CFPA	SAAPPA / SASPA / SAT	DFTS	Winetech
Canning Fruit Producers' Assoc. Submit to: Wiehahn Victor Tel: +27 (0)21 872 1501 **inmaak@mweb.co.za**	Fruitgro Science Submit to: Louise Liebenberg Tel: +27 (0)21 882 8470/1 **louise@fruitgro.co.za**	Dried Fruit Technical Services Submit to: Dappie Smit Tel: +27 (0)21 870 2900 **dappies@dtd.co.za**	Submit to: Jan Booysen Tel: +27 (0)21 807 3324 **booysenj@winetech.co.za**

			X

Indicate (X) client(s) to whom this final report is submitted.
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FINAL REPORT
FOR 2012

PROGRAMME & PROJECT LEADER INFORMATION

	Programme leader	Project leader
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PROJECT INFORMATION

Project number	*US/EE/SJ*
Project title	*Exploiting landscape heterogeneity: An investigation into vigour and physiology of grapevines on and off 'heuweltjies'*
Project Keywords	*Termite,* Microhodotermes viator*, soil, hydrology, vigour*

Industry programme	**CFPA**	
	Deciduous	
	DFTS	
	Winetech	*X*
	Other	

Fruit kind(s)	Vitis vinifera
Start date (dd/mm/yyyy)	*January 2009*

End date (dd/mm/yyyy)	***December 2010***

FINAL REPORT

(Completion of points 1-5 is compulsory)

1. Executive summary

Give an executive summary of the *total* project in no more than 250 words

Landscape heterogeneity is a topic that has received much attention both in natural and agricultural landscapes, the latter especially as crop vigour and product quality are often linked to the 'quality' of various landscape units or parts of landscape units differing in soil, hydrological and other characteristics. These aspects have been extensively investigated in this study. Heuweltjies are landscape features putatively created by the termite Microhodotermes viator *through their activities of burrowing and nest-building. They have been closely examined in the natural veld of the Western Cape in the recent past and are the focus of many ecological studies. Despite the extensive history of studies in natural veld, the role of heuweltjies in modifying crop vigour and quality in cultivated landscapes (e.g. vineyards, orchards and wheat lands) remains largely unexplored.*

We set out to test the overarching hypothesis that heuweltjies occurring in cultivated areas can significantly affect crop yield and quality, thereby playing an important role in the agricultural economy of the Western Cape (see also Bekker 2011 for more detail). We used two vineyard blocks on farms in two climatic regions of the Western Cape, Stellenbosch (Mediterranean climate, Cabernet Sauvignon) and Robertson (semi-arid climate, Shiraz) to better understand how differences in heuweltjie soil characteristics may be carried through to vine ecophysiology, berry quality and wine characteristics. Soils on heuweltjies were compared to non-heuweltjie soils with respect to physical and chemical properties. Grapevines growing on and off heuweltjies were also compared to determine any variation in vine vigour, physiology, phenology, berry characteristics and wine quality. We used ANOVA and Fisher's LSD posthoc tests to indicate statistical significance in soil and grapevine characteristics.

It was apparent that heuweltjies induce substantial changes in soil and vine properties. Differences in the soil water content between heuweltjies and non-heuweltjie areas were observed. Soils on heuweltjies exhibited higher values in comparison to the non-heuweltjie soils in the Stellenbosch study area, with opposite results in Robertson, which confirmed earlier assumptions based on scant information on soils of heuweltjies under cultivation. Further, soils associated with heuweltjies also displayed higher exchangeable calcium and magnesium and higher total carbon and total nitrogen values compared to non-heuweltjie soils in both study areas, despite the soil environment having been modified considerably due to soil preparation and subsequent management.

There were little differences in ecophysiology, but vine vigour was significantly altered on the heuweltjie-associated vines, exhibiting excessive vegetative growth in Stellenbosch, leading to variations in berry characteristics on and off the heuweltjies, with the opposite trend observed for Robertson. Lower sugar and

alcohol percentages and higher titratable as well as malic acid concentrations were observed in the wines emanating from the heuweltjies in Stellenbosch. Sensory analyses showed lower astringency and alcohol burn were detected in the Cabernet Sauvignon heuweltjie wines compared to the non-heuweltjie wines in the Stellenbosch study area. No differences were observed in the wines from the Robertson study area, but fruitiness was significantly lower in the Shiraz heuweltjie-wines when compared to the non-heuweltjie wines. We found that differences in soil water content between heuweltjies and its adjacent soils was the most prominent difference, and was probably the underlying factor that affected the soil-grapevine characteristics.

Our study contributes significantly to the understanding of the legacy of these landscape features in determining soil properties, ecophysiology and berry and wine quality of vines growing on and off heuweltjies. The results of our study also suggest that some consideration may be given to heuweltjies as landscape features within vineyards blocks that may affect wine style and quality, and that vineyard management practices may be used to manipulate these outcomes.

