Infiltration, Runoff and Particle Mobilization on Canola fields at Langgewens Experimental Farm, Mooreesburg, Western Cape.

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A thesis submitted in partial fulfilment of the requirements for the degree of Magister Scientiae in the Department of Earth Science, University of the Western Cape.

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Key words

Infiltration

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Erosion

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Organic matter

Abstract

The primary origin of this project is due to a high demand for freshwater supply in the Berg Water Management Area (WMA). Most of the Berg WMA`s freshwater supply does not live up to the high ecological standards. This is mainly due to high sediments loading in the Berg River which is one of the water supplies to the Berg WMA.

The project was conducted on a small-scale catchment at Langgewens experimental farms in Swartland district. The focus of this study was to address some of the hydrological processes active in the research catchment: infiltration, run-off and sediment mobilization on different soil types under wheat and canola vegetation cover. This was done to investigate the origin of sediments in the Berg River.

Considering the results, one might conclude that the decayed root systems from the canola and wheat vegetation covers, organic matter content, soil cracks, slope orientation, and soil composition, all played a major role in influencing the ability of the soil to absorb the simulated rainfall.

Because the infiltration was calculated using the difference between the incoming simulated rainfall and the measured run-off, there was an inverse relationship between run-off and infiltration. When run-off was low, the infiltration was high and vice versa.

Factors that governed sediment mobilisation within the ring area are micro topography within the ring area, the slope gradient and vegetation covers.

Considering the results, vegetation cover played a pivotal role and it must be maintained at all times. It is advisable that the land users leave crop residual cover behind after the annual harvest and not expose the land surface in bare form for too long as this will generate more run-off and increase sediment mobilisation. The analyses showed that wheat crop protects the soil from rain drop impact than on canola crop.

Declaration

I declare that ***Infiltration, Runoff, and Particle Mobilization on Canola fields at Langgewens Experimental Farm, Mooreesburg, Western Cape*** is my own, that it has not been submitted before for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged as a complete reference

Thandi Nthabiseng Mmachaka 2013

Signed ……………………………..

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CHAPTER ONE: INTRODUCTION

1.1 Background

The primary origin of this project is due to a high demand for freshwater supply in the Berg Water Management Area (WMA). Most of the Berg WMA`s freshwater supply does not live up to the high ecological standards. This is mainly due to high salt and sediments loading in the Berg River which is one of the water supplies to the Berg WMA.

The research on which this thesis is based forms part of a multidisciplinary project financed by the Water Research Commission (WRC) focusing amongst others on sediment mobilisation from agricultural fields in the Berg WMA. The project is conducted in a small scale catchment at Langgewens experimental farm in the Swartland Municipality.

The study area has a Mediterranean climate where salinization is the problem (de Villiers, 2007). To address the problem, the overarching question to be answered is whether natural salt load of the Berg River is being altered by land use practices. To answer the overarching question about the natural salt load of the Berg River, a number of subprojects were identified, one of which is to understand the hydrological process in the soil under Wheat and Canola vegetation covers. These processes, among others, include infiltration, runoff and sediment mobilisation.

The focus of this thesis is to investigate and compares runoff, infiltration and sediment mobilization generated by wheat and canola vegetation covers. Each vegetation cover will generate different runoff, infiltration and sediments. These differences, although hypothesized to fundamentally affect ecological processes, have been poorly quantified. In order to quantify these, rainfall simulation is used.

Rainfall simulator is an ideal research tool for demonstrating the accumulation and movement of sediments from different land cover. Agricultural activities are one of the major sources of non-point source of sediments, due to application of organics such as pesticides and fertilizers that have greatly contributed to the siltation of water resources (Poesen and Hooke, 1987).

1.2 Rational

This study is a very crucial research topic in a sense that there is limited understanding of many of the fundamental concepts relating to the salinization problem in the Berg WMA. It is important to pursue this research because Berg River is one of the rivers that supply different water services providers (municipalities, water boards, etc.) and users (Agriculture, domestic, etc.) with water for different uses. Secondly it is important to pursue this study because siltation of water resources due to sediment mobilization seriously affects the utility of water for different purposes and degrade the aesthetic value of natural watercourses (Herngren et al., 2004).

In the introductory paragraphs of this dissertation, the salinization problem in the Berg River Catchment was mentioned. The importance of the process of infiltration and run off was stressed. The latter two processes and sediment mobilization by run-off form the focus of this study. Because the study area has a Mediterranean climate with rainfall mainly in winter, rainfall simulation was used, so that data collection could also take place during summer, when no or very little rainfall occurs.

The use of small test plots to ensure homogeneity will assist in reducing the larger number of variables and lessen the location specific nature of the outcomes usually inherent to Berg River sediment mobilization research. In conclusion rainfall simulation is the most reliable tool for sediment mobilization research and can be used to simulate sediment wash off (Herngren et al., 2004).

1.3 Statement of the problem

Sediment mobilization through soil erosion usually occurs due to transport by water (Zhang et al., 2008). Erosion is a natural process, but it has been increased dramatically by human land use, especially industrial agriculture, deforestation, and urban sprawl (Renard et al., 1997). Land that is used for conservational agriculture generally experiences a significantly greater rate of erosion than that of land under natural vegetation, or land used for sustainable agricultural practices. The poor protection offered against rainfall impact by a sparse vegetation cover is a major factor contributing to severe splash erosion and runoff, which are major processes in providing detached soil particles and sediments for transport by overland flow (Quansah, 1981).

Agricultural activities release pesticides and fertilizers that accumulate in the soil and cause contamination of water bodies. In this way rivers in general and the Berg River in particular become degraded and lose their aesthetic value. Surface water is contaminated at an increasing rate due to sediments that are generated from agricultural activities. Efficient measures are necessary to improve our understanding of the way in which sediments are mobilized and contaminating water bodies in general.

Crop rotation contribute to the problem of increasing runoff and sediment mobility, because different land covers tend to accumulate different residues that will have an effect on the organic matter content of that soil. This will indirectly affect run off, water quality, infiltration and sediment mobility since crop residue contains nutrients that can serve as a substitute for inorganic fertilizer. Organic matter can furthermore improve soil characteristics including infiltration, porosity, and water holding capacity (Horton, 1933).

1.4 Aim(s) and Objective(s)

The main aim of this research is to measure the amount of infiltration and runoff from different soils with canola or wheat at Langgewens Experimental Farm and secondly to measure the amount of solids in runoff from two lands use types (canola and wheat).

The main objective of this study is to investigate runoff generated on the two land use types (canola and wheat) and the sediment content in the runoff associated with each. It seeks to establish how much sediment agricultural activities at Langgewens Experimental Farm between Malmesbury and Mooreesburg contribute to runoff that eventually ends up in the Berg River.

1.4.1 Specific Objectives

The specific objectives were to:

1. Determine factors playing the major role during the infiltration process and how they influence the depth of infiltration.
2. Determine how different soil types, land use and infiltration rates influence runoff.
3. Determine factors playing a role during sediment mobilisation and how will sediment mobility be influenced.

To answer research questions 1 and 2, the objective was to analyse moisture distribution in the A-horizon in a fixed area and to determine the run-off after a simulated rainfall event.

To answer research question 3, the objective was to analyse the solid content in the runoff water emanating from different soil types under wheat and canola after a simulated rainfall event.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Hydrological changes in many catchments worldwide have been attributed to the land use change. In Berg Water Management Area (WMA), a vast of land has been replaced by other land uses including agriculture and grazing. This has led to decrease in infiltration and increase in sediment mobilization through the process of erosion in many parts of the catchment.

Soil erosion is an important form of land degradation and is among the worlds and South Africa’s most critical environmental issues. Erosion is a process of detachment and transportation of soil materials by wind or water (Morgan, 1995) and although 25% of SA is highly susceptible to wind erosion (Hoffman and Todd, 2000); water is the dominant agent causing sediment mobilisation in the form of soil erosion in SA. Previous research indicates that more than 70% of South Africa (SA) is affected by varying intensities of soil erosion (Garland et al., 2000). Water erosion occurs mostly through rain-splash, in un-concentrated flow as sheet erosion, as well as in concentrated flow as rill and/or gully erosion. Outcomes depend on the combined and interactive effects of erosion factors, namely rainfall erosivity, soil erodibility, slope steepness and slope length, crop management, and support practice. More detail on the factors governing erosion, specifically in a South African context, is provided by Laker, 2004.

Although soil erosion is a natural process, it is often accelerated by human activities such as clearing of vegetation or by overgrazing (Laker, 2004). Loss of fertile topsoil and reduction of soil productivity is coupled with serious offsite impacts related to increased mobilisation of sediment and delivery to rivers. Eroded soil material leads to sedimentation/ siltation of reservoirs, as well as decrease in water quality due to suspended sediment concentrations in streams which affects water use and ecosystem health (Flügel et al., 2003). According to the latest State of Environment Report of SA, soil-erosion costs an estimated R2 bn. annually including off-site costs for purification of silted dam water (Hoffman and Ashwell, 2001; cited in (Gibson et al., 2006).

Due to versatility of certain sediments from agricultural activities (sediments from agricultural land uses are becoming an issue), similar research like this one has been done by various researchers such as (Herngren et al., 2004, Sharpley, 1994). They have concentrated on contamination of water ways by solids and chemicals in urban environments. Many of the studies in the past have generally focused on urban environments, which are easy to monitor, by using a rainfall simulator that is slightly different to the instrument that is used to carry out the research in this thesis. The use of artificial rainfall has been a common approach in agricultural research to overcome the lack of data in infiltration, runoff and erosion studies.

2.2 Rainfall simulation

The primary purpose of a rainfall simulator is to simulate natural rainfall accurately and precisely. Rainfall simulations are used to help understand the effects of rainfall on soil properties under various conditions (Blanquies et al., 2003).

Rainfall is complex, with interactions among properties (drop size, drop velocity, etc.) and large climatic variation based on topography and marine influences. Properly simulated rainfall requires several criteria such as:

1. Drop size distribution near to natural rainfall (Bubenzer, 1979a).

2. Drop impact velocity near natural rainfall of terminal velocity (Laws, 1941; Gunn and Kinzer, 1949)

3. Uniform rainfall intensity and random drop size distribution (Laws and Parsons, 1943)

4. Uniform rainfall application over the entire test plot

5. Vertical angle of impact and

6. Reproducible storm patterns of significant duration and intensity (Moore et al., 1983).

2.3 Advantages and Disadvantages of Rainfall simulators

2.3.1 The main advantages are:

1. The ability to take many measurements quickly without having to wait for natural rain.
2. To be able to work with constant controlled rain, thereby eliminating the erratic and unpredictable variability of natural rain.
3. It is usually quicker and simpler to set up a simulator over existing cropping treatments than to establish the treatments on runoff plots.

2.3.2 Disadvantages of Rainfall simulators

It is cheap and simple to use a small simulator which rains onto a test plot of only a few square metres, but simulators to cover field plots of say 100 m² are large, expensive and cumbersome. Sometimes measurements of runoff and erosion from simulator tests on small plots cannot be extrapolated to field conditions (Laws and Parsons, 1943). They are best restricted to comparisons, such as which of three cropping treatments suffers least erosion under the specific conditions of the simulator test, or the comparison of relative values of erodibility of different soil types.

