Efficiency of irrigation practices for table grapes in the Hex River Valley

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DECLARATION

I, the undersigned, hereby declare that the work contained in this Masters thesis is my own original work and that I have not previously in its entirety or in part submitted it as any university for a degree

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Abstract

In order to produce table grapes of export quality economically, irrigation must be practised conservatively without adversely affecting the crop. To use water as conservatively as possible effective irrigation scheduling practices must be applied. The highest water use efficiency (WUE) is only possible if irrigation scheduling practices lower the amount of water applied, while at the same time they increase the yield.

The first aim of this project is to investigate whether current irrigation practices make efficient use of water by comparing irrigation requirements determined using theoretical models with actual irrigation applied for two seasons (2005/6 and 2006/7). Secondly, the effect of cumulative irrigation on the chemical status of soil in 16 blocks was investigated to establish whether nutrient leaching as a result of differential water use may have had an influence on yield.

Six blocks (three dripper and three microsprinkler blocks) were selected and irrigation requirements were determined using evaporation pan calculations, SAPWAT and Vinet and compared with actual irrigation applications. Furthermore, a yield-irrigation index (kg/m^3) and an income-irrigation index (R/m^3) were determined for each of the six blocks and compared.

To investigate the effect of cumulative water use on the chemical status of the soils of 16 blocks, soil samples were taken and analysed for pH (1M KCl), EC (1:5); soluble cations and anions (Ca, Mg, Na, K, SO_4, NO_3, and Cl), ammonium acetate extractable cations (Ca, Mg, Na and K) and micro elements (Zn, Fe, Mn, Cu and B).

The irrigation requirements predicted by the different irrigation scheduling methods are variable. For Vinet, the irrigation requirement determined for microsprinkler irrigation is much higher than that determined using the evaporation pan or SAPWAT approaches. Comparison of the irrigation applied to each of these blocks does not clarify whether any irrigation scheduling takes place. Results showed a relationship between the yield-irrigation index and income-irrigation index. It has not however been verified whether this relationship is statistically significant.

Opsomming

Om tafeldruiwe van uitvoergehalte ekonomies te produseer, moet bespoeiing optimaal aangewend word sonder om die oes te benadeel. Om water so optimaal moontlik te verbruik, moet effektiewe besproeiingskedulering toegepas word. Die hoogste waterverbruiksdoeltreffendheid (WVD) is slegs moontlik indien besproeiingskedulering die hoeveelheid water toegedien verminder en oesopbrengs terselfdertyd verhoog.

Die eerste doel van hierdie projek is om te ondersoek of die huidige besproeiingsskeduleringspraktyke van die boere in die Hexriviervallei effektief is deur die besproeiingsbehoeftes te vergelyk – deur gebruik te maak van teoretiese modelle – met die werklike besproeiing van twee seisoene (2005/6 en 2006/7). Die tweede doel was om te bepaal of kumulatiewe besproeiing enige effek gehad het op die chemiese status van die grond. Daar is spesifiek gekyk na die grond in sestien blokke om te bepaal of differensiële besproeiingshoeveelhede tot voedingstofloging gelei het en wat die invloed daarvan op opbrengs was.

Ses blokke (drie drup- en drie mikrosproeierbesproeiingsblooke) is geselekteer en besproeiingsbehoeftes bepaal deur gebruik te maak van verdampingspanberekeninge, die SAPWAT- en Vinetmodelle. Hierdie is vergelyk met werklike besproeiingstoepassing. Vergelykings is getrek tussen ‘n opbrengsbesproeiingsindeks (kg/m^3) en ‘n inkomstebesproeiingsindeks (R/m^3) wat bepaal is vir elk van die ses blokke.

Om die effek van kumulatiewe waterverbruik op die chemiese status van die grond van die 16 blokke te bepaal is grondmonsters ontleed vir pH (1M KCl); elektriese geleiding (EG) (1:5); water ekstraheerbare katione en anione (Ca, Mg, Na, K, SO_4, NO_3 en Cl); ammonium asetaat ekstraheerbare katione (Ca, Mg, Na en K) en spoorelemente (Zn, Fe, Mn, Cu en B).

Die besproeiingsbehoeftes wat deur verskillende besproeiingskedules bepaal is, toon ‘n redelike variasie. Die besproeiingshoeveelhede vir mikrobesproeiing soos bepaal deur die Vinet-model was heelwat hoër as die van SAPWAT- en die verdampingspan-metodes. ‘n Vergelyking van die toegediende besproeiing aan elke blok kan nie bewys met enige sekerheid of enige besproeiingskedulering plaasvind nie. Resultate toon ‘n verwantskap tussen die opbrengsindeks en die

inkomstebesproeiingsindeks. Geen aanname kan gemaak word aangaande die verwantskap en of dit statisties betekenisvol is nie.

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Chapter 1
A review of soil water relationships and chemical properties of the soil as factors contributing to efficiency of water use by table grape vineyards

1.1 Introduction

For plants to grow optimally, an adequate water supply is required. In humid areas, precipitation occurs frequently with the result that plants very rarely experience water deficiencies. In sub-humid and semi-arid regions however, precipitation is very often limited during the growing season. Crop growth can subsequently be hindered, because plant growth is sustained by water that is stored in the soil. Under these circumstances irrigation is required to ensure that a crop can be produced. It is important that irrigated agriculture takes part in efforts to conserve water because any water removed for irrigation reduces the amount of water for future use (Unger and Howell, 1999).

Ensuring that it is used sparingly and thoughtfully can conserve water. A term, which encompasses this concept, is water use efficiency (WUE). It is defined as the yield of crop produced per unit volume of water applied (Equation 1.1).

$$WUE = P/\Delta W \qquad (1.1)$$

where P is the crop produced or yield (kg/ha) and ΔW is the volume of water applied (mm or m^3) (Fried and Barrada, 1967; Hillel, 1998; van der Watt and van Rooyen, 1995).

Factors which influence the volume of water applied (ΔW), are defined by Equation 1.2.:

$$\Delta W = (I + P) - (R + D + E + T) \qquad (1.2.)$$

where I is the amount of irrigation applied (mm), P is the amount of precipitation fallen (mm), R is the amount of water lost due to runoff (mm), D is the amount of water that undergoes deep percolation (mm), E is the amount of water that evaporates from the soil and/or water surface (mm) and T is the amount of transpiration (mm) (Hillel, 1998). It is these factors which play a large part in determining the amount of irrigation required by a crop.

It can be deduced from Equations 1.1 and 1.2 that by lowering ΔW and/or increasing P, WUE of any crop can be increased. This can be done by considering a variety of practices, such as weed, disease and pest control, reducing evaporative losses of water from the soil surface, application of fertilizers, adjusting the irrigation frequency and preventing over-irrigation (Fried et al., 1967). This study however concentrates on applying irrigation efficiently and for this reason the focus of this chapter is mainly on irrigation. It should be mentioned here that in order to reduce irrigation requirements controllable factors such as runoff, drainage, evaporation and transpiration should be kept to a minimum in order to obtain the same yield. This chapter therefore briefly describes how the environment, crop management practices and physical characteristics of the soil will influence irrigation requirements. The effect of irrigation on soil nutrients will also be discussed and reference will me made to the ultimate effect on yield.

1.2 Environmental factors

The irrigation requirement of table grapes is largely dependent on the amount of evaporation and transpiration (evapotranspiration) that is lost by a vineyard. Evapotranspiration is in turn determined by the prevailing environmental conditions (radiation, temperature, precipitation, relative humidity and wind). Having knowledge and an understanding of how these influence water losses from table grape vineyards will aid in efficient irrigation management.

Evaporation is the process in which liquid water is converted to water vapour and removed from an evaporating surface. *Transpiration* is the vaporization of liquid water in plant tissues and the vapour removal by the atmosphere. Energy, provided by direct solar radiation and air temperatures, is required to convert the water molecules from there liquid state to vapour. The difference in vapour pressure between the evaporation surface and the surrounding atmosphere is the driving force that removes the water vapour. As evaporation continues, the surrounding atmosphere slowly becomes saturated which forces the process to slow down. Replacement of the saturated air with drier air is largely dependent on wind speed (Allen et al., 1998).

Radiation emitted from the sun (solar radiation) is the driving force of all physical and chemical processes on earth. Most of the solar radiation which reaches the earth's surface is reflected back into space (long-wave radiation), while the radiation that is absorbed directly from the sun (short-wave radiation) by the earth's surface heats it up, providing the energy required to convert water from liquid to gas (Rose, 2004). Solar radiation that reaches the plant surface can be used for photosynthesis, transpiration and/or convection, it can be transmitted by the leaves or it can be emitted as heat energy. Solar radiation that reaches the soil surface is used for evaporation which can take place from open water surfaces and/or from moist terrestrial surfaces (Mullins, Bouquet and Williams, 1992; Rose, 2004).

Temperature is the measure of heat (thermal) energy emitted by an object that absorbs solar radiation and affects the amount of water vapour which can be held by the air. This is because the vapour concentration of the air is a simple function of temperature. Furthermore, if the vapour concentration of the air is much lower than that of the plant leaf or soil surface, transpiration and/or evaporation will take place rapidly. This is because water vapour moves along a vapour pressure gradient (Plaut and Moreshet, 1973; Rose, 2004).

Precipitation is water in either liquid or solid form that falls to the ground from the atmosphere. Rainfall, snow, dew, sleet and hail are all natural examples of precipitation and are able to replenish the soil water. Important characteristics of rainfall in particular, which influence WUE, are intensity and duration, since they will determine how much water will be lost via runoff and drainage. It is important to keep in mind that often during a precipitation event the water does not reach the soil surface. Especially in cases where vegetation cover is dense, water will be intercepted by the leaves and stems of the plants, where it can evaporate before reaching the soil surface (Blair and Fite, 1965; Cole, 1970; Rose, 2004).

Wind is the horizontal displacement of air particles. When the air particles become displaced, a difference in atmospheric pressure is created across which air will move, resulting in wind. Wind removes water vapour directly at the soil and/or leaf surface, creating a gradient along which water vapour can move, thus increasing the rate of evapotranspiration. However, experiments have shown that when the wind speed is very high, the conductance is lowered, limiting transpiration (Cole, 1970; Kombriger, Kliewer and Lagier, 1984).

1.3 Crop management factors

The degree of shading by the canopy of the crop and the amount of water available at the evaporating surface are factors that will affect evaporation from the soil surface. Transpiration from crops mainly takes place through their stomata. The water, along with some nutrients, is taken up by the roots of plants and is mostly lost via transpiration; only a small fraction is used for other plant processes. Although transpiration is also influenced by environmental conditions, it is largely dependent on the crop's characteristics and cultivation practices (which not be discussed in detail) (Allen et al., 1998).

Crop management practices can affect the severity with which environmental factors influence evapotranspiration and consequently irrigation requirement. The row direction of a vineyard, for example, will influence the amount of radiation intercepted by the block and the higher the intensity of the solar radiation, the higher the evapotranspiration. In South Africa, a vineyard positioned on a north-facing slope will intercept more radiation than one on a south-facing slope. The result is that the north-facing vineyard will experience higher temperatures than a south-facing one and consequently have higher evaporative demands (Mullins et al., 1992).

Vine density (vines/ha) affects the vine's growth and productivity for its entire life, because vines compete with each other for water, nutrients and space. The vine density influences the amount and rate of water uptake and the density of the above ground vegetative growth. Shoot growth and leaf area per vine decrease with increased vine density. It is likely that the decreased shoot growth is due to more efficient and rapid utilization of soil water (Mullins et al., 1992).

In order to reduce the rate of transpiration without negatively affecting the photosynthetic rate of the vineyard and consequently carbohydrate production in the grapevines, the older leaves situated at the top of the shoot can be removed. These leaves transpire at the same rate as the new leaves, but photosynthesise less efficiently. Removal of the older leaves will subsequently reduce vine leaf density and the water use of the crop, thus decreasing irrigation requirement (Candolfi-Vasconcelos et al., 1994).

Trellis systems influence the soil-water relations by affecting the amount of radiation exposure of the vine and the soil, ultimately influencing the evapotranspiration of the vineyard. By spreading the canopy in such a way that more leaves are exposed to radiation interception, for example, the photosynthetic rate of the vine is increased, while the amount of soil exposed to the sun is decreased, lowering the amount of evaporation from the soil surface. Furthermore, the trellis system will influence the amount of vegetative growth and yield size. A trellis system that encourages greater vigour and yield will also encourage greater root numbers, in particular fine root growth, thus improving the nutrient uptake of the vine (Mullins et al., 1992).

Mulch is any material that is placed on the soil surface to reduce evaporation, control weeds and obtain beneficial changes to the soil environment. Mulches can be plant residues, manure, gravel or plastic sheets, for example. Any mulch that reduces the effect of environmental factors will influence the evaporative demand. Mulches that are comprised of plant residues must be sufficiently thick to be effective in reducing evaporation. This is because the air flow through these materials is elevated due to their high porosity. Mulching to restrict weed growth is an effective way to reduce evapotranspiration because weeds are able to extract large quantities of stored soil water. Using gravel mulches enhances the infiltration of the water into the soil and may suppress evaporation (Brady, 1974; Hillel, 1998; Lal and Shukla, 2004).

1.4 Irrigation

Vineyard irrigation determines the vigour of the vineyard and affects the microclimate and canopy size, thus encouraging excessive growth when too much water is applied. The amount of water needed by a vineyard is largely dependent on the soil water availability, leaf area and evaporative demand of the crop. In order to ensure good yields in semi-arid climates, irrigation must be applied to maintain and regulate grapevine growth. The grapevine water requirement is characterised by lower water use before bloom and after harvest, up until leaf fall, with higher requirements for the rest of the season (Cuevas, Baeza and Lassarrague, 1999; Hillel, 1998; Mullins et al., 1992).

Irrigation deficit is the constraint with greatest influence on grape production under semi-arid conditions. This along with high leaf water potential, high radiation exposure and high temperatures, slowly reduce vine growth and yield. Furthermore, there is a major increase in the leaf surface area under irrigated conditions and consequently on photosynthesis. When the vine is placed under water stress, a reduction in stomatal conductance and leaf photosynthesis is observed (Cuevas et al., 1999; Escalona, Delgado and Medrano, 1997).

Irrigation regime has long-term effects on vine growth and performance. Traditional irrigation practices consisted of a regime where the soil was saturated with water and then exposed to a prolonged period of soil-moisture extraction by the crop. Irrigation scheduling is thus based on soil moisture content and irrigation is applied to bring the soil water back to field capacity. Newer irrigation techniques which take plant and soil properties, as well as meteorological conditions into account, have however been developed. The meteorological conditions have the biggest influence on the evapotranspiration and consequently the irrigation requirement of the crop because the new irrigation techniques do not limit soil moisture content, and therefore allow the grapevine to take up water at a rate which meets its transpirational demands. In this way any moisture stress is prevented during the growing season. Furthermore, there is no longer a need to rely on the storage capacity of the soil and evaporation as a result of runoff and drainage is prevented (Hillel, 1998; Myburgh, 1996; National Research Council, 1996).

1.5 Physical properties of the soil

"Soil morphology is defined as the particular structural properties of the soil profile as exhibited by the kinds, thickness and arrangements of the horizons in the profile and by the texture, structure, colour, consistence and porosity of each horizon" (van der Watt et al., 1995). Soil morphology is therefore a complex term that encompasses the major physical properties of the soil, as discussed below.

A soil horizon is a layer that is more or less parallel to the soil surface. Soil horizons develop certain characteristics, determined by the soil forming factors (parent material, topography, biospheric factors, climate and time). This results in different combinations of the different morphological characteristics that in turn influence the unique behaviour of each soil (Brady, 1974).

Soil texture is determined by the quantities of the soil fractions (sand, silt and clay) present in the soil. Of these, clay has the greatest influence on the properties of the soil because it has a larger surface area, due to its small size. The affinity of a soil for water is a function of the surface area, charge density, nature of the cations on the ion exchange complex and the pore size (determined by the packing arrangement). Studies show that soils with high content of swelling clay minerals and higher specific surface area have a higher affinity for water and release more heat upon wetting than soils with lower clay and non-swelling clay contents. Clays adsorb water strongly because of their surface charges. While clay minerals have net negative surface charges, water molecules are bipolar and are therefore able to associate with the clay minerals. When water molecules are associated with cations on the clay mineral surface, it is referred to as water of hydration, if however it is associated with oxygen through hydrogen bonding; it is referred to as adsorbed water (Lal et al., 2004).

The type of clay will influence whether or not the soil will swell and shrink and to what degree swelling will occur. Certain types of clays swell when wetted or when exposed to highly saline conditions. In these cases the individual platelets of the silicate clay separate and disperse. In these soils, cracks often develop as the soils dry out. The result is that the soils can be dried more deeply than usual, depleting the soil water to a far greater extent. As the soils dry along their vertical cracks, the cracks deepen, allowing even more cracking and drying. In such cases the soil is dried both laterally and vertically (Hillel, 1998).

The soil structure refers to the solid particles and voids within the soil of which there are three broad categories: completely unattached and loose (single-grained), tightly packed in cohesive blocks (massive) and between these extremes (aggregated). To understand the three packing arrangements of soils better, they are described in terms of uniform spheres (Hillel, 1998; Lal et al., 2004):

A. The cubic form is the most open which has the highest porosity.
B. The orthorhombic configuration which is a geometric form that has three axes perpendicular to one another.
C. The rhombohedral configuration which is a six-sided prism, whose faces form parallelograms.

Under natural conditions, close packing is more common than open packing. Furthermore, it is found that smaller particles are usually found within the larger pore spaces. The number and size of the pores will influence the amount of water that can be held by the soil (Hillel, 1998; Lal et al., 2004).

The colour of the soil plays a role in determining how much radiation will be reflected or absorbed by the soil. The ratio between the number of short wave rays being reflected and the total number reaching the surface of the earth is known as albedo (α). The albedo varies according to the colour of the soil surface. White surfaces will have high albedo values (close to 1.0), while the darker the surface, the closer the value is to zero. Thus, the lower the albedo, the warmer the soil will become and the higher the potential for evaporation (Hillel, 1998).

The retention and movement of water in the soil, the uptake and translocation of water in plants and the loss of water to the atmosphere are all energy related processes. For each process, a different type of energy is required. The sum of these energies is known as the soil water potential (SWP) (Equation 1.3).

$$SWP = \Psi_0 + \Psi_{sp} + \Psi_g + \Psi_m \quad (1.3)$$

Where Ψ_0 is the osmotic potential, Ψ_{sp} is the hydrostatic potential, Ψ_g is the gravitational potential and Ψ_m is the matric potential. Each of these factors influence the ability of the water to move from one site to the next and determines the ease with which a plant is able to take up water (Brady, 1974). This in turn determines the ease with which water is able to transpire or evaporate.

Water applied to the soil surface will either penetrate (infiltrate) or run off over the surface (surface runoff). If penetration occurs, the water becomes absorbed into the soil, where the plant can use it. The rate at which the water is able to infiltrate is determined by rainfall intensity and the ease with which water is absorbed by the soil. The infiltration therefore controls the amount of water, which will enter the root zone, and consequently the amount of water lost due to runoff and/or evapotranspiration (Hillel, 1998).

Infiltration can be affected by the susceptibility of the soil to crusting, which in turn is determined by the sodium content of the soil. Sodium-containing soils exhibit varying abilities to exchange the sodium with other cations, determined by the soil's sodium concentration and quantified by the percentage exchangeable sodium (ESP). When this value is greater than 15% the soil becomes dispersed. When sodium ions are adsorbed by the clay surface, the forces of attraction between the clay particles are over-powered by the repulsion forces caused by an increase in distance between particles (the sodium ions increase the radius between clay particles). The result is that clay particles no longer associate with each other and become dispersed. The dispersed clay particles are then able to slide into the soil macro- and mesopores, blocking them up. Subsequent drying out of the soil results in crust formation (Miller and Donahue, 1990).

The downward movement of water through the soil profile is one of the methods in which water is lost (consumed) and is known as percolation. In addition to this, percolation often results in the loss of soluble salts, essential to plant growth. Percolation takes place under saturated conditions, due to the influence of gravity and suction gradients. When the water has drained to field capacity, percolation into the substrata will take place. Thus, maximum percolation takes place in winter when evaporation is lowest (Brady, 1974; Hillel, 1998).

Redistribution is characterised by the movement of water under unsaturated conditions. Its effect is therefore to redistribute the soil water, increasing the wetness of successively deeper soil layers. The importance of redistribution is to determine the amount of water retained at various times by the different layers of the soil in the soil profile and can subsequently affect the water economy of plants. The rate and duration of downward flow determines the effective soil water storage (Hillel, 1998). The rate of redistribution contributes quite significantly to the water consumption of vineyards because it plays a part in determining how much water is taken up by the plant and how much is lost due to drainage.

1.6 Soil nutrients, irrigation and yield

Although water is essential for grapevine growth, it is important to keep in mind that in order to grow optimally, grapevines should not receive essential nutrients in excess or be exposed to shortages thereof. These will result in toxicities and deficiencies, respectively. Toxicities and deficiencies prevent optimal growth and subsequently reduce crop production (Mullins et al., 1992; Weaver, 1976). The macronutrients required in relatively large quantities by grapevines are nitrogen, phosphorus, potassium, calcium, magnesium and sulphur. The trace elements (required in small amounts) are boron, iron, manganese, zinc, molybdenum, copper and chlorine (Weaver, 1976).

Depending on the H^+ concentration of the soil, soils can be divided into one of two classes. It can either be acidic or alkaline. A soil that has an H+ ion concentration that exceeds the OH- concentration is known as an acid soil (Tan, 1992). The soil complex adsorbs large portions of H+ ions that are present in soils as exchangeable cations. These H^+ ions can dissociate and become free H^+ (McBride, 1994; Tan, 1992). Of particular importance however, is that soil acidity has a direct influence on the ease of use of nutrients by the grapevine because it influences their solubility and availability (Linhoff, 2005; Tan, 1992). This is because H^+ ions have high bonding energies, and ions with higher bonding energies tend to displace ions with lower bonding energies. Therefore, the type and concentration of ions present in solution is largely dependent on the concentration of H^+ ions in solution (Bidwell, 1974).

Electrical conductivity is a measure of the concentration of salts (mainly sodium, but also potassium, calcium and magnesium) present in the soil solution and is based on the principle which states that the ease (conductivity) with which an electric current can move through a solution is proportional to the quantity of ions in the solution. More specifically it is an indication of the salt content of the soil (Hazelton and Murphy, 2007; McBride, 1994; Tan, 1992; van der Watt et al., 1995). The salinity of the soil is expressed as electrical conductivity (EC_e) for salt content and sodicity as exchangeable sodium percentage (ESP). The EC_e is measured in millisiemens per centimetre (mmS/cm) and determined by extracting the exchangeable salts from a saturated paste (Tan, 1992). ESP is determined by finding the percentage of exchangeable sodium ions of the soil cation exchange capacity (Equation 1.3).

$$ESP = [(\text{exchangeable sodium ions}) / (\text{soil cation exchange capacity})] \times 100 \quad ....(1.3)$$

High concentrations of sodium in the soil can cause clay dispersion and consequently soil crusting. Soluble salt accumulation inhibits plant growth because it induces plasmolysis, a condition that encourages water to exit the plant and to enter the soil solution (Miller et al., 1990; Tan, 1992). Table 1.1 shows effect of the degree of salinity on crop yields.

Table 1.1. The effect of degree of soil salinity, in EC_e values, on yields of crops according to the U.S. Salinity Laboratory (Tan, 1992).

Salinity effects mostly negligible	Yields of very sensitive crops may be restricted	Yields of many crops restricted	Only tolerant crops yield satisfactorily	Yields of a few very tolerant crops are satisfactory

0 2 4 8 16

ECe (electrical conductivity) in mS/cm at 25˚C ⟶

The forms of nitrogen (N) that are taken up by plants are nitrate (NO_3^-) and ammonium (NH_4^+). However, nitrate is easily leached and ammonium volatilized out of the soil, especially sandy soils (Singh, 2006). Large amounts of N are release into the soil via mineralization, even when soil has low organic matter. It is important not to over-supply the grapevine with N because it can cause greater vigour, which will lead to greater susceptibility to disease, lower grape load and an increase in transpiration. Deficiencies lead to pale yellow/green leaves and result in poor growth of the grapevine (Conradie and Saayman, 1989; Singh, 2006).

Calcium (Ca) is a structural component of grapevines and is therefore essential for optimum functioning of the grapevine. In wet climates substantial leaching of Ca out of the soil, can take place, causing acidification. It has been found that some fertilizers are able to increase Ca leaching by displacing the Ca^{2+} from the cation exchange complex. Furthermore, Ca^{2+} losses due to leaching are usually greater than the amounts taken out in farming products. Deficiencies usually occur on Mg-rich materials or highly leached Al-saturated soils and symptoms are often as a result of the suppression of Ca caused by the presence of high Mg and Al concentrations (Rengel, 2002; Singh, 2006; Treeby, Goldspink and Nicholas, 2004).

Magnesium (Mg) is the central component of chlorophyll and consequently plays a pivotal role in sugar production by the leaves and subsequently yield size and quality (Bolan, Arulmozhiselvan and Paramasivam, 2002; Treeby et al., 2004). It is a natural component of sedimentary and igneous rocks and consequently of the soil that develops from them. Soil developed from basic rocks usually contains higher levels of Mg than those that originate from granite and sandstone. Soil Mg is usually present in forms that are not easily available to plants because it exists in primary and secondary minerals (Bolan et al., 2002).

If K levels are low enough to cause deficiencies, K fertilizer is required to prevent these deficiencies from affecting maximal fruit production. Excessive applications however, affect the pH of the berry juice by affecting the formation of sugars and starches, protein synthesis and cell division. It neutralizes organic acids, regulates other mineral activities, activates enzymes and maintains and adjusts water relationships. Each of the processes mentioned has an influence on the taste and appearance and consequently the quality of the grapes (Dundon, Smart and McCarthy, 1984; Morris, Cawthon and Fleming, 1980; Singh, 2006; Treeby et al., 2004).

Sulfur (S) commonly occurs in the mineral fraction of the soil, but may also be present as elemental sulfur or sulfides (FeS and FeS_2) which are not available to plants. Sulfur forms part of the amino acids cysteine, cystine and methionine and is an important constituent of proteins. It is also the active site for redox and electron transfer and it forms part of the structure of enzymes and proteins, and is thus a factor which may affect the quality of the grapes produced (Bidwell, 1974).

Chlorine (Cl) is absorbed by the plant as the chloride ion (Cl^-). Chloride plays a vital role in photosynthesis and it balances the positively charged mineral nutrients such K (Bidwell, 1974; Treeby et al., 2004). Chloride accumulation can occur in the leaves and may cause leaf injury and dieback. In grapevines symptoms of Cl toxicity may appear as leaf burn. Studies have shown that the minimal levels of accumulation in leaves (for leaf burn symptoms) are 0.5 to 1.2 percentage dry weight. Chlorine toxicities are associated with salinity effects and therefore Na accumulation (Bernstein and Hayward, 1958). Changes in nutrient status may contribute to the long-term effects of salinity on grapevine productivity (Prior, Grieve and Cullis, 1992).

Copper (Cu) is involved in the synthesis of chlorophyll and various biochemical reactions and deficiencies therefore result in a lower photosynthetic rate. Cu deficiencies are rare because it is a component of many fungicidal sprays which can cause accumulation at the soil surface. Toxicities do not occur often though, because grapevines have deep root systems. However, if Cu leaches deeper into the soil profile, toxicities can occur (Flores-Vélez et al., 1996; Singh, 2006; Treeby et al., 2004). Cu occurs in the soil as Cu sulphides (mostly in the +I oxidation state), oxides, carbonates, silicates, sulphates and chlorides. Most of which is complexed by organic matter, occluded in oxides and a component of primary and secondary minerals.

Furthermore, Cu is proven to be one of the least mobile micronutrients and is therefore resistant to leaching (Pedler and Parker, 2002).

Manganese (Mn), the key role player in photosynthesis, is taken up by plants in its divalent form. Deficiency symptoms present themselves as interveinal chlorosis (on the leaves) that occurs in older leaves first. Toxicities, which are rarely seen, occur as black spots on the leaf blades, shoots and bunch stems (Singh, 2006; Treeby et al., 2004).

Iron (Fe) is an essential micronutrient that plays a role in chlorophyll production and is responsible for energy transfer and strengthening of cells. Iron, together with molybdenum, is involved in the conversion of nitrate to forms of nitrogen which can be used by the vine. Deficiency symptoms appear as chlorosis in young leaves, yellow shoots and stunted growth. When severe deficiencies occur, the veins become chlorotic, almost the entire leaf appears white and necrotic spots occur between the veins. With mild deficiencies however, veins remain green but with less intense colour (Singh, 2006; Treeby et al., 2004).

Zinc (Zn) is required for membrane integrity. It is a structural component of biomembranes and also plays a role in the detoxification of free oxygen radicals (e.g. $O_2^{\cdot -}$) which potentially damage membranes. In plants which are exposed to Zn deficiencies, membrane permeability is increased and solutes such as K^+ and NO_3^-, sugars, amino acids and phenolics can leak out of cells more easily (Zhang, Romheld and Marschner, 1991). Futhermore, Zn is involved in a number of essential processes of the grapevine and plays a role in protein synthesis, hormone production, pollination and fruit set (Singh, 2006; Treeby et al., 2004).

Boron (B) is taken up in the form of boric acid and is transported very slowly through the plant. Deficiencies often occur when soils are derived from granitic or basaltic parent material, while in soils derived from marine sediments B levels are higher and sometimes even toxic. B has a very narrow range between deficiency and toxicity for both plant tissue and soil concentrations (Christensen, Beede and Peacock, 2006; Peacock and Christensen, 2005; Singh, 2006; Treeby et al., 2004). The reproductive tissues of the grapevine are most sensitive to boron deficiencies in grapevines, resulting in reduced fruit-set, small "shot berries" which are round to pumpkin-shaped and flower and fruit cluster necrosis. This is because B is required for germination and growth of pollen during flowering. Deficiencies can have an effect on the quality and yield, even if symptoms are moderate (Christensen et al., 2006; Peacock et al., 2005).

This study forms a small part of a larger one which aims to determine an irrigation application "recipe" which will allow for more conservative water use. Subsequently, a superficial look at the efficiency of irrigation scheduling and the effect of cumulative irrigation will be done. To investigate the efficiency of the irrigation scheduling, irrigation requirements will be calculated using the evaporation pan calculation, SAPWAT and Vinet. These will be compared with the actual irrigation applied for two seasons (2004/5 and 2005/6). Furthermore, superficial soil samples will be taken to investigate any interactions between cumulative water application for a number of seasons and soil nutrient status.

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Chapter 2
An introduction to the study: the study area and initial data collection and analysis

2.1 Introduction

The purpose of this chapter is to introduce the study area. It describes the geology, geomorphology, soils and climate of the Hex River to create a better understanding of the area. Furthermore, the details of the preliminary research done by the Department of Agriculture (Western Cape) to investigate water management practices of table grape farmers of the Hex River Valley are described here. The results of some of the analyses are also discussed.

2.2. Site location and description

The Hex River Valley is surrounded by high mountains, which separate it from Worcester to the south-west and Ceres to the north (Jooste and Zietsman, 1973). Figure 2.1 from Google Earth shows the approximate situation of the Hex River Valley (see De Doorns on the map). De Doorns is the main town of the area and lies in the Hex River Valley. Figure 1.1 of Appendix 1 shows the infrastructure of the study area.

2.2.1 Geology and geomorphology

In *Guide to the Relief-Map of the South-Western portion of the Cape Province (1926)*, S.H. Haughton describes the Matroosberg, in the Hex River Range, as the highest mountain in the south-western part of the Western Cape, with an elevation of approximately 2255m. This and the other mountains surrounding the Hex River Valley form part of the Folded Belt of the Western Cape. The Folded Belt contains a number of wide valleys of which the Hex River Valley is one. The Hex River Mountains, like other mountains of the Folded Belt, owe their existence to earth movements of the Late Karoo times. The valley is syncline and forms part of the Bokkeveld Series, while a smaller portion (on the Worcester side) forms part of the Malmesbury Series (Figure 2.2). Figure 1.2 of Appendix 1 shows the slope variation across the Hex River Valley and indicates the positioning of the initial 32 blocks included in the study.

Figure 2.1: Map of De Doorns positioned in the Hex River Valley (Google Earth, 2007).

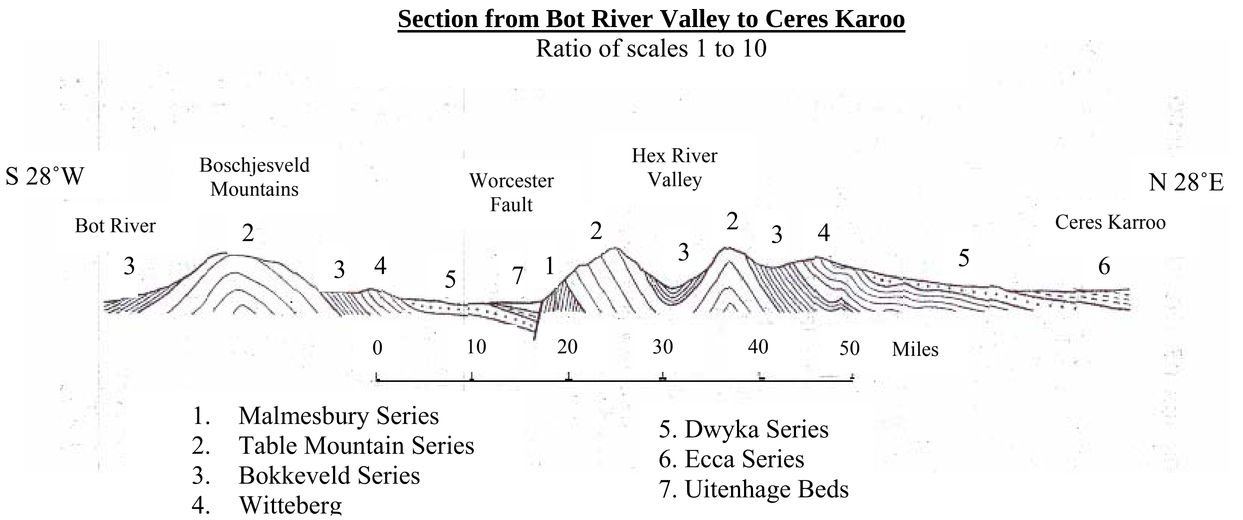

Figure 2.2. The geology and the basic geomorphology of the Hex River Valley (Haughton, 1926).

Table 2.1 shows the formations of which each of these series is a part and the material of which they are made. The series typed in bold are those that are found in the Hex River and only the component materials of those are mentioned.

Table 2.1. Formations and series of the Hex River Valley and the components of which they are made (Belcher and Kisters, 2003; Haughton, 1926; Jooste et al., 1973; Roger, Schwartz and Du Toit, 1906).

Formation	Series	Materials
Cape System	Witteberg Series	
	Bokkeveld Series	Shale, Sandstones, quartzites and marine fossils
	Table Mountain Sandstone Series	Sandstone, Quartzite with shale bands, tillite
Transvaal System	Ibiquas Beds	
	Malmesbury Series	Slates, phyllites, quartzites and limestones

The oldest group of sediments is the Malmesbury Series. It is a blue sandy clay slate and when it erodes or decomposes it produces sandy clay that can be white, red, brown or yellow. The soil formed is thin and clayey. The Malmesbury Series is in some cases covered by the Table Mountain Sandstone (TMS) series. Table mountain sandstone is the most prominent material out of which the Western Cape is carved and it therefore also forms the skeleton of the Hex River Valley. The basal portion of the TMS is usually made up of red micaceous gritty shale. When the TMS weathers, it either becomes a whitish-grey or a reddish-brown rock. The TMS may contain thin segments of shale, but a frequent feature is the occurrence of rounded quartz pebbles. The mountains of the Hex River Valley are made up of anticlines and synclines, of which a band of tillite often overlies the synclines. The Bokkeveld Series comprises alternating beds of sandstone and shale and it may consist of marine fossils (Haughton, 1926; Roger, Schwartz and Du Toit, 1906).

The Hex River area owes its current landform to a period of intensive erosion, which took place during the late-Triassic, early-Jurassic times by the Hex River (a tributary of the Breede River). The river shaped the landscape by carving into the TMS and the Bokkeveld Shale. These effects are most prominently seen in the Bokkeveld Shale, which is softer. The erosion led to the weathering and transportation of the eroded materials. The result was a deeply carved river valley with alluvial fans, covered by alluvium and terrace gravel, surrounded by high TMS peaks (Jooste et al., 1973). Figure 2.3 shows the distribution of these materials across the Hex River Valley (The framed area in Figure 2.3 is the area of interest for this study).

The alluvial fans of the Hex River Valley were formed due to a reduction in stream flow because of a flattening gradient which occurs at the footslope. The reductions in stream flow led to the accumulation of alluvial and terrace gravel at a specific area. Periods of high rainfall intensity alternated with periods of lower rainfall intensity assisted in alluvial fan formation. The periods with higher rainfall intensity resulted in higher stream flow rates, which allowed for alluvial material to be transported further, than under conditions of lower intensity. It is on these alluvial and terrace gravel deposits that the majority of the Hex River vineyards are established (Jooste et al., 1973).

2.2.2 Soils

As mentioned in the previous section, the soils on which most table grapes of the Hex River Valley are grown are alluvial and terrace gravel. Figure 1.4 of Appendix 1 shows the distribution of these soils across the valley. Soils derived from the TMS of the surrounding mountains are present on the curves which extend from the mountains and gradually lead to the valley floor, as well as in the alluvial fans. This soil comprises a mixture of sand and alluvial stones (Jooste et al., 1973). Soils derived from sandstones are generally acid with low fertility and water-holding capacity (Jooste et al., 1973; Taylor, 1978).

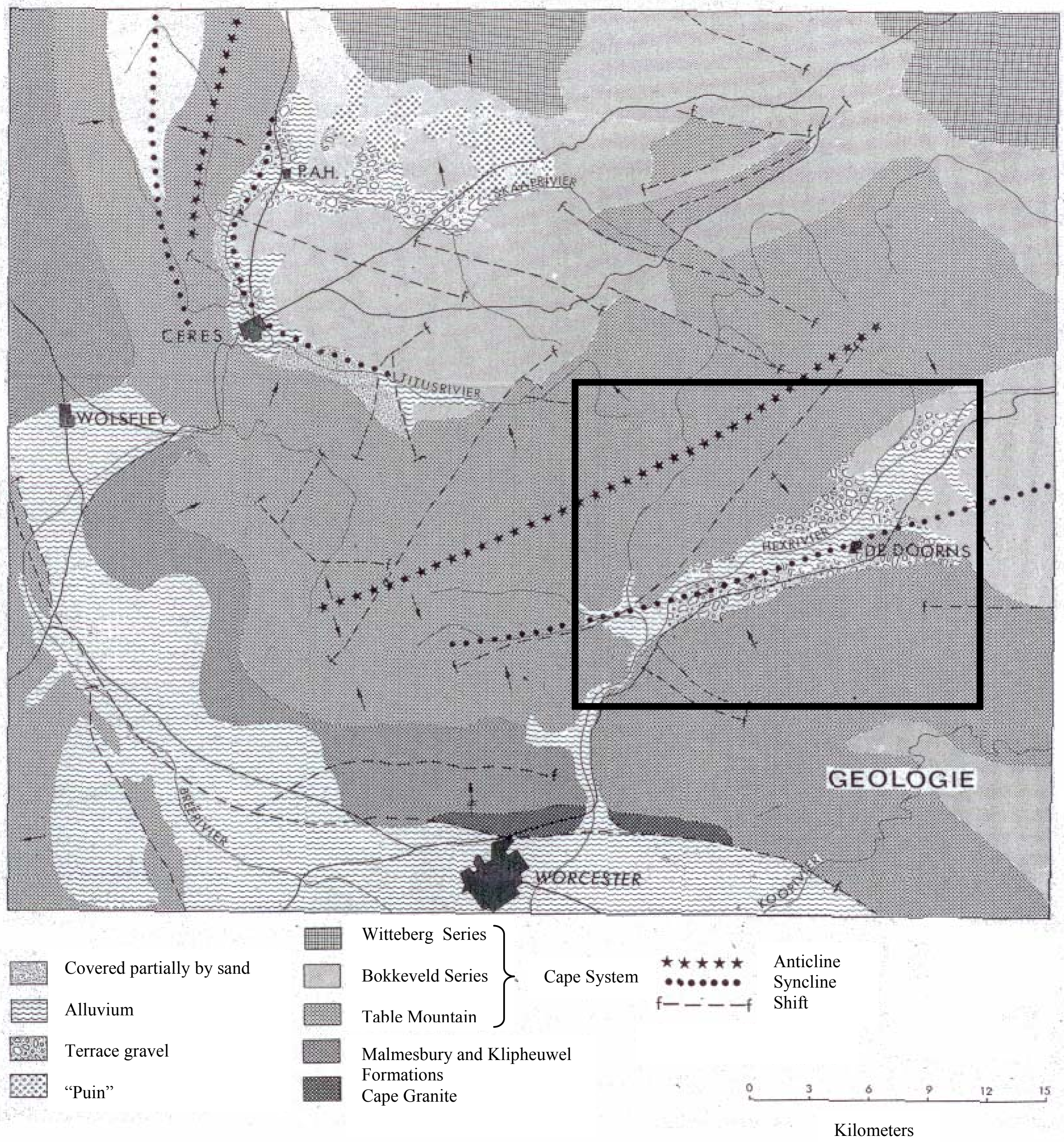

Figure 2.3. A map of the geology of the Hex River Valley (Jooste et al., 1973).

The soils of the central portion of the valley floor, derived from the Bokkeveld series are more fertile and have a good texture (combination of finer and coarser textured soil particles), especially in cases where they have been mixed with some sand from the surrounding mountains (Taylor, 1978). These soils are darker in colour and have variable texture. In spots, this soil may be very clayey. This is considered to be the best soil in the valley on which a variety of crops can be planted. The soils of the north-easterly portion of the valley are reddish-brown sandy loams and are formed from the weathering of the Bokkeveld series (Jooste et al., 1973).

The flow of water and water retention capabilities of each of these types of soils is very different because they are determined by the texture and structure of the soil. The soils which are derived from shale (E, M and Mv in Figure 1.4 of Appendix 1), which are the more clayey soils, are able to retain water with greater efficiency than the alluvial soils (Ha1, Ia, K and L). This is because the alluvial soils have larger pores and consequently lower capillary rise (smaller adhesion forces) (Bidwell, 1974; Or and Wraith, 2000). The result is that the soil particles do not have a strong affinity for the water molecules in its pores, with the consequence that water is not retained well by the soil and it drains through the soil profile with relative ease (van der Watt and van Rooyen, 1995). Some of the soils in the area have a mixture of the shale derived clayey soil and the alluvial material. It is expected that these soils are intermediate. These soils are best for the cultivation of crops (Jooste et al., 1973).

2.2.3 Climate

The climate is affected by the relief of the area and varies over a relatively short distance. Figure 2.4 shows how the Hex River region is divided into groups according to the Köppen classification. The framed area of the map is the portion of importance to this project. Table 2.2 defines each of the symbols.

The rainfall for the areas represented by these symbols varies. The area marked BSks has an average rainfall of approximately 255 mm per annum. Csa and Csb are areas which have higher rainfall figures. The Csb climate occurs in the mountains surrounding the Hex River valley some of which can receive more than 3000 mm of rain per annum. For the rest of the area which falls within the Csb climate, the amount of rainfall received per annum decreases 140 mm for every 100 m of decreased elevation. The area which falls in the Csa climate may receive between 300 and 700 mm of rainfall per year (Jooste et al., 1973).

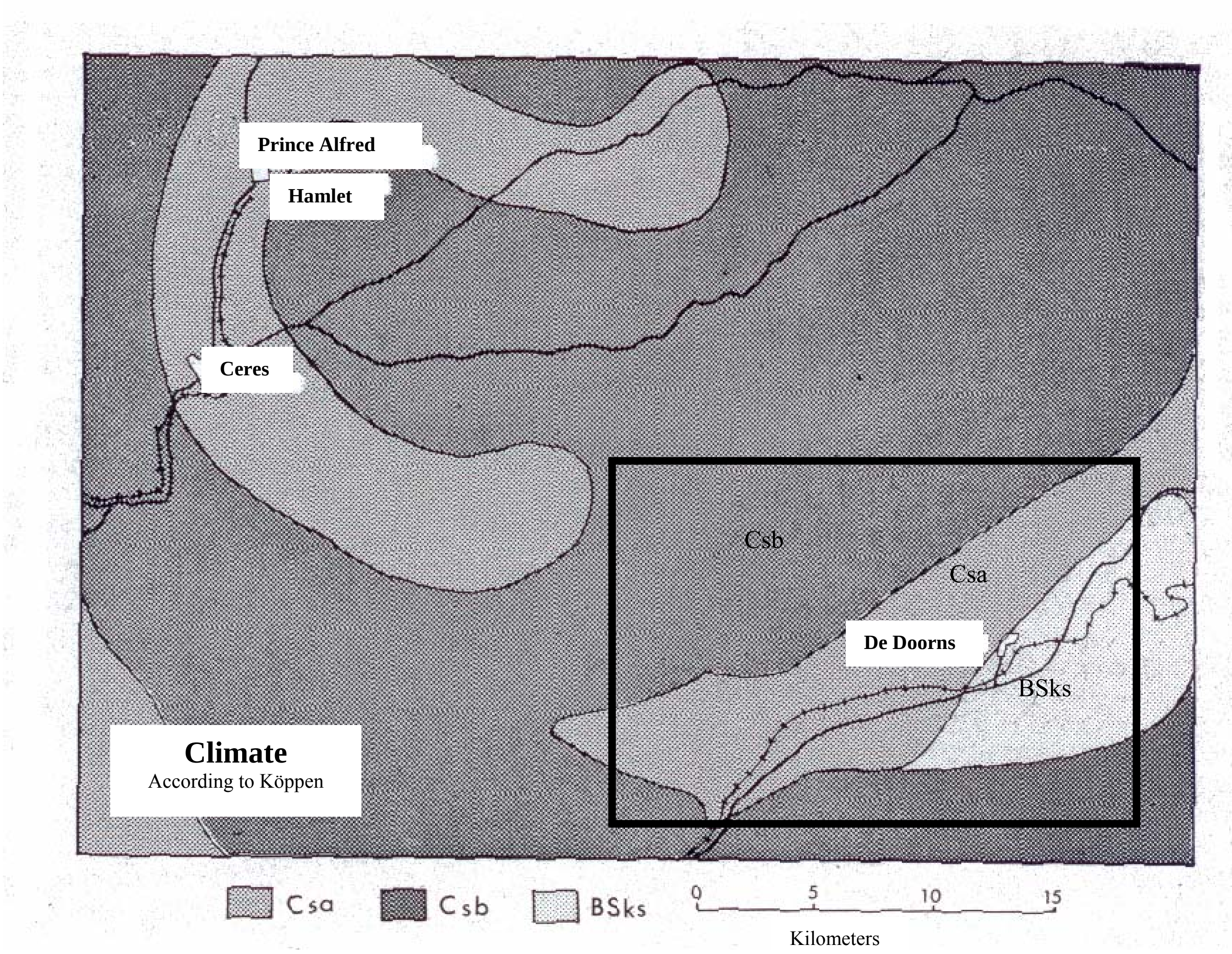

Figure 2.4. Climatic classification according to Köppen for the Hex River Valley (Jooste et al., 1973).

Table 2.2. Definitions of map symbols of climatic map (Jooste et al., 1973; Schulze and McGee, 1978)

Symbol	Definition
BSks	B Arid zones S Steppe climate k dry-hot, mean annual temperature over 18˚C
Csa	C Warm temperate climate s Summer dry season a Warmest month over 22˚C
Csb	C Warm temperate climate s Summer dry season b Warmest month below 22˚C, but at least 4 months above 10˚C

The Hex River Valley is a winter rainfall area; this means that in order to grow fruit such as table grapes, irrigation is required during the dry summer months. The main reason for this is that the amount of water required for a crop is based on the amount of evapotranspiration that occurs. In summer the amount of water that is lost to the atmosphere (from the soil or plant) is greater than the amount of water which precipitated from the atmosphere on the earth's surface. The water which is lost must be replenished to ensure crop survival.

The solar radiation of the area is shown in Appendix 1, Figure 1.3 and gives an indication of the area and blocks which will experience higher radiation intensities and those which will experience lower intensities. According to the figure, as expected the north facing slopes receive higher solar radiation than south facing slopes.

2.3. Data collection

Since the 1999/2000 production year, the Department of Agriculture of the Western Cape, (and initially the Agricultural Research Council (ARC)), has been collecting table grape production data in order to determine whether, in general, the farmers of the Hex River Valley use water wisely. In the first year of the project, they were able to include 22 blocks from various farms across the valley. From the 2001 to the 2005 production season the number of blocks increased to 32, while for the 2005/6 and 2006/7 seasons another five blocks were included. Blocks were chosen by considering cultivar, soil type and environmental conditions. The positioning and distribution of these farms across the Hex River Valley are indicated in Appendix 1, Figure 1.2.

