Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Soil and Environment

Opportunities for improved environmental sustainability of a wine producer in South Africa

– natural resource management and climate change adaptation and mitigation

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Master's Thesis in Soil Science
Agriculture Programme – Soil and Plant Sciences

Examensarbeten, Institutionen för mark och miljö, SLU Uppsala 2013
2013:20

SLU, Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
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EX0728 Independent project/degree project in Soil Science, 30 credits, Advanced level, A1E
Agriculture Programme – Soil and Plant Sciences 270 credits (Agronomprogrammet – inriktning mark/växt 270 hp)

Series title: Examensarbeten, Institutionen för mark och miljö, SLU
2013:20

Uppsala 2013

Keywords: wine production, erosion, carbon footprint, climate change mitigation, viticulture, Greenhouse Gas Emissions, soil conservation, life cycle analysis

Online publication: http://stud.epsilon.slu.se

ABSTRACT

South Africa has been among the top ten wine producing countries for at least 20 years. Even though the land under grapevines is decreasing globally it is still increasing in Africa. The awareness of environment has strengthen the last years and South African producers experience a high demand of environmentally friendly produced wine, especially from the European market. This demand was the driving force behind the development of the world unique sustainability certification, Integrated Production of Wine (IPW), which is inscribed in the South African legislation. What makes this certification unique is that consumers can trace their product all the way back to the farming practices owing to the identity number specified on the IPW Integrity & Sustainability seal on certified products. The guidelines are still quite vague and unclear.

In this report, sustainable wine production in South Africa is studied. More specifically a case study of Kanonkop Wine Estate was performed which focuses on soil, water and climate. Kanonkop is a well renowned wine producer, situated in an area known as “the Red Wine District of South Africa” on the mountain foot with low but beneficial influence on the climate from Indian Ocean and the Atlantic sea. Both the cellar and farming activities are IPW certified. The results showed that erosion was a major threat to the sustainability, especially to the infrastructure. Erosion control measures have been implemented to a limited extent and with varying performances. As vineyards are the most exposed to erosion among all arable land types this was a more or less expected finding. By simulating the biophysical conditions in GIS the cause of erosion could be understood. Erosion can be controlled by implementing erosion control measures such as extending and improving mechanical constructions for controlling runoff, improving the establishment of cover crops and practicing soil management which prevents erosion. Very few products are more sensitive to climate change than wine. With changes in climate the Western Cape, South Africa’s main wine region, is expected to experience more drought and floods which further leads to increased risks of erosion. South Africa is approaching water scarcity but for Kanonkop there is no threat of water scarcity at present. The water demand is low due to low irrigation water requirement while the water access is significantly higher owing to the artificial dam on the estate. South Africa is making efforts to reduce its contribution to climate change. Vineyards are therefore likely to be obliged to perform Carbon Footprint audits in the future as the agricultural sector is a large contributor to climate change. The Carbon Footprint of the production on Kanonkop was determined in this report, aiming to define opportunities to decrease the greenhouse gas emissions. To improve the accuracy of the Carbon Footprint in the future improved recording is necessary. Electricity meters should be installed for the different parts of the production chain so that sources of high electricity use can be defined. Defined opportunities for climate change mitigation lies within electricity, where coal based electricity can be exchanged for renewable electricity sources.

Sammanfattning

Sydafrika har sedan tjugo år tillbaka varit bland de tio främsta vinproducerande länderna i världen. Globalt minskar den vinproducerande markarealen men i Afrika ses en ökning. Miljömedvetenhet hos vinkonsumenter världen över har stärkts de senaste åren och sydafrikanska vinproducenter upplever en ökad efterfrågan på miljövänligt producerat vin. Efterfrågan är kommer främst från europeiska konsumenter. Den ökade efterfrågan var den främsta drivkraften bakom utvecklingen av den världsunika hållbarhetscertifieringen, *Integrated Production of Wine* (IPW), som infattas i den sydafrikanska lagstiftningen. IPW skiljer sig från andra certifieringssystem genom att slutkunden ges möjlighet att spåra den specifika varan hela vägen till produktionsmetoderna i vingården. Detta är möjligt med hjälp av identitetsnumret som specificeras på *IPW Integrity & Sustainability* märkningen. Dock är riktlinjerna bakom denna certifiering ännu relativt vaga och otydliga.

I denna rapport studeras vinproduktionen i sydafrika ur ett perspektiv av miljömässig hållbarhet. Rapporten inkluderar en fallstudie av Kanonkop Wine Estate där fokus ligger på mark, vatten och klimatfrågor. Kanonkop tillhör de mest välmeriterade och historiskt influerande producenterna i Sydafrika. Vingården är belägen i ett område, känt som ”Sydafrikas rödvinsdistrikt”, vid foten av berget Simonsberg. Både vingård och vinkällare är IPW certifierade. Resultatet av studien i denna rapport visar att erosion utgör det främsta hotet mot en hållbar produktion och särskillt utsatt är infrastrukturen. Åtgärder för att kontrollera den pågående erosionen har sats in men är idag ännu otillräcklig och ofta bristande i sin funktion. Vinodlingar är mest utsatta för erosion av alla kultiverade landtyper. Förekomsten av erosion var därför mer eller mindre förväntad. De bakomliggande orsakerna till förekomsten av erosion studerades genom simulering av biofysikaliska förhållanden i GIS (Geografiska Informationssystem). Erosionen kan kontrolleras genom att utvidga och förbättra den mekaniska kontrollen av ytvattenflöden, gynna god etablering av täckgrödor och genom att använda förebyggande markbearbetningsmetoder. Få produkter är mer känsliga mot klimatförändringar än vin. I Västra Kapprovinsen, Sydafrikas främsta vinregion, förväntas effekterna av klimatförändringarna i huvudsak utgöra omväxlande torka och översvämningar. Detta ökar risken för erosion ytterligare. I framtiden förväntas Sydafrika uppleva stor vattenbrist men Kanonkop är i dagsläget väl förberedd för ett torrare klimat. Den artificiella dammen kan förse vinodlingen med betydligt större mängder vatten än vad som krävs för att täcka dagens behov. Vattenförbrukningen ligger under medel för denna storlek på producent.

Sydafrika arbetar nu för att minska landets växthusgasutsläpp. Jordbruket är en stor bidragskälla, inkluderat vinindustrin, och det är troligt att beräkningar av växthusgasutsläpp kan komma att bli obligatoriskt för alla vinproducenter. I denna rapport beräknas och kartläggs växthusgasutsläppen för Kanonkop Wine Estate i syfte att definiera möjligheter att minska utsläppen. Dokumenteringen av nödvändiga data var bristfällig på flera punkter vilket bidrar till en viss osäkerhet i beräkningar och allokering av utsläppen. Utökad dokumentering är nödvändig för att få en mer korrekt bild av produktionens utsläpp. För att identifiera källor till hög elförbrukning bör elmätare installeras inom de olika delarna av produktionen. I dagens läge ligger de främsta möjligheterna till minskade växthusgasutsläpp inom elförbrukningen och det finns enorm potential att minska utsläppen genom att gå över från kolbasserad energi till förnyelsebar.

Populärvetenskaplig sammanfattning

Vad ligger egentligen bakom en flaska vin? Att druvsort och region påverkar vad man får i glaset vet de flesta. Att vinproduktionen påverkar miljön är inte lika väl känt. Visste du till exempel att vinodlingar är de mest eroderade jordbruksmarkerna i världen? Idag kan man som konsument välja vin med ett antal olika märkningar men vad säger egentligen dessa om hur vinet producerats?

Denna rapport tar upp vinproduktionen ur ett miljöperspektiv och beskriver hur kvalitet och miljö hänger ihop. Vinet och miljön beskrivs och diskuteras ur ett globalt perspektiv med fokus på Sydafrikansk vinproduktion. Mycket har hänt i Sydafrika de senaste åren vad gäller miljöarbete. Bland annat har man utvecklat ett certifieringssystem som inkluderar hela produktionskedjan och ett brett spektra av miljörisker. Detta certifieringssystem har sedan kompletterats genom en världsunik märkning som möjliggör för konsumenter, oavsett land, att spåra produkten ända ner till produktionsmetoder i vinkällaren och vingården. Ännu finns dock ett stort behov av utveckling av detta certifieringssystem, framförallt vad gäller användarvänlighet och mer strikta och tydliga riktlinjer. Det finns också behov att inkludera riktlinjer kring erosion.

På en rödvinsgård i Stellenbosch i Västra Kapprovincen i Sydafrika studerades vattenanvändning, erosion, utsläpp av växthusgaser samt behov av att anpassa verksamheten till framtida klimatförändringar. De förväntade klimatförändringarna i Västra Kapprovincen är ökad risk för översvämningar och torrperioder med reducerad total årsnederbörd. Studien visar att vinproducenten är väl förberedd för allvarligare torrperioder men mindre förberedd för perioder med intensiva regn. Rådande topografi och jordarter i kombination med regnfall medför hög risk för erosion. Det finns tydliga spår av erosion, och skyddsåtgärderna är genomgående bristande. För att säkra möjligheten till vinproduktion även i framtiden bör ett ytvattenavledningssystem införas genomgående. En livscykelanalys av vinet som produceras på gården visade mycket höga växthusgasutsläpp. En flaska vin motsvarar ungefär 8 km bilresa. De höga utsläppen är främst tillskrivet att energiförsörjningen är kolbaserad. Att gå över till förnyelsebar energi, t.ex. installation av solceller, skulle sänka växthusgasutsläppen avsevärt.

Sammanfattningsvis går arbetet för en mer miljövänlig och hållbar vinodling i Sydafrika framåt. Omfattande regler och kontroller har införts på senare år och fler väntas. Sydafrika är nytänkande och kan till viss del ses som ett föregångsland. Det praktiska miljöarbetet och implementerandet av reglerna är dock mindre framgångsrikt och det finns stort behov av utveckling.

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ACKNOWLEDGEMENT

First and foremost, I would like to thank the people at Kanonkop for the opportunity to conduct my Master's degree project at their fantastic vineyard. They took me in as a part of the big Kanonkop family from day one and showed me what passion and harmony are about, qualities which are also reflected in their excellent wines.

Acknowledgement for contribution to my success in performing and completing this project is my supervisor Professor Anna Mårtensson (department of soil and environment at SLU). Anna is always prompt in replying e-mails and finding time for meetings which was really appreciated, especially in the initial period, for getting the project moving. I would also like to thank Heinrich Schloms, GIS Soil Scientist at VinPro, for providing me with immense GIS data and Shelly Fuller, at the *Confronting Climate Change* project of *A South African Fruit and Wine Initiative*, for assisting me during the Carbon Footprint auditing and on very short notice solving problems related to the calculator tool software. In addition my friends and family members are acknowledged, especially those who took their time to read and comment on this report. I am grateful for their constant support and their belief in me, and I am convinced that my adventures along the way would have been more circuitous and less pleasant without them by my side. A special acknowledgement to my mother who made me believe that I can achieve anything I want, encouraging me to go my own way and for making me realise that the choice is mine of getting what I want out of life. A special acknowledgment, also, to my true friend and guardian angel who gave me the strength, courage and faith in the belief that I can live my dreams.

LIST OF ACRONYMS AND ABBREVIATIONS

ARC	Agricultural Research Council, South Africa
BWI	Biodiversity in Wine Initiative, South Africa
CA	Controlled Atmosphere
CCC	Confronting Climate Change programme, South Africa
CWR	Crop Water Requirement
DEM	Digital Elevation Model
EF	Emission Factor
GDD	Growing Degree Days
GHG	Greenhouse Gas
GIS	Geographical Information Systems
GWP	Global Warming Potential
GWSESP	Global Wine Sector Environmental Sustainability Principles
IFOAM	the International Federation of Organic Agricultural Movements
IPM	Integrated Pest Management
IPW	Integrated Production of Wine
LCA	Life Cycle Assessment
NL fak	Faculty of Natural Resources and Agricultural Sciences at SLU (see below)
NTU	Natural Terroir Unit
OIV	International Organization of Vine and Wine
PET	Polyethylentereftalat
RDI	Regulated Deficit Irrigation
SLU	Swedish University of Agricultural Sciences
SOM	Soil Organic Matter
SWSA	Sustainable Wine South Africa
W.O.	Wine of Origin
WOSA	Wines of South Africa
WSB	Wine and Spirit Board

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1. INTRODUCTION

Viticulture is one of the most diffused cultivations in the world. Even though viticulture constitutes only 0.5 % of the total agricultural area, the wine and grape market, globally, turned over 300 billion dollars in 2009. Wine and grapes thereby count as one of the top products on the agricultural market (Corti et al., 2011). The total world wine consumption is increasing (OIV, 2007) but the area under grapevine (Vitis Vinifier) has decreased on a global scale since it peaked during the 70's. Even so, the area planted with vine still increases in the "New World" (all countries outside of Europe, where winegrowing has most recently been introduced). The decrease of viticultural land therefore lies mainly within the "Old World" (European countries). In Africa, the viticultural area is still expanding (Corti et al., 2011) and South Africa has been among the top ten wine producing countries for the last 20 years and the export is still increasing (OIV, 2007). The wine relation between Sweden and South Africa is quite clear. According to Systembolaget's quarterly sales reports, South African wines have been the most popular among the Swedish population for several years, only overtaken by Italian wines since the fourth quarter of 2011. Sweden is also the 3rd largest consumer of South African wine in the world, after the UK and Germany (Wintech, 2012). Sweden is the country showing the highest increase in wine consumption per person within the EU (OIV, 2007). The total alcohol consumption is increasing and since the year 1994 wine has been the single product constituting the highest proportion of the total consumption, about 43 %, shown in a study made by Statistics Sweden (2007).

The interest and awareness of environmentally friendly produced wine is increasing on the global market, both among consumers and producers (VinIntell, 2012). A number of labelling and certification systems have been introduced, guaranteeing environmentally friendly production (Karlsson & Karlsson, 2012). The competitiveness of the wine market is further driving the production systems towards improved sustainability, a fact shown all over the world. This movement has been faster in Europe and is still quite new in the rest of the world (Duminy, 2004). The environmental awareness among local South African consumers is low but South African producers experience high environmental queries on the international market, especially from EU countries which are their key export market (Knowles & Hill, 2011). Fortunately, vineyards have not been affected by agricultural constraints such as soil sterilisation, pollution and waste management issues to a worrying extent. Such constraints are wide spread in other African countries and on other agricultural land uses, caused by intensive farming (Duminy, 2004). On the other hand, most soils planted with vines have fine textures and lie on moderate to steep slopes (5-30°) under climates subjected to alternate dry and rainy seasons. Because of these conditions most vineyards are subject to soil erosion. A study, made in Mediterranean parts of Europe, showed that vineyards are the most exposed to erosion of all arable lands. Only bare lands show larger soil losses than vineyards. Therefore, this last decade, soil water erosion in vineyards received a lot of attention (Corti et al., 2011). Few products are more sensitive to climate change than wine. Adapting to climate change is therefore becoming a significant issue to consider for the wine industry worldwide. In the South African Winelands extreme weather events such as alternating droughts and flooding are expected, which further contributes to increased risk of erosion among other things (VinIntell, 2012). South Africa is one of the countries with the highest emissions of greenhouse gases per capita in the world. As it is one of the signatory countries of the Kyoto Protocol the country is committed to reduce their greenhouse gas emissions significantly. This will affect the wine industry and companies are likely to be obliged to perform a Carbon Footprint Calculation for their operations in the future.

In this study, Kanonkop Wine Estate was chosen for a case study of the environmental sustainability within South African vineyards. This mid-sized farm is especially interesting to study for several reasons. It is one of the best known red wine producers in the country with a history reaching four generations back. It is located in the Simonsberg-Stellenbosch ward, known for its high quality red wines, and well suited to wine production. Kanonkop also exports a significant amount of wine to Sweden, which creates a natural connection between the two countries, making it more interesting for both parties to perform this study. As I discovered from the first verbal conversation with the Kanonkop winemaker, the ambition for environmental sustainability is high on Kanonkop. According to the winemaker inadequate knowledge considering enviornmentalsustainability is experienced. On these bases Kanonkop makes it particularly well suited as the case farm.

The intended audience of this report is South African wine producers who wish to increase their understanding for environmental sustainable wine production and gain inspiration for development of their own production. The report also appeal to agriculturists and environmentalists who wish to study environmental issues specific for the wine industry.

Treat the earth well, it was not given to you by your parents.
It was loaned to you by your children"

1.1. MAIN OBJECTIVES

Determine environmental risks within the production on the case farm and give recommendations for how some of these risks can be mitigated for improvement of the environmental sustainability in the future. Investigate environmental risks focusing on soil, water and climate related issues.

1.2. SPECIFIC OBJECTIVES

- Investigate the sustainability situation of South African wine production
- Determine the environmental risks at Kanonkop Wine Estate and how these risks are influenced by the biophysical conditions and management practices.
- Determine development potential for environmental sustainability.

1.3. RESEARCH QUESTIONS

1. What systems are in place to improve environmental sustainability of South African wine production?
2. Which are the biophysical conditions at Kanonkop Wine Estate influencing wine quality and environmental risks?
3. What are the current practices related to wine and grape production?
4. Which environmental risks concerning climate, soil and water resources can be defined on Kanonkop Wine Estate?
5. How can current risks be reduced to improve the environmental sustainability?

2. LITERATURE REVIEW

2.1. WINE PRODUCTION IN SOUTH AFRICA

In 2012, South African wine producers exported a total of 431.6 million litres of wine to countries outside the Southern Africa Customs Union (Botswana, Lesotho, Namibia and Swaziland) with an increased export predicted for the coming years. The South African market is relatively stable. South Africa’s main wine market is Europe and North America (SAWIS, 2013-02-20; SAWIS, 2011-08-10). Approximately 3 500 primary wine grape producers cultivate a total area of just over 100 000 hectares. The total area planted with wine grapes increased during the first years of the 21^{st} century until it reached a more stable level, except from a small decrease in the most recent data from year 2011. Each farm produces between 1 and 10 000 tons of grapes each year, of which about 41 % of the farms produce 1-100 tons and 36 % produce 100-500 tons (SAWIS, 2012).

Winegrowers are obliged to adhere and operate according to the South African framework of governmental legislation. The South African Constitution states; “*Everyone has the right to an environment which is not harmful to their health and well-being and to have the environment protected for the benefit of future generations through reasonable legislative and other measures that prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable social development*” (Act no.108 of 1996, Article 24). The environmental risk factor for each producer should be identified (Act no.73 of 1989, Article 21) and the use and protection of cultivated land, wetlands and vegetation is regulated in Act no 43 of 1983. The farmer must follow the regulations in a number of acts regarding air remedies and stock remedies, health and safety, prevention of fires, fauna and flora etc (act no. 45 of 1965, act no.36 of 1947, act no.28 of 1969, act no.19 of 1974, act no.85 of 1993, act no.101 and 107 of 1998). The National Water Act (no.36 of 1998) states that water cannot be privately owned, only the right to use water can be acquired. Any water user, regardless of whether the water source is natural or wastewater, must register and be granted a water license. The Water Act comprises extraction, disposal and storage of water and wastewater, irrigation, discharging of purified wastewater, erection and maintenance of dams and pollution of water penalties. All measures altering beds, banks, course or characteristics of a watercourse require license (article 21), even if the watercourse is erratic.

In 1973, legislation and a Wine of Origin (W.O.) certification scheme was officially instituted in order to protect the uniqueness of the South African wine producing areas and farms, specific cultivars and vintage (WOSAb, 01-02-2013). Today all wines (and Brandy) certified by the governmental Wine and Spirit Board use the seal shown in figure (SAWIS, 2012)). The two numbers on the seal are identification numbers and an indication of strict control by the Wine and spirit board (WSB), from the pressing of grapes to a final product.

Source: WOSAa, 2013
Figure 1 Wine of Origin (W.O.) seal. Label used on packages for South African wine to guarantee the stated origin and enable customers to track their product.

This seal guarantees the trustworthiness of all information relating to origin, cultivar and vintage stated on the label (WOSAa, 01-02-2013). W.O. together with the name of the production area (e.g. Stellenbosch or Kanonkop Wine Estate) appearing on the label, confirms that 100% of the grapes originate from that particular area and at least 85 % of the grapes are of the stated cultivar. The borders of all production units are defined by law, from a single vineyard to a geographical unit (geographical units are described in chapter 2.4.2.) (WOSAd, 01-02-2013). On the website of Sustainable Wine South Africa (SWSA) custumers can track their bottle, down to product level, by entering the identification number stated on the seal (WOSAe, 01-02-2013).

2.2. SUSTAINABLE WINE PRODUCTION

Sustainable development is defined by the UN as; "*Development which meets the needs of the present without compromising the ability of future generations to meet their own needs*" (IISD, 2010). There are a number of different concepts of sustainable and environmental-friendly production of wine, each with their own philosophy and production system. A producer can be certified and allowed to label the bottle with **Organic**, **Biodynamic**, **Sustainable, Fairtrade, Natural** and/or **Carbon neutral** (Karlsson & Karlsson, 2012). It is not easy to separate these labels or to understand how each one has been produced, and there is no simple or true answer for which is better than the other. To make this even more complex, different countries and certification bodies have their own requirement and certification standards (Karlsson & Karlsson, 2012). To properly define sustainability, each of the mentioned concepts must be defined.

Organic agriculture is defined by the South African government as; "*Produce produced by the scientific management practices indicated in the regulations, which take care of the environment and soil, and synthetic chemicals (including pesticides and fertilizers) are not permitted other than those allowed*" (act no.119 of 1990). This is based mainly on the IFOAM (the International Federation of Organic Agricultural Movements) basic principles: improvement and maintenance of soil fertility, no use of chemically manufactured pesticides or artificial nitrogen fertilizers and guaranteed animal welfare (IFOAM, 2005 & Duminy, 2004).

Biodynamic is similar to organic since the farms primarily must be certified as organic. In addition, Biodynamic farming is heavily influenced by the theories of Rudolph Steiner, the founder of the anthroposophical movement, and dimensioned by the cosmic background of astronomy. This means that vineyard operations are governed by the positions of the planets and phases of the moon. Biodynamic also involves application of homeopathic preparations (Demeter, 2012).

The concept Sustainable Farming means; conservation of natural resources while sustaining profitability. Being sustainable is not the same as being organic. You can be both at the same time or sustainable but not organic and vice versa. Although sustainable farming is similar to organic it can also include precision farming in addition to the whole production chain from farm to cellar and packaging. It also includes aspects like water and energy saving, protecting air, soil and water, minimizing transport and maintaining employee' wellbeing that is retaining a holistic view of sustainability. While all these factors are included in sustainability, wine quality must be the focal point in order to maintain the reputation and the survival of the business. Sustainability is also about continual improvements. Due to climatic conditions all wine-growers cannot practice organic production due to e.g. fungus and insects. Sustainable farming allows for use of pesticides etc when the crop is hit severely (Karlsson & Karlsson, 2012).

Fairtrade, on the other hand, has its focus on the workers aspects of sustainability, not the environmental. Use of chemicals is controlled from a human health point of view as are minimum salaries, working conditions etc. Wine labeled with "Naturally produced" refers to the production in the cellar. Harvest is made by hand, fermentation is made with only natural yeast and all additives should be avoided. There is, however, no official definition of the word "natural" when it comes to wine and anyone can call themselves "Natural". "Carbon Neutral", however, is something different.

Carbon Neutral has contribution to global warming by carbon emissions from the production as the only focus point. “Carbon neutral” meaning carbon emissions are minimized and the emissions that can’t be reduced are compensated for (Karlsson & Karlsson, 2012).

2.3. SUSTAINABLE WINE IN SOUTH AFRICA

Sustainable Wine-growing is, in South Africa, called Integrated Production of Wine (IPW). ISO14001 is an international Environmental Management Standard which is spreading among South African Winegrowers, though not yet to a large extent (Knowles & Hill, 2001). IPW’s philosophy is to “*Produce healthy grapes with minimum input and interference. Fewer actions in the vineyard results in less impact on the environment and lower input costs*” (ARC b, 2012). This is an environmental management scheme including specifications for farm, cellar and bottling complying with the South African government, Wine and Spirit Board (WSB) (Duminy, 2004). The latest information and technology are used in order to produce grapes and wine in an environmentally friendly and sustainable way in all aspects of production and implementations are made through application of guidelines, training of producers and managers, extensions and research (ARC a, 2012). IPW has had great success in South Africa and the philosophy is now spreading internationally. IPW is one of four environmental sustainability programs, existing or under development, complying with the Global Wine Sector Environmental Sustainability Principles (GWSESP). All four programmes are developed by Countries in the New World; South Africa, California, New Zealand and Australia. These programmes all operate on a self-assessment basis where training and communication plays a fundamental role in achieving continuous improvement of environmental sustainability (GWSESP, 2006). IPW also complies with the *OIV Guidelines for sustainable Viti-viniculture* developed by International Organisation of Vine and Wine (IPW, 01-02-2013; Castellucci, 2008; GWSESP, 2006).

IPW is a joint initiative from the Agricultural Research Council (ARC) Infruitec-Nietvoorbij and the South African wine industry (Duminy, 2004). The programme is controlled and managed by the IPW Committee operating under the governmental WSB (WOSAc, 01-02-2013). The IPW Scheme was first published in 1998 under the Liquor Products Act no.60 of 1989 and is updated every second year to comprise the latest research. The most recent update was in August 2012. The broad guidelines consist of recommendations and minimum standards (ARC a, 2012). By adapting to the minimum standards producers can achieve an Integrity & Sustainability certification. The first producer was certified in the year 2000 (IPW, 01-02-2013). To qualify for IPW certification both the minimum requirements and South African legislation and requirements of W.O. must be fulfilled. The IPW scheme is run by self-assessment and individual operations (ARCa, 2012). To qualify for a certificate a farm and/or cellar must score at least 60% of the total credits of the evaluation form (ARC b, 2012). The credibility of the IPW-scheme and the evaluation system is largely dependent on record keeping. All points awarded must be confirmed by the relevant documentation and records must be available for inspection and verification. Control and auditing are managed by periodic inspections and analysis of grapes and wine for chemical residues. If the legislation listed in the guidelines is not followed, WSB can suspend the member’s membership temporarily or permanently (ARC a, 2012). The IPW Guidelines, Manual, Evaluation Form, Certification and Auditing Policy can be downloaded at www.ipw.co.za.

The certification seal for W.O. has been in existence for many years. From the 2010 harvest season an alternative seal was introduced: the Integrity & Sustainability seal (fig 2), the world’s first visual guarantee combining guarantees for integrity of origin, vintage and cultivar with sustainable production and traceability up to product level (WOSAe, 01-02-2013). Farmers who do not comply with the IPW requirements or who for some reason do not wish to make use of the Integrity & Sustainability

Source: WOSAe, 2013
Figure 2 Seal for guaranteeing the origin stated on the bottle and that the product have been produced in a sustainable way

seal will use the original W.O. seal. In that way each container will bear only one seal (WOSAe, 01-02-2013). By entering the identification number on SWSA's website, as for W.O. (See chapter 2.3), customers can track their bottle back to the IPW practices in the vineyard (WOSAe, 01-02-2013). IPW influences the whole South African wine industry and includes collaborations between a number of organizations and the government. In the list below, is a description of the stakeholders which together drive the South African wine industry to a sustainable production (WOSAf, 01-02-2013).

- Biodiversity in Wine Initiative (BWI), aiming to protect the unique nature in the South African Vineyards (SWSA, 01-02-2013). BWI guidelines have now been written into the IPW guidelines (Karlsson & Karlsson, 2012; WOSAf, 01-02-2013; ARCa, 2012).
- South African wine and spirit board (WSB).
- WOSA (Wines of South Africa - representing wine producers who export their products).
- *A South African Fruit and Wine Initiative*, works for minimized climate change impact by the *Confronting Climate Change* (CCC) project. Carbon Footprint calculation has now been introduced in the IPW Guidelines (Wine and Fruit Initiative, 22-03-2013).
- Sustainable Wine South Africa (SWSA) is the alliance between WSB, IPW, BWI and WOSA.

2.4. PRODUCTION PARAMETERS AFFECTING WINE QUALITY

2.4.1. TERROIR VS. GEOGRAPHICAL ORIGIN

The word *Terroir* has its origin in the French language and is widely used in wine contexts. A natural terroir unit (NTU), or terroir, is a place and a natural environment sharing the same conditions such as meso-climate, soils, altitude, topography, geology etc. These factors cannot easily be modified by man or management, even though some like to include practices in the wine cellar etc in *Terroir* (Saayman et al., 2010). These conditions are expressed in the final wine, and a wine with a distinct character of its terroir is seen as a product of high quality and individuality (Vink et al, 2009). Quality wine is highly correlated with favorable terroir. A good terroir ensures a slow but complete maturation of cultivars with a certain regularity of product from vintage to vintage (Knight & Taljaard, 2002). NTU influences wine character by affecting the physiological processes in the grapevine (photosynthesis, grape color and development, sugar and organic acid formation, mineral accumulation and flavor development). Climate and soil in interaction has the greatest influence (Hunter & Bonnardot, 2011) and temperature is the single most important terroir determining factor (Knight & Taljaard, 2002). Different grape varieties favors in different environmental conditions for which reason the choice of grape variety should be based on the specific conditions at the particular site (Knight & Taljaard, 2002). Even though the NTU has a great impact on the characteristics and quality of the wine, viticultural practices and the winemaker should not be forgotten (Saayman et al., 2010).

The wine producing areas are concentrated to the Western Cape (fig 3). South Africa's winegrowing regions are diverse in soil, climate and geography. The Atlantic and Indian oceans create beneficial conditions such as regular coastal fog and cooling breezes (WOSAe, 01-02-2013). In many European countries wine production is governed by appellation systems that link specific grape varieties to specific geographic locations, based on the concept of terroir and viticultural practices of the location. For example, a true french Sauvignon Blanc must come from Bordeaux (VinIntell, 2012). In South Africa appellation systems based on terroir are not applied for indicating the origin or quality of

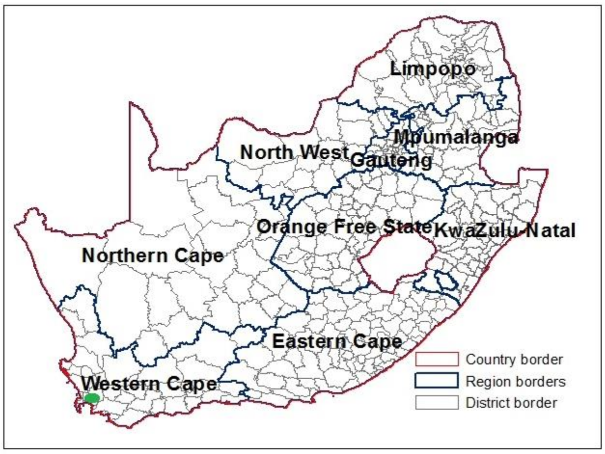


Figure 3 Administrative borders within South Africa. The case farm is situated by the green mark.

a wine. Instead, *geographical origin* is used as a quality convention: Wine of Origin (W.O.) (Vink et al., 2009). Geographical origin is less precise than *terroir* and divided into different layers of *geographical units*. The largest geographical units are the provinces, e.g. Western Cape. The next level of geographical units is *region*, which usually is built up around a common broad geographic trait such as a river or plateau (Vink et al., 2009). There are four wine regions in South Africa: Breede River Valley, Coastal, Klein Karoo and Olifants River (Saayman et al., 2010). The next level is *district,* e.g. Stellenbosch and Robertson. There are 21 viticultural districts, which do not necessarily follow the borders of the former Regional Council districts ($WOSA_d$, 01-02-2013: Saayman et al., 2010). They are built up around macro characteristics like mountain ranges and rivers but are still quite diverse in soil, climate and geographic conditions (Vink et al., 2009). These conditions are more homogenous first at the geographical unit *Wards,* a combination of different farms (e.g. Franschhoek, Cederberg and Constantia). At this level a more distinct and recognizable character of the terroir can be sensed in the wine (Vink et al., 2009). There are 64 wards defined at the moment (Saayman et al., 2010). The level after *Ward* is *Estate* and the smallest unit is *Single Vineyard*, which may not exceed six hectares. Certain areas of origin deliver better quality for specific wine types and may only be used for marketing of that specific wine type, e.g. Boberg region is only used for marketing of dessert wines. A higher level of geographical unit, e.g. Coastal Region, allows the producer to blend wines from different districts while marketing under the same origin (WOSAd, 01-02-2013).

