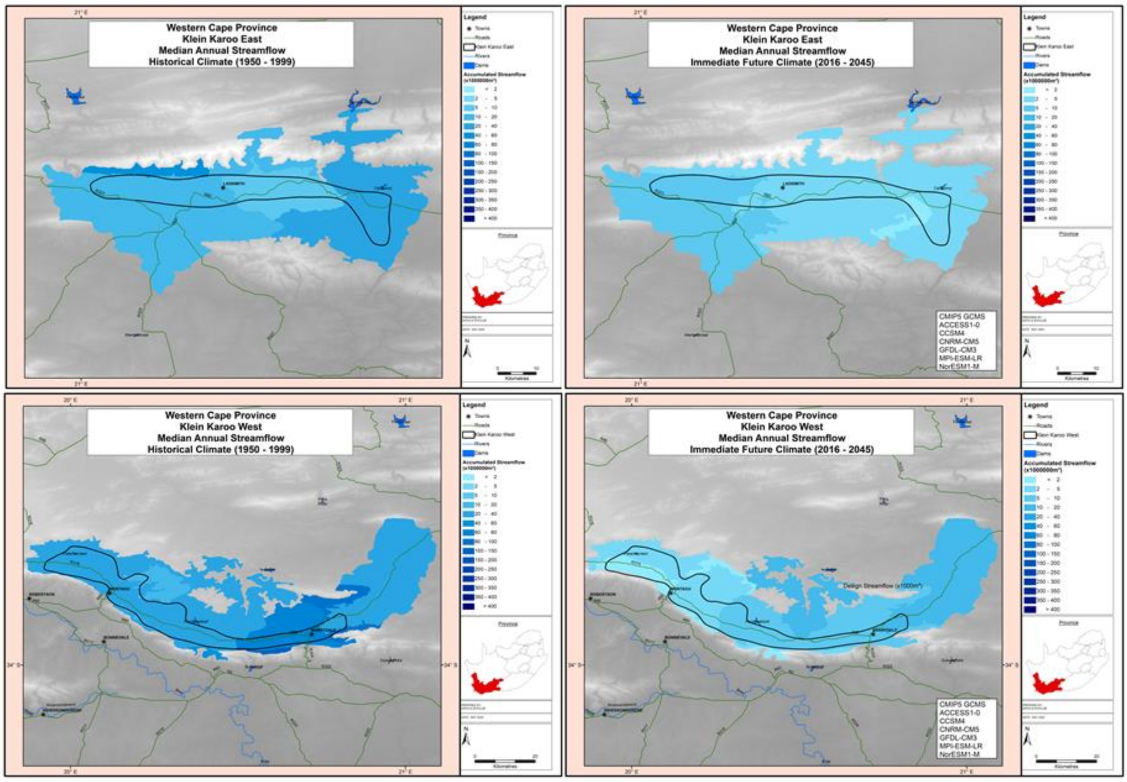


Figure 13. ACRU model derived median annual streamflow (in mm) under historical climatic conditions (left column), and under projected climatic conditions for the immediate future (right column) for two pome and stone fruit production regions in the Klein Karoo (those of greatest concern). The immediate future maps are derived from multiple CMIP5 GCMs.

Streamflows in the Klein Karoo are historically low and erratic, and any possibly decreases in the future would have severe impacts on the fruit sector. Fig. 13 presents the results for median annual streamflow in mm equivalents for the historical period (left column), and for the immediate future of the 2030s (right column). Present day streamflows are generally lower in Klein Karoo East (especially around Zoar) compared to Klein Karoo West. Projected changes into the future are highly variable, with increases up to 10 mm indicated for the Barrydale area and parts of the Klein Karoo East, and decreases up to 10 mm indicated over all other areas. These changes are relatively small in absolute (volumetric) terms, but when considered as percentage changes relative to present streamflows, relatively high reductions of 10-30%, and up to 50% in the Zoar area, are seen in the two regions (with the exception of the Barrydale area).

In an already water stressed region, any projected reductions in streamflows do not auger well for the pome and stone fruit sectors which are heavily irrigation dependent. In addition to these streamflow projections, the higher temperatures and enhanced evaporation rates will imply higher irrigation demands. However, in some catchments, projected increases in streamflows could alleviate future conditions to some extent. Given the relatively small volumetric changes one should, however, be cautious in over-interpreting the significance and impact on agriculture.