2.3.1 Soils

In the 1999/2000 and 2000/1 seasons, soil profile descriptions for the blocks HT1 to HT32 were done by Mr P. Feyt during which the soils of the participating blocks were classified, using the Taxonomic System for classifying South African soils (Appendix 3), and effective root depths (Appendix 3, Tables 3.1 and 3.2) were determined. The soils were sampled for analysis.

2.3.2 Block information

Block information was collected and includes cultivar and rootstock, block size, planting date, vine spacing, trellis system, depth to which soil preparation was done, the existence of drainage and soil management practices with regard to weed control, both between and in the rows (Appendix 2, Tables 2.1 to 2.4). Surveys were done to collect information regarding the management practices in each block, as well as disease or insect destruction, which may have an influence on the yield, was also collected. This information is available in Appendix 2, Tables 2.9 to 2.11.

2.3.3 Irrigation system and water application

Information concerning the irrigation system and practices such as system type, maintenance techniques, delivery rate, design pressure, water source and whether or not the system is pressure compensated was collected (Appendix 2, Tables 2.5 to 2.8). Also recorded were dates when some of the irrigation systems changed from microsprinkler to drip irrigation (Appendix 2, Table 2.8).

Water meter readings, from meters installed by the Department of Agriculture within each block were taken on a weekly basis in order to monitor the amount of water applied (Appendix 5, Tables 5.1 to 5.7). Yield information was collected from each producer using questionnaires, this way correlations between water application and yield could be drawn up.

2.3.4 Climatic data

Climatic data was collected from three weather stations, De Doorns, De Vlei and Jolette, shown in Appendix 4, Tables 4.1 to 4.3. The climatic data for Jolette and De Vlei is for 2004 to 2006. The exact location of these three weather stations is given in Table 2.3. The climatic data was used to determine the amount of evaporation which occurred during the different parts of the year. This is of particular importance for irrigation scheduling.

Table 2.3. Weather station locations.

Name	Co-ordinates	Altitude (m)
De Doorns	33.4667˚S 19.6667˚E	457
De Vlei	33.4333˚S 19.6833˚E	490
Jolette	33.5000˚S 18.5500˚E	559

2.3.5 Other

The yield produced each year for each of the blocks was collected from the farmers. From this a yield-irrigation index could be determined by dividing yield by the amount of water applied to that block (Appendix 2, Tables 2.9 to 2.11). Management practices for the blocks were also recorded as well as the average growth vigour for December to April (Appendix 2, Table 2.12).

It is important to note that during the data collection period (1999/2000 to 2006/7) some of the blocks were replaced by other blocks or completely removed from the study. In the 2005/6 season, five new blocks were added to the study (Appendix 2, Table 2.4).

2.4 Data analysis

2.4.1 Soils

Some physical and chemical analyses were done on soil samples taken from selected plots. The physical analysis included particle size analysis and water retention capability. Resistance, pH (1mol KCl), H, stone percentage, P, K, exchangeable cations (Na, K, Ca and Mg) and some micro-nutrients (Cu, Zn, Mn and B) analyses were also done. The results are shown in Appendix 3, Table 3.4.

2.4.2 Water application

Cumulative water application values for the 1999/2000 to 2001/2 seasons were plotted on graphs in order to visualise water consumption in each block; this is shown in Figures 2.5 to 2.10. A yield-irrigation index was determined by dividing the total yield (t/ha) by the total monthly water reading (taken from the water meters) in m^3/ha. This was also plotted for each block (Figures 2.11 to 2.13).

2.4.3 Climatic data

Long-term ET_0 and rainfall were plotted with actual ET and rainfall for each of the seasons, so that actual values could be compared with theoretical values. Climatic data for 1999 to 2007 was collected from the De Doorns weather station. Weather data for the De Vlei and Jolette weather stations was collected for 2003 to 2007. The climatic data is valuable for determining the irrigation scheduling (see Chapter 3).

2.4.4 Yield data

Yield data for each of the seasons (Tables 5.8 to 5.14, Appendix 5), starting 2000/1 was plotted in order to compare production on each of the farms. This is shown in Figures 2.14 to 2.16. In each graph the total yield (for local and export markets) and export yield is shown.

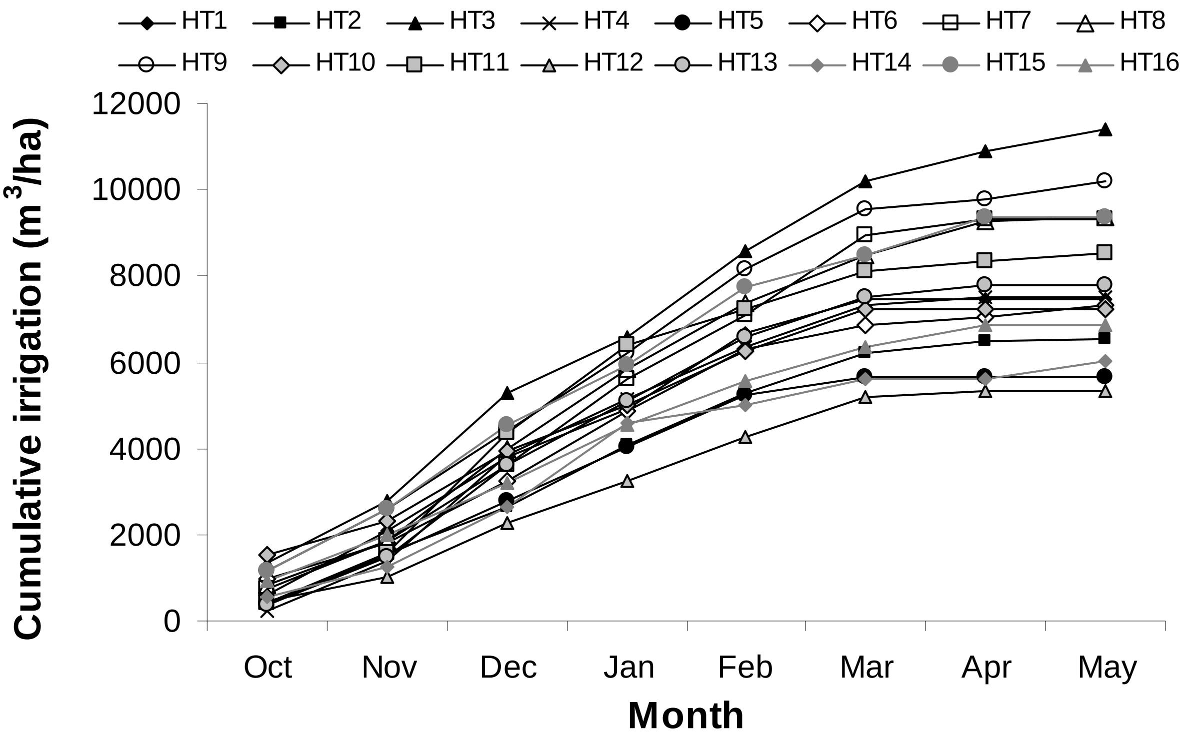

Figure 2.5. Cumulative irrigation of blocks HT1 to HT16 for 2000/1.

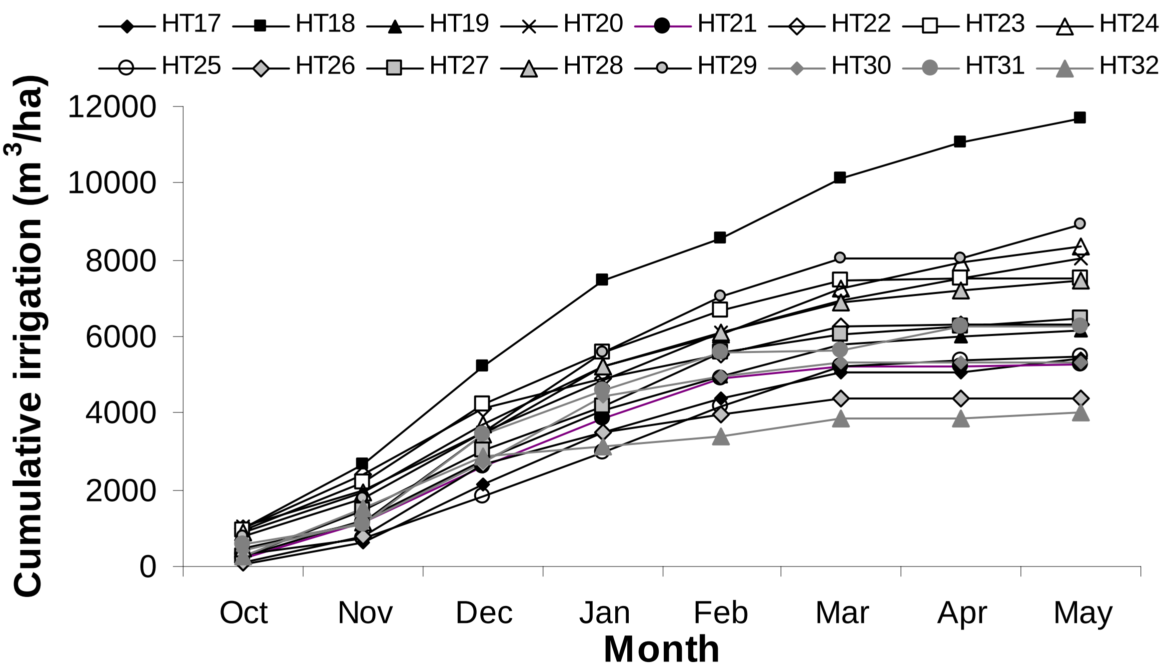

Figure 2.6. Cumulative irrigation of blocks HT17 to HT32 for 2000/1.

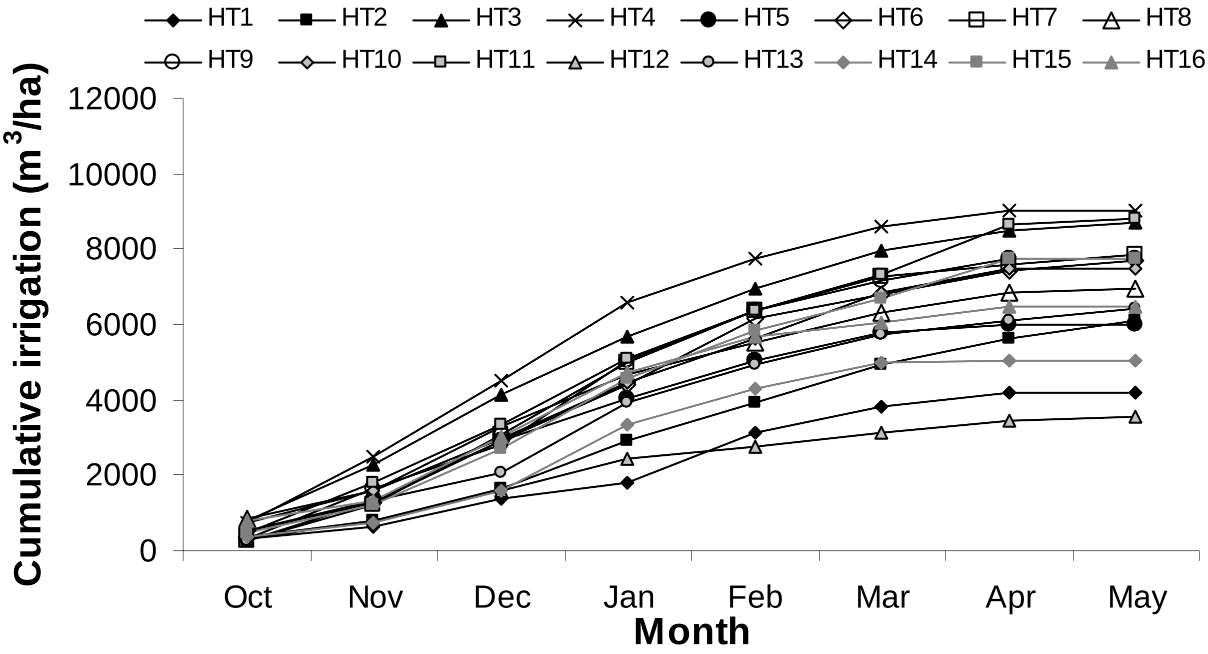

Figure 2.7. Cumulative irrigation of blocks HT1 to HT16 for 2001/2.

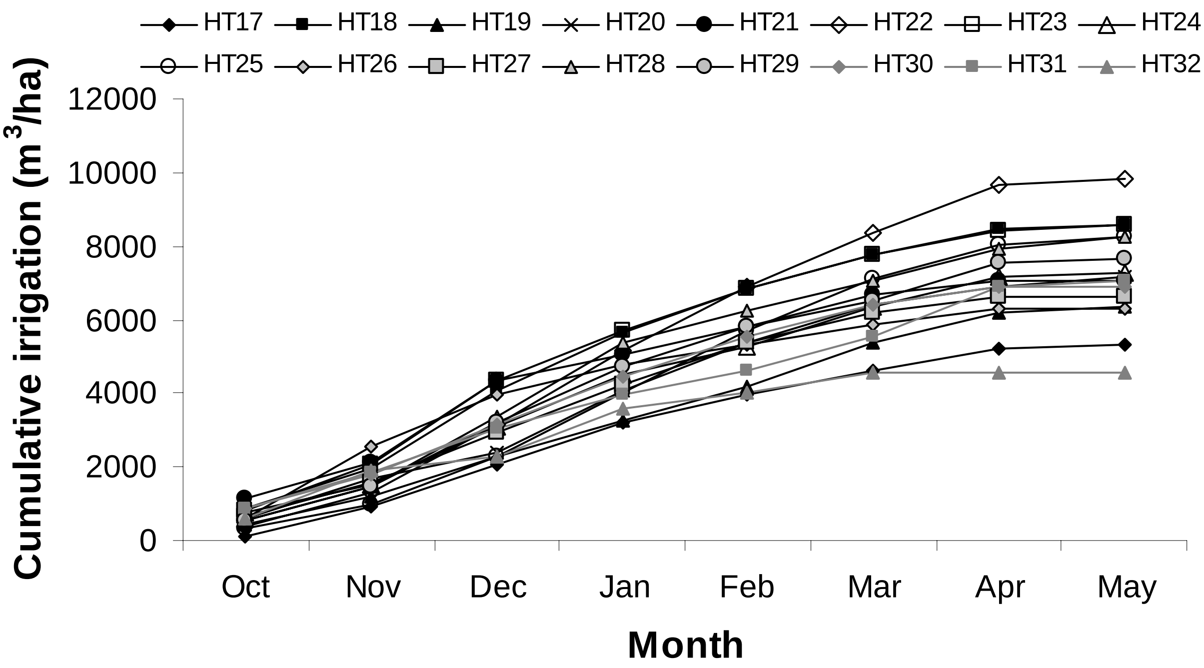

Figure 2.8. Cumulative irrigation of blocks HT17 to HT32 for 2001/2.

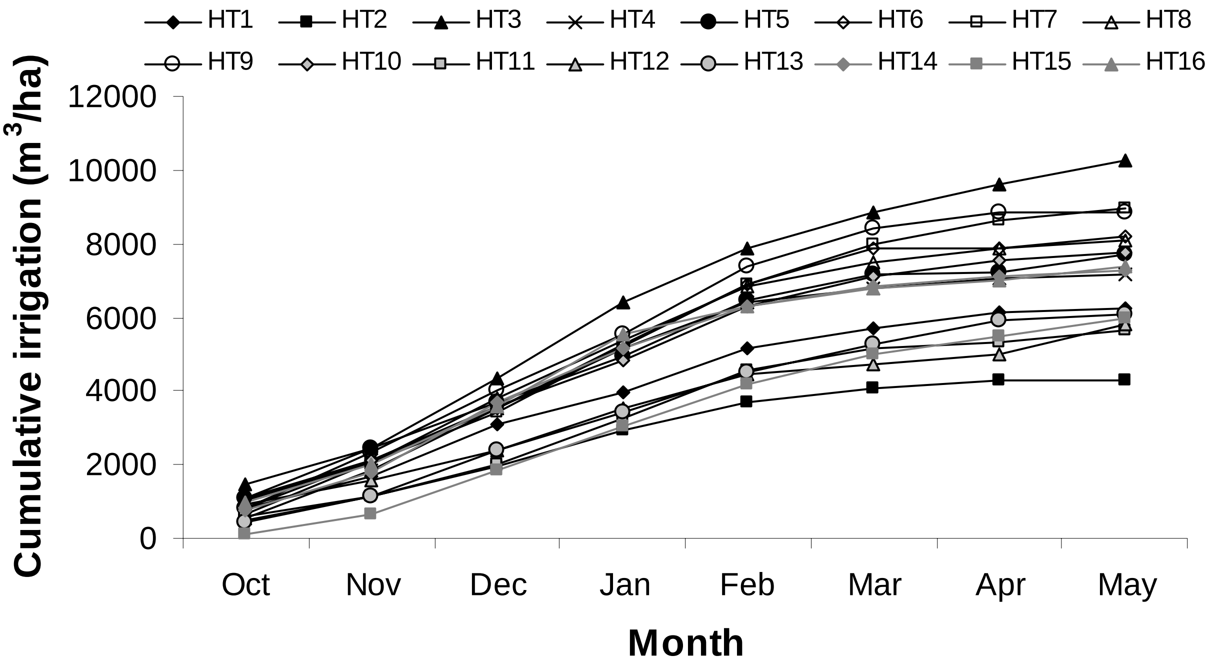

Figure 2.9. Cumulative irrigation of blocks HT1 to HT16 for 2002/3.

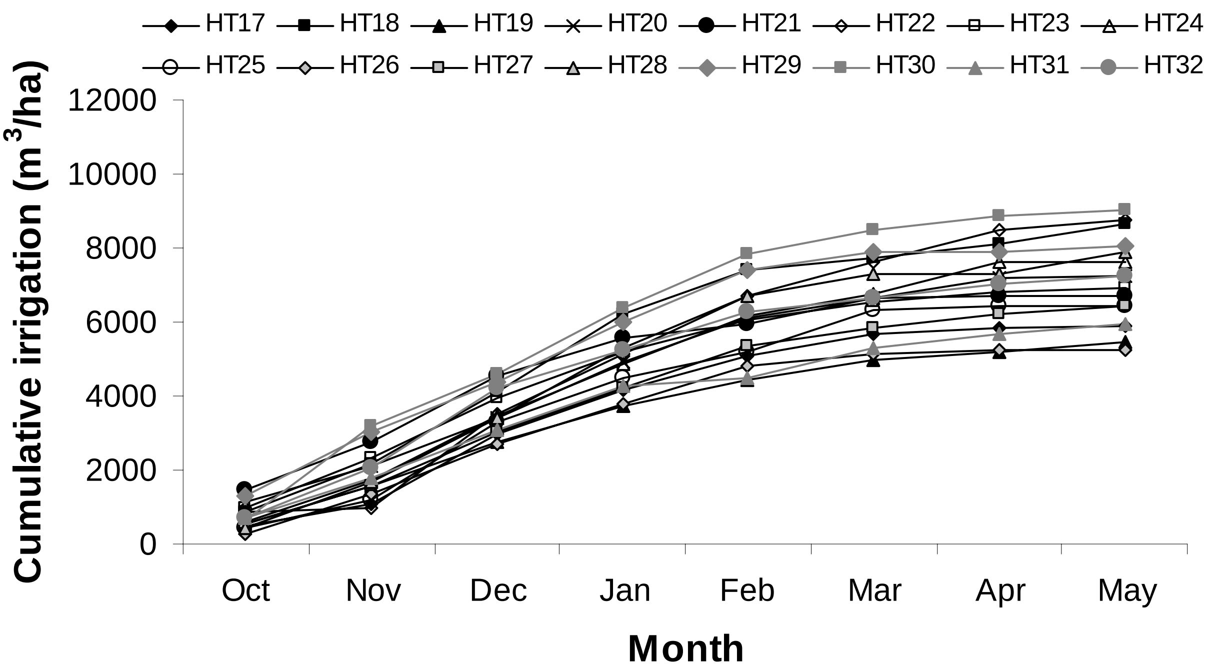

Figure 2.10. Cumulative irrigation of blocks HT17 to HT32 for 2002/3.

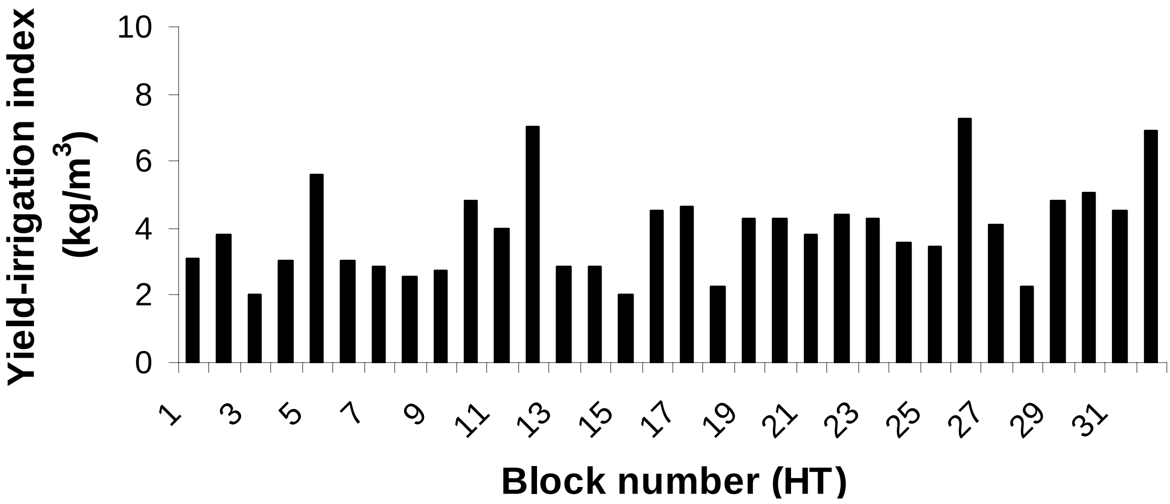

Figure 2.11. Comparison of the yield-irrigation index (kg/m^3) for the 2000/1 season.

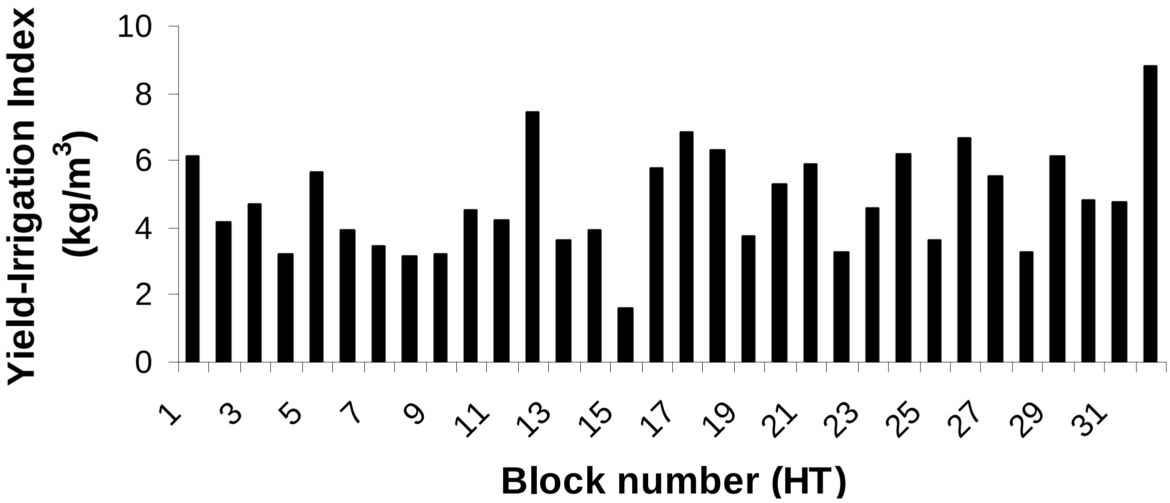

Figure 2.12. Comparison of the yield-irrigation index (kg/m^3) for the 2001/2 season.

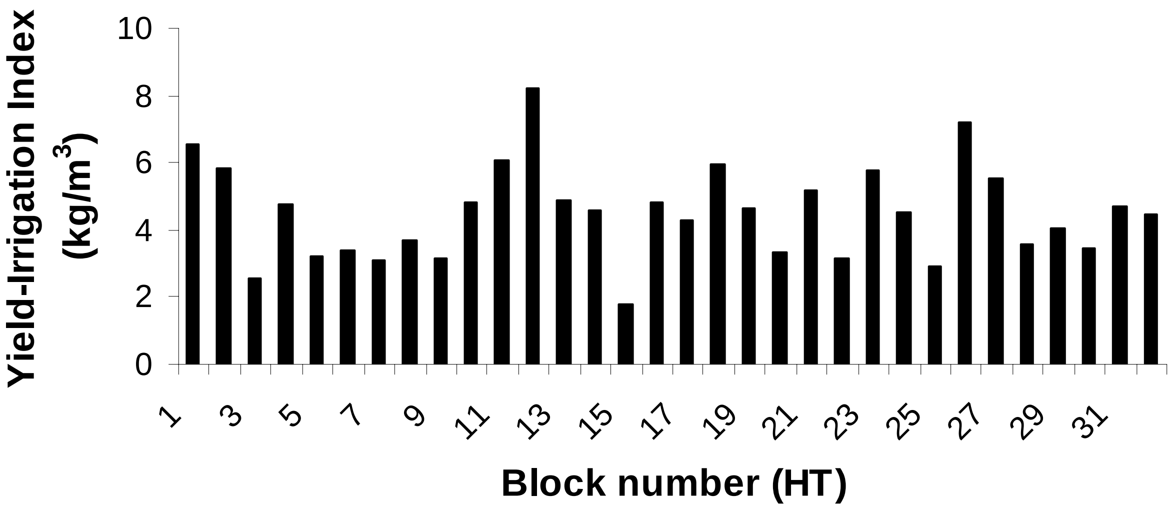

Figure 2.13. Comparison of the yield-irrigation index (kg/m^3) for the 2002/3 season.

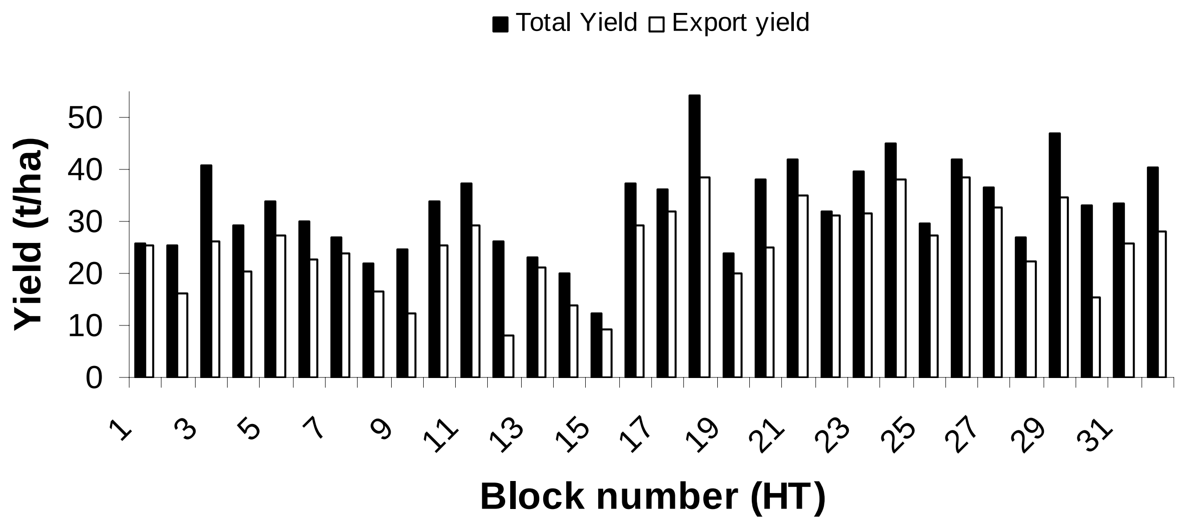

Figure 2.14. Total and export yields (t/ha) for all blocks 2000/1 season.

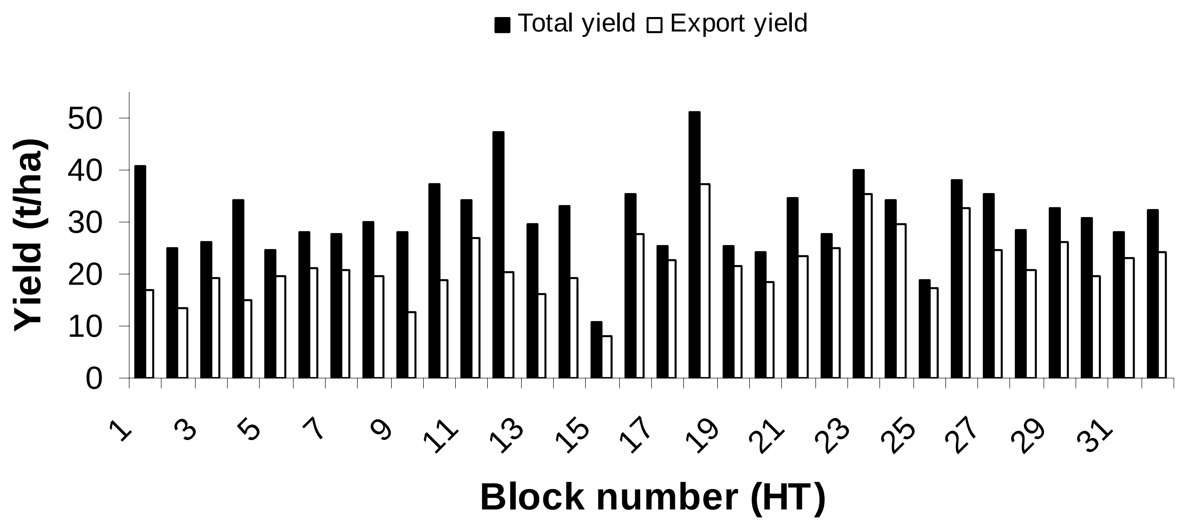

Figure 2.15. Total and export yields (t/ha) for all blocks 2001/2 season.

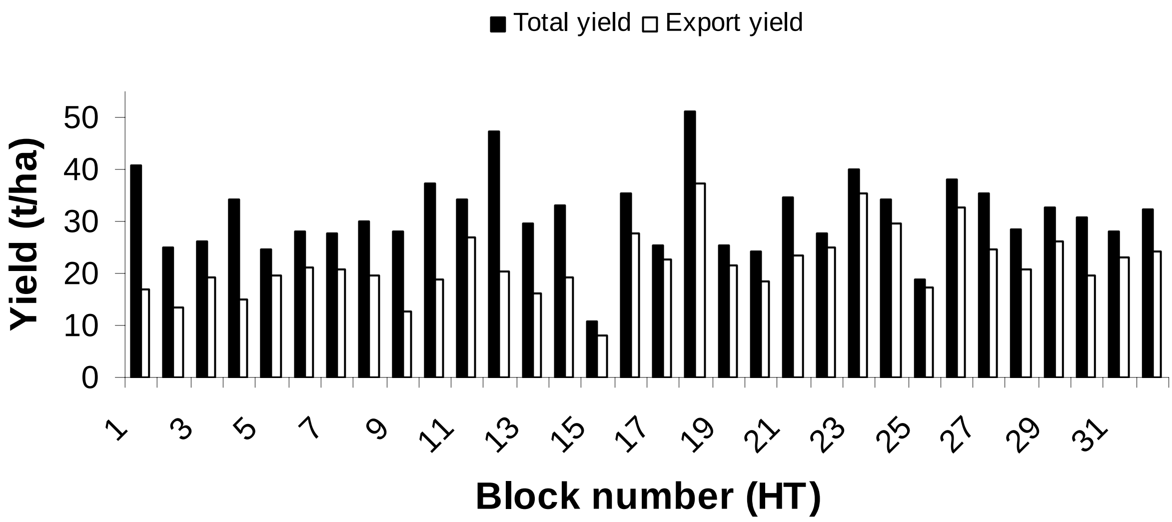

Figure 2.16. Total and export yields (t/ha) for all blocks 2002/3 season.

2.4.5 Other

Other correlations were drawn up in an attempt to determine whether any other correlations existed. Water application and yield were correlated with the chemical analysis data and these were also plotted against WUE. No significant correlations could be found in the data. Examples of these are shown in Figures 2.17 to 2.22 where the relationship between the amounts of water applied per block was correlated with yield.

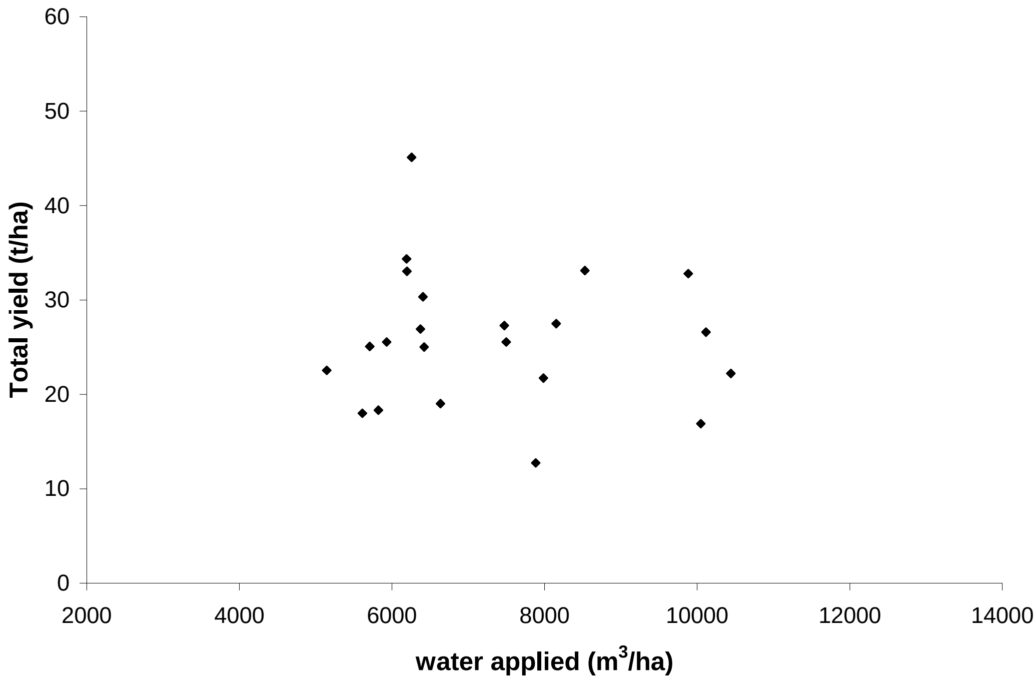

Figure 2.17. Correlation between water application and total yield for the 1999/2000 season.

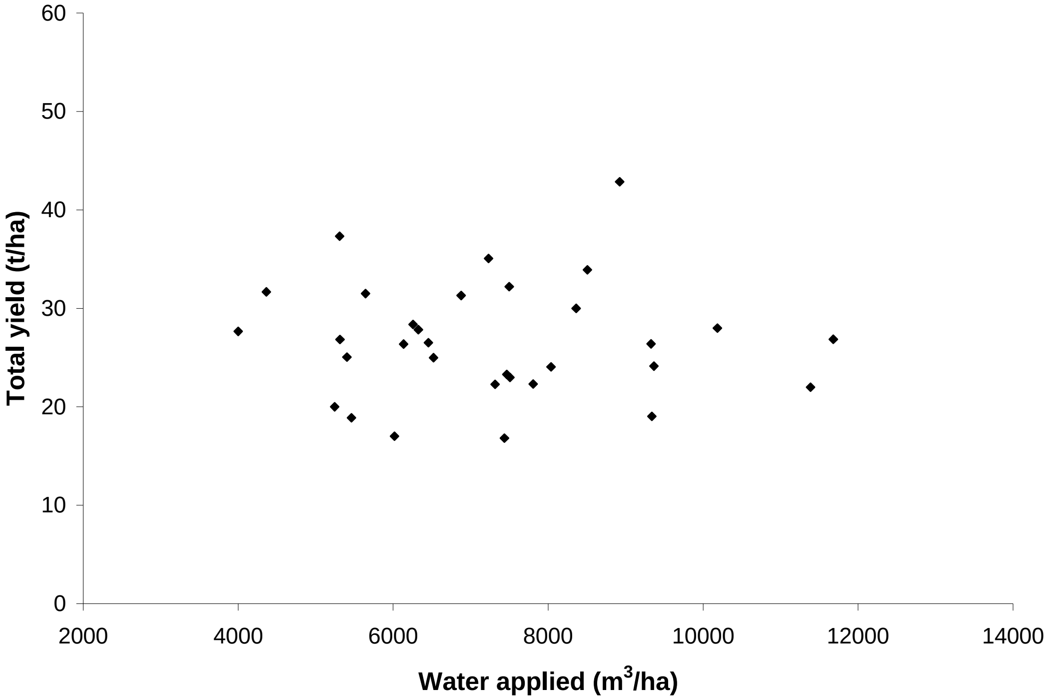

Figure 2.18. Correlation between water application and total yield for the 2000/1 season.

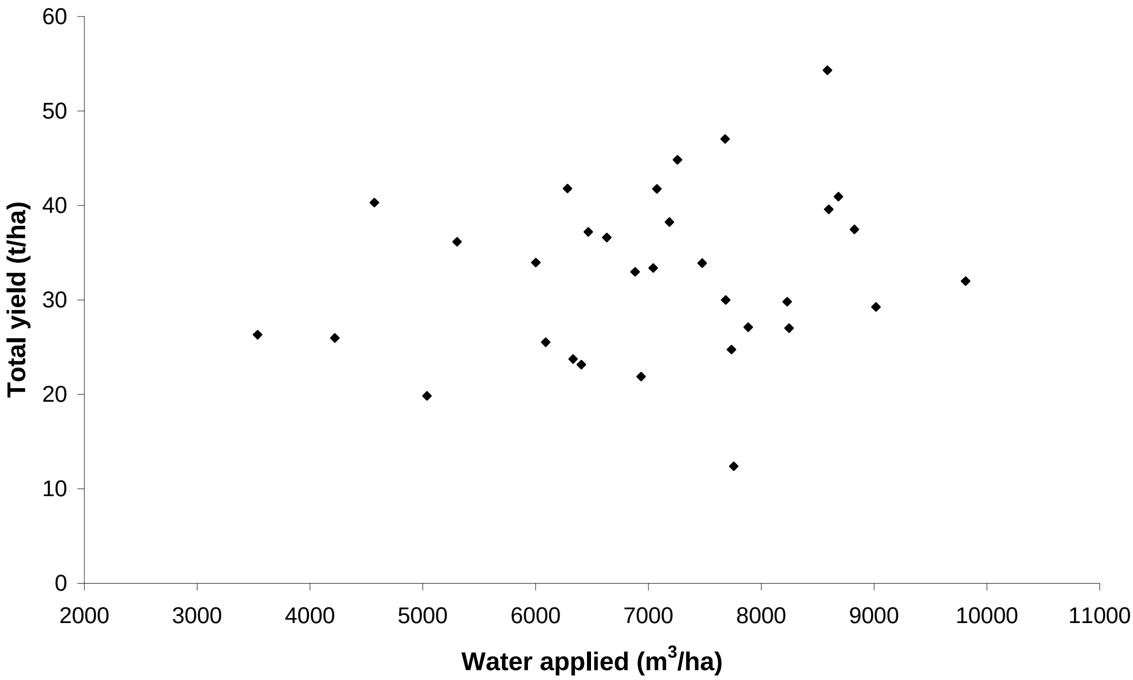

Figure 2.19. Correlation between water application and total yield for the 2001/2 season.

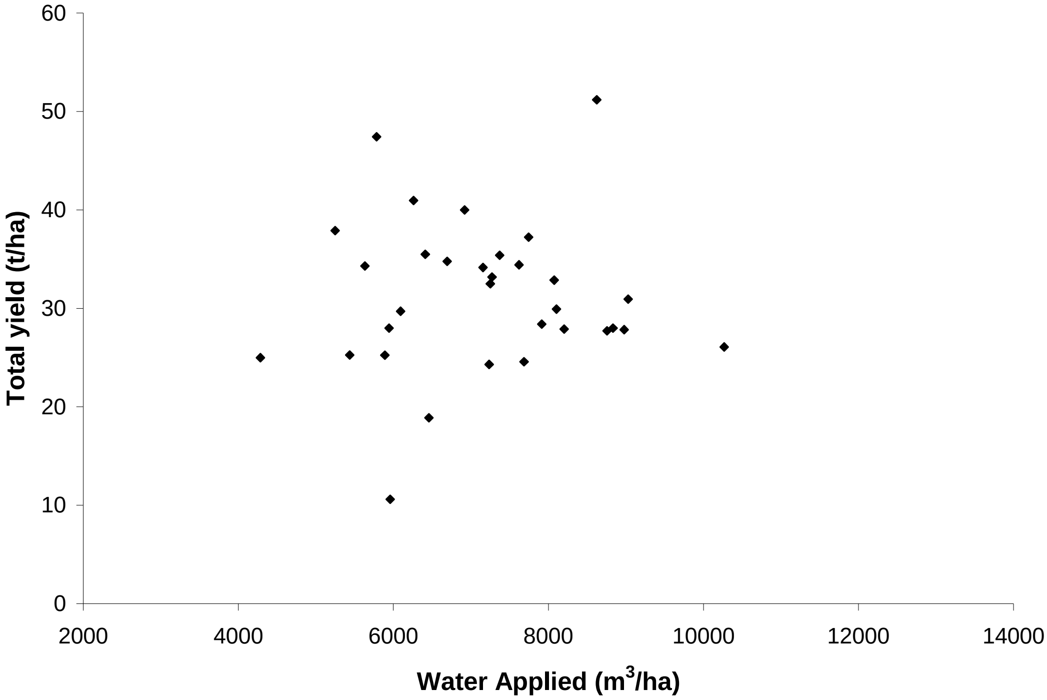

Figure 2.20. Correlation between water application and total yield for the 2002/3 season.

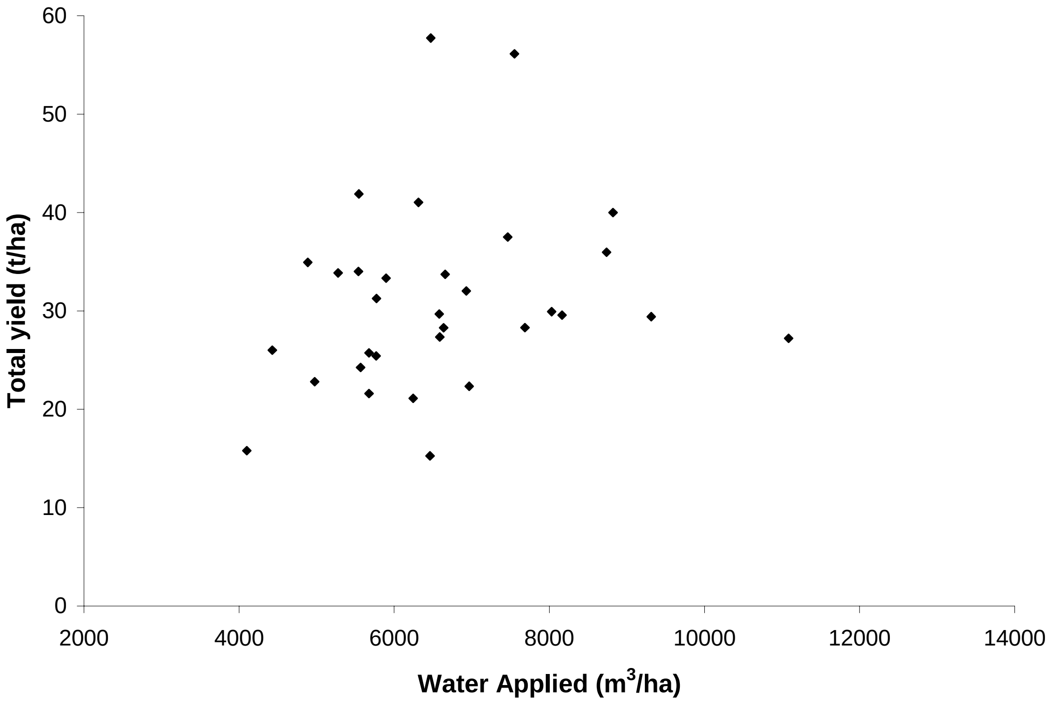

Figure 2.21. Correlation between water application and total yield for the 2003/4 season.

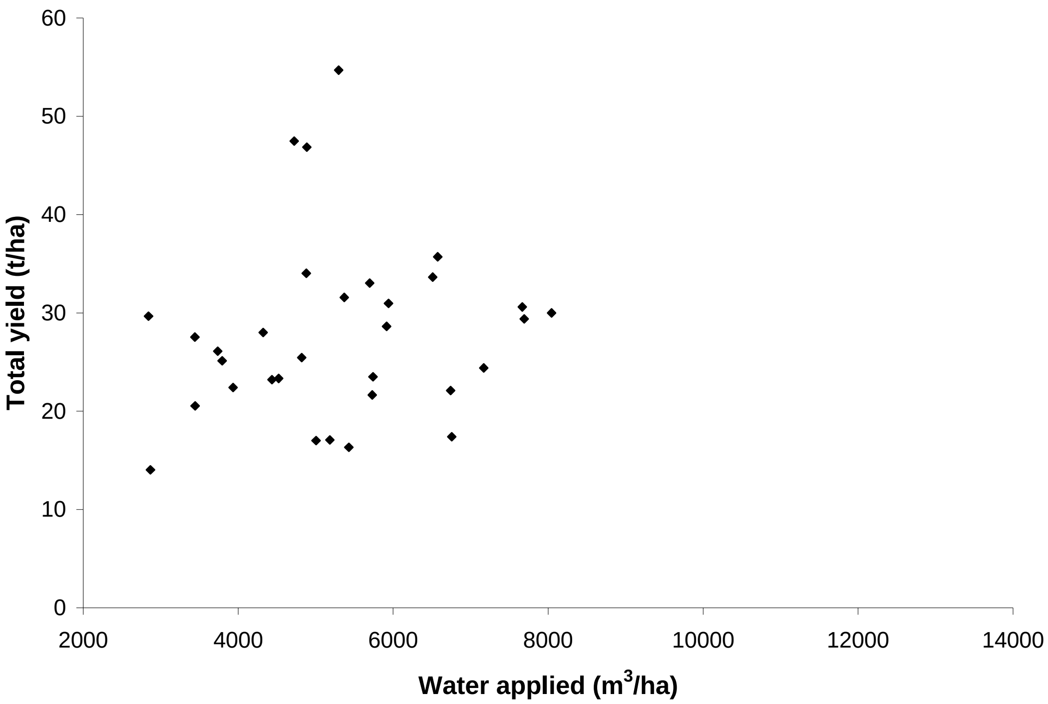

Figure 2.22. Correlation between water application and total yield for the 2004/5 season.

2.5 Discussion

From the data investigation, it becomes clear that it is difficult to say whether any specific range of water application has an influence on the size of the yield. There is no consistency in the data from one year to the next i.e. not one block achieves uniformly high yields or low yields. It is therefore difficult to find a range of water application rates which is most efficient. This is demonstrated in Figures 2.11 to 2.16. In these figures, if the yield-irrigation index is examined for each block for each year and then compared to the yield, it becomes clear that low yield-irrigation indices cause low yields. However, high yield-irrigation indices do not necessarily mean there will be resultant high yields.

A better way to approach the study and the area in which it has taken place is to look at specific aspects of the production of table grapes, for example, correlations such as the one between magnesium and water application shown in Figure 2.23.

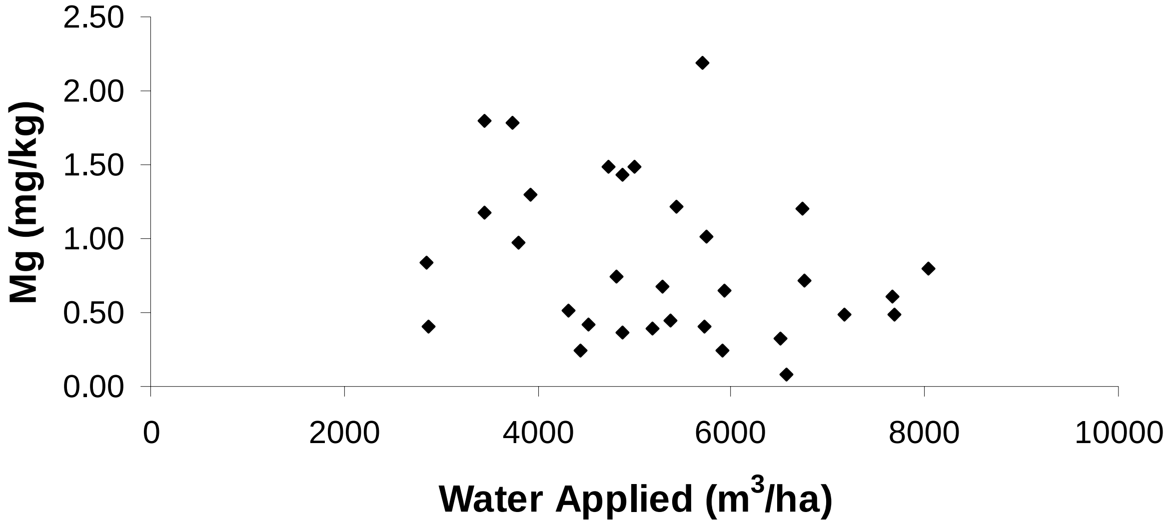

Figure 2.23. Correlation between water applied to each block and the magnesium content of the soil of that block.