The case farm, Kanonkop Wine Estate, is situated within Simonsberg Stellenbosch Ward (green mark in figure 3). Stellenbosch wine district is the most prolific and successful area for winegrowing in South Africa and the number of wine growers is dense and rapidly increasing (Wine SA, 29-01-2013; Saayman et al., 2010). Some of the most famous farms in South Africa are situated in this district which also contains a mix of historic estates and contemporary wineries. Almost all of the noble wine grape varieties are produced here but best known are the red blends (Saayman et al., 2010). The most coveted farming areas are the western, south-western and southern slopes of Simonsberg, the Bottelary hills, Stellenbosch Mountain and Helderberg (Saayman et al., 2010). The complex topography and interplay of sea and land winds cause a diverse environment for viticulture. Further, a wide number of identified natural terrior units (NTU) have been identified (Saayman et al., 2010). The Simonsberg-Stellenbosch ward is known as “the Red Wine District of South Africa”, producing the best red wines in the country (Kanonkop, 29-01-2013). Approximately 50 % of the vines planted within the ward consist of the locally bred Pinotage, one third of Cabernet Sauvignon and the rest is shared by Merlot and Cabernet Franc. Pinotage vines are among the most favoured of all the vines in South Africa (Wine SA, 31-01-2013). Simonsberg Mountain provides a mixture of soils, dominated by bright red clay mixed with shale and decomposing granite, enabling growth of every vine variety (Wine SA, 29-01-2013). The so called Oakleaf and Tukulu soils are deeply weathered mountain foothill soils with good drainage and water holding capacity, typically situated at altitudes of 150-400 ma.s.l. (Saayman et al., 2010). The lower down the mountain, the more red clay there is. Granite however, contributes the most to the character of the wine. Estates located higher up the mountain are given a cool to cold climate contributing to slow grape development, giving more character to the grapes. Consistently low temperatures produce wines with a very definite character and distinct aroma. A cold climate can also reduce the need for additives in the wine (Wine SA, 29-01-2013). The annual average precipitation in Stellenbosch varies between 600 and 800 mm and in Simonsberg between 600-700 mm. Simonsberg has an average February temperature of 21.5˚C (Saayman et al., 2010).

2.4.2. Geology and Topography

Topography mainly effects viticulture through altitude, aspect and inclination. The effect can be direct or indirect on both soil and meso-climate. The direct effect is of the immediate effect of sun rays on the earth’s surface, wind and ventilation. The indirect effects are impacts on soil characteristics (Saayman et al., 2010). Upslope the drainage and temperatures are more favourable than downslope. Increased knowledge about the vines’ (the plant which produce grapes, Vitis Vinifiera) requirements among farmers has contributed to extension of plantings upslope in many wine growing countries (Saayman et al., 2010). In South Africa, the tendency of decrease in temperature is about 0.3℃/100 m upslope (Knight & Taljaard, 2002). The aspect of a slope determines a slopes exposure to prevailing winds, sea breezes and solar radiation (Knight & Taljaard, 2002). Southern and eastern slopes in the Southern Hemisphere (corresponding to the northern and western slopes on the northern hemisphere) are cooler than northern and western due to lower inception of sunlight. Eastern slopes will warm up faster and cool down earlier than western slopes (Saayman et al., 2010). Steepness of a slope affects the exposure to solar radiation. A slope which is perpendicular to the sun's rays is more exposed than one tilted away from the sun. In addition, steepness regulates air and water drainage which further affects what machinery and viticultural practices are suitable. Convex slopes are generally better drained than concave slopes where water logging can occur during the rainy season (Knight & Taljaard, 2002). This varied terrain creates a divers variety of mesoclimates and soil types (Saayman et al., 2010). The varying climate of the Western Cape enables farmers to differentiate between styles of the same cultivar or to plant several varieties with different climate requirements on the same farm (Saayman et al., 2010). Even though eastern slopes generally are cooler than western, they are often found to be cooler on the west coast due to the sea breeze from the Atlantic Ocean. Since the sun rises in the east vines will dry faster on eastern slopes than on western. This may further contribute to reduced disease problems (Knight & Taljaard, 2002). During the summer months the sun rises late and sets early. The mountainous terrain casts shadows over the vineyards on the mountain slopes in the early morning and late afternoon, restricting the hours of sunlight on the vineyards. During mid-summer the Cape vineyards seldom receive more than 10 hours of sunlight (Saayman et al., 2010).

The Western Cape Province has been exposed to high pressure from tectonic movements during millions of years. This has, with influences of other geologic factors, formed the Cape's majestic sandstone mountains with steep slopes, deep valleys and soaring peaks which later eroded into rolling hills (Saayman et al., 2010). Sandstone represents a combination of sand granules and clay minerals which have been compacted together by pressure and time (Corti et al., 2011). Sandstone mountains, such as Table Mountain and Simonsberg (1000-1300 ma.s.l.), often rest on granitic foothills and are surrounded by shale at lower altitudes (Saayman et al., 2010). Granite is an igneous rock with a hard and granular texture and high content of quartz. Shale is a fine-grained sedimentary rock (Corti et al., 2011). These foothills are associated with exposed granite plutons or domes, visible in form of e.g. Paarl Mountain, Perderberg (500-700 ma.s.l.) or ranges of hills like Bottelary, Malmesbury and Darling (200-400 ma.s.l.). Further inland shale parent material and river deposits predominately forms the geology (Saayman et al., 2010). Vineyards are planted in a wide variety of locations, from valley floors to steep mountain slopes or beneath high peaks, on altitudes varying from 50 to 600 ma.s.l.

2.4.3. Soil

Vine performance and soil properties are strongly related. Regions continuously producing high quality wines have soils with good properties; well developed structure, good aeration, high permeability, can resist the effects from extreme climate conditions (e.g. drought and heavy rainfall). Vine performance can broadly be defined as improved grape quality, better vine balance or more specifically as low water use, smaller berry size and reduced vigour. Roots are directly affected by soil properties and its size and health governs the size and performance of the Canopy. High grape quality is associated with optimal root development, not necessarily maximum or minimum root development, since availability of water and nutrients are necessary but in order to obtain high quality grapes water and/or nutrient availability must be limited and cause the plant a mild stress (Lanyon, Cass & Hansen, 2004). Soil structure affects, indirectly and directly, the physical, chemical and biological factors. Such factors are soil strength (the soils capacity to resist external disturbances), water and nutrient movement, aeration, hydraulic properties, workability, seedbed preparation and erodability. The two most important aspects of soil suitability for viticulture are water supply and aeration (Layon, Cass & Hansen, 2004). Lack of water is associated with climate, soil water storage and root access. Inter-row areas is a source of soil water which is often not utilized by vines due to poor root penetration into the mid-row caused by e.g. compaction from wheels. Soil texture strongly influences soil water storage, thus, coarse sand does not hold a lot of water while clay binds water too hard and obstructs root penetration (Wiklander, 2005). Even in situations where water and nutrient availability are not limiting factors the size of the root system has a direct effect on shoot growth and vine balance (Rowe, 1993; Wang et al., 2001). Nutrient deficiency causing a mild stress to the vine most often affect the quality of the final wine product positively. Grapevines has fewer nutrient deficiency problems than other horticultural crops. Gernerally only nitrogen, potassium, zink and boron are widely supplemeted but in some areas supplement of other nutrients may be necessary (Hirschfelt, not dated). Nitrogen is the most important nutrient as is comes to crop growth, berry quality and disease susceptibility. Phosphorus plays a role in the photosynthesis and respiration of the vine hence having a direct effect on yield and quality. Potassium plays a role in the nutrient and water uptake and transport processes within the plant and affect sugar accumulation and color development of the berry. Calcium is mainly used to build up cell walls and affect quality, color and aroma of the berry (Raath, 2012). Nutrient uptake is depending on the pH in the soil. Even though the soil contains high amounts of a nutrient it may not be available to the vines due to that it is in an unavailable for due to the pH. Vines performe best on soils with pH between 5.5 and 8 (Lanyon, Cass & Hansen, 2004)1.

The greatly varying geology and topography of the **Western Cape**, various weather cycles and periods of inundation by the sea have contributed to the development of great soil diversity over short distances (Saayman et al., 2010). The formation of these soils was influenced by high rainfall in a, past, tropical era which has exposed the soils to high weathering contributing to high acidity, high stability, good drainage and good water holding capacity (Saayman et al., 2010). The three most important soil groups in winegrowing regions are displayed in table 1.

Table 1 The most important soil groups for winegrowing in the Western Cape and their characteristics (Saayman et al., 2010).

Derivation	Characteristics
Table Mountain sandstone	• Sandy structured • Low nutrient and water retention properties
Granite	• Red to yellow colour • Acidic • Found on mountain foothill slopes and ranges of hills • Good physical and water retention properties
Shale	• Brownish colour • Strongly structured • Found on partly decomposed parent rock • Good nutrient reserves and water retention properties

Soil developed from granite or sandstone often has a sandy texture, drains and dries out very quickly. Such soils are often acidic and store heat but presence of limestone in the parent material will slow down the development of soil acidity. Soils from granite occur in many wine-producing areas of the world (Corti et al., 2011) and are often found on steep slopes on altitudes of 150-400 ma.s.l. (Saayman et al., 2010). On the gently undulating granitic hills between the mountains and the sea (20-150 ma.s.l.) soils are characterized by a duplex structure of coarse blended sand and yellow-brown gravel on wet, gleyed clay. Extreme wetness and drought in these soils restrict vigour. Highly appreciated soils, such as the reddish and yellowish brown soil, are usually associated with granitic hills. These soils consistently ensure good quality wines, especially together with exposure to the cool sea breezes (Saayman et al., 2010). On the shale landscape of the undulating Malmesbury soils typically vary from stony, weathered rock residuals on hill crests to strongly structured soils on mid and foot slopes but usually with the weathered shale still within reach to be exploited by vine roots (Saayman et al., 2010). Soils formed from Shale are usually moderately fertile, retain heat well but have very low porosity and slow drainage. These properties make Shale soils prone to erosion on impervious morphologies. Alluvial deposit soils are characterized by combinations of gravel, sand, silt and clay which formed over time from mineral deposits. These deposits were transported by running water and colonized geological terraces. These soils are frequently interesting for viticultural purposes (Corti et al., 2011).

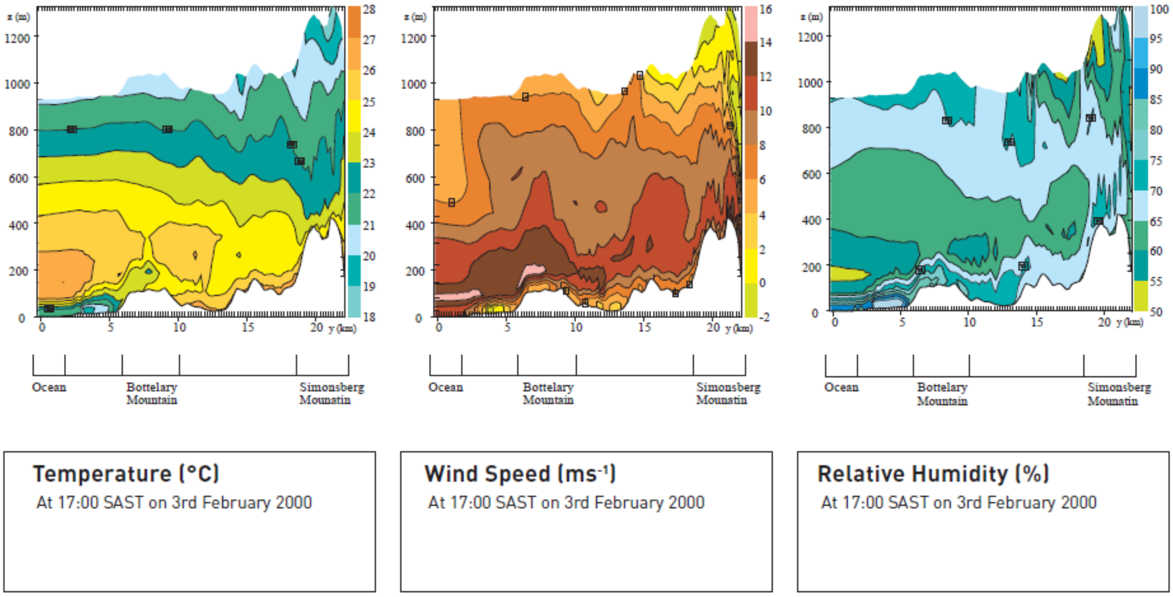
2.4.4. Climate

To obtain an optimal photosynthetic activity, colour expression and flavour development the grapevine has specific physiological requirements of the climatic parameters. Of these, temperature is considered the most important factor followed by relative humidity and then wind speed (Bonnardot, 2002; Saayman et al., 2010). Humidity plays a role for the occurrence of disease outbreaks where high humidity favours fungal diseases. Wind speed can impact positively or negatively. Strong winds during early season may injure young growth and reduce fruit set. Light winds may though have a more favourable effect on the vines (Knigh & Taljaard, 2002). Assessment of climatic suitability for grapevine production usually focus on monthly or seasonal temperature analyses and seldom includes different climatic parameters combined or considered at finer temporal scales (Saayman et al., 2010). Plant functions are linked to temperatures exceeding 10℃. The process of extracting moisture and nutrients from soil, as well as transpiration, becomes more efficient with rising temperatures up to about 25 ℃. At temperatures above 28℃ the plants demand for water is greater than what can be extracted by the roots. Therefore, growth and ripening rates slow down or stop. Enzyme activity is optimal at 16-22℃ and relates to flavour production. High berry temperature results in undesirable reductions in colour, total phenolic and malate levels (Knight & Taljaard, 2002). Optimum for vine growth is, according to Kinight & Taljaard (2002), 23-25℃ and optimum for ripening 20-22℃ while Hunter and Bonnardot (2001) state an optimal temperature of 25-30˚C (table 2).

Table 2 Climatic conditions for grapevine production (Hunter & Bonnardot, 2011).

Climatic parameter	Optimal	Unsuitable
Temperature (°C)	25-30	<20, >35
Wind speed (m/s)	<4	>4
Relative humidity (%)	60-70	<50, >80

Climate is often referred to on three different levels; Macroclimate, Mesoclimate (or topoclimate) and Microclimate. **Macroclimate** is the predominating climate of a region. **Mesoclimate** usually describes the climate of a particular vineyard. It differs from the macroclimate of the region due to differences in altitude, slope inclination, aspect or distance from large water bodies. **Microclimate** is surrounding the vine canopy and may differ within a few centimetres. Micro climate is influenced by macro and meso climate and it is the micro climate that determines vine growth and fruit flavour (Knight & Taljaard, 2002; Saayman et al., 2010). Globally, the most suitable macro climate for winegrowing lies on the two geographical bands with latitudes of 30-50˚ on the northern and southern hemisphere. Viticulture in South Africa, mainly takes place at latitude of 27-34˚S. The climate is Mediterranean, cooler than indicated by the position, attributed to the cooling breeze of the seas. The Atlantic, chilled by the Benguela current following the west coast of Africa from Antarctica, moderates the warm summer temperatures by several degrees (Saayman et al., 2010). The continentally of a climate measures the extremity of temperature fluctuations and specifies the influences of the sea or other large water bodies. Continentally is calculated by subtracting the mean July temperature from the January mean temperature. Values less than 10℃ indicate influences from the seas, a so called maritime climate (Knight & Taljaard, 2002). A study performed by Saayman et al. (2010), illustrated in figure 4, shows the influence of the ocean varying with distance. This study showed that land temperature increases with a northern direction and with distance from the sea while wind speed and relative humidity decrease with distance. The same study showed that precipitation diminished in north to north-western direction due to the mountain ranges along the coastline. The climate of Western Cape brings warm summers and cool winters where frost rarely is a problem. Precipitation is unevently distributed over the year as a consequence of the mediteranean climate with dry and rainy seasons. Rainy season occurs between May and August, the coolest period of the year. This lead to that in the end of the grape growing season soils are likely to beome dry and cause water efficiencies. The south-eastern spring and summer wind from the ocean, called “The Cape Doctor”, inhibits the development of disease in the vineyards. Traditional wine areas along the coastal zone are seldom located more than 50 km from the ocean (Saayman et al., 2010).



Source: ©Saayman et al., 2010.
Figure 4 A sea breeze's influence on climatic parameters varying with distance from the sea to Simonsberg Mountain. Left vertical axis: altitude. Right vertical axis: Climatic paramters as stated below each diagram. White colored fields: Topography.

2.4.5. VITICULTURE

The Viticultural year in South Africa begins with the spring, September to November. During this season nodes on the shoots begin to swell and bud. Eventually they shoot leaves and form small flower clusters. During the spring soil is ploughed and fertilized, excess shoots removed and shoots growing from the rootstocks are broken off. Water is essential during this time of the year and irrigation may be necessary in some hot and dry areas ($WOSA_f$, 2013). In the end of October, flowering and pollination take place. December to February are the summer months, where the weather becomes warmer and grapes ripen. Growth control by topping and irrigation is applied if necessary to ensure maximum ripeness. When the grapes are ripe they are harvested and taken to the wine cellar. In the autumn, March to May, the harvest has been completed and vines gathers reserve stocks of nutrients for the winter and wood grows hard to enable the shoots to resist cold. Leaves change colour and fall off after which shoots are removed by clean pruning to control diseases. Fertilisation is necessary and vineyards, where irrigation is applied, are sprayed to encourage development of reserves. The vines are resting during June-August, which are the South African winter months ($WOSA_f$, 2013).

There are several viticultural factors and practices affecting grape quality (Lanyon, Cass & Hansen, 2004). Cultivar has a critical effect on disease susceptibility, use of chemicals, quality etc. Rootstocks differ in their resistance to pests and soil conditions (ARC_a, 2013). Long term influencing practices include establishment techniques, row orientation, vine spacing, trellising and pruning systems. In the short term irrigation, fertilization, canopy management and applied harvest criteria contribute to the final character. All these practises significantly influence on microclimate conditions (Hunter & Bonnardot, 2011). Irrigation affects susceptibility to diseases and grape quality (ARC_a, 2013). Excess irrigation may lead to decreased grape quality by producing too vigorous a growth, vegetative character, lack of color and body (Wine $Institute_b$, 2011). Sufficient fertilization and balanced nutrition is important to achieve optimal growth and fruit quality. Over fertilization, especially of nitrogen, causes growth and leaf density which subsequently encourages diseases, susceptibility to fungal diseases and insects and hinders penetration of chemicals. The extent and timing of canopy management are critical for interior-canopy photosynthetic active radiation, temperature, humidity, wind velocity and eventual photosynthetic efficiency (Hunter, 2000; Hunter et al., 2004).

2.5. ENVIRONMENTAL RISKS IN WINEGROWING

2.5.1. SOIL EROSION AND SOIL QUALITY

Soil erosion involves movement of soil particles by water or wind (Martinson et al., 2006). A study in the Mediterranean parts of Europe concludes that vineyards are the arable lands with the highest runoff rates and soil losses,except from bare lands (Martínes-Casasnovas & Ramos, 2006). This is due to combined factors of soil, climate and topography. Most vineyards are planted on moderate to steep slopes (5-30°) which contribute to high speed of runoff. Soils texture are often of fine sand which easily attaches to moving water. The Mediterranean climate is the most common climate in winegrowing regions and is associated with dry and rainy seasons which involves heavy rainfalls during the rainy season (Corti et al., 2011). Soil erosion causes loss of soil, nutrients and soil carbon, loss of rooting depth and subsequently loss of long-term productivity (Martínes-Casasnovas & Ramos, 2006). A wide range of environmental problems follow with soil erosion such as sediment transport and transport of fertilizers and pesticide residues causing pollution of streams and lakes (Martinson et al., 2006; Wise et al, 2009). Ponded runoff may infiltrate and percolate through permeable soils and eventually transport fertilizers and pesticide residues into ground water. As soil is a non-renewable resource (Martínes-Casasnovas & Ramos, 2006) erosion should be of major concern for everyone growing grapes on sloping land (Shanks, Moore & Sanders, 1998).

There are three types of water erosion; Sheet, rill and gully. Sheet erosion is caused by raindrops breaking the bonds between soil particles. Soil particles are splashed sort distances due to the force of the raindrop hitting the ground. These particles become more prone to water flowing on the soil surface. Sheet erosion starts when runoff carries soil particles that were detached by raindrop impact downslope as a sheet (Shanks, Moore & Sanders, 1998). Rill erosion is caused by concentrated water flow, often during heavy rainfall, transporting soil particles. Rills are small and well defined channels a few inches deep. These may eventually form gullies on saturated soil, which expand rapidly and may become very deep. (Martinson et al., 2006; Shanks, Moore & Sanders, 1998). Erosion is associated with high costs such as for replacement of nutrient loss, maintenance of drainage channels, filling of gullies etc. (Martínes-Casasnovas & Ramos, 2006). Several factors play a role for the risk and severity of erosion. In table 3 these factors are described together with their parameters and expected effects.

Table 3 Factors influencing the severity of soil erosion (Martinson et al., 2006; Shanks, Moore & Sanders, 1998).

Factor	Parameters	Effect on
Rainfall	Amount & intensity,	Amount of runoff and leaching
Soil type	Composition, particle size and reaction to freeze/thaw cycles	Erosivity and erodability of the soil
Slope	Length & steepness (gradient)	Amount, speed and force of water flow
Crop	Type and sequence	Force of rain drops on soil surface
Management	Tillage, crop residues, terracing, contouring.	Erosivity and erodability of the soil

The effect the rainfall has on the soil depends on its intensity and the amount of rainfall. During intense rainfall the water drops are large, hence, hitting the ground with higher force than during low intensity rainfall. Compare mist with monsoonal rainfall. The amount of rain determines the amount of runoff produced, also influenced by soil properties (Martinson et al., 2006). Depending on its properties soils are also more or less prone to erosion. Most erosive are soils with poor aggregation as a result of low content of soil organic material (SOM), high percentage of silt and very fine sand (Shanks, Moore & Sanders, 1998; Prichard, 1998). Silt is the most erosive size of soil particles, wherefore silt deposits downslope resulting in eroded land is a common occurrence. These silt deposits may emerge in a creek or waterway where it may impact water quality (Sonoma County Agricultural Commissioner's Office, 2010). Steep slopes are generally more vulnerable to water erosion than gentle slopes. The longer the slope the higher the speed runoff can get up to and thereby cause more damage since the force increases with the speed of water (Sonoma County Agricultural

Commissioner's Office, 2008). The vegetation influences the extent of erosion as it protects the soil from the raindrops, slows down the speed of runoff and stabilizes the soil particles. How well the vegetation protects the soil depends on several factors such as density and growth type, this will be further described in chapter 2.6.4. (Wine Institute, 2002). Management plays a major role in the occurrence of erosion. Soil disturbances from farming practices may contribute to creating erosion prone soils as it loosens and pulverize soil particles. Thereby, the particles more easily attach to water (Sonoma County Agricultural Commissioner's office, 2010). Frequent and heavy traffic cause compaction. Tillage or even light traffic on wet soil highly contributes to compaction as well. Compacted soils are highly susceptible to erosion due to high runoff rates which is caused by low infiltration capacity as a consequence of compaction. Compacted soils are also more sensitive to surface crusting than soils with good structure. Soil crusting, as well, implies high runoff rates and is susceptible to erosion. Soils of textures like loamy sand, sandy loam, sandy clay loam and sandy clay are especially susceptible to hard settings, which is a dense cover much thicker than surface crust (O´Green et al., 2006). Vineyard roads are often subjected to erosion wherefore they should be well planned and properly located. Eroded roads then form part of the infrastructure and access to different parts of the vineyards (Sonoma County Agricultural Commissioner's Office, 2006).

2.5.2. Water Scarcity

Water scarcity can be the result of many different factors, not necessarily lack of rainfall. Uneven distribution over the year causes dry spells, implying water scarcity for a limited time period (Machiara, 2004). Soil characteristics influence water scarcity as it acts as storage media. The total soil moisture storage depends on the water holding capacity, plant available water content, infiltration capacity and evapotranspiration (Lanyon, Cass & Hansen, 2006). These factors are influenced by texture, structure, surface characteristics and depth. Coarse textured soils generally have lower water holding capacity than finer textured. Soils with high proportion of fine particles, such as clayey soils, bind water very hard wherefore plant available water can be low even though the soil holds a lot of water. Coarse soils usually have better infiltration rates than fine textured. Fine textured soils with good structure can have good infiltration capacity. Soil structure means the arrangement of soil particles and the space between them. Soil organic material strongly affects structure in a positive way. Good structure, good aggregation and aggregate stability, has positive effects on water holding capacity, aeration, infiltration etc. As compacted soils (often poorly structured) contain very little pores combined with poor root penetration water scarcity may occur in such soils (SAI Platform, 2010; Wiklander et al., 2005). Poor structured soils may be sensitive to crusting which further affect infiltration rates negatively which subsequently increase runoff rates and the risk of water scarcity (Prichard, 1998). When it comes to evapotranspiration a number of factors influence its size, such as temperature, wind speed, humidity, tillage, soil properties, water consumption by crop, competition for water from weeds, cover crops etc (Eckersten et al., 2004).

Water scarcity also depends on the availability and quality of water resources. Water scarcity can be either physical or economical. Physical water scarcity occurs when water demand exceeds water availability. Such areas are not necessarily water scarce. Economical water scarcity is defined as human, institutional and/or financial capital limiting the access to water (FAO, 2007; IWMI, 2006). South Africa is approaching physical water scarcity while economic water scarcity is the case for most other African countries (FAO, 2007). Physical water scarcity may be man-made, as for polluted or over-extracted rivers and ground water resources. Physical water scarcity may induce severe environmental degradation (IWMI, 2006). In areas where physical water scarcity is the case, water productivity becomes very important. Water productivity means the efficient use of water, or simply "more crop per drop". This comes with more efficient irrigation schemes, water storage facilities, re-use and multiple uses of water resources (IWMI, 2006). Today most wineries have water meters which enables them to track water-use performance, identifying leakage or need of maintenance and set up objectives for water use reduction. Cleaning of the cellar consumes a lot of water but there are also many water saving alternatives such as high pressure or steam cleaning equipment (Waldorff, van Kraayenburg & Barnardt, 2004). Except from over extraction and pollution of water sources many risks are associated with incorrect irrigation practices. These are, for example, rising water tables, water logging, soil compaction, salinization and susceptibility to diseases (Boland & Tee, 2005; ARCa, 2012). Excessive irrigation may cause temporarily perched water table, especially on compacted subsoils and cause water logging which leads to poor crop growth and damages to vines and other vegetation (Boland & Tee, 2005). As mentioned earlier, water cannot be privately owned in South Africa. One can only be given the permit of using a water resource. Irrigation with wastewater is today the preferred disposal of wastewater among South African wine producers. It must, however, be at least 100 m between the irrigated land and natural watercourses and irrigation is prohibited during rainy season to avoid water logging (Waldorff, van Kraayenburg & Barnardt, 2004).

2.5.3. Climate Change

Climate change is becoming a significant issue for the wine industry, especially since few products are more sensitive to climatic changes (VinIntell, 2012). Increased temperatures and changes in rainfall affects terrior and appellation, pest and disease distribution, flowering and fruiting seasons, choice of cultivars and pruning methods and water resources. This further affects the taste of the wine (Gerhard et al., 2010; VinIntell, 2012). The wine industry is likely affected by climate change by limited diversity in the type and style wine can be produced. Higher temperatures bring higher alcohol levels, over-sunned aromatic ranges and denser textures. In some wine countries recorded temperature increase was followed by rising quality ratings (VinIntell, 2012). Warmer temperatures, generally, produce more consistent grape harvests, ripening hastens, bolder flavours, more sugar and more alcohol than cooler temperatures (VinIntell, 2012; Gerhard et al., 2010)). On a global level, wine production is moving south in the southern hemisphere and north in the northern hemisphere (Gerhard et al., 2010; Vinintell, 2012). In some areas wine production is moving uphill. Projections indicate on a shift of the geographical bands of 275-550 km towards each pole in the next hundred years (VinIntell, 2012). Expected climatic changes in South Africa are increased temperature and rainfall distribution. Temperature increase is expected to affect wine quality in positive or negative aspects and increase the requirement for irrigation. Rainfall is likely to decrease during spring and summer, controlling berry size and vigor, limit disease outbreaks but may also limit the possibility to fill dams with water (Midgley et al., 2005). Frequency and intensity of extreme weather events is projected, especially in the Western Cape. These are for example drought and flooding (VinIntell, 2012).

South Africa is one of the top 20 countries with the highest GHG emissions and is per capita one of the worst emitters in the world (Dillon, 2011), contributing to 1.8 % of the global GHG emissions. It corresponds to 42 % of Africa's total GHG emissions. In South Africa there is no formalized mandatory limit regarding GHG emission levels. Since South Africa is one of the signatory countries of the Kyoto Protocol they are committed to reduce their emissions. At the Conference of Parties (COP) conference, held in Durban 2011, the South African government confirmed the commitment targets that emissions will continue to increase until 2025, where after be held at a stable level for a decade. Decreases will start first towards the mid-century. This is a commitment which requires immediate and effective actions throughout all industries. (Shelly, 2012). The agricultural sector is a large contributor to the total GHG emissions but is considered the sector with the highest potential of reduction, this mainly by increasing the soil carbon sink capacity (CCC, 2012). The South African fruit and wine industry experience a competitive market where consumers' awareness of human-driven climate change is emerging. The focus is increasing on the Greenhouse Gases (GHG) footprint and on identifying climate change mitigation opportunities (CCC, 2009). The agricultural sector is a large source of GHG emissions and activities such as land use change, agrochemical application and the use of fossil fuel releases high amounts of GHGs but have high potential for mitigation. In South Africa, energy is mainly supplied by coal. This contributes to a large carbon footprint for the whole nation compared to their agricultural competitive nations which in large part base their energy supply on renewable sources. This high carbon footprint may become a market barrier for South African producers (Wine and Fruit Initiative$_a$, 22-03-2013). The Wine Industry contributes to global warming during farming, winemaking, packaging, storing and distribution activities. The electricity use varies between different activities and is dependent on the electricity source. Within the farming activities irrigation, lighting and heating of offices and housing staff consume electricity but pumping of irrigation water is the largest consumer (CCC, 2009). Electricity consumption from winemaking activities lies within the cooling, lights and appliances (Waldorff, van Kraayenburg & Barnardt, 2004) and during storing it is lighting and cooling. Refrigerant gases used in the cooling equipment have very powerful GWP (CCC, 2009). In 2005 and 2006 more than 70 % of cellars used Freon 22 gas (HCFC) for refrigeration. As a consequence of signing the Montreal Protocol, HCFC is being phased out in South Africa from 1 January 2013. Producers are now implementing the new Freon 22 systems (Dillon, 2011). The electricity use for distribution has not yet been fully investigated nor understood (CCC, 2009). The contribution of fuel usage to the Carbon Footprint depends on the type and quantity of fuel. On the farm the fuel used depends on the number of tractor passes in the vineyard, distance to winery and number of deliveries, vehicles used for farm management and transport of staff and other. Fuel use in winery may come from equipment, on-site transport, labor transport and other. Distribution is of course a large consumer of fuel (CCC, 2009). The Carbon Footprint contribution from the distribution part of the chain depends on the quantities of wines sold on local and the export markets, distance and transportation means used (CCC, 2009).