Days conducive to red colour development in apples

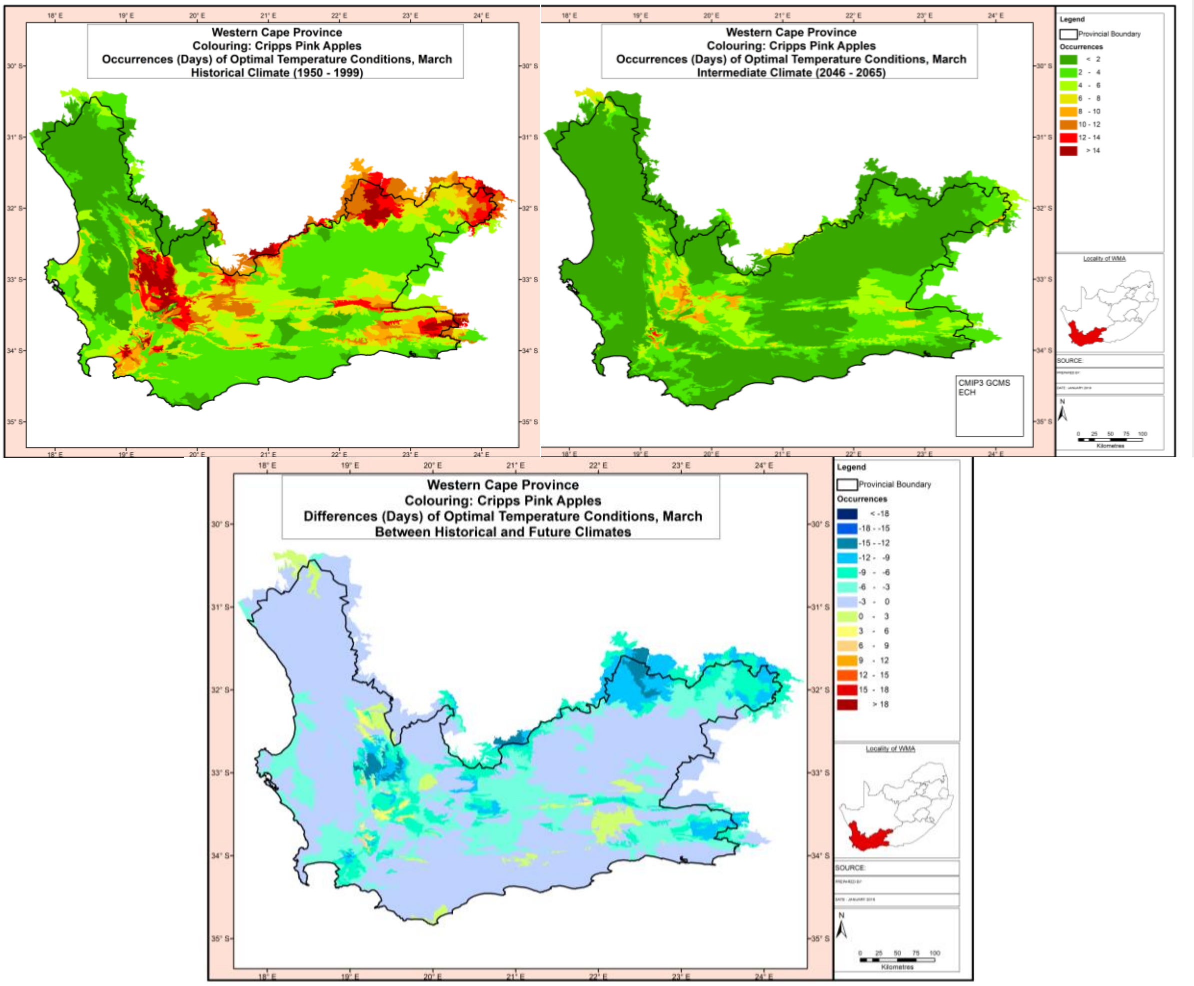


Figure 14. Number of days in March that climatic criteria are met for red colouring of mid- to late-season blushed or bi-colour apples (e.g. 'Cripps Pink') under historical climatic conditions (top left) and into the intermediate future climates of the 2050s (top right), with the difference (in days) in optimal climatic conditions shown in the bottom map. The latter two are derived from the CMIP3 ECH GCM.