2. Problem identification and objectives

State the problem being addressed and the ultimate aim of the project.

Heuweltjies are landscape features commonly observed in vineyards and natural veld, putatively formed by a termite species, and occupied by the extant termite species Microhodotermes viator*. Heuweltjies in natural veld show significant differences from surrounding soil in physical, chemical and hydrological properties. These differences results in different vegetative communities. From visual observation, crop physiology and vigour of* Vitis vinifera *may be influenced by the legacies of heuweltjies, even decades after cultivation. It is not clear, however, what these differences are, and whether these differences are similar in mesic and arid areas (e.g. the Stellenbosch and Robertson areas). The role of changes in vigour due to the presence of heuweltjies on wine characteristics has also never been quantified.*

Thus the overarching objective of our project is to determine what the effects are of the persistence of heuweltjies in cultivated landscapes in mesic and arid climates (the Stellenbosch and Robertson areas, respectively) for grapevine vigour and physiology, and what advantages and/or disadvantages this lend to agricultural activities (culture, harvesting and wine making).

The specific objectives were:

1. To determine underlying basic soil properties of heuweltjies and adjacent non-heuweltjie areas at one site each in two regions (Stellenbosch and the Robertson valley), and at three blocks within each site

2. To determine vigour of grapevines growing at one site each in two regions (Stellenbosch and the Robertson valley), on heuweltjies and in adjacent non-heuweltjie areas

3. To determine physiological traits/properties of grapevines growing at one site each in two regions (Stellenbosch and the Robertson valley), on heuweltjies and in adjacent non-heuweltjie areas

4. To determine, at each site and block, the grape characteristics and grape juice and wine chemical and sensory attributes from vines growing on heuweltjies and in adjacent non-heuweltjie areas

5. To determine the contribution of heuweltjies to vine productivity and wine quality of vineyard blocks

3. Workplan (materials & methods)

List trial sites, treatments, experimental layout and statistical detail, sampling detail, cold storage and examination stages and parameters.

In 2009 one site (farm) each in the Stellenbosch area (mesic; Ernie Els Wines) and one in the Robertson valley (arid; Graham Beck Wines) was selected. At each site one block was selected with clearly-defined heuweltjies and off heuweltjie areas (showing at least 4-5 heuweltjies). The precise site locations and sampling points were determined using a combination of remote sensing, through interaction with farmers and field surveying. Some consideration as given to carrying out the study at the sites used by Shange et al (2006), however, this was not deemed feasible as vines in that particular vineyard have recently been removed. In each block four heuweltjies were sampled, along with four paired off-heuweltjies sites. We used a sampling strategy where the heuweltjie was divided into sections, and soil samples taken from each section (centre, edge). At the same time we selected five representative vines (based on measured stem circumference); these vines were used for measuring vegetative parameters and for foliar sampling. For each heuweltjie a paired off-heuweltjie area was selected.

A student, Stefan Bekker carried out the soils, growth and berry and wine analyses as part of his MSc thesis. In a previous study the winter period was found to be the most stable period for soil nutrient sampling, and we carried out our initial soil sampling was carried out from April to June 2009, the winter period. Samples were taken from three depths: 0-30cm, 30-60cm, 60-90cm. The five soil samples per heuweltjie were bulked for every soil depth, and the same strategy was followed for the off-heuweltjie plot. The following soil characteristics were determined: soil texture, pH, electrical conductivity, bulk density, soil total C, organic C, total N available P (Bray 2), available cations and micronutrients. We installed access tubes (external diameter: 44 mm) for a neutron probe in August 2009. Two access tubes were installed per heuweltjie (one in the centre and one near the edge) and two was installed in the off-heuweltjie areas. After calibration of the instrument we determined available water on a monthly basis for the period of one year (Milestone 5). At each monthly date readings were taken at 20cm, 50cm and 80cm depths.

We aimed to compare our results with those of Shange et al 2006, and therefore planned to determine grapevine vegetative characteristics during the pruning season, after bud burst, at 50% flowering and after harvest. However, a severe windstorm occurred in Stellenbosch in January 2010 and another at Robertson, we were unable to carry out all the productivity measures. Damage was, however, confined to the leaves and there was no evidence that berries were also affected. Thus, where possible leaf canopy density was determined using a ceptometer. Phenological information was collected where possible, considering that damage occurred to the *vines due to the windstorms. In concert with the plant metric measurements described above, we measured stomatal conductance using a Decagon porometer.*

Also at these sampling dates we measured xylem water potential at predawn and at midday. During harvesting, foliar samples were taken for analysis of carbon isotopes (intrinsic water use efficiency). Foliar samples were analysed for total N and C (included as part of the analysis at the Archaeometry Unit at the University of Cape Town). These samples were due to be analyzed for phosphorus and cations, however, this part of the analysis was not carried out, mainly due to the fact that we carried out more intensive measurements in Robertson than planned. Initially, we planned to scale down measurements in Robertson and concentrate on the Stellenbosch area, however, we put more emphasis on some of the other measurements and sampling in Robertson so as to produce comparative results (e.g. winemaking).