This graph shows that there may be a correlation between the amount of water applied to a block and the magnesium content of the soil of that block. If a wedge-shaped "envelope" is drawn on the boundary of the data as shown Figure 2.24, it becomes clearer that the amount of water applied may be one of the factors that affect the magnesium content of the soil. The scattered nature of the graph also however indicates that a number variables, other than water application, are having an effect on the magnesium content of the soil. These results are however not for certain though, because this kind of statistical analysis is usually done on larger sample sizes. For this reason new soil samples should be taken in order to increase the sample size and determine whether this correlation truly does exist.

It is also recommended that in order to determine some sort of water application "recipe" for the table grapes of the Hex River Valley, that each aspect of table grape production be studied separately and more intensely. The conclusions for each of the individual studies can then be considered as a whole.

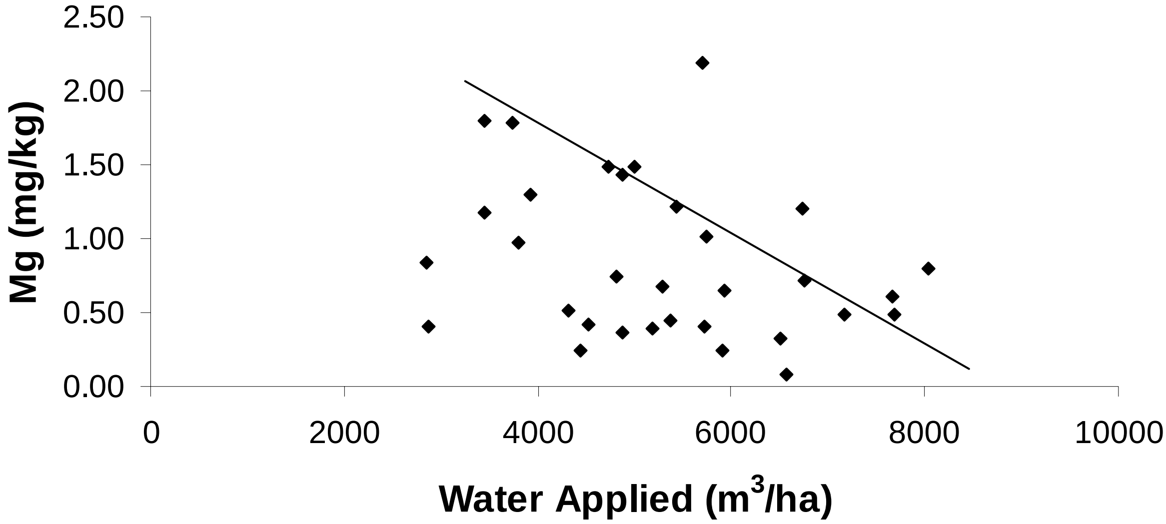

Figure 2.24. Magnesium and water correlation with a boundary line.

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Chapter 3
A comparison of the irrigation requirement determined by different scheduling methods

3.1 Introduction

Due to the scarcity of water in South Africa, making use of irrigation practices that ensure its efficient utilization has become increasingly important. Such practices are essential for production and social and economic sustainability (Bennie and Hensley, 2001). Irrigation scheduling is a way to encourage conservative water use, by predicting the amount of water required for production, based on the soil water content and meteorological conditions. Modern irrigation systems make this possible because they are able to deliver water to the soil at more controllable rates and are thus able to maintain almost optimal soil water conditions (Hillel, 1998). Consequently, the purpose of this chapter is to briefly discuss the principles of the irrigation scheduling methods adopted by the producers of the Hex River Valley, and to compare these to current irrigation practices.

3.2 Scheduling techniques

The different methods adopted to schedule irrigation can be divided into six groups a) intuition or subjective-based scheduling, b) atmospheric based quantification of ET, c) soil water measurement, d) plant based monitoring, e) integrated soil water balance methods and f) irrigation control/automation (Stevens, 2007). In the Hex River Valley, Class A pan evaporation (atmospheric based quantification of ET) and soil water measurement are the most popular (sometimes in combination) for scheduling irrigation. Vinet and SAPWAT (both integrated water balance methods (Stevens, 2007)), are however, discussed and evaluated as possible alternatives to the current methods adopted by the producers.

3.2.1 Evapotranspiration (ET)

Evaporation pans are low cost methods for indicating the amount of evaporation and their simplistic data has encouraged their wide use (Hatfield, 1990). These open water pans are able to indicate the amount of water lost by crops due to evapotranspiration (ET) because they are subjected to the same conditions. This method assumes that over a given period ET is directly proportional to the pan evaporation (PET). A cumulative record of depleted water is kept and when this estimate equals the readily available water (RAW), the crop must be irrigated (Hatfield, 1990; Smajstrla et al., 2000).

There are a number of problems that arise with the use of evaporation pans. Firstly, it does not take differences between cultivars into account because the amount of evaporation is dependent on the prevailing climatic conditions. Factors which will influence the amount and rate of evaporation are type of pan, amount of water in the pan, the pan location and the microclimate. Secondly, the water in the pan serves as source of water for wildlife. Although this can be overcome by making use of screens, they tend to influence the amount of water that evaporates, resulting in inaccurate measurements. Furthermore, water can be lost during rainfall due to splash (Hatfield, 1990; Smajstrla et al., 2000).

Vinet is a water consumption prediction model that was developed by P. Myburgh and C. Beukes at the ARC Infruitec-Nietvoorbij. Vinet is a model that takes the variation of different vineyards into account and makes use of an empirical model to simulate crop ET. Furthermore, it distinguishes the different factors that will influence the transpiration of the grapevine: leaf layers, trellis system, cultivar characteristics, plant density and climatic factors. Vinet therefore takes factors which affect both evaporation and transpiration into account. Models were developed to measure sap flow and to predict leaf area index of the grapevine. These models are combined with Boesten and Stroosnijder evaporation model to predict the evapotranspiration (Stevens, 2007).

SAPWAT is a programme which ensures irrigation estimates that are correct and that can be applied unconditionally (van Heerden, Crosby and Crosby, 2001). It is linked to and an extension of the FAO planning model, CROPWAT (based on FAO irrigation and drainage reports). SAPWAT is a planning and management aid that is supported by an extensive South African climate and crop database. Some major improvements, which relate to irrigation and management, have been incorporated into SAPWAT and include replacement of the American Class A evaporation pan with reference evaporation from a short grass surface, calculation of the reference evaporation using the Penman-Monteith calculation and the ability to adjust and adapt crop factors for almost all circumstances (Stevens, 2007; van Heerden et al., 2001).

The potential role of SAPWAT for water use, management and planning is described in a Water Research Commission report by P.S. van Heerden, C.T. Crosby and C.P. Crosby (2001). The report tests and proves that SAPWAT can be used with confidence for the following:

- Estimation of irrigation requirement
- Estimation of irrigation requirement of crop rotation systems
- Estimation of irrigation requirements of areas and subareas

- Evaluation of existing management strategies
- Estimation of irrigation with inclusion or exclusion of leaching requirements
- Estimation of the irrigation of alternative crop combinations

SAPWAT determines a monthly irrigation "budget" which can be used by the manager (planner) with confidence, to plan and manage irrigation for the crop (van Heerden et al., 2001).

3.2.2 Soil water content

In situ measurements are used to determine water content of the soil either as soil volumetric content (amount of water per volume of soil, measured as a percentage of total volume) or soil moisture tension (measure of the suction required by the plant to draw water into the soil, measured in kPa) (van der Watt and van Rooyen, 1995). The main instruments used in the Hex River Valley are listed and briefly discussed below.

Tensiometers take readings of the water potential of the soil. They are sealed, water-filled tubes that have porous cups on one end and pressure gauges on the other. The porous cup is permeable to water and solutes, but not to the soil matrix and gases. Water moves in through the porous cup until the pressure inside the tensiometer is equal to the water potential of the soil matrix. These easy-to-use instruments take measurements at the same site throughout the season and are relatively inexpensive. They are however only accurate within a certain range and require frequent servicing (Campbell and Mulla, 1990; Stevens, 2007).

Electrical resistance blocks are typically made up of two electrodes that are embedded in a gypsum block. As the soil dries out, water is drawn from the gypsum block, into the soil matrix causing an increase in electrical resistance between electrodes. Wires that extend from the electrodes to the soil surface record this on a meter. The ions of the solution determine its electrical conductivity and can therefore affect the resistance between the electrodes. Although the gypsum does buffer the solution at approximately 2dS/cm, soil solutions with salt concentrations higher than this affect the calibration of the instrument (Campbell et al., 1990).

Neutron probes are comprised of a radioactive source and a detector, suspended from a cable which is housed in a shielded container. The source is lowered down an aluminium access tube to each depth of measurement. High speed neutrons pass through access tube and enter the soil matrix, where they collide with the hydrogen atoms of the soil water and are slowed down. The neutrons are reflected back and counted by the detector. The measurement is an indirect measure of the soil water content because water is the main source of hydrogen in the soil. A universal calibration equation can therefore be used to convert the reading to volumetric soil water content (Campbell et al., 1990).

3.2.3 Irrigation application

In general, two different irrigation systems are used in the Hex River Valley: microsprinklers and drippers. Both of which are classified as micro systems. By making use of these systems water loss is reduced because small amounts of water is applied close to the soil surface (Kruse, Bucks and von Bernuth, 1990).

Drippers apply water through small emitter openings at or near the soil surface. Advantages of using this system are that it is easy to install, field inspections and changing and cleaning emitters can be done effortlessly. In general, water use efficiency is higher than with other systems because of lowered evapotranspiration and limited runoff losses. These systems have an efficiency of 95 percent (Kruse et al., 1990; McCarthy, 2004; Sparrow and Norton, 2004).

Microsprinklers apply water via a small mist or spray. Unlike with drip, this method distributes the water through the air which encourages water losses via wind and evaporation, especially when there is little vegetative cover and has a system efficiency of 80 percent. Microsprinklers are comprised of fast-rotating rotors which distribute the water (Kruse et al., 1990; McCarthy, 2004; Sparrow et al., 2004). Table 3.1 compares a number of aspects of drippers and

microsprinklers. It lists aspects to consider when deciding on which system to use and includes the advantages and the disadvantages of each.

Table 3.1. A comparison between microsprinklers and drippers (Sparrow et al., 2004).

Factors to consider	Drip irrigation	Microsprinklers
Site		
Suitability to steeply sloping topography (design capability/erosion potential)	Most suitable	Suitable for many situations
Suitable soil texture	All except where texture very light e.g. sands/gravels or heavy poor permeability	All Soils
Impact of wind	Low	Medium
Water supply and quality		
Limited total water supply	Well suited	Rarely suitable
Water cleanliness/filtration needs/ potential for clogging	Fine filtration, often chlorination	Fine filtration
Use of saline water	Most tolerant	Tolerant with adequate leaching
Efficiency of water use		
Water distribution uniformity	High	High
Evaporation losses	Low	Medium
Water lost by passing through the rootzone	Low	Low to medium
Overall water use efficiency	Highest, particularly for young vines	High
Management		
Management skills needed	High	Medium
Potential for automation	High	High
Margin for error in water application/system failure	Low	Medium (depending on soil water storage)
Interval between irrigations	Small	Medium (depending on soil water storage)
Potential for foliage/fruit wetting, causing diseases	Nil	Low
Potential to cause under vine weed growth	Low due to small wetted area, difficult to incorporate pre-emergence herbicides	High, need to control to stop interference with spray
Vineyard access after irrigation e.g. for pesticide sprays	Few restrictions	Can be restricted after irrigation depending on the soil type
Fertigation efficiency	Highly efficient, but more expensive fertiliser is required	Medium
Suitability to establish a cover crop, ability to control dust	May be difficult in dry season, No dust control	Suitable
Suitability for vineyard cooling	Not suitable	Some control
Soil compaction	Low as inter-row is not wetted	Low to medium

3.3 Materials and methods

3.3.1 Comparison of the theoretical irrigation requirements with actual irrigation applied

Six similar blocks were chosen based on soil type, cultivar and irrigation system for the comparison of actual irrigation figures with those determined using the evaporation pan calculation, SAPWAT and Vinet. The dripper blocks chosen are HT3, HT6 and HT9 and the microsprinkler blocks are HT 5, HT7 and HT9, the details of each of which are listed in Table 3.1.

Table 3.1. Characteristics of the dripper (HT3, HT6, HT12) and microspinkler (HT5, HT7, HT9) blocks.

	HT3	HT6	HT12	HT5	HT7	HT9
Block size (ha)	2.25	1.74	1.33	0.96	0.83	1.54
Cultivar/Rootstock	Dauphine/ Ramsey	Dauphine/ 99Richter	Dauphine/ Ramsey	Dauphine/ Ramsey	Dauphine/ Ramsey	Dauphine/ Ramsey
Vine spacing (mxm)	3.5 x 1.5	3.0 x 1.2	3.0 x 1.8	3.0 x 1.8	2.4 x 1.8	2.7 x 1.8
Planting date	1996	1994	1987	1995	1990	1990
Soil Type	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Sandy Loam
Irrigation system	Drip	Drip	Drip	Micro	Micro	Micro
Area wetted (%)	40	40	40	100	100	100
Delivery rate (L/hr)	4.0	4.0	4.0	30.0	32.0	32.0

Current irrigation scheduling practiced on the farms of the Hex River Valley is based on evaporation pan calculations (using long-term data from the De Doorns weather station; Appendix 4). Dripper blocks are irrigated everyday and microsprinkler blocks are irrigated twice weekly.

In order to determine the irrigation requirement using the evaporation pan calculation, Equation 3.1 is used.

$$ET_c = PET \times K_c \qquad (3.1)$$

ET_c = daily evapotranspiration from the crop (mm)
PET = daily A pan evaporation (mm)
K_c = correction co-efficient (crop factor)

The crop factors for this calculation are values adjusted specifically for the Hex River Valley from those published by van Zyl and Fourie (1988) and are listed in Table 3.2.

Table 3.2. Crop factors for calculation of ET_c using the evaporation pan, adjusted specifically for the Hex River Valley.

Month	Crop factor
October	0.35
November	0.45
December	0.55
January	0.60
February	0.55
March	0.50
April	0.45

Actual irrigation applied in two different seasons was compared to irrigation requirements determined using evaporation pan calculations, SAPWAT and Vinet. Evaporation pan calculations were done using long-term weather data. Vinet and SAPWAT produce "customized" results based on specific block information inserted into each programme (see Tables 3.3 and 3.4). Furthermore, SAPWAT only determines results for September to February, while Vinet determines irrigation requirements starting in October. For this reasons comparisons of the results will be done for October to February. Results are only presented for 2004/5 and 2005/6 seasons because prior to these seasons the dripper blocks were equipped with microsprinklers.

Table 3.3. Data required for Vinet

Required information	**Remarks**
Block size (ha)	Insert block size into programme
Vine spacing (m x m)	Insert vine spacing into programme
Trellis system	Options are either vertical or horizontal
Pruning mass (kg)	If not recorded options are available in programme
Soil type	A list of soil types is described by a number that the programme understands.
Soil water retention (mm/m)	Determined water retention values are inserted
Root depth (m)	Determined root depths are inserted
Cultivar	All cultivar are available to choose from
Available soil water depletion (%)	Bud break, flowering, pea size, véraison, harvest, leaf fall The date of each event must be known
Irrigation system	There is list of the different irrigation systems from which a choice can be made
Delivery rate (L/hr)	The irrigation system delivery rate must be inserted into the programme
Emitter spacing (m x m)	Insert emitter spacing
Wetted volume (%)	Insert the percentage volume wetted by irrigation system
Irrigation, soil water content readings, rainfall	Dates of readings/measurements must be known

Table 3.4. Options chosen in SAPWAT for the table grapes of the Hex River Valley.

Option	**Remark**
Crop	Table grape
Crop option	Early or late depending on whether the cultivar is was an early or a late one
Geographic Region	Semi-arid
Planting date	By default the programme selected the 1 September, this could not be changed.
Cover at full growth	For all blocks this was 85%
Wetted area	This was retrieved from the data of Table 2.5, Appendix 2. For drip it was 40%
Irrigation frequency	This information was collected from each of the producers. It is shown in Appendix 6, Table 6.1.2.
Irrigation system	Either microsprinkler or drip
Type of season	Normal
Crop factors	Values were used which were calculated for FAO56
Soil type and soil depth	Values retrieved from data in table 3.1, Appendix 3
Root distribution	Drip 60%; Microsprinkler 75%
Depth to which irrigation application should occur	0mm below field capacity

3.3.2 The investigation of the relationship between a yield-irrigation index and an income-irrigation index

Using the measured water use and yield data collected by the Department of Agriculture, calculations were done to determine a yield-irrigation index (YII) and as well as an income-irrigation index (III) for each of the six blocks for 2005/6 and 2006/7. The calculations for the YII (Equation 3.2) and the III (Equation 3.3) are shown below. The results were then compared and conclusions drawn.

YII (kg/m^3) = [Total yield (t/ha)] / [Water applied (kg/m^3)] .... (3.2)

EII (R/m^3) = [cartons exported / ha x price per carton (ZAR)] / [Water applied (kg/m^3)] ...... (3.3)

3.4 Results and discussion

All results for irrigation requirements determined using evaporation pan, SAPWAT and Vinet are listed in Tables 6.1 to 6.13 of Appendix 6.

3.4.1 Comparison of the theoretical irrigation requirements with actual irrigation applied

In general irrigation requirements determined for dripper blocks are similar (Figure 3.1 and 3.2). Results for microsprinkler blocks vary considerably, especially for Vinet, which tends to be higher (Figure 3.3 and 3.4). There are a number of possible reasons why there are differences in the results determined for microsprinkler and dripper blocks:

- Drip irrigation occurs on a daily basis (high irrigation frequency), the result is that little stress is placed on the grapevine to extract water from the soil because the crop does not have to rely on the soil's ability to store water.
- The different methods for determining irrigation requirements view soil water in different ways. Evaporation pan calculations do not consider soil water content, irrigation frequency or soil water holding capacity, while Vinet and SAPWAT do.
- Differences between SAPWAT and Vinet could be related to soil water readings. Vinet requires the insertion of soil water readings, which were taken once weekly. Irrigation in these blocks also occurred once a week. It is possible therefore that soil water readings were constantly taken on days when soil water content was low, this would result in higher irrigation requirement results.

When actual irrigation is compared with determined irrigation requirements (2005/6 and 2006/7), it is difficult to tell whether or not the farmers are following the evaporation pan irrigation requirements strictly. This is because the specific situation of the block may have very different climatic conditions to that of the De Doorns weather station. For this reason it is recommended that scheduling be done based on climatic data obtained from the weather station that it is closet to that block.

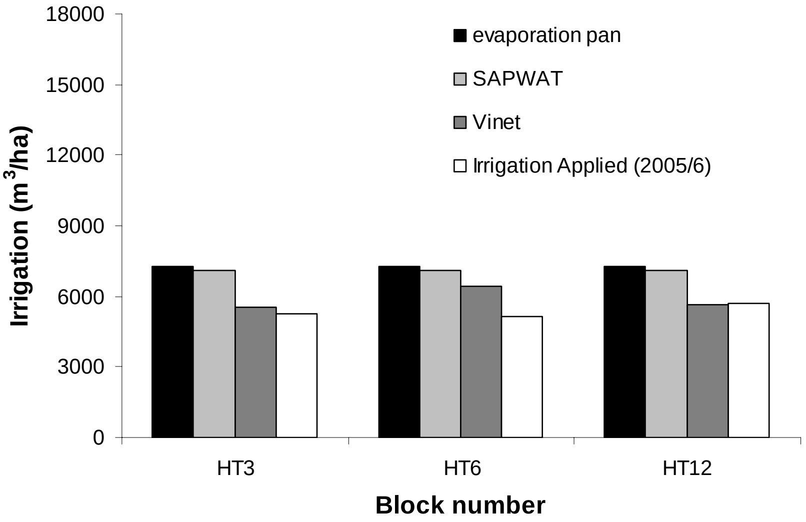

Figure 3.1. Comparison between the irrigation requirements determined for the drip blocks using the evaporation pan method, SAPWAT and Vinet with the actual irrigation applied during the 2005/6 season.

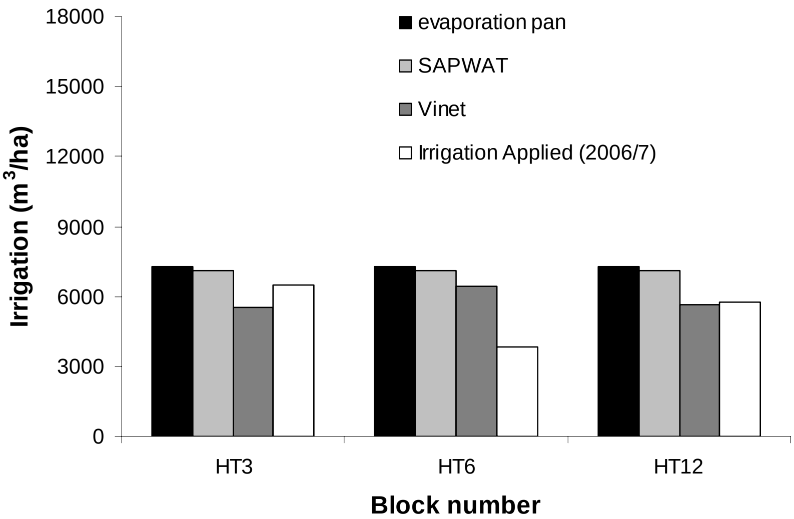

Figure 3.2. Comparison between the irrigation requirements determined for the drip blocks using the evaporation pan method, SAPWAT and Vinet with the actual irrigation applied during the 2006/7 season.

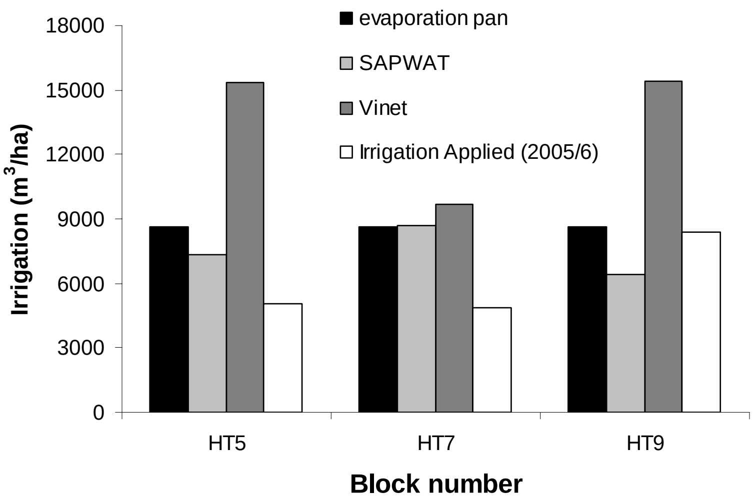

Figure 3.3. Comparison between the irrigation requirements determined for the microsprinkler blocks using the evaporation pan method, SAPWAT and Vinet with the actual irrigation applied during the 2005/6 season

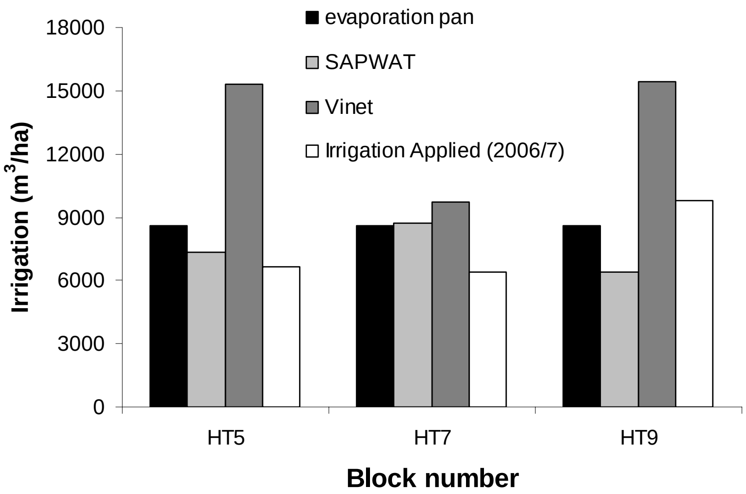

Figure 3.4. Comparison between the irrigation requirements determined for the microsprinkler blocks using the evaporation pan method, SAPWAT and Vinet with the actual irrigation applied during the 2006/7 season

3.4.2 The investigation of the relationship between a yield-irrigation index and an income-irrigation index

Tables 3.5 and 3.6 display all of the data related to yield, water use and export of table grapes of the six blocks for the 2005/6 and 2006/7. Although there are a variety of factors (such frost, soil type, disease incidence, etc) that may influence the yield of a crop there seems to be a relationship between the irrigation and yield. Results indicate that the amount of water applied to the block has an influence on the yield.

A relationship seems to exist between YII and III. Tables 3.5 and 3.6 show that when YII is higher, the III is also higher and when the YII is low, the III is also low. This suggests that although using water more efficiently will not necessarily result in the highest possible yield, high returns can be achieved. For example, HT5 is a producer that faces water shortages most years and has to irrigate very conservatively. However, lower III achieved in the other blocks are likely to be a result of factors such as disease, frost, soil type, poor set, etc.

Table 3.5. Total yield, export yield, export percentage, water use efficiency (WUE), price per carton, number of cartons exported, income made on exported cartons, amount of water used and economic water use efficiency (EWUE) of each of the six blocks for the 2005/6 season.

	Total Yield (t/ha)	Export Yield (t/ha)	Export Percentage	YII (Kg/m^3)	Price/carton (ZAR)	No. cartons exported	Income (ZAR)	Water Applied (m^3/ha)	III (R/m^3)
HT3	27.08	18.41	68	3.87	28,48	4091	116511,68	6990	16.67
HT6	17.82	14.79	83	2.49	32,00	3286	105152,00	7151	14.70
HT12	33.23	26.59	80	4.44	32,00	5908	189056,00	7489	25.24
HT5	31.25	23.75	76	5.11	29,13	5277	153719,01	6113	25.15
HT7	20.96	14.88	71	3.60	33,00	3306	109098,00	5825	18.73
HT9	21.69	19.30	89	2.09	22,00	4288	94336,00	10393	9.08
Average for drip	26.04	19.93	77	3.6	30,82	4428	136906,56	7210	18.87
Average for micro	24.63	19.31	78	3.6	28,04	4290	119051,00	7444	17.65
Overall average	25.34	19.62	77	3.6	29,44	4359	127978,78	7327	18.26

Table 3.6. Total yield, export yield, export percentage, water use efficiency (WUE), price per carton, number of cartons exported, income made on exported cartons, amount of water used and economic water use efficiency (EWUE) of each of the six blocks for the 2006/7 season.

	Total Yield (t/ha)	Export Yield (t/ha)	Export Percentage	YII (Kg/m^3)	Price/carton (ZAR)	No. cartons exported	Income (ZAR)	Water Applied (m^3/ha)	III (R/m^3)
HT3	23.76	18.77	79	2.71	40,48	4171	168842,08	8753	19.29
HT6	28.13	22.50	80	4.92	38,00	5000	190000,00	5711	33.27
HT12	49.21	39.86	80	4.02	36,00	8857	318852,00	12115	26.32
HT5	38.58	33.18	86	4.86	39,42	7373	290643,66	7933	36.64
HT7	26.02	23.16	89	3.34	36,00	5146	185256,00	7798	23.76
HT9	35.92	30.00	85	6.50	35,00	6666	233310,00	7565	30.84
Average for drip	33.70	27.04	80	3.88	38,16	6009	225898,03	8860	26.29
Average for micro	33.51	28.78	87	4.90	36,81	6395	236403,22	7832	30.41
Overall average	33.60	27.91	83	4.39	37.48	6202	231150,62	8313	28.35

In conclusion, it can be said that it is difficult to tell from this data whether or not the farmers of the Hex River Valley follow a strict irrigation scheduling programme. Furthermore, it is important to use a weather station which is located as close to the block/farm to be irrigated as possible. Amount of water applied to the block does have influence on the yield of the block and a relationship seems to exist between YII and III. Lastly, is possible to achieve high yields with well managed, low water application rates, as long as the crop is managed well.

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Chapter 4
Assessment of soil properties in irrigated soils

4.1 Introduction

In order to manage any crop efficiently, it is important to understand the soil-water-chemical interactions that take place, because applying the right fertilizers at the right time at the right quantities has a significant effect on the quantity and quality of the yield. Furthermore, it is important to understand the effect the application of irrigation has on the nutrient status of the soil. The following sections therefore discuss the relationships between water and irrigation and the water status in relation to the nutrient content of the soil. This chapter takes a look at the possibility that high water application rates over a number of years could be leaching the soils.

4.2 The soil-chemical relationships of irrigated soils

4.2.1 Ion exchange

The net negative charge of soils is usually carried by the clay particles present in the soil and is neutralized by the cations that are adsorbed to its surface. Cations can be exchanged for other cations, in solution, of stoichiometrically equivalent amount of other ions. Ca and Mg are the main cations found in the soil solution in irrigated soils. When soils are irrigated with water of low water quality (i.e. high SAR), an excess of soluble salts accumulates and Na becomes a dominant soil cation. In cases like these, Ca and Mg are replaced by the accumulated Na. The physical and mechanical properties of the soil are sensitive to this type of exchangeable process. Divalent cations are responsible for the “good” physical properties of the soil, hence chemical exchanges like this result in more undesirable physical soil properties (McBride, 1994; Shainberg, 1973). It is important therefore that irrigation water does not contain excessive amounts of Na^+ as it could result in displacement of the desirable cations with less desirable ones. This can result in the leaching of the desirable cations from the soil profile.

4.2.2 Solute movement

The water and soluble salts that enter the soil via irrigation make up an important part of the root environment. For example, salts may accumulate in the root zone or they may be leached out depending on the transport processes and solute interactions taking place in the soil. To manage irrigation in an attempt to prevent the hazardous effect of salt on the plant and the soil, it is important to understand the processes involved. Solutes can move via two processes: diffusion and convection (Bresler, 1973).

Diffusion is the movement of individual particles of molecular size as a result of thermal energy. The energy causes the particles to move at random within the phase causing other particles to move from points of high concentration to points of low concentration. *Convection* is the movement of dissolved ions that are carried away by moving water. When the solution flows through the soil, the flow velocity determines the convective transport of the solutes. Flow in large pores is greater than flow in small pores and much faster in the centre than along the edges of any pore (Bresler, 1973).

4.2.3 Soil nutrients and water

Plants get their nutrients from different sources in the soil and from the chemicals such as fertilizers and manures which are added to the soil. Even though fertilizers only make up a small percentage of the nutrient requirements of irrigated crop production, misuse may lead to reductions in yield size and yield quality (Kafkafi, 1973). The sections to follow will focus on the effect of over-irrigation on the nutrient status of the soil.

Nitrogen occurs in the soil as N_2 gas and in humus as both organic and inorganic nitrogen. The different forms of nitrogen interact through a series of processes known as the nitrogen cycle. The transformation of nitrogen to forms which are useable by plants is dependent on the moisture content of the soil. At optimum soil moisture contents the biological processes (plant uptake and growth, decomposition, ammonification and nitrification) proceed at a maximum rate (depending on the soil temperature). At limited soil moisture contents, the biological processes are stunted, when soil is excessively wet, NO_3-N is lost via leaching. Furthermore, excessively wet soils limit the oxygen content of the soil resulting in denitrification and a reduction in root respiration. Thus, if either water or nitrogen is not at optimum levels, yield will be negatively affected (James, Hanks and Jurinak, 1982).

Soil potassium is commonly found in the following three forms: a) in feldspars, micas and illite clay minerals, b) at exchange sites on clay mineral surfaces and c) in the soil solution as dissolved potassium. Potassium on clay mineral surfaces and dissolved potassium are the forms that are readily taken up by plants. The potential of potassium to leach out of the soil is determined by the cation exchange capacity of the soil along with the cation concentration of the irrigation water. Soils that have high cation exchange capacity will limit the amount of potassium leaching that occurs (James, 1982; Kafkafi, 1973).

Calcium and magnesium are present in the soil as minerals and as exchangeable cations or in the soil solution. In general, the application of Ca to the soil encourages Mg leaching because the adsorption affinity to soils and organic matter is higher for Ca than Mg. Furthermore, leaching of both Ca and Mg is accelerated by the acidification of soil as a result of nitrification of ammonium because under dry conditions, H^+ and Al^{3+} ions displace Ca and Mg (Camberato and Pan, 2000).

Sulfur is adsorbed by plants as sulfate (SO_4^{2-}) in solution. Sulfate can adsorb to the positive exchange sites or clay minerals, organic material and Fe and Al oxides. The capacity of the soil to adsorb sulfate is decreased by an increase in the soil pH and P content. Binding is due to electrostatic attraction and ligand exchange mechanisms and is highly dependent on the presence of positive charge in the soil colloids. The retention of sulfates in the soil is enhanced by the presence of Ca in the soil. When water is applied (both irrigation and rain), sulfates are easily leached out of the soil (Camberato, 2000).

Iron is the most abundant micronutrient found in soils and mainly occurs in various forms of Fe^{2+} and Fe^{3+}. The most common form of iron is Fe_2O_3 which is very stable and insoluble in water. Manganese is similar in chemistry to Fe. The most important form of Mn with regards to crop production is the divalent form (Mn^{2+}) because it is the most stable. Copper usually occurs in the soil in sulfide form and is present in adsorbed form or as organic complexes. Zinc is present in the soil as a divalent cation (Zn^{2+}) and is considered the most mobile of the micronutrients (Mortvedt, 2000).

4.3 Materials and methods

4.3.1 Soil sampling

It was decided that only the Dauphine blocks (HT1 to HT16), as well as the five new blocks (HT33 to 37) would be sampled. The Dauphine blocks were chosen because over the eight years of data collection, only these late cultivar blocks have remained consistent (no blocks have been removed from the study or replaced by other blocks). The five new blocks were chosen because no soil analysis had been done on them yet.

The sampling procedure involved extracting soil at two depths, a 0-20 cm and a 20-40 cm, at nine positions in each block. The exact sampling position was based on a technique described by D. Walvoort (2006), called Sudoku Sampling. The technique is based on the sudoku grid (Figure 4.1).

1	4	**7**	2	5	8	3	6	9
2	5	8	3	6	9	4	**7**	1
3	6	9	4	**7**	1	5	8	2
4	**7**	1	5	8	2	6	9	3
5	8	2	6	9	3	**7**	1	4
6	9	3	**7**	1	4	8	2	5
7	1	4	8	2	5	9	3	6
8	2	5	9	3	6	1	4	**7**
9	3	6	1	4	**7**	2	5	8

Figure 4.1. The Sudoku grid used to collect the soil samples for chemical analysis.

Each vineyard block and, in cases where the blocks were not square or rectangular, some of the surrounding area was included. Each row of the block was then counted and the total number of rows was divided by nine. The answer indicated in which row the sample should be taken. For example if a block contained 180 rows, then a sample was taken every 20 rows. To determine the exact sampling position in each row, the width of each row was measured by stepping it out. The number of steps taken to cross the block was then divided by nine (e.g. if it took 90 steps to cross the block, each block on the sudoku grid represented 10 steps across that block).

To choose nine positions in the block would mean that one number from the grid was chosen. In this case seven was chosen and the positioning of seven in the grid presented the position where the sample should be taken within the block.

If for example the seven in Figure 4.2 was chosen and the dimensions discussed above are for the block to be discussed, then the following procedure was followed. Starting at one end of the vineyard (on the left hand side of the block) 20 rows are counted. In the 20th row, because seven is the number eighth number from the left, 8 x 10 steps were taken to reach the sampling position. Samples are then taken somewhere in the vicinity of the 80th step. Samples were taken in the vine row using an auger. In some cases samples could not be taken at both depths (0-20cm and 20-40cm) because the soils contained shallow alluvial boulders and/or rocks. Under these circumstances the soils were only sampled at 0 to 20cm. The collected samples were air dried; any clods were broken up and the soil was sieved through a 2mm sieve. They were then analysed.

1	4	**7**	2	5	8	3	6	9
2	5	8	3	6	9	4	**7**	1
3	6	9	4	**7**	1	5	8	2
4	**7**	1	5	8	2	6	9	3
5	8	2	6	9	3	**7**	1	4
6	9	3	**7**	1	4	8	2	5
7	1	4	8	2	5	9	3	6
8	2	5	9	3	6	1	4	**7**
9	3	6	1	4	**7**	2	5	8

Figure 4.2. Sudoku grid with arrows showing the orientation when using the grid.

4.3.2 Chemical Analysis

Soil pH was determined using 1M KCl at a soil:solution ratio of 1:5 (White, 1997). A 1:5 soil:water solution was used to determine the EC (dS/cm) of the soil. The filtrate was analysed for soluble cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) using atomic absorption spectroscopy (AAS) and for anions using ion chromatography (Rhoades, 1982). The filtered supernatant from a 1:5 soil: NH_4OAc extract was analysed by AAS for K^{+}, Na^{+}, Ca^{2+} and Mg^{2+} (White, 2006). A 5.0g subsample was milled and used for EDTA extraction for trace elements. The filtrate of 1:3 soil:EDTA solution was analysed using AAS to determine the concentrations of Cu, Fe, Mn and Zn (Barnard et al, 1990). B was extracted using the hot water extraction method (Bingham, 1982). The filtrate of which was analysed using inductively coupled plasma-optical emission spectroscopy (ICP-OES) (Jobin-Yvon Emission, 1999)

4.4 Results and discussion

In order to investigate if relationships exist between irrigation application and each of the chemical parameters, a single value for each block needed to be determined for each set of results. Therefore, for each block the mean was determined for the results of the nine sampling points (Tables 7.1 to 7.68, Appendix 7) and is discussed below. Included in these tables are the 90th and 10th percentiles which were also used to determine if any interactions exist between cumulative irrigation and the analysed chemical parameters of the soil.

Figures 8.1 to 8.11 of Appendix 8 illustrate the relationships between the averages of the various chemical parameters and the cumulative irrigation application (total irrigation of all eight seasons). The results imply that under continuous high irrigation application, nutrients are leaching out of the soil, emphasising the need to irrigate efficiently. The results are however inconclusive because there are too few points.

The correlations of the results of the various chemical analyses with each other did not prove to have any significant results, except for the one between Ca and sulfate (Figure 4.3). This shows a strong relationship between these two soil nutrients and suggests that the main form of sulfate present in the soil is bound to Ca ($CaSO_4$).

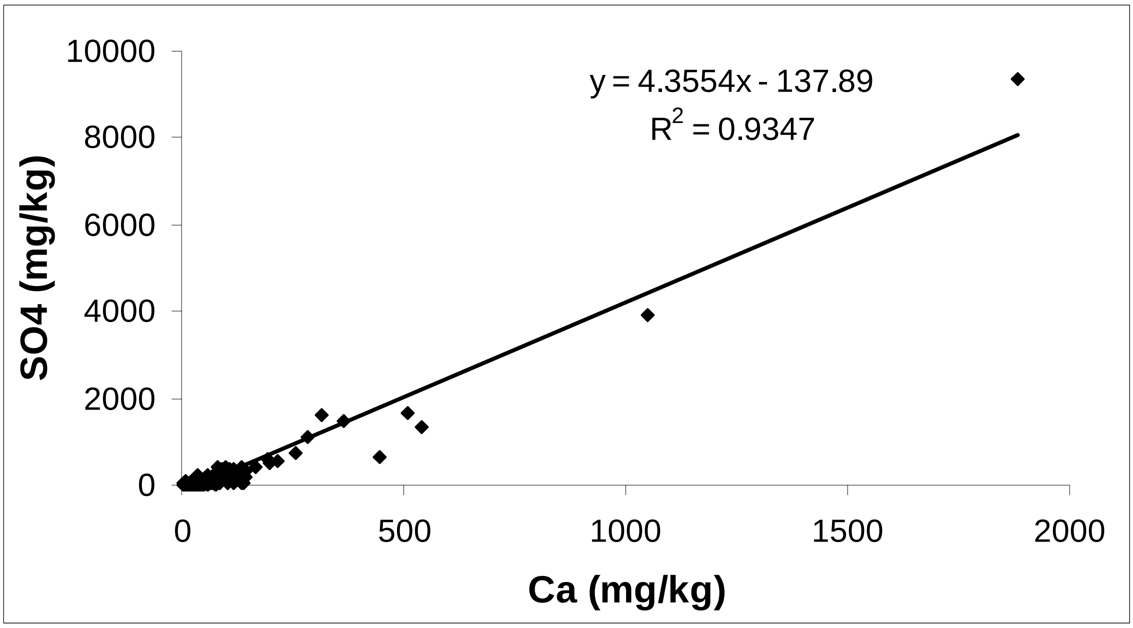

Figure 4.3. The relationship between Ca (mg/kg) and SO_4 (mg/kg) in the soils of the Hex River Valley.

Furthermore, the following should be highlighted as reasons for possible relationships between yield and the nutrient status of the soil:

- The average pH values for the blocks vary. In some instances the pH is below the optimum range of 5.5 to 8.0 (Lanyon et al., 2004), while in the remainder of cases the pH does fall within the optimum ranges. The pH distribution is inconsistent because in a few instances the pH of both sampling depths is below 5.5, while in most cases, a deficiency is only present in one of the sampling depths.

- The average Ca (mg/kg) values mostly fall outside the adequate range of 100 to 250 mg/kg (Lanyon et al., 2004). Only a few of the blocks fall within the adequate range. The remainder of the blocks are either deficient or marginal. Although there is no significant correlation between Ca and water application, it is possible that many of the blocks have low concentrations because it is leached out. More intensive irrigation application data collection could possibly clarify this.

- For all trace elements (Cu, Mn, Fe and Zn), the average concentrations are either toxic or high. It would almost seem obvious that toxicity symptoms would have been present on the vines during the growing season and consequently that yield was affected.

In general, soil properties cannot be well related to vine performance because of the complexity of the root-soil system. This is because there are so many factors that affect the uptake of nutrients from the soil by the root. The result may be that although a particular nutrient may be abundant in the soil, it is deficient in the grapevine (Lanyon et al., 2004).

4.5 References

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Chapter 5
Conclusions and recommendations

Based on the results of this study it is difficult to determine whether or not irrigation of vineyards is guided by a scheduling programme. The main reason for this is that each farm (and block) has a unique microclimate and management practices, and comparing the irrigation to long-term data for only one weather station prevents any accurate conclusions from being drawn. What is made clear however, is the importance of using weather data from a weather station as close to the blocks as possible. In addition to this, despite soils being grouped into the same category (e.g. sandy loam); each block has its own unique soil properties which will influence water consumption. In addition to this, microclimates of vineyards differ. It is the intricate combination of the microclimate and the soil that must influence irrigation of a vineyard.

Evapotranspiration determined using the evaporation pan method is entirely dependent on the data collected from weather stations. Therefore using a weather station that has a completely different microclimate to the block/s in need of irrigation could over- or under-predict the irrigation requirements. Programmes such as SAPWAT and Vinet are based on evapotranspiration models which take both evaporation and transpiration into account. Furthermore, such programmes consider climatic conditions as well as soil properties when predicting irrigation requirements.

The results determined by each of the three methods mentioned here were similar for dripper blocks (although Vinet results were slightly lower in all cases). Results for the microsprinkler blocks varied considerably for all methods, in particular for Vinet. In some instances the irrigation requirement determined by SAPWAT was lower than that determined by the evaporation pan. For Vinet however, in all cases the predicted irrigation requirement was higher. Possible explanations for the results are as follows:

- Drip irrigation occurs frequently and is applied directly to the root zone. Under these circumstances water is freely available to the plant for uptake and there is thus little soil water influence because the pores are frequently filled and water is freely available water. The environmental factors therefore are the main determinants of the irrigation requirement.
- Microsprinkler irrigation occurs less frequently and is applied to a larger area and not directly to the root zone. Evaporation can therefore take place directly from the sprinkler spray during irrigation and from the soil surface area wetted by microsprinkler. Evaporation pan does not take these factors into account while SAPWAT and Vinet do.

- The high irrigation predictions determined by Vinet are likely due to the manner in which Vinet takes the soil and water application data into account. As apposed to SAPWAT and evaporation pan, Vinet takes detailed soil and irrigation system information into account.

It can be deduced that a relationship exists between YII and III i.e. that there is a tendency for III to be higher when YII is higher. The aim would therefore be to optimize the income that can be earned, rather than to produce the highest possible yield. This could possibly be achieved with more careful irrigation scheduling. When irrigation is applied luxuriously more water will be lost due to evapotranspiration, runoff and drainage. Furthermore, vigorous growth is encouraged, which in turn increases the potential for disease and infection. Water lost due to drainage encourages nutrient leaching. These are all factors which can negatively affect yield. The ability to produce good quality crops is inhibited when vines are under irrigated. It is important however to keep in mind that irrigation is not the only factor which may have an influence on the quality and size of grape yield. However, it is good practice to ensure that when scheduling irrigation that vineyards are not over-irrigated or under irrigated.

An important factor that any producer should keep in mind is that by applying water at optimum levels, rather an excessively, allows for the opportunity to reduce inputs costs. The money and water saved could be used to invest in the establishment of a new block (should the land be available).

The data suggests that the long-term application of high water rates may be leaching essential nutrients out of the soil. Many of the soils of the Hex River Valley have high sand percentages. The ability of sands to retain nutrients in the soil is much lower than for clays. It is therefore important that the soils be irrigated carefully in order to prevent any unnecessary leaching which can occur.

The study therefore proves that in some instances farmers are using water efficiently, while in other cases water is wasted, possibly resulting in leaching of nutrients out of the soil. It is recommended however that in order to determine if leaching is occurring a more intense study be conducted on the chemistry of the soil in relation with water application. It is also recommended that for every sampling point, water use and yield data be obtained. The study cannot determine optimum water use efficiency for the farmers of the Hex River Valley because of the multitude of factors that influence table grape quality. Good irrigation management is therefore a reflection of good management skills. It can furthermore be deduced that good grape quality cannot be attributed to irrigation alone, but rather to good overall management of the block.

Appendix 1

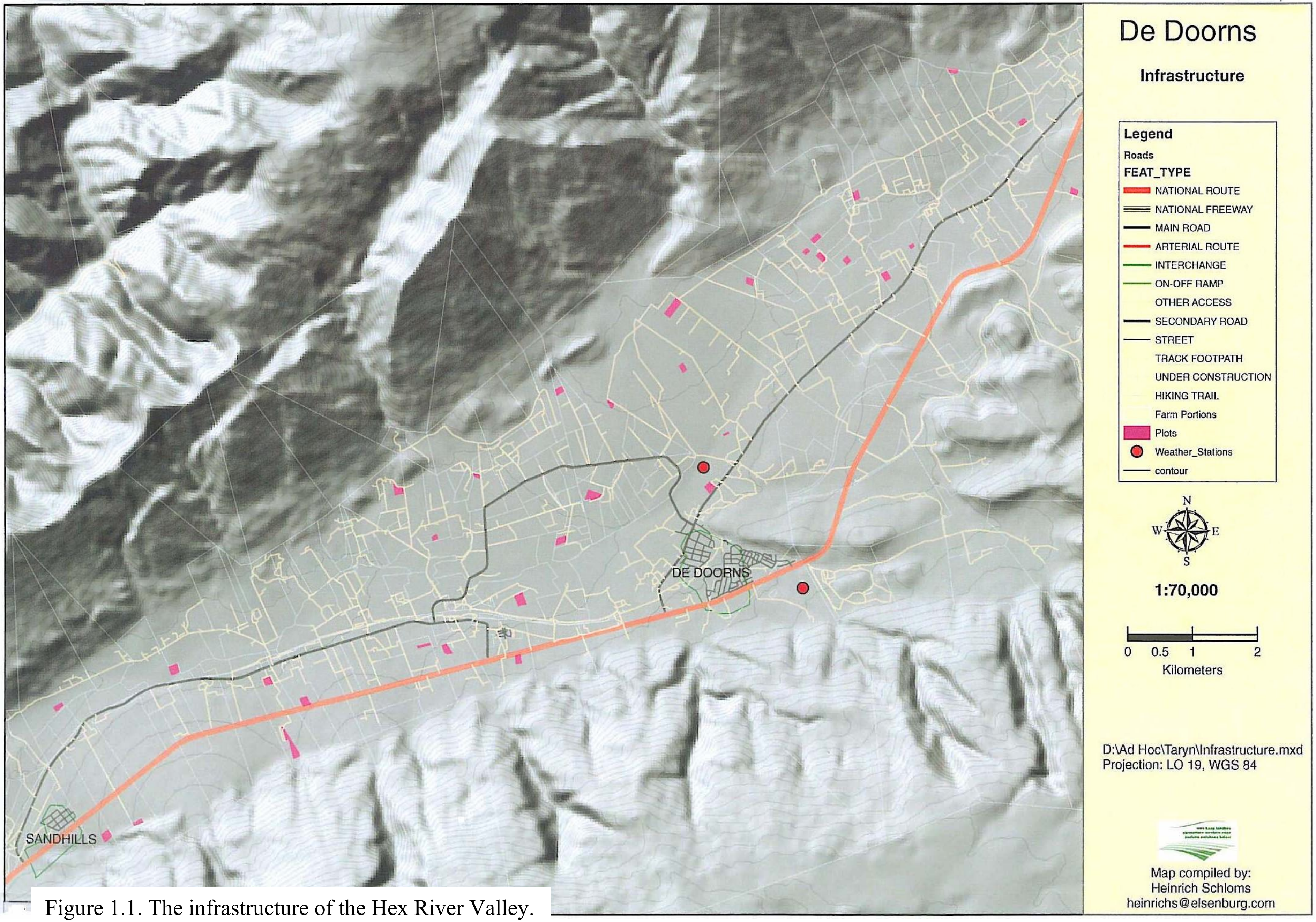


Figure 1.1. The infrastructure of the Hex River Valley.