2.4 Rainfall Simulators

Simulators can be separated into two main groups: drop-forming and pressurized nozzle simulators (Thomas and El Swaify, 1989: Cited by Blanquies et al., 2003). Drop-forming simulators are impractical for field use since they require such a huge distance (10 m) to reach terminal velocity (Grierson and Oades, 1977). The drop-forming simulators do not produce a distribution of drops unless a variety of drop - forming sized tubes are used. Another disadvantage of the drop forming simulators is their limited application to small plots (Bubenzer, 1979b). Several points of raindrop production must be closely packed to create an intense enough downpour.

Pressurized nozzle simulators on the other hand are suited for a variety of uses. They can be used in the field and their intensities can be varied more than the drop forming type (Grierson and Oades, 1977). Since drops exiting the nozzles have an initial velocity greater than zero due to the pressure driving them out, a shorter fall distance is required to reach terminal velocity. Nozzle intensities vary with orifice diameter, the hydraulic pressure on the nozzle, and the spacing of the nozzle (Blanquies et al., 2003).

For all the rainfall experiment studies carried out in different parts of the globe, different simulators have been used by different investigators that are designed to suit the local requirements (Dunne and Dietrich, 1980). Like earlier studies, in this study the rainfall simulator used has been designed following Dunne and Dietrich, 1980.

2.5 The use of rainfall simulator in South Africa

Controlled experiments under simulated rainfall for studying infiltration and soil erodibility are not new concepts amongst the scientists concerned with soil erosion and land management. However, most of these experiments have been conducted in technologically advanced nations where there is abundant availability of capital, skilled labour and water resources. Rainfall simulation experiments to evaluate rainfall run-off relations and soil erosion have been overwhelmingly conducted in Europe and North America; similar studies are limited in South Africa. Very few studies have been reported focusing on infiltration, run-off and erosion studies based rainfall simulator experiment (Bhardwaj and Singh, 1992, Twahirwa, 2010). In an agriculture-based country like South Africa, where there is ever increasing pressure of population on land and water resources, such field experiments would be of great help in the proper understanding of the widespread problem of land degradation and soil erosion. There are formidable practical difficulties in carrying out such long-term monitoring experiments under natural conditions due to anthropogenic disturbances (change of land use and urbanisation).

In South Africa, a rainfall simulator was used to measure erosion and infiltration on sugar cane fields (Platford, 1982). A method for simulating rain storms at the rate of 63 mm of precipitation per hour for an hour, using a rotating boom rainfall simulator, was used. The soils subjected to this treatment ranged from weakly structured, low sand to well-structured clay. The measured erodibilities for the weakly structured soils showed a close correlation with those determined by the monograph method developed in the United State of America (USA) (Platford, 1982). The results obtained for the structured Bonheim soil showed little correlation between the factor predicted by the nomograph and that determined by actual measurements in the trials.

Blanquies et al., 2003 used rainfall simulation to determine the beneficial effect of palm geotextiles on inter-rill erosion. Geotextile mats made of woven palm leaves showed potential using a rainfall simulator for their effectiveness in reducing surface runoff and sediment load from a range of South African soils and mine tailings. Plots at four localities (Bergville, Ladybrand, Roodeplaat and Mabula) were used. Results showed that average runoff under the palm mats decreased by between 45% and 70% at Bergville, and by between 38% and 41% at Ladybrand, compared to bare soil. Sediment load under the mats decreased by between 54% and 75% at Ladybrand, and by between 38% and 89% at Roodeplaat, for three different combinations of slope, mat density and mat mesh size. At Roodeplaat, splash erosion decreased by between 62% and 68%, while at Ladybrand and Mabula, re-vegetation increased by between 38% and 58%. Organic carbon content and topsoil surface levels also increased under the mats. Organic, bio-degradable, easy to manufacture geotextiles, such as palm leaf mats, show much potential, especially in combining employment opportunities with enhanced environmental protection in many susceptible areas of South Africa.

In South Africa, a rainfall simulator was used to measure infiltration, runoff and sediment mobilization on wheat fields (Twahirwa, 2010). A method for simulating rainfall at the rate of 63 mm of precipitation per hour for an hour, using a rotating boom rainfall simulator, was used. The results obtained showed that the decayed root systems from the rows of plants, soil cracks, small channels and openings created by small animals as well as slope orientation and soil composition, all played a major role in influencing the ability of the soil to absorb the simulated rainfall.

2.6 International Experiences on using rainfall simulation to determine infiltration, runoff and sediment mobilisation.

It has become a tradition to use a rainfall simulation for agricultural research because rainfall simulators allow generation of rainfall with a known intensity and duration on an erosion plot in a controlled manner, making it possible to quantify superficial runoff and soil loss, while at the same time allowing very detailed erosion predictions (Martínez- Mena et al., 2001). In this way, simulators have widely contributed to the understanding of soil erosive processes, and though there are differences between natural and simulated rainfall, it is possible to find good correlations between the values of soil loss measured in an erosion plot under simulated rainfall and what occurs in a watershed (Hamed et al., 2002). On the other hand, data generated in the measurements allow calibrating, validating, and verifying erosion predictive models such as Universal Soil Loss Equation-USLE (Wischmeier and Smith, 1978).

Various studies can be found in specialized literature where a rainfall simulator has been used to analyse the different processes involved in erosion.

Cornelis et al., 2004 constructed a wind tunnel and a rainfall simulator to study the effect of wind and rainfall characteristics on soil erosion. The simulator consisted of three pipes covering a 12 x 1.2 m section with sprinklers working with pressurized water. Arnaez et al., 2007 used a rainfall simulator to compare runoff and sediment production under distinct rainfall intensities in a vineyard plantation in Spain. The simulator consisted of a sprinkler located at a height of 2.5 m with pressurized water for 30-min simulations on a 0.45 m diameter plot. Three different types of sprinklers were used for three rainfall intensities: < 40, between 45 and 70, and > 70 mm h-1. The authors mention in their conclusions that both the reduced plot size and the difficulty to reproduce natural rainfall limit the information obtained.

In India, Moore et al., 1983 used a rainfall simulator to measure runoff, infiltration and sediment mobilisation. The main objective of the study was to measure the effect of slope and grass-cover on infiltration rate, run-off and sediment yield under simulated rainfall conditions in a bad land area located in the upper Pravara Basin in western India. An automatic rainfall simulator was designed following Dunne and Dietrich, 1980 and considering the local conditions. Experiments were conducted on six selected experimental fields of 2 × 2m within the catchment with distinct variations in surface characteristics – grass-covered area with gentle slope, recently ploughed gently sloping area, area covered by crop residue (moderate slope), bare bad land with steep slope, gravelly surface with near flat slope and steep slope with grass-cover. The results indicate subtle to noteworthy variations in runoff, infiltration and sediment mobilisation amongst the plots depending on their slope angle and surface characteristics. An important finding that emerges from the study was that the grass-cover was the most effective measure in inducing infiltration and in turn minimizing run-off and sediment yield. Sediment yields are lowest in gently sloping grass-covered surfaces and highest in bare bad land surfaces with steep slopes.

In Italy, Pieri et al., 2009 used a rainfall simulation to investigate different characteristics of runoff and eroded sediments as well as changes in textural composition of the original soil on experimental plots. The objectives were to investigate the particle size distribution of the eroded sediments, as a function of soil, crop, and meteorological variables, and changes in texture due to water erosion over time. The study was performed on experimental plots in the Apennines mountain range, in northern Italy, where a rainfall simulator was used. Runoff water, sediment yield and sediment mean diameters were analysed as a function of land cover, rainfall kinetic energy and stream power. In particular, the study investigated: (a) the sediment particle size distribution using laser diffraction, (b) the effect of rainfall kinetic energy, stream power and crop coverage on runoff, sediment yield and sediment particle size distribution and (c) the changes in soil texture on the cultivated field plots, over a period of 6 months. The results of the study showed: (a) the particle size distribution of the eroded sediment was generally unimodal and the dominant fraction characterizing the eroded sediment was the one with a mean particle diameter ranging from 4.3 to 13.1μm, compromised in the silt range, (b) the mean particle diameter changed depending on the rainfall kinetic energy and stream power, with a positive correlation between particle diameter and rainfall kinetic energy under bare soil, and (c) the effect of long-term erosion showed that the original soil textural composition experienced a statistically significant change over a period of 6 months, with a decrease in the silt fraction and a relative increase in the clay fraction, due to losses of silt in the eroded sediments.

In Canada, Dunne and Dietrich, 1980 used a rainfall simulator to measure runoff and soil loss from conventional (CT), reduced till (RT) and zero till (ZT or, direct seeded) field plots in the Peace River region. We approximated a one in two year storm with the simulator on five year old ZT, CT, and RT at Dawson Creek (clay loam Solonetzic Gray Luvisol) and a one in ten year storm on three year old CT and ZT at Rycroft (silty clay Dark Gray Luvisol). The results of the study showed that soil loss decreased from CT (to RT at Dawson Creek) to ZT at both sites. Compared with CT, RT reduced soil loss by 30% and ZT reduced soil loss by 72% at Dawson Creek. Runoff was also greatest from CT (to RT at Dawson Creek) to ZT at both sites. Reduced soil loss and runoff from all three treatments were statistically related to increased amounts of residue cover and increased surface roughness.

2.7 Sediment mobilisation through soil erosion.

Soil erosion is the removal of surface material by wind or water (Kirkby and Chorley, 1980). Soil erosion is a natural process. It becomes a problem when human activity causes it to occur much faster than under natural conditions. Excessive erosion causes problems such as desertification, decreases in agricultural productivity due to land degradation, sedimentation of waterways, and ecological collapse due to loss of the nutrient rich upper soil layers. Water and wind erosion are now the two primary causes of land degradation; combined, they are responsible for 84% of degraded acreage, making excessive erosion one of the most significant global environmental problems we face today (Kirkby and Chorley, 1980).

2.8 Causes of soil erosion

The causes of erosion can loosely be grouped into two main categories: inappropriate cropping or livestock regimes, and bad management practices (growing crops on inappropriate land). In many areas, it is possible to identify cropping regimes that are inappropriate for the types of soil and topography present (Kirkby and Chorley, 1980).

2.8.1. Growing crops on steep sided slopes

Wheat can often be found growing on steeply sided slopes adjacent to water courses. Given the fact that wheat is to be harvested in December, it is often the case that harvesting takes place in wet conditions which leads to problems with soil compaction and an associated increase in run-off and soil mobilisation. Once wheat is harvested, fields of bare soil are often left exposed to December and January rainfall events which can result in extremely high rates of erosion taking place (Inman, 2006). However this is not the case in the study area as it experiences winter rainfall.

2.8.2. Lack of ground cover

Modern farming systems have increasingly favoured gully erosion. If crops are not planted early enough after ploughing, they would not establish sufficient crop cover to protect the soil from erosion by heavy rainfall events. This situation would result in gully erosion (Inman, 2006).

2.9 Factors controlling soil erosion

There are several factors that affect how rapid a soil will erode. Soil erosion includes the detachment of soil particles from the soil mass and the subsequent transport and deposition of those sediment particles. Erosion is the number one source of decrease in water quality in the world (Pitt, 1995). Erosion is the source of 99% of the total suspended solids in waterways in the Republic of South Africa and undoubtedly around the world (DWAF, 2007). Somewhat over half of the approximately 5 billion tons of soil eroded every year in the Republic of South Africa reaches small streams (DWAF, 2007). This sediment has a tremendous societal cost associated with it in terms of stream degradation, disturbance to wildlife habitat, as well as direct costs for dredging, and reservoir storage losses. This does not even begin to account for the cost of losing productive soil from agricultural land.