About 50 grapes were hand-harvested approximately 1 month before actual harvest at each site in both Stellenbosch and Robertson to measure the sugar content, titratable acidity (TA) and pH. Grapes were selected randomly from bunches on and off the heuweltjie, and we were careful to ensure that grapes were selected from all parts of the bunch, e.g. front, back, top, bottom.

A similar strategy was followed for selection of berries for microvinification, wine chemical analyses and wine sensory analyses, where we used a trained tasting panel; this was carried out at the ARC- Infruitec in Stellenbosch. Samples are to be chemically analysed for pH, TSS, potassium, TA and malic acid.

The full set of milestones and response (achievements) to the milestones are given in the following table:

Milestone	**Achievement**
1. Recruitment and appointment of MSc student January 2009	*A student, Stefan Bekker was recruited and registered for an MScAgric degree*
2. Site Selection	*Two sites elected, one in Robertson (arid) and one in the Stellenbosch area (mesic)*
3. Soil sampling and analysis	*Soil profile description and soil physicochemical analyses carried out*
4. Foliar sampling and analysis	*Foliar samples were carried out, however, scaled down somewhat as more emphasis were placed on wine and berry analyses than originally planned*
5. Basic hydrological measurements	*Carried out and both the mesic and arid sites*

6. Plant growth, physiological and phenological measurements	*Carried out and both the mesic and arid sites*
7. Wine making and testing	*Carried out and both the mesic and arid sites*
8. Presentation of preliminary results at the Fynbos forum	*Not achieved, however, data was presented at the South African Association of Botanists Conferences in January 2011 in Grahamstown (oral presentation), and was presented at the MEDECOS XII Mediterranean ecosystems conference in Los Angeles in September 2011 (poster presentation)*
9. Preparation and submission of MSc and scientific publication(s)	*Partially completed. MScAgric thesis submitted and student graduated; peer-reviewed publications in progress.*

4. Results and discussion

State results obtained and list any benefits to the industry. Include a short discussion if applicable to your results. This final discussion must cover ALL accumulated results from the start of the project, but please limit it to *essential* information.

The project was carried out at two sites differing in annual rainfall, namely Ernie Els Wines (before 2010 part of Rust-en-Vrede wines), and at Graham Beck Wines at Robertson. The rainfall differs markedly, with the Stellenbosch site receiving 673 mm and Robertson 255 mm per annum (long term means). This afforded the opportunity to compare characteristics of heuweltjies and non-heuweltjie soils at the two sites, growth trends and wine and berry characteristics. It is important to note that we did not attempt to compare heuweltjie and non-heuweltjie soils, growth trends and wine and berry characteristics directly between the two regions as the wine cultivars were different (Cabernet Sauvignon in Stellenbosch and Shiraz in Robertson), however, trends can be deduced.

Our results show that several soil properties differed significantly between heuweltjie and non-heuweltjie areas at both sites, and soil profiles also showed visual differences between the heuweltjies and non-heuweltjie areas (Figure 1).

Figure 1: *Remnants of a calcrete hardpan in a profile of a heuweltjie at the Robertson study area.*

Soil texture was different between heuweltjie and non-heuweltjie areas, despite the history of cultivation at both sites. Higher pH (Robertson; Figure 2) and exchangeable cation values (Stellenbosch; Figure 3) were found on the heuweltjie when compared to the adjacent surrounding soils.

These results suggest that soil preparation (e.g. ripping and other types of preparation) is not able to extinguish the legacy effect of heuweltjies, which may be carried over into hydrology and ecophysiology.