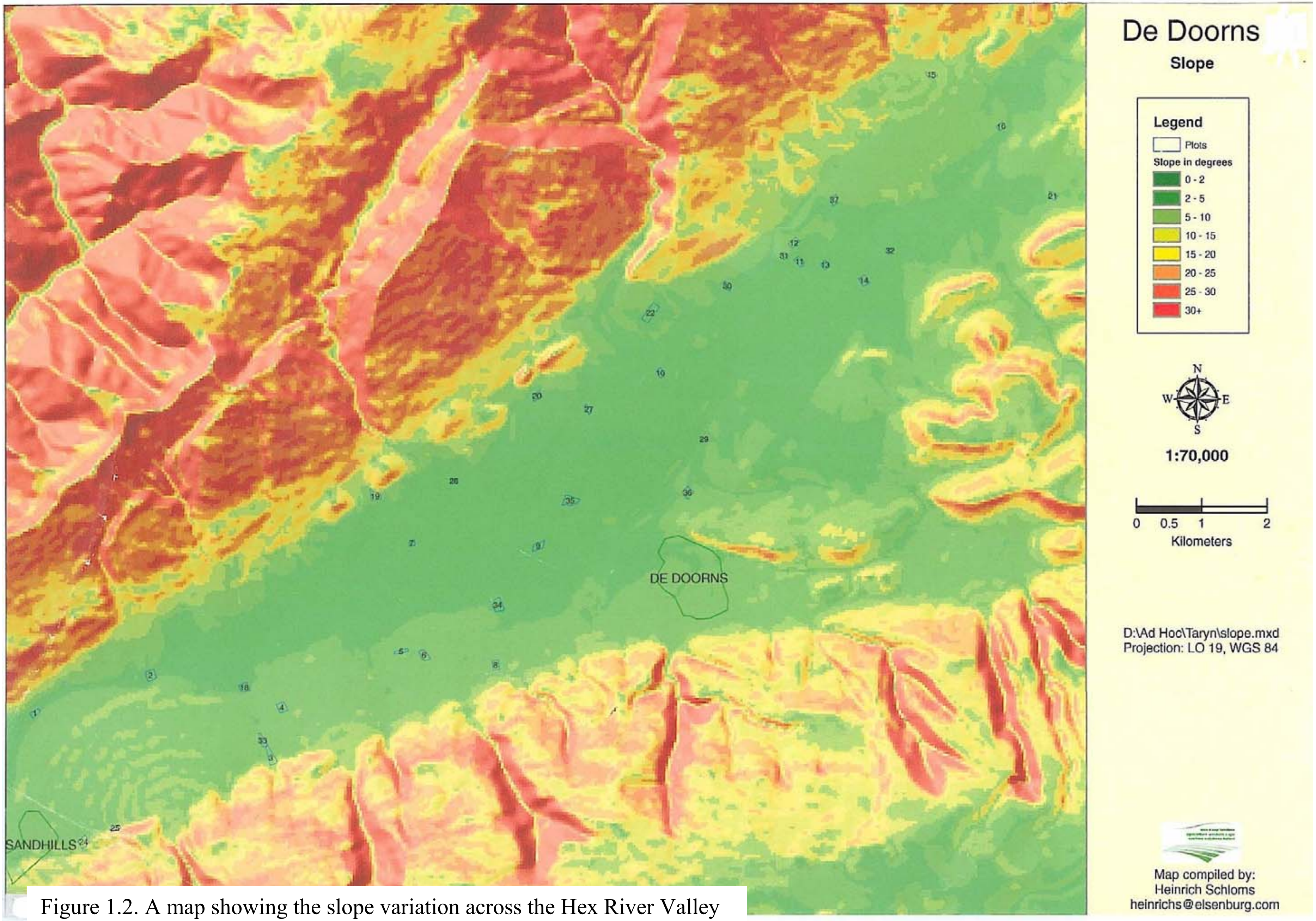


Figure 1.2. A map showing the slope variation across the Hex River Valley

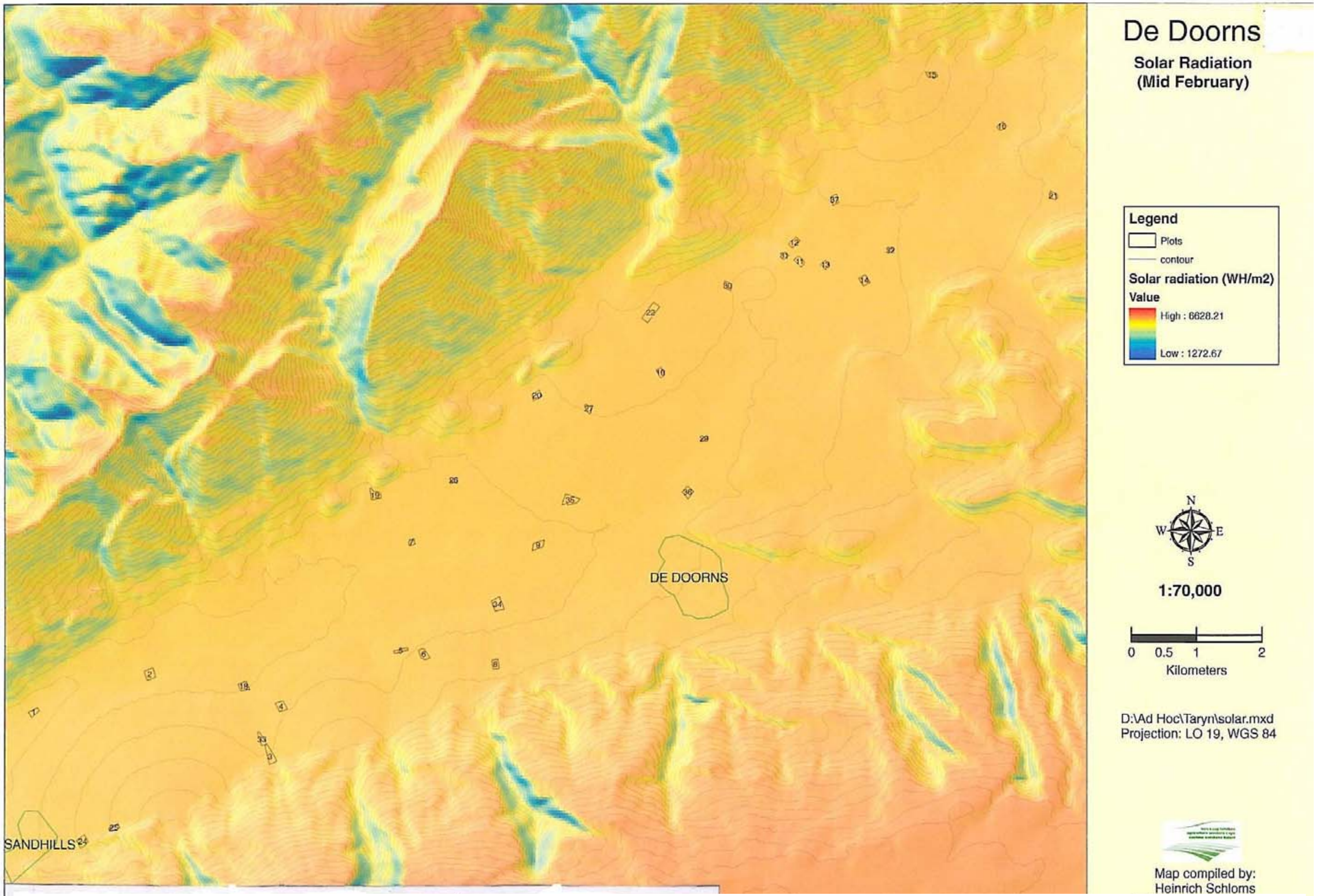
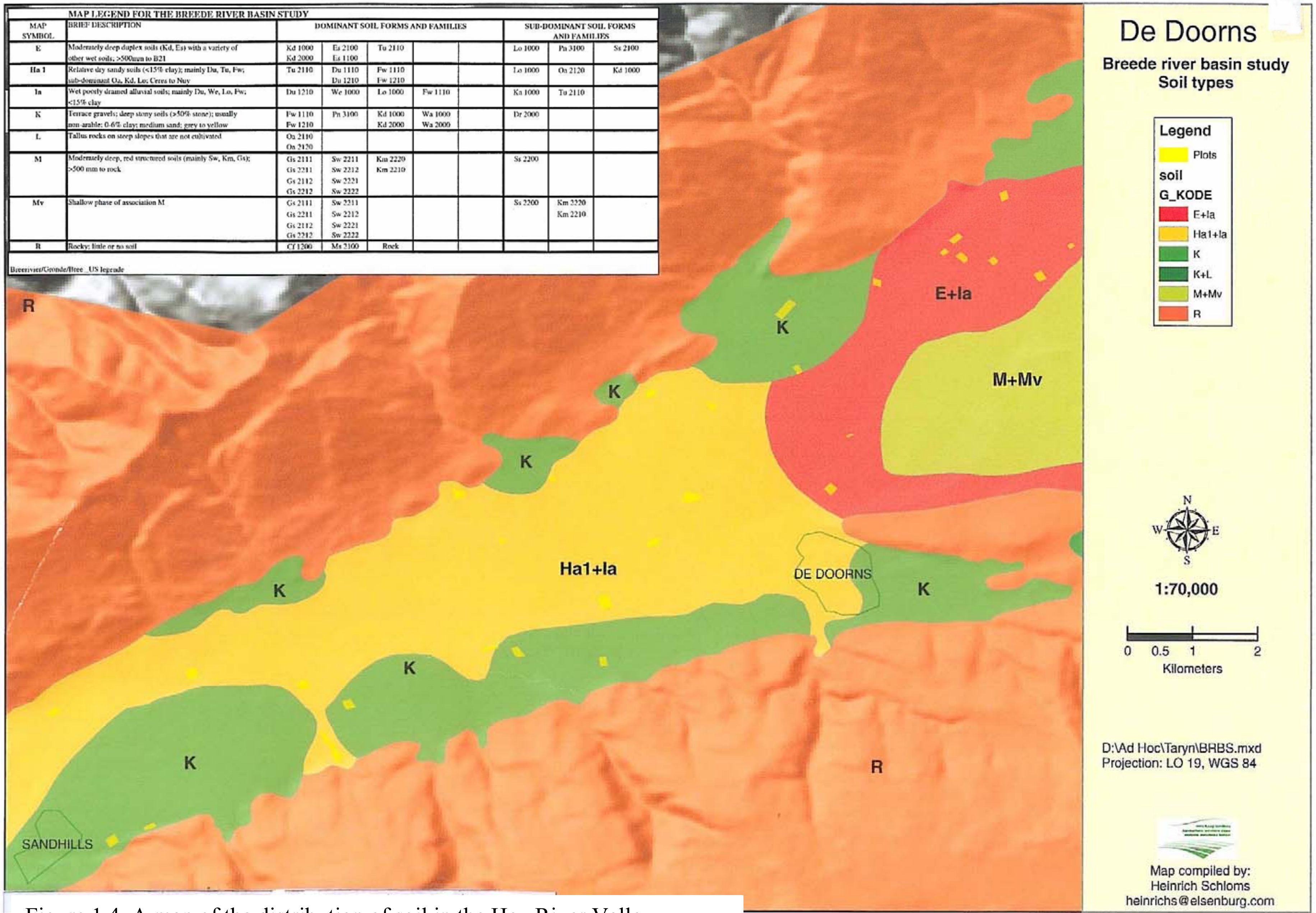


Figure 1.3. A map showing the solar radiation of the Hex River Valley. The map also indicates the location of the first 32 blocks.



MAP LEGEND FOR THE BREEDE RIVER BASIN STUDY

MAP SYMBOL	BRIEF DESCRIPTION	DOMINANT SOIL FORMS AND FAMILIES					SUB-DOMINANT SOIL FORMS AND FAMILIES		
E	Moderately deep duplex soils (Kd, Es) with a variety of other wet soils; >500mm to B21	Kd 1000 Kd 2000	Es 2100 Es 1100	Tu 2110			Lo 1000	Pa 3100	Ss 2100
Ha 1	Relative dry sandy soils (<15% clay); mainly Du, Tu, Fw; sub-dominant Oa, Kd, Lo; Ceres to Nuy	Tu 2110	Du 1110 Du 1210	Fw 1110 Fw 1210			Lo 1000	Oa 2120	Kd 1000
Ia	Wet poorly drained alluvial soils; mainly Du, We, Lo, Fw; <15% clay	Du 1210	We 1000	Lo 1000	Fw 1110		Ka 1000	Tu 2110	
K	Terrace gravels; deep stony soils (>50% stone); usually non-arable: 0-6% clay; medium sand; grey to yellow	Fw 1110 Fw 1210	Pn 3100	Kd 1000 Kd 2000	Wa 1000 Wa 2000		Dr 2000		
L	Tallus rocks on steep slopes that are not cultivated	Oa 2110 Oa 2120							
M	Moderately deep, red structured soils (mainly Sw, Km, Gs); >500 mm to rock	Gs 2111 Gs 2211 Gs 2112 Gs 2212	Sw 2211 Sw 2212 Sw 2221 Sw 2222	Km 2220 Km 2210			Ss 2200		
Mv	Shallow phase of association M	Gs 2111 Gs 2211 Gs 2112 Gs 2212	Sw 2211 Sw 2212 Sw 2221 Sw 2222				Ss 2200	Km 2220 Km 2210	
R	Rocky; little or no soil	Cf 1200	Ms 2100	Rock					

Breerivier/Gronde/Bree _US legende

Figure 1.4. A map of the distribution of soil in the Hex River Valley.

Appendix 2

Table 2.1. Block information for late cultivars (Dauphine).

Block Number	Crop information								Soil information	
	Block size (ha)	Cultivar	Rootstock	Planting date	Plant spacing (mxm)/number of vines per ha	Trellis system	Depth of soil preparation (m)	Drainage (Yes/No)	Soil management technique: Between rows	Soil management technique: In rows
HT1	1.04	Dauphine	Ramsey	1992	2.7 x 1.8 (2057)	Factory roof	1.0	No	Weed control	Weed control
HT2	1.96	Dauphine	Jaquez	1989	3.0 x 1.8 2.4 x 1.8 (2183)	Double gable	0.9	No	Weed control	Weed control
HT3	2.25	Dauphine	Ramsey	1996	3.5 x 1.5 (1905)	Factory roof	1.0	No	Weed control	Weed control
HT4	1.81	Dauphine	Ramsey	1986	2.7 x 1.8 (2057)	Factory roof	1.0	No	Weed control	Weed control
HT5	0.96	Dauphine	Ramsey	1995	3.0 x 1.8 (1851)	Factory roof	1.0	No	Mulch Weed control	Mulch Weed control
HT6	1.74	Dauphine	99Richter	1994	3.0 x 1.2 (2777)	Double gable	0.9	No	Weed control	Weed control
HT7	0.83	Dauphine	Ramsey	1990	2.4 x 1.8 (2315)	Slanting	0.9	No	Weed control	Weed control
HT8	1.32	Dauphine	Ramsey	1995	3.5 x 1.5 (1905)	Double gable	0.9	Yes	Weed control	Weed control
HT9	1.54	Dauphine	Ramsey	1990	2.7 x 1.8 (2057)	Double gable	0.6	Yes	Mulch	Mulch Weed control
HT10	0.94	Dauphine	Ramsey	1989	3.0 x 1.1 (3030)	Double gable	0.5	No	Clean tillage Mulch Weed control	Mulch Weed control
HT11	1.38	Dauphine	Ramsey	1991	3.0 x 1.8 (1851)	Trentina	0.9 – 1.1	No	Mulch	Mulch
HT12	1.33	Dauphine	Ramsey	1987	3.0 x 1.8 (1851)	Double gable	0.9	No	Mulch Weed control	Clean tillage Weed control
HT13	1.01	Dauphine	Ramsey	1995	2.4 x 1.8 (2315)	Factory roof	1.0	No	Weed control	Weed control
HT14	1.55	Dauphine	Ramsey	1991	3.5 x 1.2 (2380)	Double gable	0.8	No	Mulch Weed control	Weed control
HT15	1.17	Dauphine	Ramsey	1995	3.0 x 2.1 (1587)	Double gable	1.5	No	Weed control	Weed control
HT16	0.99	Dauphine	Ramsey	1993	2.4 x 1.8 (2315)	Trentina	0.6	No	Clean tillage Mulch Weed control	Clean tillage Mulch Weed control

Table 2.2. Block information gathered for early cultivar blocks during the 1999/2000 season.

Block Number	Crop information								Soil information	
	Block size (ha)	Cultivar	Rootstock	Planting date	Plant spacing (m xm)/ number of vines per ha	Trellis system	Depth of soil preparation (m)	Drainage (Yes/No)	Soil management technique: Between rows	Soil management technique: In rows
HT18	1.22	Alphonse Lavallée	Ramsey	1990	2.7 x 1.8 (2057)	Factory roof	0.9	No	Weed control Mulch	Weed control
HT19	1.10	Alphonse Lavallée	99Richter	1990	2.7 x 1.8 (2057)	Slanting	2.0	No	Weed control	Weed control
HT20	1.28	Alphonse Lavallée	Ramsey	1993	2.7 x 1.8	Factory roof	1.2	No	Weed control	Weed control
HT22	2.38	Alphonse Lavallée	Jaquez	1990	2.5 x 1.55 (2581)	Slanting	-	No	Weed control	Weed control
HT23	0.9	Alphonse Lavallée	99Richter	1991	2.7 x 1.8 (2057)	Slanting	0.5	Nee	Weed control Clean tillage Mulch	Weed control
HT25	2.04	Red Globe Sunred Seedless	Ramsey	1993	3.0 x 1.5 (2222)	Double gable	0.7	No	Weed control	Weed control

Table 2.3. Block information collected for early cultivars not included in the project during 1999/2000 season.

Block Number	**Crop information**								**Soil information**	
									Soil management technique	
	Block size (ha)	**Cultivar**	**Rootstock**	**Planting date**	**Plant spacing (m xm)/number of vines per ha**	**Trellis system**	**Depth of soil preparation (m)**	**Drainage (Yes/No)**	**Between rows**	**In rows**
HT17	1.98	Alphonse Lavallée	Ramsey	1990	3.0 x 1.2 (2778)	Double gable	1.0	No	Weed control	Weed control
HT21	0.88	Alphonse Lavallée	US2-1	1997	3.0 x 1.8	Single cordon	1.0	No	Clean tillage	Clean tillage
HT24	1.95	Sunred Seedless	99Richter	1995	3.0 x 1.8 (1852)	V-system	1.0	No	Clean tillage Mulch Weed control	Weed control
HT26	0.57	Sunred Seedless	Ramsey	1994	3.5 x 1.2 (2381)	Double gable	-	No	Weed control	Weed control
HT27	0.84	Sunred Seedless	Ramsey	1994	3.0 x 1.8 (1852)	Singe cordon	1.0	No	Clean tillage	Clean tillage
HT28	1.33	Sunred Seedless	Ramsey	1995	3.0 x 1.2 (2778)	Factory roof	1.0	Yes	Weed control	Weed control
HT29	0.32	Sunred Seedless	99Richter	1994	2.7 x 1.8 (2057)	Trentina	1.0	No	Mulch	Weed control
HT30	1.20	Sunred Seedless	Ramsey	1995	3.0 x 1.5 (2222)	Double gable	1.0	No	Weed control	Weed control
HT31	0.71	Sunred Seedless	Ramsey	1991	3.5 x 1.2 (2381)	Double gable	1.2	No	Mulch	Mulch
HT32	0.45	Sunred Seedless	Ramsey	1983	3.5 x 1.2 (2381)	Double gable	0.6	No	Mulch	Mulch

Table 2.4. Changes/replacements from that occurred after 2001 production.

Block replaced	**Crop information**								**Soil information**		**First season monitored**
									Soil management technique		
	Block size (ha)	**Cultivar**	**Rootstock**	**Planting date**	**Plant spacing (m x m)/number of vines per ha**	**Trellis system**	**Depth of soil preparation (m)**	**Drainage (Yes/No)**	**Between rows**	**In rows**	
HT17					Removed from project at the end of the 2004/5 season						N/A
HT18	1.7	Dauphine			2.7 x 1.8						2004/5
HT19		Sunred Seedless			2.7 x 1.8						2004/5
HT21	1.15	Red Globe									2001/2
HT22		Crimson Seedless			2.7 x 2.5						2005/6
HT28		Sunred Seedless			3.0 x 1.2						2005/6
HT28					Removed from project at the end of the 2005/6 season						N/A

Only where information is filled in did changes take place, all other information remains the same.

Table 2.5. Irrigation system data collected during the 1999/2000 season.

Block number	Irrigation system					Water provision scheme	
	Type	**Maintenance**	**Delivery rate (l/hr)**	**Wetting area (%)**	**Design pressure (kPa)**	**Source**	**Pressure compensation in blocks (Yes/No)**
HT1	Micro sprinkler	-	50	100	100	Borehole Scheme	No
HT2	Micro sprinkler	Rinse lateral ends	32	80	100	Borehole Dam Scheme	Yes
HT3	Micro sprinkler	Rinse pipes before the season starts	32	100	100	Borehole Scheme	Yes
HT4	Micro sprinkler	Rinse filter every 300m^3 of water applied	32	100	120	Borehole	Yes
HT5	Micro sprinkler	-	30	100	80	Borehole Scheme	Yes
HT6	Micro sprinkler	Rinse pipes weekly	32	100	100	Borehole Scheme	Yes
HT7	Micro sprinkler	-	32	100	100	Borehole Scheme	Yes
HT8	Micro sprinkler	Rinse lateral ends before the season starts	32	80	100	Borehole Scheme	Yes
HT9	Micro sprinkler	Rinse pipes before the season starts	32	100	100	Borehole Scheme	Yes
HT10	Micro sprinkler	Chlorine, rinse lateral ends every 2 months	20	100	100	Borehole Scheme	Yes
HT11	Micro sprinkler	Rinse lateral ends every week	32	100	100	Borehole Scheme	Yes
HT12	Micro sprinkler	Rinse pipes before the season starts	32	100	100	Scheme	Yes
HT13	Dripper	-	4	40	100	Borehole Dam Scheme	Yes
HT14	Micro sprinkler	Rinse pipes before the season starts	20	40	100	Dam Scheme	Yes
HT15	Micro sprinkler	Filter is rinsed every 2 weeks	32	100	100	Borehole Scheme	Yes
HT16	Micro sprinkler	-	32	100	100	Borehole Scheme	Yes

Table 2.6. Irrigation system data collected during the 1999/2000 season for early cultivars.

Block number	Irrigation system					Water provision scheme	
	Type	Maintenance	Delivery rate (l/hr)	Wetting area (%)	Design pressure (kPa)	Source	Pressure compensation in blocks (Yes/No)
HT18	Micro sprinkler	Rinse for 15 sec every hour	32	100	100	Own dam	Yes
HT19	Micro sprinkler	-	32	100	90	Borehole Scheme	Yes
HT20	Micro sprinkler	The dam yearly Filters every 2 weeks Rinse every 2 hours	32	100	100	Borehole Scheme	No
HT22	Dripper	Rinse lateral ends at every irrigation event and with chlorine every 1-2 times	2	25	100	Borehole	Yes
HT23	Micro sprinkler	Chlorine pills monthly Rinse pipes every 2 hours	20	100	100	Borehole Scheme	Yes
HT25	Dripper	With chlorine monthly First acid May 2000 Rinse lateral ends weekly	1.6	25	100	Borehole	Yes

Table 2.7. Irrigation system data collected during the 2000/1 season for blocks not included in the project during the previous season, for early cultivars.

Block number	Irrigation system					Water provision scheme	
	Type	Maintenance	Delivery rate (l/hr)	Wetting area (%)	Design pressure (kPa)	Source	Pressure compensation in blocks (Yes/No)
HT17	Dripper	Rinse lateral ends weekly Filter automatically	1.6	25	100	Borehole Scheme	Yes
HT21	Dripper	Rinse lateral ends and filter as necessary	4	40	100	Borehole	Yes
HT24	Micro sprinkler	Rinse filters weekly	32	100	100	Own dam	Yes
HT26	Micro sprinkler	Inspect pipes weekly	32	80	100	Own dam	Yes
HT27	Dripper	Rinse lateral ends and filter as is necessary	4	40	100	Borehole	Yes
HT28	Micro sprinkler	Inspects pipes weekly	32	100	100	Own dam Scheme	Yes
HT29	Micro sprinkler	Inspects pipes every 3 weeks	32	100	100	Scheme	Yes
HT30	Micro sprinkler	Rinse filter as is necessary Sprinklers are cleaned weekly	32	100	100	Borehole	Yes
HT31	Micro sprinkler	Inspect pipes during irrigation	32	80	100	Borehole Scheme	Yes
HT32	Micro sprinkler	Rinse every 2 weeks	32	80	100	Own dam Scheme	Yes

Table 2.8. Irrigation system for block that were replaced or for those that changed from micro to drip irrigation

Block number replaced/ changed	**First season monitored**	**Irrigation system**		
		Type	**Delivery rate (l/hr)**	**Wetting area (%)**
HT2	2006/7	Dripper	4	40
HT3	2006/7	Dripper	4	40
HT6	2006/7	Dripper	4	40
HT12	2006/7	Dripper	4	40
HT17	Not repositioned after 2004/5 season			
HT18	2005/6	Micro sprinkler	32	100
HT19	2006/7	Micro sprinkler	32	100
HT21	2002/3	Micro sprinkler	32	80
HT22	2006/7	Dripper	2.3	25
HT28	2006/7 Removed from project at end of season	Dripper	2.3	25

Table 2.9. Data which describes the management practices of each of the late cultivar blocks, collected during 2000.

Block Number	Irrigation scheduling		Winter Pruning	Thinning		Fertilization programme	Yield losses	
	Method	Recorded (Yes/No)		Flowering	Bunches per vine		Cause	%
HT1	Dig pits	Yes	Long bearers		22	Own	Powdery mildew	0.5
HT2	Neutron water meter Dig pits Tensiometer	Yes	4 Half-long 4 Short bearers		20	Own	Sunburn Bacterial infection	10 3
HT3	Neutron water meter Tensiometer	Yes	Long bearers		26	Consultant		
HT4	Neutron water meter	Yes	5 short 5 Half-long bearers		26	Consultant		
HT5	Tensiometer	No	Long bearers		18	Consultant + own		
HT6	Tensiometer	No	Long bearers	Suckering	22	Own		
HT7	Tensiometer	Yes	Half-long bearers	Remove week bunches		Own	Sunburn	1
HT8	Tensiometer Evaporation pan	Yes	Half-long bearers		20	Consultant		
HT9	Tensiometer	Yes	Long bearers		Harvest Management	Own	Downy mildew Sunburn	35 15
HT10	IRRITEL 2000	Yes	4 half-long 8-12 short bearers	Suckering	16-20	Consultant + own		
HT11	Neutron water meter Dig pits	Yes	4 long bearers 2-3 short bearers		Cut out berries with blemishes	Consultant	Downy mildew Botrytis Birds/insects	1 10 1
HT12	Diviner 2000 Calendar Tensiometer	Yes	Half-long bearers	1 bunch/shoot		Consultant	Powdery mildew Bacterial infection	1 33
HT13	Tensiometer	No	2-3 short bearers with runner shoots		20-24	Consultant + own		
HT14	Neutron water meter	Yes	Half-long bearers	Suckering		Consultant	Sunburn	20
HT15	Neutron water meter	Yes	Cane pruned with spurs for renewal		20-24	Consultant + own	Sunburn Birds/insects	5 5
HT16	Tensiometer	Yes	H-shaped Half long bearers			Own	Downy mildew Sunburn Birds/insects	1 1 0.5

Table 2.10. Data which describes the management practices of each of the early cultivar blocks, collected during 2000.

Block Number	Irrigation scheduling		Winter Pruning	Thinning		Fertilization programme	Yield losses	
	Method	Recorded (Yes/No)		Flowering	Bunches per vine		Cause	%
HT18	Neutron water meter Tensiometer	Yes	Short bearer (spur)		26	Consultant	Botrytis Birds/insects	2 15
HT19	Tensiometer	No	Spurs			Own	Botrytis Birds/insects	2 2
HT20	Calendar	Yes	Spurs		18	Own	Botrytis Sunburn Birds/insects Bacterial infections	2 3 2 3
HT22	Dig pits Calendar	Yes	Spurs and long bearers	One shoot/bud, hand-width apart		Consultant	Sunburn	20
HT23	IRRITEL 2000	Yes	H-shaped 4 half-long 12 spurs			Own Consultant	Powdery mildew Botrytis Birds/insects	1 1 2
HT25	Dig pits Tensiometer	Yes	Spurs Long bearers		18	Consultant	-	0

Table 2.11. Data which describes the management practices of each of the early cultivar blocks, collected during 2000/1 for cultivars not part of the project during the 1999/2000 season.

Block Number	Irrigation scheduling		Winter Pruning	Thinning		Fertilization programme	Yield losses	
	Method	Recorded (Yes/No)		Flowering	Bunches per vine		Cause	%
HT17	Dig pits Tensiometer	Yes	Spurs		20	Soil analysis Examine vigour Leaf analysis	Powdery mildew Sunburn	2 2
HT21	Calendar A-pan	Yes	Spurs	Small berries are removed from bunches twice during December	24	Consultant Leaf analysis		
HT24	Dig pits Tensiometer Neutron water meter	Yes	Spurs		22	Consultant Leaf analysis Soil analysis Growth vigour		
HT26	Dig pits	Yes	Spurs		20	Soil analysis	Birds/insects	5
HT27	Calendar A-pan	Yes	18 spurs per vine			Consultant Leaf analysis		
HT28	Neutron water meter	Yes	Spurs		20	Consultant	Birds/insects	2
HT29	Calendar A-pan Dig pits	Yes	Spurs Cordon system	Top Removal of small berries	22	Soil analysis Vigour at veraison		
HT30	A-pan	Yes	Spurs	Removal of small berries	20	Consultant	Powdery mildew Birds/insects	2 5
HT31	Neutron water meter	Yes	Spurs	Suckering	20	Consultant Leaf analysis Soil analysis		
HT32	Neutron water meter A-pan Dig pits Tensiometer	Yes	Spurs		18	Consultant	Birds/insects	10

Table 2.12. Long-term average vigour values per block for December to January for all years

Block number	Months				
	December	January	February	March	April
HT1	3	3	3	3	3
HT2	2+	2+	2+	2+	3
HT3	3	3	3	3	3+
HT4	3-	3-	3-	3-	3-
HT5	2+	2+	2+	2+	3-
HT6	3	3	3	3	3
HT7	3	3	3	3	3
HT8	3	3	3	3	3
HT9	3	3	3	3	3
HT10	3	3	3	3	3-
HT11	3	3	3	3	3
HT12	3	3	3	3	3-
HT13	2	2+	2+	3-	3
HT14	3	3	3	3	3
HT15	2	2	2	2	2
HT16	3	3	3	3	3
HT17	3	3	3	3	3
HT18	3	3	3	3	3
HT19	3	3	3	3	3
HT20	3	3	3	3	3
HT21	3	3	3	3	3
HT22	2	2+	2+	3-	3
HT23	3	3	3	3	3+
HT24	3	3	3	3	3+
HT25	2+	2+	3	3	3+
HT26	2	2	2+	2+	3-
HT27	3	3	3	3	3+
HT28	3	3	3	3	3+
HT29	3	3	3	3	4
HT30	2	2	2	2+	3
HT31	3	3	3	3	3+
HT32	3	3	3	3	3+

1. Weak: Shoot length is 50-90cm long
Shoots are pencil thickness
Internodes are short
Leaves are light-green in colour
Sunspots visible – more than 50%
Active growing points are absent when grapes are marble-sized

2. Average: Shoot length is 90-100cm long
Shoots are medium thickness
Active growing points are absent at véraison

3. Ideal: Shoot length is 110-150cm
10-12 leaves per bunch
Sunspots visible – 20%
20-30% active growing points during véraison

	Light topping is required
4. Vigorous:	Shoot length longer than 150cm
	Leaves are yellow due to insufficient light exposure
	Black grapes colour badly
	Bunches tend to be sparse
	Sunspots visible – less than 20%
	More than 50% active growing points
	2-3 topping actions required per season
	Fertility is low and are at risk of being spoilt easily
5. Very vigorous:	Long thick shoots that can be up to 5m long are present
	Basal leaves are large and dark green
	Bunches are blue-green and sparse
	There are few to no sunspots visible
	Strong lateral shoots develop
	Shoots must be cut open every 2-3 weeks
	High risk of spoiling

Appendix 3

Table 3.1. Water holding capacity per metre of root depth, soil texture and stone content for each of the blocks (late cultivars).

Block number	**Water-holding capacity (mm/m)**	**Effective root depth**	**Soil Texture (%)**					**Stone (%)**
			Clay	Silt	Fine sand	Medium sand	Coarse sand	
HT1	66.3	0.8	5.6	8.2	27.5	33.6	25.1	0.5
HT2	136.6	0.5	6.1	7.4	20.6	34.2	31.7	0.3
HT3	46.8	0.9	7.4	7.9	26.7	45.4	12.6	3.4
HT4	53.8	0.4	8.5	9.2	27.5	39.5	15.3	85
HT5	48.1	0.6	8.0	9.1	23.3	44.8	14.8	80
HT6	29.6	0.7	7.2	14.8	28.3	40.5	9.2	70
HT7	112.4	0.8	7.2	6.8	27.8	43.6	14.6	1.1
HT8	58.9	0.9	12.4	10.5	24.0	33.9	19.2	75
HT9	106.7	0.6	9.4	12.7	27.1	34.5	16.3	0.8
HT10	34.1	0.8	7.4	7.2	27.4	50.0	8.0	70
HT11	136.0	0.7	5.8	6.6	28.1	43.3	16.2	1.3
HT12	42.3	0.7	9.6	10.5	24.7	41.6	13.6	1.6
HT13	151.6	0.2	21.8	20.8	44.8	9.0	3.6	3.0
HT14	133.3	0.6	10.6	10.0	21.3	34.8	23.3	15.3
HT15	66.6	0.8	5.4	7.1	31.8	42.8	12.9	60
HT16	69.3	0.6	9.5	9.8	30.7	36.8	13.2	0.2

Table 3.2. Water holding capacity per metre of root depth, soil texture and stone content for each of the blocks (early cultivars).

Block number	**Water-holding capacity (mm/m)**	**Effective root depth**	**Soil Texture (%)**						**Stone (%)**
			Clay	**Silt**	**Fine sand**	**Medium sand**	**Coarse sand**	**Stone**	
HT17	33.0	0.5	5.3	3.2	32.1	34.2	25.2	26.1	40
HT18	66.6	0.7	6.2	6.6	23.5	40.3	23.4	28.9	45
HT19	36.2	0.7	6.4	7.3	21.0	29.7	35.6	8.0	80
HT20	83.9	0.8	13.0	17.3	18.3	33.8	17.6	26.6	60
HT21	79.5	0.8	15.2	14.6	53.0	12.8	4.4	11.4	
HT22	37.8	0.6	4.6	5.7	34.5	46.2	9.0	48.8	80
HT23	50.5	0.8	5.4	10.9	26.7	41.0	16.0	40.0	70
HT24	22.0	0.7	3.9	1.7	34.3	37.0	23.1	36.6	60
HT25	105.1	0.7	12.5	10.4	30.5	37.9	8.7	3.9	75
HT26	20.9	0.7	2.6	2.3	7.5	36.5	51.1	57.1	60
HT27	47.2	0.5	3.5	5.3	30.3	37.6	23.3	26.4	60
HT28	134.2	0.7	14.6	14.2	37.6	23.0	10.6	12.0	
HT29	125.5	0.4	6.8	9.0	48.7	30.9	4.6	0.6	
HT30	15.6	0.7	5.3	3.9	17.0	46.7	27.1	29.3	60
HT31	43.8	0.7	3.3	1.8	14.1	43.5	37.3	3.8	
HT32	133.3	0.6	10.6	10.0	21.3	34.8	23.3	15.3	

Soils

The soils of the Hex River Valley primarily originate from Table Mountain Sandstone and Bokkeveld series. In this region three main soils can be distinguished: (i) Table Mountain Sandstone soils, (ii) alluvial soils and (iii) the Bokkeveld soils (Jooste *et al*, 1973).

Soil profile descriptions

The first 32 profile classifications and descriptions discussed were done by P. Feyt. Figure shows where each of the 37 blocks is situated.

Profile HT1

The profile is situated on an alluvial flood plain. The terrain is flat. The soil allows for good root development to a depth of 80cm.

Classification: We 1000

Orthic A

0 – 30cm Moist; brown 10YR5/3; medium sand; apedal crumb; slightly firm; clear transition;

Soft plinthic B1

30 – 80cm Moist; light yellowish brown 10YR6/4; yellow mottles; medium sand; apedal crumb; slightly firm; clear transition;

Soft plinthic B2

>80cm Moist; very pale brown 10YR7/4; medium sand; apedal crumb; firm; transition not reached.

Profile HT2

The profile is situated on an alluvial flood plain and has a 1% gradient. The soil type allows for relatively deep root growth, but which is restricted by a fluctuating water table. This can rise to 45cm below the soil surface. The water holding capacity is favourable, but restricted root depth reduces the water availability.

Classification: We 2000

Orthic A

0 – 45cm Dry; very pale brown 10YR7/3; fine sand; apedal crumb; soft; clear, smooth transition;

Soft plinthic B

45 – 60cm Dry; brown 10YR5/3; yellow mottles; silty sandy clay loam; apedal crumb; slightly hard; transition not reached.

Profile HT3

The profile is situated on an alluvial fan which has a south-west facing slope, with a gradient of 5%. The soil allows for good root development to a depth of at least 100cm.

Classification: Fw 1110

Orthic A

0 – 45cm Dry; pale brown 10YR6/3; coarse sand; apedal crumb; soft; clear transition;

E horizon

45 – 100cm Dry; white 10YR8/1; coarse sand; medium and large, angular sandstone alluvial stones; apedal crumb; soft; transition not reached.

HT4

The profile is situated on an alluvial fan with a north-facing slope (4% gradient). The soil does not limit root development. It is well-drained and has low water-holding capacity. There is good root development to a depth of 40cm.

Classification: Oa 2110

Orthic A

0 – 20cm Moist; dark brown 10YR3/3; coarse sand apedal; crumb; blocky; sharp, smooth transition;

Neocutanic B

20 – 60cm Moist; pink 7.5YR7/4; coarse sand; medium and large, angular sandstone alluvial stones apedal single grain; loose; large, transition not reached.

HT5

The profile is situated on a terrace, on a north-west facing slope with a 3% gradient. There is good root development to a depth of approximately 60cm.

Classification: Fw 1110

Orthic A

0 – 20cm Dry; light grey 10YR7/2; coarse sand; apedal crumb; soft; gradual transition;

E horizon

20 – 60cm Dry; light grey 10YR7/1; coarse sand; slightly rounded, sandstone stones; apedal crumb; very large, transition not reached.

Profile HT6

The profile is situated on an alluvial fan, on a south-west facing slope with a 7% gradient. A well developed root system with abundant fine roots occurs to a depth of 70cm.

Classification: Fw 2110

Orthic A

0 – 30cm Dry; greyish brown 10YR5/2; coarse sand; 60 percent volume medium, angular sandstone stones; apedal crumb; soft; medium, clear transition;

E horizon

30 – 90cm Dry; very pale brown 10YR8/3; coarse sand; medium and large, 80 percent volume medium and large, angular sandstone alluvial stones; apedal crumb; soft; transition not reached.

Profile HT7

The profile is situated on an alluvial terrace that has a slope gradient of 1%. The soil allows for the development of a good root system to a depth of approximately 90cm.

Classification: Du 1110

Orthic A

0 – 45cm Moist; dark greyish brown 10YR4/2; medium sand loam apedal crumb; firm; clear transition;

Stratified alluvium (C1)

45 – 70cm Moist; greyish brown 10YR5/2; medium sand; apedal crumb; blocky; clear transition.

Stratified alluvium (C2)

70 – 90cm Moist; light brownish grey 10YR6/2; coarse sand; apedal single-grain; loose; transition not reached.

Profile HT8

The profile is situated on a tertiary alluvial fan, with a north-west facing slope with a 3% gradient. The soil allows for good root development to a depth of approximately 90cm. Internal drainage is favourable, but the water holding capacity is poor.

Classification: Fw 1110

Orthic A

0 – 40cm Dry; light brownish grey; fine sand; 60 percent volume slightly rounded, medium and large sandstone stones; apedal crumb; soft; clear transition;

40 – 90cm Dry; light grey 10YR7/2; gravelly fine sand; 90 percent volume slightly rounded, large sandstone stones and rocks; apedal crumb; soft; transition not reached.

Profile HT9

The profile is situated on a flat, alluvial flood plain. Root development is restricted and therefore only occurs to a moderate degree.

Classification: Oa 1110

Orthic A

0 – 15cm Moist; brown 10YR4/3; fine sand; apedal crumb; firm; gradual transition;

Neocutanic B

20 – 80cm Moist; dark greyish brown 10Yr4/2; fine sand; apedal crumb; firm; transition not reached.

Profile HT10

The profile is situated on a tertiary alluvial flood plain, on a north-east facing slope with a gradient of approximately 3%. The soil allows for good root development of up to a depth of 80cm.

Classification: Oa 1110

Orthic A

0 – 20cm Dry, brown 10YR5/3, gravely fine sand; 60 percent volume medium, slightly rounded, angular sandstone stones, apedal crumb; soft; gradual transition;

Neocutanic B

15 - 80cm Moist; light yellowish brown 10YR6/4; gravelly fine sand; 80 percent volume medium, slightly rounded, angular sandstone stones; apedal crumb; soft; transition not reached.

Profile HT11

The profile is situated on an alluvial flood plain. The terrain is flat. The current A horizon was originally part of the B horizon. However during soil preparation, it was displaced to the soil surface. Good root development occurs to a depth of approximately 70cm.

Classification: Tu 1120

Orthic A

0 – 20cm Moist; brown 10YR5/3; silty sandy clay loam; weak, coarse blocky; firm; gradual transition;

Neocutanic B

20 – 70cm Moist; dark brown 10YR3/3; silty sandy clay loam; apedal crumb; slightly firm; clear transition;

Unspecified with signs of wetness

70 – 90cm Moist; brown 10YR5/3; yellow mottles; silty sandy clay loam; weak coarse blocky; firm; transition not reached; transition not reached.

Profile HT12

The profile is situated on a flat, alluvial flood plain. Root development is restricted at a depth of approximately 50cm. A possible reason for this is that the profile was dug in the middle of working row; with the result that compaction has prevented root development deeper than this. No root development occurs in the E horizon.

Classification: Fw 2110

Orthic A

0 – 50cm Moist; very dark grey 10YR3/1; medium sand; apedal crumb; very blocky; sharp transition;

E horizon

50 – 80cm Moist; white 10YR8/1; coarse sand; apedal single-grained; loose; transition not reached.

Profile HT13

The profile is situated on an alluvial flood plain, with a slope gradient of approximately 1%. Root development is restricted to a depth of approximately 20cm. Possible reasons for this are: a fluctuating water table (particularly prevalent during winter); and soil compaction in the subsoil layers.

Classification: We 2000

Orthic A

0 – 20cm Dry; pinkish grey 7.5YR6/2; silty sandy loam; apedal massive that breaks into medium-sized fragments when placed under pressure; slightly hard; gradual, smooth transition;

Soft plinthic B

20 – 60cm Dry; brown 7.5YR5/4; distinct yellow mottles; silty sandy clay loam; apedal massive that breaks into medium and large fragments when placed under pressure; slightly hard; transition not reached.

Profile HT14

The profile is situated on an alluvial flood terrace, with a north-west slope with a gradient of approximately 1%. Compaction in the subsoil prevents good root development. Infiltration and drainage is slow.

Classification: Oa 1220

Orthic A

0 – 30cm Dry; reddish brown 2.5YR5/4; sandy clay loam; apedal massive; hard; gradual, wavy transition;

Neocutanic B

30 – 80cm Dry; reddish brown 2.5Yr5/4; sandy clay; apedal massive; very hard; transition no reached

Profile HT15

The profile is situated on an alluvial fan, on a north-east facing slope with a gradient of approximately 4%. There is good root development up to a depth of 80cm.

Classification: Oa 2210

Orthic A

0 -15cm Dry; pale brown; fine sand; apedal crumb; soft; clear transition;

Neocutanic B

15 – 80cm Dry; pink 5YR7/4; moist; reddish yellow 5YR6/6; fine sand; 60 percent volume medium and large, slightly rounded, angular sandstone stones; apedal crumb; soft; transition not reached.

Profile HT16

The profile is situated on an alluvial terrace with a north-east facing slope (gradient of approximately 2%).Very little fine root development occurs in the top 60cm of the profile.

Classification: We 1000

Orthic A

0 – 30cm Moist; brown 10YR4/3; fine sandy loam; apedal crumb; brittle; merging boundary;

Soft plinthic B

30 – 80cm Moist; yellow 10YR7/6; fine sand texture; apedal crumb; brown mottles; slightly firm; transition not reached.

Profile HT17

The profile is situated on an alluvial fan with a south-west facing slope and a gradient of 3-4%. Relatively good root development is present in the A horizon, while roots are developed more poorly in the B horizon.

Classification: Oa 1110

Orthic A

0 – 15cm Moist; light brownish grey 10YR6/2; fine sand; apedal crumb; brittle; gradual, smooth transition;

Neocutanic B

15 – 70cm Moist; yellowish brown 10YR5/8; fine sand; 40 percent volume large, slightly rounded sandstone; apedal crumb; brittle; transition not reached.

Profile HT18

The profile is situated on an alluvial fan with a south-west facing slope (gradient of approximately 5%). Few roots are visible below a depth of approximately 70cm.

Classification: Oa 1110

Orthic A

0 - 25cm	Dry; light brownish grey 10YR6/2; gravely fine sand; 40 percent volume slightly rounded, medium sandstone stones; apedal crumb; soft; clear transition;

Neocutanic B

25 – 70cm	Dry; pale brown 10YR6/3; gravely fine sand; 50 percent volume slightly rounded, medium and large sandstone alluvial stones; apedal crumb; soft; transition not reached.

Profile HT19

The profile is situated on an alluvial plain, on a north-east facing slope with a gradient of approximately 4%. Very good root development is visible to 70cm and probably extends deeper.

Classification: Oa 1110

Orthic A

0 – 30cm	Dry; dark brownish grey 10YR4/2; fine sand; large to very large sandstone alluvial stones; apedal crumb; soft; clear transition;

Neocutanic B

30 – 70cm	Dry; greyish brown 10YR5/2; gravely fine sand; large sandstone alluvial stones; pedal crumb; soft; transition not reached.

Profile HT20

The profile is situated on a flat, alluvial flood plain. There Good root development can be seen to a depth of 80cm.

Classification: Oa 1110

Orthic A

0 – 20cm Dry; greyish brown 10YR5/2; coarse sand; 40 percent volume medium, slightly rounded; angular sandstone stones; apedal crumb; soft; clear transition;

Neocutanic B

20 – 80cm Dry; very pale brown 10YR7/4; coarse sand; 80 percent volume medium and large slightly rounded; angular sandstone stones; apedal crumb; soft; transition not reached.

Profile HT21

The profile is situated on an alluvial fan, with a slope gradient of approximately 1%.