Soil erosion is a very complicated problem to solve, because there are so many factors, which affect the rate of erosion. These factors include: **rainfall, soil type, slope, slope length, and type of crops,** (Kirkby and Chorley, 1980). The Universal Soil Loss Equation (USLE) is used to predict the soil loss from fields using these five factors. The USLE is a mathematical model used to describe soil erosion processes. Erosion models play critical roles in soil and water resource conservation and nonpoint source pollution assessments, including: sediment load assessment and inventory, conservation planning and design for sediment control, and for the advancement of scientific understanding (Kirkby and Chorley, 1980).

Rainfall is the first soil erosion factor that will be discussed. As rain falls from the sky it has tremendous force and as it impacts the soil it can break away small portions of soil (Pitt, 1995). This is why rainfall is an important soil erosion factor, but the amount of rain, type of rain, and the distribution of rain are what really need to be looked at.

The majority of the rainfall occurs between the months of May and September and hence it is referred to as a winter rainfall region. Rainfall is of a frontal nature, generally moving from the Atlantic Ocean to the north-west over the Western Cape. The orographical influence of the high mountain ranges in the Cape Peninsula and on the eastern side of the WMA, introduces a large spatial variability in the mean annual precipitation (MAP). In the high lying areas of the Upper Berg River, the upper reaches of the Eerste River and the Steenbras River, the maximum MAP exceeds 3 000mm per annum. In the lowlands, the precipitation is between 600mm and 400mm per annum, being greater in the small mountain outcrops and hills and reducing to 300mm per annum in the north-west of the WMA, where the Berg River flows into the sea. The average potential mean annual evaporation (measured by S-pan) ranges from 1 400mm in the south to 1 700mm in the north of the WMA (ISP, 2004).

Rainfall will be a much more important factor controlling soil erosion. The rains in the Berg WMA tend to come as gentle to heavy down pours. Some areas only have light rain, even though they may receive rain every day, the rain generally does not fall with enough force to detach much soil. When considering rainfall it is important to look at when it generally rains. The Berg WMA receives heavy winter rains and just occasional summer rains. Farmers in the Berg WMA start cultivating during winter season, so runoff is expected to be low since the soil will be tilled (prepared) at that time (DWAF, 2007). If the rainfall generally comes when fields are being prepared, there is a much higher likelihood for erosion not occurring. Runoff is expected to be high during summer rainfall, because at that stage the soil is not prepared or tilled

There are thousands of different **soil types** around the world and each of them has properties, which make them unique (Pitt, 1995). One of their properties is their soil erodibility. Some soils are just much more susceptible to eroding than others. The silty type soils tend to be the most erosive. In some parts of the world (Argentina, North America, China etc) there is a layer of silt, which was deposited by wind (Pitt, 1995). Windblown silt, referred to as loess, is probably the most erosive soil. Soils that have a relatively high content of clay tend to be the least erosive soils. Malmesbury shale that dominates the Berg WMA has high clay content and is high in salt composition (sodium and chlorine contents are relatively high). High clay content of the Malmesbury shale causes the soil to have low infiltration rate and thus high runoff rate (DWAF, 2007).

Soils display a mixture of sand silt and clay in them referred to as their texture, and in many soils the ratio is very similar. However, even in soils with similar ratios of sand, silt and clay they may have drastically different soil erodibility properties. There are two factors that changes soil erodibility: soil structure, and stone content. Soil with good soil structure will allow more water infiltration and thus reducing runoff water and erosion (Hester, 1997). This is also true of stoney soils. They also tend to have greater water infiltration rates.

Slope and Length of slope are critical factors in determining soil erosion. There are fields with all kinds of slope (Pitt, 1995). Flat fields with 0.5-1 percent slopes may not be very prone to erosion, but fields with slopes more than 2.5 percent slopes will likely be very prone to erosion. However, not only the slope of the land should be taken into consideration, the length of the slope should also be considered. Long fields with a constant slope of 2 percent may erode severely, because as the water runs off the field it builds momentum and the faster the water runs the more energy it has for transporting soil (Pitt, 1995). The slopes in the study area (Langgewens Experimental Farm) range between 1 to 2.0 percent which is classified as moderate, therefore these areas will be prone to high runoff and low infiltration.

Another factor, which has a great impact on how much erosion takes place, is the **crop** being grown and how it was planted (Thurow et al., 1986). The crop in the field protects the soil from the impact of raindrops. However, different crops provide different levels of protection. In the study area, both wheat and canola are planted. Wheat is planted in the fall of the year and it covers the soil in the fall, winter, and spring before it is harvested. Canola on the other hand is planted in the spring and harvest in the late summer. Therefore the field has little protection in the fall winter and early spring. Wheat has a denser cover than canola. Runoff is therefore much less on wheat fields compared to canola (Thurow et al., 1986).

As mentioned earlier it also makes a difference how the crop was planted. Soybeans for example, planted on completely plowed fields in one meter wide rows are much worse than soybeans planted in 0.5 meter rows on fields with previous crop residue left on the soil surface.

The water use of crops is very closely related to evaporation. In fact, crop water use is composed of evaporation of water from the soil surface and transpiration of water through the leaves. Combined, this is called evapotranspiration. While evaporation is easily measured, transpiration is not. Therefore, it is much simpler to relate the crop evapotranspiration to daily evaporation via a crop factor. A crop factor is related to the percent of ground covered by the crop canopy and therefore will vary depending on the crop stage (see Table 2.1).

Table 2.1 Different Canopy covers and their crop factors (Thurow et al., 1986)

Canopy Cover	Crop Factor	High / Moderate / Low
Bare ground	0.3	Low
¼ canopy	0.4	Low
½ Canopy	0.6	Moderate
¾ Canopy	0.7	Moderate
Full Canopy	0.85	High
Maturing Crop	0.65	High

For instance, soybeans planted with spring plowing have a crop factor of 0.35; wheat planted with fall plowing has a crop factor of 0.10; corn planted with spring plowing has a crop factor of 0.25 (Thurow et al., 1986). At Langgewens Experimental Farm the farmer practices the crop residue technique and wheat & canola are planted in 6m wide rows respectively.

2.10 Effects of erosion

The effects of soil erosion can be sub-divided into on-farm and off-farm impacts. On- farm impacts are predominantly borne by the farmer and are essentially related to loss of production capacity. As soil erosion takes place, the ability for cereal crops and grass to flourish is reduced which, in turn, has a direct impact on the productivity of the land (Inman, 2006). Off-farm impacts are not always as apparent as the on-farm impacts. Eroded soil, deposited down slope can inhibit or delay the emergence of seeds, bury small seedling and necessitate replanting in the affected areas. Sediment can be deposited on properties down slope and can contribute to road damage (Kirkby and Chorley, 1980).

Pesticides and fertilizers, frequently transported along with the eroding soil can contaminate downstream water sources and recreational areas. Because of the potential seriousness of some of the off-site impacts, the control of "non-point" pollution from agricultural land has become of increasing importance (Pitt, 1995).

2.10.1. Contamination of water resources

Soil erosion has a significant effect on the water resources. Not only do suspended sediments affect the taste of water but the associated phosphate loads also have to be removed by water companies to provide drinking water fit for human consumption (Pitt, 1995).

2.11 Soil erodibility

Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with higher infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and result in compacted surfaces which contribute to increases in soil erodibility (Kirkby and Chorley, 1980).

The subsurface soil layers at Langgewens farm are compacted thus the reason for high runoff rates and low infiltration rates (DWAF, 2007).

Past erosion has an effect on a soil's erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter (Kirkby and Chorley, 1980).The lower nutrient levels often associated with sub soils contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil (Davies and Day, 1998).

2.12 Infiltration

Infiltration is the process by which water on the ground surface enters the soil (see Figure 2.1). Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer (Kirkby and Chorley, 1980).

Infiltration can be visualized by pouring water into a glass filled with dry powdered soil, slightly tamped. The water seeps into the soil; the colour of the soil becomes darker as it is wetted (see Figure. 2.1).

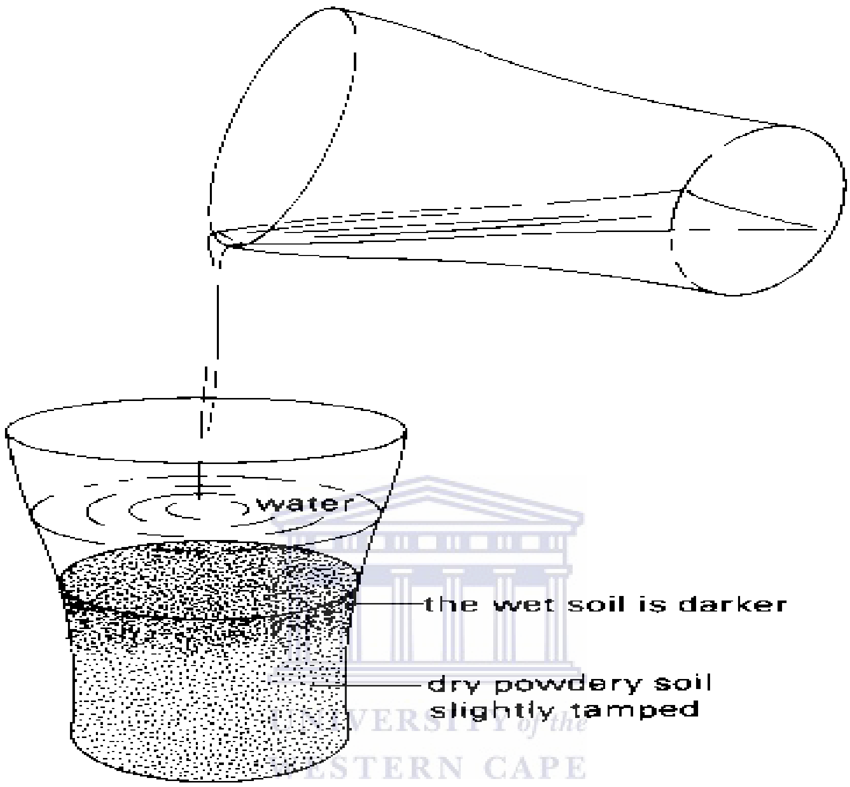


Figure 2.1 Infiltration of water into the soil (Kirkby and Chorley, 1980)

Infiltration is mainly governed by two common forces, gravity and capillary action. Gravity force is more efficient in small pores whereas capillary action in very small pores (Kirkby and Chorley, 1980). The top layer of leaf litter that is not decomposed protects the soil from the pounding action of rain. Without this the soil will become far less permeable. In chapparal vegetated areas (plants that require fire or heat to germinate), the hydrophobic oils in the succulent leaves can be spread over the soil surface with fire, creating large areas of hydrophobic soil (Kirkby and Chorley, 1980). Other conditions that can lower infiltration rates or block them include dry plant litter that resists re-wetting, or frost. If soil is saturated at the time of an intense freezing period, the soil can become a concrete frost on which almost no infiltration would occur. Over an entire watershed, there are likely to be gaps in the concrete frost or hydrophobic soil where water can infiltrate (Kirkby and Chorley, 1980)

Once water has infiltrated the soil it remains in the soil, percolates down to the ground water table, or becomes part of the subsurface runoff process (Kirkby and Chorley, 1980)

2.12.1 Process of infiltration

The process of infiltration can continue only if there is space available for additional water at the soil surface. The available volume for additional water in the soil depends on the porosity of the soil and the rate at which previously infiltrated water can move away from the surface through the soil (Kirkby and Chorley, 1980). The maximum rate that water can enter a soil in a given condition is the infiltration capacity. If the arrival of the water at the soil surface is less than the infiltration capacity, all of the water will infiltrate. If rainfall intensity at the soil surface occurs at a rate that exceeds the infiltration capacity, ponding begins and is followed by runoff over the ground surface, once depression storage is filled. This runoff is called Horton overland flow. The entire hydrologic system of a watershed is sometimes analyzed using hydrology transport models, mathematical models that consider infiltration, runoff and channel flow to predict river flow rates and stream water quality (Botkin and Keller, 1997).