During the production and application of Agrochemicals significant quantities of GHGs are emitted. Nitrous oxide from nitrogen-based fertilizers has a notable contribution to global warming, approximately 300 times the global warming potential (GWP) of CO_2 (CCC, 2009; Dillon, 2011). This gas forms naturally during the nitrification and denitrification soil processes and is a source of nitrogen losses (Dillon, 2011). To fully understand the impact of different farming techniques on the Carbon Footprint it is important to account for all relative GHG emissions from the agrochemicals used. Currently, there is not enough information available on the GHG emissions for other organic fertilizers than compost and manure (CCC, 2009). Land use change release GHGs, especially after change from virgin land. The quantity of GHGs released depends on the former land use i.e. forest or grasslands etc as well as the size of the land converted into agriculture (CCC, 2009). Packaging material acconts for the main part of the GHG emissions from the packaging and bottling facilities and is highly correlated to the quantities packed (CCC, 2012). 95 % of all wines sold, globally, are in glass bottles which confirms that glass traditionally is the preferred packaging material, as for South Africa (WRAP, 29-03-2013). Consol Glass SA has introduced light-weighting bottles and use of cullet (recycled glass) on the South African market to remain competitive within global markets. Since the year 2006 Consol's 750 ml natural wine bottles have decreased from 516 g to 437, corresponding to 15 % weight loss. In 2010, the first 350 g bottle was released. PET and Tetra-Pak are however more attractive from a climate impact perspective. That same year the first PET bottle was released on the South African market (Dillon, 2011). Almost 40 % less fuel is used to transport PET bottles compared to glass bottles and 1.5 ton CO_2 is saved during the production of 1 ton recycled PET bottles (WRAP, 29-03-2013). From a wine quality point of view, PET bottles have been criticized for allowing more oxygen ingress than glass. PET bottles are thereby limited as packaging material for early drinking wine. Tetra Pak carton packaging is also associated with low GHG emissions. A screw cap has 24 times higher GHG emissions than natural cork and plastic closure has 10 times higher emissions (Dillon, 2011). Wastes are another source of GHG emissions and depend on tons produced and disposed of as well as the type of waste and treatment. Recycled material contributes less to the Carbon Footprint than virgin packing material (CCC, 2012). Large quantities of CO_2 and methane are released during anaerobic treatment of waste water and depends on the amount of raw materials (own grapes + bought in grapes + bought in Bulk Wine) and total liters wine produced during the year. If these gases are captured and flared or used as energy it will not contribute to the Global Footprint. Winemaking also releases CO_2 during the fermentation process (CCC, 2009).

2.6. RISK MITIGATION PRACTICES

2.6.1. CONTROLLING WATER FLOW FOR SOIL CONSERVATION

Water flow can be controlled in a number of ways but of the earlier mentioned factors that play a role in causing erosion rainfall is the only factor that cannot be influenced by man. By controlling water flow contaminants may be significantly reduced and productivity preserved on the vineyard. In table 4 a number of specific measures for controlling water flow and erosion are described. These can be grouped into the following three basic methods for reducing runoff and erosion; Diverting excess water around the vineyard, filtering of water through soil (drainage systems) and ground cover protecting soil surface from the force of raindrops.

Table 4 Practices preventing soil erosion (Martinson et al., 2006; Thurp et al., 2006).

Soil Conservation Practices	Function
Control Basins	Collect runoff to let sediment settle
Cover crops/mulch	Absorbs the force of raindrops hitting bare soil. In tilled row middles seeded cover crops should be used from fall to spring. (see chap 2.6.4.)
Diversion ditch/cutoff drain & terraces	Break up slopes and reduce water flow.
Grassed strips & perennial hedgerows	Filter soil particles carried by runoff.
Grassed or artificial waterways	Used in areas with concentrated water flow.
Subsurface drainage tiles	Reduce surface flow
Subsoiling	Break up compacted soil layers to increase infiltration
Temporary barriers	Should be installed during soil disturbance to retard sediment flow
Terracing	Increase infiltration and slow down water speed
Vineyard rows	Should be planted across the slope to break up water flow

Diversion Ditches collect water from slopes, constructed perpendicular to the slope at intervals to channel water around vineyards. Grassed waterways are seeded and gently graded to slow the water down to reduce its erosive force. Artificial waterways are often constructed on sloping lands and strengthened with stones or bricks. Diversion ditches reduce the amount of water running through a vineyard by up to 80 % (Martin et al., 2006). Water from Diversion Ditches can be led to inlets and through underground outlets (pipes) towards a creek. Inlets along the hillsides divert water from bench terraces if such structures are in place (Shanks, Moore & Sanders, 1998). Water and Sediment *Control Basin* is an embankment, spillway or release structure at the bottom of a sloping vineyard. It collects and retains runoff and lets the sediments settle. Thereafter the water enters a swale or waterway. Straw bale, fabric or plastic material can be used to prevent erosion and retain soil by acting as a barrier (Thurp et al., 2008). Such structures are especially important if the soil is tilled regularly (Sonoma County Agricultural Comissioner’s Office, 2010). *Drainage Tiles c*ontrol the drainage and reduce soil erosion (Shanks, Moore and Sanders, 1998); and protect water quality by reducing surface runoff that otherwise would occur when soils become saturated and allowing water to be filtered through the soil, removing contaminants that would be present in surface runoff. (Martinson et al., 2006). Grassed areas, so *called filter or Buffer strips*, are areas between vineyards and waterways covered by dense annual or perennial grass or other vegetation. These strips improve water penetration, infiltration and slow down water flow (Thurp et al., 2008). These also have a similar effect as Control Basins when it comes to preventing sediment from reaching streams (Sonoma County Commissioner’s Office, 2010). Grass buffer strips along both sides of a creek help to filter sediment, nutrients and pesticides (Martinson et al., 2006; Thurp et al., 2008). Headlands and grassed areas are required around vineyards allowing machinery to turn around. About 12 meters is an adequate width (Martinson et al., 2006), however, implementing grassed areas may result in loss of income on productive land (Thurp et al., 2008). Vineyard layout contributes to the amount of runoff produced (Sonoma County Agricultural Commissioner’s Office, 2010) and thereby to reducing erosion on sloping land (ARC_a, 2013). Vineyards should be planned to take advantage of natural drainage features and maximizing infiltration. Vine rows running across the slope rather than up and down can reduce erosion by 50 % (Martinson et al., 2006). On steeper slopes land leveling, terracing or stone walls can be used to minimize water speed and increase infiltration (Pla & Nacci, not dated). Terraces are structures (fig 5) which aim to collect surface runoff and thus increase water infiltration. Steep slopes are reformed to level lands along the contours. The use of terracing is though limited in areas with sparse vegetation and is expensive to construct and maintain (Widomski, not dated). The main types of terraces are:

- Bench terrace, and back-sloping bench terraces
- Stone Wall terraces
- Fanya juu

Bench terraces (fig 5) consist of leveled platforms (benches), separated by embankments (also called risers) and meant to reduce slope length and steepness. These allow mechanized farming practices and irrigation. Bench terraces may be used on slopes up to 55° depending on soil stability. The back-sloping version has back-sloping benches with small drainage channels. This version is usually used in heavy rainfall regions (Widomski, not dated). Stone Wall Terraces are based on stone walls, also called stone bunds, to reinforce the riser. Stone bunds are placed along the contour and with time sediment deposits create terraces. These are suitable on steep slopes with shallow soils as they are more stable than bench terraces but associated with higher construction costs. Fanya juu terraces (fig 6) are constructed by digging a trench along the contour and throwing the soil uphill to form an embankment. To strengthen the structure the embankment should be protected with vegetation. This embankment works in the same way as the stone bund. Construction of Fanya juu requires less labour and less costs than earlier mentioned structures and are suitable even on shallow soils (Widomski, not dated).

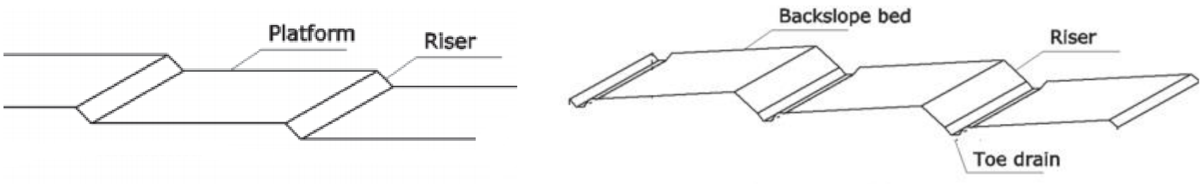


Figure 5 Two designes of bench terraces which is meant to reduce the slope and reduce the risk of erosion. Back-sloping bench terrace (to the left) which is gently sloping backwards in order to let excessive water to be collected by the drain channel.

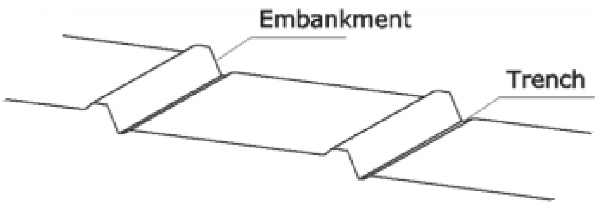


Figure 6 Fanya Juu Terrace. Embankments are constructed by digging a small channel and placing soil directly upslope. Water and sediment will be trapped and eventually form a levelled terrace plane.

A system for mechanical erosion control should be designed consisting of: cutoff drains, terrace channels and waterways. The principal concept is illustrated by figure 7. Cutoff drains are laid out to collect and protect lower laying areas against peak rates of runoff from the upper catchment. Collected runoff from the upper catchment is transported at a non-erosive velocity across the hillside into an artificial waterway, to safely carry the water down. Cutoff drains should never be constructed if the water is not carried down the slope safely. Therefore, cutoff drains should never be constructed to collect water from the upper catchment if a waterway or similar is not in place. Terrace shelves means to drain arable land across the hillsides at a gentle gradient into the artificial waterway.

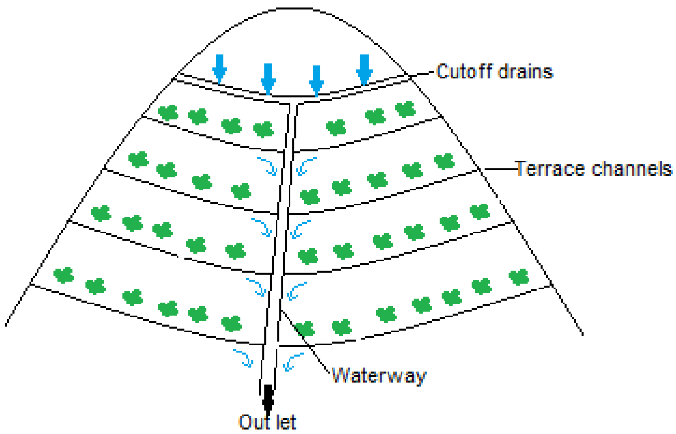


Figure 7 Basic components of mechanical erosion control. Water is diverted from upper catchment into an open channel, cutoff drain, and lead in a waterway down the slope. Runoff generated from the vine rows is collected in terrace channels which divert the water towards the waterway.

Vineyard floor management has great potential to reduce soil erosion and improve water quality. Clean tillage between vine rows for weed control involves 4-5 passes through the vineyard annually, making the vineyard prone to erosion during much of the growing season. There are many options to reduce soil erosion while controlling weeds. Straw mulch can be applied in row middles, preferably on eroded sites. Straw mulch conserve soil moisture, increases nutrient availability, provides a barrier to reduce the force of raindrop by 98 % and can directly increase yield by up to 20 % (Martinson et al., 2006). If a gully starts to form it can be filled with straw or an emergency ditch can be built to control drainage (Sonoma County Agricultural Commissioner's Office, 2010).In cases where soil layers have been compacted, subsoiling might become a necessary measure to break the compact layer and achieve improved infiltration. After soil disturbances like tillage, sub soiling etc temporary barriers should be installed to inhibit soil particles to transport water flows (Martinson et al., 2006).

Progressive practices should be used during construction of vineyard roads. Daily traffic roads should be weatherproofed or hardened to resist erosion. On temporary or seasonal ranch roads a thick cover crop should be established. This may though, depend on traffic, requiring seeding annually. Roads should also be bladed during dry weather but while still moistened to minimize dust and maximize compaction for preventing fines from being discharged from the road surface. Bladed material should be placed where it does not risk eventually entering a stream by rainfall or runoff. Roads should be out-sloped to promote even draining of the road surface. Roads on slopes steeper than 15˚should have Water Bars (fig 8), not more than 15-30 meters apart depending on the steepness of the slope, the steeper the slope the smaller the distance. The Water Bars should have a gentle slope, perpendicular to the hill slope, to divert runoff to the side of the road. The outlet should be stabilized with gravel or similar erosion prevention (Sonoma County Agricultural Commissioner's Office, 2010). As for ditches, it is necessary to protect them from erosion as well as from any other soil construction on the farm. This can be done in several ways. Generally a more gently sloping ditch wall is less prone to erosion than a steep one. Vegetation cover also has a great effect on preventing erosion. Vegetation armor the soil, and acts as a flow resistant and lowers the soil water content which has a positive effect on slope stability. If there is greater risk of erosion there are more advanced erosion protection measures to put in place; such as geo textiles, concrete blocks etc (Ohlsson et al., 1994).

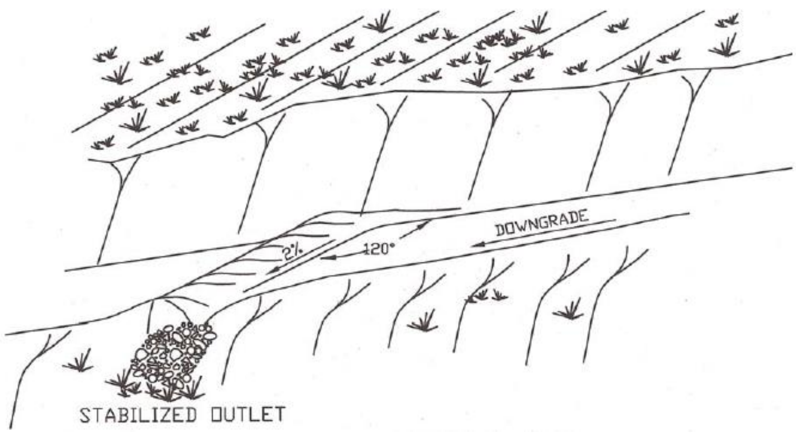


Figure 8 Water Bar on vineyard road. Small gently sloped channels across the road divert runoff to the side of the road to prevent erosive forces from water flows along the road. Water bars should be stabilized with gravel at the outlet.

2.6.2. WATER CONSERVATION

Water conservation is defined as any beneficial reduction in water use, loss or waste for the benefit of people or environment. Water use efficiency and water productivity are important measures for water conservation. Increased efficiency implies reduction of the amount of water used and using water more efficiently. Increasing water productivity means increasing the amount of products produced per unit of water (Alberta, 30-03-2013). Measuring and monitoring is important for achieving low water use as well as efficient equipment and systems. Installing water meters is highly important for thorough monitoring and recording of water use (CSWA, 2011; Thurp et al, 2008; Boland & Tee, 2005).

As part of the design and establishment of a vineyard, water conservation should be considered. By planting with a suitable spacing root development is promoted at the same time as water demand is reduced (Thurp et al., 2008). Irrigation systems and schemes highly influence the extent of water use efficiency and productivity and should be maintained and serviced regularly. An efficient irrigation system has high mechanical efficiency and high uniformity. Irrigation should be tailored to the different parts of the vineyard and the design based on soil uniformity. Water applications should be short and frequent. By using drip irrigation a mild water stress can be timed, a system that generally applies water more efficiently than sprinkler or furrow irrigation (Thurp et al., 2008). Sub-surface drip irrigation is even more water efficient than the regular drip irrigation system (Prichard, et al., 2004). Drip irrigation also allows excellent precision and minimal water requirement at the specific active root zone (Thurp et al., 2008). By practicing partial root zone drying (PRD) or regulated deficit irrigation (RDI) the crop is allowed to dry out a bit before water is applied. RDI implies water applications less than full potential of Crop Water Requirement (CWR). RDI has also been shown to reduce the energy use significantly on the farm and fewer tractor passes are needed due to reduced vegetative growth and thereby reduce canopy management. Economic benefits have been experienced as well. The yield may decrease moderately but grape quality increases (Wine Institute$_b$, 2011). Using drought-tolerant crops implies that the delay before irrigation applied can be prolonged. During irrigation over-extraction of water resources should be avoided. Evaporation losses can be mitigated by avoiding irrigation during daytime heat (Greenspan, 2007) or by covering the soil surface. This can be done by using cover crop or mulch, which is thoroughly described in chapter 2.6.4. By storing water in a pond or similar reservoir rainwater falling during rainy season can be stored until the dry season and used when it's needed. Cellar wastewater is a commonly used water source for irrigation of South African vineyards (Waldorff, van Kraayenburg & Barnardt, 2004).Wastes from the wine cellar may, however, cause pollution of water resources if not properly treated, (Dillon, 2011). All wineries must however have a definite waste water management plan, generally on-site, complying in terms of quality, storage and disposal of wastewater. Water usage should be measured and recorded weekly, with monthly tests conducted and reported. The size of winery in terms of tonnage harvested and wastewater generated determine the choice of water treatment plant to be installed. For example a small winery may process its wastewater through a wetland (Dillon, 2011).

2.6.3. Soil Management

Favorable soil conditions created by sufficient soil preparation and correct vineyard layout can be destroyed by incorrect cultivation practices, such as injudicious chemical or mechanical weed control (ARC_a, 2013). Careful soil management is crucial for maintaining productivity and minimizing runoff and leaching (Wise et al., 2009). In some winegrowing countries terracing and vine-row direction has been abandoned for the benefit of mechanization and increased land productivity and terraces has been exchanged to land leveling. This has subsequently made soils more prone to erosion, higher in bulk density, reduced water penetration and filed capacity (Dillon, 2011). To ensure good soil quality management, soil properties and nutrient status must be evaluated regularly. Nutrient analysis is of importance for making wise decisions in soil and nutrient management and avoiding excessive nitrogen fertilization. All soil management practices should be recorded, such as leaf nitrogen analyses, soil sampling results, water holding capacity and erosion potential (Thurp et al., 2008). Soil tillage should be avoided due to risk of erosion and soil compaction. Tillage during early spring or late in the fall, as well as on slopes greater than 5-10˚ or on highly erodible soils, should be avoided. If tillage during early spring and late autumn can't be avoided filter strip areas or other erosion control measures should be in place (Dillon, 2011). Heavy and repeated traffic on eroded soil should be avoided, especially tillage and traffic during wet conditions, in order to avoid soil compaction (Boland & Tee, 1998). Reduced tillage in vineyards means that at least the row middles are left with plant residues on the surface the whole year around. Reduced tillage allows SOM to build up and reduce erosion by up to 60 % (O´Green et al., 2006). It is important to use measures to facilitate the breaking of surface crusting and enhancing infiltration. Tillage increases the surface roughness which subsequently can decrease the erosive energy of water flows (O'Green et al., 2006). Turning areas should be left untilled to avoid compaction (Dillon, 2011). Soil structure greatly influences the soil's capacity to withstand disturbances such as soil tillage, traffic, high water flow etc. Poor soil structure can be improved by building up soil organic matter (SOM) or in adding gypsum (Lanyon, Cass & Hansen, 2004). At least 1-3 % SOM is preferred (Thurp et al., 2004) and can be built up by using mulch, cover crops etc (see chapter 2.6.4.). Soils troubled by root zone water logging and restricted root distribution caused by shallow surface soils with dense impervious subsoil can be improved by mounding. Mounding means relocating topsoil from the row middles to the vine rows to form a ridge. This method can improve soil physical properties relative to the initial conditions. Some benefits are lower bulk density, rapid root development and more healthy vines (Lanyon, Cass & Hansen, 2004).

2.6.4. Cover Crops & Mulch

Cover crops are the most cost-effective measure to reduce erosion and are especially effective in preventing sheet erosion (Sonoma County Agricultural Commissioner's Office, 2010). Use of cover crops is an important measure in vineyards for protection and improvement of soil quality. By planting cover crops soil erosion can be reduced, nutrients added, organic matter and soil structure improved, soil moisture retained and biodiversity of beneficial insects increased. Cover crops prevent leaching of nutrients and agro-chemicals and reduce weeds (Ingels et al., 1998; Wine Institute, 2002). Cover crops should be seeded at least one month before the initial rainy season and may require irrigation and fertilization for a good establishment. To provide adequate protection the cover crop should look like a lawn by the first heavy rains. In cases where this is not possible, the seeded cover crop should be protected by mulch (Sonoma County Agricultural Commissioner's Office, 2010). Self-reseeding is of importance for erosion control and timing for mowing. If weeds are a problem in perennial cover crop mowing should be done in early spring to reduce competition and shading for perennial seedlings. Thereafter 1 or 2 mowings per year at no less than 10 cm tall, depending on the crop, are preferable. Most effective for erosion control is fast growing grasses together with clover or crops with similar surface cover. Grass alone, does not provide the same protection. Different mixes of cover crop spicies are suitable for different usage and biophysical conditions (Sullivan, 2003; Sonoma County Agricultural Commissioner's Office, 2010). Both perennial and annual crops can be used as well as legumes, grasses or managed native vegetation (Sullivan, 2003). The best cover crops, in order to reduce erosion, are perennial with dense foliage and root systems such as perennial ryegrass, tall fescue or strawberry clover (Shanks, Moore % Sanders, 1998). Grasses are, however, the most cost-effective cover crop (Thurp et al., 2008). Though, most perennial grasses do not develop and establish as rapidly as annual cover crops. Therefore, during the first year of establishment of perennial cover crops it is advantageous to mix in a small amount of annual grass seed. After the first year no tillage is required if properly managed. They may though require replanting after some years if weeds invade.

When it comes to annual crops winter grasses are among the best cover crops for erosion prevention (Shanks, Moore & Sanders, 1998). Winter grasses are seeded in late summer/autumn to provide cover during the winter, reseed and die as vine growing begins in early spring (Sullivan, 2003; Shanks, Moore & Sanders, 1998). Before the root system is sufficiently developed the soil may be prone to heavy rainfall. Winter annuals as cereal rye, barley and oat do not reseed so they protect the soil for only one season. These are often used in new established vineyard where soil needs to be protected but further disturbance for planting, trellising, irrigation or other activities is required during the spring. Less effective, but still commonly used, are winter annual legumes which have less dense root system. When established, legumes can be effective in preventing erosion but disking is required for planting which may cause serious erosion if heavy rainfall. Legumes have other positive factors such as binding nitrogen and improving diversity (Shanks, Moore & Sanders, 1998). Legumes and cereal crops can be mixed to achieve both nitrogen fixing effect and proper soil protection (Sullivan, 2003).

Cover crops do compete with vines for nutrients and water (Thurp et al., 2008) but they also have an effect of reducing evaporation losses (Greenspan, 2007). Apart from competition of water, cover crops may also inhibit vine root growth near the soil surface (Prichard, 1998). Disking of the cover crop at bud break of grape vines may be a way to manage the competition in times of water shortages (Prichard, 1998). Moving of cover crops or disking alternate rows is another way of managing water scarcity situations (Greenspan, 2007). Other drawbacks with cover crops are that they may act as a habitat for pests, spread to undesirable places and become weeds, reduce solar warming of soil and increase the risk of frost damage to vines during spring. Risk reduction can be assessed by planting the cover crop in every other row, use of overhead irrigation or timely mowing (Thurp et al., 2008).

Cover crops may reduce yields if they are not rotated every few years, especially in young vineyards under dry land conditions (Prichard, 1998). Generally, the benefits of cover crops outweight the drawbacks (Thurp et al., 2008). Cover crops may not be a good alternative on all farms. In such cases mulch can be used with similar effect. Mulch is a non-erosive organic or inorganic material. Inorganic mulch is e.g. gravel, pumice, stone and sand. Organic mulch can be wood chips, leaves, saw dust or straw. Mulch protects the soil from the force of raindrops and compaction, reduces evaporation and holds down weeds (O´Green et al., 2006). It may also be used for protection of new established vegetation. Where cover crops are sparse, straw mulch can be used as a complement during rainy seasons or when cover crops are planted in the late autumn. If high wind speed it may become necessary to anchor the mulch to the ground by tracking or crimping (Sonoma County Agricultural Comissioner's Office, 2010). For a proper erosion protection at least 4.5 tons of straw mulch per hectare should be applied over 80-100 % cover of the ground surface (Martinson et al., 2006).

2.6.5. Climate Change Mitigation

To be able to determine opportunities for climate change mitigation it is essential to be aware of the size and sources of Greenhouse Gas (GHG) emissions. One method for this is Life Cycle Analysis (LCA) of the particular product produced. *Carbon Footprint* is a LCA measuring the GHG contribution from a product or activity (Abbot, 2008). Often Carbon Footprint comprises emissions during the whole chain from raw material, production processes, transport, trade, and use to disposal or recycling (Gerhard et al., 2010). A Carbon Footprint of value 0 means that the activity is *Carbon Neutral*, it does not contribute to global warming. Carbon neutrality can be achieved by decreasing the GHG emissions as much as possible and then compensating for the rest of the emissions with so called *Carbon Credits* where the money goes to external projects for renewable energy, planting trees etc (Abbot, 2008). A well performed GHG auditing or Carbon Footprint Analysis has:

- High relevance – Ensure appropriate reflections of the GHG emissions of the company
- Completeness – Including all relevant sources and information and well defined boundaries
- Consistency – Enabeling meaningful compairisions in GHG-related information
- Accuracy – Reducing bias and uncertainties
- Transparency – reveal sufficient and relevant information to make well informed decisions

To be able to compare the different GHG with different Global Warming Potential (GWP) as stated in table 5, or emission factor (EF), the amount emitted of each GHG is multiplied with the GHG's GWP and compared to the GWP of carbon dioxide which is equal to 1 (CCC, 2009).

Tabel 5 Greenhouse Gases' GWP compared to GWP of CO_2 (CCC, 2009).

Greenhouse Gas (GHG)	Global Warming Potential (GWP)
Carbon dioxide (CO_2)	1
Methane (CH_4)	25
Nitrous oxide (N_2O)	298
Hydrofluorocarbon (HFC) 134a	1 430
Perfluorocarbon (PFC)	6 500
Hydrofluorocarbon (HFC) 23	14 800
Sulfur hexafluoride (SF6)	22 800

Decreasing an activity's GHG emissions usually comes with reduction of costs (Abbot, 2008). Crop production measures which reduce energy requirements and at the same time maintain the yield's quality and quantity is important for a long term sustainable agricultural system (CCC, 2009). The following measures, relevant for South Africa include technologies in (CCC, 2009).

- Sustainable water utilization, waste- and rainwater management
- Accumulation of SOM through integrated nutrient management, cover crop and mulching.
- Integrated Pest Management (IPM)
- Implementation of alternative energy sources (e.g. solar, micro-hydro, biogas and biodiesel)

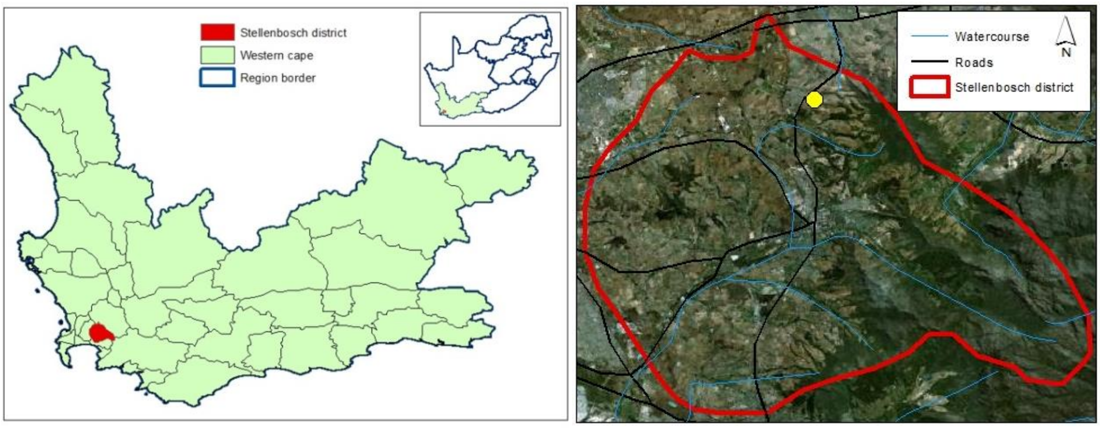
The Carbon Footprint contributions from electricity can be reduced by changing to renewable energy, if nonrenewable energy is used at the moment of auditing, and by minimizing the use of electricity. Minimizing the electricity use can be achieved by switching of cooling during the winter, doing the stabilization of wine during winter rather than during summer, switching lights and appliances off when not in use etc (Waldorff, van Kraayburg & Barnardt, 2004: Dillon, 2011). By using light-weight bottles, PET-bottles or Tetra Pak the Carbon Footprint from the packaging facilities can be reduced. Moving from virgin packing material to recycling significantly contributes to reducing the Carbon Footprint (Dillon, 2011).Organic wastes from the farm, winery etc could be used as feedstock for biogas. One winery alone does, however, not produce enough waste to drive a biogas chamber alone. External wastes from other farms, or other activities, or sharing a biogas chamber between several wineries would be necessary. By treating organic wastes in a biogas chamber methane emissions can be reduced by a factor of 10 compared to landfill and at the same time as renewable fuel is being produced (Dillion, 2011). Improving soil management and reducing energy and diesel usage are the two most effective mitigation measures within the agricultural sector. Sustainable farming practices and resource conservation methods and technologies are likely to have a positive impact on yield and are cost-effective measures of adapting to climate change. Climate change adaptation and mitigation does not necessarily imply high costs and complicated interventions (CCC, 2009). The decrease of Nitrogen Oxides from the soil after nitrogen fertilization can be achieved by changes in nutrient regime and fertilization techniques, use of nitrification inhibitors according to the soil type, soil sink potential and management practice (Gerhard et al., 2010). Cover crops bind carbon and may add nitrogen to the soil but may, though, enhanced nitrogen mineralization and N_2O-emissions under certain humid conditions (Gerhard et al., 2010).

3. MATERIAL AND METHODS

3.1. KANONKOP WINE ESTATE, STELLENBOSCH

3.1.1. General Description

Kanonkop Wine Estate is a fourth generation family estate located in Simonsberg-Stellenbosch ward, Stellenbosch district in the coastal region of Western Cape (fig 9). Stellenbosch is the highest producing wine district (SAWIS, 2012) in South Africa, called the "Town of Oaks". The winemaking tradition stretches back to the mid-17th century (Kanonkop b, c, 30-01-2013). Kanonkop is situated on the south-western slopes on the foot of Simonsberg Mountain (Kanonkop, 29-01-2013), approximately 35 km from the Atlantic Ocean and 27 km from the Indian Ocean, at the longitude 18.859864 and latitude -33.855572 along the highway R44 between Stellenbosch and Paarl (Google Earth).



Source: derived from DIVA and Satellite image from © Google earth, 2013.
Figure 9 Location of Kanonkop Wine Estate in the Western Cape Province ( ).