Classification: Fw 2110

Orthic A

0 – 20cm Dry; dark brownish grey 10YR4/2; 60 percent volume rounded, medium sandstone stones; apedal crumb; soft; clear smooth transition;

E Horizon

20 – 70cm Dry; light brownish grey 10YR6/2; gravely coarse sand; 90 percent volume rounded, medium and large sandstone stones; apedal crumb; soft; transition not reached.

Profile HT22

The profile is situated on a quaternary alluvial fan, on a north-east facing slope with a gradient of 1 to 2%. Good root development occurs to a depth of at least 60cm. A dense mat of roots occurs between a depth of 10 and 15cm.

Classification: Oa 1110

Orthic A

0 – 30cm Dry; yellowish brown 10YR5/4; 80 percent volume very large, slightly rounded; angular sandstone stones; apedal single-grain structure; loose; unclear transition;

Neocutanic B

30 – 45cm Dry; yellowish brown 10YR5/4; 80 percent volume very large, slightly rounded; angular sandstone stones; apedal single-grain structure; loose; transition not reached.

Profile HT23

The profile is situated on an alluvial flood plain, on a north-east facing slope with a gradient of approximately 3%. The soil allows for good root development up to a depth of 80cm.

Classification: Oa 1110

Orthic A

0 – 20cm Dry, brown 10YR5/3, gravely fine sand; 60 percent volume medium, slightly rounded, angular sandstone stones, apedal crumb; soft; gradual transition;

Neocutanic B

15 - 80cm Moist; light yellowish brown 10YR6/4; gravely fine sand; 80 percent volume medium, slightly rounded, angular sandstone stones; apedal crumb; soft; transition not reached.

Profile HT24

The profile is situated on an alluvial fan, on a south-west facing slope with a gradient of approximately 5%. Moderate root development occurs in the A horizon, while thick roots develop in the B horizon.

Classification: Oa 1110

Orthic A

0 – 20cm Moist; dark greyish brown 10YR4/2; coarse sand; apedal crumb; soft; gradual smooth transition;

Neocutanic B

20 – 90cm Moist; brownish yellow 10YR6/6; coarse sand; 60 percent volume medium and very large, slightly rounded sandstone stones; apedal crumb; soft; transition not reached.

Profile HT25

The profile is situated on an alluvial fan, on a north-west facing slope with a gradient of approximately 7%. Good root development occurs throughout the profile.

Classification: Oa 1110

Orthic A

0 – 20cm Dry; light brownish grey 10YR4/2; fine sand; 60 percent volume slightly rounded, medium sandstone stones; apedal crumb; soft; clear transition;

Neocutanic B

20 – 70cm Dry; light yellowish brown 10YR6/4; fine sand; 90 percent volume slightly rounded, medium and large sandstone alluvial; apedal crumb; soft; transition not reached.

Profile HT26

The profile is situated on an alluvial fan that has a gradient of about 1%. Moderate development of roots occurs in the A horizon, while good root distribution occurs in the E horizon.

Classification: Fw 2110

Orthic A

0 – 10cm Dry; dark greyish brown 10YR4/2; fine sand; 60 percent volume round, medium sandstone stones; apedal crumb; slightly hard; sharp, smooth transition;

E horizon

10 – 80cm Dry; light brownish grey; gravely fine sand; 90 percent volume rounded, small and medium sandstone stones; apedal crumb; soft; transition not reached.

Profile HT27

The profile is situated on an alluvial fan, with a gradient of approximately 1%.

Classification: Fw 2110

Orthic A

0 – 20cm Dry; dark brownish grey 10YR4/2; 60 percent volume rounded, medium sanstone stones; apedal crumb; soft; clear smooth transition;

E Horizon

20 – 70cm Dry; light brownish grey 10YR6/2; gravely coarse sand; 90 percent volume rounded, medium and large sandstone stones; apedal crumb; soft; transition not reached.

Profile HT28

The profile is situated on a flat, alluvial flood plain. There are few fine roots in the B horiozon.

Classification: We 2000

Orthic A

0 – 15cm Moist; dark greyish brown 10YR4/2; silty, sand clay loam; apedal crumb; firm; gradual smooth transition;

15 – 70cm Dry; dark greyish brown 10YR4/2; rust-coloured mottles; silty sandy clay loam; apedal crumb; firm; transition not reached.

Profile HT29

The profile is situated on a flat, alluvial flood plain. Very few fine roots are present in the soil.

Classification: We 1000

Orthic A

0 – 15cm Moist; yellowish brown 10YR5/4; fine loamy sand; apedal crumb; slightly firm; gradual, smooth transition;

Soft plinthic B

15 – 70cm Dry; yellowish brown 10YR5/4; rust-coloured mottles; fine sandy loam; apedal crumb structure; firm; transition not reached.

Profile HT30

The profile is situated on an alluvial fan with a slope gradient of approximately 1%. Medium roots occur abundantly in the A horizon, while no root development occurs in the E horizon.

Classification: Fw 1110

Orthic A

0 – 20cm Dry; grey 10YR5/1; fine sand; 60 percent volume rounded, medium sandstone stones; apedal crumb; slightly hard; gradual smooth transition;

E horizon

20 – 80cm Dry; grey 10YR6/1; fine sand; 90 percent volume rounded, large sandstone stones; apedal crumb; slightly hard; transition not reached.

Profile HT31

The profile is situated on an alluvial flood plain, with a slope gradient of approximately 1%. Abundant medium roots occur in the A horizon, while roots are absent in the E horizon.

Classification: Fw 1110

Orthic A

0 – 30cm Dry; grey 10YR5/1; coarse sand; apedal crumb; soft; sharp, smooth transition;

E horizon

30 – 90cm Dry; white 10YR8/1; coarse sand; apedal single grain; loose; transition not reached.

Profile HT32

The profile is situated on an alluvial flood terrace, on a north-west facing slope with a gradient of approximately 1%. The subsoil of the profile is quite compacted which prevents good root development. The water infiltrates and drains out of the soil relatively slowly

Classification: Oa 1220

Orthic A

0 – 30cm Dry; reddish brown 2.5YR5/4; sandy clay loam; apedal massive; hard; gradual, wavy transition;

Neocutanic B

30 – 80cm Dry; reddish brown 2.5Yr5/4; sandy clay; apedal massive; very hard; transition no reached

Profile HT33

Altitude: 458m

Co-ordinates: 33˚22'12.1" S; 19˚38'54.3" E

Classification: Tu 2120

Orthic A

0 – 20cm Dry; light yellowish brown 2.5Y6/3; medium fine sand; apedal; wavy transition;

Neocutanic B

20 – 70cm Dry; yellowish brown 10YR5/4; medium sand; apedal; wavy transition;

Unspecified material with signs of wetness

>70cm Dry; yellowish brown 10YR5/4; medium sand; apedal; transition not reached.

The soil is very compacted. It has been deep ploughed to a depth of 50cm.

Profile HT34

Altitude: 477m

Co-ordinates: 33˚28’09.1” S; 19˚40’06.2” E

Classification: Du 1210

Orthic A

0 – 20cm Dry; pale brown 10YR6/3; medium fine sand; 40 percent volume large, rounded river cobbles; apedal; clear wavy transition;

Stratified alluvium

20 – 70cm Dry; yellowish brown 10YR5/4; medium sand; 80 percent volume large, rounded river cobbles; apedal; transition not reached.

Profile HT35

Altitude: 527m

Co-ordinates: 33˚25'43.4" S; 19˚41'32.3" E

Classification: Du 1210

Orthic A

0 – 20cm Dry; greyish brown 10YR5/2; medium coarse sand; 20 percent volume angular sandstone stones; apedal; wavy transition;

Stratified alluvium

>20cm Dry; grey 10YR5/1; medium coarse sand; 40 percent volume angular sandstone stones; apedal; transition not reached.

Profile is not very compacted, not even under tyre tracks.

Profile HT36

Altitude: 528m

Co-ordinates: 33˚29’04.9” S; 19˚38’13.2” E

Classification: Fw 11/210

Orthic A

0 – 20cm Dry; light grey 10YR7/2; moist; light brownish grey 10YR6/2; medium coarse sand; apedal; gradual transition;

E horizon

>20cm Dry; very pale brown 10YR7/3; moist; very pale brown 10YR7/4; medium coarse; apedal; transition not reached.

Good root distribution exists throughout the profile and no real compaction is present.

Profile HT37

Altitude: 428m

Co-ordinates: 33˚30’14.0” S; 19˚35’53.9” E

Classification: Du 1210

Orthic A

0 – 20cm Dry; light grey 10YR7/2; moist; light brownish grey 10YR6/2; coarse medium sand; apedal; unclear transition;

Stratified alluvium

>20cm Dry; very pale brown 10YR7/3; moist; pale brown 10YR6/3; coarse medium sand; apedal; transition not reached

Table 3.4. Results of chemical analysis for block numbers HT1 to HT32, done during 2000.

Block number	pH (KCl)	Resistance (ohm)	H (cmol/kg)	Stone %	P (mg/kg)	K (mg/kg)	Exchangeable cations (cmol/kg) Na	K	Ca	Mg	S-value	Cu (mg/kg)	Zn	Mn	B
1	5.4	2480	0	1	46	55	0.3	0.14	1.47	0.32	2.23	1.69	1.7	7.3	0.23
2	6.6	860	0	1	65	176	0.38	0.45	2.57	0.65	4.05	2.37	2.3	22.9	0.43
3	6.0	3320	0	2	51	59	0.37	0.15	1.12	0.08	1.72	0.73	1.8	9.7	0.12
4	7.1	1470	0	32	168	23	0.42	0.06	2.44	4.40	3.32	3.25	3.9	18.1	0.26
5	7.2	1200	0	4	209	16	0.35	0.04	2.4	0.52	3.31	3.65	6.8	21.4	0.38
6	7.4	560	0	49	220	133	0.49	0.34	5.24	1.22	7.30	7.64	14.4	45.2	0.86
7	6.3	630	0	1	232	59	0.52	0.15	4.02	1.30	5.99	4.63	4.8	18.3	0.61
8	7.2	3520	0	17	75	31	0.36	0.08	1.87	0.49	2.80	7.00	4.3	24.7	0.26
9	6.5	1600	0	1	171	141	0.43	0.36	2.83	0.80	4.42	7.92	7.1	17.8	0.37
10	6.6	970	0	56	113	63	0.40	0.16	8.79	1.43	10.78	33.75	19.2	55.3	0.66
11	4.3	190	2.35	1	70	266	1.0	0.68	4.02	1.22	9.27	1.73	3.6	8.9	0.44
12	5.3	1160	0	2	176	47	0.34	0.12	2.05	0.37	2.88	4.13	3.7	13.7	0.31
13	6.5	320	0	2	36	94	0.61	0.24	9.60	1.78	12.23	4.05	4.0	54.0	0.55
14	5.6	1380	0	8	35	74	0.50	0.19	4.17	1.49	6.35	1.60	2.1	20.2	0.28
15	5.9	2540	0	32	20	63	0.36	0.16	2.75	1.02	4.29	1.32	1.0	19.60	0.30
16	7.8	350	0	1	221	39	0.55	0.10	4.59	0.72	5.96	1.19	7.2	38.7	0.37
17	6.3	1370	0	16	53	16	0.16	0.04	1.99	0.41	2.60	2.57	2.4	0.4	0.21
18	5.7	1360	0	16	228	82	0.37	0.21	3.15	0.75	4.48	18.33	13.3	31.8	0.34
19	6.4	2360	0	5	169	35	0.35	0.09	2.68	0.39	3.51	5.2	8.4	14.2	0.25
20	5.7	1360	0	16	228	82	0.37	0.21	3.15	0.75	4.48	18.33	13.3	31.8	0.34
21	6.2	670	0	24	19	199	0.55	0.51	10.73	2.19	13.98	2.08	1.6	21.4	0.26
22	6.7	210	0	34	110	152	0.40	0.39	7.56	0.97	9.32	5.17	3.7	19.2	0.96
23	6.9	1540	0	26	78	78	0.41	0.20	5.13	0.84	6.58	27.47	13.1	39.8	0.49
24	4.5	1310	0.31	24	3	4	0.16	0.01	0.80	0.24	1.52	0	0.3	0.2	0.1
25	5.3	640	0	3	7	117	0.39	0.30	1.65	0.67	3.01	0.53	1.0	16.4	0.26
26	6.0	4370	0	42	83	23	0.04	0.06	1.77	0.45	2.32	3.08	8.1	0.5	0.15
27	6.7	850	0	16	157	55	0.13	0.14	5.45	1.17	6.89	11.56	23.3	1.2	0.34
28	5.5	980	0	7	94	90	0.16	0.23	5.54	1.80	7.73	1.89	2.9	1.8	0.21
29	5.6	3970	0	0	146	63	0.07	0.16	3.05	0.61	3.89	8.18	5.5	0.6	0.11
30	6.6	2350	0	18	163	43	0.07	0.11	2.56	0.42	3.16	7.08	5.6	0.4	0.11
31	5.4	1210	0	2	41	23	0.16	0.06	1.18	0.25	1.65	0.86	0.5	0.3	0.03
32	5.6	1380	0	8	35	74	0.50	0.19	4.17	1.49	6.35	1.60	2.1	20.2	0.28

Appendix 4

Table 4.1. Climatic data for the De Doorns weather station for January 1999 to May 2007.

Year	Month	Rain (mm)	Tmax (˚C)	Tmin (˚C)	Tave (˚C)	Windspeed (m/s)	A-pan evaporation (mm)	RH (%)	Radiation (MJ.m^{-2}. day^{-1})
1999	1	0.10	32.10	14.50	23.30	1.25	8.60	87.20	43.10
1999	2	0.50	30.70	14.90	22.80	1.13	7.60	87.90	38.90
1999	3	0.00	31.40	14.00	22.70	0.93	6.20	87.50	32.90
1999	4	0.50	26.30	11.60	18.90	1.05	4.00	86.30	25.40
1999	5	0.90	21.80	7.90	14.90	0.88	2.10	91.00	19.50
1999	6	1.10	20.50	5.30	12.90	1.05	2.00	85.10	16.70
1999	7	1.30	19.50	6.20	13.00	1.47	2.80	81.90	17.90
1999	8	1.80	20.80	5.10	13.00	1.27	3.00	87.30	22.90
1999	9	0.80	20.90	5.60	13.20	1.28	3.80	91.10	30.10
1999	10	0.00	26.90	10.70	18.80	1.37	6.30	84.60	37.00
1999	11	0.10	28.10	11.00	19.50	1.29	7.30	88.40	42.00
1999	12	0.40	32.50	15.40	24.00	1.21	8.20	90.40	44.10
2000	1	0.00	30.50	14.80	22.60	1.49	8.10	84.70	43.10
2000	2	0.10	31.10	15.30	23.20	1.13	7.40	90.20	38.90
2000	3	0.70	27.50	14.10	20.80	1.04	4.80	91.70	32.70
2000	4	0.10	25.70	9.90	17.80	0.95	4.00	92.20	25.20
2000	5	0.30	22.30	6.00	14.20	0.90	2.40	93.40	19.30
2000	6	0.90	21.50	4.70	13.10	1.00	2.00	92.70	16.70
2000	7	2.60	19.10	3.80	11.50	1.29	2.40	89.10	18.00
2000	8	0.60	21.70	6.00	13.90	1.11	2.70	90.70	23.10
2000	9	0.50	21.00	6.10	13.50	1.58	4.40	87.20	30.30
2000	10	0.00	25.40	8.70	17.00	1.60	5.80	88.00	37.20
2000	11	0.30	28.20	11.60	19.90	1.34	7.20	89.00	42.10
2000	12	0.10	30.20	10.80	20.50	1.27	8.10	88.10	44.10
2001	1	0.00	31.20	12.30	21.80	1.30	8.30	92.00	43.10
2001	2	0.40	31.80	14.10	23.00	1.27	7.30	90.50	38.90
2001	3	0.00	30.40	12.50	21.40	1.04	5.80	94.60	32.90
2001	4	0.70	24.30	11.00	17.70	0.95	2.90	no value	25.40
2001	6	0.60	19.90	4.00	11.90	0.97	1.80	95.70	16.70
2001	5	1.60	22.90	8.70	15.80	1.12	2.70	85.30	19.50
2001	7	3.30	17.40	5.80	11.60	1.42	2.00	89.30	17.90
2001	8	2.20	17.90	6.80	12.40	1.34	2.30	90.60	22.90
2001	9	1.10	20.60	7.90	14.20	1.47	3.60	92.40	30.10
2001	10	0.90	25.40	11.00	18.20	1.25	5.00	92.80	37.00
2001	11	0.60	27.40	12.90	20.10	1.31	7.00	94.30	42.00
2001	12	0.00	29.50	12.50	21.00	1.29	7.90	91.90	44.10
2002	1	1.20	28.90	12.70	20.80	1.30	7.20	93.20	43.10
2002	2	0.60	31.00	13.50	22.30	1.13	7.10	93.60	38.90
2002	3	0.00	31.10	12.80	22.00	1.02	6.20	93.30	32.90
2002	4	0.70	26.30	9.50	17.90	0.93	3.90	92.60	25.40
2002	5	1.90	21.00	6.30	13.60	0.95	2.10	93.90	19.50
2002	6	0.70	18.10	4.40	11.20	1.17	1.80	90.90	16.70
2002	7	3.30	17.50	3.80	10.60	1.24	1.70	90.70	17.90
2002	8	1.40	19.10	5.70	12.40	1.28	2.70	91.20	22.90
2002	9	0.50	24.40	8.60	16.50	1.22	4.50	90.60	30.10
2002	10	0.30	25.40	8.60	17.00	1.42	6.40	83.40	37.00
2002	11	0.10	27.60	8.70	18.10	1.41	8.10	84.50	42.00
2002	12	2.00	30.50	14.40	22.40	1.08	8.40	81.30	44.10

Table 4.1 (continued). Climatic data for the De Doorns weather station for January 1999 to May 2007.

	1	0.20	31.00	14.40	22.70	0.93	8.70	91.60	43.10
2003	2	0.00	32.20	14.70	23.40	1.11	8.00	92.90	38.90
2003	3	1.40	28.80	12.90	20.90	1.01	5.80	93.00	32.90
2003	4	0.50	26.20	10.90	18.50	0.68	3.50	93.90	25.40
2003	5	0.50	22.30	6.70	14.50	0.63	2.20	95.40	19.50
2003	6	0.00	20.60	2.60	11.60	0.70	1.90	91.10	16.70
2003	7	0.20	19.70	3.30	11.50	1.27	2.60	84.90	17.90
2003	8	2.10	17.70	4.00	10.80	1.19	2.70	86.30	22.90
2003	9	1.40	21.50	6.90	14.20	1.13	4.10	89.70	30.10
2003	10	0.40	25.70	10.50	18.10	1.18	5.90	83.90	37.00
2003	11	0.00	29.10	11.10	20.10	0.96	8.00	79.30	42.00
2003	12	0.10	28.10	11.90	20.00	1.01	8.10	70.00	44.10
2004	1	0.20	31.50	14.80	23.10	1.01	8.90	75.90	43.10
2004	2	0.00	31.70	15.20	23.40	1.11	8.20	82.10	38.90
2004	3	0.00	28.30	10.90	19.60	1.03	6.60	85.30	32.70
2004	4	0.60	26.30	10.30	18.30	0.82	4.10	85.80	25.20
2004	5	0.00	24.90	8.10	16.50	0.75	3.10	87.90	19.30
2004	6	1.30	19.80	5.20	12.50	0.85	1.90	90.00	16.70
2004	7	1.50	18.90	2.60	10.70	0.80	2.00	84.30	18.00
2004	8	0.50	20.40	6.70	13.60	1.02	2.70	86.00	23.10
2004	9	0.20	23.70	7.00	15.30	1.10	4.90	74.10	30.30
2004	10	1.60	26.30	10.60	18.40	1.05	6.00	80.80	37.20
2004	11	0.10	29.70	12.20	20.90	0.89	8.20	83.80	42.10
2004	12	0.50	31.00	14.90	22.90	0.84	8.90	78.50	44.10
2005	1	0.80	30.60	15.60	23.10	0.86	8.50	83.40	43.10
2005	2	0.10	32.70	15.10	23.90	0.76	8.30	83.00	38.90
2005	3	0.00	30.20	13.60	21.90	0.91	6.50	86.20	32.90
2005	4	2.30	24.50	10.50	17.50	0.78	3.40	91.60	25.40
2005	5	0.30	21.40	8.60	15.00	1.00	2.60	86.20	19.50
2005	6	1.50	17.90	5.20	11.60	0.88	1.50	84.40	16.70
2005	7	1.40	21.40	5.10	13.20	0.79	2.20	74.80	17.90
2005	8	2.20	17.70	5.10	11.40	1.23	2.60	84.50	22.90
2005	9	0.50	23.60	7.70	15.60	1.14	4.60	79.20	30.10
2005	10	0.00	25.90	9.20	17.60	1.42	7.00	72.60	37.00
2005	11	0.70	27.80	11.80	19.80	1.25	7.90	84.50	42.00
2005	12	0.00	29.70	10.80	20.20	1.23	9.40	81.00	44.10
2006	1	0.10	32.00	14.30	23.20	2.20	7.00	53.10	25.60
2006	2	0.00	32.60	15.60	23.90	2.10	6.60	58.00	23.50
2006	3	0.10	29.10	10.80	19.60	2.00	5.30	54.30	19.30
2006	4	1.70	25.50	10.00	17.10	1.60	3.40	65.70	12.90
2006	5	2.60	20.20	6.20	12.40	1.60	2.30	71.30	9.70
2006	6	1.80	20.60	4.60	11.60	1.80	2.40	65.70	8.80
2006	7	2.20	19.30	5.80	12.30	1.90	2.40	65.20	8.10
2006	8	2.4	18.7	6.3	12.1	2.00	2.7	67.5	11.1
2006	9	0.5	23.5	8.3	15.5	1.80	3.9	60.4	15.8
2006	10	1.6	20.1	7.8	13.7	2.10	3.9	58	14.4
2006	11	0.7	27.9	8.6	21.1	2.10	6.3	56.6	27.7
2006	12	1	28.9	11	20.6	2.10	6.7	53.8	26.9
2007	1	1.10	33.20	1.30	22.20	2.10	7.80	53.10	26.70
2007	2	1.70	30.60	13.50	22.00	1.90	6.20	55.80	23.90
2007	3	0.30	29.50	11.80	20.20	1.80	5.30	56.90	20.30
2007	4	11.60	26.10	9.80	17.30	1.70	3.70	63.10	14.60
2007	5	3.10	23.60	5.30	14.00	1.70	3.00	64.40	10.70

Table 4.2. Climatic data for the De Vlei weather station for January 2004 to December 2006.

Year	Month	Rain (mm)	Tmax (˚C)	Tmin (˚C)	Tave (˚C)	Windspeed (m/s)	A-pan evaporation (mm)	RH (%)	Radiation ($MJ.m^{-2}.day^{-1}$)
2004	1	0.28	31.22	15.33	23.27	2.06	8.69	54.56	27.57
2004	2	0.00	31.16	15.48	23.32	1.85	7.54	58.38	24.23
2004	3	0.06	27.78	11.16	19.47	1.63	5.49	62.85	20.05
2004	4	0.79	25.75	10.68	18.22	1.40	3.42	67.35	13.41
2004	5	0.00	24.29	8.25	16.27	1.22	2.64	67.36	10.47
2004	6	2.34	19.28	5.40	12.34	1.19	1.92	70.01	7.70
2004	7	2.10	18.64	3.17	10.91	1.23	2.06	65.43	9.57
2004	8	0.90	20.14	6.51	13.32	1.38	2.84	69.75	12.79
2004	9	0.39	22.98	7.79	15.39	1.67	4.72	60.80	18.76
2004	10	1.75	25.78	10.62	18.20	1.73	5.71	62.02	21.78
2004	11	0.19	29.32	12.51	20.92	1.80	7.42	62.44	26.87
2004	12	0.90	30.51	15.10	22.81	1.84	7.70	63.26	27.81
2005	1	0.67	30.08	15.70	22.89	1.86	7.19	63.87	26.01
2005	2	0.04	32.31	15.47	23.89	1.79	7.46	62.56	25.43
2005	3	0.05	29.62	14.18	21.90	1.53	5.25	64.02	18.79
2005	4	3.12	23.97	10.84	17.40	1.30	2.90	73.14	12.37
2005	5	0.27	20.98	8.41	14.69	1.48	2.32	71.38	8.82
2005	6	2.51	17.19	5.62	11.40	1.27	1.61	74.54	8.09
2005	7	2.15	20.72	5.86	13.29	1.31	2.24	67.39	9.75
2005	8	3.05	17.52	4.94	11.23	1.57	2.75	71.01	12.56
2005	9	0.97	23.34	7.96	15.65	1.44	4.31	65.53	18.26
2005	10	0.02	25.46	8.90	17.18	1.88	6.25	57.36	22.99
2005	11	0.86	27.42	11.58	19.50	1.89	6.83	62.63	25.49
2005	12	0.00	29.33	10.96	20.15	1.88	8.27	59.22	30.14
2006	1	0.10	31.01	15.24	23.12	1.90	7.46	64.96	26.53
2006	2	0.00	32.06	15.78	23.92	1.76	7.18	65.45	25.00
2006	3	0.02	28.25	10.87	19.56	1.63	5.66	62.63	20.77
2006	4	1.64	24.70	10.60	17.65	1.32	3.26	72.23	13.56
2006	5	3.39	19.25	6.68	12.97	1.08	1.83	78.35	9.34
2006	6	1.91	19.63	4.96	12.30	1.17	1.89	72.59	8.68
2006	7	1.45	18.50	6.18	12.34	1.30	2.15	67.80	8.53
2006	8	2.23	17.58	6.00	11.79	1.48	2.71	66.99	11.66
2006	9	0.24	22.39	8.29	15.34	1.40	4.06	65.12	17.20
2006	10	0.59	24.42	9.20	16.81	1.63	5.65	64.70	21.92
2006	11	1.44	26.73	10.86	18.80	1.76	6.94	64.32	26.65
2006	12	0.09	27.38	12.56	19.97	1.83	7.58	59.85	27.97

Table 4.3. Climatic data for the Jolette weather station for January 2004 to December 2006.

Year	Month	Rain (mm)	Tmax (˚C)	Tmin (˚C)	Tave (˚C)	Windspeed (m/s)	A-pan evaporation (mm)	RH (%)	Radiation ($MJ.m^{-2}.day^{-1}$)
2004	1	0.34	30.71	15.31	23.01	2.07	8.35	53.83	27.19
2004	2	0.00	30.67	15.79	23.23	2.11	7.35	53.50	22.85
2004	3	0.00	27.38	10.72	19.05	1.83	5.69	61.01	20.49
2004	4	0.81	25.70	9.21	17.46	1.40	3.48	68.57	13.99
2004	5	0.00	24.48	6.53	15.50	1.27	2.85	69.00	11.25
2004	6	1.82	20.65	3.02	11.84	1.17	2.09	73.92	8.96
2004	7	1.41	19.48	0.64	10.06	1.32	2.39	70.26	10.87
2004	8	0.52	20.77	5.96	13.37	1.67	3.21	71.21	12.91
2004	9	0.20	23.61	7.11	15.36	1.96	5.18	61.48	18.92
2004	10	1.63	25.67	10.27	17.97	1.95	5.90	61.58	21.62
2004	11	0.20	29.27	13.19	21.23	1.93	7.32	59.90	26.38
2004	12	0.27	30.09	15.61	22.85	1.98	7.50	60.39	27.19
2005	1	0.35	29.80	16.37	23.09	1.98	7.11	62.03	25.80
2005	2	0.08	31.61	15.70	23.66	2.11	7.40	61.01	25.14
2005	3	0.10	29.44	13.66	21.55	1.81	5.65	62.36	19.86
2005	4	3.15	24.25	10.28	17.27	1.33	2.95	73.46	12.66
2005	5	0.32	21.32	7.42	14.37	1.32	2.45	71.72	9.97
2005	6	1.67	17.78	3.95	10.87	1.12	1.76	76.11	9.10
2005	7	0.68	21.10	2.99	12.05	1.20	2.52	71.33	11.18
2005	8	2.25	17.89	4.14	11.02	1.66	3.05	70.64	13.20
2005	9	0.51	22.99	6.90	14.95	1.90	4.98	65.58	19.53
2005	10	0.02	25.49	8.65	17.07	1.93	6.40	57.40	23.78
2005	11	1.19	26.84	11.60	19.22	2.06	7.14	60.71	26.74
2005	12	0.00	28.54	11.36	19.95	2.13	8.38	57.28	30.60
2006	1	0.05	30.23	15.28	22.76	2.16	7.89	62.67	28.28
2006	2	0.01	31.20	15.71	23.46	2.16	7.61	62.54	26.25
2006	3	0.00	27.81	10.85	19.33	1.79	6.03	57.35	21.00
2006	4	1.29	24.30	9.49	16.90	1.34	3.31	71.42	13.93
2006	5	2.93	20.02	5.95	12.98	0.94	2.02	77.17	10.38
2006	6	2.39	20.44	3.45	11.94	1.08	2.17	73.90	10.06
2006	7	1.41	19.31	5.27	12.29	1.12	2.06	72.64	9.43
2006	8	2.54	18.34	6.05	12.19	1.34	2.48	74.15	12.20
2006	9	0.30	23.01	8.03	15.52	1.25	3.79	71.88	17.78
2006	10	0.46	25.85	9.54	17.69	1.40	5.27	69.25	22.78
2006	11	0.99	28.20	11.71	19.96	1.44	6.47	68.26	27.56
2006	12	0.07	29.07	13.48	21.27	1.56	7.18	63.82	29.32

Appendix 5

Table 5.1. Cumulative water applied to each block (m^3/ha) during the 1999/2000 season.

Block number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	854	1609	2532	3804	4492	5233	5816	6373
2	372	1060	2408	3570	4663	5690	6818	7885
3	703	1733	3296	5313	7088	8305	9296	10047
4	243	1714	3329	4614	5929	6660	7240	7427
5	585	1664	2724	3941	5266	5476	5753	5931
6	434	1327	2496	3423	4322	4985	5168	5613
7	460	1572	3000	4741	6016	7341	8152	8152
8	1088	2577	5029	6852	8385	9246	9695	9885
9	545	2245	3969	6541	8408	9341	9621	10441
10	866	1747	4127	5857	7231	7910	8411	8529
11	530	1534	2667	3374	4994	5618	5764	6198
12	165	946	2041	3223	5229	5688	5990	6259
13	0	0	1438	2922	4182	5363	5686	5824
14	732	1633	3290	4303	5282	5959	6149	6421
15	931	1760	3156	4258	5002	5830	6152	6407
16	866	1712	3389	4254	4700	5095	5880	6193
17	0	0	0	0	0	0	0	0
18	1011	2802	4650	6358	7445	8866	9383	10115
19	399	1554	2596	3363	4248	5230	5709	5709
20	800	1989	3997	5521	6352	7443	7784	7986
21	0	0	0	0	0	0	0	0
22	76	769	1820	3138	4693	5003	6405	6636
23	1329	2402	4245	5218	5795	6834	7396	7498
24	0	0	0	0	0	0	0	0
25	222	828	2175	3428	4308	4770	4909	5145
26	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0

Table 5.2. Cumulative water applied to each block (m^3/ha) during the 2000/1 season.

Block number	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
1	618	2064	3798	4931	6691	7466	7466	7466
2	379	1560	2641	4080	5282	6198	6471	6522
3	1332	2769	5293	6589	8569	10189	10893	11386
4	246	1386	3826	5129	6362	7329	7507	7507
5	417	1510	2785	4023	5246	5642	5642	5642
6	990	1789	3240	4883	6297	6841	7037	7316
7	764	1847	3602	5616	7078	8924	9328	9328
8	823	1858	4002	5821	7364	8486	9244	9366
9	1179	2608	4416	6229	8155	9534	9795	10183
10	1544	2339	3959	5009	6261	7218	7230	7230
11	408	1582	4351	6386	7222	8114	8352	8507
12	468	1030	2277	3251	4284	5178	5308	5308
13	358	1490	3613	5101	6584	7513	7806	7806
14	553	1244	2663	4605	4985	5626	5626	6017
15	1173	2609	4538	5912	7728	8501	9337	9337
16	915	1991	3202	4525	5550	6370	6878	6878
17	48	652	2134	3497	4385	5048	5048	5402
18	997	2661	5193	7477	8556	10099	11044	11680
19	257	1181	2755	4067	4949	5808	6002	6136
20	1045	1990	3498	4827	6102	6918	7499	8037
21	206	1141	2588	3858	4909	5217	5227	5244
22	993	2408	4113	4895	5531	6277	6326	6326
23	930	2196	4220	5568	6687	7480	7498	7498
24	870	1938	3711	5230	6041	7247	7928	8362
25	316	749	1822	2976	4161	5213	5349	5462
26	105	774	2647	3504	3942	4365	4365	4365
27	280	1445	3007	4199	5570	6058	6261	6455
28	480	1136	3427	5238	6130	6866	7220	7436
29	771	1769	3503	5606	7069	8043	8043	8923
30	403	1153	2708	4433	4963	5307	5307	5315
31	558	1115	3462	4594	5589	5634	6256	6256
32	273	1531	2896	3109	3369	3851	3887	4000

Table 5.3. Cumulative water applied to each block (m^3/ha) during the 2001/2 season.

Block Number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	323	636	1379	1829	3132	3818	4220	4220
2	358	782	1655	2934	3929	4952	5616	6089
3	800	2260	4135	5670	6957	7966	8488	8684
4	749	2472	4497	6608	7759	8625	9017	9017
5	521	1344	2906	4035	5069	5773	6002	6002
6	528	1260	2929	4431	6172	6771	7414	7684
7	240	1234	3086	4971	6383	7248	7602	7884
8	827	1588	3270	4685	5520	6314	6825	6935
9	331	1629	2813	5023	6364	7158	7735	7735
10	731	1574	2976	4459	5621	6872	7477	7477
11	457	1826	3326	5109	6348	7326	8630	8826
12	328	821	1592	2435	2757	3148	3435	3535
13	274	1342	2054	3936	4926	5717	6086	6406
14	345	756	1595	3337	4305	5001	5037	5037
15	483	1214	2695	4559	5846	6665	7757	7757
16	789	1320	3052	4718	5699	6067	6467	6467
17	126	907	2066	3217	3980	4624	5221	5304
18	846	1933	4089	5673	6846	7757	8471	8586
19	421	1221	2297	3258	4189	5358	6201	6332
20	582	1678	2374	4057	5388	6383	6902	7185
21	1116	2097	4345	5055	5806	6678	7075	7075
22	382	1279	3170	5156	6913	8356	9692	9811
23	836	2081	4329	5698	6868	7761	8433	8599
24	735	1530	3114	4532	5285	6337	7144	7257
25	337	986	2307	4039	5707	7136	8019	8230
26	604	2542	3986	4777	5346	5861	6282	6282
27	663	1599	2940	4233	5367	6169	6630	6630
28	565	1467	3357	5371	6223	7048	7921	8247
29	540	1483	3186	4697	5789	6537	7549	7680
30	885	1775	3125	4465	5551	6414	6881	6881
31	845	1859	3042	3944	4620	5521	6873	7042
32	573	1889	2300	3587	4000	4556	4571	4571

Table 5.4. Cumulative water applied to each block (m^3/ha) during the 2002/3 season.

Block number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	838	1687	3101	3940	5182	5715	6117	6261
2	463	1138	1968	2952	3679	4085	4285	4285
3	1469	2467	4361	6406	7870	8865	9595	10269
4	546	1837	3529	5176	6408	6799	7070	7156
5	1085	2450	3702	4963	6463	7152	7242	7685
6	1074	2131	3532	5288	6895	7865	7865	8203
7	648	2075	3407	5190	6881	7995	8612	8977
8	1052	2086	3802	5400	6825	7490	7849	8103
9	796	2313	3993	5527	7364	8393	8834	8834
10	807	2126	3573	4836	6289	7093	7530	7745
11	596	1119	2021	3240	4557	5143	5297	5634
12	941	1567	2386	3520	4469	4722	5021	5784
13	441	1134	2381	3441	4533	5278	5912	6094
14	745	1812	3703	5171	6312	6852	7089	7272
15	91	666	1862	3050	4204	5021	5484	5959
16	1003	2022	3596	5538	6324	6772	6998	7372
17	493	1059	2968	4155	5061	5687	5814	5890
18	889	2140	4085	6220	7393	7750	8104	8624
19	540	1542	2756	3710	4426	4957	5205	5438
20	1147	2124	3402	4920	6117	6654	7165	7237
21	1477	2758	4526	5583	5937	6636	6695	6695
22	863	961	3517	5146	6718	7631	8476	8758
23	967	2322	3967	5186	6046	6528	6838	6919
24	599	1718	3440	4877	6159	6781	7622	7622
25	432	1206	3274	4490	5180	6331	6458	6458
26	267	1354	2719	3781	4789	5161	5249	5249
27	565	1567	3027	4219	5352	5836	6189	6413
28	458	1651	3421	5275	6693	7294	7294	7914
29	1320	3037	4403	5991	7386	7874	7877	8074
30	673	3179	4583	6369	7853	8493	8886	9028
31	728	1801	3077	4269	4482	5290	5682	5946
32	709	2047	4242	5224	6244	6649	7040	7251

Table 5.5. Cumulative water applied to each block (m^3/ha) during the 2003/4 season.

Block number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	271	1137	1977	3237	3972	4856	5063	5277
2	510	1226	2243	3411	4696	5815	6190	6588
3	1025	2028	3342	4800	6311	7517	8372	9313
4	362	1472	2849	4106	5112	5962	5962	6462
5	367	1131	2113	3554	4871	5594	5594	5896
6	1010	2011	2966	3340	3737	4012	4202	4428
7	548	1499	3253	4765	5969	7014	7506	7686
8	785	1797	3436	5086	6448	7435	7539	8029
9	569	1759	3448	5641	7744	9579	10885	11084
10	246	1313	2470	4130	5538	6430	6536	6657
11	354	1038	2246	3542	4404	5333	5800	6314
12	376	971	1806	2555	3269	3695	3789	4100
13	75	736	2250	3330	4149	5109	5493	5676
14	190	1136	2652	4041	4895	5626	5626	5772
15	125	837	2398	3783	4632	5427	5985	6243
16	632	1900	3633	5226	6101	6896	6896	7463
17	416	1149	1895	2767	3775	4476	5121	5567
18	756	1985	3765	4785	4975	4975	4975	4975
19	196	801	2295	3452	4195	4787	5406	5674
20	526	1814	3224	4589	5424	6232	6631	6929
21	996	1638	4213	5550	6422	7059	7881	8163
22	629	1607	3415	5150	6217	7948	8620	8737
23	539	1639	2987	3848	4651	5182	5348	5540
24	600	1556	3206	4343	4832	5589	6001	6637
25	324	1074	2137	3618	5099	6097	6520	6966
26	612	1735	3579	5128	6302	6954	7223	7551
27	674	1339	2494	3630	4285	4926	5317	5543
28	402	1240	2263	3203	3986	4655	5522	5766
29	1889	3183	4903	6691	7909	8640	8640	8820
30	433	1212	2353	3333	4123	5133	5840	6581
31	404	1061	2270	3207	3824	4225	4421	4887
32	484	1447	3462	5098	5844	6107	6309	6471

Table 5.6. Cumulative water applied to each block (m^3/ha) during the 2004/5 season.

Block number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	644	1663	3163	4338	5298	6180	6278	6510
2	1807	2609	3594	4722	5234	5593	5678	5939
3	542	1473	2691	4295	5585	6576	6576	6576
4	504	2022	3167	4331	5285	5658	5658	5730
5	148	868	1779	2923	3591	3925	4077	4323
6	1297	2876	3951	4493	5078	5279	5428	5428
7	530	1588	2434	2975	3755	3935	3935	3935
8	1111	2460	4142	5564	6670	7318	7579	7692
9	1350	2927	4445	5871	6818	7629	8045	8045
10	120	578	2199	3093	4102	4807	4867	4878
11	748	1675	2451	3531	4607	5693	6740	6740
12	398	987	1571	2284	3008	3635	4505	4886
13	242	1041	2002	3031	3466	3466	3718	3737
14	850	1921	2646	3499	4491	4779	4779	5005
15	336	1290	2379	3340	4698	5561	5620	5740
16	1159	2135	3829	5115	5787	6503	6756	6756
17	773	1367	2085	2802	2867	2867	2867	2867
18	593	1667	2962	4735	5714	6746	6991	7168
19	1580	2856	3987	4746	4747	5124	5182	5182
20	838	1878	2986	3901	4537	4819	4819	4819
21	1119	2721	4480	5156	5580	5697	5697	5697
22	468	1014	1916	2725	3505	3792	3792	3792
23	124	713	1458	2233	2571	2799	2840	2843
24	685	1789	2907	3900	4542	5546	5739	5915
25	835	1833	2772	3713	4627	5124	5215	5297
26	1054	2423	3758	4488	4974	5275	5358	5368
27	814	1551	2367	2924	3133	3338	3389	3443
28	395	1150	1792	2502	2959	3273	3444	3444
29	214	1226	2549	3880	5220	6426	7037	7666
30	918	1510	2142	3008	3478	4362	4446	4523
31	659	1521	2276	2873	3066	3531	4362	4437
32	891	2180	3542	4280	4411	4713	4722	4722

Table 5.7. Cumulative water applied to each block (m^3/ha) during the 2005/6 season.

Block number	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	271	1137	1977	3237	3972	4856	5063	5277
2	510	1226	2243	3411	4696	5815	6190	6588
3	1025	2028	3342	4800	6311	7517	8372	9313
4	362	1472	2849	4106	5112	5962	5962	6462
5	367	1131	2113	3554	4871	5594	5594	5896
6	1010	2011	2966	3340	3737	4012	4202	4428
7	548	1499	3253	4765	5969	7014	7506	7686
8	785	1797	3436	5086	6448	7435	7539	8029
9	569	1759	3448	5641	7744	9579	10885	11084
10	246	1313	2470	4130	5538	6430	6536	6657
11	354	1038	2246	3542	4404	5333	5800	6314
12	376	971	1806	2555	3269	3695	3789	4100
13	75	736	2250	3330	4149	5109	5493	5676
14	190	1136	2652	4041	4895	5626	5626	5772
15	125	837	2398	3783	4632	5427	5985	6243
16	632	1900	3633	5226	6101	6896	6896	7463
17	416	1149	1895	2767	3775	4476	5121	5567
18	547	1436	2724	3462	3599	3599	3599	3599
19	196	801	2295	3452	4195	4787	5406	5674
20	526	1814	3224	4589	5424	6232	6631	6929
21	996	1638	4213	5550	6422	7059	7881	8163
22	629	1607	3415	5150	6217	7948	8620	8737
23	539	1639	2987	3848	4651	5182	5348	5540
24	600	1556	3206	4343	4832	5589	6001	6637
25	324	1074	2137	3618	5099	6097	6520	6966
26	612	1735	3579	5128	6302	6954	7223	7551
27	674	1339	2494	3630	4285	4926	5317	5543
28	402	1240	2263	3203	3986	4655	5522	5766
29	1889	3183	4903	6691	7909	8640	8640	8820
30	433	1212	2353	3333	4123	5133	5840	6581
31	404	1061	2270	3207	3824	4225	4421	4887
32	484	1447	3462	5098	5844	6107	6309	6471

Table 5.8. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 1999/2000 season.

Block number	Area (ha)	Export %	Yield (ton/ha)		Yield-irrigation index (kg/m^3)	
			Total	Export	Total	Export
1	1.04	97	26.92	26.11	4.22	4.09
2	1.96	69	12.75	8.80	1.62	1.12
3	2.25	82	16.89	13.85	1.68	1.38
4	0.59	76	27.28	20.73	3.67	2.79
5	0.96	84	25.56	21.47	4.31	3.62
6	1.74	77	18.00	13.86	3.20	2.46
7	0.83	86	27.50	23.65	3.37	2.90
8	1.32	75	32.80	24.60	3.32	2.49
9	0.54	91	22.22	20.22	2.13	1.94
10	0.94	77	33.11	25.49	3.88	2.99
11	0.46	89	33.04	29.41	5.33	4.74
12	1.33	42	45.11	18.95	7.21	3.03
13	1.01	97	18.32	17.77	3.15	3.06
14	1.55	90	25.02	22.52	3.90	3.51
15	1.17	83	30.34	25.18	4.74	3.93
16	1.00	86	34.34	29.53	5.55	4.77
17	1.98	0	0.00	0.00	0.00	0.00
18	1.23	91	26.60	24.21	2.63	2.39
19	1.10	89	25.09	22.33	4.39	3.91
20	1.36	96	21.72	20.85	2.72	2.61
21	0.88	0	0.00	0.00	0.00	0.00
22	2.38	91	19.03	17.32	2.87	2.61
23	0.90	87	25.55	22.23	3.41	2.97
24	1.95	0	0.00	0.00	0.00	0.00
25	2.04	78	22.54	17.58	4.38	3.42
26	0.57	0	0.00	0.00	0.00	0.00
27	0.84	0	0.00	0.00	0.00	0.00
28	1.33	0	0.00	0.00	0.00	0.00
29	0.32	0	0.00	0.00	0.00	0.00
30	1.20	0	0.00	0.00	0.00	0.00
31	0.71	0	0.00	0.00	0.00	0.00
32	0.45	0	0.00	0.00	0.00	0.00

Table 5.9. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2000/1 season.

Block number	Area (ha)	Export %	Yield (t/ha)		Yield-irrigation index (kg/m^3)	
			Total	**Export**	**Total**	**Export**
1	1.04	96	23.30	22.37	3.12	3.00
2	1.96	71	25.00	17.75	3.83	2.72
3	2.25	88	21.99	19.35	2.02	1.78
4	1.81	69	22.98	15.86	3.06	2.11
5	0.96	97	31.51	30.56	5.59	5.42
6	1.74	81	22.28	18.05	3.04	2.46
7	0.83	89	26.40	23.50	2.83	2.52
8	1.32	73	24.14	17.62	2.58	1.88
9	1.54	90	28.00	25.20	2.75	2.48
10	0.94	72	35.07	25.25	4.85	3.49
11	1.38	93	33.91	31.54	3.98	3.70
12	1.33	62	37.32	23.14	7.03	4.36
13	1.01	87	22.31	19.41	2.86	2.49
14	1.55	59	17.01	10.04	2.83	1.67
15	1.17	74	19.03	14.08	2.04	1.51
16	1.00	75	31.30	23.48	4.55	3.41
17	1.98	88	25.05	22.04	4.64	4.08
18	1.23	95	26.86	25.52	2.28	2.17
19	2.20	83	26.38	21.90	4.30	3.57
20	1.36	75	34.06	25.55	4.30	3.23
21	0.88	77	20.00	15.40	3.81	2.93
22	2.38	76	27.83	21.15	4.40	3.34
23	0.90	68	32.21	21.90	4.30	2.92
24	1.95	89	30.00	26.70	3.59	3.20
25	1.04	92	18.89	17.38	3.46	3.18
26	0.57	87	31.67	27.55	7.25	6.31
27	0.84	74	26.51	19.62	4.11	3.04
28	1.33	92	16.82	15.47	2.26	2.08
29	0.35	75	42.86	32.15	4.80	3.60
30	1.20	78	26.85	20.94	5.05	3.94
31	0.71	92	28.36	26.09	4.53	4.17
32	0.45	70	27.67	19.37	6.91	4.84

Table 5.10. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2001/2 season.

Block number	Area (ha)	Export %	Yield (t/ha)		Yield-irrigation index (kg/m^3)	
			Total	Export	Total	Export
1	1.04	98	25.96	25.44	6.15	6.03
2	1.96	63	25.51	16.07	4.19	2.64
3	2.25	64	40.93	26.19	4.71	3.02
4	1.81	70	29.25	20.47	3.24	2.27
5	0.96	80	33.96	27.17	5.66	4.53
6	1.74	75	30.00	22.50	3.90	2.93
7	0.83	88	27.11	23.86	3.44	3.03
8	1.32	76	21.89	16.64	3.16	2.40
9	1.54	50	24.75	12.38	3.20	1.60
10	0.94	75	33.88	25.41	4.53	3.40
11	1.38	78	37.46	29.22	4.24	3.31
12	1.33	31	26.32	8.16	7.45	2.31
13	1.01	91	23.15	21.07	3.61	3.29
14	1.55	70	19.85	13.90	3.94	2.76
15	1.17	73	12.39	9.05	1.60	1.17
16	1.00	79	37.20	29.39	5.75	4.54
17	1.98	88	36.16	31.82	6.82	6.00
18	1.23	71	54.30	38.55	6.32	4.49
19	2.20	84	23.75	19.95	3.75	3.15
20	1.36	65	38.24	24.85	5.32	3.46
21	1.15	84	41.74	35.06	5.90	4.96
22	2.38	97	32.00	31.04	3.26	3.16
23	0.90	80	39.59	31.67	4.60	3.68
24	1.95	85	44.84	38.11	6.18	5.25
25	1.04	91	29.81	27.13	3.62	3.30
26	0.57	92	41.79	38.45	6.65	6.12
27	0.84	89	36.60	32.57	5.52	4.91
28	1.33	83	27.00	22.41	3.27	2.72
29	0.35	74	47.03	34.80	6.12	4.53
30	1.20	47	32.98	15.50	4.79	2.25
31	0.71	77	33.38	25.70	4.74	3.65
32	0.45	70	40.30	28.21	8.82	6.17

Table 5.11. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2002/3 season.