Horton, 1933 suggested that infiltration capacity rapidly declines during the early part of a storm and then tends towards an approximately constant value after a couple of hours for the remainder of the event. Previously infiltrated water fills the available storage spaces and reduces the capillary forces drawing water into the pores. Clay particles in the soil may swell as they become wet and thereby reduce the size of the pores. In areas where the ground is not protected by a layer of forest litter, raindrops can detach soil particles from the surface and wash fine particles into surface pores where they can impede the infiltration process.

The transient infiltration capability process of a sloped soil surface under rainfall, runoff, and erosion impacts is of great significance in hydrology, crop water use, irrigation system design and management as well as soil erosion (Horton, 1933).

The infiltrability or infiltration capability of a soil is usually referred to as the infiltration flux of water at the soil surface, per unit area in a unit time, under unlimited water supply and standard atmospheric pressure (Horton, 1933). This parameter is controlled by the soil properties and determines the amount of water entering into the soil and running off the hill slope.

The infiltration capability of a soil determines the surface runoff, while runoff is closely related to flood prediction, reservoir water resources estimation, irrigation water allocation, runoff induced pollutants transportation, etc. (Botkin and Keller, 1997). The soil infiltration capability also determines the amount of water draining into the soil profile under a given rainfall condition. The infiltrated water either percolates down as groundwater or is transferred into soil water available to crops, where it may influence the irrigation scheduling. Runoff, as controlled by the infiltration process, is the driving force responsible for soil erosion (Botkin and Keller, 1997).

The infiltration capability of soil is a function of soil texture, structure and soil profile moisture distribution (Horton, 1933). Infiltration capability has a very high value initially when soil is dry, and decreases with time of the infiltration process and finally approaches a constant, the so called steady infiltration rate. Only when the water supply to the soil surface reaches or exceeds the infiltration capability does the actual infiltration rate equal the infiltration capability of the soil. This forms the basis for measuring the infiltration capability of a soil (Horton, 1933).

Soil infiltration capability is the actual infiltration rate under unlimited water supply at the soil surface. The very high infiltration capability at the beginning of the infiltration process requires very high rate of water supply. As the process proceeds, soil infiltration capability decreases (Horton, 1933).

Soil texture is a term commonly used to designate the proportionate distribution of the different sizes of mineral particles in a soil. It does not include any organic matter. These mineral particles vary in size from those easily seen with the unaided eye to those below the range of a high-powered microscope (see Table 2.2 (a)). According to their size, these mineral particles are grouped into "separates" (Kirkby and Chorley, 1980).

Table 2.2 (a) Showing different particle sizes (Kirkby and Chorley, 1980)

Name of the particles	Size limits in mm	Distinguishable with naked eye
Gravel	Larger than1	Obviously
Sand	1 – 0.5	Easily
Silt	0.5- 0.002	Barely
Clay	Less than 0.002	Impossible

Farmers often talk of light soil and heavy soil. A coarse-textured soil is light because it is easy to work, while a fine-textured soil is heavy because it is hard to work (see Table 2.2 (b)). The amount of sand, silt and clay present in the soil determines the soil texture. In coarse textured soils: sand is predominant (sandy soils), in medium textured soils: silt is predominant (loamy soils) and in fine textured soils: clay is predominant (clayey soils) (see Table 2.2(b)). The texture of a soil is permanent, the farmer is unable to modify or change it.

Table 2.2 (b) Showing different soil textures (Kirkby and Chorley, 1980)

Expression used by the farmers	Expression used in literature	
Light	Sandy	Coarse
Medium	Loamy	Medium
Heavy	Clayey	Fine

In the field, soil texture can be determined by rubbing the soil between the fingers (see Figure. 2.2).

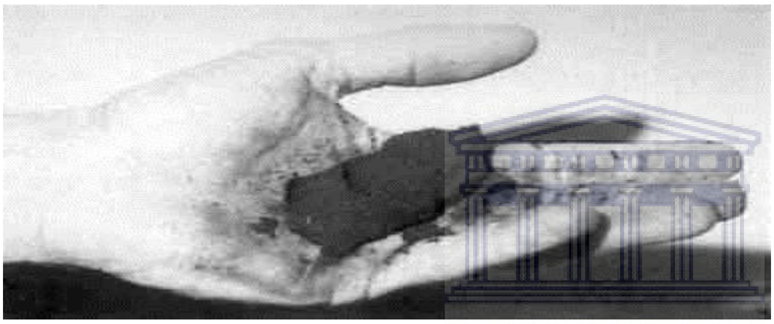


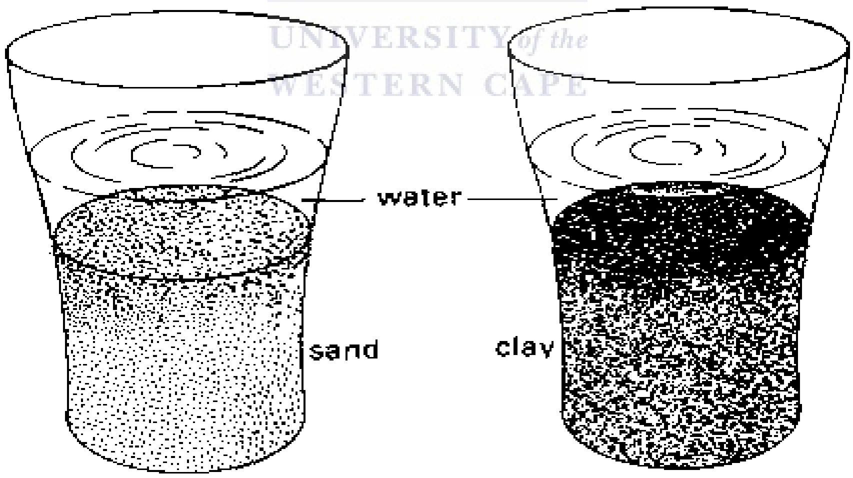
Figure 2.2 showing medium textured soil feel very soft (like flour) when dry. It can be easily pressed when wet and then feels silky (Kirkby and Chorley, 1980).

The infiltration rate of a soil is the velocity at which water can seep into it. It is commonly measured by the depth (in mm) of the water layer that the soil can absorb in an hour. Soils with low infiltration reach equilibrium state (a steady state where the condition of a system in which all competing influences are balanced) quicker than those with high infiltration rate (see Table 2.3). A range of values for infiltration rates is given below (see Table 2.3):

Table 2.3 showing a range of infiltration (Kirkby and Chorley, 1980)

Infiltration rate	**Time (mm/hour)**
Low infiltration rate	Less than 15 mm/hr.
Medium infiltration rate	15 – 50 mm/hr.
High infiltration	More than 50 mm/hr.

Another important factor that plays a vital role in infiltration rate is the type of soil. The infiltration of water into the sand is faster than into the clay. The sand is said to have a higher infiltration rate (see Figure 2.3).



After one hour

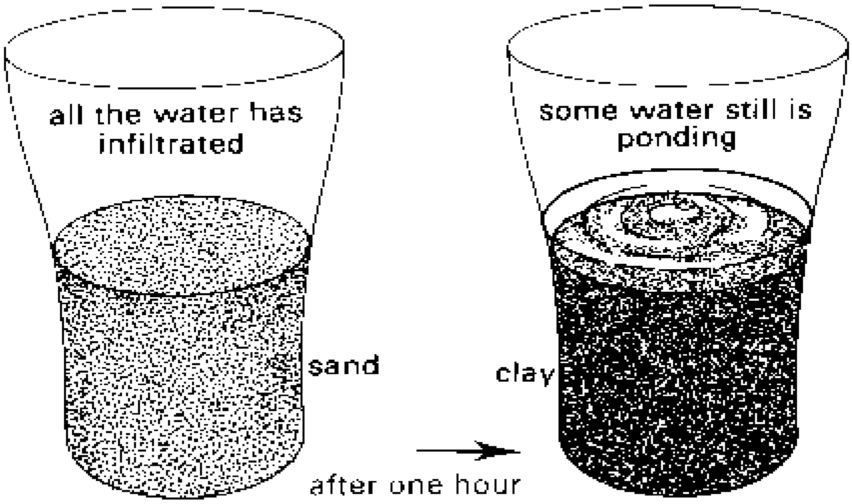


Figure 2.3 Showing infiltration rate for sand and clay soils (Kirkby and Chorley, 1980)

After one hour the water has infiltrated in the sand, while some water is still ponding on the clay (Kirkby and Chorley, 1980).

An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the surface of the soil will take one hour to infiltrate

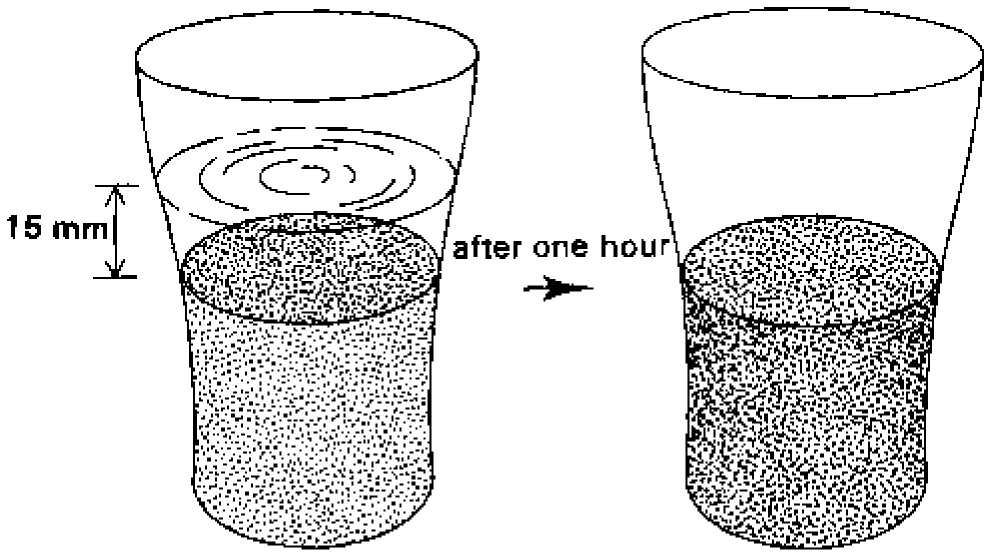


Figure 2.4.Soil with an infiltration rate of 15 mm/hour (Kirkby and Chorley, 1980)

2.12.2. Factors influencing infiltration rate

The infiltration rate of a soil depends on factors that are constant, such as the soil texture as well as factors that vary, such as the soil moisture content and soil structure.

(a) Soil Texture

Coarse textured soils have mainly large particles with large pore space. On the other hand, fine textured soils have mainly small particles with small pore spaces (see Figure. 2.5).