Kanonkop is one of the best known vineyards in South Africa, renowned for its red wines Kadette, Pinotage, Cabernet Sauvignon, Paul Sauer and Black Label. Recently, Kadette Pinotage Rosé was introduced in the assortment (Wine SA, 31-01-2013). Pinotage is a locally bred grape variety, a cross of Pinot Noir and Cincaut (In South Africa known as Hermitage), which Kanonkop was among the first farms to grow commercially (Wine SA, 31-01-2013). Kanonkop has a long list of international and national awards. John Platter awarded Kanonkop as the *Winery of the Year 2009*. In 2005 and 2009 they won the *Dave Huges Trophy* for *Best South African Producer* (Kanonkop b and c, 30-01-2013). The Winemaker Abrie Beeslaar was awarded *International Winemaker of the Year* in 2008 at the *International Wine and Spirit Competition (IWSC)*. The former Winemaker won the same trophy in 1991. The farm has its own wine cellar and bottling facilities and employs about 50 people (Kanonkop Estate, 30-01-2013). The farm is mid-sized with about 125 hectares whereof approximately 100 hectares are used for grape growing but grapes are bought in from other farms as well (Abrie Beeslaar, 26-03-2012). Grapes are punched manually, using wooden sticks. Only a handful of cellars still crush grapes manually in South Africa (Enviroscientific, 2008).

Source: © Google Earth, 2013.
Figure 10 Satellite image of Kanonkop Wine Estate. derived in ArcGIS.

3.1.2. CLIMATE

A study of climate statistics for Kanonkop and two nearby vineyards, made by Knight & Taljaard (2002), showed that the number of GDD (Growing Degree Days) is 1595 days. This falls within region II, indicating potential for "Good quality red and white table wine". Mean February temperature was 21.8℃ indicating a moderate climate, potentially producing high quality red table wine, high in acids, low in pH and with excellent cultivar character. The continentally is 9.15℃ which indicates a marginally maritime climate (<10℃). Climate statistics used in this study were recorded at Elsenburg, less than 5 km from Kanonkop. Dominant winds are southeast during the summer and northwest during the winter. The geology is dominated by Phanerozoic quartzitic sandstones of the Peninsula Formation of the table Mountain Group surrounded by biotite granites of the Cape Granite Suite (Enviroscientific, 2008). According to a study, made by Hunter and Bonnardot (2011), Stellenbosch district has the best conditions for grapevines compared to the wine producing districts Robertson and Upington. This despite periods of optimal temperature that are shorter in Stellenbosch than the other two districts. Stellenbosch has a temperate to hot climate, with average warm temperate, with warm summers. The proximity to the sea evens out seasonal and daily temperature variations but in combination with a complex topography the influences of the sea contributes to high heterogeneity of the meso climate within the district. The climatic conditions in Stellenbosch enable cultivation with to low intensity irrigation or growing under dry land conditions (Hunter & Bonnardot, 2011).

3.1.3. SUSTAINABILITY

Kanonkop is IPW certified for both farm and cellar with bottling facilities. According to the IPW Self Application for 2012 the farm scored 100 % (200 out of 200 credits) and the cellar 65 % (100 out of 155 credits). According to their IPW members page at the IPW web site Kanonkop submitted their first Self Application for the farm in 2009 and for the cellar in 2010. In 2010 the Self Application in 2010 resulted in 67 % for the farm and 84 % for the cellar. The result of the IPW audit (performed by Enviroscientific as an independent auditing body) for the same year resulted in 95 % for the farm and 57 % for the cellar. The cellar did not pass the IPW requirement that year. In 2011 the farm scored 98 % on the self-application and the cellar was audited by the IPW scoring 66 % which made it pass the requirements. Improvements made between the two audits included (Louw, 2011; Louw, 2010):

- Implementation of pest control in the winery measures
- Analysis of the quality of incoming water
- Improved recording of water use
- Analyses of waste water quality (March, April & May) was performed and resulted in adequate quality for irrigation water
- Improvement in disinfectants and cleaning agents used
- A glass breakage procedure was implemented for the bottling activities
- Recording of breakage during bottling

Recommendations given in the IPW auditing report (2011) include improvements of (Louw, 2011):

- Improved record keeping throughout the activities
- Recording energy consumption of each production or financial year, for future comparison
- Annual analysis of incoming water quality
- Ensure adequate recording and storage facilities for wine additives and cleaning chemicals
- Replacing use of e.g. tartaric acid by more environmental friendly alternatives
- Monthly analyses of wastewater quality
- Obtain a contract from the company removing solid waste and a confirmation letter of that waste is recycled or disposed in a responsible manner.
- Keeping records of removed solid waste
- Implement a formal procedure for cleaning of wastewater dams, pipes and other equipment.
- Recording recycling of plastic, glass and paper waste.

Some guidelines which were not completely fulfilled for the cellar were nr 3*Energy use and Carbon emissions*, where 3.3. (bonus points) scored 0 credits due to no CO_2-calculation being made and *Energy use and CO_2-emmissions from harvest and transport.* Monitoring, storing and disposal of waste water as well as disposal of solid waste also show opportunities for enhanced sustainability at Kanonkop. In addition to the IPW membership and certification, Kanonkop is also certified for BWI (Biodiversity of Wine Initiative). The interest of sustainability and constant improvement of the activities at Kanonkop are strong. Though, they do exhibit a lack of knowledge concerning sustainability. When the government comes out with new criteria and demands they do their best to comply with them and adopt their operations. They want to be as environmentally friendly as possible without affecting the quality of their wines (Abrie Beeslaar, personal communication).

3.2. BIOPHYSICAL CONDITIONS

3.2.1. Mapping in GIS

Monthly average of climate parameters was calculated from monthly data for the years 2005-2012 from the climate station Elsenburg, located on an altitude of 171 m.a.s.l. on latitude -33.6 and longitude 18.83. The evapotranspiration measurements are not accurate, as they indicate on an annual evapotranspiration of 1300 mm which gives a very arid climate and does not reflect the real climate.

Base maps were made in ArcMAP, using the software ArcGIS. The projection system used was WGS1984 UTM S34. Satellite images were imported from Google Earth and administrative data (shapefiles) was acquired from DIVA-GIS, a web-portal for GIS data. DIVA-GIS is attached to the Consortium of Spatial Information (CGIAR-CSI) and Bioversity International. Data are free for download on http://diva-gis.org/gdata. GIS-data of 20m DEM (Digital Elevation Model), 5m DEM (derived from 20 m DEM and 5 m contour data), land type, relief points, contours & soils was provided by VinPro, located in Paarl, Western Cape, South Africa. Soil data does, though, not align with what is experienced by the viticulturist and winemaker. Where soil data indicate shallow soils, soils are in fact very deep. Since no other data is available soil types cannot be studied further in this report. Vineyard border was created by drawing a polygon in GIS by using satellite images and paper maps of the vineyard. For simulations of topography and drainage network of the surrounding area filled 20m DEM data was used. Topographic base maps of the vineyards were simulated from 5m DEM and 5 m contour data. Soil maps were computed by using provided GIS soil type data provided by VinPro. Watersheds were defined by using pour points located on the two major stream networks as well as on the three smaller watercourses to which Kanonkop contributes as a drainage area. The watershed of the artificial dam was defined by using pour points located on the watercourse crossing the dam, right at the farm border. Flow accumulation was computed from filled 5m DEM.

3.3. AGRICULTURAL PRACTICES

Maps of Vineyard Blocks, irrigated fields and cultivars were computed in GIS. Blocks and the labeling were drawn according to paper maps provided by Kanonkop and in consultation with the winemaker. Comparisons of vine row direction and contour lines were computed by laying contour lines above a satellite image imported from Google Earth in ArcGIS. As a complement, an ocular view of the vineyard was made and compared to the simulations in GIS. Interviews were held with the winemaker and viticulturist. Interview questions were formed with support from relevant literature and the IPW guidelines. Both background questions and questions of a more specific character were formulated. In addition to the interviews IPW auditing reports of Kanonkop and the wastewater treatment investigation made by Enviroscientific were used as an information source.

3.4. DETERMININATION OF ENVIRONMENTAL RISKS

3.4.1. DETERMINATION OF RISKS

Sustainability is a broad concept which needs to be defined in each specific context. In this report sustainability is limited to the aspect of climate, soil and water resources. These aspects are discussed in the IPW Guidelines; 3-Soil and Terrain, 6-Vineyard layout, 7-Cultivation practices, 8-Nutrition and 9-irrigation. The aspect of herbicides and pesticide management and handling of chemical will not be studied in this project, ergo, the issue of water quality will be discussed in the context of erosion-related matters only. The guidelines; 1-IPW training, 10-Pruning, training and trellising, 11-Crop and canopy management, 12-Growth regulators and 13-Integrated pest management (IPM), 14-Handling of chemicals and 15-Record keeping will not be focused on in this report. Guidelines 4-Cultivars and 5-Rootstock will be mentioned briefly. In the IPW guidelines conservation of natural areas is included but in this report only cultivated areas will be studied. Environmental risks could be determined with support from literature concerning environmental risks specific for vineyards, factors influencing wine quality, reports concerning wastewater treatment at Kanonkop and IPW auditing reports. Initially an ocular view of the vineyard was performed and discussions were held with the winemaker and viticulturist. Water scarcity and soil erosion were determined as risks to study more into detail. A request from the winemaker was made to focus on determining Kanonkop's Carbon Footprint.

3.4.2. DETERMINATION AND MAPPING OF EROSION

The erosion on the southern and central part of the vineyard will not be studied in detail. General recommendations may be applied for the southern part. Using ocular assessments of the vineyard events of on-going erosion were determined on the hillslopes and plotted on the vineyard map in GIS. On the same map existing erosion control measures was plotted to enable an accurate overview of the power and movement of runoff. By plotting events of erosion and control measures in the same map it facilitates a deeper understanding of how implemented control measures reduce but also contribute to erosion and cause risks of erosion for the future. By studying the biophysical conditions and agricultural practices together with the events of erosion more closely the background to the occurrence of erosion can be understood. With this understanding as a base suitable erosion control measures and their prioritizing can be recommended for future implementation in the vineyard.

3.4.3. CLIMATE CHANGE IMPACT

By performing a Life Cycle Assessment (LCA) the overall carbon footprint of the wine production can be assessed. For calculations of Kanonkop's carbon footprint, a freely available online calculation tool was used, the *South African Fruit and Wine Industry Carbon Calculator*. This calculator is based on international standards; *Greenhouse Gas Protocol*, ISO 14064 (*Greenhouse Gases Standards* published in 2006) and PAS 2050 (*Publically Available Specification 2050:2008* published in October 2008) (Fruit and Wine Initiative$_c$, 22-03-2013]. This tool is provided by *South African Fruit and Wine Initiative* and is available at their website www.climatefruitandwine.co.za. All relevant data is added into the calculator which carries out the computing and provide the result in a number of graphs and tables. The calculator does not include the retailer side of the supply chain, customer use or final disposal of packaging and unused products. The calculator can be calibrated for the individual user's boundaries of the business activities (Fuller, 2012). The responsibility for the quality of the data is the user's and the quality of the data directly affects the result. More information about the calculator tool can be found in *South African Fruit and Wine Industry Carbon Calculator – The Protocol* and *Carbon Calculator Data Collection* on www.climatefruitandwine.co.za

One *Business Unit* was added in the calculator including the boundaries; *Farm*, *Winery* and *Distribution*. As commodities only *Red Wine Grapes* were designated. The audit period was set to January-December 2012, after which the carbon footprint will be audited in January each year going forward. The farm boundary stretches all the way to the winery door and the winery stretches from there to the gate. The distribution boundary starts at the winery gate and continues to the market or international port where applicable. Clearly defined boundaries are important, especially for the allocation of shared inputs; electricity and fuel. The electricity source is coal based grid. Recently prices rose by 300 %, which lead to installation of electricity meters on irrigation pumps, bottling and packaging facilities and staff houses in order to determine the consumption sources. The total electricity consumption was gathered from the grid electricity bill from Eskom. The allocation is performed according to table 2 (appendix 2). The electricity used within the farm is subdivided into vineyard activities, infrastructure, housing and others. Irrigation is the only vineyard activity consuming electricity and generally accounts for most of the consumption of all farming activities (CCC, 2012). Housing electricity use was estimated due to lack of data for the entirety of 2012. The estimation was done by multiplying the 22 houses' consumption for one month multiblied by 12 to get the annual electricity use. The calculator does not include housing in the final Carbon Footprint calculations. This due to the fact that the way the staff use the electricity does not directly reflect the farming practices and should therefore not affect the final result (CCC, 2012). In infrastructure, lighting and heating of offices is included. Electricity consumed within the winery is subdivided into processing activities, cooling, bottling and other. The electricity consumption of bottling and packaging facilities was estimated by calculating the average electricity use for the 11 days recorded in June and July 2012 and multiplying by the number of the number of days in operation. Approximately 1953 kWh/day are consumed over 5 months. This gives an annual consumption of 300 000 kWh. The distribution does not consume electricity. For the other electricity consuming sources there was no data available to assist in estimating the consumption. Only guidance from CCC (2012) on which are the main electricity consumers could be used to support the allocation.

Fuel consumption (diesem ppm 500) is divided into direct and indirect consumption. Direct fuel refers to fuel consumed by company owned vehicles and equipment. Indirect fuel is consumed by a contractor. No indirect fuel is used in the production activities since no contractor is hired. Fuel used for transporting employees to Kanonkop is not included in the calculations even though costs for their transport are paid for by the company. Employees' transport does not reflect the production practices and where employees choose to live should not affect the final result. Business travels are not included either, as instructed in the calculator's user guide. Labor transport is added into the calculator but not included in the final result for same the reason as earlier mentioned (CCC, 2012). Allocated of fuel usage is described in table 1 and 3 (appendix 1).

Sources and sinks which are a part of the short-term carbon cycle are not included in the GHG auditing. These are; CO_2 released during the fermentation process in the winery, vineyard growth and CO_2 emissions from aerobic waste treatment of both solid and liquid wastes. If additional CO_2 is bought and used in the fermentation process it must be included. There is no anaerobic wastewater treatment at Kanonkop. Carbon sequestration is strongly dependent on microclimatic conditions and therefore requires site-specific calculations since no industry level average exists for different regions. Emissions of non-CO_2 gases released during the above mentioned activities are not a part of the short-term carbon cycle and therefore not included in the GHG auditing. This includes methane released from waste systems and nitrous oxide from soil management. Carbon sequestration may, however, be included in future versions of the calculation tool. At this time it is not included due to that accurate data cannot yet be provided by the industry (CCC, 2009). Farm level waste is excluded from the tool due to data quality and the 1 % materiality rule. This may though change in future versions when better understanding of the waste cycles at farm level is gained (CCC, 2012). As soil disturbance and tillage are not major farming practices in vineyards it has been excluded as well but may be included in future versions if it is found to be a significant contributor to the overall carbon footprint (CCC, 2012). There has been no change in land use on Kanonkop during the last 20 years.

Agrochemicals used in 2012 are shown in table 4 (appendix 1). Green sulfur and Super phosphate was applied in rates equivalent to the fertilizing plan recommended by Omnia Nutriology but no records was kept on actual application. In total 1040 kg pure Nitrogen, 920 kg pure Phosphorus and no Potassium were applied. Phosphorus is converted to kg P_2O_5, the active ingredient, by multiplying with 2.29 according to the carbon calculator protocol (CCC, 2009). The total application was divided with the area planted to vine (100 ha). Since fertilization is done by hand variation of application is likely to be large. Lime was added on only one field, in the form of Calcitic lime. Chicken manure was applied as a complement to the fertilizers. The amount of chicken manure applied was estimated from memory by the viticulturist. There is no record on how much pesticides was used. There is, however, a spray program which is assumed has been followed. Insecticides was used but a very small amount according to the viticulturist. Due to no records being kept and it is insignificant to affect the total Carbon Footprint audit has therefore been neglected.

Wine is produced from grapes produced on Kanonkop's fields (table 5 in appendix 1) and from bought-in grapes from neighboring farms. Quantities are specified in table 6 (appendix 1). Wine is stored, bottled and packed on the estate, table 7 (appendix 1). The wines are subsequently sold over the farm's counter, on the local and export market. The values in table 8 in appendix 1 was calculated from sales records of each product that was bought by each customer, both national and international.

GHG emitted from the bottling and packaging depends on the quantity of material used and how it has been produced. Packaging material used during 2012 is displayed in table 9 (appendix 1). Glass is only used for bottles. All bottles are assumed to be of the size 0.75 liter, even though this is not the case. Including the few magnum bottles etc at this point would make the estimations more complicated. By recording material use in the future different sizes of bottle could be taken into account. The weight of glass bottles was estimated by dividing the total liters of packed wine with the volume of the bottles and thereafter multiplying with the weight of a bottle (640 g). The number of used bottles was according to estimation 910 864, which is fairly close to the 1 000 000 bottles ordered. These bottles are made from 20 % recycled glass. Pallets are delivered with 5 cardboards (4.5 kg per board) per pallet and the delivery company takes non-damaged ones back. One pallet can be loaded with 720 bottles. This gives rise to an estimate of approximately 1300 pallets needed. This gives about 6300 cardboards of which approximately 5 % is assumed to be damaged and not retaken by the company. Boxes made for packing the glass bottles (6 bottles/cartoon) are made of Corrugated Cardboard Cartons. All bottles are packed in these boxes but approximately 90 % of the boxes packed with bottles that are being sold over the counter are reused over the coming year. The weight of cartons used could be estimated by multiplying the weight of each carton with the number of cartons used, which was gained by dividing the number of bottles by 6. From these the reused boxes were subtracted. The weight of used labels (back and front) was estimated by dividing the number of bottles with the number of labels per package (3000). Thereby number of packages could be multiplied by its weight. Labels are made of virgin material to avoid discoloration. For wrapping, 30 % recycled plastic and plastic tape is used. Plastic is grouped under LDPE. In 2012, 36 boxes of tape were bought in which it is assumed stands for the use during the year. One roll of each was weighed, from which the total use of plastic wrapping could be estimated. Disposable wood pallets and CHEP were estimated by dividing the number of bottles packed on pallets with number of bottles per pallet. CHEP Pallets are used for local transports and transports to Southern African countries and UK. These clients stand for 224 500 Liters. This quantity was divided by liters packed per pallet (calculated from number of bottles per pallet (720) multiplied with the volume of each bottle (0.75 liters) to obtain the number of pallets used. Wood pallets are used for all exports outside of UK and Southern Africa, totally 205 500 liters. Both these types of pallets are reused and circulated between customers. The tool accounts for the usage of each pallet during its life time. Approximately 3500 oak wine barrels used in the production. These are reused and in 2012, 343 barrels were bought in. The calculator count for the GHG emissions for one year presupposed a one year average lifetime of a barrel. The cooling units operate with R407c as a refrigerant which according to the IPW guidelines falls into the good category. The cooling units were serviced in September 2012 and no chemicals were used.

Waste water produced is not recorded, however, there are records of annual water useage. This should be equal to the wastewater as there is no water added to the wine or discharged in any other part of the wine production. The total waste water generated is specified in table 10 in appendix 1. Only waste from the winemaking process is included in organic waste from the winery. There is as yet no recycling of food waste etc by the administration but this will be introduced in the near future. To avoid complication of the calculation of the Carbon Footprint all other organic waste than which is produced in the wine making process is counted in to the non-organic wastes which are not recycled (table 11, appendix 1). Organic waste produced in the winemaking process was estimated by subtracting the weight of grapes entering the cellar from the weight of wine exiting the cellar. Wine is assumed to have the same density as water, even though it is in reality is slightly lower.

Recycling was introduced in October 2012, except from glass which had previously been collected by Consol. Approximately 2 drums á 220 kg of glass was produced per month during the 5 month bottling period and one drum per month during the rest of the year. Table 6 show the total weight of recycled glass. January to October 8 containers á 15 m^3 was collected by Enviroserv which is equivalent to 12 m^3/month. November-December Easy Skip collected one container of 2 m^2/ week, equivalent to 8 m^3/month. The difference in volume is assumed to be the volume of recycled paper and plastic, 4 m^3/month. Easy Skip specifies that their 2 m^2 container has a maximum capacity of 2 500 kg. Winery wastes are generally not high in density. The average weight per m^3 is assumed to be 500 kg. Plastic material for wrapping is very low in density and assumed to stand for 10 % of the total paper and plastic. The weights of wastes are shown in table 11 in appendix 1been calculated.

All distribution to national and southern African clients is done by road freight and all exports outside Southern Africa are done by sea freight. Table 12 show routes, destinations, weights of deliveries and truck types used for road freights. The distance for road freights was measured in Google Earth. The network of distribution is difficult to get a clear picture of. All deliveries are transported in a company owned 12 ton diesel truck to Wellington. From there the wine is repacked and distributed to the harbor in Cape Town (CT) or for repacking with another distributor to Johannesburg or to nearby end destinations according to Johann Rademan, the owner of the Vineyard Connection which do all the deliveries from Wellington. Generally, short distances within Western Cape (except Cape Town) is done using a diesel van or, if larger deliveries, a small rigid truck. Since diesel van seemed to be the most commonly used vehicle for shot transports that will be the specified truck type for transports in Western Cape, except from to Cape Town. Most transports to Johannesburg are made by long haul truck >17 tons. Most transport pass either Johannesburg or Cape Town for repacking, which of the two destinations depends on the day. Transports to Southern Africa have been group with Johannesburg and transport to Eastern Cape and Durban with Cape Town. All exports except Southern Africa are also transported to the harbor in Cape Town. Small deliveries, like those to Limpop and Kimberly has been grouped with Johannesburg. These are 30 liters each wherefore their grouping won’t have any significant impact on the final result. Deliveries to Cape Town vary a lot depending on the size of the delivery. All from vans to mid-sized trucks are used. Mid-sized trucks are specified in the calculator. From Cape Town to Eastern Cape and Durban a long haul truck will be specified as vehicle type.

The routes, distances and weight of deliveries for sea freights are seen in table 13 in appendix 1. In the user guide distances for USA, Europe and Far East is stated. Distances to all other destinations were estimated by measuring the distance in Google Earth. Exports to South and Central America compose of more than 93 % to Brazil, wherefore the harbor in Rio De Janeiro was used for measuring the distance. Distance to Oceania was measured from Cape Town to Australia. Most exports to Northern and Eastern Africa goes to Dubai and a very small part to Kenya. The distance was therefore set to Dubai.

4. RESULTS

3.5. BIOPHYSICAL CONDITIONS

3.5.1. CLIMATE

South Africa is located in the southern hemisphere where the seasons are invert compared to on the northern hemisphere. This implies winter season during June to august, as can be seen on the temperature variations in figure 11. The annual precipitation is 625 mm and the average annual temperature is 16.6˚C. Average maximum temperature is 23.5℃ and minimum 10.7˚C (Appendix 2). The potential evapotranspiration should only be seen as an indication of variation in evapotranspiration during the year. If comparing precipitation and evapotranspiration (1300 mm) there is a difference of -675 mm. This is an indication of very arid climate which is not right for this area.

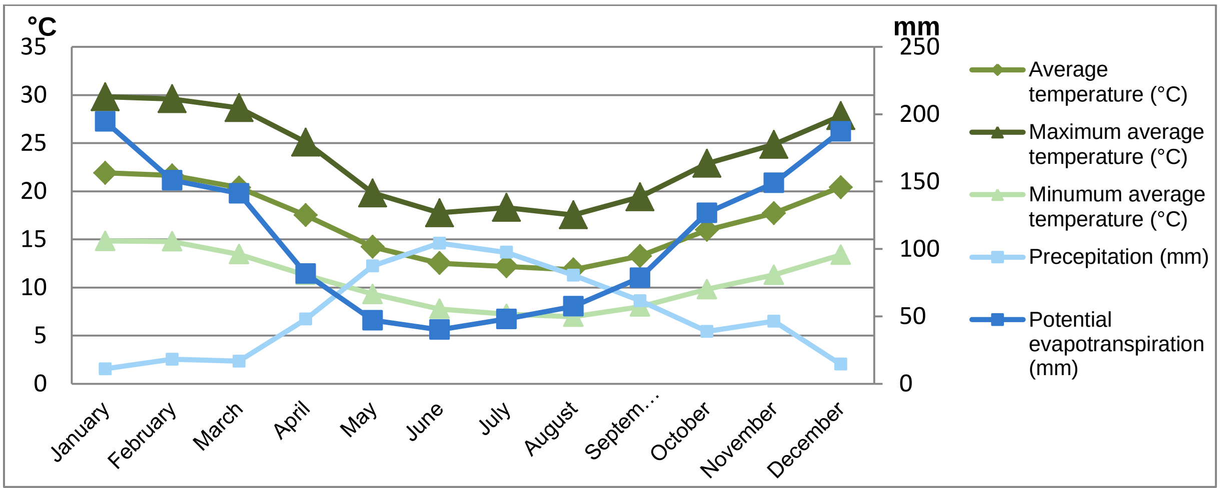


Figure 11 Climate data from nearby climate station. Evapotranspiration is not directly comparable to precipitation and shall therefore only be used for indicating the variation of evapotranspiration during the year.

3.5.2. TOPOGRAPHY

Kanonkop is situated on the foot of Simonsberg Mountain, on its northwestern side, as illustrated in figure 12. The drainage network streams extend through Kanonkop. To this watercourse runoff from parts of the Simonsberg catchment will be drained. Water is transported in western direction and will pass the dam located along the western border before reaching the outlet and eventually join the main drainage network streams.

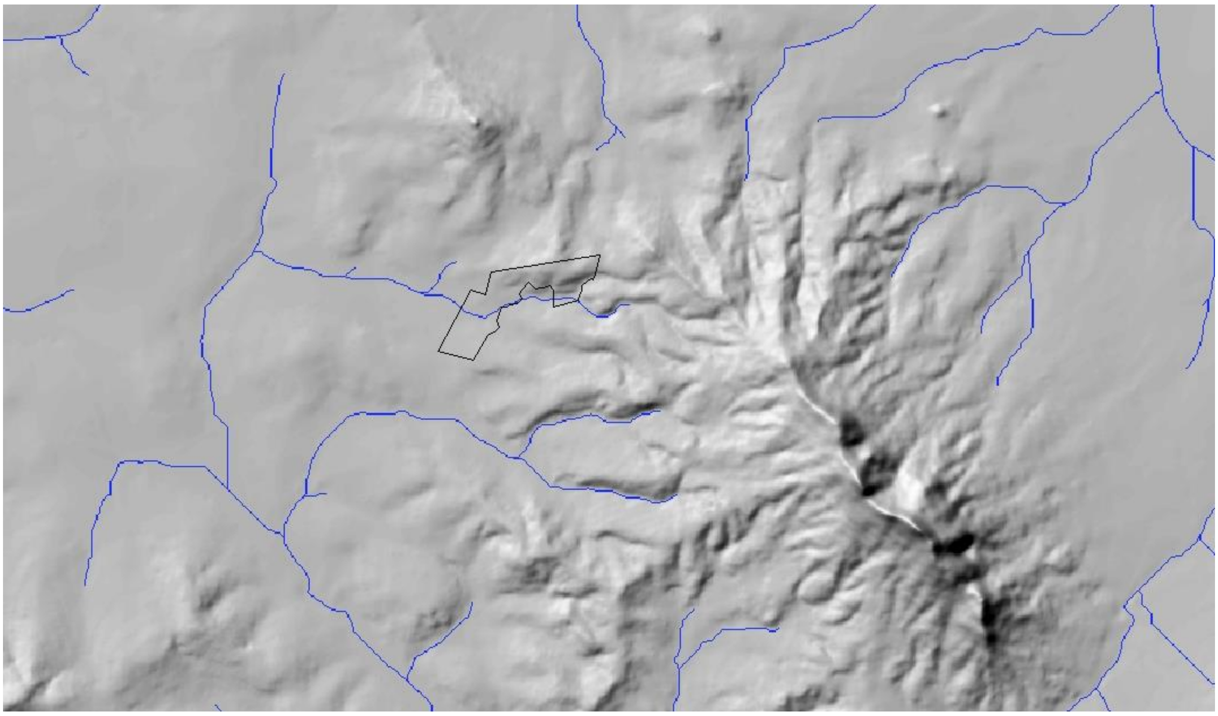


Figure 12 Kanonkop's location relative to the hillsides of Simonberg Mountain (seen to the right) and the drainage network (blue lines).

The topography is greatly varying with altitudes approximately ranging between 190 and 360 meter above sea level (fig 13). Highest are the altitude on the north-northeast part of the farm and lowest in the center of the farm. On the northern farm border there is a hill top, on which high wind is experiences causing damage on the vines which reduce the yields significantly. The central parts are located in a local valley which is surrounded by hills on both sides.

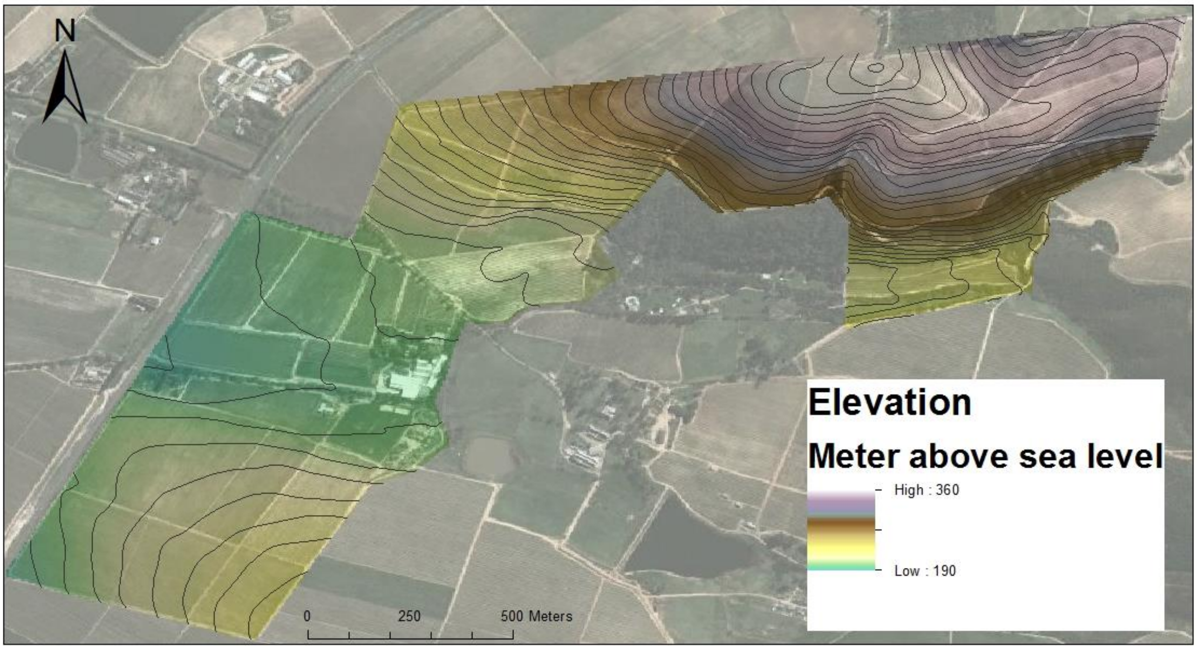


Figure13 Variation in altitude within the farm borders.

Slopes range from 0 to more than 25 degrees. The slopes are generally steeper on the northern part and more gentle in the central and southern part of the vineyard, as shown by figure 14. In the central and southern part of the vineyard slopes range from 0 to a maximum of 10 degrees while the south facing slopes on the northern part reach steepness up to 36.5 degrees.