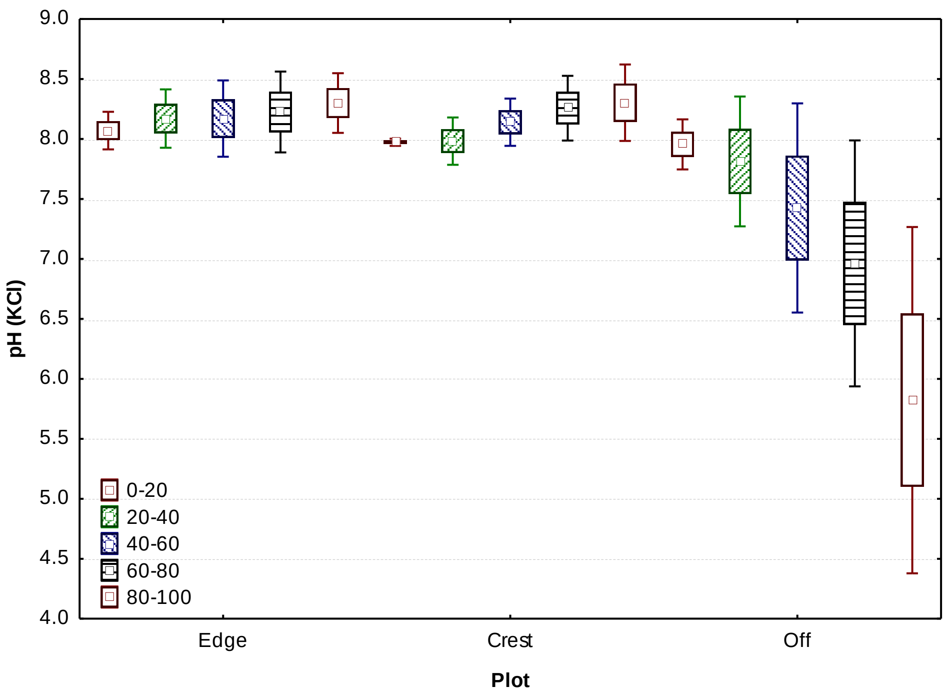

Figure 2*: Average pH values on the different plots on and off the heuweltjie in the Robertson study area at different depths. n=4.*

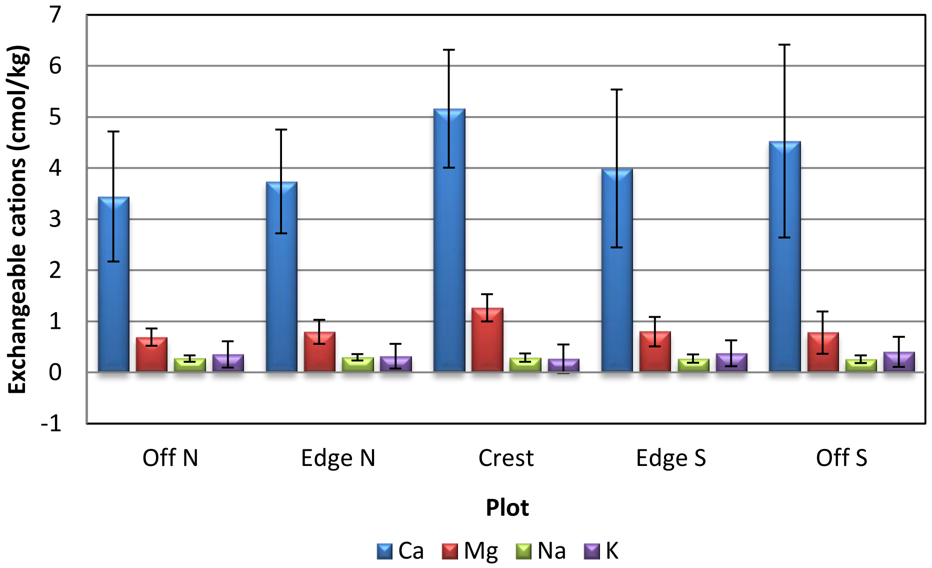

Figure 3: *Exchangeable cation values on the different plots on and off the heuweltjie in the Stellenbosch study area. n=4.*

Indeed, through examination of the soil water content readings, it is clear that differences in water content exist between heuweltjie and non-heuweltjie plots. In the Stellenbosch study area (Table 1), the heuweltjies exhibited higher soil water content than off the heuweltjies. The difference was not significant though. In Robertson (Table 2) the opposite were discerned, with the non-heuweltjie plots exhibiting a higher soil water content than the heuweltjie plots. The differences proved much more substantial in Robertson.

Table 1*: Average volumetric soil water contents of heuweltjie and non-heuweltjie plots in the Stellenbosch study area over the course of seven months (November 2009 to May 210), as well as the evapotranspiration (ET) that occurred from that plots.*