The number of days in March on which the climatic criteria are met for red colouring of mid- to late-season blushed or bi-colour apples under historical climatic conditions and into the intermediate future climates are shown Fig. 14, top left and top right, respectively. The climatic criteria are met more than 8 times, and in some areas more than 14 times in the pome fruit regions (Fig. 14, top left). In the intermediate future (Fig. 14, top right), projections show that much of the region could warm to the extent that climatic criteria for red colouring are met up to 6 times in the warmer southern areas and the Langkloof, and up to ten times in the cooler northern areas. The greatest reductions (9-15 days less) are seen in the high-lying northern areas (Fig. 14, bottom), and the lowest reductions (0-9 days fewer) are seen in the coastal south-west and eastern Langkloof.

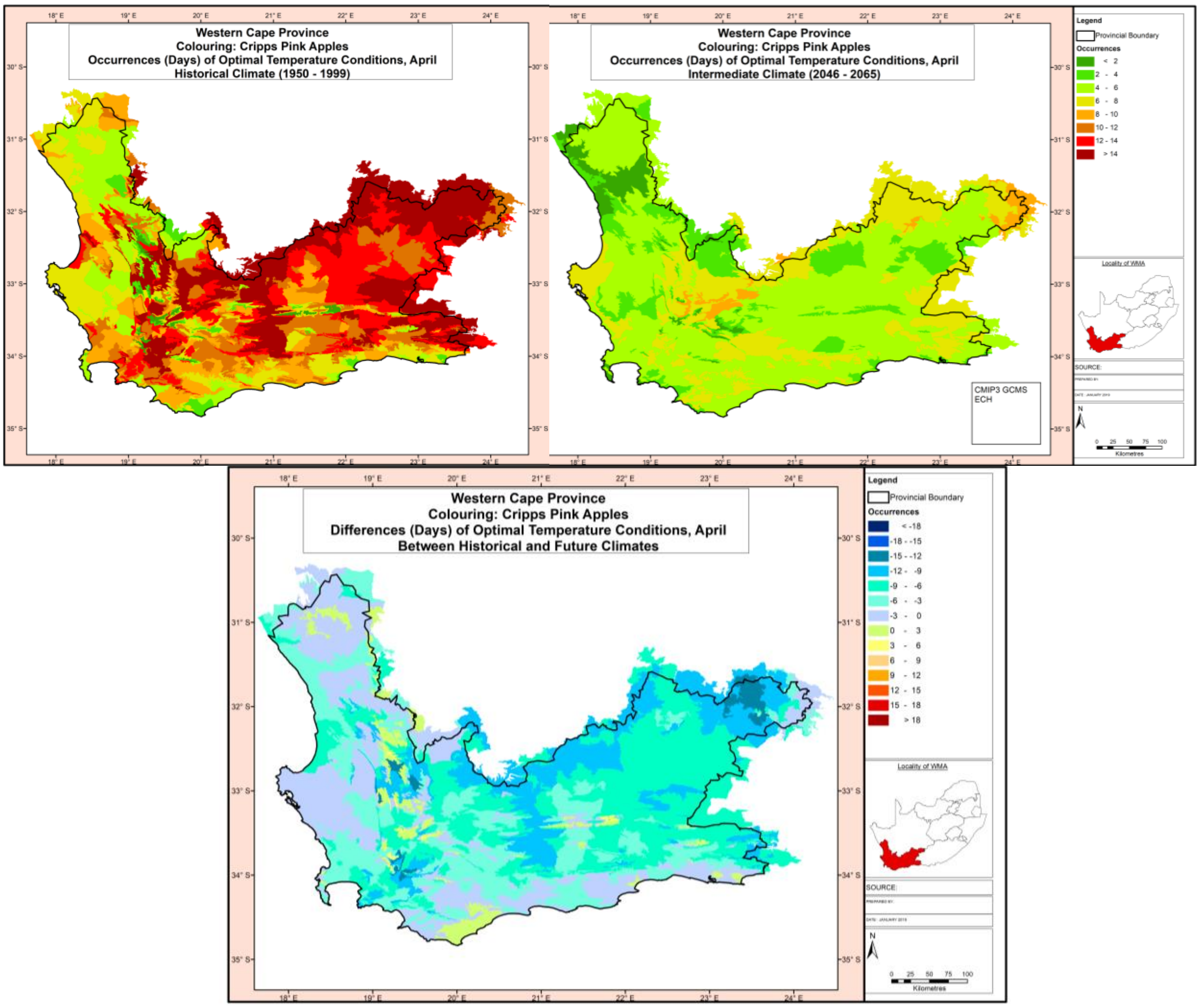


Figure 15. Number of days in April that climatic temperature criteria are met for red colouring of mid- to late-season blushed or bi-colour apples (e.g. 'Cripps Pink') under historical climatic conditions (top left) and into the intermediate future climates of the 2050s (top right), with the difference (in days) in optimal conditions shown in the bottom map. The latter two are derived from the CMIP3 ECH GCM.

Conditions for red colouring come into their own in April, when under the historical climatic regime the spatial patterns, although patchy, indicate that the apple production areas meet the red colouring criteria on 10 or more days, and in several areas more than 14 times (Fig. 15, top left). However, the April of the intermediate future (Fig. 15, top right) sees projected reductions in qualifying days to 2-4 days in the south and 2-8 days in the north and Langkloof (Fig. 15, top right). This represents a reduction of up to 15 days in April in apple production regions (Fig. 15, bottom).