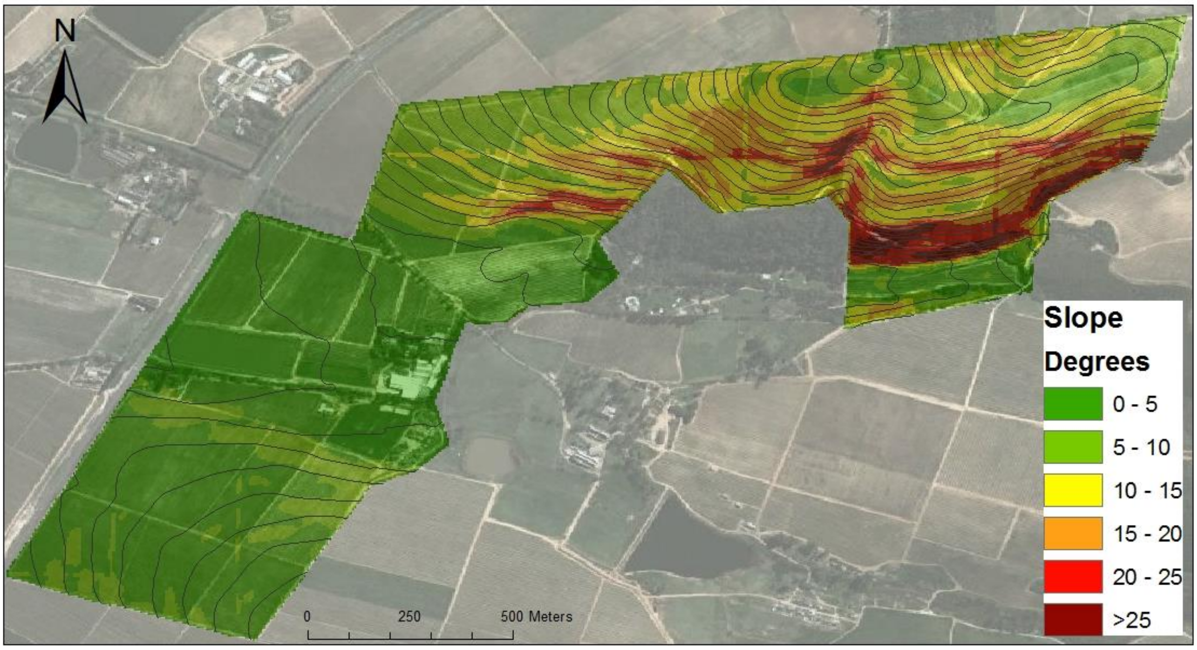


Figure 14 Slope inclination, showing the steepness of slopes measured in degrees.

The aspects of slopes are dominating south and southwest, towards the direction of the two oceans as can be seen on figure 15. On the south part of the vineyard the dominating aspects of slopes are north and northwest. On the most southern edge of the vineyard the aspect is west. The northeastern edge has strongly varying aspects varying as east-north-northwest-north-east.

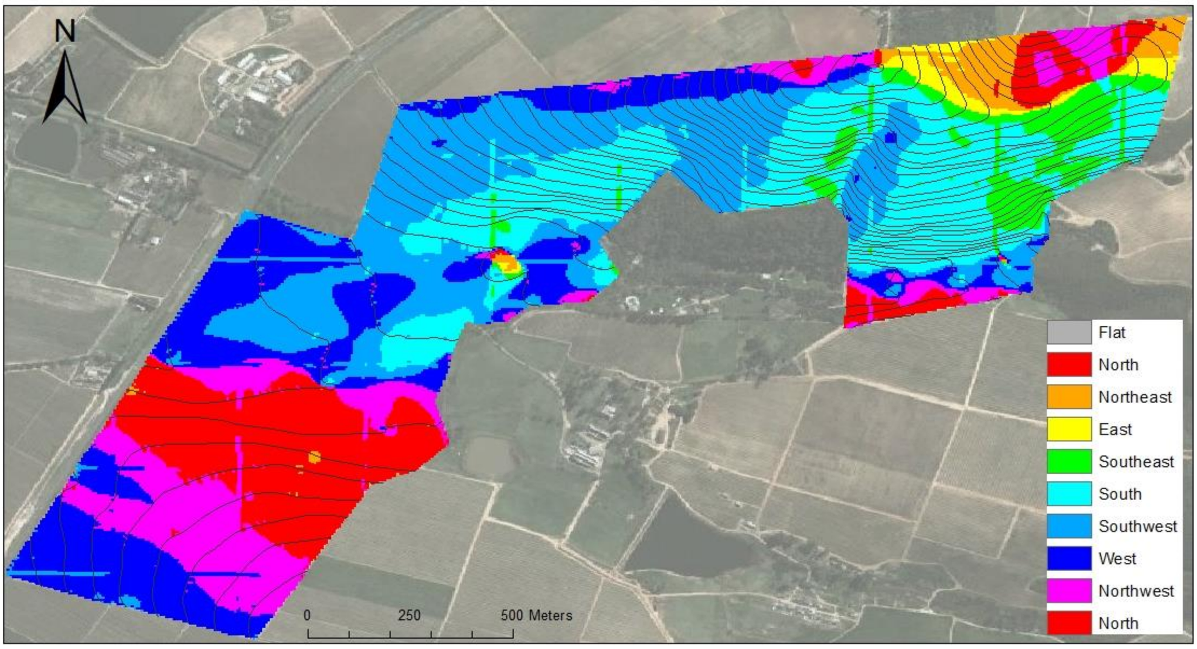


Figure 15 Aspect of slopes influencing solar radiation and wind.

Figure 16 illustrate the variations in solar radiation across the vineyard. North facing slopes generally has the highest solar radiation and are therefore warmer than the steep south facing hillsides, which are more protected from the direct solar radiation.

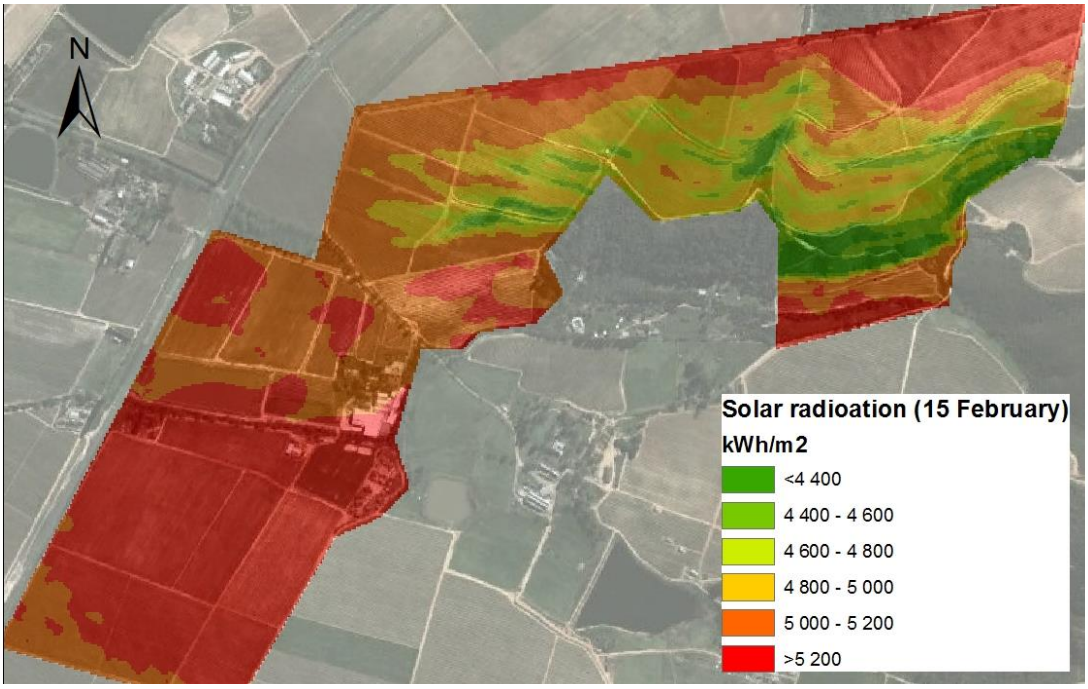


Figure 16 Variation in solar radiation, critical time period was set as15th of February

3.5.3. HYDROLOGY

Kanonkop act as a catchment, or drainage area, for two major drainage networks (fig 17, left). Both of these major watersheds include parts of Simonsberg Mountain. Kanonkop is mainly a part of the watershed which drains the whole southwestern half of Simonsberg Mountain. Only a small area on Kanonkop, located at the northeastern edge of the farm, is drained by the watershed which drains a smaller part of the northern area of Simonsberg Mountain. When studying watersheds at a smaller scale, Kanonkop is found to contribute as a watershed for three different watercourses (fig 17 right). However, Kanonkop is mainly situated within the watershed that includes the watercourse running through the farm. As mentioned, a small area on the northeastern edge lies within the watershed for a north located watercourse. The southernmost edge lies within the watershed for a southern watercourse. Figure 18 illustrates the area which acts as a watershed for the artificial dam, situated by the outlet of the stream running through Kanonkop. This figure does however not give a fully true picture of the watershed. There is a ditch along the western and northern border which transports runoff from a small area, not included in the watershed, into the watershed and ends up in the dam.

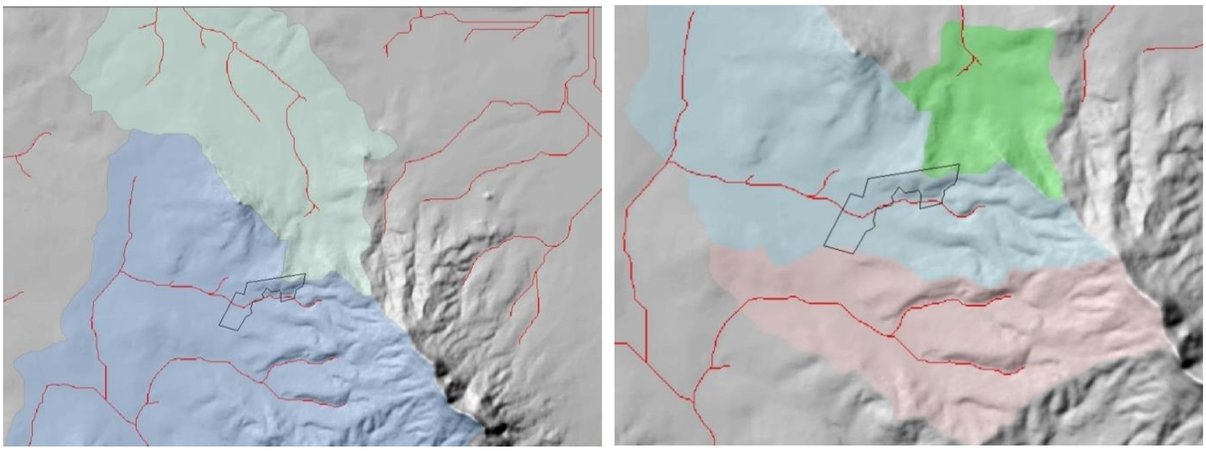


Figure 17 Left: Major watershed in which Kanonkop is situated. Right: Kanonkop is situated within the watersheds of three smaller watercourses.

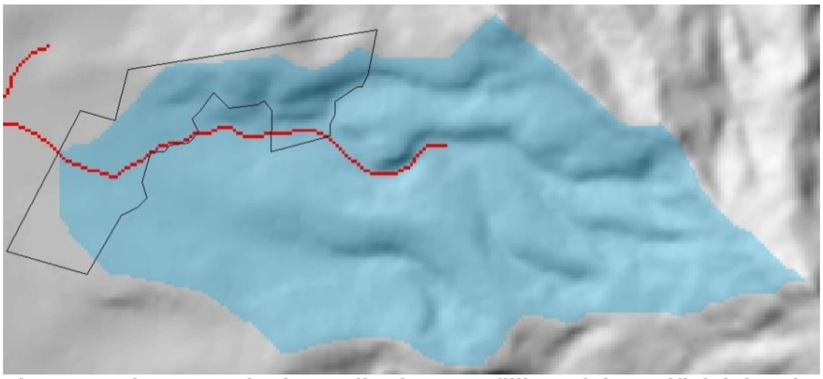


Figure 18 The Watershed contributing to refilling of the artificial dam located along the western border.

Figure 19 illustrate the transport of runoff water on the vineyard. Greenish to bluish colors indicate high water flows. At the area where the blue lines join each other an artificial dam has been constructed. The dark blue line continuing in northeastern direction is a small watercourse. It continues through the area of natural vegetation (the M-like formation not covered by the Flow Accumulation simulation). Water flow is especially high on the southern half of the northern part of the vineyard, in a small area on the northeastern corner and south of the dam.

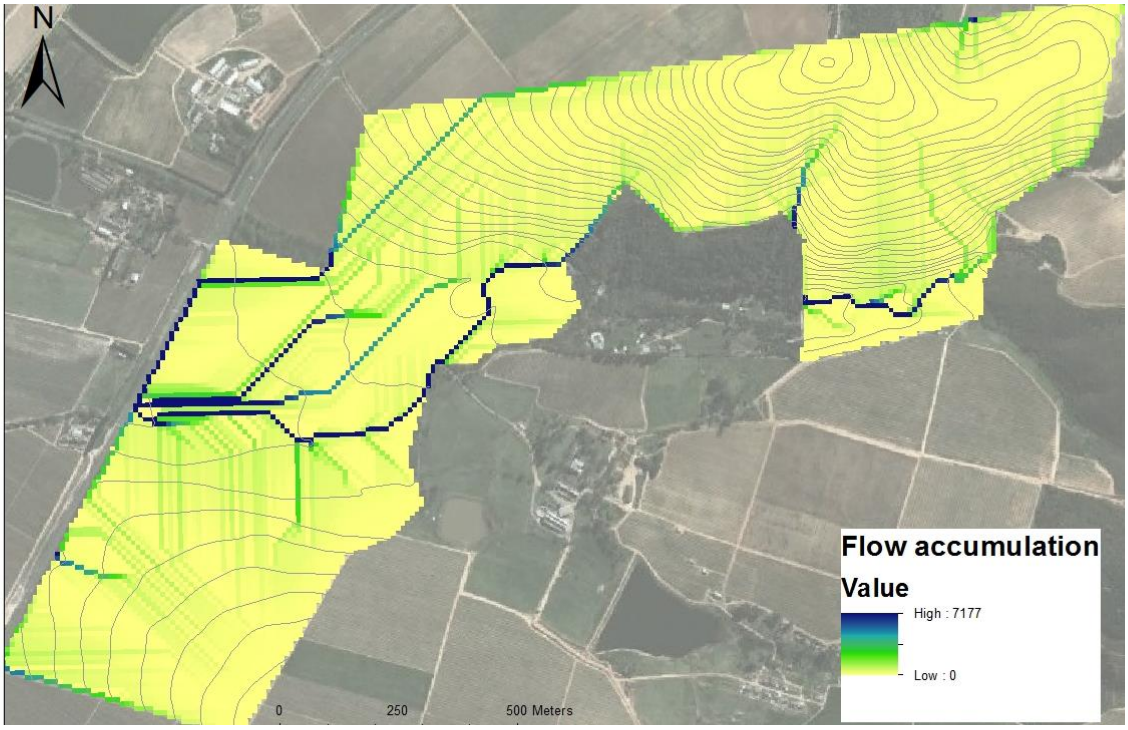


Figure 19 Illustrating the flow pattern of excess water within the vineyard.

3.6. CURRENT PRACTICES

3.6.1. VINI- AND VITICULTURE

The Kanonkop viticulturist witness of that there has been a big change the last years as it comes to the economic situation on vineyards. Five years back it was possible to live on a yield of 5 tons per hectare. Now 15 tons is often not enough. This is attributed to higher cost for labor, electricity, fuel etc. Kanonkop produces high quality wines and grape quality is therefore highest priority. With increased yields grape quality usually is decreased. By adding a bit more water and trellising the vines in ways which enable them to carry more grapes per plant Kanonkop has managed to increase the yields slightly without affecting the grape quality significantly. Owing to the high prices they get for their wine it is still economically possible to keep low yields with high grape quality (Koos de Toit, 14-03-2013). Grapes for winemaking preferably have dark skins, good acidity/low pH, small berries and thick skin. They should have been ripening slowly and be above average quality in general. The acidity reflects how well the grapes can handle the vintage and is important for the maturation of the wine. Small berries give more colours to the wine and thick skins give the wine a better structure. To achieve high quality the most important factor is the climate of the specific year. Cool conditions and high winter rainfall is preferred (Abrie Beeslaar, personal communication, 26-03-2013). The time of harvest is also having a large influence on the wine quality. When to harvest is decided based on measurements and tasting of the grapes. Measurements consist of sugar, pH and acid content. In tasting, considerations are taken to the color of the pulps, chewing the skin and the color of the spit after chewing of the grapes (Abrie Beeslaar, personal communication, 26-03-2013).

On the vineyards, no tillage system is practices. Exceptions made from establishment of cover crop. After seeding seeds are placed into the soil by disking or draw a a light harrow over the row middles. Cover crop management is performed approximately two times per year but varies from year to year. Spraying of agrochemicals is done 9 times per year according a spraying programme developed by an external advisor. Weeding is done more or less three times per year using Glyphosate, Simanex, Tyllanex and mechanical weeding. One of the spraying machines spray two rows simultaneously which reduce the tractor passes in the vineyard, saves time and fuel and thereby reduce costs. During the harvest the tractor only passes every 5-6 rows. Fertilizing is combined with the cover crop management after harvest. Both trellised and bush vines are planted, depending on the slope and aspect as well as on the grape variety (Koos de Toit, personal communication, 10-04-2013).

3.6.2. Vineyard Layout

On the northern part of the vineyard Pinotage is the dominating grape cultivar (Fig 20). In the northeastern corner Cabernet Sauvignon is cultivated and on block 411A Cabernet Franc. On the lower blocks 27 and 28 the cultivar is Ruby Cabernet and block 510 is divided between Merlot and Petit Verdot. On the southern, lower altitude, part of the vineyard Cabernet Sauvignon is the dominating grape cultivar. The eastern part of block 107A and block 201 is planted to Merlot, 107C and 102 to Cabernet Franc and 106 to Petit Verdot. Block 105 is not cultivated this year. The age of the vines is as much as 65 years on some blocks. In the next coming 2-4 years block 104 will be replanted (Abrie Beeslaar, 26-03-2013). Otherwise no replanting is expected for at least 10-15 years (Koos de Toit, 10-04-2013).

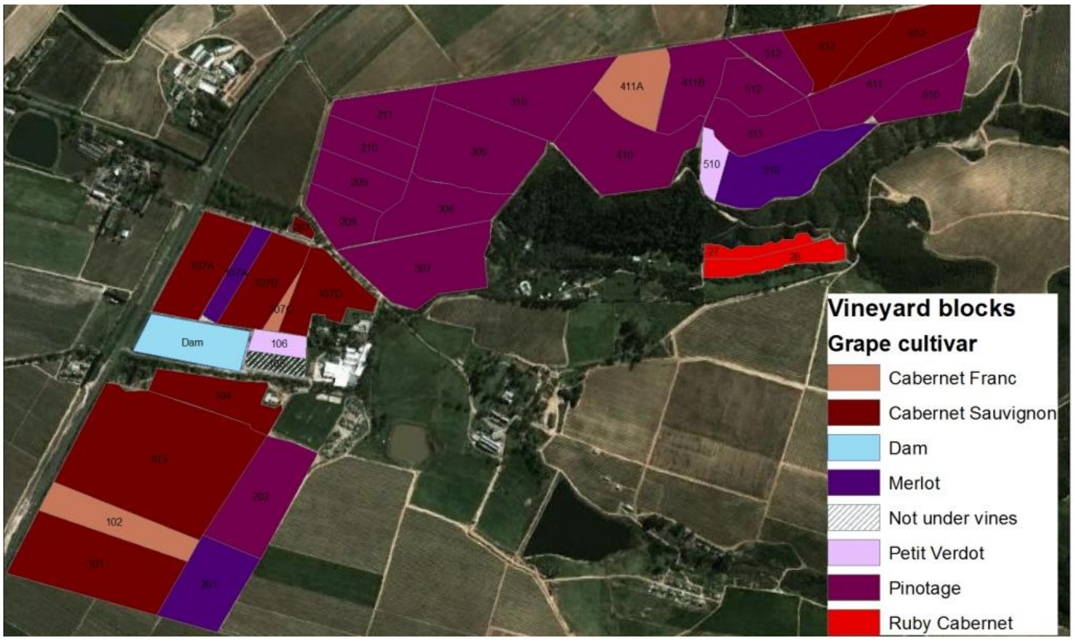


Figure 20 Grape cultivar varieties on the different vineyard blocks (Abrie Beeslaar, personal communication, 26-03-2013).

Vine row direction was designed to follow the contour lines on the sloping parts and north-south direction on the flat parts, if trellised, of the vineyard as the vines receive more sunlight hours than in east-west direction. North-south direction requires more of the pruning and management since there is a risk of grapes suffering from sun burn. Row direction plays a minor role for bush vines on the flat parts due to circular growth (Abrie Beerslaar, 26-03-2013). As seen in figure 21 and 22 the extent of convergence of vine rows and contours varies. Figure 21 shows that the convergence is high on block 208, 410 and partly on 308, 309, 411A and 411B. There are fairly convergences on block 209, 210 and 310 while notably lower on 207, 211, 307 and northern part of 411B.

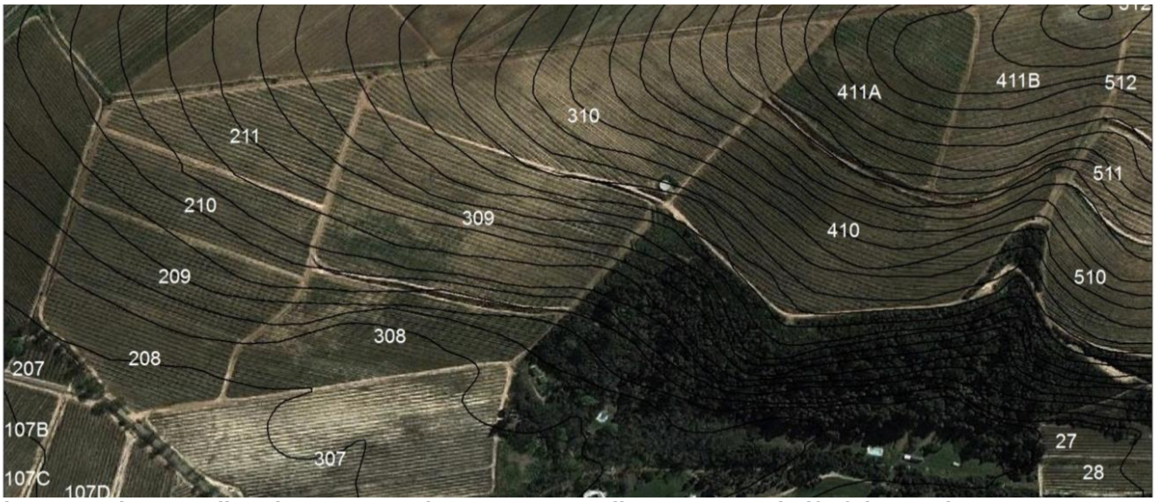


Figure 21 Vine row direction compared to 5 m contour lines, western half of the northern part.

Figure 22 shows the eastern half of the northern part of the vineyard. The convergence between vine row directions and contours are varying, both within and between vineyard blocks but is significantly better than on the western side. It is high convergence on blocks 510, 511, 512, 610 and on parts of 612. The convergence is low on the central and eastern part of 612 and the western part of block 611.

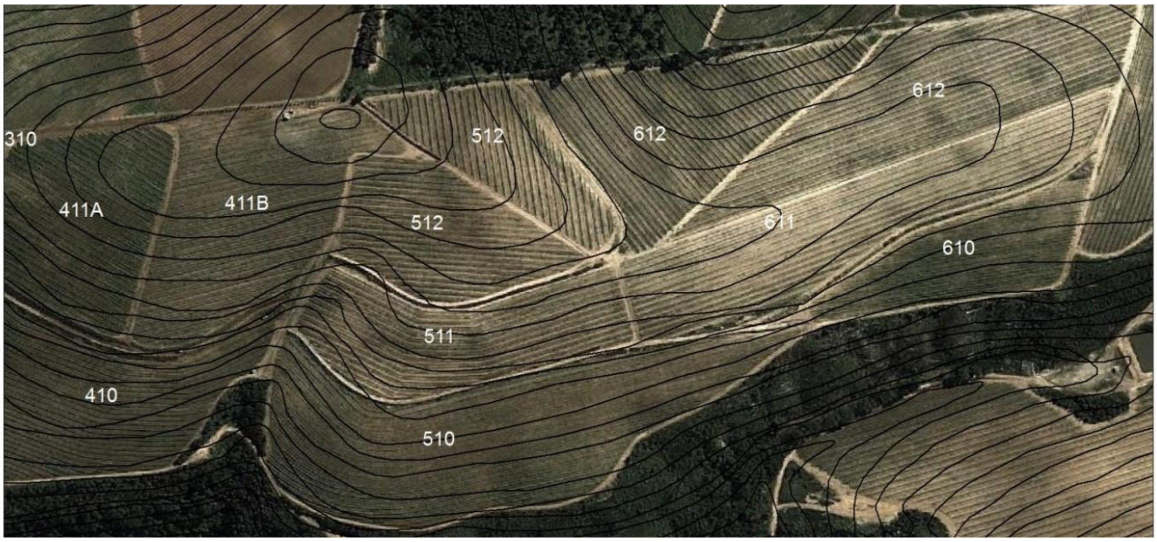


Figure 22 Vine row direction compared to 5 m contour lines, eastern half of the northern part of the vineyard. The numbers are the labels of each vineyard blocks.

Terraces have been constructed in hilly parts of the vineyard in consultation with an expert. On block 510 very distinct terrace shelves are formed while the rest of the terrace shelves are lower and less distinct. Generally there is one vine row on each terrace shelf. Formerly, there were three vine rows per shelf on block 510 but this were converted approximately 5-10 years ago to save space (koos de Toit, 10-04-2013). On the lower and wetter parts of the vineyard vines are planted on ridges to increase soil depth and avoid water saturated, reducing, soil conditions in the root environment.

3.6.3. Soil Management

No tillage is practiced on the whole vineyard to avoid unnecessary soil disturbance weakening the soil. The only soil disturbance is done when seeding the cover crop by disking after seeding. Branches from trellising, weeds etc are cut into small pieces and put into the vine rows to create a better soil environment for earth worms and increase the carbon content. This mulch is thereafter pressed down to the ground using a roller. Nutrient applications are made after soil analysis on each block. Fertilizer applications are thereafter scheduled by an external advisor according to the soil analyze results. Generally, very little fertilizer is applied (Koos de Toit, 10-04-2013). No fertigation is used and nutrient applications are made either by hand or by tractor. In ridged blocks tractor cannot be used as the fertilizer/manure needs to be put on the ridges and not in between (Koos de Toit, 10-04-2013). The fertilizer used is Green sulf and Super fosfate. On blocks where vines don't grow well chicken manure or compost is added as a complementary. Compost is produced from organic waste from the cellar, such as skins and stems. Nutrient applications are made after harvest, approaching the winter, as recommended by the external advisor and provider of specialized chemical products, Omnia Holdings.

3.6.4. Water Management

Blocks are irrigated only when necessary. This is generally during the summer and after harvest if the rains start late. The need of irrigation is determined by the leaf position in the morning. If leaf stand up there is enough water while if they hang down irrigation is necessary. From next year a pressure chamber, which was recently bought in, will be used for determining the irrigation requirement. In the future a neutron probe might be purchased as well but not within the next few years (Koos de Toit, 10-04-2013). Most part of the vineyard is under dry land cultivation, approximately 1/3 is under irrigation (Koos de Toit, 10-04-2013). Figure 23 shows which blocks that are under irrigation and supplementary irrigation. As the winter year 2011 was the driest winter in 40 years drip irrigation system was implemented on four formerly dry land cultivated blocks. These drip irrigation systems are only for use if such extreme dry conditions appear again. As vines were in bad shape from the dry 2011 irrigation was necessary in 2012. Drip irrigation is used throughout the irrigated blocks, except from on the supplementary irrigated block 104. Generally, irrigation is avoided since non-irrigated vines develop a better rooting system (Abrie Beeslaar, personal communication, 26-03-2013).

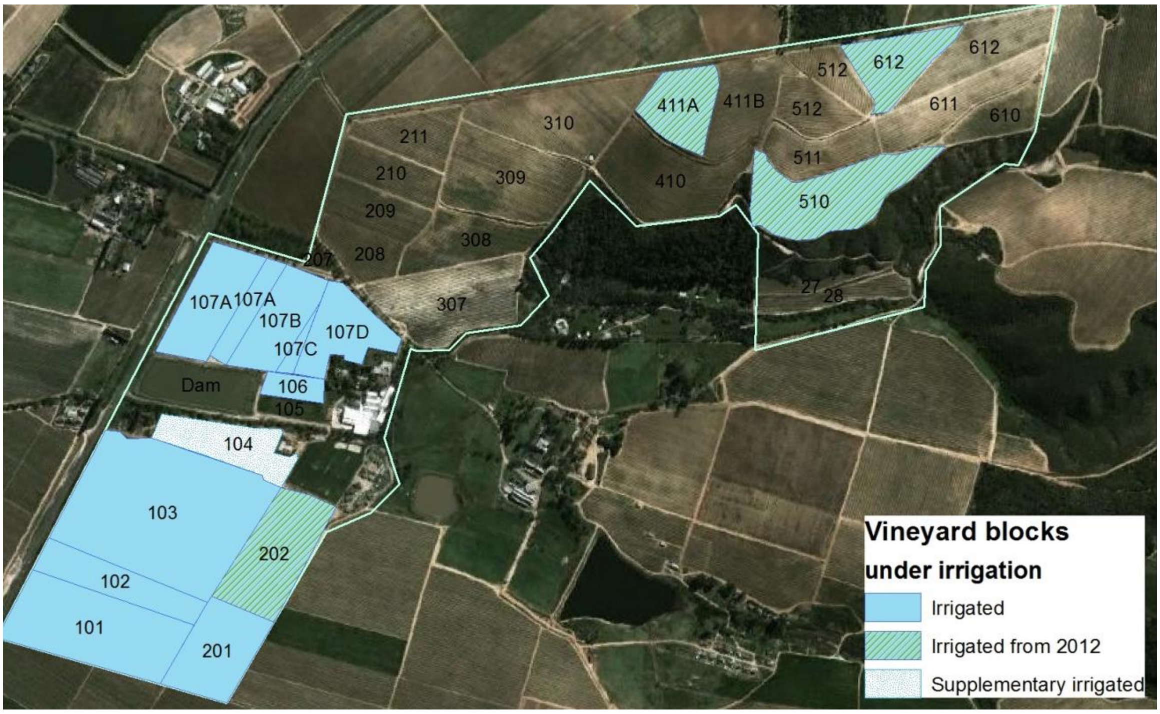


Figure 23 Irrigated and supplementary irrigated vineyard blocks and blocks where irrigation systems was introduced in 2012.