Block number	Area (ha)	Export %	Yield (t/ha)		Yield-irrigation index (kg/m^3)	
			Total	**Export**	**Total**	**Export**
1	1.04	41	40.96	16.79	6.54	2.68
2	1.96	54	25.00	13.50	5.83	3.15
3	2.25	73	26.09	19.04	2.54	1.85
4	1.81	44	34.15	15.03	4.77	2.10
5	0.96	80	24.58	19.67	3.20	2.56
6	1.74	76	27.90	21.21	3.40	2.59
7	0.83	75	27.83	20.87	3.10	2.33
8	1.32	65	29.92	19.45	3.69	2.40
9	1.54	45	28.00	12.60	3.17	1.43
10	0.94	51	37.23	18.99	4.81	2.45
11	1.38	79	34.31	27.11	6.09	4.81
12	1.33	43	47.42	20.39	8.20	3.53
13	1.01	55	29.70	16.34	4.87	2.68
14	1.55	58	33.17	19.24	4.56	2.65
15	1.17	76	10.60	8.05	1.78	1.35
16	1.00	78	35.40	27.61	4.80	3.75
17	1.98	90	25.25	22.73	4.29	3.86
18	1.23	73	51.19	37.37	5.94	4.33
19	2.20	85	25.27	21.48	4.65	3.95
20	1.36	76	24.30	18.47	3.36	2.55
21	1.15	68	34.78	23.65	5.20	3.53
22	2.38	90	27.71	24.94	3.16	2.85
23	0.90	88	40.00	35.20	5.78	5.09
24	1.95	86	34.42	29.60	4.52	3.88
25	1.04	92	18.89	17.38	2.93	2.69
26	0.57	86	37.89	32.59	7.22	6.21
27	0.84	69	35.49	24.49	5.53	3.82
28	1.33	73	28.40	20.73	3.59	2.62
29	0.35	80	32.86	26.29	4.07	3.26
30	1.20	64	30.93	19.79	3.43	2.19
31	0.71	83	28.00	23.24	4.71	3.91
32	0.45	74	32.49	24.04	4.48	3.32

Table 5.12. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2003/4 season.

Block number	**Area (ha)**	**Export %**	**Yield (t/ha)**		**Yield-irrigation index (kg/m^3)**	
			Total	**Export**	**Total**	**Export**
1	1.04	66	33.85	22.34	6.41	4.23
2	1.96	41	27.35	11.21	4.15	1.70
3	2.25	71	29.41	20.88	3.16	2.24
4	1.81	51	15.26	7.78	2.36	1.20
5	0.96	72	33.33	24.00	5.65	4.07
6	1.74	69	26.00	17.94	5.87	4.05
7	0.83	72	28.31	20.39	3.68	2.65
8	1.32	65	29.92	19.45	3.73	2.42
9	1.54	89	27.21	24.21	2.45	2.18
10	0.94	81	33.73	27.32	5.07	4.10
11	1.38	68	41.04	27.91	6.50	4.42
12	1.33	94	15.79	14.84	3.85	3.62
13	1.01	69	25.74	17.76	4.54	3.13
14	1.55	51	31.26	15.94	5.42	2.76
15	1.17	61	21.11	12.88	3.38	2.06
16	1.00	78	37.50	29.25	5.02	3.92
17	1.98	94	24.24	22.79	4.35	4.09
18	1.23	82	22.80	18.69	4.58	3.76
19	2.20	91	21.59	19.65	3.81	3.46
20	1.36	73	32.02	23.38	4.62	3.37
21	1.15	82	29.57	24.24	3.62	2.97
22	2.38	78	35.96	28.05	4.12	3.21
23	0.90	80	34.02	27.22	6.14	4.91
24	1.95	63	28.28	17.82	4.26	2.68
25	1.04	94	22.34	21.00	3.21	3.01
26	0.57	73	56.14	40.98	7.43	5.43
27	0.84	85	41.90	35.62	7.56	6.43
28	1.33	68	25.41	17.28	4.41	3.00
29	0.35	66	40.00	26.40	4.54	2.99
30	1.20	80	29.68	23.75	4.51	3.61
31	0.71	64	34.93	22.35	7.15	4.57
32	0.45	50	57.73	28.87	8.92	4.46

Table 5.13. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2004/5 season.

Block number	Area (ha)	Export %	Yield (t/ha)		Yield-irrigation index (kg/m^3)	
			Total	**Export**	**Total**	**Export**
1	1.04	77	33.65	25.91	5.17	3.98
2	1.96	56	30.97	17.35	5.22	2.92
3	2.25	74	35.71	26.42	5.43	4.02
4	1.81	59	21.66	12.78	3.78	2.23
5	0.96	70	28.02	19.61	6.48	4.54
6	1.74	91	16.33	14.86	3.01	2.74
7	0.83	74	22.41	16.58	5.70	4.21
8	1.32	69	29.40	20.29	3.82	2.64
9	1.54	42	30.00	12.60	3.73	1.57
10	0.94	80	34.04	27.23	6.98	5.58
11	1.38	54	22.10	11.93	3.28	1.77
12	1.33	19	46.86	8.90	9.59	1.82
13	1.01	49	26.10	12.79	6.98	3.42
14	1.55	50	17.01	8.51	3.40	1.70
15	1.17	57	23.50	13.40	4.09	2.33
16	1.00	9	17.40	1.57	2.58	0.23
17	1.98	86	14.03	12.07	4.89	4.21
18	1.70	71	21.41	15.20	2.99	2.12
19	2.20	90	17.07	15.37	3.29	2.97
20	1.36	67	25.46	17.06	5.28	3.54
21	1.15	56	33.04	18.50	5.80	3.25
22	2.38	66	25.13	16.58	6.63	4.37
23	0.90	46	29.67	13.65	10.43	4.80
24	1.95	73	28.63	20.90	4.84	3.53
25	1.04	83	54.69	45.39	10.32	8.57
26	0.57	80	31.58	25.26	5.88	4.71
27	0.84	75	27.55	20.66	8.00	6.00
28	1.33	78	20.55	16.03	5.97	4.65
29	0.35	58	30.60	17.75	3.99	2.32
30	1.20	46	23.33	10.73	5.16	2.37
31	0.71	74	23.21	17.18	5.23	3.87
32	0.45	50	47.49	23.74	10.06	5.03

Table 5.14. Yield (t/ha) and yield-irrigation index (kg/m^3) data for 2005/6 season.

Block number	Area (ha)	Export %	Yield (t/ha)		Yield-irrigation index (kg/m^3)	
			Total	Export	Total	Export
1	1.04	41	33.85	13.88	6.41	2.63
2	1.96	54	27.35	14.77	4.15	2.24
3	2.25	73	29.41	21.47	3.16	2.31
4	1.81	44	15.26	6.71	2.36	1.04
5	0.96	80	33.33	26.67	5.65	4.52
6	1.74	76	26.00	19.76	5.87	4.46
7	0.83	75	28.31	21.23	3.68	2.76
8	1.32	65	29.92	19.45	3.73	2.42
9	1.54	45	27.21	12.24	2.45	1.10
10	0.94	51	33.73	17.20	5.07	2.58
11	1.38	79	41.04	32.42	6.50	5.13
12	1.33	43	15.79	6.79	3.85	1.66
13	1.01	55	25.74	14.16	4.54	2.49
14	1.55	58	31.26	18.13	5.42	3.14
15	1.17	76	21.11	16.04	3.38	2.57
16	1.00	78	37.50	29.25	5.02	3.92
17	1.98	90	24.24	21.82	4.35	3.92
18	1.70	73	16.49	12.04	4.58	3.35
19	2.20	85	21.59	18.35	3.81	3.23
20	1.36	76	32.02	24.34	4.62	3.51
21	1.15	68	29.57	20.10	3.62	2.46
22	2.38	90	35.96	32.36	4.12	3.70
23	0.90	88	34.02	29.94	6.14	5.40
24	1.95	86	28.28	24.32	4.26	3.66
25	1.04	92	22.34	20.55	3.21	2.95
26	0.57	86	56.14	48.28	7.43	6.39
27	0.84	69	41.90	28.91	7.56	5.22
28	1.33	73	25.41	18.55	4.41	3.22
29	0.35	80	40.00	32.00	4.54	3.63
30	1.20	64	29.68	19.00	4.51	2.89
31	0.71	83	34.93	28.99	7.15	5.93
32	0.45	74	57.73	42.72	8.92	6.60

Appendix 6

Table 6.1. Monthly ET_c values calculated for the De Doorns weather station, using the A-pan evaporation.

		A-pan	Crop Factor		ET_c (mm/day)	
Year	Month	Evaporation (mm/day)	Early	Late	Early	Late
2004	January	8.9	0.55	0.60	4.90	5.34
2004	February	8.2	0.55	0.55	4.51	4.51
2004	March	6.6	0.40	0.50	2.64	3.30
2004	April	4.1	0.30	0.45	1.23	1.85
2004	October	6.0	0.45	0.35	2.70	2.10
2004	November	8.2	0.55	0.45	4.51	3.69
2004	December	8.9	0.60	0.55	5.34	4.90
2005	January	8.5	0.55	0.60	4.68	5.10
2005	February	8.3	0.55	0.55	4.57	4.57
2005	March	6.5	0.40	0.50	2.60	3.25
2005	April	3.4	0.30	0.45	1.02	1.53
2005	October	7.0	0.45	0.35	3.15	2.45
2005	November	7.9	0.55	0.45	4.35	3.56
2005	December	9.4	0.60	0.55	5.64	5.17
2006	January	7.0	0.55	0.60	3.85	4.20
2006	February	6.6	0.55	0.55	3.63	3.63
2006	March	5.3	0.40	0.50	2.12	2.65
2006	April	3.4	0.30	0.45	1.02	1.53
2006	October	3.9	0.45	0.35	1.76	1.37
2006	November	6.3	0.55	0.45	3.47	2.84
2006	December	6.7	0.60	0.55	4.02	3.69
2007	January	7.8	0.45	0.60	3.51	4.68
2007	February	6.2	0.55	0.55	3.41	3.41
2007	March	5.3	0.60	0.50	3.18	2.65
2007	April	3.7	0.55	0.45	2.04	1.67

Table 6.2. Monthly ET_c values calculated for the De Vlei weather station, using the A-pan evaporation.

		A-pan	Crop Factor		ET_c (mm/day)	
Year	Month	Evaporation (mm/day)	Early	Late	Early	Late
2004	October	5.7	0.45	0.35	2.57	2.00
2004	November	7.4	0.55	0.45	4.08	3.34
2004	December	7.7	0.60	0.55	4.62	4.24
2005	January	7.2	0.55	0.60	3.95	4.31
2005	February	7.5	0.55	0.55	4.10	4.10
2005	March	5.3	0.40	0.50	2.10	2.63
2005	April	2.9	0.30	0.45	0.87	1.31
2005	October	6.3	0.45	0.35	2.81	2.19
2005	November	6.8	0.55	0.45	3.76	3.07
2005	December	8.3	0.60	0.55	4.96	4.55
2006	January	7.5	0.55	0.60	4.10	4.48
2006	February	7.2	0.55	0.55	3.95	3.95
2006	March	5.7	0.40	0.50	2.26	2.83
2006	April	3.3	0.30	0.45	0.98	1.47
2006	October	5.7	0.45	0.35	2.54	1.98
2006	November	6.9	0.55	0.45	3.82	3.12
2006	December	7.6	0.60	0.55	4.55	4.17

Table 6.3. Monthly ET_c values calculated for the Jolette weather station, using the A-pan evaporation.

Year	Month	A-pan Evaporation (mm/day)	Crop Factor		ET_c (mm/day)	
			Early	Late	Early	Late
2004	October	5.9	0.45	0.35	2.66	2.07
2004	November	7.3	0.55	0.45	4.03	3.29
2004	December	7.5	0.60	0.55	4.50	4.13
2005	January	7.1	0.55	0.60	3.91	4.27
2005	February	7.4	0.55	0.55	4.07	4.07
2005	March	5.7	0.40	0.50	2.26	2.83
2005	April	3.0	0.30	0.45	0.89	1.33
2005	October	6.4	0.45	0.35	2.88	2.24
2005	November	7.1	0.55	0.45	3.93	3.21
2005	December	8.4	0.60	0.55	5.03	4.61
2006	January	7.9	0.55	0.60	4.34	4.73
2006	February	7.6	0.55	0.55	4.19	4.19
2006	March	6.0	0.40	0.50	2.41	3.02
2006	April	3.3	0.30	0.45	0.99	1.49
2006	October	5.3	0.45	0.35	2.37	1.84
2006	November	6.5	0.55	0.45	3.56	2.91
2006	December	7.2	0.60	0.55	4.31	3.95

Table 6.4. Monthly and daily Crop ET (mm) values determined by SAPWAT.

Block number		September	October	November	December	January	February
HT3	**Monthly**	**52**	**95**	**129**	**149**	**132**	**77**
	Daily	1.73	3.06	4.30	4.81	4.26	2.75
HT6	**Monthly**	**52**	**95**	**129**	**149**	**132**	**77**
	Daily	1.73	3.06	4.30	4.81	4.26	2.75
HT12	**Monthly**	**52**	**95**	**129**	**149**	**132**	**77**
	Daily	1.73	3.06	4.30	4.81	4.26	2.75
HT5	**Monthly**	**58**	**100**	**132**	**152**	**135**	**81**
	Daily	1.93	3.23	4.40	4.90	4.35	2.89
HT7	**Monthly**	**58**	**101**	**134**	**154**	**140**	**90**
	Daily	1.93	3.26	4.47	4.97	4.52	3.21
HT9	**Monthly**	**58**	**101**	**134**	**154**	**140**	**90**
	Daily	1.93	3.26	4.47	4.97	4.52	3.21

Table 6.5. Irrigation requirement as determined by Vinet for HT3

Month	**ET (mm/cycle)**	**Irrigation requirement (hrs)**	**Irrigation requirement (m^3)**	**Irrigation frequency (days)**
October	1.2	1.1	27	1
November	3.5	3.2	80	1
December	4.2	3.8	94	1
January	4.7	4.3	106	1
February	4.8	4.4	109	1
March	4.5	4.1	100	1
April	3.5	3.2	79	1

Table 6.6. Irrigation requirement as determined by Vinet for HT6

Month	**ET (mm/cycle)**	**Irrigation requirement (hrs)**	**Irrigation requirement (m^3)**	**Irrigation frequency (days)**
October	0.8	0.6	14	1
November	3.8	3.0	67	1
December	4.9	3.8	84	1
January	5.8	4.5	101	1
February	6.1	4.8	107	1
March	5.9	4.6	102	1
April	4.7	3.7	82	1

Table 6.7. Irrigation requirement as determined by Vinet for HT12

Month	ET (mm/cycle)	Irrigation requirement (hrs)	Irrigation requirement (m^3)	Irrigation frequency (days)
October	1.7	1.3	2.2	1
November	3.5	2.8	47	1
December	4.1	3.2	55	1
January	4.7	3.6	62	1
February	4.7	3.7	63	1
March	4.4	3.4	58	1
April	3.4	2.7	46	1

Table 6.8. Irrigation requirement as determined by Vinet for HT5

Month	ET (mm/cycle)	Irrigation requirement (hrs)	Irrigation requirement (m^3)	Irrigation frequency (days)
October	52.2	9.4	501	7
November	94.9	17.1	911	7
December	42.2	7.6	405	3
January	40.3	7.2	387	3
February	35.6	6.4	342	3
March	29.1	5.2	279	3
April	98.6	17.7	947	14

Table 6.9 Irrigation requirement as determined by Vinet for HT7

Month	ET (mm/cycle)	Irrigation requirement (hrs)	Irrigation requirement (m^3)	Irrigation frequency (days)
October	39.1	5.3	325	7
November	45.5	6.1	378	6
December	46.6	6.3	386	6
January	54.9	7.4	456	6
February	56.5	7.6	469	6
March	52.0	7.0	431	6
April	42.0	5.7	348	6

Table 6.10 Irrigation requirement as determined by Vinet for HT9

Month	ET (mm/cycle)	Irrigation requirement (hrs)	Irrigation requirement (m^3)	Irrigation frequency (days)
October	37.6	5.7	579	7
November	83.6	12.7	1288	7
December	87.8	13.3	1351	7
January	90.0	13.7	1386	7
February	86.4	13.1	1331	7
March	71.5	10.9	1102	7
April	52.1	7.9	802	7

Table 6.11. Data for evaporation pan method of ET_c calculation.

Month	Crop factor (late cultiars)	PET (mm/day)	PET (m^3/ha/month)
October	0.35	6.9	749
November	0.45	8.7	1175
December	0.55	9.9	1688
January	0.60	10.2	1897
February	0.55	9.0	1386
March	0.50	6.9	1070
April	0.45	4.6	621

Table 6.12 Total irrigation requirement per month as determined by SAPWAT (m^3/ha)

Month	HT3	HT6	HT12	HT5	HT7	HT9
September	632.89	632.76	633.08	852.08	1021.69	607.79
October	1182.22	1182.18	1181.95	1412.50	943.37	1066.88
November	1576.89	1577.01	1576.69	1618.75	1591.57	1259.74
December	1804.89	1805.17	1805.26	2121.88	2254.22	1655.19
January	1587.11	1586.78	1587.22	1967.71	1680.72	1520.78
February	958.22	958.05	957.89	1210.42	1197.59	897.40

Table 6.13 Long-term daily and monthly irrigation requirements for drip and micro irrigation respectively, as determined by SAPWAT

Month	Daily irrigation requirement for drip irrigation (m^3/ha)			Weekly irrigation requirement for micro irrigation (m^3/ha)		
	HT3	HT6	HT12	HT5	HT7	HT9
September	21.10	21.09	21.10	213.02	255.42	151.95
October	38.14	38.13	38.13	353.13	235.84	266.72
November	52.56	52.57	52.57	404.69	397.89	314.94
December	58.22	58.23	58.23	530.47	563.56	413.80
January	51.20	51.19	51.20	491.93	420.18	380.20
February	34.22	34.22	34.21	302.61	299.40	224.35

Appendix 7

Table 7.1. Results for pH, EC and water soluble cations for block HT1 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg) Ca	Mg	Na	K	Water soluble anions (mg/kg) Cl	NO_2	NO_3	SO_4
HT1.1.1	4.97	0.13	23.15	8.95	17.75	15.95	39.20	0.00	135.00	28.95
HT1.2.1	5.28	0.13	22.80	9.20	42.05	55.60	33.35	0.00	169.10	33.25
HT1.3.1	5.62	0.18	53.65	18.65	43.00	60.30	43.15	0.00	141.95	42.30
HT1.4.1	5.23	0.09	20.45	5.30	38.05	36.00	30.25	0.00	37.45	35.80
HT1.5.1	4.75	0.09	9.20	2.45	44.80	50.40	31.40	0.00	62.60	30.65
HT1.6.1	4.61	0.13	21.30	7.00	64.25	39.50	52.40	0.00	86.95	73.25
HT1.7.1	4.95	0.10	15.80	4.70	40.20	58.30	27.90	0.00	66.55	30.00
HT1.8.1	5.45	0.09	22.75	7.10	63.50	64.20	49.00	0.02	85.55	36.65
HT1.9.1	4.98	0.09	19.25	4.35	38.50	37.25	30.45	0.00	58.75	32.05
Average	5.09	0.11	23.15	7.52	43.57	46.39	37.46	0.00	93.77	38.10
std deviation	0.31	0.03	11.57	4.45	13.18	14.60	8.42	0.01	42.06	13.02
90th percentile	5.48	0.14	29.25	11.09	63.65	61.08	49.68	0.00	147.38	48.49
10th percentile	4.72	0.09	14.48	3.97	33.99	31.99	29.78	0.00	54.49	29.79

Table 7.2. Results for pH, EC and water soluble cations for block HT1 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg) Ca	Mg	Na	K	Water soluble anions (mg/kg) Cl	NO_2	NO_3	SO_4
HT1.1.2	4.11	0.08	10.35	3.60	44.90	20.30	29.85	0.00	75.15	22.55
HT1.2.2	4.50	0.07	19.30	5.50	44.60	64.25	35.80	0.00	62.35	26.65
HT1.3.2	4.19	0.04	7.05	1.75	48.45	25.85	33.60	0.00	34.15	31.45
HT1.4.2	3.86	0.03	4.10	0.90	46.55	18.55	31.60	0.00	18.70	32.90
HT1.5.2	4.70	0.09	12.45	4.00	56.80	26.70	43.95	0.00	47.45	42.20
HT1.6.2	3.73	0.16	32.70	12.35	70.15	33.70	92.00	0.00	57.85	88.15
HT1.7.2	4.12	0.05	13.85	5.40	8.60	29.75	32.15	0.00	18.65	14.90
HT1.8.2	4.76	0.08	6.60	1.95	46.40	33.75	30.00	0.00	50.75	25.00
HT1.9.2	4.13	0.08	15.40	3.55	42.40	17.95	29.05	0.00	41.10	46.55
Average	4.23	0.07	13.53	4.33	45.43	30.09	39.78	0.00	45.13	36.71
std deviation	0.33	0.04	8.13	3.20	15.34	13.33	18.95	0.00	18.05	20.36
90th percentile	4.71	0.10	21.98	6.87	59.47	39.85	53.56	0.00	64.91	54.87
10th percentile	3.83	0.04	6.10	1.58	35.64	18.43	29.69	0.00	18.69	21.02

Table 7.3. Results for pH, EC and water soluble cations for block HT3 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg) Ca	Mg	Na	K	Water soluble anions (mg/kg) Cl	NO_2	NO_3	SO_4
HT3.1.1	6.65	0.04	11.75	2.15	48.50	10.50	30.50	0.00	39.70	25.00
HT3.2.1	4.79	0.08	20.75	6.05	14.45	45.55	41.85	0.00	87.50	27.45
HT3.3.1	6.38	0.03	42.90	10.20	68.35	79.20	49.85	0.00	138.55	53.10
HT3.4.1	4.89	0.08	7.55	1.00	51.90	22.45	35.85	0.00	18.85	45.35
HT3.5.1	5.49	0.02	8.30	1.95	52.75	16.30	40.00	0.00	34.50	90.90
HT3.6.1	6.22	0.05	14.55	4.65	22.90	44.50	64.10	0.00	37.90	18.20
HT3.7.1	6.84	0.08	44.50	6.05	12.05	18.60	27.70	0.00	80.85	40.20
HT3.8.1	6.82	0.07	29.75	5.80	7.00	22.45	29.05	0.00	32.80	16.25
HT3.9.1	6.30	0.06	21.30	6.90	15.85	42.00	23.95	0.00	13.30	19.95
Average	6.04	0.06	22.37	4.97	32.64	33.51	38.09	0.00	53.77	37.38
std deviation	0.75	0.02	13.17	2.73	21.32	20.33	11.95	0.00	38.26	22.49
90th percentile	6.82	0.08	43.22	7.56	55.87	52.28	52.70	0.00	97.71	60.66
10th percentile	4.87	0.03	8.15	1.76	11.04	15.14	26.95	0.00	17.74	17.81

Table 7.4. Results for pH, EC and water soluble cations for block HT3 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT3.1.2	5.57	0.03	9.60	2.75	7.70	25.90	22.20	0.00	6.00	6.30
HT3.2.2	5.14	0.05	8.10	1.95	47.25	26.70	34.35	0.00	42.80	29.70
HT3.3.2	6.60	0.11	33.55	6.40	69.15	30.85	36.50	0.00	92.05	49.40
HT3.4.2	3.97	0.13	7.50	1.90	9.35	18.55	27.55	0.00	0.00	15.40
HT3.5.2	5.30	0.10	14.25	3.50	16.10	14.85	34.60	0.00	15.65	27.50
HT3.6.2	6.43	0.05	5.50	1.15	48.00	46.40	29.70	0.01	45.90	29.70
HT3.7.2	6.64	0.02	5.90	1.10	39.25	11.40	22.30	0.00	19.15	20.85
HT3.8.2	6.86	0.04	21.75	4.20	6.45	18.30	22.65	0.00	19.90	11.75
HT3.9.2	5.40	0.02	9.25	2.10	9.65	12.50	26.75	0.00	5.00	7.55
Average	5.77	0.06	12.82	2.78	28.10	22.83	28.51	0.00	27.38	22.02
std deviation	0.89	0.04	8.73	1.60	21.84	10.46	5.30	0.00	27.35	12.93
90th percentile	6.68	0.11	24.11	4.64	52.23	33.96	34.98	0.00	55.13	33.64
10th percentile	4.91	0.02	5.82	1.14	7.45	12.28	22.28	0.00	4.00	7.30

Table 7.5. Results for pH, EC and water soluble cations for block HT5 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT5.1.1	6.41	0.04	19.20	4.55	32.60	18.55	20.10	0.00	36.00	18.60
HT5.2.1	6.26	0.09	31.85	5.35	53.20	56.75	30.25	0.00	126.90	38.65
HT5.3.1	4.87	0.07	25.10	5.25	60.85	29.95	31.60	0.02	83.75	42.55
HT5.4.1	6.47	0.07	25.00	5.20	60.40	25.85	74.25	0.00	26.95	33.30
HT5.5.1	6.01	0.32	117.35	22.65	76.80	139.75	104.75	0.00	427.50	147.35
HT5.6.1	5.76	0.14	62.60	11.45	46.95	36.35	25.20	0.00	285.05	43.05
HT5.7.1	5.32	0.07	15.00	2.80	50.70	49.40	40.75	0.00	64.50	34.85
HT5.8.1	4.13	0.07	5.95	1.50	47.50	54.55	53.75	0.00	58.70	29.65
HT5.9.1	5.88	0.17	35.55	17.20	57.75	117.15	40.95	0.00	202.40	49.80
Average	5.68	0.12	37.51	8.44	54.08	58.70	46.84	0.00	145.75	48.64
std deviation	0.73	0.08	31.95	6.77	11.47	39.60	25.64	0.01	127.60	35.90
90th percentile	6.42	0.20	73.55	18.29	64.04	121.67	80.35	0.00	313.54	69.31
10th percentile	4.72	0.06	13.19	2.54	44.08	24.39	24.18	0.00	34.19	27.44

Table 7.6. Results for pH, EC and water soluble cations for block HT6 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT6.1.1	6.68	0.07	19.55	7.20	12.70	43.95	33.45	0.00	27.15	14.20
HT6.2.1	6.97	0.06	15.90	6.20	16.40	20.65	33.30	0.00	38.15	11.40
HT6.3.1	7.03	0.04	11.40	4.30	16.05	23.60	27.50	0.01	11.50	8.65
HT6.4.1	6.56	0.04	71.95	24.40	16.85	51.85	29.05	0.00	151.05	24.90
HT6.5.1	7.14	0.07	28.35	9.50	11.25	21.55	24.90	0.01	47.75	9.55
HT6.6.1	7.17	0.14	44.10	15.75	27.10	61.25	50.75	0.01	98.05	23.95
HT6.7.1	7.17	0.28	135.70	41.95	46.80	83.45	60.20	0.00	327.00	45.95
HT6.8.1		0.11	31.60	11.70	64.10	52.05	43.15	0.00	92.00	36.15
HT6.9.1	7.15	0.32	139.60	45.55	72.95	105.55	58.40	0.03	30.10	43.70
Average	6.98	0.12	55.35	18.51	31.58	51.54	40.08	0.01	91.42	24.27
std deviation	0.22	0.10	47.16	14.65	22.31	27.33	12.75	0.01	93.17	13.81
90^{th} percentile	7.17	0.29	136.48	42.67	65.87	87.87	58.76	0.01	186.24	44.15
10^{th} percentile	6.64	0.04	15.00	5.82	12.41	21.37	26.98	0.00	24.02	9.37

Table 7.7. Results for pH, EC and water soluble cations for block HT7 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT7.1.1	6.20	0.09	30.20	8.00	39.20	18.00	15.65	0.00	61.70	20.15
HT7.2.1	6.17	0.14	28.75	7.45	54.45	60.95	23.75	0.00	145.90	28.55
HT7.3.1	5.48	0.11	37.45	9.95	21.90	62.70	26.40	0.00	135.75	34.20
HT7.4.1	5.97	0.25	82.90	23.50	29.20	139.95	37.75	0.00	351.35	67.15
HT7.5.1	5.93	0.52	283.00	22.50	40.50	36.15	18.30	0.00	78.95	1117.05
HT7.6.1	5.08	0.07	17.35	4.75	13.80	72.70	21.65	0.00	63.90	13.20
HT7.7.1	5.30	0.10	28.35	6.70	58.55	57.95	28.52	0.00	143.60	31.30
HT7.8.1	5.53	0.22	92.15	11.10	66.80	39.35	29.95	0.00	145.05	207.40
HT7.9.1	6.25	0.65	457.35	25.90	47.90	48.05	26.15	0.00	88.25	1545.75
Average	5.77	0.24	117.50	13.32	41.37	59.53	25.35	0.00	134.94	340.53
std deviation	0.41	0.20	143.22	7.76	16.49	32.43	6.21	0.00	83.57	542.07
90th percentile	6.21	0.55	317.87	23.98	60.20	86.15	31.51	0.00	186.99	1202.79
10th percentile	5.26	0.09	26.15	6.31	20.28	32.52	17.77	0.00	63.46	18.76

Table 7.8. Results for pH, EC and water soluble cations for block HT7 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT7.1.2	5.04	0.08	19.80	4.25	49.10	14.60	22.30	0.00	46.95	29.95
HT7.2.2	5.80	0.09	19.85	2.05	42.00	47.05	19.60	0.00	35.90	23.55
HT7.3.2	5.02	0.25	106.60	27.15	70.05	40.00	71.35	0.00	117.35	345.75
HT7.4.2	5.85	0.35	317.55	76.60	63.45	81.95	54.25	0.02	167.00	1597.25
HT7.5.2	4.85	0.12	24.80	6.90	73.05	21.25	36.30	0.00	103.70	51.75
HT7.6.2	4.36	0.10	15.00	5.60	55.05	32.65	33.10	0.00	88.95	35.25
HT7.7.2	4.52	0.14	46.30	12.40	74.60	52.15	56.35	0.00	163.20	109.35
HT7.8.2	5.26	0.15	60.30	11.10	56.45	22.95	22.35	0.00	163.70	46.15
HT7.9.2	6.45	0.15	29.45	9.70	59.25	22.30	30.40	0.00	76.55	38.85
Average	5.24	0.16	71.07	17.31	60.33	37.21	38.44	0.00	107.03	253.09
std deviation	0.64	0.08	91.30	22.06	10.41	19.84	17.08	0.01	47.15	484.79
90th percentile	5.97	0.27	148.79	37.04	73.36	58.11	59.35	0.00	164.36	596.05
10th percentile	4.49	0.09	18.84	3.81	47.68	19.92	21.76	0.00	44.74	28.67

Table 7.9. Results for pH, EC and water soluble cations for block HT8 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT8.1.1	6.54	0.04	12.10	4.00	43.75	30.65	24.15	0.00	56.70	21.85
HT8.2.1	6.41	0.03	5.20	1.75	46.70	23.25	28.80	0.00	35.30	18.80
HT8.3.1	5.40	0.25	105.60	25.50	57.55	70.05	72.90	0.00	444.35	56.80
HT8.4.1	4.23	0.03	4.35	1.15	44.95	21.95	26.40	0.00	47.25	17.60
HT8.5.1	6.62	0.06	21.45	8.70	44.25	22.05	20.10	0.00	84.60	21.15
HT8.6.1	6.26	0.07	25.20	9.10	45.50	30.40	24.05	0.02	77.95	27.15
HT8.7.1	6.21	0.05	4.90	1.35	41.15	57.35	30.50	0.00	73.55	21.50
HT8.8.1	7.00	0.04	14.55	7.00	44.60	20.70	27.70	0.00	64.70	18.50
Average	6.08	0.07	24.17	7.32	46.06	34.55	31.83	0.00	110.55	25.42
std deviation	0.82	0.07	31.63	7.51	4.59	17.49	15.82	0.01	127.08	12.18
90th percentile	6.73	0.12	49.32	14.02	49.96	61.16	43.22	0.01	192.53	36.05
10th percentile	5.05	0.03	4.74	1.29	42.97	21.58	22.87	0.00	43.67	18.23

Table 7.10. Results for pH, EC and water soluble cations for block HT9 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT9.1.1	7.25	0.24	115.30	42.20	43.75	68.85	128.00	0.04	74.35	68.40
HT9.2.1	6.89	0.19	56.35	23.05	46.70	49.65	86.45	0.00	216.05	77.70
HT9.3.1	6.89	0.31	121.25	54.10	57.55	66.95	49.40	0.08	249.70	71.90
HT9.4.1	6.86	0.19	54.10	22.80	44.95	46.30	63.50	0.03	226.05	51.85
HT9.5.1	7.06	0.16	38.15	15.10	95.90	54.10	62.65	0.00	188.65	55.15
HT9.6.1	6.61	0.24	70.75	28.45	45.50	51.50	137.15	0.00	151.30	137.70
HT9.7.1	6.40	0.13	26.90	11.25	41.15	65.35	78.25	0.00	66.05	50.20
HT9.8.1	6.98		29.10	11.60	44.60	12.10	39.00	0.00	23.60	45.60
HT9.9.1	6.86	0.13	37.20	17.65	49.10	44.40	62.65	0.00	48.80	49.95
Average	6.87	0.20	61.01	25.13	52.13	51.02	78.56	0.02	138.28	67.61
std deviation	0.23	0.06	33.35	13.68	16.08	16.23	31.78	0.03	81.20	26.95
90th percentile	7.10	0.26	116.49	44.58	65.22	67.33	129.83	0.05	230.78	89.70
10th percentile	6.57	0.13	28.66	11.53	43.23	37.94	47.32	0.00	43.76	49.08

Table 7.11. Results for pH, EC and water soluble cations for block HT9 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT9.1.2	7.26	0.23	62.75	27.95	73.60	29.75	111.95	0.04	116.20	87.55
HT9.2.2	6.98	0.22	78.20	37.50	72.20	40.90	133.25	0.03	44.90	181.30
HT9.3.2	6.77	0.17	52.85	23.85	61.45	43.30	59.15	0.03	48.15	36.65
HT9.4.2	6.89	0.18	50.55	18.95	63.55	43.05	57.50	0.00	230.40	48.55
HT9.5.2	6.95	0.77	46.35	20.25	62.85	38.90	66.05	0.02	60.80	54.00
HT9.6.2	6.61		69.40	32.55	112.20	50.35	173.25	0.00	166.00	192.75
HT9.7.2	6.49	0.10	24.75	10.95	50.25	44.90	77.15	0.00	12.60	47.80
HT9.8.2	6.71	0.12	35.90	13.40	45.00	31.50	83.00	0.00	57.05	58.90
HT9.9.2	6.86	0.07	22.90	9.15	36.70	11.65	51.10	0.00	21.30	28.15
Average	6.84	0.23	49.29	21.62	64.20	37.14	90.27	0.01	84.16	81.74
std deviation	0.21	0.21	18.02	9.21	20.51	10.86	38.86	0.02	68.56	58.42
90th percentile	7.04	0.39	71.16	33.54	81.32	45.99	141.25	0.03	178.88	183.59
10th percentile	6.59	0.09	24.38	10.59	43.34	26.13	56.22	0.00	19.56	34.95

Table 7.12. Results for pH, EC and water soluble cations for block HT10 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT10.1.1	6.63	0.08	39.50	14.00	43.25	16.95	22.95	0.00	111.20	25.80
HT10.2.1	5.12	0.05	29.45	12.60	10.00	12.40	18.95	0.00	89.00	18.10
HT10.3.1	6.27	0.08	59.20	13.15	15.20	10.50	26.35	0.00	81.70	26.25
HT10.4.1	4.60	0.05	16.20	6.35	7.00	26.75	16.50	0.00	58.30	8.35
HT10.5.1	6.22	0.07	38.25	7.85	7.50	17.65	18.45	0.00	91.50	20.15
HT10.6.1	6.33	0.09	43.35	14.50	8.75	17.50	20.90	0.00	143.30	17.85
HT10.7.1	5.25	0.03	15.40	5.25	8.45	26.00	24.50	0.00	8.65	4.80
HT10.8.1	5.99	0.07	25.95	10.65	5.65	37.20	14.00	0.00	96.65	12.40
HT10.9.1	6.10	0.17	68.15	30.60	10.80	29.95	20.80	0.00	332.55	23.70
Average	5.83	0.08	37.27	12.77	12.96	21.66	20.38	0.00	112.54	17.49
std deviation	0.64	0.04	16.96	7.06	11.02	8.31	3.67	0.00	85.17	7.17
90th percentile	6.39	0.10	60.99	17.72	20.81	31.40	24.87	0.00	181.15	25.89
10th percentile	5.02	0.04	16.04	6.13	6.73	12.02	16.00	0.00	48.37	7.64

Table 7.13. Results for pH, EC and water soluble cations for block HT10 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT10.1.2	6.63	0.17	82.65	32.25	12.65	16.65	22.85	0.07	302.15	35.90
HT10.2.2	5.29	0.07	31.00	12.55	8.25	17.00	20.40	0.00	103.05	18.85
HT10.3.2	6.12	0.12	85.20	20.25	17.60	16.60	21.60	0.09	123.70	25.35
HT10.5.2	5.59	0.07	43.85	10.15	8.10	17.85	17.70	0.00	62.10	18.85
Average	5.91	0.09	49.12	16.61	12.10	19.05	18.70	0.02	150.09	20.09
std deviation	0.51	0.05	24.84	9.00	4.34	7.15	5.85	0.03	96.61	8.54
90th percentile	6.48	0.17	83.16	30.93	18.24	30.24	23.25	0.07	308.23	27.89
10th percentile	5.38	0.04	16.78	6.88	7.83	11.28	13.53	0.00	59.35	7.55

Table 7.14. Results for pH, EC and water soluble cations for block HT11 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT11.1.1	5.25	0.15	56.10	11.05	39.50	60.70	21.50	0.00	242.85	59.00
HT11.2.1	5.06	0.31	81.35	31.60	95.30	144.35	129.35	0.00	89.10	413.45
HT11.3.1	5.15	0.09	25.20	5.10	56.10	62.95	31.25	0.00	114.55	38.30
HT11.4.1	6.23	0.11	63.05	10.05	68.55	75.05	39.15	0.00	183.80	58.95
HT11.5.1	4.21	0.45	97.35	39.20	130.30	161.45	212.80	0.00	213.90	407.05
HT11.6.1	6.28	0.32	115.30	19.25	163.85	33.55	197.75	0.00	102.10	318.55
HT11.7.1	6.82		109.05	32.20	142.85	84.70	174.65	0.00	121.20	166.50
HT11.8.1	5.07	0.47	111.60	5.00	138.50	224.45	260.90	0.00	488.65	279.80
HT11.9.1	5.46	0.16	42.10	13.85	78.05	104.65	42.90	0.00	95.55	111.10
Average	5.50	0.26	77.90	18.59	101.44	105.76	123.36	0.00	183.52	205.86
std deviation	0.75	0.14	31.00	12.01	41.33	56.90	86.63	0.00	119.94	142.79
90th percentile	6.39	0.46	112.34	33.60	147.05	174.05	222.42	0.00	292.01	408.33
10th percentile	4.89	0.10	38.72	5.08	52.78	55.27	29.30	0.00	94.26	54.82

Table 7.15. Results for pH, EC and water soluble cations for block HT11 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT11.1.2	4.66	0.06	29.05	5.25	54.85	38.35	27.10	0.00	68.85	46.25
HT11.2.2	6.02	0.07	26.20	8.10	50.30	49.25	27.10	0.00	74.25	48.65
HT11.3.2	5.57	0.07	19.55	6.30	57.65	61.50	34.20	0.00	92.50	66.50
HT11.4.2	5.06	0.16	36.55	6.90	63.55	50.35	36.35	0.00	43.85	199.40
HT11.5.2	4.26	0.16	37.50	12.35	88.45	68.80	61.70	0.00	46.70	246.65
HT11.6.2	6.11	0.51	191.65	34.70	189.85	30.95	267.05	0.00	68.35	601.00
HT11.7.2	5.53	0.24	28.45	5.30	67.80	101.30	36.00	0.00	113.55	48.50
HT11.8.2	4.34	0.54	165.95	50.05	144.20	175.65	273.90	0.16	431.85	408.80
HT11.9.2	4.99	0.13	53.40	14.30	76.55	78.45	39.15	0.00	72.60	108.60
Average	5.17	0.22	65.37	15.92	88.13	72.73	89.17	0.02	112.50	197.15
std deviation	0.64	0.17	61.58	14.89	44.86	41.58	97.39	0.05	114.67	183.24
90th percentile	6.04	0.52	171.09	37.77	153.33	116.17	268.42	0.03	177.21	447.24
10th percentile	4.32	0.07	24.87	5.29	53.94	36.87	27.10	0.00	46.13	48.05

Table 7.16. Results for pH, EC and water soluble cations for block HT12 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT12.1.1	6.61	0.10	24.00	8.80	50.65	69.55	27.80	0.00	128.30	32.20
HT12.2.1	5.81	0.05	10.20	4.05	39.85	43.55	21.20	0.00	81.05	20.40
HT12.3.1	5.93	0.04	9.10	3.35	39.15	30.85	28.15	0.00	56.85	23.55
HT12.4.1	6.55	0.16	59.10	22.45	49.25	39.90	25.65	0.00	73.25	223.80
HT12.5.1	6.16	0.09	16.55	7.40	45.40	35.55	21.25	0.00	84.15	26.75
HT12.6.1	5.56	0.05	6.25	2.45	50.45	25.00	28.15	0.00	40.60	24.85
HT12.7.1	5.88	0.05	7.20	2.45	39.00	48.90	17.95	0.00	42.50	22.80
HT12.9.1	6.00	0.09	25.15	8.70	9.45	52.00	30.85	0.01	158.70	34.25
Average	6.06	0.08	20.27	7.22	41.90	42.46	25.34	0.00	79.06	50.74
std deviation	0.34	0.04	15.54	5.88	12.62	12.44	4.00	0.00	38.33	61.70
90th percentile	6.57	0.11	31.94	11.53	51.31	55.51	28.69	0.00	134.38	83.20
10th percentile	5.74	0.05	7.01	2.45	33.09	29.68	20.55	0.00	42.12	22.32

Table 7.17. Results for pH, EC and water soluble cations for block HT12 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT12.1.2	6.54	0.12	34.75	12.70	50.95	75.45	32.70	0.00	161.35	42.75
HT12.2.2	5.87	0.07	14.70	6.45	82.90	44.45	30.15	0.00	81.00	35.25
HT12.3.2	5.98	0.07	14.30	5.55	48.35	47.60	23.30	0.00	100.35	35.35
HT12.4.2	6.39	0.13	42.80	18.75	57.50	27.80	24.60	0.00	89.25	156.45
HT12.5.2	6.16	0.03	103.95	19.95	163.60	22.60	89.55	0.00	163.90	360.60
HT12.6.2	5.51	0.05	7.05	2.55	43.40	33.05	24.30	0.00	57.60	24.25
HT12.7.2	5.33	0.05	8.50	3.20	41.30	41.80	21.05	0.00	45.85	22.80
HT12.8.2	6.03	0.04	11.45	4.50	53.45	18.65	24.40	0.00	55.45	25.60
HT12.9.2	5.50	0.09	29.50	9.20	46.00	33.00	20.30	0.00	163.50	35.30
Average	5.92	0.07	29.67	9.21	65.27	38.27	32.26	0.00	102.03	82.04
std deviation	0.39	0.03	28.81	6.17	36.66	16.04	20.60	0.00	45.99	106.07
90th percentile	6.42	0.12	55.03	18.99	99.04	53.17	44.07	0.00	163.58	197.28
10th percentile	5.47	0.04	8.21	3.07	42.98	21.81	20.90	0.00	53.53	23.96

Table 7.18. Results for pH, EC and water soluble cations for block HT13 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT13.1.1	6.63	0.14	48.60	8.60	92.65	46.55	51.45	0.00	141.05	93.60
HT13.2.1	6.33	0.58	258.75	48.05	196.85	71.95	361.50	0.00	98.20	734.95
HT13.3.1	6.88	0.22	109.55	14.65	90.35	58.90	56.25	0.04	124.30	174.40
HT13.4.1	7.25	0.29	143.00	12.20	147.75	9.35	114.75	0.00	108.05	302.30
HT13.5.1	6.81	0.23	79.95	15.05	183.45	25.55	93.45	0.00	118.55	330.75
HT13.6.1	6.66	0.80	508.40	58.80	159.00	109.30	107.25	0.00	394.05	1658.05
HT13.7.1	7.08	0.16	76.20	12.60	118.30	18.45	71.85	0.00	93.10	137.00
HT13.8.1	6.85	1.55	135.85	12.60	131.80	10.05	105.45	0.00	86.95	277.25
HT13.9.1	5.19	0.42	198.25	38.55	152.30	73.05	162.55	0.00	267.10	563.65
Average	6.63	0.49	173.17	24.57	141.38	47.02	124.94	0.00	159.04	474.66
std deviation	0.57	0.43	133.46	17.64	34.83	32.29	89.51	0.01	97.71	461.26
90th percentile	7.11	0.95	308.68	50.20	186.13	80.30	202.34	0.01	292.49	919.57
10th percentile	6.10	0.15	70.68	11.48	92.19	9.91	55.29	0.00	91.87	128.32

Table 7.19. Results for pH, EC and water soluble cations for block HT13 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT13.1.2	6.60	0.08	37.20	7.10	84.80	14.45	43.10	0.00	74.30	74.15
HT13.2.2	6.08	0.25	89.45	14.80	149.70	20.20	115.90	0.00	31.15	365.80
HT13.3.2	6.49	0.16	60.45	11.40	95.80	39.95	56.70	0.00	78.35	147.35
HT13.4.2	7.25	0.27	1049.85	84.10	249.15	262.40	231.80	0.00	441.45	3913.85
HT13.5.2	6.19	0.29	92.40	16.35	203.80	22.30	116.05	0.00	119.40	385.45
HT13.6.2	5.56	0.28	23.45	9.95	59.95	42.20	26.85	0.02	145.60	35.40
HT13.7.2	6.76	0.16	62.55	12.70	126.20	17.70	67.80	0.00	65.95	161.95
HT13.8.2	5.50	0.41	136.95	26.10	189.65	68.10	202.30	0.00	321.50	348.95
HT13.9.2	5.06	1.00	541.30	115.00	239.90	103.60	449.40	0.00	792.40	1346.30
Average	6.17	0.32	232.62	33.06	155.44	65.66	145.54	0.00	230.01	753.24
std deviation	0.66	0.26	325.40	36.62	64.96	74.71	126.17	0.01	236.27	1177.72
90th percentile	6.86	0.53	643.01	90.28	241.75	135.36	275.32	0.00	511.64	1859.81
10th percentile	5.41	0.14	34.45	9.38	79.83	17.05	39.85	0.00	58.99	66.40

Table 7.20. Results for pH, EC and water soluble cations for block HT14 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT14.1.1	6.23	0.11	65.55	18.60	27.35	85.40	33.60	0.00	44.10	54.40
HT14.2.1	6.60	0.20	106.55	14.90	64.85	96.20	32.15	0.00	116.55	121.00
HT14.3.1	6.84	0.10	45.65	8.80	71.10	75.40	3.35	0.00	9.20	5.30
HT14.4.1	6.09	0.08	80.40	11.70	14.75	79.15	22.85	0.00	8.75	24.25
HT14.5.1	5.76	0.38	214.25	33.50	89.25	67.65	55.05	0.13	322.65	554.45
HT14.6.1	6.21	0.25	145.80	15.40	32.15	71.50	20.35	0.00	88.85	342.65
HT14.7.1	5.87	0.15	65.90	16.70	27.75	55.25	35.55	0.00	142.50	92.10
HT14.8.1	6.63	0.29	142.25	19.55	62.10	122.25	45.15	0.00	376.65	196.15
HT14.9.1	6.61	0.26	119.20	31.25	17.30	102.55	19.35	0.00	312.55	84.45
Average	6.32	0.20	109.51	18.93	45.18	83.93	29.71	0.01	157.98	163.86
std deviation	0.35	0.10	49.69	7.84	25.35	19.16	14.42	0.04	134.55	168.48
90th percentile	6.67	0.31	159.49	31.70	74.73	106.49	47.13	0.03	333.45	385.01
10th percentile	5.85	0.09	61.57	11.12	16.79	65.17	16.15	0.00	9.11	20.46