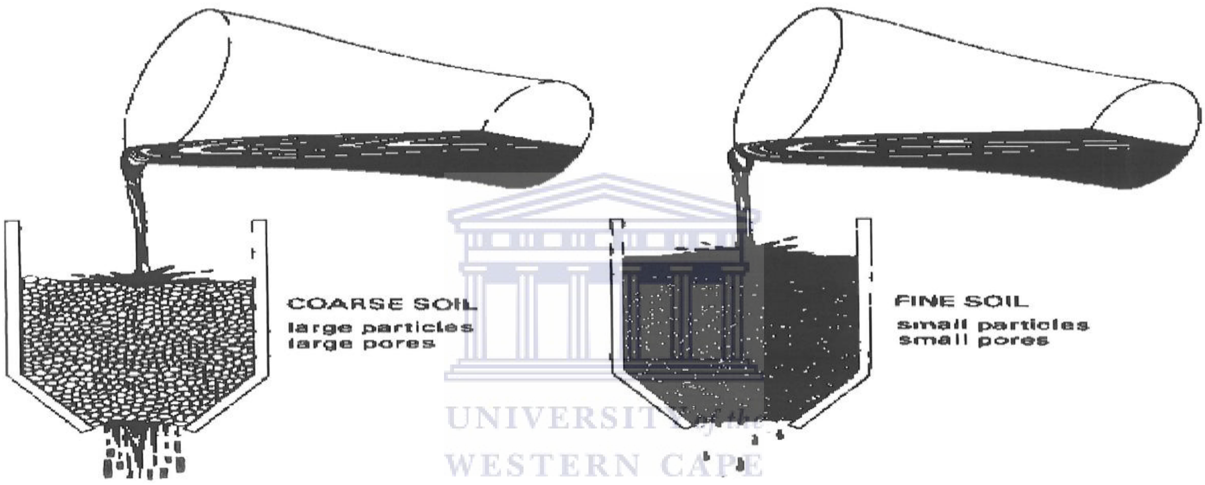


Figure 2.5 Infiltration rate and soil texture (Kirkby and Chorley, 1980)

In coarse soils, the rain or irrigation water enters and moves more easily into larger pores; it takes less time for the water to infiltrate into the soil. In other words, infiltration rate is higher for coarse textured soils than for fine textured soils.

(b) The soil moisture content

The water infiltrates faster (higher infiltration rate) when the soil is dry, than when it is wet (see Figure 2.6). As a consequence, when irrigation water is applied to a field, the water at first infiltrates easily, but as the soil becomes wet, the infiltration rate decreases.

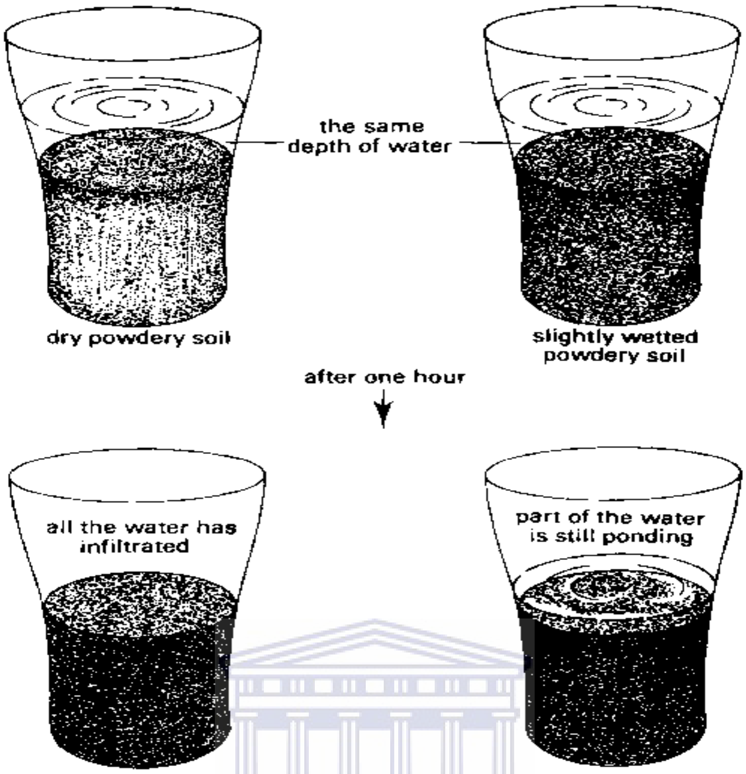


Figure 2.6 Infiltration rate and soil moisture content (Kirkby and Chorley, 1980)

(c) The soil structure

Generally speaking, water infiltrates quickly (high infiltration rate) into granular soils but very slowly (low infiltration rate) into massive and compact soils.

Because the farmer can influence the soil structure (by means of cultural practices), he can also change the infiltration rate of his soil.

Infiltration rate is dependent on a variety of vegetation factors, especially type and amount of vegetation present. Because cover values are generally greater on woody dominated sites, infiltration rates are often observed to be highest under trees and shrubs, followed in decreasing order by bunchgrass and short grass sites (Thurow et al., 1986). Cover breaks the erosive force of raindrops and the litter build-up obstructs runoff. The litter also contributes to building better soil structure which maintains large stable pores in the soil through which water can pass. For these reasons, infiltration rates were higher underneath the canopies of Ashe Juniper than either bunchgrass or short grass sites (Thurow et al., 1986). These results are comparable to studies on Pinyon-Juniper rangelands where infiltration rates were strongly related to vegetation cover. Runoff recorded under shrub was low compared to runoff generated on an area covered by grass.

2.13 Runoff

Runoff is the total amount of water flowing into a stream. It is the part of precipitation that reaches streams and rivers by flowing over or through the ground (Herngren et al., 2004).

Runoff may be generated by several processes; including Hortonian Overland flow (HOF), saturation overland flow (SOF), and subsurface storm flow or interflow (IF).

SOF occurs mainly at the base of slopes and in concavities, which become saturated during prolonged rain (by the combination of infiltration, interflow (flow down slope within the soil) and groundwater flow - once the soil is saturated its infiltration capacity is zero, so any additional rain will not infiltrate - it be will stored on the surface or become overland flow (Pitt, 1995).

HOF is common in semi-arid regions, sparsely vegetated and/or disturbed areas, and locations containing dense, clay rich layers, where the soils are very fine textured and on heavily compacted or frozen soils (Pitt, 1995).

HOF is the portion of rain, snow melt, irrigation water, or other water that moves across the land surface and enters a wetland, streams, or other body of water. The flow generally occurs when precipitation exceeds the infiltration capacity of the soil (Herngren et al., 2004).

Saturation excess overland flow is precipitation that cannot be absorbed by the soil because the soil is already saturated with water, so it flows across the land surface to a stream or other body of water (Pitt, 1995). This type of flow occurs when the water table rises to the ground surface and prevents rainfall infiltration.

Interflow is the water that travels laterally or horizontally through the zone of aeration without reaching the water table during or immediately after a precipitation event and discharges directly into a stream or other body of water. Interflow is lateral shallow subsurface flow that occurs on hill slopes with shallow permeable soil layers overlying low permeability layers (Pitt, 1995).

Through-flow is a shallow subsurface flow that occurs above the groundwater table. Though-flow is water that infiltrates into the soil and percolates rapidly, largely though macro pores such as cracks and root animal holes, and moves laterally in a temporarily saturated zone, often above a layer of low hydraulic conductivity (Herngren et al., 2004). A major requirement for through- flow is a good infiltration capacity. It commonly occurs in humid climates containing thick soil layers and a good vegetation cover (Herngren et al, 2004). The runoff that was observed in the study area is the SOF.

Although the litter layer markedly reduces the amount of water reaching the mineral soil, it does have some beneficial aspects as well. Due to the large amounts of organic matter and cover, it contributes to improved soil structure. This increases the infiltration rate of the soil below the canopy (Herngren et al., 2004). The thick litter layer often associated with wheat also minimizes evaporation loss from soil below the canopy and obstructs runoff that originates from interspace areas. This greater infiltration rate enables the area under wheat crops to accept water inflow faster than the crop interspace which usually has a much lower infiltration rate (Herngren et al., 2004). Therefore, wheat groves will harvest water flowing off of interspaces. This gives the wheat crop a further competitive advantage. This also explains why runoff yield from a pasture may not change as wheat density increases. The water is simply redistributed within the pasture since it may flow from the interspace until it encounters a higher infiltration capacity of soils beneath the crop (Herngren et al., 2004).

2.14 Sediment Mobilization

Sediment mobilization is the movement of solid particles (sediment), typically due to a combination of the force of gravity acting on the sediment, and/or the movement of the fluid in which the sediment is entrained. An understanding of sediment mobilization is typically used in natural systems, where the particles are clastic rocks (sand, gravel, boulders, etc.), mud, or clay; the fluid is air, water, or ice; and the force of gravity acts to move the particles due to the sloping surface on which they are resting. Sediment mobilization due to fluid motion occurs in rivers, the oceans, lakes, seas, and other bodies of water, due to currents and tides; in glaciers as they flow, and on terrestrial surfaces under the influence of wind. Sediment transport due only to gravity can occur on sloping surfaces in general, including hill slopes, scarps, cliffs, and the continental shelf—continental slope boundary (Herngren et al., 2004).

Knowledge of sediment mobilization is most often used to know whether erosion or deposition will occur, the magnitude of this erosion or deposition, and the time and distance over which it will occur (Herngren et al., 2004).

There are different mechanisms in which sediment can be transported. *Aeolian* or *eolian* (depending on the parsing of æ) is the term for sediment transport by wind. This process results in the formation of ripples and sand dunes. Typically, the size of the transported sediment is fine sand (<1 mm) and smaller, because air is a fluid with low density and viscosity, and can therefore not exert very much shear on its bed. Bed forms are generated by aeolian sediment transport in the terrestrial near-surface environment. Ripples and dunes form as a natural self-organizing response to sediment transport. Aeolian sediment transport is common on beaches and in the arid regions of the world, because it is in these environments that vegetation does not prevent the presence and motion of fields of sand.

Another mechanism is by fluvial process, fluvial processes relate to flowing water in natural systems. This encompasses rivers, streams, periglacial flows, flash floods and glacial lake outburst floods. Sediment moved by water can be larger than sediment moved by air because water has both a higher density and viscosity. In typical rivers the largest carried sediment is of sand and gravel size, but larger floods can carry cobbles and even boulders. Fluvial sediment transport can result in the formation of ripples and dunes, in fractal-shaped patterns of erosion, in complex patterns of natural river systems, and in the development of floodplains (Herngren et al., 2004).

Coastal sediment transport takes place in near-shore environments due to the motions of waves and currents. At the mouths of rivers, coastal sediment and fluvial sediment transport processes mesh to create river deltas. Coastal sediment transport results in the formation of characteristic coastal landforms such as beaches, barrier islands, and capes (Herngren et al., 2004).

As glaciers move over their beds, they entrain and move material of all sizes. Glaciers can carry the largest sediment, and areas of glacial deposition often contain a large number of glacial erratics, many of which are several meters in diameter. Glaciers also pulverize rock into "glacial flour", which is so fine that it is often carried away by winds to create loess deposits thousands of kilometers afield. Sediment entrained in glaciers often moves approximately along the glacial flow lines, causing it to appear at the surface in the ablation zone (Herngren et al., 2004).