Irrigation water used is sourced from the dam and pumped through pipes to the irrigated vineyard blocks. This dam is filled by rainwater and waste water from the cellar (Abrie Beeslaar, personal communication, 26-03-2013) with an outlet hindering over flow. The dam has been filled every year since it was constructed (Koos de Toit, 10-04-2013). High pressure hoses are used in the cellar to reduce waste water volumes. Monitoring of wastewater quantities has been carried out since January 2008. For a small cellar Kanonkop produce exceptionally low quantities of wastewater, only 1 320 m^3 per year which is 50 % less than expected (Enviroscientific, 2008). There is no chemical waste water treatment on site (Abrie Beeslaar, personal communication, 26-03-2013). Solid separation is done by hand in the cellar. Caustic soda has been replaced with potassium hydroxide to avoid sodicity of the waste water. From the cellar water is pumped over a “hill slide type” fine sieve, placed on a cement slab for pollution prevention. No pH correction is done at present. From there, waste water is lead to a reed bed and overflow into a 50 000m^3 irrigation dam. This dam is also filled by rainwater (Enviroscientific, 2008). The quality of the waste water is controlled onve per month (Abrie Beeslaar, personal communication, 26-03-2013). A study made by Eviroscientific (2008) showed that the soil is in health conditions and no visual symptoms, toxicities or deficiencies were identified. It was also concluded that the, then existing, irrigation sites was suitable for irrigation with winery waste water. The amount of water storage is big enough for irrigation of the vineyard. In 2008 only 382 m^3 was used, compared to the 50 000 m^3 storage capacity in the dam. Compared with other available alternatives, it showed that this is the most cost-effective and environmental friendly alternative. Though, annual soil sampling must be carried out to adjust the fertilizer additions to the fertigazion effect by using the winery waste water for irrigation.

3.6.5. Cover Crop Management

Currently Korog is used as cover crop which is an annual cross breed of wheat and rye. Generally cover crop is seeded in every second row alternate years to reduce costs of establishment. Korog is self-reseeded which, together with weeds, create a very sparse vegetation cover during the second year. Korog grows particularly well in cold climates and during the summer very little growth is experienced in the vineyard. The ground cover was found sparser on the higher altitude hillsides on the vineyard and very well established on lower gently sloping or nearly leveled blocks. On the hillsides there were often no clear distinction between seeded and not seeded row middles as it comes to ground cover. Determining which rows had been seeded this year or the year before was not always easy due to reseeding of the cover crop and the establishment of alien plants both in seeded and not seeded rows. From next year, Korog will be exchanged to perennial clover, on an experimental level, to favor growth also during summer and to reduce the need of reseeding (Koos de Toit, 10-04-2013).

3.7. ENVIRONMENTAL RISKS

3.7.1. Erosion

Erosion is extensive all over the vineyard (fig 24). Attempts to restrain the damages caused by concentrated water flow have been made in some of the problem areas. The damages are especially severe on the northern part of the vineyard. In general, damages are worst on earthen roads but do occur within certain vineyard blocks as well.

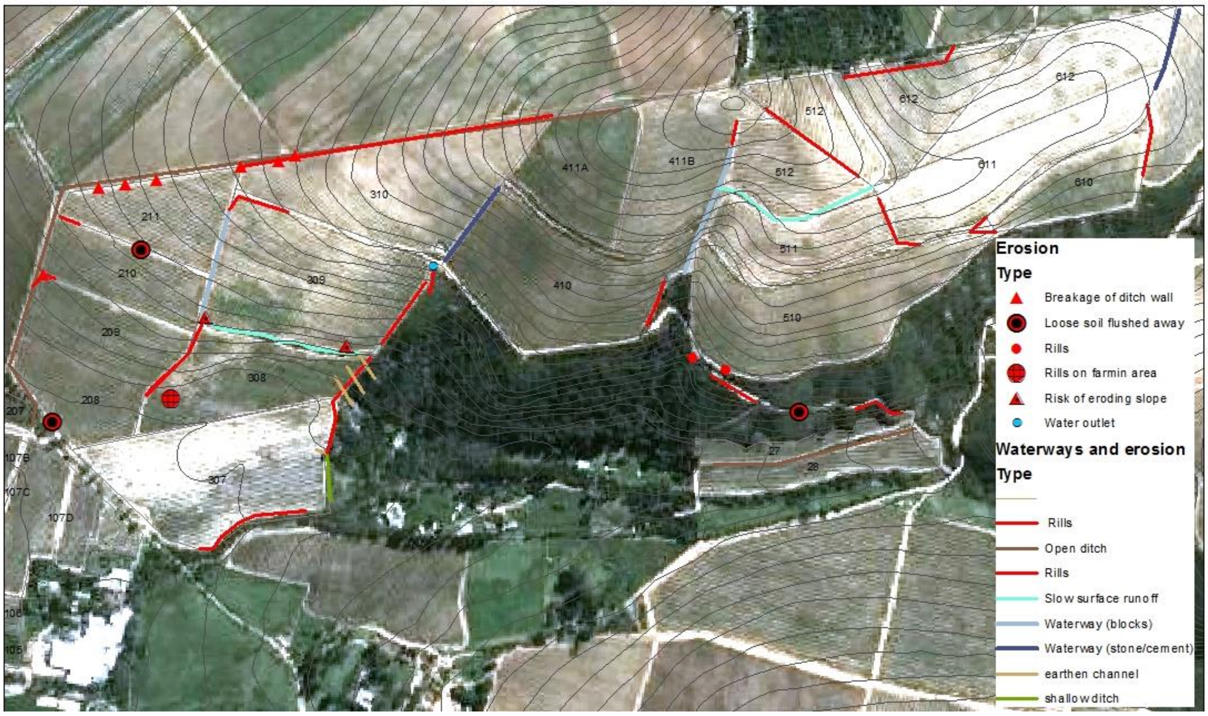


Figure 24 Signs of erosion in the vineyards and implemented erosion control measures.

Erosion is clearly visual along the northern vineyard border. Rills occur on the road along block 612. Severe damages downslope is hindered since runoff is diverted into the nearby forest, where dense vegetation reduces the damaging force caused by large volume and high speed. Worse is the erosion on the western side of the highest top. Rill erosion starts immediately at the steep slope at block 411A and continues downslope on the road along block 310. Along this road there is an open ditch which continues all the way down along the western border, eventually connecting to the dam. Erosion occur since the rode is cambered concavely, inhibiting runoff from reaching the open ditch (fig 25).

Figure 25 Road cambered concavely, inhibiting runoff from reaching the open ditch (right), instead causing erosion.

The ditch has a very poor protective vegetation cover. Along the northern side it's close to nonexistent. The ditch is designed with vertical walls, perpendicular to the ground surface. The poor design of the ditch and lack of protective vegetation has caused collapses of the wall at several places where the edge is particularly exposed to concentrated water flows (fig 26) Additional signs of the extensive ongoing erosion is the high amount of soil sediments which can be seen in, particularly along field 309 where erosion is severe.

Figure 26 Open ditch at the western/northern vineyard border. Steep, vertical walls with poor vegetation cover, especially on the right side. The wall has collapsed in places.

Erosion is less along the western border than along the northern. Rills are though occurring, especially at the road between blocks 210 and 211 (fig 27). Rills are quite marked but as they end up in the ditch they do now cause damage further down slope. On this road the sign of great water volumes is conspicuous. Loose soil particles has been flushed away (fig 28) from the road and the first vine row upslope the road and released at the first vine row downslope the road, leaving a bare compact earthen road. Same event appears at the road downslope, south of block 208.

Figure 27 Rill erosion along the western vineyard border, between block 210 and 211.

Figure 28 Loose soil flushed away by runoff from upper catchment, leaving a compact bare surface.

East of block 211, between block 309 and 310, further rill erosion is seen (fig 24). These rills turn around the northern corner of block 309, eventually ending up at the top of a waterway (fig 29). It is located between vineyard block 210/211 and 309. Runoff water is led by the waterway downhill, ending abruptly at the western corner of block 309. Downslope the end of the waterway there is a slope with a road below. The slope is only partly sufficiently covered by vegetation. The runoff water is lead on a gentle slope right above the road along block 309 and is eventually partly released into the forest, after crossing the earthen road by a man made earthen channel.

Figure 29 Waterway ending on top of a plateau right above the road.

Runoff from upper catchment is partly collected by the waterway. Runoff not diverted continues along the road. As the road curves runoff continues straight downslope causing erosion within the vine rows on block 308 (fig 30), causing collapse of terrace walls. Runoff is further transported downhill causing erosion several vine rows down the slope (fig 31). Large water flow exits block 209 through each vine row. The excess water is further transported downslope along the road in large volumes, forming rills on the road between block 308 and 209 (fig 32). Rills are formed all the way from the end of each vine row on field 209. In the end of the road the slope’s steepness decrease and the rills stop.

Figure 30 Left: Large water flows causing erosion on the road and further enters the vineyard block, together with runoff from upper catchment causing erosion within vineyard block. Upper right: Soil bank forcing runoff to enter the vine row. Lower right: Terrace breakage due to concentrated water flow.

Figure 31 Signs of large water flow within vineyard block 308. Red arrow showing rill erosion.

Figure32 Rills formed from water flow released from the vine rows on block 209.

Further east on the vineyard, on the road on the eastern side of block 308, 309 and 310 erosion occur to a sever extent as well. Water from upper catchment is transported in large flows along the road between blocks 310 and 410. Here, a waterway (fig 33) has been established to withstand the force of the water . This waterway continues along the blocks but ends at the next cross. On the other side of the cross there is a water outlet pipe. The ground right next to the outlet has been strengthened with stones but the additional water transported by the waterway expose the soil to great forces which it cannot withstand. Severe rills are formed on the slope and continue along the side of the road further down the hill. Eventually the water flow is diverted into the forest where the vegetation is dens, reducing the speed and subsequently the water force.

Figure33 Upper left: Waterway between block 310 and 410. Ending at the next crossroad. Upper right: Downslope the end of the waterway. Outlet pipe releasing water with great forces from large water flow create severe rill erosion. Lower left: Deep rills continuing downslope. Lower right: Rills eventually ending in the natural area, seen on the left side of the photo.

Further down the hill, runoff water enters the road from the terraces on the farming land. According to the extent of erosion, the force of these water flows is not worryingly great at present. The road is declining towards the forest and just below the vineyard block water is diverted into the forest by an earthen channel. This channel, however, is exposed to additional water flows originating from northwestern catchment areas. The waterway, seen in figure 29, ends abruptly. Water released at its end is slowly transported along a gentle slope, not causing any significant damages, until it unites with runoff from block 309 and the slope is increasing (fig 34). These water flows end up at the mentioned earthen channel, bringing the water to the forest. As seen in the figure rill erosion is already an occurring event. However, not all of the water is transported to the forest by the channel. Traces of runoff indicate that part of the water flow escapes the channel and continue downslope on the road.

Figure 34 Water released by the waterway, seen in figure 29, is transported on a gentle slope cause rill erosion when uniting runoff from block 309. Eventually, diverted to the forest by an earthen channel.

The escaping water, together with runoff originated from block 308, act with great force on the road. Despite the relatively short distance, there are three semi-horizontal earthen channels diverting the runoff towards the forest. However, large volumes of runoff water continues downslope creating a rill (fig 35) along the border to the forest. This indicates that the volume of water flow is great. Erosion within the block is seen as well. At places water flow has caused small breakage of the terrace walls. Runoff water continues further down the slope and is divided into two separate water flows at the northern corner of block 307. The water flow on the eastern side is eventually diverted into the forest by a shallow vegetated ditch. Water flow on the northern side is hindered from entering block 307 by a low wall along the road. Movement of surface water is also limited within the block since vines are planted on ridges, slope is gentle and the vegetation cover is dense.

Figure 35 Runoff escaping the above channel and runoff from block 308 causing erosion on the road.

South of the highest top rill erosion occurs before the runoff water joins an artificial water way, situated between block 411B and 512/511, a few meters down (fig 36). It is narrower in the top and wider towards the outlet, designed to carry an increasing water flow downslope and safely release it at the outlet in the forest. At the lower part of the waterway alien plant has established. At the end of the waterway the road split in two, continuing on each side of the forest. Rill erosion occurs on the road on the western side. On the eastern side, along block 510, signs of excess water flow are visible on the road and within the vine rows (fig 37). This excess water is likely to origin from block 510 and 511, as the majority of runoff from block 512 is hindered from further transport downslope by an earthen wall. This water is diverted in western direction on gentle slope towards the waterway.

Figure 36 Waterway bringing water safely down the slope, releasing it in the forest. Some alien plants has established in the waterway.

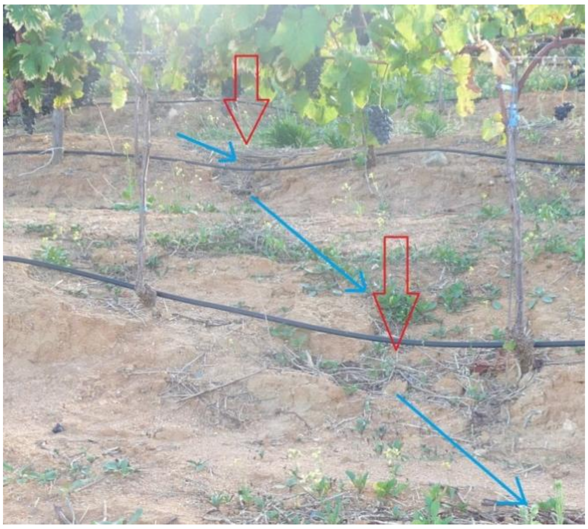


Figure 37 Signs of excess water flow on the south eastern side of block 510. Red arrows showing breakage of the forming terrace wall.

Even though this excess water does not cause any major damage at this spot it is one of three originating flows contributing to the most severe event of erosion in the vineyard further downslope. As can be seen in figure 38 large water flows are likely to move straight down wards on block 511 and 510. As seen in the field, there are water flows moving on the road connecting block 410 and 520. These flows moves in direction towards block 510. Instead of continuing straight along the block it continue down the road towards block 27 and 28 where it reunites with the two above mentioned water flows. The area where this road is situated has the steepest slopes in the whole vineyard, up to 36.5 degrees, as illustrated in figure 14. On these sleep slopes the land use is natural vegetation with indigenous grass and bush vegetation protecting most of the slopes. However, on the road surface is bare leaving the road highly exposed to enormous forces from large volume of water transported in high speed, concentrated to the mid center of the road.

Figure 38 Three flows of excess water reunite to one major flow down the road leading to block 27 and 28.

In addition to this enormous water flow, excess water from the central part of block 510 and 511 continues over the edge, at the road along the southern side of block 510, down slopes far steeper than 25 degrees. Signs of great water flows from these blocks are also seen further east along this road.

Small rills are seen perpendicular to the road. Excess water from central parts of the blocks immediately reaches the road leading to block 27 and 28, further contributing to the severity of erosion. As seen in figure 39, runoff transported along the road is reaching an even steeper sloping part (the road is seen from below on figure 40). This is the case of real severe erosion where rills are turning into a gully (fig 41), a more severe form of rill erosion, more difficult to control. Eventually, when the steepness of the slope is less, water is transported to the side of the road entering an area of natural grass and bush vegetation where the force of water flow is diminished to a non-harmful extent (fig 42) and eventually ends in the watercourse. However, excess water running over the edge and down the steep slopes, originating from the center of block 510 and 511, down the road is flushing soil particles from the road, leaving the road surface bare and compact. This water is then transported downhill along the road, creating further rill erosion at the end of the road.

Figure 39 Excess water originating from block 510 and 511 is transported down the steep hillsides, seen to the left on this photo. Together with enormous water flows illustrated in figure 19 this water flow contributes to eroding of the road.

Figure 40 Road seen from block 27/28.

Figure 41 Left: Erosion seen from the top of the slope. Right: Erosion seen from the middle of the slope, looking upwards.

Figure 42 Water flow eventually reach an area of natural vegetation where the speed of water is slowed down by natural vegetation and safely transported down the steep slope, to the left, not causing any further damages.

Less severe than the above described event of erosion, but still of concern, is the rill erosion occurring on the road dividing block 512 in two (fig 24). Rills start some 20 meters down the highest top, continuing down the road. Reaching the end of the road, runoff water is trapped by an earthen wall (fig 43). This water, partly, moves to the west on a gentle slope ending up safely at the waterway (fig 44). Water which escapes the wall continues downslope, creating rills on the road between block 511 and 611. In the end of that road water is again trapped by an earthen wall which slows down the speed and power of the water and direct is on a gently sloping road along block 611. Right next to this road, adjacent to block 611 there is a steep slope on which there are traces of large water flows. Furrow has been formed vertically on the slope, as seen on in figure 45.

Figure 43 Left: Rill erosion occuring on the road in the middle of block 512. Right: At the cross-road runoff is trapped by an earthen wall which slow down the speed and force of water flow significantly.

Figure 44 Left: Water safely transported on gently sloping ground towards the waterway. Right: Water which has escaped the earthen wall continues down a steep slope on the road between block 511 and 611.

Figure 45 Large water flow from upper catchment flowing down the hillside, creating vertical furrows.

Following this road a bit further erosion occurs again. The sequence of the event is illustrated in figure 46. Runoff, mainly originating from block 612, has been transported in an earthen, man-made channel on a gently sloping ground. As the channel get closer to the road the slope increase giving higher force to the transported water. The walls of the channel cannot resist the force from the water flow wherefore they collapse leading to uncontrolled water transport. It is also likely that the collapse is caused by additional water running down the steep hillside adjacent to block 611. This water takes a curve and continues down the road down additional slopes causing rill erosion. Eventually water is diverted into an area of natural vegetation.

Figure 46 Runoff is initially transported safely in a man-made channel on a gentle slope (upper left). As the slope increase and additional runoff unite channel walls collapse (upper middle). The water is transported uncontrolled and takes a curve (upper right and lower left) continuing down the road (lower middle), eventually diverted into an area with natural vegetation (lower left).

A waterway has been constructed in the road along the eastern border, using stone and cement, starting between block 610 and 612 in northern direction. Rills do, however, still occur in southern direction (fig 47). Rills start within the two blocks, continues in eastern direction and turns south down the slope.

Figure 47 Left: Rills seen from the south. Right: Rills seen from east, starting within the two blocks 610 and 612.

3.7.2. Greenhouse Gas Emissions

The total Carbon Footprint from the wine production at Kanonkop is 1 723 ton $CO_{2,}$ equal to 0.75 kg CO_2/kg grapes and 1.76 kg CO_2/liter of wine. Summarized one 750 ml bottle of wine contributes with 1.88 kg CO_2e. According to the Carbon Footprint calculation model developed by the Carbon Trust for New Zeeland's wine industry this quantity is equal to 314 g CO_2e/small (125 ml) glass or 8 km car drive per bottle. The winery boundary has the highest contribution to the total carbon footprint, almost 3 times higher than farm and distribution together (fig 48). Scope 1 (direct fuel) stands for 5 % of the emissions, scope 2 (electricity) for 48.0 % and scope 3 (indirect emissions) for 47 %.

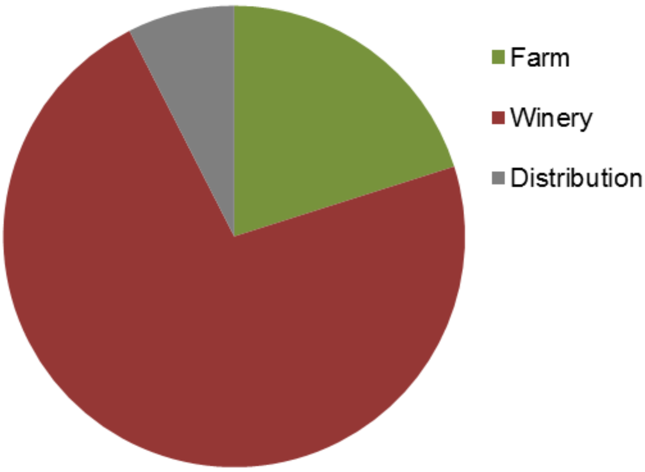


Figure 48 Left: Production boundaries' contribution to the total Carbon Footprint.

From figure 49 it is seen that electricity from the farm activities is the single largest contributor to the total GHG emissions. GHG emissions from electricity is more than twice of the other sources together. Figure 50 show the break down from the winery. Packaging and electricity are the major sources of GHG emissions while direct fuel and waste compose very small parts of the total contribution of the winery activities. Figure 51 show that the GHG emissions from road freight are larger than for sea freight.

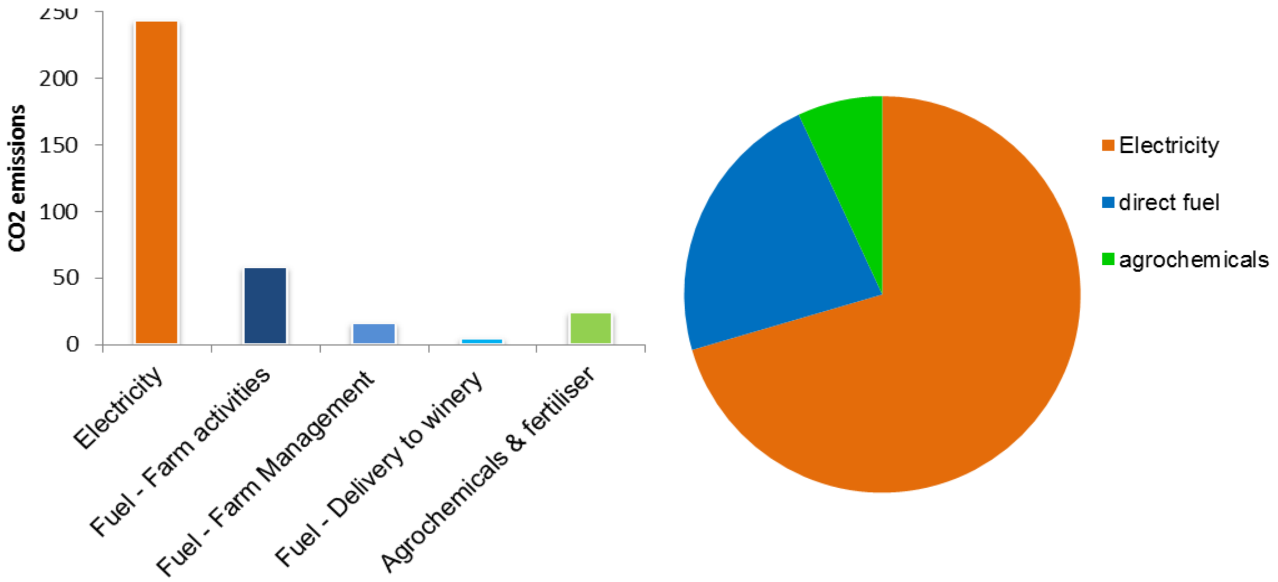


Figure 49 Breakdown of sources contributing to the total emissions from the farm boundary.

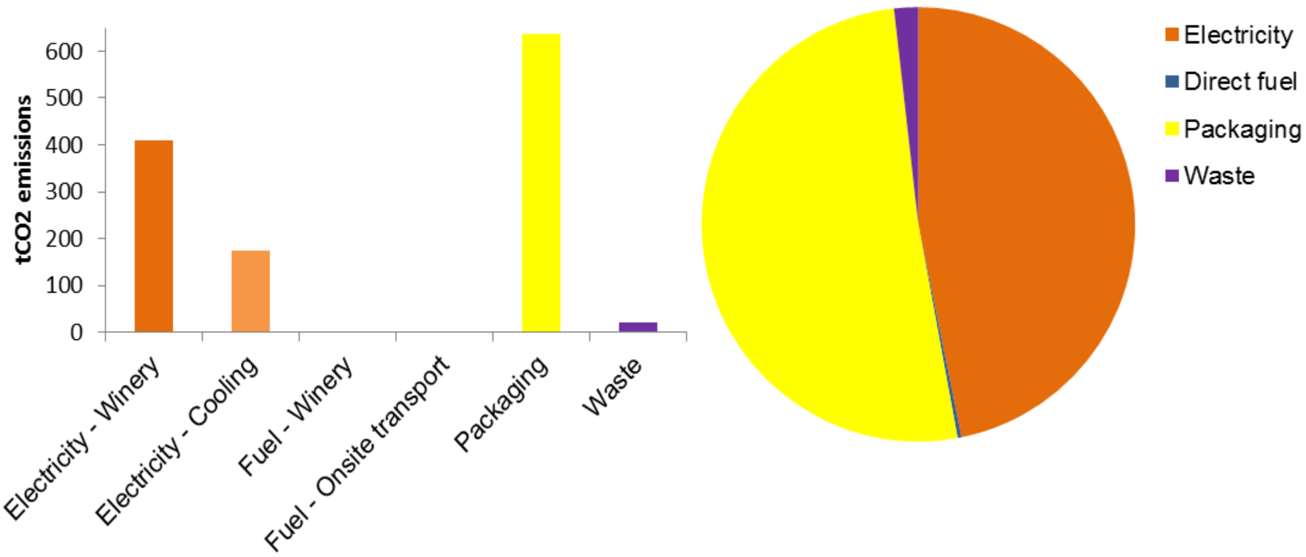


Figure 50 Breakdown of winery activities' GHG emissions, shown in Carbondioxide equivalents.

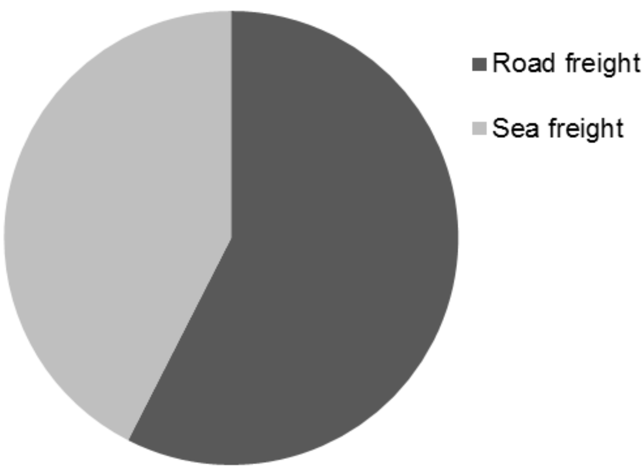


Figure 51 Distribution boundary.

4. DISCUSSION

4.1. SUSTAINABILITY AND THE IPW

IPW does not run on any specific general minimum standards nor is it limited to a few environmental aspects. This enables a holistic perspective of sustainability and is applicable on all vineyards. Its applicability is reflected in the high percentage of members, 95 % of all wine producers in South Africa (WOSAe, 01-02-2013). The fact that the industry and not the government were taking the lead in the development of IPW is likely to play a large part in contributing to this high compliance rate. IPW gives a truer picture of the environmental performance than e.g. organic certifications which focus on a few environmental aspects. IPW also enables the producers to develop their production where it will have the largest environmental and/or cost-effective impact. It is, however, surprising that more significance is not put on erosion control measures in the guidelines, considering that vineyards are the most eroded arable lands and given the importance of the soils to future sustainable production. As IPW has both an advisory and certifying function (Dillon, 2011) there is a risk of economic advantage of the wine producers. However, the IPW control auditing is undertaken by external operators which reduces the risk of having unfair advantages occuring. The credibility of self-monitored systems is criticized in a report of Knowles and Hill (2001) where they state that it may be difficult to achieve confidence from stakeholders for such a system. Barber (1998) criticizes the way the guidelines are formulated. The scoring systems have weaknesses which makes it difficult to complete the scorecard. In the guidelines there is no indication of how to weigh the different criteria against each other to assess the score correctly. Some of the guidelines are open to interpretation e.g. “The use of chemical herbicides must be kept to a minimum” (Barner, 1998) and “any cultivation of vine rows must aim to improve water retention, soil structure and controlling unwanted weeds”. Words as “should” and “recommended” make the guidelines vague and therefore do not give a reliable indication of the environmental performance. Some guidelines only demands record keeping but do not mention anything about the result of the records. The IPW system is, however, one of a kind as it gives the consumers the possibility to trace the product all the way back to the farming practices on the vineyard by the identity number on the W.O. (Wine of Origin) Sustainability & Integrity sealing. The foundation of sustainable environmental practices is included in the legislation in the South African Constitution and it is likely to be the most democratic and progressive constitution in the world on this matter according to Dillon (2011). IPW is broad and all-inclusive and “new thinking” but there is still great development potential of the system as a whole as well as of specific guidelines

Key reasons for joining the IPW are personal environmental interest and belief that IPW may be important in marketing wine (Knowles & Hill, 2001). It is a bit ironic that EU, who is the main driving force behind the development of IPW, have not yet developed a corresponding system. Similar systems only exist in the New World. Only as recent as 2012 certification of organic wine was introduced in the EU. Formerly, only wine made from organically-produced grapes was available (Karlsson & Karlsson, 2012). Possibly, the demand of environmentally friendly produced wine has been lower for the Old World producers due to a possible higher confidence among consumers that the production has a higher environmental standards and regulations of chemicals. This could explain why sustainability initiatives have not been as far developed as in the New World. IPW is in a perfect position to put pressure on the wine industry to work towards a more environmentally sustainable production both nationally and globally but seems to be acting passively and not taking the lead in this regard. This is also the discussed by Knowles and Hill (2001). More efforts are necessary for informing and educating members about global trends, new technology and innovations. It may be beneficial to open up the industry to debates and make producers more active in the development process of IPW. Deeper knowledge and understanding with each actor is necessary to enable daily wise and informed decisions. Today, a onetime IPW education for one person in leading position every three years is enough to achieve full scoring on Guideline 1 – *Education and training*. This is not enough for long-term sustainability and continually improvement. My own experience is that wine producers are not aware of why enivornmental sustainability matters, especially the Carbon Footprint.

Kanonkop is located within the ward known for the best red wines in the country which strongly reflects high suitability for this production. Kanonkop can thereby be considered practicing a production type suitable for the location. The farm scored 100 % on the IPW evaluation (2012) but the development potential is great (discussed below). IPW no longer incentivize development of the farming practices. All further developments are therefore motivated only by Kanonkop's own will and desire for awareness of environmental sustainability. This great potential for highly relevant improvements indicates that IPW is too vague! Similar systems have been developed in other New World Countries. New York and Californian wine industries have developed more comprehensive and clear guidelines where guidelines can be complied with in varying degrees and scores are achieved according to the extent it is fulfilled. *The New York Guide to Sustainable Viticultural Practices* and *Growers Self-assessment Workbook* can be accessed, free of charge, on www.vinebalance.com and *California Sustainable Winegrowing Alliance* provides the Californian equivalent *California Code of Sustainable Winegrowing Workbook* on their website www.sustainablewinegrowing.org.

4.2. BIOPHYSICAL AND AGRICULTURAL INFLUENCE ON ENVIRONMENTAL RISKS AT KANONKOP

4.2.1. SOIL EROSION

Soil Erosion is wide spread over the farm but is worst on the northern part of the vineyard due to steeper hill slopes. The heavy winter rainfalls associated with Mediterranean climate expose soils to erosive forces and generate high runoff rates. Soils are prone to erosion due to its texture and sparse cover crop. The no tillage system practiced and hacking mulch into the rows have a positive effect on the soils capacity to resist erosion owing to the increasing of SOM. Erosion occurs mainly as rills on the roads while it's rare within the vineyard blocks. However, signs of high water flows occurs within fields on the north-western parts of the vineyard. On the roads, there is nothing that breaks the slope or slows down the water flow. The surface roughness is very low which further allows water to reach high speed and compacted soils result in very low infiltration rates. Within vineyard blocks vegetation and, sometimes, terraces slow down the water speed. Vines are planted in rows, generally, following the contours will which reduce erosion. On the easternmost part of block 612 rows are, though, running perpendicular to the contours, contributing to development of rills (fig 47) which has been partly controlled by the construction of a waterway. The low convergence between vine rows and contours on block 211 (fig 21) is likely contributed to the collapse of the ditch wall (fig 24 and 26) due to water speed not having been slowed down by the vines. On parts of block 411B rows are perpendicular to the slope (fig 22) but does not cause any direct damages. This field is located on the hilltop (fig 13) and has therby a small catchment from which little runoff is generated. The slope is less than 5 % and short and water flows are slowed down by the vine rows down slopes. These vine rows are sloping towards the ditch (fig 22) contributing to rill erosion on the road and collapse of the ditch wall. The low convergence on block 307 is of minor concern since the slope is gentle and vines are planted on ridges which inhibit runoff from entering the block.