	Heuweltjie soil water content (mm)							
	Date	November	December	January	February	March	April	May
Depth (cm)	0-30	43.9	25	16.5	13.7	22.3	19.1	46.7
	30-50	41	27.9	18.6	13.5	19	19.2	41.6
	50-80	40.6	32	21.6	15.2	19.4	19.9	42.7
	80-100	47.9	41.8	24.1	19.4	23.7	23.8	43.9
	Total	173.3	126.6	80.8	61.8	84.4	82	174.9
	Difference	x	46.7	45.9	19	-22.6	2.4	-93
	Rainfall (mm)	x	0.25	7.87	0.51	37.07	10.41	141.97
	Irrigation (mm)	x	0	0	13.8	24.8	0	0
	ET (mm)	x	46.9	53.8	33.3	39.2	12.8	49
	ET/day (mm)	x	2.1	2	1.3	1.5	0.4	1.4
	Non-heuweltjie soil water content (mm)							
	Date	November	December	January	February	March	April	May
Depth (cm)	0-30	35.9	22.4	16	11.7	20.1	16.4	42.4
	30-50	34.9	24.9	14.6	10	18.8	15.9	36.1
	50-80	37.9	30	17.5	13.9	20.8	19.1	41.7
	80-100	45.3	38.8	25.1	20.2	25.6	23.7	44.8
	Total	153.9	116	73.1	55.8	85.3	75.1	165

Difference	x	37.9	42.9	17.4	-29.5	10.2	-90
Rainfall (mm)	x	0.25	7.87	0.51	37.07	10.41	141.97
Irrigation (mm)	x	0	0	13.8	24.8	0	0
ET (mm)	x	38.1	50.7	31.6	32.3	20.6	52
ET/day (mm)	x	1.7	1.9	1.2	1.2	0.6	1.5

***Table 2**: Average volumetric soil water contents of heuweltjie and non-heuweltjie plots in the Robertson study area over the course of seven months (November 2009 to May 2010), as well as the evapotranspiration (ET) that occurred from that plots.*

	Heuweltjie soil water content (mm)							
	Date	November	December	January	February	March	April	May
Depth (cm)	0-30	13.7	18.7	16	17.1	17.8	14.3	17.2
	30-50	11.4	14	12.8	11.8	13.8	13.1	14.8
	50-80	11.3	11.3	11.4	9.2	12.2	12.6	14
	80-100	14.5	12.3	12	8.7	11.7	13.9	14.8
	Total	51	56.3	52.2	46.8	55.6	53.8	60.8
	Difference	x	-5.3	4.1	5.4	-8.8	1.8	-7
	Rainfall	x	5.4	9	4.6	43.8	11.8	3.9
	Irrigation	x	100	108.4	113.5	103.4	100	60
	ET	x	100.1	121.5	123.5	138.4	113.6	56.9
	ET/day	x	4.4	4.3	4.3	5.1	3.2	2.3
	Non-heuweltjie soil water content (mm)							
	Date	November	December	January	February	March	April	May
Depth (cm)	0-30	14.9	17.3	15.9	15.7	19.5	17.7	16.6
	30-50	14.4	15.1	15.4	15.4	16.8	16.6	15
	50-80	16.3	14.5	16.8	14	17	18.2	15.7
	80-100	18.7	17.4	18.6	15.4	17.9	20.6	17.3
	Total	64.3	64.2	66.7	60.4	71.2	73.2	64.5
	Difference	x	0.1	-2.5	6.2	-10.7	-2	8.7
	Rainfall	x	5.4	9	4.6	43.8	11.8	3.9
	Irrigation	x	100	108.4	113.5	103.4	100	60
	ET	x	105.5	114.9	124.3	136.5	109.8	72.6
	ET/day	x	4.6	4.1	4.3	5.1	3	2.9

The exact occurrence in time of the vine's phenological stadia differed on and off the heuweltjies. At Ernie Els, budburst occurred much later on the vines associated with the heuweltjies than the non-heuweltjie vines. Berry maturation was also delayed on the heuweltjies in comparison to the non-heuweltjie vines. Therefore, we can conclude that the different phenological stadia were induced later on the heuweltjie plots. The opposite was true of the Robertson study area.

As observed with other characteristics, contrasting observations were made on vine vigour between the two regions. In the Stellenbosch study area, apparently due to the higher soil water content observed on the heuweltjies, more vigorous growth of the grapevines and thus denser canopies associated with the heuweltjies were observed. In contrast, in Robertson, lower soil water content was found on the heuweltjies, resulting in *lower vine vigour with less dense canopies. These differences were apparent in the ceptometer values for Stellenbosch and Robertson (Table 3).*

***Table 3**: Means (±SE) of the light radiation (μ E m^{-2} s^{-1}) in the canopy of grapevines on and off heuweltjies as well as the average percentage of light reaching the bunch zone in different stadia of the season in the Stellenbosch and Robertson study area. Sites were compared using a paired t-test. n = 4; this value was arrived at after averaging the 4 vines for each heuweltjie and non-heuweltjie area. Means followed by the same letter are not significantly different (p > 0.05; paired t-test).*