Table 7.21. Results for pH, EC and water soluble cations for block HT14 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT14.1.2	5.60	0.12	40.85	11.55	95.05	25.00	43.50	0.00	85.15	146.50
HT14.2.2	6.27	0.21	135.30	20.10	25.35	95.55	31.20	0.02	52.10	215.40
HT14.3.2	6.31	0.13	56.70	10.65	59.00	104.95	2.80	0.00	6.00	4.80
HT14.4.2	5.97	0.09	53.55	11.75	23.85	42.25	31.85	0.00	5.00	78.05
HT14.5.2	5.97	0.40	198.55	33.40	92.75	57.65	51.40	0.00	317.40	521.35
HT14.6.2	6.01	0.23	136.20	16.15	14.30	54.85	27.85	0.00	46.35	434.50
HT14.7.2	5.84	0.76	447.00	76.25	86.45	119.50	100.00	0.00	1036.75	645.70
HT14.8.2	6.74	0.17	89.20	15.40	67.65	82.95	31.45	0.00	273.20	118.00
HT14.9.2	6.60	0.26	87.45	25.90	66.95	127.65	10.25	0.00	62.80	35.90
Average	6.15	0.26	138.31	24.57	59.04	78.93	36.70	0.00	209.42	244.47
std deviation	0.35	0.20	118.92	19.59	29.24	33.79	26.41	0.01	311.21	218.29
90th percentile	6.63	0.47	248.24	41.97	93.21	121.13	61.12	0.00	461.27	546.22
10th percentile	5.79	0.11	51.01	11.37	21.94	38.80	8.76	0.00	5.80	29.68

Table 7.22. Results for pH, EC and water soluble cations for block HT15 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT15.1.1	6.42	0.10	38.30	11.65	64.20	28.20	47.35	0.05	107.75	45.70
HT15.2.1	5.89	0.05	18.15	7.85	21.10	38.05	14.55	0.00	56.60	8.50
HT15.3.1	6.17	0.07	37.05	8.60	8.30	57.45	39.85	0.00	80.85	16.00
HT15.4.1	6.46	0.14	50.55	14.30	10.25	45.95	69.10	0.00	161.85	20.75
HT15.5.1	6.24	0.07	28.20	7.20	5.50	47.70	15.30	0.00	88.90	25.60
HT15.6.1	6.69	0.26	77.45	34.60	14.80	31.80	433.25	0.00	85.20	10.95
HT15.7.1	5.65	0.32	136.10	42.40	70.30	31.10	99.55	0.00	641.10	86.50
HT15.8.1	5.69	0.16	42.95	18.75	14.90	22.20	47.75	0.00	185.90	40.45
HT15.9.1	5.88	0.13	44.00	19.65	47.10	34.40	53.80	0.00	117.50	43.30
Average	6.12	0.14	52.53	18.33	28.49	37.43	91.17	0.01	169.52	33.08
std deviation	0.34	0.09	33.32	11.72	23.72	10.42	123.40	0.02	171.09	23.01
90th percentile	6.51	0.27	89.18	36.16	65.42	49.65	166.29	0.01	276.94	53.86
10th percentile	5.68	0.06	26.19	7.72	7.74	27.00	15.15	0.00	76.00	10.46

Table 7.23. Results for pH, EC and water soluble cations for block HT15 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT15.1.2	6.60	0.14	70.70	25.00	18.30	17.45	50.30	0.00	199.15	82.70
HT15.2.2	6.25	0.10	41.25	16.30	34.40	38.00	28.10	0.00	113.70	16.60
HT15.3.2	6.11	0.10	45.85	12.05	9.25	56.40	26.40	0.03	122.40	27.00
HT15.4.2	6.30	0.16	55.90	16.55	8.65	42.80	64.15	0.02	208.90	27.25
Average	6.32	0.13	50.99	18.16	27.01	34.84	68.75	0.01	161.69	35.25
std deviation	0.18	0.06	18.17	7.94	18.40	13.84	47.03	0.01	57.93	20.85
90th percentile	6.51	0.18	74.40	27.23	50.76	51.00	131.97	0.02	222.51	59.63
10th percentile	6.15	0.08	31.89	10.92	8.47	16.04	24.15	0.00	106.16	15.37

Table 7.24. Results for pH, EC and water soluble cations for block HT16 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT16.1.1	5.90	0.12	50.65	7.75	6.35	33.10	39.55	0.00	105.45	76.35
HT16.2.1	5.30	0.71	366.50	76.35	120.75	105.15	91.40	0.00	374.05	1465.00
HT16.3.1	6.53	2.08	1883.50	61.25	89.25	118.70	32.45	0.00	158.80	9350.00
HT16.4.1	5.67	0.11	30.45	7.90	32.70	32.25	31.50	0.00	110.55	50.85
HT16.5.1	6.82	0.09	42.25	10.85	57.75	27.25	24.80	0.00	91.60	35.50
HT16.6.1	5.03	0.12	39.70	5.20	46.05	14.90	10.00	0.00	33.35	50.00
HT16.7.1	5.61	0.16	53.85	17.60	35.85	33.30	24.85	0.00	247.65	55.70
HT16.8.1	5.62	0.12	41.50	8.85	43.30	7.75	36.30	0.00	141.50	56.05
HT16.9.1	6.24	0.08	39.90	9.15	53.85	25.90	32.75	0.00	118.70	49.90
Average	5.86	0.40	283.14	22.77	53.98	44.26	35.96	0.00	153.52	1243.26
std deviation	0.55	0.62	574.79	25.07	31.52	37.21	21.22	0.00	95.05	2899.78
90th percentile	6.59	0.98	669.90	64.27	95.55	107.86	49.92	0.00	272.93	3042.00
10th percentile	5.25	0.09	37.85	7.24	27.43	13.47	21.84	0.00	79.95	47.02

Table 7.25. Results for pH, EC and water soluble cations for block HT16 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT16.1.2	6.31		68.00	29.25	51.70	9.45	54.75	0.03	75.45	149.80
HT16.2.2	5.89	0.12	45.20	11.80	49.15	11.75	60.50	0.00	94.30	114.15
HT16.3.2	4.93	0.29	117.50	12.80	52.30	53.80	57.05	0.00	100.05	350.40
HT16.4.2	6.07	0.18	60.95	17.15	39.00	56.95	101.25	0.00	112.70	156.20
HT16.5.2	6.65	0.07	26.40	5.95	35.15	38.10	39.50	0.00	79.75	45.30
HT16.6.2	6.27	0.21	80.85	20.35	58.65	28.25	51.25	0.00	340.60	96.85
HT16.7.2	5.95	0.13	36.50	30.65	93.00	81.95	63.55	0.00	94.20	84.65
HT16.8.2	6.25	0.22	39.20	8.40	38.85	12.50	29.10	0.00	93.40	45.05
Average	6.04	0.17	59.33	17.04	52.23	36.59	57.12	0.00	123.81	130.30
std deviation	0.48	0.07	27.69	8.58	17.17	24.43	19.80	0.01	82.64	91.82
90th percentile	6.41	0.24	91.85	29.67	68.96	64.45	74.86	0.01	181.07	214.46
10th percentile	5.60	0.10	33.47	7.67	37.74	11.06	36.38	0.00	78.46	45.23

Table 7.26. Results for pH, EC and water soluble cations for block HT33 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT33.1.1	7.04	0.09	26.95	7.15	42.95	13.80	26.75	0.00	52.05	29.80
HT33.2.1	6.62		27.50	5.05	55.60	54.70	27.50	0.00	53.05	61.35
HT33.3.1	6.10	0.06	12.30	2.75	55.05	69.80	21.35	0.00	50.95	22.75
HT33.4.1	6.02	0.02	27.05	7.20	94.00	51.30	27.75	0.00	34.40	19.60
HT33.5.1	6.10	0.09	7.50	1.30	82.50	25.85	35.40	0.00	38.95	45.70
HT33.7.1	6.12	0.10	26.45	5.55	69.90	26.60	28.60	0.00	69.70	41.80
HT33.8.1	6.08	0.12	23.55	6.40	91.80	27.00	22.75	0.00	130.45	36.15
HT33.9.1	6.67	0.12	21.05	4.55	82.65	30.25	34.15	0.00	86.70	50.00
Average	6.34	0.09	21.54	4.99	71.81	37.41	28.03	0.00	64.53	38.39
std deviation	0.36	0.03	7.12	1.96	17.69	17.71	4.56	0.00	29.36	13.25
90th percentile	6.78	0.12	27.19	7.17	92.46	59.23	34.53	0.00	99.83	53.41
10th percentile	6.06	0.05	10.86	2.32	51.42	22.24	22.33	0.00	37.59	21.81

Table 7.27. Results for pH, EC and water soluble cations for block HT33 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT33.1.2	7.02	0.10	37.85	9.45	44.15	19.03	39.40	0.00	37.20	38.60
HT33.2.2	6.53	0.17	74.00	9.60	57.65	51.15	31.00	0.00	55.40	169.90
HT33.3.2	6.70	0.06	12.90	2.45	73.20	51.05	24.00	0.00	27.15	29.75
HT33.4.2	5.71	0.08	14.45	4.45	64.90	52.40	25.45	0.00	73.35	35.80
HT33.5.2	5.39	0.07	5.30	1.05	61.15	57.30	30.05	0.00	23.30	32.05
HT33.7.2	5.93	0.10	14.35	3.20	60.20	31.15	41.65	0.00	43.80	58.50
HT33.8.2	6.15	0.07	11.85	2.60	62.90	74.85	18.05	0.00	56.50	18.20
HT33.9.2	6.53	0.12	22.90	5.95	72.90	20.45	25.15	0.00	81.90	36.60
Average	6.25	0.10	24.20	4.84	62.13	44.67	29.34	0.00	49.83	52.43
std deviation	0.51	0.03	20.91	3.02	8.62	18.16	7.46	0.00	19.59	45.63
90th percentile	6.80	0.13	48.70	9.50	72.99	62.57	40.08	0.00	75.92	91.92
10th percentile	5.61	0.06	9.89	2.03	53.60	20.02	22.22	0.00	26.00	26.29

Table 7.28. Results for pH, EC and water soluble cations for block HT34 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT34.1.1	6.44	0.07	34.65	9.45	97.60	54.25	22.50	0.00	29.50	134.20
HT34.2.1	6.34	0.15	46.45	18.85	119.55	107.50	30.05	0.00	40.20	76.55
HT34.3.1	4.88	0.15	95.60	5.50	67.50	22.75	28.70	0.00	17.55	242.25
HT34.4.1	5.56	0.59	24.65	6.20	63.25	54.70	22.15	0.00	23.75	45.80
HT34.5.1	6.05	0.05	9.20	2.60	68.65	39.75	28.35	0.01	27.30	30.20
HT34.6.1	5.62	0.07	28.30	10.60	12.45	114.00	45.00	0.00	9.25	50.45
HT34.7.1	5.83	0.04	19.45	4.10	73.05	108.05	20.10	0.00	9.25	10.30
HT34.8.1	6.26	0.08	30.70	11.80	14.70	141.30	22.95	0.00	22.35	58.30
HT34.9.1	5.63	0.05	18.05	3.90	7.30	17.50	25.35	0.00	36.55	8.00
Average	5.85	0.14	34.12	8.11	58.23	73.31	27.24	0.00	23.97	72.89
std deviation	0.46	0.16	23.95	4.85	37.02	42.38	7.06	0.00	10.22	69.81
90th percentile	6.36	0.24	56.28	13.21	101.99	119.46	33.04	0.00	37.28	155.81
10th percentile	5.42	0.05	16.28	3.64	11.42	21.70	21.74	0.00	9.25	9.84

Table 7.29. Results for pH, EC and water soluble cations for block HT35 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT35.1.1	6.18	0.07	27.80	5.15	9.95	7.30	17.50	0.00	62.85	16.25
HT35.2.1	6.57	0.09	35.80	7.30	13.40	16.40	31.95	0.00	99.25	19.20
HT35.3.1	6.39	0.13	56.45	13.50	8.70	27.15	80.75	0.00	58.55	77.65
HT35.4.1	5.23	0.11	6.65	11.65	11.30	61.95	40.80	0.01	133.95	53.20
HT35.5.1	5.88	0.10	63.65	13.60	24.45	54.05	37.75	0.00	68.85	61.10
HT35.6.1	5.41	0.15	66.70	14.55	11.65	54.25	33.50	0.00	265.55	40.40
HT35.7.1	5.73	0.16	76.70	11.00	57.10	67.20	50.60	0.00	138.05	115.50
HT35.8.1	4.75	0.25	105.00	15.05	15.10	81.45	42.00	0.06	93.60	324.50
HT35.9.1	5.01	0.04	16.75	22.25	4.95	30.55	13.40	0.00	27.45	13.30
HT35.1.2	6.02	0.08	32.45	7.30	9.35	75.05	21.55	0.00	71.10	13.25
Average	5.72	0.12	48.80	12.14	16.60	47.54	36.98	0.01	101.92	73.44
std deviation	0.57	0.06	28.67	4.67	14.36	24.25	18.31	0.02	63.39	89.40
90th percentile	6.41	0.17	79.53	15.77	27.72	75.69	53.62	0.02	150.80	136.40
10th percentile	4.98	0.07	15.74	7.09	8.33	15.49	17.09	0.00	55.44	13.30

Table 7.30. Results for pH, EC and water soluble cations for block HT35 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT35.2.2	6.16	0.07	33.05	6.55	11.25	27.75	26.35	0.00	65.35	22.00
HT35.3.2	6.56	0.12	93.05	18.25	6.50	19.15	41.20	0.02	29.70	53.50
HT35.4.2	4.62	0.15	69.30	13.70	12.25	66.65	37.35	0.00	171.15	112.60
HT35.5.2	5.98	0.09	42.40	8.90	21.85	35.10	34.65	0.00	90.20	43.50
HT35.6.2	6.28	0.12	59.45	12.00	13.90	44.50	36.00	0.00	126.45	34.55
HT35.7.2	5.95	0.17	99.05	15.55	14.20	71.90	37.75	0.05	70.10	92.00
HT35.8.2	5.00	0.13	55.90	10.35	13.20	65.80	40.70	0.00	119.10	111.30
HT35.9.2	2.10	0.07	34.00	5.00	5.75	35.00	15.60	0.00	64.55	44.95
Average	5.33	0.12	60.78	11.29	12.36	45.73	33.70	0.01	92.08	64.30
std deviation	1.37	0.03	23.53	4.21	4.69	18.66	8.08	0.02	41.85	33.37
90th percentile	6.36	0.16	94.85	16.36	16.50	68.23	40.85	0.03	139.86	111.69
10th percentile	3.86	0.07	33.72	6.09	6.28	25.17	23.13	0.00	54.10	30.79

Table 7.31. Results for pH, EC and water soluble cations for block HT36 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)					Water soluble anions (mg/kg)		
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT36.1.1	5.47	0.08	35.10	7.30	48.55	77.15	28.85	0.00	81.15	42.00
HT36.2.1	5.88	0.16	65.00	24.15	19.50	44.85	55.20	0.00	155.35	112.35
HT36.3.1	5.91	0.06	27.05	7.00	7.60	39.10	24.35	0.00	45.50	11.15
HT36.4.1	6.61	0.16	76.15	17.90	26.50	36.95	62.40	0.00	48.50	147.30
HT36.5.1	5.66	0.19	90.80	21.00	26.80	21.70	48.05	0.00	121.50	195.85
HT36.6.1	6.38	0.13	59.80	11.85	31.55	26.35	40.15	0.00	16.54	141.80
HT36.7.1	6.38	0.08	58.15	21.35	18.70	44.55	29.30	0.00	21.90	27.70
HT36.8.1	5.11	0.04	11.65	3.75	11.50	40.80	22.05	0.00	6.70	31.75
HT36.9.1	6.82	0.37	139.85	73.15	7.10	63.25	215.75	0.00	135.10	383.95
Average	6.02	0.14	62.62	20.83	21.98	43.86	58.46	0.00	70.25	121.54
std deviation	0.53	0.10	35.89	19.73	12.46	16.20	57.18	0.00	52.22	111.02
90th percentile	6.65	0.22	100.61	33.95	34.95	66.03	93.07	0.00	139.15	233.47
10th percentile	5.40	0.06	23.97	6.35	7.50	25.42	23.89	0.00	14.57	24.39

Table 7.32. Results for pH, EC and water soluble cations for block HT36 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT36.1.2	4.95	0.10	44.65	10.25	17.15	39.40	55.60	0.00	121.65	45.20
HT36.2.2	6.38	0.21	81.50	30.60	20.15	40.05	70.55	0.00	156.00	154.85
HT36.3.2	6.01	0.08	35.75	9.15	8.00	44.75	23.35	0.00	64.15	15.10
HT36.4.2	6.15	0.17	70.15	17.95	34.30	33.50	70.80	0.00	62.10	157.25
HT36.5.2	5.95	0.21	106.65	23.70	30.40	17.10	45.30	0.00	62.40	305.55
HT36.6.2	6.10	0.15	62.75	12.40	29.45	49.05	68.35	0.00	52.45	125.40
HT36.7.2	5.79	0.08	38.95	14.70	20.00	40.85	27.15	0.00	36.30	37.80
HT36.8.2	5.80	0.10	40.60	15.50	22.85	26.40	32.65	0.00	26.30	141.90
HT36.9.2	6.77	0.32	117.00	63.60	57.75	29.05	159.80	0.00	104.60	318.10
Average	5.99	0.16	66.44	21.98	26.67	35.57	61.51	0.00	76.22	144.57
std deviation	0.47	0.08	28.42	16.04	13.28	9.43	38.93	0.00	40.03	102.58
90th percentile	6.46	0.23	108.72	37.20	38.99	45.61	88.60	0.00	128.52	308.06
10th percentile	5.62	0.08	38.31	10.03	15.32	24.54	26.39	0.00	34.30	33.26

Table 7.33. Results for pH, EC and water soluble cations for block HT37 (0-20cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT37.1.1	5.60	0.10	45.70	10.15	10.25	21.10	26.60	0.00	162.25	26.95
HT37.2.1	5.50	0.14	58.60	17.90	58.95	18.65	48.45	0.00	64.05	169.75
HT37.3.1	5.48	0.15	36.60	10.05	46.95	45.20	38.45	0.00	58.25	113.80
HT37.4.1	5.70	0.15	64.15	19.50	17.55	26.90	50.65	0.00	132.30	91.30
HT37.5.1	5.83	0.09	24.95	6.25	18.10	55.40	31.75	0.00	60.50	47.65
HT37.6.1	5.41	0.08	30.90	10.05	14.95	24.30	28.60	0.00	73.10	46.85
HT37.7.1	5.20	0.12	54.75	9.70	9.45	42.20	20.45	0.01	169.30	85.60
HT37.8.1	6.40	0.12	44.00	10.75	52.40	44.25	25.30	0.00	95.85	81.30
HT37.9.1	5.15	0.05	9.10	2.50	51.95	29.05	21.35	0.00	42.45	34.40
Average	5.59	0.11	40.97	10.76	31.17	34.12	32.40	0.00	95.34	77.51
std deviation	0.35	0.03	16.54	4.93	19.53	12.14	10.49	0.00	44.94	42.61
90th percentile	5.94	0.15	59.71	18.22	53.71	47.24	48.89	0.00	163.66	124.99
10th percentile	5.19	0.07	21.78	5.50	10.09	20.61	21.17	0.00	55.09	32.91

Table 7.34. Results for pH, EC and water soluble cations for block HT37 (20-40cm)

Block number	pH	EC (dS/cm)	Water soluble cations (mg/kg)				Water soluble anions (mg/kg)			
			Ca	Mg	Na	K	Cl	NO_2	NO_3	SO_4
HT37.1.2	5.64	0.14	59.90	15.70	10.85	24.45	27.30	0.00	269.60	33.60
HT37.2.2	5.67	0.15	61.50	20.15	20.55	25.30	59.95	0.00	95.55	126.65
HT37.3.2	6.04	0.18	62.85	19.20	14.70	56.15	52.85	0.00	71.90	204.25
HT37.4.2	5.66	0.13	50.65	16.30	14.50	28.80	34.45	0.00	138.75	66.10
HT37.5.2	6.18	0.12	31.70	9.60	17.20	76.85	33.15	0.00	104.95	69.00
HT37.6.2	5.90	0.07	28.05	7.95	12.30	17.60	31.00	0.01	63.55	47.75
HT37.7.2	5.71	0.09	50.40	7.55	9.40	22.35	25.70	0.01	131.35	97.05
HT37.8.2	6.21	0.09	37.55	9.75	12.50	35.60	27.05	0.01	121.90	88.10
HT37.9.2	4.93	0.08	30.35	8.05	13.90	26.70	30.95	0.00	53.45	77.40
Average	5.77	0.12	45.88	12.69	13.99	34.87	35.82	0.00	116.78	89.99
std deviation	0.37	0.03	13.34	4.82	3.16	18.18	11.45	0.00	61.03	47.83
90th percentile	6.19	0.15	61.77	19.39	17.87	60.29	54.27	0.01	164.92	142.17
10th percentile	5.50	0.08	29.89	7.87	10.56	21.40	26.78	0.00	61.53	44.92

Table 7.35. Results for ammonium acetate extract and trace element extractions for block HT1 (0-20cm)

Block number	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B (mg/kg)
	Ca	Mg	Na	K	Cu	Mn	Fe	Zn	
HT1.1.1	386.70	69.30	93.50	93.30	9.06	20.52	67.20	8.58	
HT1.2.1	494.10	102.10	95.70	119.90	1.86	3.42	40.80	1.68	
HT1.3.1	1244.20	187.40	78.20	135.00	11.10	27.90	62.52	10.32	
HT1.4.1	525.40	81.60	89.00	103.60	3.12	4.56	50.76	4.80	0.32
HT1.5.1	474.70	92.70	101.30	185.40	17.70	53.04	99.12	18.66	
HT1.6.1	464.80	71.00	96.10	107.80	3.66	16.14	72.36	5.76	
HT1.7.1	614.10	113.20	83.20	206.00	13.32	33.30	91.98	12.06	0.26
HT1.8.1	468.30	77.10	86.10	118.60	1.62	7.08	36.18	3.54	
HT1.9.1	380.20	50.10	70.20	92.90	6.06	14.10	112.62	7.86	
Average	561.39	93.83	88.14	129.17	7.50	20.01	70.39	8.14	
std deviation	250.26	37.51	9.26	38.02	5.33	15.13	24.90	4.84	
90th percentile	740.12	128.04	97.14	189.52	14.20	37.25	101.82	13.38	
10th percentile	385.40	65.46	76.60	93.22	1.81	4.33	39.88	3.17	

Table 7.36. Results for ammonium acetate extract and trace element extractions for block HT1 (20-40cm)

Block number	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B (mg/kg)
	Ca	Mg	Na	K	Cu	Mn	Fe	Zn	
HT1.1.2	146.50	31.90	82.60	103.00	8.34	19.26	119.76	9.18	
HT1.2.2	173.10	46.30	79.10	49.10	8.64	19.44	87.48	8.10	
HT1.3.2	236.10	50.60	88.00	83.60	2.88	2.82	214.80	5.82	
HT1.4.2	116.20	26.40	94.40	88.40	10.02	27.66	120.66	11.16	
HT1.5.2	466.20	87.60	93.40	95.00	3.30	6.66	101.22	4.74	
HT1.6.2	485.70	123.00	125.40	105.40	9.72	37.47	55.59	11.31	
HT1.7.2	83.00	23.50	86.90	93.50	3.18	15.96	47.94	4.92	
HT1.8.2	168.40	35.60	79.80	78.70	9.12	27.63	77.46	9.75	
HT1.9.2	217.60	31.60	92.20	41.00	2.40	6.75	51.00	5.76	
Average	232.53	50.72	91.31	81.97	6.40	18.18	97.32	7.86	
std deviation	137.38	31.42	13.19	21.36	3.14	10.84	49.08	2.47	
90th percentile	470.10	94.68	100.60	103.48	9.78	29.62	139.49	11.19	
10th percentile	109.56	25.82	79.66	47.48	2.78	5.89	50.39	4.88	

Table 7.37. Results for ammonium acetate extract and trace element extractions for block HT3 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT3.1.1	397.20	40.50	71.90	60.70	4.14	12.90	25.98	3.84	
HT3.2.1	148.20	29.20	96.60	66.20	1.71	6.81	18.06	1.26	
HT3.3.1	870.30	90.30	97.50	143.90	1.59	18.90	27.30	5.16	
HT3.4.1	201.00	47.00	118.40	96.10	2.73	13.80	25.62	2.10	0.04
HT3.5.1	247.00	27.10	75.10	22.50	5.79	34.74	46.74	8.34	0.03
HT3.6.1	123.10	24.60	71.30	67.80	3.81	39.15	51.69	7.47	
HT3.7.1	465.10	30.80	93.90	41.10	1.17	2.55	18.72	1.02	
HT3.8.1	579.90	39.50	96.30	38.80	0.75	0.63	9.33	0.51	
HT3.9.1	141.00	28.50	86.80	59.80	4.11	23.79	27.15	4.68	0.07
Average	352.53	39.72	89.76	66.32	2.87	17.03	27.84	3.82	
std deviation	237.51	19.19	14.42	33.82	1.60	12.75	12.72	2.68	
90th percentile	637.98	55.66	101.68	105.66	4.47	35.62	47.73	7.64	
10th percentile	137.42	26.60	71.78	35.54	1.09	2.17	16.31	0.92	

Table 7.38. Results for ammonium acetate extract and trace element extractions for block HT3 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT3.1.2	182.90	33.40	87.50	54.00	1.65	2.58	29.04	1.38	
HT3.2.2	194.20	25.30	136.80	55.30	2.64	12.09	15.24	2.22	
HT3.3.2	617.50	67.70	67.10	87.30	2.64	5.55	14.49	1.89	0.10
HT3.4.2	57.90	9.20	71.60	26.70	4.05	8.37	47.97	10.08	0.02
HT3.5.2	202.80	23.50	56.80	27.70	1.44	2.52	8.19	1.80	0.03
HT3.6.2	245.30	34.80	93.20	99.80	4.95	18.75	27.81	5.55	0.06
HT3.7.2	161.90	17.80	84.30	32.50	3.39	13.92	22.50	3.42	
HT3.8.2	490.70	36.40	76.70	46.90	3.57	26.82	37.59	5.07	
HT3.9.2	140.80	16.20	78.40	20.90	1.92	5.37	17.40	2.40	0.03
Average	254.89	29.37	83.60	50.12	2.92	10.66	24.47	3.76	
std deviation	169.72	16.09	21.47	26.07	1.11	7.68	11.83	2.63	
90th percentile	516.06	42.66	101.92	89.80	4.23	20.36	39.67	6.46	
10th percentile	124.22	14.80	65.04	25.54	1.61	2.57	13.23	1.72	

Table 7.39. Results for ammonium acetate extract and trace element extractions for block HT5 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT5.1.1	497.40	55.50	82.10	33.30	11.07	51.90	119.79	15.96	
HT5.2.1	741.80	58.80	79.60	108.10	13.08	58.89	89.67	14.19	
HT5.3.1	426.20	33.10	96.30	176.40	5.73	19.05	59.70	5.67	
HT5.4.1	452.60	44.00	81.00	46.40	10.50	18.90	127.59	9.78	
HT5.5.1	349.70	28.40	83.80	55.50	33.87	168.93	147.15	55.83	
HT5.6.1	625.00	53.20	93.10	65.20	15.60	87.60	105.06	20.28	
HT5.7.1	343.30	10.60	80.30	78.90	5.49	13.56	60.90	3.90	
HT5.8.1	146.90	0.00	28.20	98.80	4.35	2.88	50.07	1.50	
HT5.9.1	460.60	85.00	99.10	183.30	11.49	120.39	156.93	27.15	
Average	449.28	40.96	80.39	93.99	12.35	60.23	101.87	17.14	
std deviation	160.56	24.60	19.73	51.07	8.40	52.84	37.06	15.72	
90th percentile	648.36	64.04	96.86	177.78	19.25	130.10	149.11	32.89	
10th percentile	304.02	8.48	69.32	43.78	5.26	11.42	57.77	3.42	

Table 7.40. Results for ammonium acetate extract and trace element extractions for block HT6 (0-20cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT6.1.1	439.50	334.50	0.00	271.50	6.09	64.20	109.23	4.08	
HT6.2.1	206.50	333.00	0.00	381.50	10.71	40.92	55.65	9.06	
HT6.3.1	236.00	275.00	0.10	115.00	12.42	115.50	58.65	40.32	
HT6.4.1	518.50	290.50	0.00	1510.50	23.22	122.31	70.77	67.89	
HT6.5.1	215.50	249.00	0.10	477.50	28.83	182.79	89.25	44.01	0.36
HT6.6.1	612.50	507.50	0.10	980.50	26.19	194.40	92.34	52.11	
HT6.7.1	834.50	602.00	0.00	3270.00	80.28	104.52	46.11	100.08	
HT6.8.1	520.50	431.50	0.00	920.00	21.42	97.44	76.47	35.88	
HT6.9.1	1055.50	584.00	0.30	301.00	79.41	165.03	73.08	102.87	0.22
Average	515.44	400.78	0.07	914.17	32.06	120.79	74.62	50.70	
std deviation	273.29	127.54	0.09	931.67	26.50	49.04	18.78	32.89	
90th percentile	878.70	587.60	0.14	1862.40	79.58	185.11	95.72	100.64	
10th percentile	213.70	269.80	0.00	240.20	9.79	59.54	53.74	8.06	

Table 7.41. Results for ammonium acetate extract and trace element extractions for block HT7 (0-20cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT7.1.1	1054.30	121.50	94.90	93.10	17.76	11.76	84.33	6.27	
HT7.2.1	1367.90	152.10	97.80	219.80	5.07	4.62	78.51	2.88	
HT7.3.1	1015.60	115.40	120.20	230.40	27.72	35.43	154.65	17.49	
HT7.4.1	1087.90	131.20	125.00	301.90	6.75	3.63	113.61	1.83	0.13
HT7.5.1	1439.00	62.40	105.80	78.20	14.19	19.47	86.73	8.70	
HT7.6.1	553.70	65.80	101.50	230.40	6.42	5.97	81.54	3.21	
HT7.7.1	903.30	92.90	115.10	236.70	17.88	44.52	130.38	27.39	
HT7.8.1	1237.70	69.90	95.50	142.30	10.17	10.62	77.25	6.12	0.09
HT7.9.1	1945.50	68.40	112.70	136.40	23.58	46.38	102.99	36.96	0.14
Average	1178.32	97.73	107.61	185.47	14.39	20.27	101.11	12.32	
std deviation	366.94	31.41	10.48	71.26	7.54	16.30	25.46	11.70	
90th percentile	1540.30	135.38	121.16	249.74	24.41	44.89	135.23	29.30	
10th percentile	833.38	65.12	95.38	90.12	6.15	4.42	78.26	2.67	

Table 7.42. Results for ammonium acetate extract and trace element extractions for block HT7 (20-40cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT7.1.2					7.83	11.58	80.52	8.04	
HT7.2.2	856.50	39.40	104.10	185.30	15.87	15.24	94.14	9.63	
HT7.3.2	618.40	86.40	112.80	134.40	6.30	3.96	71.19	2.85	
HT7.4.2	1181.40	146.90	130.80	177.40	17.28	25.95	101.88	10.17	0.03
HT7.5.2	500.80	55.10	126.90	80.00	12.27	20.25	107.13	11.76	
HT7.6.2	448.90	68.00	115.90	87.20	18.06	34.11	152.73	17.55	
HT7.7.2	593.70	80.80	112.10	175.30	14.88	65.31	152.73	32.82	
HT7.8.2	737.00	122.50	117.80	205.50	16.59	56.85	166.50	27.15	
HT7.9.2	1260.20	77.10	98.60	166.00	11.01	17.22	98.52	6.75	
Average	774.61	84.53	114.88	151.39	13.34	27.83	113.93	14.08	
std deviation	284.51	32.75	10.00	43.37	3.99	19.59	32.55	9.37	
90th percentile	1205.04	129.82	128.07	191.36	17.44	58.54	155.48	28.28	
10th percentile	485.23	50.39	102.45	85.04	7.52	10.06	78.65	5.97	

Table 7.43. Results for ammonium acetate extract and trace element extractions for block HT8 (0-20cm)

Block number	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
	Ca	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT8.1.1	482.00	74.00	93.30	73.30	16.29	61.14	177.12	26.82	0.13
HT8.2.1	259.40	38.10	92.70	59.10	10.98	17.67	172.38	6.69	
HT8.3.1	998.10	109.30	95.60	131.00	23.76	97.38	72.78	13.41	0.06
HT8.4.1	141.40	17.60	83.10	53.70	7.95	38.28	38.22	4.29	0.24
HT8.5.1	391.10	66.20	74.00	48.80	31.77	107.37	104.82	21.66	0.04
HT8.6.1	729.40	108.20	86.00	91.10	2.73	34.47	43.53	2.79	0.06
HT8.7.1	312.20	50.10	79.20	133.10	26.28	80.76	57.60	11.01	0.08
HT8.8.1	390.60	84.40	81.70	33.90	54.18	127.38	100.32	29.58	
Average	463.03	68.49	85.70	78.00	21.74	70.56	95.85	14.53	
std deviation	258.77	30.38	7.13	34.97	15.31	36.46	50.76	9.66	
90th percentile	810.01	108.53	93.99	131.63	38.49	113.37	173.80	27.65	
10th percentile	224.00	31.95	77.64	44.33	6.38	29.43	41.94	3.84	

Table 7.44. Results for ammonium acetate extract and trace element extractions for block HT9 (0-20cm)

Block number	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
	Ca	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT9.1.1	1160.60	170.70	126.70	146.90	20.55	54.63	47.52	11.13	
HT9.2.1	914.20	167.90	181.00	114.60	31.02	76.38	58.35	12.39	
HT9.3.1	1673.50	281.00	210.90	178.50	15.69	52.53	60.96	12.00	
HT9.4.1	1236.80	199.10	138.10	139.20	13.08	51.39	72.48	10.65	0.27
HT9.5.1	1257.70	222.70	174.30	189.40	40.80	79.86	143.46	30.96	
HT9.6.1	674.10	120.10	181.00	133.00	33.84	72.06	183.75	22.86	
HT9.7.1	600.30	123.10	145.80	177.20	34.59	54.66	148.02	16.11	
HT9.8.1	749.10	124.10	130.00	39.20	32.79	36.54	134.52	16.74	0.08
HT9.9.1	855.50	149.30	142.40	109.10	47.22	73.95	281.07	4.68	0.12
Average	1013.53	173.11	158.91	136.34	29.95	61.33	125.57	15.28	
std deviation	326.15	50.65	27.22	43.52	10.74	13.84	71.55	7.27	
90th percentile	1340.86	234.36	186.98	180.68	42.08	77.08	203.21	24.48	
10th percentile	659.34	122.50	129.34	95.12	15.17	48.42	56.18	9.46	

Table 7.45. Results for ammonium acetate extract and trace element extractions for block HT9 (20-40cm)

Block number	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
	Ca	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT9.1.2	920.20	172.70	171.20	80.00	41.76	71.79	225.48	17.37	
HT9.2.2	798.20	154.50	160.60	79.40	2.67	16.50	108.96	1.89	
HT9.3.2	1107.30	193.70	195.20	179.40	3.84	13.53	101.61	2.49	
HT9.4.2	1435.10	206.30	184.60	139.40	2.49	21.51	159.54	2.52	
HT9.5.2	1186.90	203.30	165.30	165.20	1.86	11.10	96.03	1.38	0.18
HT9.6.2	664.20	127.30	200.90	128.60	18.93	37.23	95.28	12.00	0.15
HT9.7.2	444.70	95.80	146.90	115.30	2.73	8.37	92.34	1.14	
HT9.8.2	529.50	101.80	133.60	78.90	20.64	43.05	116.58	19.59	
HT9.9.2	662.80	126.80	118.80	51.80	12.30	24.06	123.33	9.00	
Average	860.99	153.58	164.12	113.11	11.91	27.46	124.35	7.49	
std deviation	310.04	40.35	26.00	41.10	12.65	19.14	40.76	6.87	
90th percentile	1236.54	203.90	196.34	168.04	24.86	48.80	172.73	17.81	
10th percentile	512.54	100.60	130.64	73.48	2.36	10.55	94.69	1.33	

Table 7.46. Results for ammonium acetate extract and trace element extractions for block HT10 (0-20cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT10.1.1	1224.80	184.40	83.70	53.10					
HT10.2.1	699.50	121.10	95.40	45.90	105.48	77.64	129.57	29.28	
HT10.3.1	1390.90	138.70	67.20	29.50	132.99	122.85	140.88	51.24	
HT10.4.1	446.70	91.10	86.90	84.60	67.59	54.42	142.17	20.70	
HT10.5.1	750.60	71.80	100.40	48.40	60.57	49.29	122.40	19.08	
HT10.6.1	1279.20	208.60	87.50	62.60	100.62	97.86	146.61	29.76	
HT10.7.1	463.70	90.00	79.30	112.70	97.89	88.08	164.58	29.52	
HT10.8.1	737.40	142.20	86.20	110.80	37.53	17.49	82.68	8.91	
HT10.9.1	1273.60	263.80	99.40	86.30	22.62	15.90	77.58	4.05	
Average	918.49	145.74	87.33	70.43	78.16	65.44	125.81	24.07	
std deviation	351.44	59.27	9.81	27.87	35.01	35.61	28.82	13.67	
90th percentile	1301.54	219.64	99.60	111.18	113.73	105.36	152.00	36.20	
10th percentile	460.30	86.36	76.88	42.62	33.06	17.01	81.15	7.45	

Table 7.47. Results for ammonium acetate extract and trace element extractions for block HT10 (20-40cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT10.1.2	1669.60	272.70	89.80	50.60	89.22	68.94	134.58	39.39	
HT10.2.2	697.70	123.40	95.10	62.00	17.13	7.14	62.04	5.73	
HT10.3.2	1299.10	162.60	97.00	44.10	64.20	51.96	104.70	20.88	
HT10.5.2	650.60	76.10	107.10	43.80	16.95	33.06	197.01	13.41	
Average	958.04	156.62	84.67	59.88	52.23	44.49	107.08	18.32	
std deviation	424.24	75.34	27.69	24.41	33.31	29.77	48.21	12.15	
90th percentile	1375.15	265.58	101.10	91.28	94.12	76.22	161.00	36.84	
10th percentile	438.53	72.73	63.47	39.67	17.09	14.15	55.40	5.39	

Table 7.48. Results for ammonium acetate extract and trace element extractions for block H11 (0-20cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT11.1.1	1140.90	117.80	103.50	210.80	8.31	13.26	134.43	5.07	
HT11.2.1	662.50	167.10	137.90	369.90	6.33	7.44	104.73	3.69	
HT11.3.1	905.60	98.20	86.80	235.20	5.64	12.36	181.80	4.23	0.06
HT11.4.1	1701.00	159.40	105.20	319.90	14.43	21.57	150.54	10.56	
HT11.5.1	580.50	162.30	201.20	451.10	8.67	11.28	184.50	7.83	0.05
HT11.6.1	1561.80	194.50	200.90	252.90	15.00	29.04	183.39	7.29	0.08
HT11.7.1	2227.30	384.20	205.90	434.30	14.55	18.78	217.47	9.51	
HT11.8.1	999.70	277.30	215.40	617.00	2.97	2.01	69.30	1.47	
HT11.9.1	1176.80	273.10	130.10	396.00	2.28	5.22	65.46	0.99	
Average	1217.34	203.77	154.10	365.23	8.69	13.44	143.51	5.63	
std deviation	498.67	85.91	48.50	121.07	4.67	8.01	51.04	3.19	
90th percentile	1806.26	298.68	207.80	484.28	14.64	23.06	191.09	9.72	
10th percentile	646.10	113.88	100.16	230.32	2.83	4.58	68.53	1.37	

Table 7.49. Results for ammonium acetate extract and trace element extractions for block HT11 (20-40cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT11.1.2	532.90	79.70	111.30	157.10	5.07	24.15	100.89	3.30	
HT11.2.2	1007.60	202.70	90.70	230.80	14.49	29.43	80.19	5.94	
HT11.3.2	955.40	133.10	97.70	196.00	6.66	12.00	137.13	1.59	
HT11.4.2	1867.00	154.90	194.00	173.60	4.98	22.95	167.07	4.62	0.07
HT11.5.2	515.70	125.80	123.80	254.30	3.60	8.52	256.71	4.05	
HT11.6.2	1872.20	217.00	310.40	220.80	5.58	20.31	131.10	2.28	
HT11.7.2	1533.20	262.90	238.90	217.60	4.20	16.32	129.00	1.68	0.16
HT11.8.2	981.10	204.20	198.20	518.80	15.69	14.79	105.93	8.94	
HT11.9.2	1120.30	220.50	148.30	333.00	15.69	14.52	145.38	7.89	
Average	1153.93	177.87	168.14	255.78	8.44	18.11	139.27	4.48	
std deviation	477.62	54.54	69.42	104.62	4.92	6.23	48.14	2.50	
90th percentile	1868.04	228.98	253.20	370.16	15.69	25.21	185.00	8.10	
10th percentile	529.46	116.58	96.30	170.30	4.08	11.30	96.75	1.66	

Table 7.50. Results for ammonium acetate extract and trace element extractions for block HT12 (0-20cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT12.1.1	898.50	148.20	117.70	209.30	11.58	6.72	104.55	4.89	
HT12.2.1	693.40	114.10	94.50	180.20	11.28	9.69	119.13	5.13	
HT12.3.1	791.80	127.90	85.90	143.20	7.02	3.03	125.97	2.79	
HT12.4.1	825.60	140.80	95.80	109.10	11.19	5.40	126.12	5.67	
HT12.5.1	600.60	100.60	80.10	93.20	14.76	7.53	136.50	4.71	
HT12.6.1	414.70	66.70	77.70	93.00	10.08	5.58	108.99	4.35	0.06
HT12.7.1					17.31	13.08	63.69	9.69	
HT12.9.1	520.00	308.50	0.10	1587.00	15.06	11.22	76.08	9.51	
Average	659.26	140.42	81.01	323.16	11.37	8.17	106.42	5.38	
std deviation	159.35	67.78	32.72	479.34	3.86	3.14	22.82	2.54	
90th percentile	847.47	196.29	102.72	622.61	15.51	11.66	128.20	9.55	
10th percentile	488.41	90.43	54.42	93.14	6.43	4.93	73.60	2.56	

Table 7.51. Results for ammonium acetate extract and trace element extractions for block HT12 (20-40cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT12.1.2	1021.30	162.90	90.70	215.70	8.28	3.54	55.08	2.19	
HT12.2.2	555.10	97.70	92.90	146.70	7.05	3.84	48.09	2.31	0.11
HT12.3.2	798.40	127.20	93.30	159.60	13.89	6.93	107.97	5.55	
HT12.4.2	761.20	136.00	81.00	87.40	12.09	7.92	137.43	4.65	
HT12.5.2	529.40	95.70	87.60	107.20	6.18	2.97	103.14	1.68	0.12
HT12.6.2	469.20	71.10	96.30	119.00	11.04	5.91	70.05	4.86	
HT12.7.2	648.20	118.90	86.50	196.20	6.18	4.02	89.07	3.75	
HT12.8.2	671.90	113.50	48.40	72.60	19.86	115.71	117.60	8.46	0.08
HT12.9.2	868.90	96.20	50.60	116.90	15.03	144.63	196.83	6.00	
Average	702.62	113.24	80.81	135.70	11.07	32.83	102.81	4.38	
std deviation	167.32	25.44	17.26	45.35	4.39	52.50	43.23	2.05	
90th percentile	899.38	141.38	93.90	200.10	16.00	121.49	149.31	6.49	
10th percentile	517.36	90.78	50.16	84.44	6.18	3.43	53.68	2.09	

Table 7.52. Results for ammonium acetate extract and trace element extractions for block HT13 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT13.1.1	1750.00	144.30	152.60	257.10	17.46	176.31	158.25	7.71	0.18
HT13.2.1	1721.00	222.70	316.70	316.80	8.64	176.43	180.84	4.83	
HT13.3.1	2848.30	185.90	135.10	319.60	18.75	115.83	72.57	10.47	
HT13.4.1	3184.90	138.30	225.50	106.00	15.96	98.25	125.25	8.40	0.07
HT13.5.1	2171.70	181.80	284.30	192.70	16.02	118.92	66.63	6.96	
HT13.6.1	691.20	109.60	137.30	190.40	12.42	146.61	77.67	6.06	
HT13.7.1	2733.60	203.10	188.20	84.30	13.44	252.27	119.91	8.76	0.10
HT13.8.1	3475.40	194.20	305.90	606.50	13.38	269.52	181.23	8.94	
HT13.9.1	1533.40	160.40	199.80	197.70	9.84	85.77	81.00	7.17	
Average	2234.39	171.14	216.16	252.34	13.99	159.99	118.15	7.70	
std deviation	846.21	33.74	67.31	146.88	3.19	61.63	43.87	1.58	
90th percentile	3243.00	207.02	308.06	376.98	17.72	255.72	180.92	9.25	
10th percentile	1364.96	132.56	136.86	101.66	9.60	95.75	71.38	5.81	

Table 7.53. Results for ammonium acetate extract and trace element extractions for block HT13 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT13.1.2	1531.20	132.80	127.30	92.70	7.05	193.35	205.83	5.40	
HT13.2.2	1751.00	171.30	174.20	136.00	8.10	195.18	93.69	3.99	
HT13.3.2	2137.10	175.20	145.60	209.60	5.82	237.30	147.33	3.57	
HT13.4.2	2906.40	129.50	184.40	93.70	11.61	81.60	41.19	10.71	
HT13.5.2	1868.30	169.00	238.20	106.20	10.05	107.22	169.95	10.17	
HT13.6.2	1808.50	170.20	241.40	155.50	15.27	83.43	162.90	8.37	
HT13.7.2	2583.20	219.60	177.90	58.20	16.80	90.39	134.46	9.36	
HT13.8.2	1606.70	164.00	283.20	297.20	13.98	157.17	84.42	5.28	
HT13.9.2	1870.60	219.70	340.50	294.60	4.17	144.06	54.51	0.90	0.19
Average	2007.00	172.37	212.52	160.41	10.32	143.30	121.59	6.42	
std deviation	432.98	29.76	65.04	83.12	4.15	53.46	52.80	3.19	
90th percentile	2647.84	219.62	294.66	295.12	15.58	203.60	177.13	10.28	
10th percentile	1591.60	132.14	141.94	85.80	5.49	83.06	51.85	3.04	

Table 7.54. Results for ammonium acetate extract and trace element extractions for block HT14 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT14.1.1	1363.00	149.30	128.00	251.30	18.18	73.23	57.66	10.44	0.15
HT14.2.1	1926.40	124.00	120.70	309.10	18.39	99.24	85.92	8.37	
HT14.3.1	1657.60	110.90	116.50	272.10	12.06	170.73	51.90	6.51	0.22
HT14.4.1	1380.30	111.20	116.50	271.40	13.53	219.75	152.58	7.20	
HT14.5.1	1353.70	133.50	136.60	238.80	13.53	55.68	235.71	7.32	0.41
HT14.6.1	1479.60	102.20	119.90	277.30	8.04	47.46	180.42	3.51	
HT14.7.1	1369.30	191.00	125.70	223.10	14.58	75.06	71.22	4.56	0.20
HT14.8.1	2546.10	149.00	112.50	362.40	14.22	77.88	70.44	4.44	
HT14.9.1	2762.80	336.80	117.10	362.40	11.64	153.87	73.29	5.34	
Average	1759.87	156.43	121.50	285.32	13.80	108.10	108.79	6.41	
std deviation	512.06	68.70	7.00	47.23	3.02	55.98	61.17	2.07	
90th percentile	2589.44	220.16	129.72	362.40	18.22	180.53	191.48	8.78	
10th percentile	1361.14	109.16	115.70	235.66	10.92	54.04	56.51	4.25	

Table 7.55. Results for ammonium acetate extract and trace element extractions for block HT14 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT14.1.2	775.80	119.60	152.10	107.00	7.53	137.04	73.80	3.87	0.09
HT14.2.2	1623.40	117.10	114.40	290.80	20.43	86.76	172.59	8.16	
HT14.3.2	1054.70	111.00	92.20	186.30	14.40	40.11	67.77	7.92	0.21
HT14.4.2	1128.30	143.70	119.40	238.40	17.28	48.75	39.84	10.89	0.19
HT14.5.2	1393.70	139.90	135.10	226.50	17.34	73.92	70.02	8.10	
HT14.6.2	1215.20	96.20	96.10	202.30	20.46	40.56	48.84	55.35	0.15
HT14.7.2					14.82	103.68	75.21	15.69	
HT14.8.2	1858.00	144.20	105.50	301.00	9.63	81.78	104.37	10.23	
HT14.9.2	1573.20	236.60	98.40	368.40	13.35	58.89	96.21	15.69	
Average	1327.79	138.54	114.15	240.09	15.03	74.61	83.18	15.10	
std deviation	328.79	40.38	19.48	74.97	4.19	30.20	36.87	14.67	
90th percentile	1693.78	171.92	140.20	321.22	20.44	110.35	118.01	23.62	
10th percentile	971.03	106.56	94.93	162.51	9.21	40.47	47.04	7.11	