By studying the runoff in detail the occurrence of erosion in correlation to surface runoff can be understood (fig 52). The correlation between surface runoff rates and erosion is high. In some places structure that shorten the length of the slope and/or divert water from upper catchment to waterways are in place. It is however necessary to extend the erosion control measures. Erosion occurs almost exclusively where runoff is great, especially in combination with steep slopes. Exceptions are the ditch on the north/west corner where water flows does not seem to be high (fig 52). Vine row direction, however, lead water to the ditch (fig 21). Poor design of the ditch, in form of vertical walls, bare surface and not stabilized Water Bar Outlets, makes it highly prone to erosions. The road on field 512 is another exception where erosion occurs even though runoff rates do not seem to be particularly high. The road is positioned perpendicular to the contours on a slope of 5-10° (fig 14) with nothing breaking the slope or speed of runoff. Down slope runoff is partly diverted towards a waterway. Lack of soil data is limiting the understanding of water movements to the topography. Understanding of the soil characteristics would provide a better understanding of water movement and erosion. Soil characteristics relies on literature indicating dominance of Sand Stone, Granite or Shale. Granitic soils are the most likely soil type based on the reddish-yellowish color, sandy texture, mountain foothill position and production of high quality grapes. The GIS soil data, which does not seem to fully reflect the soil conditions (and thereby excluded from this study), however, supports this theory. In addition to soil type, studying the quantity of soil loss per year would further improve the understanding of the severity of erosion and the progress of erosion control measures in the future. Measuring water quality of the watercourse, upstream and downstream the farm could indicate the extent of erosion and its effect on the surrounding environment.

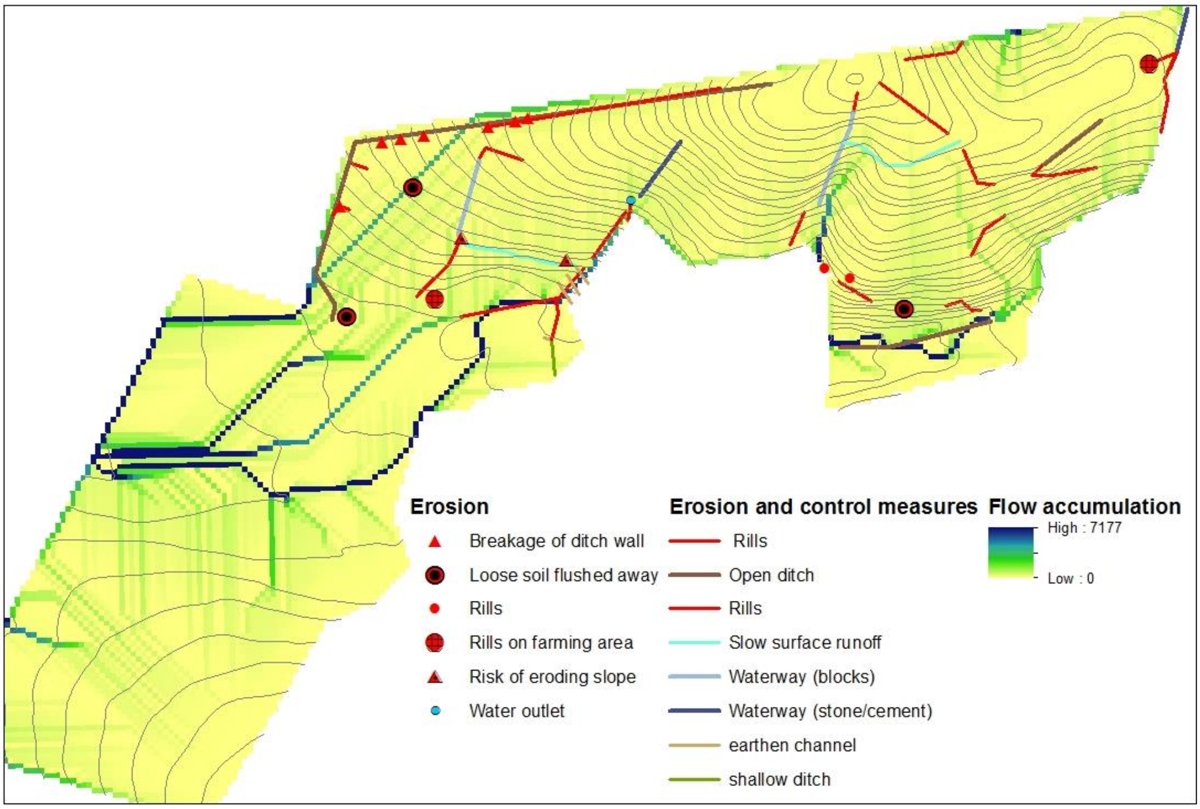


Figure 52 Runoff compared to sign of erosion and current erosion control measures.

Generally, cover crops are established in every second row contributing to slowing down water speed and stabilizing the soil to a certain extent. Cover crops are sparse on the hill slopes but dens on the gentle sloping lower altitudes. With a denser cover crop more water would be allowed to infiltrate and reduce runoff rates, subsequently reducing erosion. The current cover crop, Korog, is a winter annual cross of wheat and rye. Sparse surface cover and the difficulties of establishment indicate of low suitability for Kanonkop's conditions. Korog does well particularly in cold climates according to the viticulturist.

4.2.2. Water Scarcity

Physical water scarcity occurs on parts of Kanonkop vineyards but is dealt with in a sustainable way at the moment. This is directly and indirectly due to the strongly varying altitudes and aspects of slopes, providing a wide range of micro-climates. According to a study conducted by Saayman et al (2010) climate conditions are more favorable up slopes due to decreasing temperatures. A study made by Knight & Taljaard (2002) showed that there is a decrease of 0.3℃/100 m in this area. The dominating south and southwestern slopes, provide cool climates caused by a combination of low inception of sunlight and cooling breezes from the two oceans. By comparing figure 14 and figure 15 conclusion can be drawn that the steeper south and southwestern slopes in the north are cooler then the north and northeastern facing slopes on the southern lower lying areas and the northern-eastern facing slopes on the northern parts of the vineyard. By comparing the irrigated fields in figure 23 with the solar radiation in figure 16 it can be understood that there is strong correlations between high solar radiation and irrigation requirement (reflecting the occurrence of physical water scarcity). Due to extremely dry conditions in 2011, irrigation was introduced on several recently rainfed fields. These fields all received high solar radiation but experienced cooler temperatures due to high altitudes. They are neither planted with Pinotage, which require less water due to earlier matureness (fig 20 and 23). Pinotage performes well in areas where annual precipitation exceeds 500 mm (Pinotage Association, 24-02-2013). On the southern part of the vineyard the single block planted with Pinotage (65 years old plants producing the Black Label Pinotage wine) irrigation was introduced in 2012 as well.

Block 27 and 28 is likely to require irrigation (fig 16 and 20) due to high solar radiation and low altitude. The closeness to a watercourse located down slope an area with high of runoff (fig 19) provides enough water. Runoff is allowed to infiltrate owing to gentle sloping land (fig 14). Large runoff quantities are confirmed by severe erosion in the upper catchment (fig 37-42). In a case where runoff is diverted from the upper catchment directly into the watercourse without passing block 27 and 28 the soil water storage is likely to decrease. Soils are likely to be continually well moisturized owing to the closeness to the watercourse and the local hydrology. Blocks 107 are irrigated even though the solar radiation generally is not too high (fig 16) and the land is nearly leveled (fig14). Vines are still very young and therefore sensitive to too dry and wet conditions. As the natural conditions are alternate wet and dry the vines are planted on ridges to protect them from a wet reducing environment. As the roots systems are not yet well developed irrigation may become necessary when dry conditions.

4.2.3. Climate Change

Climate change is projected to affect the Western Cape mainly by increased temperatures and occurrence of drought and flooding. An analyze of climatic data from weather stations in Western Cape, conducted by Bonnardot and Carey (2008), showed a significant increase in temperature over the past decades where Stellenbosch have experienced an increase of 1.7℃ of the annual maximum temperature and 0.7℃ of annual minimum temperature. Subsequently the number of growing degree days (GDD) increased by 150 GDDs from 1967 to 2006. As the winegrowing regions are moving towards each pole South Africa's wine producing areas are expected to decrease since the possibility of moving south is limited by the sea. The only option to obtain areas with lower temperatures is moving up the hill, which subsequently increase the risk of erosion. Similar climatic threats are expected for the cocoa and coffe production, reported by International Centre for Tropical Agriculture (CIAT) (Palmer, 2011) and The Guardian (24-04-2013). VinIntell (2012) states that new grape varieties and new flavours will come to market as a consequence of climate change adaptation but that there are uncertainties in how the market will react to these new varieties. However, South Africa is more flexible than several European countries when it comes to climate change adaptation due to the appellation system in Europe limiting introduction of new varieties and shifting the production of existing varieties to other areas. A recent study projected that by 2049 Bordeaux region in France will have reached the upper temperature limits for growing red varieties and will be outside the ideal climate for its white grapes so there will be no more Sauvignon Blanc or Burgundy (VinIntell, 2012). In the future European countries may have to change their system.

Kanonkop do not have the possibility to move uphill wherefore adaption opportunities lies mainly within preparedness for water scarce periods and transport of great runoff volumes on the hillsides. Increased risk of water scarcity is currently more of concern as it comes to energy requirement than water resource availability as pumping of irrigation water is the largest consumer of electricity from the farm. The varying topography cause higher electricity consumption from the irrigation compared to less varying topography due to more electricity is needed to pump water upwards than horizontal or downwards The dam provides significantly more water than needed for irrigation and drip irrigation system is efficient and do not contribute to erosion to a concerning extent. In their climate change adaptation process, Kanonkop should include a study of the soil and soil water storage characteristics. Increased occurrence of dry spells (as in 2011) and flooding are expected to increase the risks of water scarcity and erosion which emphasize the need of a strategy to reduce these risks. Awareness of biophysical conditions enables predictions of water scarcity and erosion occurences and thereby make it possible to implement suitable adaptation measures in time to prevent and minimize damages. The importance of understanding the biophysical conditions on each specific block for correct adapting to climate change is also discussed by Vinkler et al (2009). They report that differences of up to 6℃ over a 4 km distance has been documented in Overberg, Stellenbosch and Paarl. Scientists have suggested that it is possible to make viticulture more adaptable, preserving some vineyards and traditional grapes, by altered pruning practices to increase shading and reduce excess heat by row orientation. VinIntell (2012) claim that trellishing and irrigation practices can be used for cooling the plants.

4.3. RISK REDUCTION AND MITIGATION

4.3.1. Erosion and Soil Quality

If erosion is not controlled soils are likely to loose quality and depth. Erosion may cause non-reparable damages in short time. Loss of soil depth leads to decreased water and nutrient storage capacity and loss of valuable top soil. Top soil developed its characteristics over a long time period and cannot be repaired once lost. Implementation of a water diversion system and establishment of cover crops are likely to reduce costs related to fertilizing, irrigation etc and in the long term preserve the soil and sustain the land’s usability for wine production

To combat erosion on Kanonkop a combination of measures must be implemented as soon as practicable. Measures should be well planned, considered in a holistic perspective and compose a part of a long term environmental strategy. Instead of “treating the symptoms”, as currently, the focus should be to control the source. Erosion control measures implemented on Kanonkop are vine row direction parallel to contours, cover crops, terraces, water diversion structures and water bars. The vine row direction is good the way it is but the ground cover from the cover crop should be enhanced. A dense cover crop should be prioritized since cover crops are the most cost-efficient erosion control measures. Grass strips around the blocks and vegetated roads is likely to reduce erosion on the roads markedly. Annual cover crops are associated with high costs for establishment and are less effective for erosion control than perennial crops. The annual cover crop should therefore be replaced with perennial crops. Irrigation and fertilization is necessary for a well established cover crop wherefore annual establishment will require very high costs on Kanonkop and a high Carbon Footprint. Perennial crops are likely to require irrigation only during the first year after seeding. High establishment costs was the reason for planting every second row alternate years. High costs combined with poor establishment of the current crop has driven the viticulturist to replace it with a perennial clover on an experimental level the coming season to make use of the rooting and spreading characteristics as well as achiving a fertilizing effect (Koos de Toit, 10-04-2013). It is though preferable to mix perennial clover with perennial grasses to achieve a better surface cover and thereby better erosion control effect. Pure cultivation of clover may also chock the vines with high nitrogen levels which may reduce grape quality as a consequence of increased vigour. Excess nitrogen may also be leaching and causing pollution in surrounding environment. Grasses may provide a beneficial competition to clover and control it to a suitable level. The grasses’ denser rooting systems is also likely to have a positive effect on soil structure and further control erosion. A well-established crop also has the benefit of reducing GHG emissions as a result of increased SOM. SOM can further be built up as erosion is reduced due to reduced leakage. If the crop has not established sufficiently before the initial rains mulch should be used for protecting the crop and soil. Alternatively, annual grass seeds can be mixed with the perennial seeds since annual grasses establish faster than perennial crops and thereby provide a better surface cover the first year after establishment. Even though electricity use is likely to increase during the year of establishment, the long term electricity use is likely to decrease with a denser cover crop.

Waterways have been constructed where rill formation on roads have been severe but they do not function optimally. Runoff generated within the vineyard blocks are, with few exeptions, not diverted into the waterways. Thereby the waterways have significant lower cost-effectivness than their potential. By adding cutoff drains, as between block 511 and 512 (fig 24 and 44) or similar, to the system waterways could become more cost-effective and potentially reduce erosion markedly. A water diversion system should be designed consisting of cutoff drains, terrace shelves, waterways and a sediment basin to let sediments settle before continuing to the dam to avoid pollution of the water (fig 7). Cutoff drains should always be constructed after the waterway to prevent large water flows to exacerbate the erosion situation. It is advisable to consult an expert soil scientist or engineer before putting structures in place. On gentle slopes grassed waterways could be constructed for lower costs compared to using bricks or stones. Well established vegetation is crucial for good performance and to avoid severe erosion of the waterways. Construction of water diversion systems require high labor wherefore it is advisable to implement such measures as soon as practicable also from an economic perspective since labor is becoming more expensive. During the year of implementation the fuel's contribution to the total Carbon Footprint is likely to increase. At this stage, the Carbon Footprint audit is aimed to make wine producers begin measuring, improving the awareness and make improvements in their productions. The results are still anonymous and will thereby not have any negative impact on the production and market.

In order to reduce erosion and stabilize the structure of the north/western located ditch (fig 24 and 26) the wall should be reconstructed from vertical to sloping. Dense vegetation should be established to improve the strength of the construction. To reduce the formation of rills on the road (fig 25) additional water bars across the road should be constructed, gently sloping towards the ditch and each outlet stabilized with gravel. Today, the management of the ditch is done by removing sediment regularly and filling holes with soil and organic waste. This is only a short-term solution and do not fix the originate problem. Instead water should be diverted to the ditch in a way that reduce the sediment transport into the ditch. This can be achived by diverting runoff safely into the ditch as well as strengthen its structure. Divertion of runoff from field 310 (fig 52) into the ditch can prevent damages downslope on blocks 208-211. It is also advisable to lead water along the road between block 201 and 211 as well as between 209 and 210 towards the ditch or the waterway (fig 52) in the same way as between block 512 and 511.

The waterway which ends abruptly just below block 309 should be kept under observation in order to resolve whether there is a risk of water saturation of the soil that may cause the slope to slide (fig 29). If it is found that there is a significant risk of sliding the waterway should be extended downslope. This would also reduce the erosion on this part of the vineyard (fig 30-32). The waterway should end up in a control basin let sediments settle before water entering the dam.

The severe erosion by the northeastern corner of block 309 (fig 33) should be mended as soon as possible. First and foremost water from the above laying waterway must be lead into the forest. The collapsed slope bellowed outlet should be strengthened by constructing brick-lined steps (fig 53) or similar construction. Below the steps a vegetated ditch should lead water into the forest. Erosion seen in figure 34 can be minimized by establishing cover crop/grass strips. If preferable, stone or brick structures can be constructed but is likely to require more labor and higher construction costs. Erosion seen in figure 35 can be reduced by establishing vegetation or constructing water bars leading water all the way into the forest. As for now water ends up on the road next to the forest causing rill erosion.

The waterway in figure 36 is being invaded by alien plants which should be removed to sustain sufficient performance.

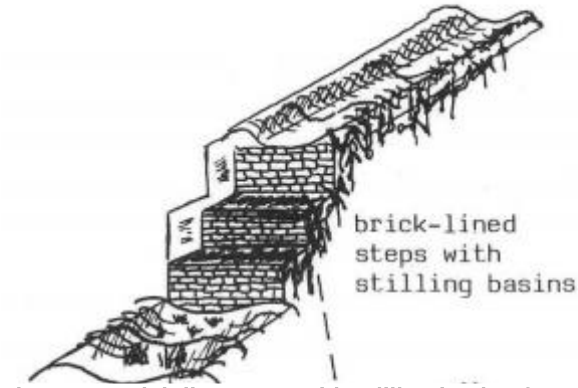


Figure 53 Brick-line steps with stilling basins for transporting water on slopes >20 degrees.

The severe rill erosion occurring on the road accessing block 27 and 28 (fig 39-42) cannot be reduced by breaking the speed of water due to the vertical slope directly upslope the road. Excess water must be diverted into the nearby forest, preferably, by construction of a vegetated ditch between the road and block 510. The ditch should be sloping gently in western direction. In that way the four water flows (fig 38) can be diverted safely will be cut off.

Rills on the road on block 512 (fig 43) can be reduced by establishing vegetative cover on the road and/or creating water bars with short distance in between leading water to the side of the road, into the vine rows, where the slope is more leveled and shorter. If this is not enough, construction of a vegetative ditch/grassed waterway on the side of the road may become necessary. Further down slope where only parts of the runoff transported on this road is diverted into the waterway. Runoff escapeing and continuing down slope further causing erosion (fig 44) can easily be blocked by constructing an earthen wall forcing water towards the waterway.

The diversion ditch below block 611 (fig 46) is an example of when vegetation cover could have prevented erosion. The ditch perform well on almost leveled land but as the slope increase the earthen structure breaks. Vegetation would strengthen the structure enough to resist the force from the water flow. In the turning and down slope water should be led in a vegetated channel and diverted into the natural vegetation. As the water cross the road it may become necessary to strengthen the diversion ditch with stone or cement material to allow traffic to pass without damaging the channel.

Along the easternmost border erosion occurs due to large water flows being transported inhibited due to the vine rows being perpendicular to the contours. A dense cover crop is likely to reduce erosion within the blocks (fig 14) after the existing rills has been repaired. Along the sloping road water must be diverted in a vegetated channel or similar.

4.3.2. Water scarcity

Physical water scarcity occurrs on Kanonkop but coped with by harvesting wastewater/rainwater in a dam providing significantly more water than required, confirmed by an investigation performed by Enviroscientific. The waste water is of satisfying quality for irrigation and drip irrigation is used almost exclusively on the irrigated blocks. Drip irrigation is the most water efficient irrigation system and has the lowest contribution to soil erosion (Thurp et al., 2008). According to the IPW auditing there are still potential for enhanced sustainability concerning the wastewater treatment and the dam. Clear recommendations are given by IPW on what should be done with regard to this matter. Further studies on the water scarcity situation are not considered a priority for this report. The water situation was not determined as a major threat to the environmental sustainability, however, increased water demad may become an issue for increased costs and GHG emissions due to increased electricity consumption for pumping. A long-term strategy for minimizing water application may become necessary. This strategy should include agricultural practices for enhancing the soil water storage capacity, reducing evapotranspiration and applying water efficiently. Increase of SOM increase the infiltration and water holding capacity at the same time as strengthen the soil to resist disturbances such as erosion. Increasing SOM decrease CO_2 emissions and thereby should be included in a strategy for climate change mitigation. Increased SOM can be achieved by establishing a dense cover crop, replace fertilizers with compost and/or manure and reducing carbon loss succeeding eroion.

Today water applications are made based on the winemakers estimations of time required for irrigation of each block. A pressure chamber for measuring plant water status in the leaves has been bought in recently which will enable a more accurate estimation of when irrigation is required. In the future, neutron probe may be bought in to further improve water productivity according to the viticulturist. These preparations and introduction of irrigation systems on recently rainfed blocks shows that adaptation to water scarce situation are ongoing on Kanonkop.

4.3.3. Climate Change

The *South African Fruit and Wine Industry Carbon Calculator* is new and under development. Other relevant calculators are; *the International Wine Carbon Calculator* (developed by South Africa, California, Australia and New Zeeland), the *Carbon Protocol of South Africa* and the *Climate Action Partnership (CAP) calculator* which is a South African calculator aimed for individual household users (Fruit and Wine Initiative$_c$, 22-03-2013). The *South African Fruit and Wine Industry Calculator* was chosen since it is an industry standard developed for the South African fruit and wine industry. Carbon Footprint auditing is included in the Evaluation Form and Guidelines for Cellars and is included in South Africa's work in decreasing the GHG emissions. The number of wineries who compiled the auditing in 2012 was very low, resulting in non-representative industry average results with a statistical relevance of only 0.4 (CCCb, 2012). The compliance rate is significantly higher for the fruit industry than for the wine industry. According to Shelly Fuller at the *Fruit and Wine Initiative South Africa*, the attitudes and interest for the auditing differs between the two sectors. The wine producers, generally, do not see the point with performing the auditing. My conclusion based on discussions with winemakers in the Western Cape is supporting this theory. They do not understand why carbon footprint is relevant, "W*ill someone ever look at the numbers and do anyone actually care?!*" Due to South Africa's commitment to reduce the GHG emissions as mentioned, wine producers are likely to be obliged to perform this carbon footprint auditing and reduce their emission in the future. An early auditing enables a smooth adaption of the operations in reducing the GHG emissions and minimizing the risk of making mistakes in the adaptation process that will have negative effects for the company. This auditing creates the possibility to further investigate opportunities to reduce GHG emissions as well as to be a foundation for further research of relevant environmental investments.

Usage of this tool has importance for more than the accuracy of the footprint of the individual farm. It contributes to further development of the tool as well as contributing to the national work in decreasing the total GHG emissions. In this stage the calculator is meant to make wine producers start measuring and improving on their GHG emissions. The actual numbers are less important (Shelly Fuller, 16-04-2013). During the calculator process there were a number of bugs which aggravated the calculation. These bugs should not affect the final result. In the future this tool may be used to enables standardised measurements, reporting and comparison of individual farm emissions as well as emissions along the supply chain (Shelly Fuller, 16-04-2013).

Carbon Footprint auditing was recently introduced in South Africa and there is little research done on GHG emissions from wine production in the world. New Zeeland is the first country to label the bottles with each bottle's carbon footprint. There is however very little material available on this matter. The Wine Industry average Carbon Footprint auditing performed in Australia is shown in figure 54. Electricity stands for 53 % (Carbon Turst, 27-04-2013) of the emissions, similar to Kanonkop. Blanketing and additive CO_2 in the wine production process is not applicable for Kanonkop.

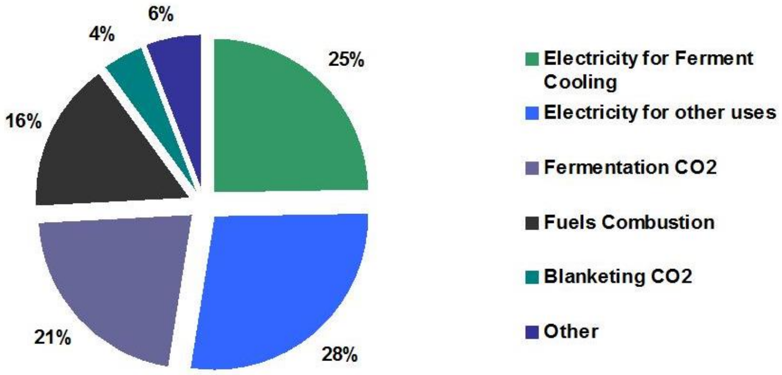


Figure 54 Wine industry average Carbon Footprint of Australia (Carbon Trust).

Industry average for different countries are though not directly comparable since it is likely that different boundaries and aspects have been included. The Industry average of South Africa's Wine Industry should only be considered as an indicative comparison due to the low statistical relevance. Based on this average it can still be understood that Kanonkop has a remarkably high Carbon Footprint. It is 2.4 times higher than for red wine grape producers and 3,9 times higher than for wineries producing red wine. Red wine grape production seems to have higher emissions than white wine grapes while production of white wine has higher emissions than red wine. As for the industry average, the winery is a larger emitter than the farm (fig 48). Electricity is the single largest source of GHG emissions (fig 48) which mainly owing to the coal based electricity. The electricity allocation does not have a high degree of accuracy due to a lack of data availability. Since electricity allocation is so roughly estimated the breakdown of each business boundary has low accuracy and should therefore not be analyzed in detail until allocation with higher accuracy can be achieved. However, most of the work in the cellar and vineyard are done manually which reduce the total electricity consumption compared to a mechanical system. As costs for labor is increasing in South Africa this labor intense system is not sustainable. With time mechanizing of the production is a likely outcome.

Two relevant alternative renewable electricity sources are REC and (Renewable Electricity Certificate) and solar power. REC is energy that can be sold or traded and is currently more expensive than Eskom, the national electricity supplier. With REC it is, however, possible to calculate and apply for fixed annual costs for electricity (Dillon, 2011). If solar power would be implemented on the estate it should be possible to put excess electricity produced into the electricity grid. Kanonkop is likely to be very suitable for solar power since there are large roof surface on the campus. According to the Eskom bills for 2012 electricity consumption is lower during winter due to no irrigation and one of the coolers is shut down. Electricity use is highest in the summer since vineyards are irrigated, coolers used both in wine cellar and storage. A couple of years back the economical feasibility of solar power was investigated but not found feasible. Since then electricity prices has raised with about 300 %. It may thereby be interesting to look into this option again (Abrie Beeslaar, 19-04-2013). Implementing of solar contributes to less dependance and sensitivity to price changes. Another renewable electricity source is biogas. The quantity of organic waste produced on site is, however, not enough for making biogas cost-effective. The recently introduced composting is the better option for treating organic waste compared to biogas production.

The allocation of direct fuel is more accurate than for electricity. The allocation can though be improved by more detailed recording of the use of vehicles. GHG emissions from direct fuel usage has a larger contribution to the carbon footprint from the farm then it has from the winery. Direct fuel and waste compose a very small part of the total emissions from the winery while packaging and electricity are large contributors.

Heavy glass bottles are likely to contribute to high emissions from the packaging as well as the use of oak barrels, both directly associated with high quality wine. Use of oak barrels is directly affecting the taste and quality of wine and Kanonkop is known for the similarity of the wines from vintage to vintage (Johann Kriege, 11-03-2013). Not using oak barrels are therefore not a realistic alternative. When it comes to heavy glass bottles, the market for quality wine still demands this packaging. It would be risky for Kanonkop to change to light weight bottles in this stage. If the development of the market goes in direction to accept light weight bottles it may become an alternative in the future. If the emissions from the electricity use is being reduced by replacing grid with renewable sources the potential of reducing emissions by replacing heavy bottles with light bottles will acquire an even higher percentage. GHG emissions from packaging can be reduced also by using cartoons made from recycled material instead of virgin material and using CHEP pallets instead of wood pallets.

As recycling was introduced in late 2012 GHG emissions from wastes are likely be lower in the 2013 audit. Compost, metal and paper from the administration has great potential of improving the recycling. Recycling should be extended and encourage each of the employees to contribute to the recycling and not place recyclable material in the bin for combustion.

Fertilization is a small emission source and will therefore have a very small contribution to the Carbon Footprint but if emissions from electricity is reduced it will play a larger part of the total emissions. Howerver, by using clover as cover crop instead of grass the need of nitrogen fertilizer is likely to be reduced. When the compost is ready for using on the fields mineral fertilization is likely to be reduced as well. This system is likely to reduce costs related to fertilizing.

The accuracy of the distribution boundary may not have high accuracy since the road network is difficult to understand. Routes and vehicles used depends on the total products being delivered by the external contractor each day. However, road deliveries are only done within southern Africa and which have relatively short distances and use of different vehicles and routes should not influence the result enough to affect the outcome significantly at the moment. The distribution boundary also play a small role for the total Carbon Footprint compared to the farm and winery.Sea freight seems to have lower total emissions than road even though distances are much longer for sea freight than for road freight. This is understandable since road freight is known for being a less environmental friendly transportation than boat.

In order to facilitating the carbon footprint auditing and improve the accuracy a number of recordings are necessary to implement in the daily activities at Kanonkop. All records should preferably be stored digitally in addition to note books, as is commonly occurring today. Digital recording facilitates in evaluating and following the records. Digital storing of data is also safer and enables sharing the data among the staff or external actors who may need access to the records e.g. IPW and advisors. Records necessary to keep are:

- Electricity consumption
    - Irrigation pump - differentiate when it’s used for household and vineyards
    - Housing electricity consumption
    - Cooling equipment after installing meters
    - Bottling & Packing
- Purpose for using vehicles, this is also beneficial for tracking unnecessary use and thereby reduce costs and fuel consumption
- All manure, compost, fertilizer and pesticide applications.
- All packaging material used e.g. bought in and stocktaking in the end and beginning of the year. Also recoding reused material.
- Damaged solid boards, pallets etc which are not taken back by the delivery company.
- Quantities of recyclable waste
- Quantities of non-recycled waste.

5. CONCLUSIONS

The main risks for environmental sustainability and future wine production are soil erosion, water scarcity and climate change. These are all correlated. Expected increases in drought and heavy rainfall are likely to increase risk the severity of erosion and reoccurrence of dry years. Kanonkop is well prepared for water scarcity as it come water resource availability and water use efficiency owing to the dam and drip irrigation system which has been extended to more fields in 2012. Irrigation consumes large quantities of electricity which would increase if larger areas are irrigated in the future. Kanonkop's high electricity consumption, based on coal, strongly contributes to the high carbon footprint and ergo contributes to rapid climatic changes. Heavy rainfall, as a result from climate change, further necessitates implementations of erosion control measures at an early stage. Cover crops will not be enough due to the varying topography and prone soils wherefore a water diversion system must get in place to protect the soils. By controlling erosion soil quality can potentially be improved, water use and emissions of Green House gases reduced.

Much has been done for improving the sustainability of the production the last years and more changes of the operations are planned for. Even though Kanonkop received 100 % on the IPW auditing in 2012 there is still large development potential in an environmental perspective. Continuously improvements should always be a driving force, one can never be "done" or sustainable enough. Opposite to organic where you either are organic or you are not. The lack of knowledge about environmental sustainability is holding back the development but it is clear Kanonkop is heading in the right direction. With a strong will and decisiveness low knowledgebase should not stop the development in a sustainable direction.

Sustainability is a direction, not a destination!