Average ceptometer value (Stellenbosch)					
Plot	December	January	February	March	April
Non-heuweltjie	26.75(±4.03)a	35.94(±1.68)a	62.81(±3.18)a	80.31(±1.66)a	92.19(±8.410a
Heuweltjie	31.81(±7.25)a	39.69(±3.19)a	33.94(±3.26)b	30.5(±0.97)b	17.63(±2.52)b
Average ceptometer value (Robertson)					
Plot	December	January	February	March	April
Non-heuweltjie	26.69(±3.45)a	29.65(±1.65)a	28.47(±1.01)a	Not determined	Not determined
Heuweltjie	38.56(±5.33)a	57.69(±3.13)b	67.44(±2.21)b	Not determined	Not determined

We also observed differences in the pruning masses of experimental vines on and off the heuweltjies (Table 4). Thus, vines on heuweltjie exhibiting significantly stronger vegetative growth in comparison to non-heuweltjie vines in the Stellenbosch study area. This could lead to a higher degree of shading with subsequent lower sun exposure, and this could affect accumulation of sugar in the berries. Again, the opposite was observed in Robertson.

***Table 4**: Means (±SE) of the results obtained from the trial test done on the pruning mass of the grapevines associated with soils on and off the heuweltjies in the Stellenbosch study area (All main shoots were topped). n = 4; this value was arrived at after averaging the 4 vines for each heuweltjie and non-heuweltjie area. Means followed by the same letter are not significantly different (p > 0.05; paired t-test).*

Stellenbosch							
Plot	Main shoot mass (g)	Main shoot length (cm)	# Nodia	# Lateral shoots	Lateral Mass (g)	Lateral length (cm)	# Nodia
On	135.43 (±8.42)a	145.34 (±9.45)a	22.38 (±2.53)a	4.56± (0.62)a	80.64 (±18.42)a	193.77 (±32.37)a	59.06 (±11.73)a
Off	85.83 (±3.76)b	108.51 (±10.13)a	19.50 (±0.68)a	3.31 (±0.33)a	42.69 (±9.75)a	109.25 (±17.22)a	35.38 (±6.61)a
Robertson							
Plot	Main shoot mass (g)	Main shoot length (cm)	# Nodia	# Lateral shoots	Lateral Mass (g)	Lateral length (cm)	# Nodia
On	89.86 (±2.04)a	152.94 (±16.40)a	19.88 (±3.09)a	2.50 (±0.00)a	108.89 (±15.75)a	19.88 (±2.23)a	25.48 (±2.08)a
Off	129.84 (±18.97)a	220.61 (±15.61) a	31.38 (±4.19)b	2.69 (±0.21)a	143.43 (±13.18a)	32.56 (±2.28)a	28.28 (±5.14)a

In spite of the differences in soil hydrological characteristics, we observed no major differences in physiology (predawn and midday water potential and stomatal conductance) between heuweltjie and non-heuweltjie areas at either farm. We found that stomatal conductance tended to be at the lower end of the spectrum for Vitis vinifera*. At the Stellenbosch study site, the stomatal conductance values seemed to be higher on the vines associated with the heuweltjies when compared to the non-heuweltjie vines, while the opposite was true for Robertson. These results could also be linked to the higher and lower soil water content associated with the heuweltjies in the Stellenbosch and Robertson study areas respectively. The leaf water potential reading yielded no significant results.*

We observed significant differences between heuweltjie and non-heuweltjie wine when we tested berries and wines for sugar -, acid – and alcohol content (Table 5), with significant variations in sensory attributes such as astringency and alcohol burn sensation. Minor variations were observed in the Robertson study area, but the major differences emerged in the Stellenbosch region.

Table 5: *Means (±SE) of the sampled wine chemical properties of the wines produced from the grapes emanating from the Stellenbosch and Robertson study areas, as analyzed by the Winescan. n = 3. Means followed by the same letter are not significantly different (p > 0.05; paired t-test).*

				Stellenbosch					
Plot	**Ethanol (% v/v)**	**Titratable acidity (g/L)**	**Volatile acid g/L**	**Lactic acid (g/L)**	**Malic acid (g/L)**	**pH**	**Glycerol (g/L)**	**Fructose (g/L)**	**Glucose (g/L)**
On	14.11 (±0.24)a	5.87 (±0.04)a	0.20 (±0.06)a	<0.3a	4.57 (±0.07)a	3.70 (±0.02)a	11.58 (±0.07)a	0.61 (±0.06)a	<0.3a
Off	16.12 (±0.15b	5.29 (±0.06)b	0.26 (±0.02)a	<0.3a	3.76 (±0.10)b	3.80 (±0.02)b	12.23 (±0.15)b	1.11 (±0.03)b	<0.3a
				Robertson					
Plot	**Ethanol (% v/v)**	**Titratable acidity (g/L)**	**Volatile acid g/L**	**Lactic acid (g/L)**	**Malic acid (g/L)**	**pH**	**Glycerol (g/L)**	**Fructose (g/L)**	**Glucose (g/L)**
On	14.42 (±0.73)a	4.91 (±0.14)a	0.37 (±0.06)a	<0.3a	3.47 (±0.2)a	3.7 (±0.02)a	11.03 (±0.31)a	0.65 (±0.07)a	<0.3a
Off	14.26 (±0.74)a	4.72 (±0.13)a	0.43 (±0.05)a	<0.3a	3.48 (±0.09)a	3.8 (±0.05)a	10.66 (±0.2)a	0.77 (±0.1)a	<0.3a