Large masses of material are moved in debris flows, hyper concentrated mixtures of mud, clasts that range up to boulder-size, and water. Debris flow move as granular flows down steep mountain valleys and washes. Because they transport sediment as a granular mixture, their transport mechanisms and capacities scale differently than those of fluvial systems (Herngren et al., 2004).

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1 Study Area

3.1.1 Introduction

The Berg Water Management Area (WMA) is situated in the extreme southwest corner of South Africa and falls entirely within the Western Cape Province. It derives its name from the largest river within its boundaries, namely the Berg River. The Berg WMA borders on the Olifants/Doring WMA to the north and on the Breede WMA to the east. It borders on the Atlantic Ocean and Indian Oceans to the west and south respectively. The Langgewens Experimental farm is located within the Berg WMA and falls under Quaternary drainage area G10L (see Figure 3.1).

Figure 3.1 Berg WMA Base Map (ISP, 2004)

3.1.2 Study site description

The study area, on the Langgewens Experimental farm, is located approximately 10 km to the NW of the town of Mooreesburg (33°17′S, 18°42′E, altitude 177m) and approximately 80 km north of Cape Town, in the Western Cape Province, South Africa (see Figure 3.2)

<u>**Study Area: Langgewens Experimental Farm**</u>

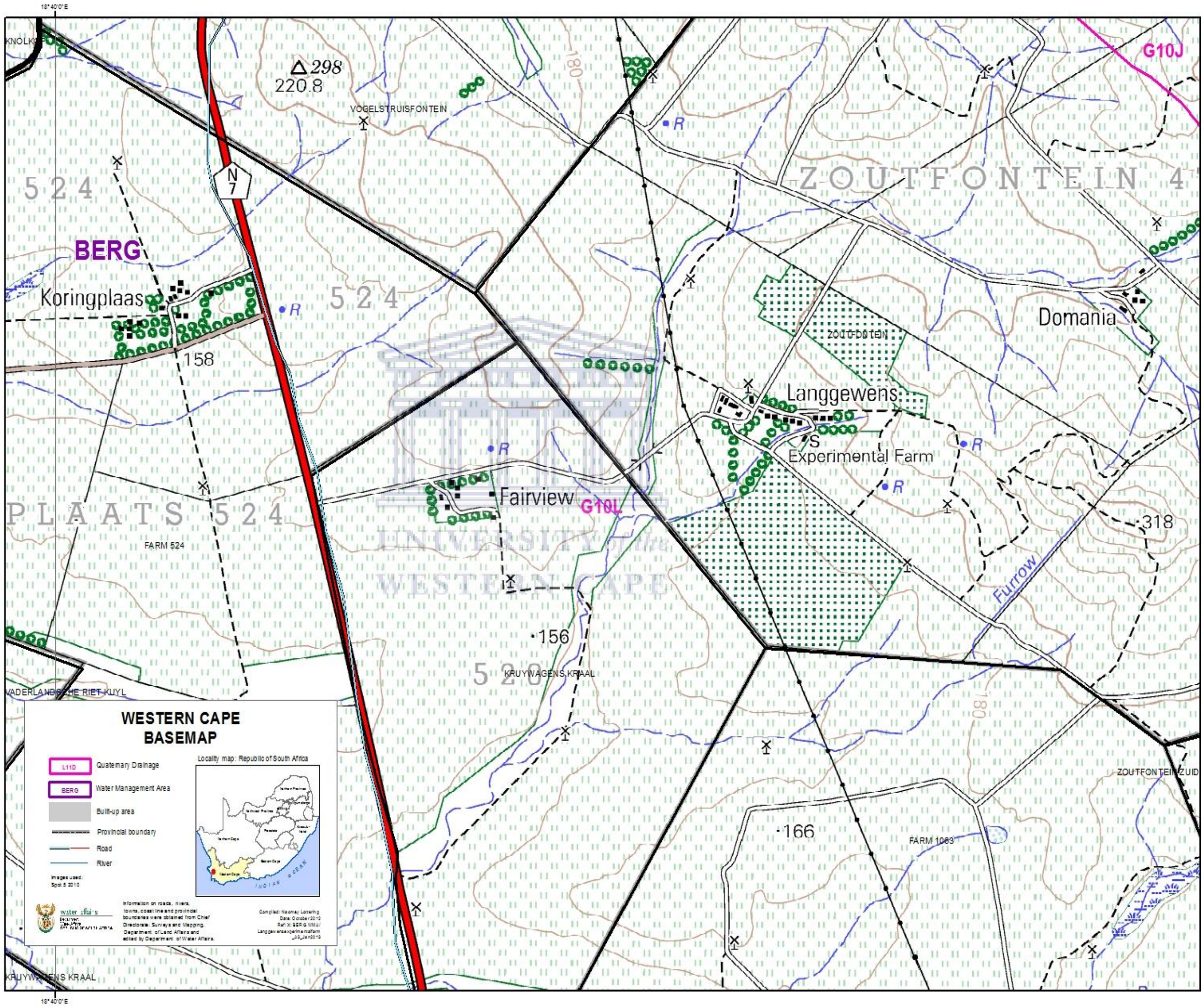


Figure 3.2 Location of the study area on a topographic map

Figure 3.3 Aerial photographic view of the study area at Langgewens Experimental Farm

3.1.3 The Berg River

The headwaters of the Berg River arise in the Groot Drakenstein Mountains and flow for over 300 km draining an area of approximately 900 km² (Gorgens and de Clercq, 2005). The river flows past two major settlements, Paarl and Wellington, each with over 50 000 inhabitants, and eventually entering the Atlantic Ocean on the west coast at Port Owen, St Helena Bay (de Villiers, 2007).

3.1.4. Topography

The Berg Water Management Area (WMA) is situated in the extreme southwest corner of South Africa and falls entirely within the Western Cape Province. It derives its name from the largest river within its boundaries, namely the Berg River. The WMA borders on the Olifants/Doring WMA to the north and on the Breede WMA to the east. It borders on the Atlantic Ocean and Indian Oceans to the west and south respectively.

3.1.5. Climate

The Berg WMA lies in a winter rainfall region with average annual rainfall ranging from 100 to 1000 mm at the watershed, but decreases from east to west to 100 mm or less at the west coast (River Health Programme, 2004) (Figure3.4). The average midday temperatures for the Berg WMA range from 16.8°C in July to 29.7°C in February. The Berg WMA is the coldest during July when the mercury drops to 6°C on average during the night.

The topography of the Berg WMA varies considerably, with consequential impact on the climate of the region. Rainfall is highest in the southern mountain ranges where the mean annual precipitation is as high as 1 000 mm per annum, whilst the north-west part of the WMA immediately inland of the coast, receives as little as 100 mm per annum (see Figure 3.4).In the study area rainfall averages approximately 53 mm per year, with the maximum rainfall in June, July and August with the rainfall intensity of approximately 60 mm/h.

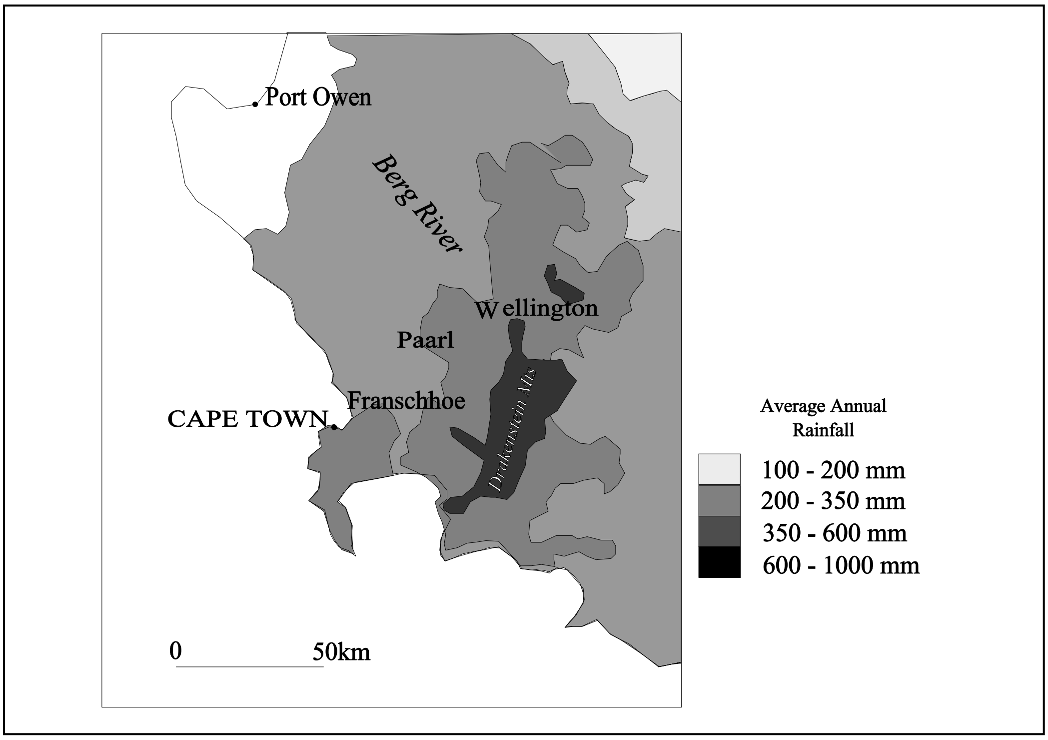


Figure 3.4 Berg WMA and rainfall regimes (River Health Programme, 2004)

3.1.6 Land Use

Most of the surrounding landscape is utilised by farming activities, mainly wheat and vineyards, as well as livestock. There are quarrying activities at the southern extent of the study area at PPC. The Berg WMA has more than 40 ha of irrigated land (estimated in 1995). Approximately 40 ha of dry land crops are cultivated, of which the predominant crop type is wheat (ISP, 2004).

3.1.7 Geology and Soils

The study area is surrounded by the Kasteelberg Mountain that is a sandstone Mountain vegetated with mountain fynbos. To the south of Kasteelberg lies the Porseleinberg, a long, narrow, Shale Mountain with dry Karooid renosterveld on it. On the flats there is a mix of shale, tertiary sands and seasonally wet alluvial soils. The soils at the site are red and yellow soils that are usually shallow, on hard or weathered rock, with limestone present in part or most of the landscape.

Soil forms that occur in the study area are known from samples that were taken from soil pits and analysed by the University of Stellenbosch. In this way, soil physical information for each soil type was obtained (Gorgens and de Clercq, 2005). These soils consist mainly clay and can be subdivided into the various soil forms. The **Glenrosa** (Gs) soil form has an Orthic A-horizon, as well as Lithocutanic B-horizon. This soil form is described as Gs 1 only when the A-horizon is bleached, when it has soft or hard B-horizon, when B-and C-horizons are non-calcareous, and also when it has slight otr no subsurface wetness. The Glenrosa form is referre to as Gs2 when it has a bleached A-horizon, a soft or hard B-horizon and when wetness is present in the B1-horizon. The Gs3 category is referred to as a Glenrosa soil form when it has a bleached A-horizon, a soft B-horizon, and slight or no wetness in the B1-horizon. In addition, it must have non-calcareous B-and B-horizons, and a slight wetness of the subsoil.

The **Mispah** (Ms) soil form has an orthic A-horizon and it is made up of hard rock. This soil is reffered to Ms1 when there is a bleached and non-calcareous a-horizon and slight or no subsoil wetness.