Table 7.56. Results for ammonium acetate extract and trace element extractions for block HT15 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT15.1.1	1323.60	170.70	95.20	103.90	4.59	15.48	57.72	2.16	
HT15.2.1	686.60	119.90	95.10	70.00	9.81	31.56	72.63	7.74	
HT15.3.1	1158.00	11.00	88.20	63.10	41.19	71.37	498.39	143.31	
HT15.4.1	1387.70	153.80	79.80	204.00	57.75	82.77	564.42	257.04	0.12
HT15.5.1	802.00	77.80	75.30	61.20	21.45	51.09	101.97	25.17	
HT15.6.1	882.30	174.70	91.30	260.30	14.43	55.71	96.12	15.99	
HT15.7.1	2920.00	387.80	85.80	239.10	21.99	64.65	61.89	15.96	
HT15.8.1	1528.20	219.40	96.50	263.70	4.41	23.37	69.24	4.83	
HT15.9.1	1612.90	240.60	89.10	123.10	61.20	97.32	144.72	83.76	
Average	1366.81	172.86	88.48	154.27	26.31	54.81	185.23	61.77	
std deviation	629.05	100.76	6.81	81.97	20.64	25.93	187.37	82.00	
90th percentile	1874.32	270.04	95.46	260.98	58.44	85.68	511.60	166.06	
10th percentile	778.92	64.44	78.90	62.72	4.55	21.79	61.06	4.30	

Table 8.57. Results for ammonium acetate extract and trace element extractions for block HT15 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT15.1.2	1497.40	220.20	98.80	66.50	27.84	87.09	100.11	45.18	
HT15.2.2	1296.70	170.70	82.10	87.30	26.10	89.13	93.57	30.81	
HT15.3.2	1436.50	160.20	104.70	59.00	6.81	93.54	168.51	14.94	
HT15.4.2	1229.90	148.60	92.90	178.10	1.68	35.34	110.34	3.66	
Average	1302.50	172.04	81.92	119.33	25.95	65.63	173.61	54.72	
std deviation	367.63	61.44	27.59	63.95	20.39	29.31	126.45	48.79	
90th percentile	1665.18	246.49	99.98	194.68	58.99	94.30	252.22	100.22	
10th percentile	748.95	93.49	64.48	61.98	3.98	25.10	87.07	4.17	

Table 7.58. Results for ammonium acetate extract and trace element extractions for block HT16 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT16.1.1	916.00	89.90	110.00	143.80	7.98	100.38	183.69	13.56	0.16
HT16.2.1	1568.10	248.00	116.10	295.20	2.94	50.46	163.50	4.71	
HT16.3.1	8255.80	125.10	91.80	221.90	6.75	70.68	84.27	11.85	0.14
HT16.4.1	669.20	83.70	103.20	160.20	5.10	94.14	219.93	13.83	0.11
HT16.5.1	1038.90	145.20	109.20	129.90	5.67	88.05	153.00	17.70	
HT16.6.1	855.50	63.60	125.90	194.20	3.06	55.59	134.43	10.29	
HT16.7.1	1024.20	183.80	0.00	183.80	9.99	122.94	178.65	23.22	0.12
HT16.8.1	900.20	117.20	0.00	144.20	5.28	85.20	143.34	11.40	
HT16.9.1	869.00	85.20	0.00	108.00	7.77	114.00	167.73	18.12	0.09
Average	1788.54	126.86	72.91	175.69	6.06	86.83	158.73	13.85	
std deviation	2298.30	55.09	52.27	53.49	2.18	23.20	35.39	5.02	
90th percentile	2905.64	196.64	118.06	236.56	8.38	115.79	190.94	19.14	
10th percentile	818.24	79.68	0.00	125.52	3.04	54.56	124.40	9.17	

Table 7.59. Results for ammonium acetate extract and trace element extractions for block HT16 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT16.1.2	1408.00	73.10	103.90	74.30	6.33	88.56	169.56	14.43	
HT16.2.2	1522.70	228.60	150.90	222.60	9.84	117.03	195.84	20.61	0.07
HT16.3.2	978.00	70.90	136.80	165.30	4.59	101.58	166.14	14.88	
HT16.4.2	730.30	85.20	19.90	90.80	6.75	91.41	249.18	23.25	
HT16.5.2	810.60	120.50	117.90	125.90	6.42	85.23	213.42	18.51	
HT16.6.2	870.30	73.30	60.70	136.20	7.14	113.58	191.64	20.37	0.13
HT16.7.2	864.40	119.50	0.00	210.80	5.31	119.49	170.25	20.16	
HT16.8.2	788.60	101.60	0.00	158.50	8.16	17.22	121.83	24.39	
HT16.9.2		862.50	108.60	0.00	156.30	6.66	18.21	116.31	18.30
Average	996.61	192.80	77.63	131.60	23.43	82.31	166.23	30.32	
std deviation	280.31	241.23	55.59	65.60	47.00	39.48	61.95	30.56	
90th percentile	1442.41	355.38	139.62	213.16	39.13	117.52	220.57	42.77	
10th percentile	771.11	72.66	0.00	59.44	5.17	15.11	101.11	14.79	

Table 7.60. Results for ammonium acetate extract and trace element extractions for block HT33 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT33.1.1	685.80	63.80	0.00	57.90	3.12	11.64	37.20	6.87	
HT33.2.1	246.60	23.50	0.00	31.10	4.17	15.45	47.64	9.39	0.05
HT33.3.1	201.30	29.30	0.00	39.70	1.38	4.23	21.39	1.80	
HT33.4.1	164.00	29.80	79.50	55.60	1.77	3.45	18.93	3.15	
HT33.5.1	310.00	26.40	82.00	66.80	1.53	6.39	26.22	2.07	
HT33.7.1	441.30	53.60	85.40	72.30	1.65	5.22	18.87	3.18	
HT33.8.1	335.70	47.50	84.20	101.00	2.58	26.16	47.01	4.62	
HT33.9.1	734.80	72.20	97.10	134.30	2.76	20.58	40.92	5.34	
Average	389.94	43.26	53.53	69.84	2.37	11.64	32.27	4.55	
std deviation	201.75	17.45	41.74	31.42	0.91	7.87	11.54	2.42	
90th percentile	700.50	66.32	88.91	110.99	3.44	22.25	47.20	7.63	
10th percentile	190.11	25.53	0.00	37.12	1.49	4.00	18.91	1.99	

Table 7.61. Results for ammonium acetate extract and trace element extractions for block HT33 (20-40cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT33.1.2	513.00	54.40	0.00	38.00	3.36	32.61	116.73	6.48	
HT33.2.2	386.90	31.60	0.00	49.20	2.94	23.64	67.23	4.32	
HT33.3.2	162.00	25.90	85.80	17.80	3.36	36.00	54.42	6.33	
HT33.4.2	127.00	27.60	82.90	57.50	1.74	26.28	54.60	2.88	0.04
HT33.5.2	232.20	24.40	82.10	32.50	3.24	17.28	85.86	8.40	0.03
HT33.7.2	352.50	40.10	97.70	50.40	2.70	26.01	109.50	9.12	
HT33.8.2	333.80	41.70	80.40	67.90	7.47	28.29	50.40	9.96	0.05
HT33.9.2	576.40	75.50	80.80	128.10	13.71	54.66	106.38	15.69	
Average	335.48	40.15	63.71	55.18	4.82	30.60	80.64	7.90	
std deviation	148.63	16.34	37.15	31.12	3.71	10.51	25.70	3.69	
90th percentile	532.02	60.73	89.37	85.96	9.34	41.60	111.67	11.68	
10th percentile	151.50	25.45	0.00	28.09	2.41	21.73	53.21	3.89	

Table 7.62. Results for ammonium acetate extract and trace element extractions for block HT34 (0-20cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT34.1.1	502.70	66.00	68.30	32.00	1.11	7.41	39.39	2.58	0.06
HT34.2.1	707.90	136.40	88.40	188.20	7.20	26.91	50.25	13.92	0.19
HT34.3.1	258.10	13.20	84.40	38.60	2.64	56.40	59.25	3.09	
HT34.4.1	312.70	40.20	89.80	75.70	6.78	14.22	55.56	6.39	
HT34.5.1	471.70	76.40	95.10	113.90	2.34	67.65	78.60	5.04	0.11
HT34.6.1	350.00	73.00	92.20	49.10	22.50	26.97	93.72	10.02	
HT34.7.1	410.30	49.50	57.70	89.60	2.07	14.31	81.54	11.16	0.08
HT34.8.1	696.90	110.60	94.40	79.00	33.54	32.31	97.80	9.33	
HT34.9.1	363.10	35.70	86.80	100.20	38.58	34.11	97.68	13.98	0.07
Average	452.60	66.78	84.12	85.14	12.97	31.14	72.64	8.39	
std deviation	151.09	36.12	12.01	44.86	13.83	18.71	20.81	4.08	
90th percentile	699.10	115.76	94.54	128.76	34.55	58.65	97.70	13.93	
10th percentile	301.78	31.20	66.18	37.28	1.88	12.86	48.08	2.99	

Table 7.63. Results for ammonium acetate extract and trace element extractions for block HT35 (0-20cm)

	Ammonium acetate extract (mg/kg)				EDTA extraction (mg/kg)				B
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT35.1.1	852.50	68.80	66.50	148.90	20.04	33.54	149.01	4.95	0.09
HT35.2.1	937.00	93.80	116.00	190.30	6.33	20.40	166.74	2.10	
HT35.3.1	1046.90	117.40	73.40	189.90	34.32	51.18	172.77	9.87	
HT35.4.1	654.50	81.40	97.20	181.20	37.92	55.86	138.33	10.71	
HT35.5.1	385.40	34.20	114.80	54.20	46.56	48.81	146.25	15.36	
HT35.6.1	914.60	104.90	90.10	197.20	44.01	44.28	151.05	15.45	
HT35.7.1	1637.50	97.70	77.90	210.00	30.27	29.16	189.00	6.48	0.07
HT35.8.1	1049.90	63.70	120.20	194.50	29.13	29.25	161.19	5.94	
HT35.9.1	655.70	38.20	100.00	119.20	30.36	38.10	103.83	8.40	
HT35.1.2	745.10	68.90	52.80	130.40					
Average	887.91	76.90	90.89	161.58	30.99	38.95	153.13	8.81	
std deviation	316.08	26.05	21.69	46.01	11.56	11.18	22.71	4.29	
90th percentile	1108.66	106.15	116.42	198.48	44.52	52.12	176.02	15.38	
10th percentile	627.59	37.80	65.13	112.70	17.30	27.41	131.43	4.38	

Table 7.64. Results for ammonium acetate extract and trace element extractions for block HT35 (20-40cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT35.2.2	721.50	77.10	81.30	147.50	33.51	41.97	154.71	7.44	0.05
HT35.3.2	1428.10	124.30	128.50	129.50	27.24	15.93	137.07	4.56	
HT35.4.2	733.60	76.90	99.50	212.60	27.09	18.27	148.23	5.19	
HT35.5.2	1152.70	123.30	89.70	151.00	26.10	15.09	108.96	7.23	
HT35.6.2	1266.50	122.10	116.90	166.10	18.00	12.87	111.72	5.97	
HT35.7.2	1689.80	106.10	96.70	239.80	25.77	15.42	79.14	8.79	
HT35.8.2	875.10	68.70	114.10	179.90	33.06	24.57	84.12	8.88	0.07
HT35.9.2	789.10	47.40	75.70	122.40	7.32	54.84	103.50	5.82	
Average	1082.05	93.24	100.30	168.60	24.76	24.87	115.93	6.74	
std deviation	336.93	27.61	17.15	38.01	7.98	14.33	26.41	1.50	
90th percentile	1506.61	123.60	120.38	220.76	33.20	45.83	150.17	8.82	
10th percentile	729.97	62.31	79.62	127.37	14.80	14.42	82.63	5.00	

Table 7.65. Results for ammonium acetate extract and trace element extractions for block HT36 (0-20cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT36.1.1	1107.00	133.30	103.40	243.50	5.52	58.95	130.17	6.84	0.10
HT36.2.1	1362.90	219.80	118.00	201.40	8.88	63.57	192.42	6.27	0.14
HT36.3.1	1341.40	174.50	78.80	250.90	8.73	64.41	217.71	5.91	0.09
HT36.4.1	1815.90	137.30	122.10	157.80	7.29	104.28	136.08	3.75	0.14
HT36.5.1					8.79	92.91	132.00	5.70	
HT36.6.1	734.50	91.00	100.10	96.80	18.21	82.23	170.04	12.63	0.10
HT36.7.1	1167.30	241.00	109.90	214.80	17.13	77.31	165.84	10.95	
HT36.8.1	467.70	108.10	101.10	191.70	14.88	95.25	172.20	7.77	
HT36.9.1	1925.80	411.40	190.70	274.70	11.55	86.91	167.58	7.32	
Average	1240.31	189.55	115.51	203.95	11.22	80.65	164.89	7.46	
std deviation	461.29	96.98	30.97	53.22	4.25	14.91	27.39	2.58	
90th percentile	1848.87	292.12	142.68	258.04	17.35	97.06	197.48	11.29	
10th percentile	654.46	102.97	93.71	139.50	6.94	62.65	131.63	5.31	

Table 7.66. Results for ammonium acetate extract and trace element extractions for block HT36 (20-40cm)

Block number	Ammonium acetate extract (mg/kg) Ca	Mg	Na	K	EDTA extraction (mg/kg) Cu	Mn	Fe	Zn	B (mg/kg)
HT36.1.2	862.60	110.70	90.60	156.00	6.51	88.98	150.72	3.39	
HT36.2.2	1608.70	237.20	100.00	187.60	7.32	80.73	135.21	4.14	
HT36.3.2	1555.10	180.50	100.40	265.30	8.61	85.05	153.72	4.68	
HT36.4.2	1548.60	131.20	136.30	154.20	6.42	88.35	120.48	3.33	
HT36.5.2	1026.50	97.60	129.90	95.60	1.89	52.71	103.68	3.60	
HT36.6.2	734.20	87.80	87.70	170.00	1.59	33.78	80.91	5.34	
HT36.7.2	1138.80	285.70	104.40	201.70	1.71	61.02	227.55	7.26	
HT36.8.2	656.80	143.30	97.70	99.10	11.16	42.96	236.55	5.52	0.06
HT36.9.2	1533.40	381.60	147.80	172.00	6.96	13.11	76.95	7.26	0.11
Average	1184.97	183.96	110.53	166.83	5.80	60.74	142.86	4.95	
std deviation	362.63	93.55	20.45	48.67	3.18	25.66	54.17	1.44	
90th percentile	1565.82	304.88	138.60	214.42	9.12	88.48	229.35	7.26	
10th percentile	718.72	95.64	90.02	98.40	1.69	29.65	80.12	3.38	

Table 7.67. Results for ammonium acetate extract and trace element extractions for block HT37 (0-20cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT37.1.1	528.30	60.00	84.10	68.10	7.08	13.92	82.05	6.69	0.07
HT37.2.1	711.40	103.30	108.50	70.30	8.97	27.63	86.79	13.50	
HT37.3.1	554.10	73.00	96.90	135.70	9.39	31.17	96.21	14.85	0.07
HT37.4.1	764.20	119.70	104.50	94.00	10.14	20.40	93.39	6.27	0.09
HT37.5.1	624.30	89.80	92.20	167.30	7.59	13.83	86.28	4.86	0.11
HT37.6.1	614.50	96.30	116.10	91.70	10.80	25.20	85.65	15.24	
HT37.7.1	857.40	71.90	133.60	144.30	7.80	19.38	65.70	11.10	
HT37.8.1	1119.00	108.10	93.60	148.40	10.59	31.26	82.02	13.02	
HT37.9.1	412.70	57.40	108.90	112.10	9.48	40.95	95.67	16.35	
Average	687.32	86.61	104.27	114.66	9.09	24.86	85.97	11.32	
std deviation	197.06	20.82	13.99	33.87	1.27	8.42	8.80	4.08	
90th percentile	909.72	110.42	119.60	152.18	10.63	33.20	95.78	15.46	
10th percentile	505.18	59.48	90.58	69.86	7.49	13.90	78.76	5.99	

Table 7.68. Results for ammonium acetate extract and trace element extractions for block HT37 (20-40cm)

	Ammonium acetate extract (mg/kg)				**EDTA extraction (mg/kg)**				**B**
Block number	**Ca**	**Mg**	**Na**	**K**	**Cu**	**Mn**	**Fe**	**Zn**	**(mg/kg)**
HT37.1.2	559.30	72.20	123.50	80.50	10.11	28.95	75.57	10.92	
HT37.2.2	644.40	106.40	128.10	81.90	5.01	10.35	39.93	5.04	0.12
HT37.3.2	632.90	100.00	98.00	149.20	11.04	44.58	84.27	21.36	0.09
HT37.4.2	651.40	101.70	90.00	99.80	10.08	36.57	84.66	17.64	
HT37.5.2	793.60	124.30	117.30	233.80	8.31	37.68	99.36	19.86	
HT37.6.2	457.70	65.00	136.40	78.30	7.32	24.69	87.21	9.99	
HT37.7.2	1484.40	108.60	53.60	234.90					
HT37.8.2	850.30	101.10	106.00	134.10	7.80	26.61	54.63	5.97	
HT37.9.2	512.90	71.00	111.70	105.10	6.57	15.60	57.39	4.71	
Average	731.88	94.48	107.18	133.07	8.28	28.13	72.88	11.94	
std deviation	290.78	19.07	23.41	58.73	1.90	10.73	18.84	6.37	
90th percentile	977.12	111.74	129.76	234.02	10.39	39.75	90.86	20.31	
10th percentile	501.86	69.80	82.72	80.06	6.10	14.03	50.22	4.94	

Table 7.69. EC (dS/cm), conversion factor and result EC_e

Block no.	EC (dS/cm)	Soil Type	Factor	Ece (dS/cm)
1.1.1	0.13	Silty loam	10	1.27
1.2.1	0.13	Silty loam	10	1.20
1.3.1	0.18	Silty loam	10	1.71
1.4.1	0.09	Silty loam	10	0.89
1.5.1	0.09	Silty loam	10	0.83
1.6.1	0.13	Silty loam	10	1.21
1.7.1	0.10	Silty loam	10	0.91
1.8.1	0.09	Silty loam	10	0.89
1.9.1	0.09	Silty loam	10	0.85
1.1.2	0.08	Silty loam	10	0.73
1.2.2	0.07	Silty loam	10	0.68
1.3.2	0.04	Silty loam	10	0.38
1.4.2	0.03	Silty loam	10	0.27
1.5.2	0.09	Silty loam	10	0.83
1.6.2	0.16	Silty loam	10	1.50
1.7.2	0.05	Silty loam	10	0.46
1.8.2	0.07	Silty loam	10	0.71
1.9.2	0.08	Silty loam	10	0.73
3.1.1	0.04	Loamy Sand	23	0.90
3.2.1	0.08	Loamy Sand	23	1.75
3.3.1	0.03	Loamy Sand	23	0.64
3.4.1	0.08	Loamy Sand	23	1.91
3.5.1	0.02	Loamy Sand	23	0.52
3.6.1	0.05	Loamy Sand	23	1.22
3.7.1	0.08	Loamy Sand	23	1.92
3.8.1	0.07	Loamy Sand	23	1.54
3.9.1	0.05	Loamy Sand	23	1.26
3.1.2	0.03	Loamy Sand	23	0.69
3.2.2	0.05	Loamy Sand	23	1.17
3.3.2	0.11	Loamy Sand	23	2.48
3.4.2	0.13	Loamy Sand	23	3.04
3.5.2	0.10	Loamy Sand	23	2.24
3.6.2	0.05	Loamy Sand	23	1.11
3.7.2	0.02	Loamy Sand	23	0.53
3.8.2	0.04	Loamy Sand	23	0.97
3.9.2	0.02	Loamy Sand	23	0.43

Table 7.69 (continued)EC (dS/cm), conversion factor and result EC_e

5.1.1	0.04	Loamy Sand	23	0.92
5.2.1	0.09	Loamy Sand	23	2.14
5.3.1	0.07	Loamy Sand	23	1.54
5.4.1	0.07	Loamy Sand	23	1.59
5.5.1	0.32	Loamy Sand	23	7.31
5.6.1	0.14	Loamy Sand	23	3.22
5.7.1	0.07	Loamy Sand	23	1.56
5.8.1	0.07	Loamy Sand	23	1.59
5.9.1	0.17	Loamy Sand	23	3.96
6.1.1	0.07	Loamy Sand	23	1.55
6.2.1	0.06	Loamy Sand	23	1.32
6.3.1	0.04	Loamy Sand	23	0.97
6.4.1	0.04	Loamy Sand	23	0.83
6.5.1	0.07	Loamy Sand	23	1.66
6.6.1	0.14	Loamy Sand	23	3.17
6.7.1	0.28	Loamy Sand	23	6.42
6.8.1	0.10	Loamy Sand	23	2.40
6.9.1	0.32	Loamy Sand	23	7.36
7.1.1	0.09	Loamy Sand	23	2.10
7.2.1	0.14	Loamy Sand	23	3.16
7.3.1	0.11	Loamy Sand	23	2.57
7.4.1	0.25	Loamy Sand	23	5.75
7.5.1	0.52	Loamy Sand	23	11.94
7.6.1	0.73	Loamy Sand	23	16.74
7.7.1	0.98	Loamy Sand	23	22.59
7.8.1	0.22	Loamy Sand	23	5.15
7.9.1	0.65	Loamy Sand	23	14.95
7.1.2	0.08	Loamy Sand	23	1.77
7.2.2	0.09	Loamy Sand	23	2.00
7.3.2	0.25	Loamy Sand	23	5.83
7.4.2	0.35	Loamy Sand	23	8.06
7.5.2	0.12	Loamy Sand	23	2.81
7.6.2	0.10	Loamy Sand	23	2.20
7.7.2	0.14	Loamy Sand	23	3.12
7.8.2	0.15	Loamy Sand	23	3.46
7.9.2	0.15	Loamy Sand	23	3.37
8.1.1	0.04	Sandy Loam	14	0.61
8.2.1	0.03	Sandy Loam	14	0.42
8.3.1	0.25	Sandy Loam	14	3.49
8.4.1	0.03	Sandy Loam	14	0.43
8.5.1	0.06	Sandy Loam	14	0.80
8.6.1	0.07	Sandy Loam	14	0.94
8.7.1	0.05	Sandy Loam	14	0.75
8.8.1	0.04	Sandy Loam	14	0.61

Table 7.69 (continued). EC (dS/cm), conversion factor and result EC_e

9.1.1	0.24	Sandy Loam	14	3.32
9.2.1	0.19	Sandy Loam	14	2.66
9.3.1	0.31	Sandy Loam	14	4.35
9.4.1	0.19	Sandy Loam	14	2.64
9.5.1	0.16	Sandy Loam	14	2.26
9.6.1	0.24	Sandy Loam	14	3.29
9.7.1	0.13	Sandy Loam	14	1.77
9.8.1		Sandy Loam	14	0.00
9.9.1	0.13	Sandy Loam	14	1.84
9.1.2	0.23	Sandy Loam	14	3.17
9.2.2	0.22	Sandy Loam	14	3.13
9.3.2	0.17	Sandy Loam	14	2.32
9.4.2	0.18	Sandy Loam	14	2.50
9.5.2	0.77	Sandy Loam	14	10.72
9.6.2		Sandy Loam	14	0.00
9.7.2	0.10	Sandy Loam	14	1.44
9.8.2	0.12	Sandy Loam	14	1.70
9.9.2	0.07	Sandy Loam	14	1.02
10.1.1	0.08	Loamy Sand	23	1.81
10.2.1	0.05	Loamy Sand	23	1.22
10.3.1	0.08	Loamy Sand	23	1.92
10.4.1	0.05	Loamy Sand	23	1.05
10.5.1	0.07	Loamy Sand	23	1.57
10.6.1	0.09	Loamy Sand	23	1.99
10.7.1	0.03	Loamy Sand	23	0.78
10.8.1	0.07	Loamy Sand	23	1.63
10.9.1	0.17	Loamy Sand	23	3.82
10.1.2	0.17	Loamy Sand	23	3.84
10.2.2	0.07	Loamy Sand	23	1.55
10.3.2	0.12	Loamy Sand	23	2.75
10.5.2	0.07	Loamy Sand	23	1.60
11.1.1	0.15	Sand	23	3.37
11.2.1	0.31	Sand	23	7.11
11.3.1	0.09	Sand	23	1.97
11.4.1	0.11	Sand	23	2.57
11.5.1	0.45	Sand	23	10.40
11.6.1	0.32	Sand	23	7.25
11.7.1		Sand	23	0.00
11.8.1	0.47	Sand	23	10.81
11.9.1	0.16	Sand	23	3.64
11.1.2	0.06	Sand	23	1.46
11.2.2	0.07	Sand	23	1.57
11.3.2	0.07	Sand	23	1.64
11.4.2	0.16	Sand	23	3.70
11.5.2	0.16	Sand	23	3.64
11.6.2	0.51	Sand	23	11.80
11.7.2	0.24	Sand	23	5.59
11.8.2	0.54	Sand	23	12.44
11.9.2	0.13	Sand	23	3.06

Table 7.69 (continued). EC (dS/cm), conversion factor and result EC_e

12.1.1	0.10	Loamy Sand	23	2.27
12.2.1	0.05	Loamy Sand	23	1.14
12.3.1	0.04	Loamy Sand	23	0.93
12.4.1	0.16	Loamy Sand	23	3.60
12.5.1	0.09	Loamy Sand	23	1.98
12.6.1	0.05	Loamy Sand	23	1.09
12.7.1	0.05	Loamy Sand	23	1.12
12.9.1	0.09	Loamy Sand	23	2.16
12.1.2	0.12	Loamy Sand	23	2.85
12.2.2	0.07	Loamy Sand	23	1.70
12.3.2	0.07	Loamy Sand	23	1.63
12.4.2	0.12	Loamy Sand	23	2.87
12.5.2	0.03	Loamy Sand	23	0.79
12.6.2	0.05	Loamy Sand	23	1.04
12.7.2	0.05	Loamy Sand	23	1.13
12.8.2	0.04	Loamy Sand	23	0.97
12.9.2	0.09	Loamy Sand	23	2.15
13.1.1	0.14	Sandy Loam	14	1.91
13.2.1	0.58	Sandy Loam	14	8.08
13.3.1	0.22	Sandy Loam	14	3.05
13.4.1	0.29	Sandy Loam	14	4.06
13.5.1	0.23	Sandy Loam	14	3.15
13.6.1	0.81	Sandy Loam	14	11.33
13.7.1	0.16	Sandy Loam	14	2.23
13.8.1	1.55	Sandy Loam	14	21.70
13.9.1	0.42	Sandy Loam	14	5.81
13.1.2	0.08	Sandy Loam	14	1.12
13.2.2	0.25	Sandy Loam	14	3.54
13.3.2	0.15	Sandy Loam	14	2.17
13.4.2	0.27	Sandy Loam	14	3.77
13.5.2	0.29	Sandy Loam	14	4.12
13.6.2	0.28	Sandy Loam	14	3.93
13.7.2	0.16	Sandy Loam	14	2.20
13.8.2	0.41	Sandy Loam	14	5.78
13.9.2	1.00	Sandy Loam	14	14.03
14.1.1	0.11	Sandy Loam	14	1.55
14.2.1	0.20	Sandy Loam	14	2.80
14.3.1	0.10	Sandy Loam	14	1.33
14.4.1	0.08	Sandy Loam	14	1.10
14.5.1	0.38	Sandy Loam	14	5.36
14.6.1	0.25	Sandy Loam	14	3.49
14.7.1	0.15	Sandy Loam	14	2.06
14.8.1	0.29	Sandy Loam	14	4.00
14.9.1	0.26	Sandy Loam	14	3.63

Table 7.69 (continued). EC (dS/cm), conversion factor and result EC_e

14.1.2	0.12	Sandy Loam	14	1.63
14.2.2	0.21	Sandy Loam	14	2.98
14.3.2	0.13	Sandy Loam	14	1.84
14.4.2	0.09	Sandy Loam	14	1.25
14.5.2	0.40	Sandy Loam	14	5.59
14.6.2	0.23	Sandy Loam	14	3.26
14.7.2	0.76	Sandy Loam	14	10.68
14.8.2	0.17	Sandy Loam	14	2.38
14.9.2	0.26	Sandy Loam	14	3.70
15.1.1	0.10	Sand	23	2.22
15.2.1	0.05	Sand	23	1.13
15.3.1	0.07	Sand	23	1.57
15.4.1	0.14	Sand	23	3.31
15.5.1	0.07	Sand	23	1.51
15.6.1	0.28	Sand	23	6.33
15.7.1	0.32	Sand	23	7.43
15.8.1	0.16	Sand	23	3.58
15.9.1	0.13	Sand	23	3.04
15.1.2	0.14	Sand	23	3.20
15.2.2	0.10	Sand	23	2.35
15.3.2	0.95	Sand	23	21.83
15.4.2	0.16	Sand	23	3.69
16.1.1	0.12	Loamy Sand	23	2.70
16.2.1	0.71	Loamy Sand	23	16.35
16.3.1	2.08	Loamy Sand	23	47.84
16.4.1	0.11	Loamy Sand	23	2.43
16.5.1	0.09	Loamy Sand	23	2.03
16.6.1	0.12	Loamy Sand	23	2.85
16.7.1	0.16	Loamy Sand	23	3.70
16.8.1	0.12	Loamy Sand	23	2.66
16.9.1	0.08	Loamy Sand	23	1.87
16.1.2	0.37	Loamy Sand	23	8.51
16.2.2	0.12	Loamy Sand	23	2.85
16.3.2	0.28	Loamy Sand	23	6.54
16.4.2	0.18	Loamy Sand	23	4.20
16.5.2	0.07	Loamy Sand	23	1.52
16.6.2	0.21	Loamy Sand	23	4.78
16.7.2	0.13	Loamy Sand	23	2.92
16.8.2	0.22	Loamy Sand	23	4.99
16.9.2	0.09	Loamy Sand	23	2.11

Appendix 8

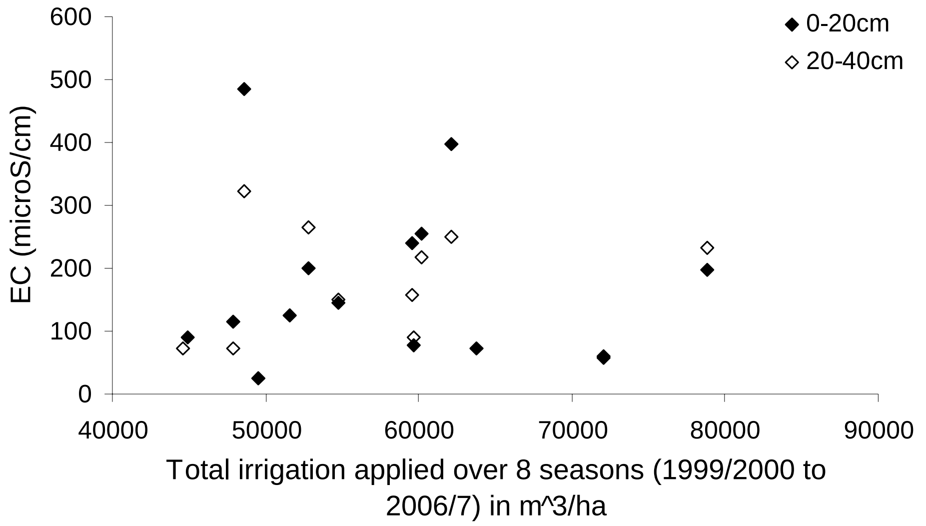


Figure 8.1. Relationship between total irrigation (m^3/ha) for all seasons and EC (μS/cm) of a 1:5 extract.

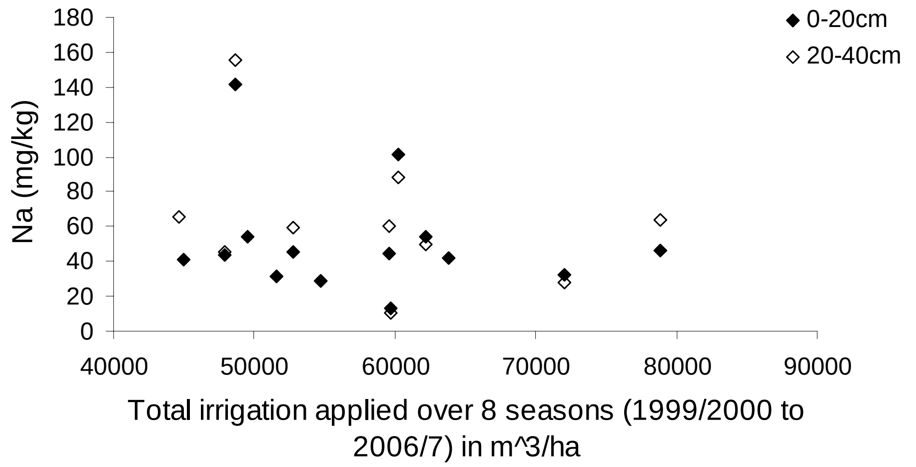


Figure 8.2. Relationship between total irrigation (m^3/ha) for all seasons and Na (mg/kg)

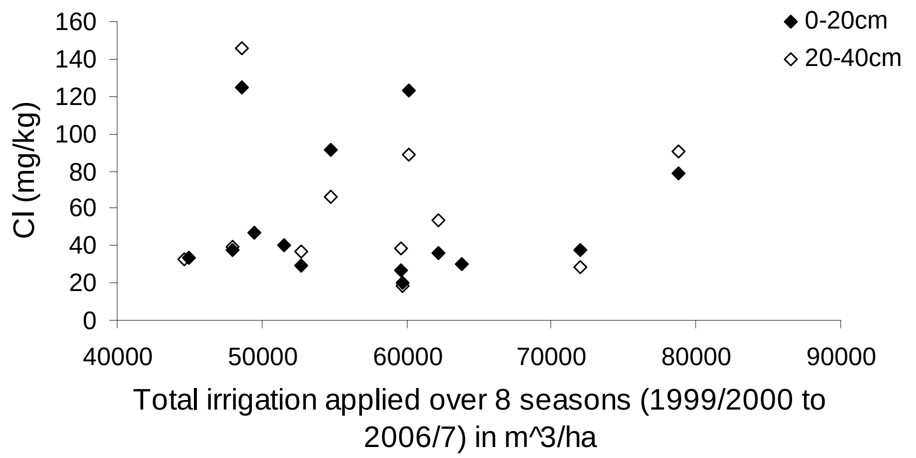


Figure 8.3. Relationship between total irrigation (m^3/ha) for all seasons and Cl (mg/kg)

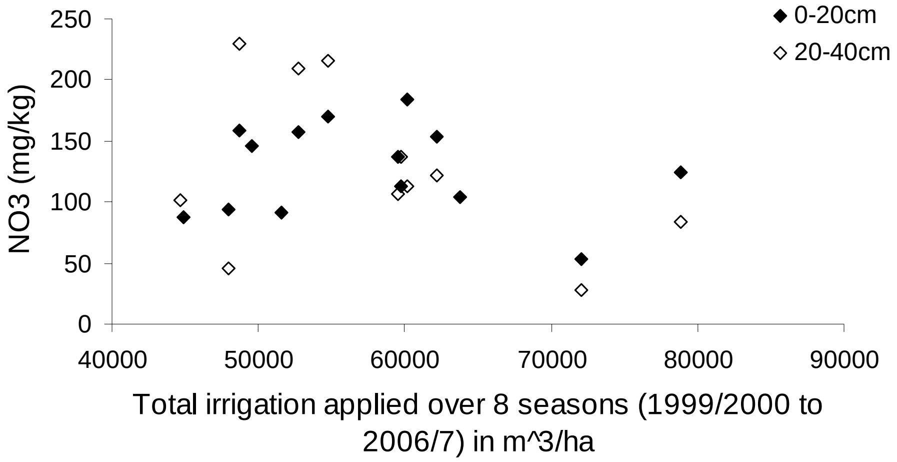


Figure 8.3. Relationship between total irrigation (m^3/ha) for all seasons and NO_3 (mg/kg)

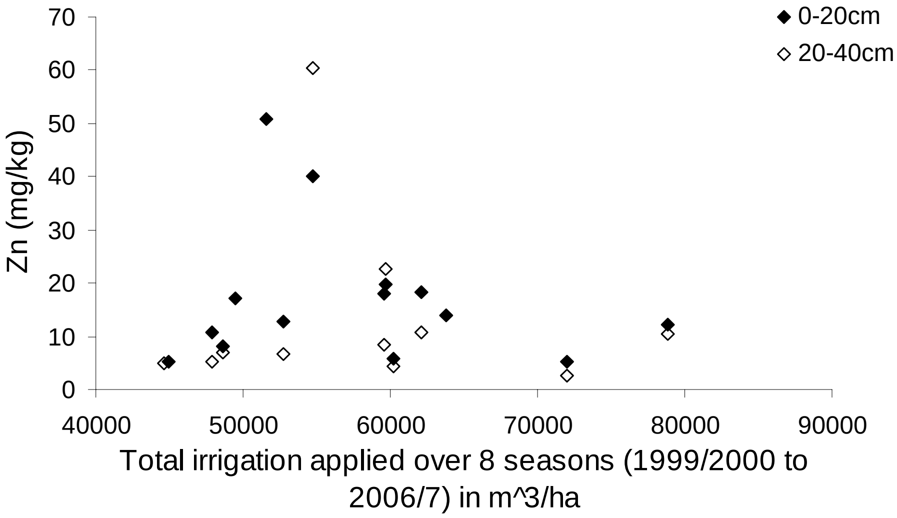


Figure 8.4. Relationship between total irrigation (m^3/ha) for all seasons and K (mg/kg)

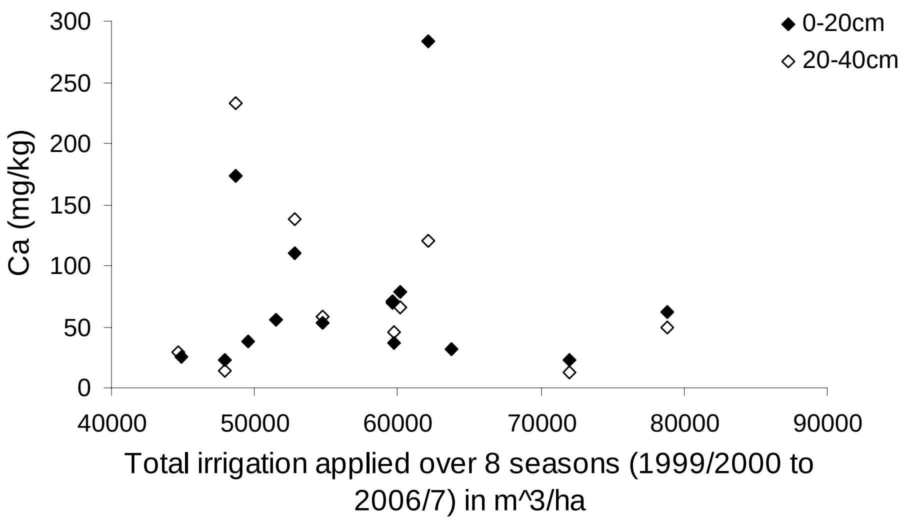


Figure 8.5. Relationship between total irrigation (m^3/ha) for all seasons and Ca (mg/kg)

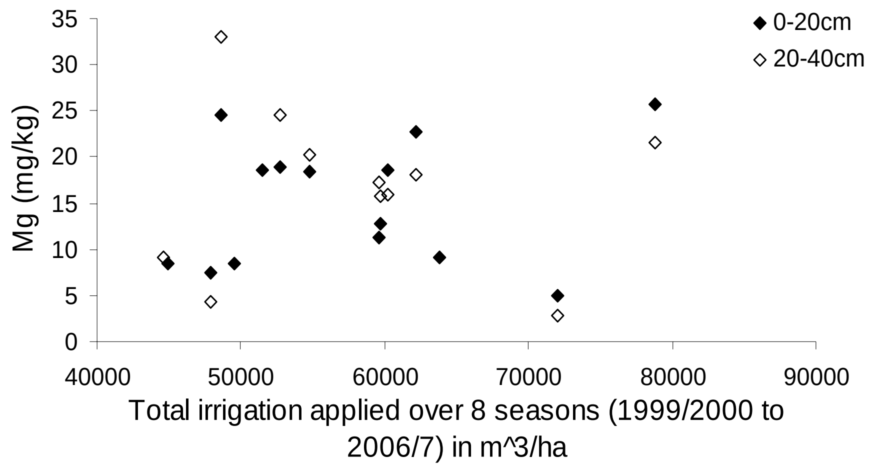


Figure 8.6. Relationship between total irrigation (m^3/ha) for all seasons and Mg (mg/kg)

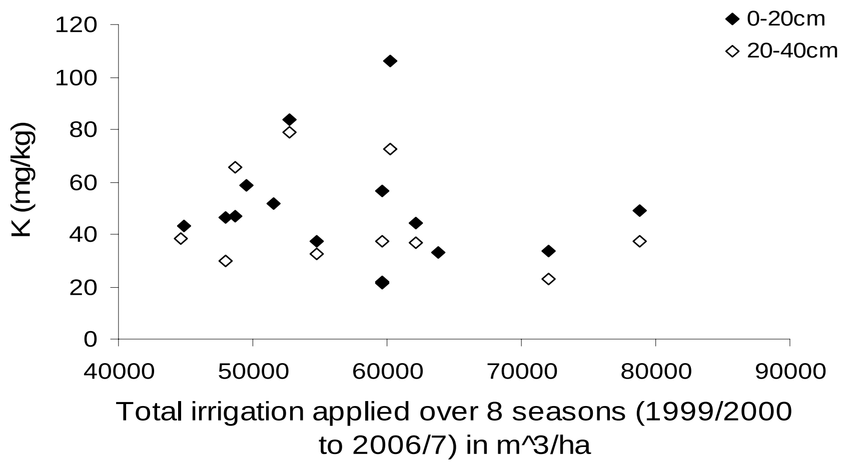


Figure 8.7. Relationship between total irrigation (m^3/ha) for all seasons and K (mg/kg)

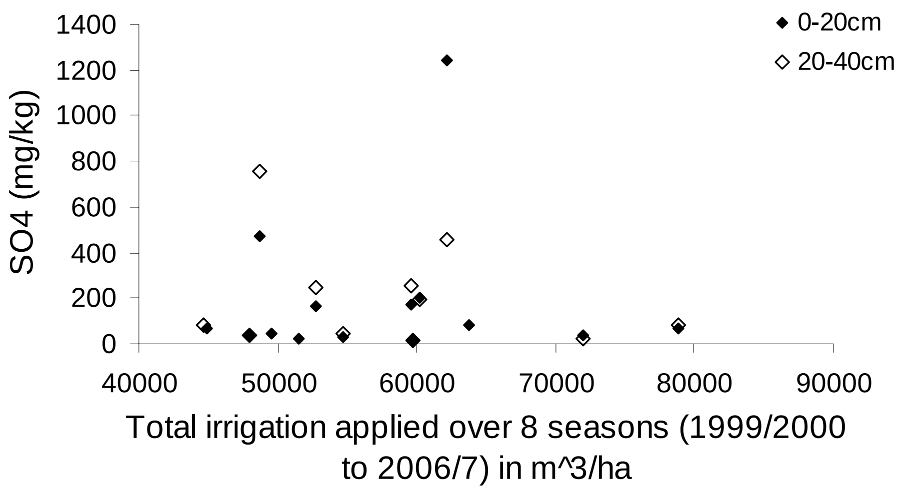


Figure 8.8. Relationship between total irrigation (m^3/ha) for all seasons and SO_4 (mg/kg)

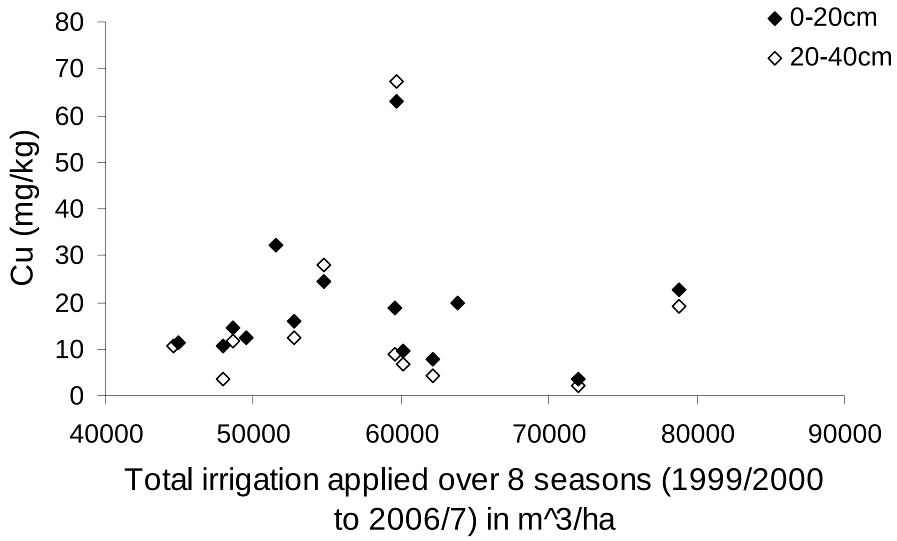


Figure 8.9. Relationship between total irrigation (m^3/ha) for all seasons and Cu (mg/kg)

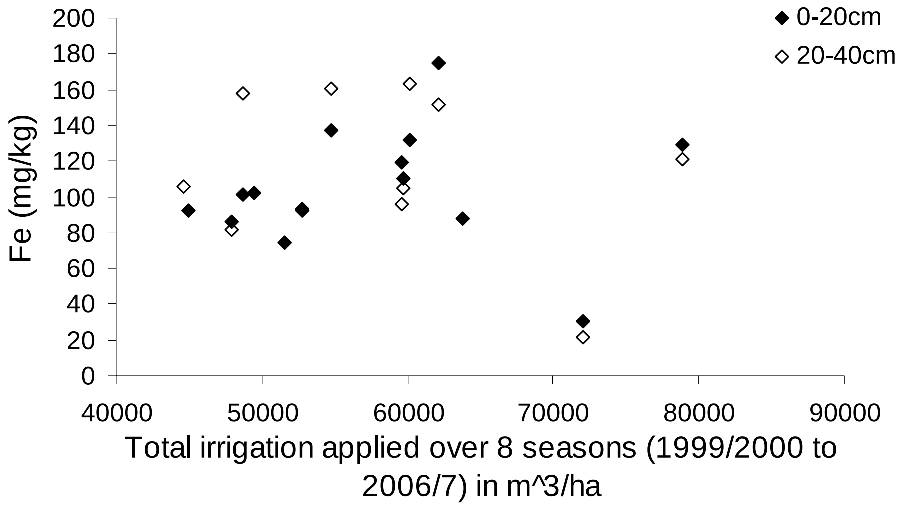


Figure 8.10. Relationship between total irrigation (m^3/ha) for all seasons and Fe (mg/kg)

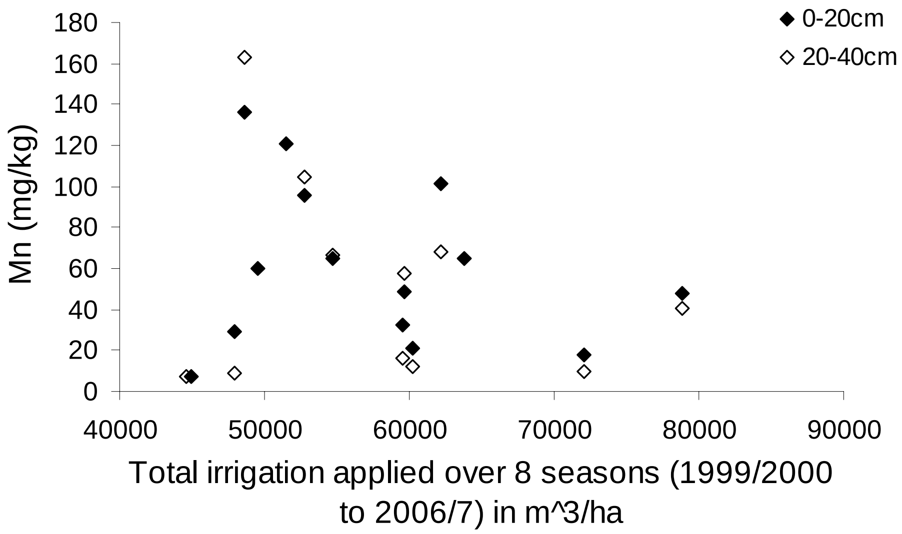


Figure 8.11. Relationship between total irrigation (m^3/ha) for all seasons and Mn (mg/kg)