As vines associated with the heuweltjies exhibited more vigour in Stellenbosch, véraison and ripening were delayed, which was associated with shading within the canopy (Principle component analysis; Figure 3). This caused a significant decrease in the sugar content, particularly fructose, and increases in acidity, and higher concentrations of titratable and malic acid. Thus, if heuweltjies form a significant part of the total area of a vineyard block, it is likely that this affect vine phenology and wine characteristics, a factor that should be kept in mind when planning harvesting, winemaking and farming practices.

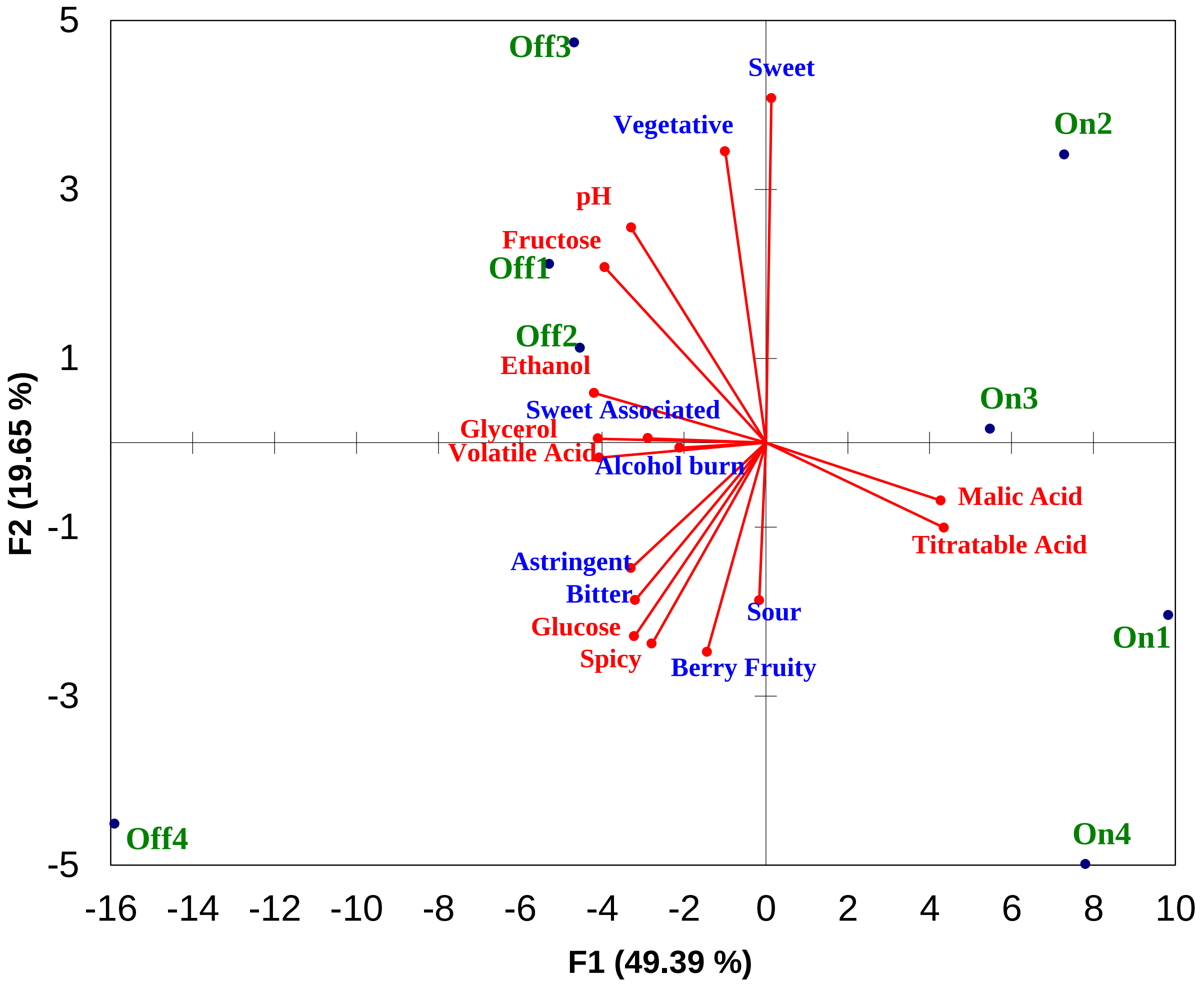

Figure 3: *Principle Component Analysis bi-plot with scores (On - and Off-plots) and loadings (chemical - together with sensory attributes) of Cabernet Sauvignon wines produced from four heuweltjie and – non-heuweltjie plots in the Stellenbosch study area.*