The **Oakland** (Oa) soil form has an orthic A-horizon, a pedocutanic B-horizon and contains unconsolidated materials with signs of wetness. When Oakland soil form is referred to as Oa1, it means it has a bleached A-horizon and medium-coarse to angular material in the B-horizon. It consists of non-calcareous B-and C-horizons, and dispalys soil wetness. The Oa2 is symbol give to the Oakland soil form when it consists of orthic A-horizon and non-red and fine structred B-horizon. It also has calcareous B-and C- horizons and moderated soil wetness.

The **Swartland** (Sw) soil form has an orthic A-horizon, a pedocutanic B-horizon and saprolite material. The Sw1 is the symbol used for the Swartland soil form division when it has a bleached A-horizon and a non-red B-horizon. It consists of non- calcareous B-and C-horizons and has moderate subsoil wetness. When the Swartland is allocated the symbol Sw2, it has a bleached a-horizon and non-red and fine structured B-horizon. It also has calcareous B-and C- horizons and moderate wetness.

3.2 Methodology

As have been indicated in the first chapter dealing with the aims / rational of the study, the main data base for this project will come from data generated by rainfall simulation on vegetated plots on a small scale catchment at Langgewens Experimental Farm between Malmesbury and Mooreesburg in the Swartland Municipality.

To answer the research questions indicated in the first chapter, rainfall simulation was used.

3.2 .1 Rainfall Simulator Design

The designed simulator consists of an extendible four legged base that supports a fixed spray boom above the plot. A small pump (0.37 kW, 0.6 bar atm) was used to draw water from a 100 litres plastic water tank to supply constant pressure to the spray boom.

The main frame onto which the boom was fixed on was 100 x 50 cm rectangular section constructed from 25 x 25 mm angle aluminium and had provision for rod and sockets joints at the four corners at an angle of 15^{0} to the vertical to accommodate the legs. The stand was made up of four (15 x 15 mm and 3.4 m long) rectangular aluminium frames having iron rod base extension (20 mm diameter and 75 cm long) to ensure that the boom reaches 2 m heights and levels when positioned on a slope up to 30 %. Many rainfall simulators are designed with the nozzle at a height of 2 m to replicate the velocity and kinetic energy of natural rain (Meyer and Harmon 1979; Humphry et al., 2002). The rainfall simulator can be easily dismantled and transported to the field.

The aluminum framework was covered by a canvas to protect the experiment against wind. A metal ring enclosing an area of 0.945m^2 was placed into the soil to direct the runoff to the outlet of the ring (see Figure 3.5).

An adjustable valve at the base of the simulator, along with a pressure gauge at the outlet of the pump were used to achieve the desired nozzle pressure (0.6 bar atm). A level and a hook for a plumb bob were attached to the nozzle for levelling and centring the boom over the plot. A pressure of 0.6 bars was used for all simulations. This gave a rainfall intensity of approximately 63 mm/h, which was the lowest intensity possible with this particular simulator. Lower pressures did not generate any droplets, and higher pressures caused a spray mist, which was unlike the general rainfall in the area. The intensity of 63 mm/h was considerably higher than the natural rainfall of 60mm/h for the study, but could not be prevented because of technical shortcomings of the simulator. It nevertheless gave an idea of what could be expected under extreme conditions.

A 0.37 kW single phase electric pump delivered water from the 500 litres plastic water tank to the simulator through 12.7 mm internal diameter pipe to the boom.

3.2.2 Intensity Calibration

The intensity of the simulated rainfall was measured by using a rain gauge. Rainfall intensity was measured by the rain gauge placed vertically in the central portion of the plot. The pump and pressure at the nozzle were set to the desired level for one minute. The water collected was poured into a measuring cylinder to determine the rainfall amount and hence the intensity. If the intensity was undesirable, the pressure was adjusted and the calibration re-run until the desired intensity for the simulation was reached.

Figure 3.5 Metal ring and pipe outlet enclosed surface with 65% coverage of wheat stubble.

3.2.3 Plot establishment

In the study area, rainfall simulations were conducted in summer of 2008 and 2009. Simulations were conducted at twenty four sites at Langgewens Experimental Farm using random sampling to select the sampling sites. Twelve sampling points for wheat and twelve for canola land cover were chosen. Random sampling was used to avoid selection bias. The latter may lead to incorrect conclusions (Heckman, 1979).

These twenty four sampling points had different vegetation cover density. For instance wheat land cover has more vegetation cover than canola (Figure 3.5 and Appendices). Sites with significant depression storage were avoided. Water samples were collected at areas with steep slope so that runoff would be generated quickly. Steep Slopes refers to any slope equal to or greater than 15 percent as measured over any minimum run of 10 feet.

3.2.4 Soil Moisture

It is important to know the initial soil moisture before conducting rainfall simulation experiments because if the soil is already saturated with water, infiltration will be low and thus more runoff is generated.

The water content of soil samples from the simulation site was measured gravimetrically as the ratio of water weight (g) to soil weight (g) (Kirkby and Chorley, 1980). To measure the initial soil moisture content, soil samples were taken to a depth of 50 mm with an auger of 50 mm diameter. The soil was placed in a sealed plastic bag and kept in a cool place. The soil samples were then taken to the lab and were weighed before placing them in the oven. The weighed soil samples were oven dried at 105 °C for 24 hours until constant weight was obtained. To calculate the initial soil moisture content, weigh of dried soil was subtracted from the wet soil. This procedure was followed for all simulation experiments at the two different land uses.

3.2.5 Simulation procedure

First thing that had to be done before conducting the simulation was to calibrate the rainfall simulator. Calibration of the rainfall simulation equipment included verification of 1) rainfall intensity; 2) uniformity of rainfall application across the holding container, and; 3) atmospheric pressure. Calibration was conducted after initial equipment set-up and following equipment maintenance. Rainfall intensity was measured over a time period, for example

1000ml in 60 seconds over a fixed area. This was converted to mm rainfall per square meter. The atmospheric pressure was known before and during the simulation and it was constant throughout the experiment. The rainfall simulator was calibrated in such a way that the volume of rainfall was 1100ml in 1min at 0.6 bar atmospheric pressure. This was converted to a rainfall of 63mm/hr.

Runoff samples were collected in 250ml bottles which were marked for each land use type. After the rainfall simulator was calibrated, runoff samples were collected in the following manner. The starting time of simulation was recorded. The initial starting time of runoff was recorded and a runoff sample was taken 3min after the initial runoff started. After each 5min interval, runoff samples were taken, until the soil was in an equilibrium state and runoff from the ring area was constant. Total runoff volume was recorded after each simulation was done. As expected, the time to saturate a particular soil type in the ring area differed from place to place (Poesen and Hooke, 1987).

After all runoff samples have been collected, they were taken to the laboratory were sediment contents were analyzed. Runoff water samples were evaporated so that the remaining sediment could be calculated.

3.2.5 Soil samples

After each simulation experiment, soil samples were taken from the wetted area within the ring area .The reason for taking soil samples after simulation was to compare the depth of infiltration on different land uses. Three samples were taken for each simulation experiment, the 10mm surface soil, and at 50mm, and 100mm depth. Samples were kept in sealed plastic bags and were marked to identify from which land use and at what date they were taken. These samples were taken to the laboratory to determine the moisture content at different depth.

The analysis was done using the basic technique for demonstration of gravimetric soil moisture content, a method often used to calibrate other instruments, such as neutron soil moisture probes (Poesen and Hooke, 1987). In the laboratory, the samples were weighed and dried in an oven for 24 hours, at a temperature of 105 °C, until a constant weight was achieved. The mass of the initial sample minus the oven –dried mass gave the moisture content in grams. This was then expressed as a percentage, by multiplying the moisture content in grams by 100 and dividing it by the mass of the oven-dried sample.

3.2.6 Sediment mobilization

To compare the solids in the run-off from the ring plots with sediment mobilization of the A-horizon of the different soil types in the study area, samples of the run-off were placed in an oven at 105 °C for 24 hours, in weighed and labeled beakers. After 24 hours, the beakers containing the samples were weighed again. The difference between the final and the initial weights gave the sediment content value in the grains. From these analyses, sediment mobilization curves were constructed. These are presented and discussed in Chapter 4.

CHAPTER FOUR: RESULTS

4.1 Evaluation of Infiltration

The purpose of this chapter is to examine infiltration in different soil types in the study area, as outlined earlier, and to investigate the factors that influence the downward movement of water in the vadoze zone.

To assess infiltration rates on different soil types in the study area, rainfall simulations were done, as mentioned earlier. Because the rainfall intensity generated by the simulator was known and could be adjusted as required, the infiltration capacity could be calculated by subtracting the run-off value from that of the rainfall intensity. Run-off values are usually measured as a volume, but in this case, they were converted to mm/hr. to make them comparable to the rainfall intensity. The following results were obtained.

The main soil types in the study area are mentioned in section 3.1.7 of Chapter 3. Most of these contain various amounts of organic matter content. Table 4.1 below summarises the organic matter content of surface material at the sites where rainfall simulations were done. Initial moisture content varies from 8.313 g/l at site 12 to low values of 6.321 g/l at site 11.

Table 4.1 the organic matter content for various soil types on the simulation sites

Rainfall simulation site number	**Soil type**	**Crop Type**	**Organic Matter Content(g/l)**
1	**Oa 2.2(4)**	Canola	**7.342**
2	**Oa 2.4(5)**	Canola	**6.432**
13	**Sw 2.5(16)**	Canola	**7.150**

8	**Gs 3.5(21)**	Canola	**7.232**
6	**Gs 3.3(25)**	Canola	**7.555**
17	**Gs 2.3 (33)**	Canola	**7.122**
11	**Ms 1.3 (19)**	Canola	**6.321**
9	**Gs 2.3 (32)**	Canola	**7.382**
7	**Oa 2.4(7)**	Canola	**7.364**
14	**Gs 2.5 (26)**	Canola	**7.700**
15	**Gs 2.5 (27)**	Canola	**7.133**
20	**Gs 3.3 (24)**	Canola	**7.324**
4	**Oa 2.4(5)**	Wheat	**7.373**
10	**Oa 2.4(7)**	Wheat	**7.233**
22	**Sw 2.4(16)**	Wheat	**7.609**
5	**Gs 3.5(21)**	Wheat	**7.139**
18	**Gs 3.3 (24)**	Wheat	**7.314**
12	**Gs 3.3(25)**	Wheat	**8.313**
19	**Gs 2.5 (27)**	Wheat	**7.470**
16	**Ms 1.3 (19)**	Wheat	**7.243**
21	**Gs 2.3 (32)**	Wheat	**7.328**
3	**Oa 2.2(4)**	Wheat	**7.177**