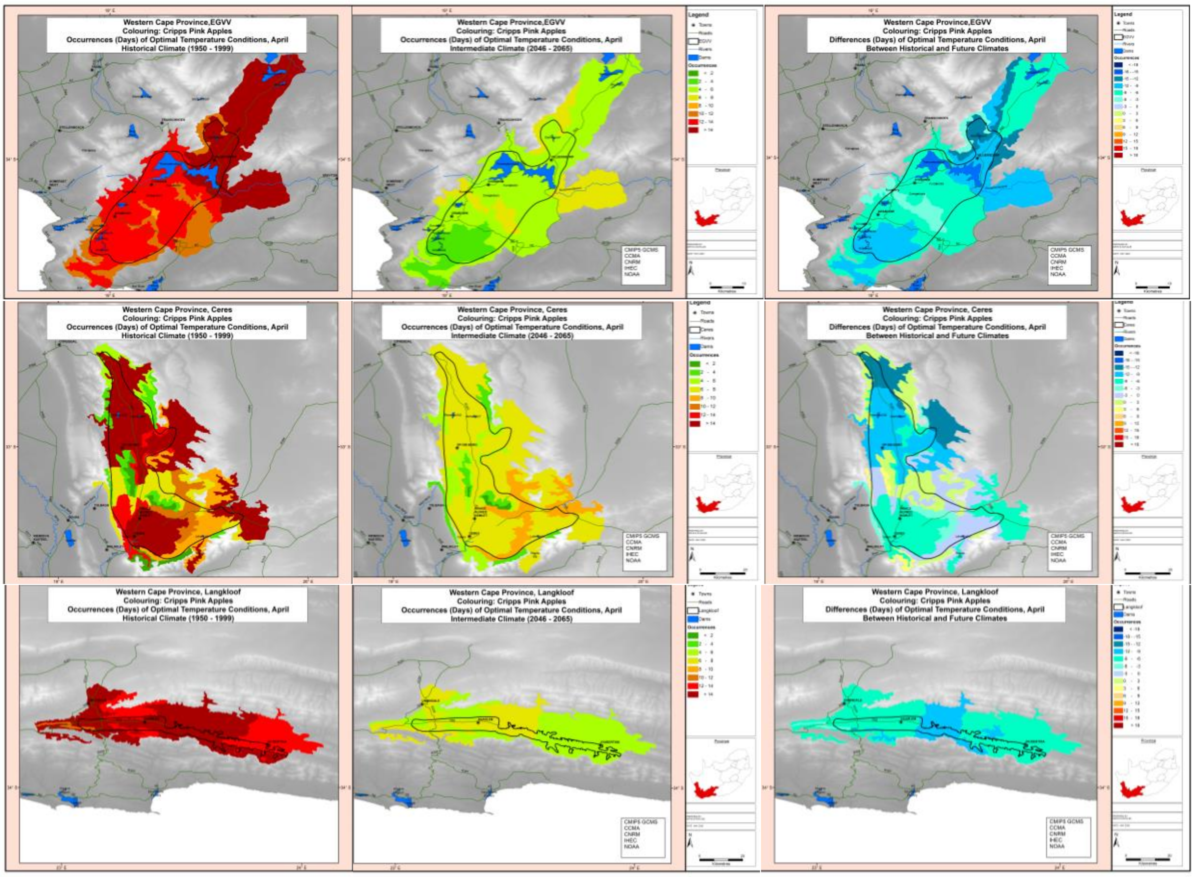


Figure 16. Number of days in April that climatic temperature criteria are met in EGVV (top), Ceres (middle) and Langkloof (bottom) for red colouring of apples (e.g. 'Cripps Pink') under historical climatic conditions (left column), under projected climatic conditions of the intermediate future (middle column), and the difference between historical and intermediate future climatic conditions (right column). The intermediate future maps are derived from multiple CMIP5 GCMs.

Fig. 16 presents the results for number of days meeting red colouring criteria for three key apple production regions, EGVV, Ceres and Langkloof, in April. Results for historical climatic conditions are shown in left column for each region, results into the intermediate future are shown in the middle column, and those for the change between the periods are shown in the right column. In April, under the historical climatic regime, the red colouring criteria are met on 6 or more days, and in several areas more than 14 days. However, the April of the intermediate future sees projected reductions in qualifying days by 3-15 days in EGVV, by 0-15 days in Ceres, and by 6-12 days in the Langkloof.

Summary for the pome and stone fruit regions

The impacts of increases in air temperature (~2°C by mid-century) and associated changes in temperature-based derivatives (potential evaporation, frost risk, chill units, heat units, sunburn, red colour, insect pests), and rainfall and its derivatives such a streamflows, are area-specific. Pome fruit production is most at risk in the south-western coastal production regions (e.g. Elgin area) owing to losses in winter chill, but these areas become more suited to stone and other fruit types. The north-western high-lying regions (e.g. Bokkeveld, Wolseley) and the Langkloof (especially the western parts) remain suited to pome fruit production from a winter chill perspective, but growers will have to adapt to warmer conditions and high temperature risks. In all the pome fruit regions, the loss of days in autumn that are conducive to