In conclusion, some differences in soil characteristics (both physical and chemical) were observed, and soil hydrology also showed that heuweltjies might have different soil moisture availability; this did not translate into physiological differences. However, this needs to be investigated further, as more sophisticated physiological instrumentation than that available during our study (e.g. photosynthesis measurements using and infrared gas analyser) may show how soil characteristics influence plant functioning. Despite the apparent lack of physiological differences, growth and berry characteristics differed between heuweltjies and non-heuweltjie areas. The climate does play a role, though, as growth was higher on heuweltjies in Stellenbosch, and lower in Robertson. Partially due to the shading effect of the more vigorous growth and more luxurious leaf growth, berries in Stellenbosch had higher acidity at the same calendar day compared to non-heuweltjie areas, which resulted in wine that had more malic and titrable acid. Thus heuweltjies had a definitive impact on wine *characteristics, which, depending on the contribution heuweltjies makes to the vineyard block, may impact wine style and/or quality.*

At the conclusion of our study, several winemakers and viticulturalists expressed an interest in our results. As an example of an intervention at the level of viticulture practice, the viticulturalist at Rustenburg Wines planted vines on heuweltjies in at least one block at a different density to the rest of the block[1]. Further, at the level of wine-making, after the completion of harvesting for microvinification for our project, the block at Ernie Els Wines were subdivided into heuweljie areas (amounting to about 30% of the block) and non-heuweljie areas, which were harvested separately. This was done after some of the initial data from our project became available, and at the behest of the viticulturist and winemaker; the result is two separate wines, made on a commercial scale. It seems likely that some of our results may be taken up into management of some farms, especially if and when differences in wine quality are obtained. Additionally, at Robertson, the drier of the two sites our data shows that different irrigation scheduling on and off heuweltjies may be an option as significant variation in soil water content on and off the heuweltjies was found.

5. Accumulated outputs

List ALL the outputs from the start of the project.
The year of each output must also be indicated.

- *MSc thesis: Bekker SJ. 2011. Exploiting landscape heterogeneity: An investigation into vigour and physiology of grapevines on and off 'heuweltjies'. Unpublished MSc Thesis, Stellenbosch University*

- *Oral Presentation (SAAB 2011): Booi N, Bekker S, Jacobs SM*, Esler KJ, Milton SJ, Hoffman E, Strever A, Ellis F. 2011. Heuweltjies are hotspots for biogechemical processes and have unique ecohydrological properties, and this affect crop quality even after cultivation. Oral Presentation, SAAB 2011, Rhodes University, Grahamstown, South Africa. (* Presenter).*

- *Poster (Medecos 2011): Jacobs S*, Booi N, Bekker S, Ellis F, Esler K, Hoffman E, Milton S, Strever A. 2011. Landscape Legacies: Biogeochemical and ecohydrological properties of natural and cultivated 'heuweltjies' (mima-like mounds) of the fynbos and succulent karoo in South Africa. Poster accepted for the MEDECOS X11 Conference in Los Angeles, September 6-9 2011. (* Presenter)*

Technology development, products and patents

Indicate the commercial potential of this project (intellectual property rights or a commercial product(s)).

- *No commercial products expected*

[1] Personal Observation, April 2009

Human resources development/training

Indicate the number and level (e.g. MSc, PhD, post doc) of students/support personnel that were trained as well as their cost to industry through this project. Add in more lines if necessary.

	Student level (BSc, MSc, PhD, Post doc)	Cost to project (R)
1.	*MSc*	*R180,000*
2.		
3.		
4.		
5.		

Publications (popular, press releases, semi-scientific, scientific)

Two in preparation

Presentations/papers delivered

Talk*: Booi N, Bekker S, Jacobs SM*, Esler KJ, Milton SJ, Hoffman E, Strever A, Ellis F. 2011. Heuweltjies are hotspots for biogechemical processes and have unique ecohydrological properties, and this affect crop quality even after cultivation. Oral Presentation, SAAB 2011, Rhodes Universite, Grahamstownm, South Africa. (* Presenter).*

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4. Total cost summary of project

	Year	CFPA	Deciduous	DFTS	Winetech	THRIP	Other	TOTAL
Total cost in real terms for year 1	***2009***				***85,000***			***85,000***
Total cost in real terms for year 2	***2010***				***95,000***			***95,000***
Total cost in real terms for year 3								
Total cost in real terms for year 4								
Total cost in real terms for year 5								
TOTAL								