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Table 1 - Allocation of direct fuel

Vehicle	Fuel usage	Allocation		Use within allocation
Boom Gif	**71**	Farm		other
Digger Loader	**5731**	Farm		vineyard activities
Forklift	**1274**			
	637	Winery (50%)		onsite transport
	637	Farm (50%)		delivery to winery
Generator	**321**	Winery		winery activitie
Chain Tractor	**1042**	Farm		vineyard activities
Same-08	**428**			
	214	Farm (50 %)		labour transport
	214	winery (50 %)		winery activitie
Snoek Braai	**57**	Farm		other
Stomer	**15**	Farm		other
Karcher	**111**	Winery		winery activitie
Tractors	**10079**	Farm		
	9171,1		90%	vineyard activities
	907,9		10%	delivery to winery
Landini Rex CL13824	1849			
Tractor Sakkie CL 11520	537			
Tractor Dirkie CL14239	1365			
Tractor Jannie CL 14315	2233			
Tractor Tommie CL 48412	1270			
Tractor Leon CL 36462	2825			
Werk Bakkie Kerneels CL18906	**1242**	Farm		vineyard activities
Werk Bakkie Jan CL 30846	**3839**	Farm		
	1535,6		40%	Farm Management
	1535,6		40%	labour transport
	767,8		20%	vineyard activities

Werk Bakkie Karel CL42617	4217	Distribution	Distribution
Koos CL48878	3447	Farm	Farm Management

Table 2 Allocation of electricity use

Boundary	kWh	% of total	Information source
Farm	**377769**	**40**	
Vineyard activities	236106	25	Estimation
Housing	141663	15	Estimation
Infrastructure		-	-
Others		-	-
Winery	**566 654**	**60**	
Processing activities	94 442	10	Estimation
Cooling	188 885	20	Estimation
Bottling	283 327	30	
Others		-	-
Distribution		-	-
Total	944 423 kWh		Electricity bills (Eskom)

Table 3 Allocation of direct fuel.

Boundary	Liter	Information source
Farm	**26 374**	
Vinery activity	17 954	Estimated/record
Delivery to vinery	1 545	Estimated/record
Farm management	4 983	Estimated/record
Labor transport	1 750	Estimated/record
Other	143	Records
Winery	**1283**	
Processing activity	646	Estimated/record
Bottling	-	-
Onsite Transport	637	Estimated/record
Labor Transport	-	-
Others	-	-
Total	**27 630**	

Table 4 Fertilizer and pesticide applications

Chemical	Total kg	Information source
Pure N (stikstof)	1040	Records/estimated
P_2O_5	2107	Records/estimated

K_2O	-	Records
Compost	-	-
Solid Manure (chicken)	114 kg N	estimated
Lime	3600	records
Fungicide	393	records
Insecticide	-	-
Herbicide	780	Records

Table 5 Total arable and productive area.

	Hectares
Total arable	100
Productive	92

Table 6 Raw materials entering the wine cellar

Raw material	Tons (T)	Information source
Own grapes	464	Records
Bought grapes	725	Records
Total	**1 189**	

Table 7 Quantities of wine bottled & packed on site

	Litres (kL)	Information source
Bottled	683	Records
Packed	681	Records

Table 8 Wine market

Market	Litres (kL)	Information source
Local	**216**	
Transported	191	Records
Counter	25	Records
Export	**239**	**Records**
Total	**455**	

Table 9 Packing material used in 2012 and the percentage of recycled material it is produced from.

Material	Quantity	% recycled	Information source
Glass (supplied by Consol)	583 000 kg	20	Records/estimation
cardboard	1400 kg	No data	
Corrugated Cardboard Cartons	46 100 kg	0	Estimation
Paper labels	2700 Kg	0	Estimation
LDPE	200 Kg	30	Estimation.

Bulk wood bins (barrels) – total	3500	0	
Bulk wood bins – bought new	343 units	0	Records
Disposable wood pallets	215	0	Estimation
CHEP Pallets	415	0	estimation

Table10 Organic waste produced in winery and its treatment

Waste/Treatment	Quantity	%	Information source
Wastewater	**1 300** (m^3)		
Grape/Wine	**506 tons**		
Compost		**100**	
Land fill		**0**	
Brenn-Okem		**0**	
Other		**0**	

Table 11 Non organic waste from winery

Treatment	kg	Information source
Recycled	**5 740**	
Glass	3740	Estimated
Paper	1 800	Estimated
Plastic	200	Estimated
Landfill	**68 000**	**Estimated**
T**otal**	**73 740**	

Table 12 Road freight of purchases

	Truck type	Distance one way (km)	Tonnage (T)	Information source
Kanonkop - Wellington	12 tons	32	430	Records/estimation
Wellington – WC (except CT)	Diesel van	45	1	Records/estimation
Wellington - CT	7.5-17 tons	60	230	Records/estimation
Wellington - JHB	>17 tons	1400	198	Records/estimation
CT-Eastern Cape & Durban	>17 tons	1500	1	Records/estimation
JHB – S.Africa	>17 tons	800	12	Records/estimation

Table 13 Sea freight of export purchases

	Distance one way (km)	Tonnage (T)	Information source
Europe	10 000	159	Records
USA & Canada	11 000	33	Records
South & Central America	6 000	4	Records

East Asia	13 000	10
Oceania	9 500	8
North & East Africa	8 000	14

MONTHLY REPORT: Monthly Averages And Totals

Start Year	Start Month	End Year	End Month
1900	1	2012	12

Comp#	**Station Name**	**Latitude**	**Longitude**	**Altitude**
30189	ELSENBURG	-33,58221	18,83048	171

Compno	Year	Month	Tx	Tn	T	Rain	RHx	RHn	Rs	U2	ET0	HU	CU	DPCU	FD
30189	1995	9	21,36	9,46	14,11	9,8	91,69	56,34	0	2,37	0	49,27	-14,5	26	0
30189	1995	10	21	9,64	15,02	89,2	89,44	57,05	0	2,54	0	155,57	-67,5	63	0
30189	1995	11	25,86	11,75	18,57	7	89,07	52,51	0	2,78	0	257	-354	1,5	0
30189	1995	12	28,99	15,73	21,82	52,2	88,32	52,54	0	2,83	0	366,38	-619,5	0	0
30189	1996	1	30,2	15,14	22,43	7,2	90,78	49,06	0	2,64	0	385,18	-613	0	0
30189	1996	2	29,71	14,13	21,35	65,6	91,77	49,24	0	2,45	0	329,28	-499,5	0	0
30189	1996	3	26,72	12,14	18,79	35,2	90,66	45,86	0	2,52	0	272,6	-395,5	0	0
30189	1996	4	26,96	11,62	18,54	50,6	88,45	49,29	0	2,3	0	256,3	-321	1,5	0
30189	1996	5	23,14	8,93	15,48	42,6	90,54	55,05	0	2,11	0	169,89	-112	24	0

30189	1996	6	18,63	8,14	13,13	167,8	91	63,19	0	2,88	0	93,84	110	159	0
30189	1996	7	16,73	6,33	11,38	75	85,42	56,13	0	2,6	0	42,65	257	307,5	0
30189	1996	8	17,63	6,59	11,77	86,6	89,17	53,05	0	2,73	0	54,78	236	253,5	0
30189	1996	9	17,5	8,33	12,62	110,6	91,94	66,25	0	2,86	0	78,66	168,5	178,5	0
30189	1996	10	21,34	9,64	15,18	103,8	92,3	65,15	0	2,53	0	160,66	-109,5	54,5	0
30189	1996	11	21,55	11,18	16,16	46,8	91,74	68,4	0	2,91	0	184,73	-198,5	13,5	0
30189	1996	12	25,9	13,05	19,28	41,2	93,29	57,71	0	2,48	0	287,64	-448,5	2	0
30189	1997	1	28,72	13,23	20,88	13,2	92,02	48,38	0	2,62	0	337,31	-522	0	1
30189	1997	2	28,29	13,46	20,53	2,2	90,64	57,35	0	2,75	0	294,72	-468,5	0	0
30189	1997	3	27,37	13,08	19,37	4,8	91,61	46,48	0	2,25	0	290,4	-451	0	0
30189	1997	4	23,55	10,58	16,08	53,4	95,31	52,07	0	2	0	182,29	-156	17,5	0
30189	1997	5	22,46	8,91	14,99	77	92,72	50,34	0	2,19	0	154,54	-54,5	45	0
30189	1997	6	16,71	7,39	11,78	122,9	92,55	60,88	0	2,77	0	53,52	222,5	238,5	0
30189	1997	7	19,16	8,13	13,42	19,2	82,35	52,02	0	2,36	0	106,16	84,5	191,5	0
30189	1997	8	17,79	8,73	13,06	73,2	93,17	62,92	0	2,87	0	95,01	104,5	162,5	0
30189	1997	9	23,01	10,55	16,28	9,6	92,1	63,78	0	2,28	0	188,4	-164,5	36,5	0
30189	1997	10	26,36	11,12	18,39	10,2	86,23	43,52	0	2,64	0	260,13	-301,5	24,5	0
30189	1997	11	24,14	12,22	17,77	64,2	87,85	50,46	0	3,06	0	233,19	-318	16,5	0
30189	1997	12	27,64	13,72	20,13	5,8	90,98	48,7	0	2,92	0	314,03	-486,5	4	0
30189	1998	1	27,95	13,82	20,81	18,2	89,41	52,02	0	3,11	0	335,15	-514	0	0
30189	1998	2	31,54	17,19	23,64	0,4	88,3	49,34	0	2,75	0	381,93	-623	0	0
30189	1998	3	27,65	13,75	20,13	20,4	89,42	49,92	0	2,62	0	314,15	-487,5	0	0
30189	1998	5	20,59	10,29	14,96	138	90,8	62,22	0	2,2	0	153,7	-76,5	56,5	0

30189	1998	6	18,35	8,06	12,99	64,8	91,58	65,89	0	2,1	0	89,72	105,5	135,5	0
30189	1998	7	17,67	6,68	11,7	107,2	89,88	59,89	0	2,57	0	52,71	238,5	267	0
30189	1998	8	19,27	6,92	12,95	24,4	89,14	54,31	0	2,86	0	91,46	138	190	0
30189	1998	9	19,9	7,6	13,71	20,8	90,36	56,66	0	2,64	0	111,26	55,5	118,5	0
30189	1998	10	23,81	9,19	16,32	18,8	88,92	47,41	0	2,47	0	196,04	-159,5	21,5	1
30189	1998	11	24,64	11,42	17,85	53,8	90,5	53,93	0	2,82	0	235,61	-316,5	20	0
30189	1998	12	28,29	14,26	21,16	35,2	89,97	51,52	0	2,75	0	345,92	-555,5	0	0
30189	1999	1	30,26	15,22	22,34	1,8	91,67	50,25	0	2,81	0	382,44	-604	0	0
30189	1999	2	31,24	15,31	22,74	1,4	89,82	48,79	0	2,63	0	356,65	-546	0	0
30189	1999	3	30,6	14,48	21,8	0,6	90	49,51	0	2,42	0	365,87	-554	0	0
30189	1999	4	26,4	12,34	18,51	49,6	90,09	54,82	0	2,47	0	255,27	-324	8	0
30189	1999	5	21,55	10,49	15,46	45	92,42	65,93	0	2,06	0	169,27	-134,5	28,5	0
30189	1999	6	20,24	8,87	14,41	87,2	89,21	61,07	0	2,36	0	132,32	-4,5	98	0
30189	1999	7	18,57	7,27	12,97	69,8	90,65	63,6	0	2,43	0	92,02	118	170,5	1
30189	1999	8	19,18	8,66	13,72	168,4	90,65	65,11	0	2,59	0	115,32	62	142	0
30189	1999	9	18,8	7,46	13,01	100,8	92,08	69,69	0	2,48	0	90,36	117	151,5	0
30189	1999	10	25,07	11,27	18,17	9,6	89,25	60,27	0	3,02	0	253,12	-347	2	1
30189	1999	11	26,31	12,35	19,01	35,8	91,65	54,41	0	2,79	0	270,36	-396,5	0	0
30189	2001	4	26	7,8	17,69	0	0	0	14,26	0	0	230,63	-313	18	0
30189	2001	5	16,4	6,1	15,56	177,6	0	0	10,78	2,34	88,82	172,3	-97,5	90	0
30189	2001	6	15,2	8,4	13,11	75,6	0	0	9,09	2,19	67	93,33	93	128,5	0
30189	2001	7	17,73	8,65	12,96	260	0	0	8,43	2,89	68,43	91,91	152,5	207,5	0
30189	2001	8	17,01	8,39	11,58	58,6	0	0	10,17	2,73	42,43	49,08	146	160	0
30189	2001	9	19,5	9,53	13,58	59,4	0	0	16,27	2,34	90,44	107,36	14	101,5	0
30189	2001	10	23,12	11,91	15,26	0,6	0	0	18,23	2,03	45,21	163,1	-105	30,5	0

30189	2001	11	26,46	13,43	17,14	2,6	0	0	27,9	1,9	79,39	214,08	-211,5	7	0
30189	2001	12	27,06	12,9	19,93	9,8	0	0	30,25	2,4	116,57	307,94	-454,5	2	0
30189	2002	1	26,62	14,45	18,42	40,4	0	0	28,04	2,21	105,88	260,93	-300	4,5	0
30189	2002	2	30,99	14,79	19,36	1,6	0	0	26,72	1,96	81,39	262,1	-270,5	4	0
30189	2002	3	30,03	14,84	19,58	1,2	0	0	21,72	2	85,23	296,92	-360	0,5	0
30189	2002	4	25,11	11,8	16,55	53,2	0	0	14,55	1,92	75,34	196,42	-192	9	0
30189	2002	5	19,79	9,42	13,92	33,8	0	0	9,62	1,92	47,49	121,41	34	99,5	0
30189	2002	6	16,96	7,27	11,81	72	0	0	6,75	2,23	42,6	54,3	170,5	187	0
30189	2002	7	16,72	7,1	11,5	141,8	0	0	7,52	2,66	69,27	46,55	282,5	294	0
30189	2002	8	19,07	7,77	13,11	110,2	0	0	10,61	2,64	88,4	96,34	123,5	185,5	0
30189	2002	9	22,4	9,7	15,41	53,8	0	0	15,23	2,44	113,63	162,29	-101,5	28,5	0
30189	2002	10	22,78	9,09	15,53	46	0	0	20,17	2,42	147,11	171,44	-108	35	0
30189	2002	11	25,63	9,99	17,34	27,2	0	0	24,64	2,64	173,66	220,32	-232	10	0
30189	2002	12	29,66	15,45	21,8	39,4	0	0	24,52	2,57	161,86	306,82	-482	0	0
30189	2003	1	29,2	14,52	21,45	12,4	0	0	26,26	2,84	176,04	354,98	-564,5	0	0
30189	2003	2	30,01	15,64	22,1	10	0	0	21,96	2,62	127,67	314,57	-482,5	0	0
30189	2003	3	27,78	14,8	20,4	83,2	0	0	17,36	2,55	117,91	322,29	-517	4	0
30189	2003	4	25,73	12,78	18,48	42,8	0	0	12,84	2,11	78,82	254,39	-364	1	0
30189	2003	5	22,3	10,06	15,56	49,8	0	0	8,6	2,06	52,86	172,48	-114,5	40	0
30189	2003	6	20,65	6,89	12,88	30,2	0	0	8,43	1,86	47,47	86,45	138,5	163,5	0
30189	2003	7	19,34	6,47	12,58	59,4	0	0	8,38	1,46	46,69	79,98	142	204,5	0
30189	2003	8	16,95	6,42	11,43	187,4	0	0	9,92	2,3	51,44	44,23	264	283	0
30189	2003	9	19,55	9,06	13,62	100	0	0	13,34	2,42	67,85	108,74	53,5	86,5	0

30189	2003	10	23,83	10,99	16,77	28,2	0	0	16,69	2,25	74,76	155,73	-176,5	12,5	0
30189	2003	11	26,58	11,42	18,64	0,2	0	0	23,26	2,55	128,82	241,86	-326	0	0
30189	2003	12	26,41	12,25	19,69	24	0	0	23,03	2,65	92,84	184,1	-263	0	0
30189	2004	1	30,52	15,02	22,6	12	0	0	25,76	2,82	178,85	390,55	-600,5	0	0
30189	2004	2	30,36	14,83	22,15	1,6	0	0	23,09	2,67	149,78	352,46	-550	0	0
30189	2004	3	26,86	11,59	18,65	24,6	0	0	18,97	2,69	123,63	268,24	-367	0	0
30189	2004	4	23,3	10,61	16,68	69	0	0	10,46	2,34	49,88	160,27	-135	11	0
30189	2004	5	23,32	10,05	15,61	10,6	0	0	8,19	1,98	49,26	173,99	-130,5	29	0
30189	2004	6	19,25	8,8	13,38	103	0	0	6,9	2,09	35,21	101,34	76	143	0
30189	2004	7	18,65	6,42	11,73	105,6	0	0	9	2,11	46,64	53,48	264	269,5	0
30189	2004	8	18,08	7,87	12,41	87,6	0	0	7,58	2,39	38,71	74,72	189	207	0
30189	2004	9	21,09	7,56	13,8	47,8	0	0	12,2	2,28	62,96	114,04	58,5	101,5	0
30189	2004	10	23,03	9,75	15,86	139,8	0	0	14,79	2,46	87,91	181,72	-145	32	0
30189	2004	11	26,2	12,37	18,88	7	0	0	22,93	2,66	137,9	266,43	-407,5	0	0
30189	2004	12	28,35	14,21	21,17	8,2	0	0	23,94	2,93	161,17	346,14	-562,5	0	0
30189	2005	1	29,26	15,81	22,36	63,6	0	0	24,15	3	171,48	383,25	-612	0	0
30189	2005	2	29,44	14,25	21,39	2,2	0	0	14,95	2,87	92,16	318,83	-502,5	0	0
30189	2005	3	28,18	13,26	20,17	14,6	0	0	14,55	2,42	104,26	315,38	-455,5	0	0
30189	2005	4	23,94	10,74	16,86	86,2	0	0	12,66	2,33	80,48	205,91	-219	13	0
30189	2005	5	18,85	9,42	13,95	99,4	0	0	7,5	2,31	44,58	122,37	22	81,5	0
30189	2005	6	16,14	6,37	11,14	106,4	0	0	6,55	2,28	33,42	34,1	287	290	0
30189	2005	7	19,76	7,45	13,06	71,4	0	0	8,12	2,44	47,22	94,93	116	164,5	0
30189	2005	8	15,39	5,94	10,44	122,8	0	0	8,14	3,19	41,7	13,58	371,5	371,5	0

30189	2005	9	20,03	7,99	13,51	38,6	0	0	16,76	2,25	80,55	105,43	75,5	144	0
30189	2005	10	22,75	9,44	15,67	18,2	0	0	24,58	2,4	130,5	175,71	-106	50	0
30189	2005	11	25,93	12,1	18,78	29,4	0	0	29,28	2,99	162,73	263,3	-375	10	0
30189	2005	12	27,19	11,96	19,47	1,8	0	0	34,99	3,21	204,71	293,64	-430,5	0	0
30189	2006	1	29,88	14,99	22,08	3,2	0	0	35,14	3,15	217,73	374,61	-607,5	0	0
30189	2006	2	30,58	15,22	22,2	15,6	0	0	29,85	2,62	171,12	341,47	-536,5	0	0
30189	2006	3	27,69	11,78	19,11	10	0	0	26,12	2,89	158,82	282,5	-371	0	0
30189	2006	4	24,65	11,48	17,39	51,4	0	0	16,47	2,7	94,32	221,61	-276	10	0
30189	2006	5	19,61	9,58	14,16	161,7	0	0	9,62	2,63	52,7	129,07	26	117	0
30189	2006	6	19,97	8,02	13,68	87,6	94,72	49,57	10,26	2,49	51,77	110,55	65	134	0
30189	2006	7	16,8	8,14	12,36	102,6	96,49	63,73	8,44	2,75	40,01	73,02	201	234	0
30189	2006	8	17,77	7,47	12,34	88,4	94,96	57,81	12,9	2,67	60,58	72,42	189,5	236	0
30189	2006	9	21,83	9,01	14,6	28,8	95,1	45,08	17,33	3,54	87,6	138,15	-47	85	0
30189	2006	10	23,8	9,84	16,48	34,4	94,46	41,31	24,93	2,58	137,64	200,82	-185,5	37,5	0
30189	2006	11	26,04	11,84	18,63	63,4	93,67	40,67	29,09	5,11	160,54	259,02	-362	3	0
30189	2006	12	25,92	13,29	19,29	21,6	90,85	41,33	30,9	3,06	176,28	287,93	-455	0	0
30189	2007	1	30,1	15,26	22,1	2,4	90,87	37,16	33,01	3,82	205,11	375,21	-604	0	0
30189	2007	2	28	14,21	20,46	38,8	93,65	39,78	28,45	2,86	154,03	292,93	-468	0	0
30189	2007	3	28,16	12,76	19,87	32,6	91,67	34,96	24,13	2,88	149,42	306,11	-448,5	0	0
30189	2007	4	24,86	11,47	17,68	87,4	93,62	42,4	15,87	3,03	94,63	230,28	-270	27	0
30189	2007	5	21,66	9,59	14,93	137,2	95,19	49,13	11,37	2,61	60,57	152,98	-53,5	99,5	0
30189	2007	6	17,72	7,91	12,81	128,4	93,93	56,94	8,11	3,71	36,5	78,57	127,5	172,5	0
30189	2007	7	17,12	7,09	11,79	131,6	91,21	54,37	9,88	4,41	48,64	55,55	249	285,5	0
30189	2007	8	17,39	7,61	12,21	114,6	94,31	56,58	11,8	2,82	55,45	68,48	213,5	231,5	0
30189	2007	9	19,78	7,99	13,59	39,6	94,89	51,46	17,35	2,61	83,14	107,67	64,5	116,5	0

30189	2007	10	24,22	9,92	16,81	40,2	93,01	42,37	25,17	2,74	140,2	211,24	-192	49,5	0
30189	2007	11	23,98	10,73	16,9	45	93,29	41,27	26,72	2,84	140,33	206,87	-247	0	0
30189	2007	12	28,23	14,7	21,13	26,6	90,25	39,64	32,62	3,76	198,13	345,07	-556,5	0	0
30189	2008	1	30,29	14,43	22,28	4,4	91,43	38,27	34,03	4,46	183,84	331,5	-496,5	0	0
30189	2008	2	28,76	14,34	20,98	40,4	92,82	43,15	26,58	2,66	152,72	318,54	-497,5	0	0
30189	2008	3	28,78	12,94	20,1	18,8	91,86	34,95	25,27	2,61	158,64	313,22	-448	0	0
30189	2008	4	25,15	10,95	17,43	12,2	91,35	37,99	18,16	2,51	103,48	222,89	-251,5	10,5	0
30189	2008	5	21,07	12,38	16,31	52	92,25	57,03	9,25	2,79	55,75	195,46	-196,5	16,5	0
30189	2008	6	17,53	8,05	12,86	60,4	91,17	56,47	8,06	2,85	40,36	85,75	101,5	147,5	1
30189	2008	7	19,73	7,39	11,27	178,5	99,8	59,15	9,01	2,84	41,29	39,4	214,5	226	0
30189	2008	8	18,03	7,44	12,19	5,4	94,44	54,19	12,34	3,88	57,82	67,79	222,5	242	0
30189	2008	9	17,24	6,95	11,74	179,4	94,52	53,23	15,86	3,67	72,14	52,24	257,5	265	0
30189	2008	10	22,55	9,72	15,84	21,7	93,35	45,31	24,6	2,41	125,34	181,18	-150,5	42	0
30189	2008	11	24,79	11,63	17,91	49,22	93,38	44,26	29,55	2,86	153,72	237,24	-317	0	0
30189	2008	12	29,66	11,56	20,63	20,32	94,15	39,46	32,24	2,63	188,15	329,63	-480	0	0
30189	2009	1	27,76	14,12	20,9	6,34	91,95	41,16	31,16	2,66	181,86	337,97	-530,5	0	0
30189	2009	2	30,36	15,21	22,37	15,47	88,7	35,45	29,92	2,8	171,02	346,27	-525	0	0
30189	2009	3	29,35	13,91	20,86	5,05	91,8	37,66	23,56	2,41	147,75	336,68	-484	0	0
30189	2009	4	27,33	12,46	18,2	40,35	90,92	37,99	14,6	2,43	89,22	245,95	-287,5	4,5	0
30189	2009	5	20,06	10,34	14,9	89,3	94,94	56,02	9,89	2,35	51,11	146,95	-64,5	47	0
30189	2009	6	18,09	9,39	13,42	152,79	94,52	63,02	8,27	2,31	38,95	102,51	62,5	110,5	0
30189	2009	7	18,99	8,44	13,48	121,54	90,92	51,31	10,5	2,25	53,95	107,76	61	175	0
30189	2009	8	18,34	7,53	12,6	87,3	94,81	58,46	12,26	2,3	58,67	80,47	166,5	188,5	0

30189	2009	9	18,46	8,72	13,45	79,31	94,51	60	16,13	2,42	73,44	103,37	61,5	102,5	0
30189	2009	10	23,76	10,72	16,81	40,32	93,45	45,45	24,69	2,41	133,52	211,01	-228,5	11	0
30189	2009	11	24,54	12,68	18,31	97,51	92,17	44,22	27,45	2,66	149,91	249,37	-332,5	0	0
30189	2009	12	27,02	12,88	19,76	3,3	91,58	39,65	31,7	2,39	182	302,59	-458,5	0	0
30189	2010	1	29,45	14,37	21,55	1,01	91,32	38,44	32,93	2,71	198,44	358,19	-562	0	0
30189	2010	2	29,71	15,06	21,6	17,24	92,29	38,26	25,58	2,47	144,3	324,84	-507	0	0
30189	2010	3	30,29	14,95	21,72	12,93	90,67	39,11	22,77	2,91	145,35	363,41	-520,5	0	0
30189	2010	4	27,81	12,74	18,78	0,25	94,94	38,06	21,27	3,7	16,45	35,14	-47	0	0
30189	2010	5	17,23	5,54	11,29	18,78	94,67	54,2	10,01	1,87	8,75	7,76	53	53,5	0
30189	2010	6	18,15	7,28	12,28	106,85	93,79	51,44	9,74	2,06	45,61	68,25	183,5	228,5	0
30189	2010	7	18,55	6,08	11,65	47,19	91,98	46,69	11,57	1,96	54,2	51,01	250	295	0
30189	2010	8	19,63	7,1	12,44	56,04	94,88	49,9	13,11	2,41	64,91	75,54	183,5	204,5	0
30189	2010	9	20,25	8,01	13,38	28,37	93,67	47,97	17,63	2,28	84,1	101,29	75	91	0
30189	2010	10	22,08	9,5	15,43	52,52	92,86	44,01	22,9	2,45	120,8	168,39	-113,5	40,5	0
30189	2010	11	24,16	10,8	17,09	32,24	92,06	42,59	27,03	2,55	143,49	212,62	-232	2,5	0
30189	2010	12	28,38	15	21,48	24,63	85,44	38,58	31,81	2,89	196,33	355,94	-569	0	0
30189	2011	1	30,91	14,38	22,14	4,31	91,29	34,64	32,96	2,67	208,76	376,27	-570	0	0
30189	2011	2	31,77	15,84	22,97	10,14	92,31	36,83	28,77	2,45	166,88	363,26	-548	0	0
30189	2011	3	28,57	13,99	20,45	6,31	92,91	39,71	20,23	2,3	130,14	324,08	-507,5	0	0
30189	2011	4	23,1	9,95	16,96	46,15	92,03	41,28	15,68	2,38	92,88	208,7	-190,5	60,5	0
30189	2011	5	20,47	9,49	14,75	81,39	92,38	51,87	8,76	2,31	51,14	147,33	-62,5	103	0
30189	2011	6	17,29	7,79	12,15	88,23	95,68	62,29	8,05	2,26	37,89	64,53	208,5	233,5	0
30189	2011	7	18,96	6,53	12,38	25,34	91,1	49,98	11,23	2,06	56,03	73,88	182,5	225,5	0

30189	2011	8	18,1	6,17	11,96	71,07	93,76	50,74	12,86	2,2	68,01	60,75	218	256,5	0
30189	2011	9	19,51	7,9	13,12	38,02	95,83	54,66	16,15	2,1	76,73	93,53	127,5	157,5	0
30189	2011	10	22,68	9,48	15,47	22,28	94,23	42,61	19,7	2,09	109,39	169,54	-109	47,5	0
30189	2011	11	23,28	9,57	16,34	38,07	93,31	43,29	25,96	2,57	135,4	190,2	-176	22,5	0
30189	2011	12	26,18	12,52	19,06	15,72	93,11	40,59	29,36	2,73	169,06	280,71	-417,5	3,5	0
30189	2012	1	30,86	15,27	22,74	2,26	92,95	36,93	29,25	2,48	189,54	394,85	-615	0	0
30189	2012	2	28,11	14,02	20,75	5,32	91,83	39,27	27,23	2,85	155,81	311,75	-490	0	0
30189	2012	3	28,23	14,03	20,44	32,98	92,64	40	21,71	2,56	135,57	323,51	-501,5	0	0
30189	2012	4	23,92	10,48	16,63	59,3	92,15	43,99	14,39	2,22	81,47	198,8	-191,5	14,5	0
30189	2012	5	19,47	8,11	13,29	59,1	96,34	55,94	10,36	1,8	51,64	102,03	84	119,5	0
30189	2012	6	17,14	7,28	11,81	103,99	95,8	61,97	7,84	2,07	35,43	54,19	243	280	0
30189	2012	7	16,43	6,74	11,32	100,45	94,63	58,85	8,98	2,39	42,54	40,77	306,5	328	0
30189	2012	8	15,66	6,41	10,65	98,01	95,36	60,26	11,3	2,68	52,21	20,19	365	365,5	0
30189	2012	9	18,25	7,41	12,7	60,44	95,32	58,18	15,6	2,16	71,65	81,14	153,5	180	0
30189	2012	10	21,18	9,89	15,34	80,72	90,85	52,2	22,85	2,53	115,73	165,48	-125,5	114,5	0
30189	2012	11	25,1	11,13	17,82	16,19	92,26	42,38	27,16	2,64	146,39	234,47	-302,5	10	0
30189	2012	12	30,01	15,11	22,38	1,5	91,38	39,18	28,91	2,58	184,27	383,72	-603,5	0	0

KEY NOTES FOR MONTHLY REPORT [Draft]

ELEMENT	DESCRIPTION	UNIT	STATION TYPE

Tx	Average Maximum Temperature	°C	AWS
Tn	Average Minimum Temperature	°C	AWS
T	Average Temperature [Calculated From Hourly Data]	°C	AWS
Rain	Average Total Rainfall [Calculated From Hourly Data]	mm	AWS
RHx	Average Maximum Relative Humidity	%	AWS
RHn	Average Minimum Relative Humidity	%	AWS
Rs	Average Total Radiation [Calculated From Hourly Data]	MJ/m2	AWS
U2	Average Wind Speed [Calculated From Hourly Data]	ms	AWS
ET0	Average Total Relative Evapotranspiration [Calculated From Hourly Data]	mm	AWS
HU	Average Total Heat Units [Calculated From Hourly Data]	Unitless	AWS
CU	Average Total Cold Units [Calculated From Hourly Data]	Unitless	AWS
DPCU	Average Daily Positive Chilling Units	Unitless	AWS

	[Calculated From Hourly Data]		
FD	Total Frost Days Per Month Where Min Temp Below 0 ¦C	Days	AWS
FD	Total Frost Days Per Month Where Min Temp Below 0 ¦C	Days	MWS
Tx	Average Maximum Temperature	°C	MWS
Tn	Average Minimum Temperature	°C	MWS
Rain	Total Rainfall	mm	MWS
RHx	Average Maximum Relative Humidity	%	MWS
RHn	Average Minimum Relative Humidity	%	MWS
UTot	Average Windrun	Km/day	MWS
APan	Total Daily Apan Evaporation	mm	MWS
Suns	Sunshine Hours	Hours	MWS
HU	Average Heat Units [Not yet available]	Unitless	MWS
CU	Average Cold Units [Not yet available]	Unitless	MWS
DPCU	Average Daily Positive Chilling Units [Not Yet Available]	Unitless	MWS