red colour development of apples will require a greater use of high-colouring, less temperature-sensitive cultivars and mutants. For stone fruit production, the presently warmer parts of the Klein Karoo (e.g. Calitzdorp) are expected to become marginal from both temperature and water resources perspectives. The northern parts of the Berg region (Wellington-Gouda area) are projected to become much warmer and possibly drier than at present. Climatically suitable stone fruit cultivar choices will become an important component of adaptation responses in all the stone fruit regions. In all production regions, rising evapotranspiration will increase the irrigation demand and water resources availability and efficient irrigation strategies will become critical.

Adaptation to climate change

The following types of adaptation options can be considered. Further details are provided in Part 1 of this Guide, and in Midgley et al. (2016) and Schulze (2018).

- Adapting to higher winter temperatures and reduced chilling
- Adapting to higher growing season temperatures
- Adapting soil and water management practices
- Adapting to changing pest and disease pressures
- Adopting agro-ecological / regenerative farming systems
- Using weather and climate data smartly

Adaptation to the impacts of climate change is dealt with in more detail in the Guide (and see). The following types of adaptation options can be considered:

Conclusion and Recommendation

The results are very concerning. However, the different production regions are affected differentially, and opportunities exist for continued pome and stone fruit production with adaptations. These must be addressed in a spatially explicit and crop-specific manner. We recommend further research on alternative production regions outside the Western Cape - Langkloof, and continued research on cost-effective adaptation approaches and technologies. Key results should be re-assessed using the new set of GCMs now becoming available, specifically focusing on rainfall and rainfall-based parameters.

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