23	**Gs 2.5 (26)**	Wheat	**7.213**
24	**Gs 2.3 (33)**	Wheat	**7.332**

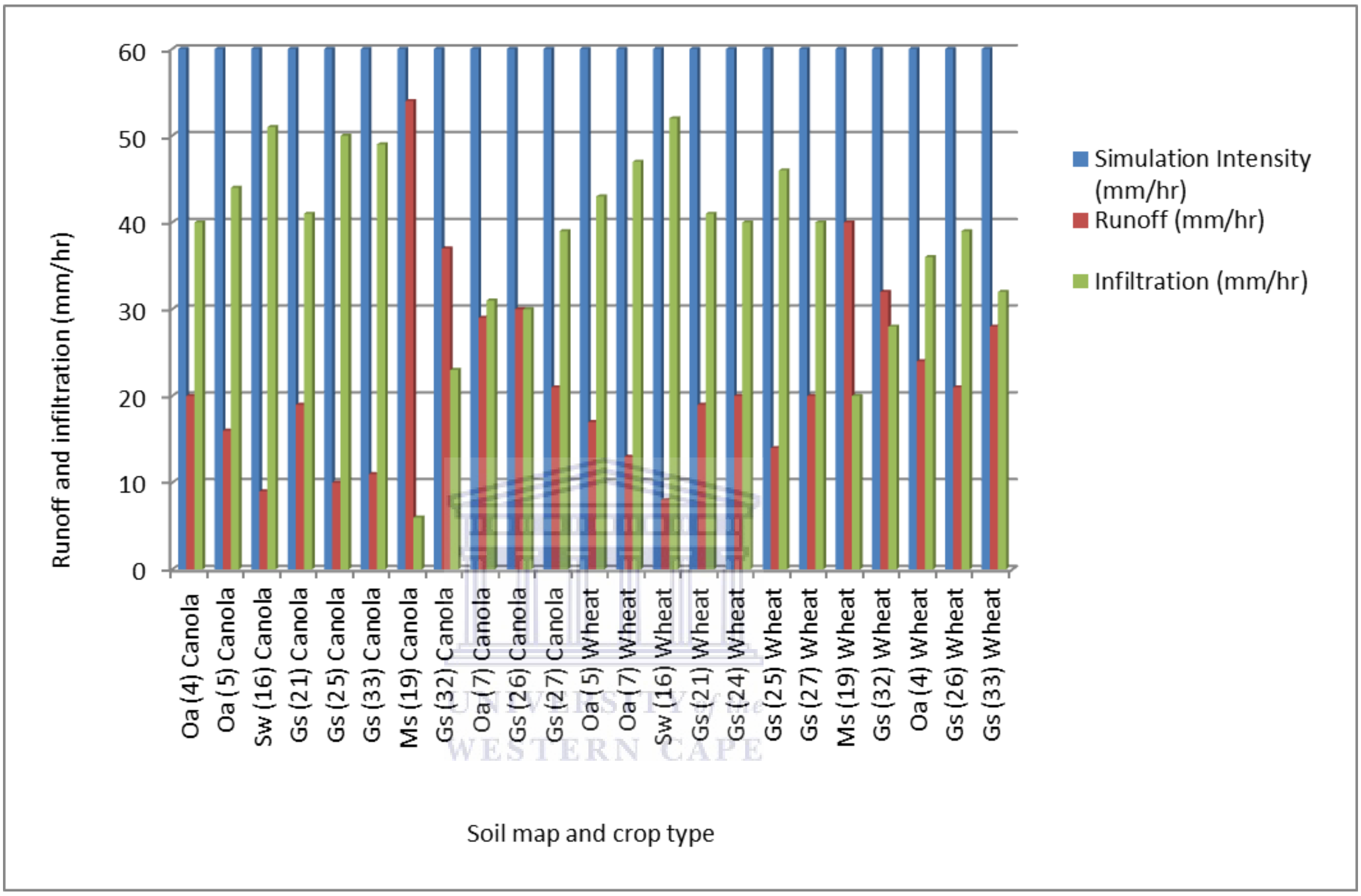


Figure 4.1 Indicates run-off and infiltration in mm/hr. generated through rainfall simulation at the various sites

Because the infiltration was calculated using the difference between the incoming simulated rainfall and the measured run-off as indicated above, there was an inverse relationship between run-off and infiltration. When run-off was low, the infiltration was high and vice versa.

Usually one would expect soils with high organic matter content to show high infiltration and low run-off rates, because organic matter increases soil permeability. A comparison of the infiltration results displayed in Figure 4.1 with the organic matter content for each of the simulation sites in Table 4.1 clearly shows that organic matter content is one of the factors affected the amount of infiltration and run-off rates in the study area. In the following sections, the infiltration results for the different sites are discussed in detail.

Table 4.2 Summarises the infiltration results obtained with the simulations done on the various soil types under similar rainfall intensities.

Soil map symbol, grid number and crop type	Gradient of the soil surface (%)	Simulation period (minutes)	Infiltration Rate (mm/hr.)		Moisture content (%) at different depths after simulation		
			At start	At end	Surface 10mm	50mm	100mm
Oa 2.2(4) Canola	**18.11**	**65**	**55**	**40**	**17**	**17**	**9**
Oa 2.4(5) Canola	**17.14**	**68**	**54**	**44**	**19**	**13**	**5**
Sw 2.5(16) Canola	**18.23**	**51**	**60**	**51**	**5**	**10**	**7**
Gs 3.5(21)	**19.55**	**80**	**51**	**41**	**8**	**8**	**9**

Canola								
Gs 3.3(25) Canola	**20.00**	**65**	**58**	**50**	**19**	**11**	**7**
Gs 2.3 (33) Canola	**17.55**	**70**	**58**	**49**	**9**	**9**	**5**
Ms 1.3 (19) Canola	**18.21**	**43**	**43**	**6**	**21**	**9**	**1**
Gs 2.3 (32) Canola	**18.11**	**46**	**46**	**23**	**13**	**8**	**6**
Oa 2.4(7) Canola	**16.21**	**56**	**56**	**31**	**5**	**4**	**2**
Gs 2.5 (26) Canola	**15.13**	**59**	**44**	**30**	**12**	**10**	**5**
Gs 2.5 (27) Canola	**16.23**	**59**	**54**	**39**	**13**	**10**	**9**
Oa 2.4(5) Wheat	**17.23**	**53**	**60**	**43**	**6**	**9**	**13**
Oa 2.4(7) Wheat	**19.13**	**93**	**52**	**47**	**10**	**7**	**8**
Sw 2.4(16) Wheat	**18.34**	**135**	**55**	**52**	**13**	**6**	**13**
Gs 3.5(21) Wheat	**16.43**	**60**	**57**	**41**	**6**	**9**	**7**

Gs 3.3 (24) Wheat	**20.21**	**93**	**53**	**40**	**7**	**10**	**8**
Gs 3.3(25) Wheat	**19.11**	**74**	**49**	**46**	**21**	**16**	**11**
Gs 2.5 (27) Wheat	**18.14**	**60**	**56**	**40**	**8**	**5**	**6**
Ms 1.3 (19) Wheat	**18.13**	**55**	**42**	**20**	**7**	**6**	**6**
Gs 2.3 (32) Wheat	**17.11**	**107**	**14**	**28**	**13**	**14**	**8**
Oa 2.2(4) Wheat	**20.21**	**63**	**45**	**36**	**10**	**10**	**8**
Gs 2.5 (26) Wheat	**18.14**	**62**	**58**	**39**	**14**	**11**	**8**
Gs 2.3 (33) Wheat	**17.23**	**91**	**49**	**32**	**9**	**7**	**7**

The codes in column one correspond to the codes on the preliminary soil map of the Langgewens area of June 2007 and the number in brackets to the grid number on the same map indicating where the particular simulation was performed. The gradient in column two is the gradient of the area where the simulation was done. "Infiltration rate" given in millimetres/hour is the difference between the incoming rainfall and the measured runoff (converted to mm/hr.). These are calculated for the first sample taken after runoff was initiated as well as the last one for the simulation. Moisture content was calculated for samples taken at various depths from the ring area after completion of the simulation and this is illustrated in column five. Because all the simulations were done during summer, the initial moisture content of the soil for all simulations was very low.

The results displayed in column five, therefore give some indication of the ease with which water infiltrated into the various soils towards the end of each simulation. Comparing these values with those from other columns, as well as with the observed soil structure, could help to clarify the reasons for the variations in the infiltration rates for the various soils.

This section gives an overview of the infiltration results, simulations were divided into two categories :simulation sites showing relatively high infiltration rates (>40 mm/hr), then looking at those with moderate infiltration rates (between 20mm/hr. to 39mm/hr.) and those with lower infiltration rates (< 20mm/hr.).

4.1.1 Comparing simulations of various soil types under canola and wheat vegetation covers

4.1.1.1 Simulation 13 Sw 2.4(16) under canola and simulation 22 Sw 2.4(16) under wheat vegetation covers

Infiltration rates under canola vegetation cover varied between 60 mm/hr. initially, when run-off started, and 51 mm/hr. towards the end of the simulation. The first run-off for this simulation happened only after 51 min and the entire simulation process lasted for 1 hr. and 45min. As for simulation under wheat cover, it only experienced its first run-off after 90 min and simulation process lasted for 2 15 min. The vegetation cover for both simulated area was 65% but wheat crop is more densely populated than canola crop, as a result, simulation 22 experienced higher infiltration rates than simulation 13 mainly because of the vegetation cover and its density.

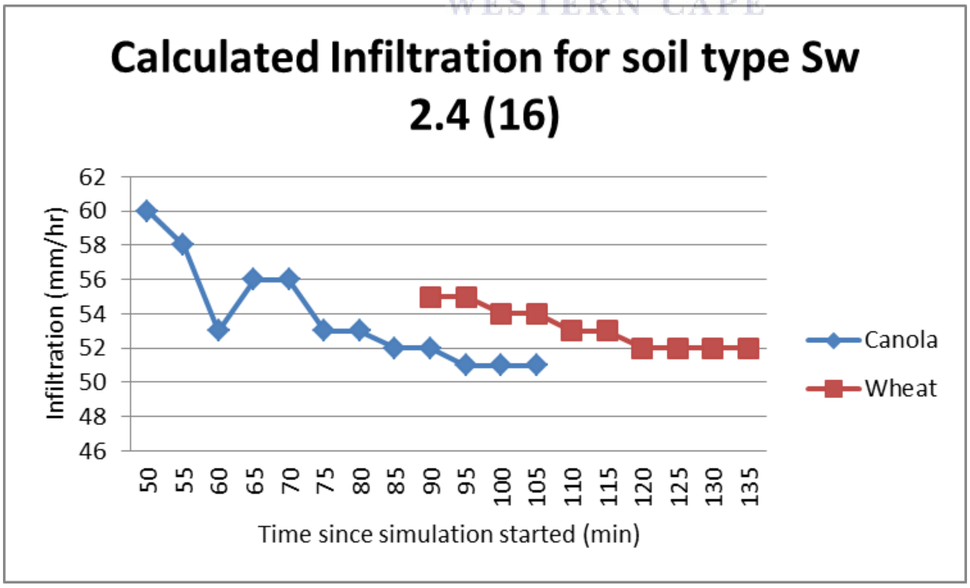


Figure 4.2 Indicates infiltration curve for simulation 13 and 22

Simulation under canola vegetation cover was done on a south-facing slope of 18.23%. The soil type for this location was of the Swartland Form (Sw) and it had an organic content of 7.55g/l.

Simulation under wheat vegetation cover was done on a south-facing slope of 18.34%. The soil type for this location was of the Swartland Form (Sw) and it had an organic content of 7.609g/l. As expected, the soil with higher organic matter content had high infiltration rate because organic matter increases the soil infiltration capacity and permeability.

The distribution of moisture content in the soil within the ring area directly under a wheat and canola row after completion of the simulation, is illustrated in Figure 4.3. It indicates a general downward trend of decreasing in the moisture content dropping from 17% at the surface to approximately 10% at 100mm depth under canola vegetation cover and 14% at the surface to approximately 8% at 100mm depth under wheat vegetation cover. Moisture content under wheat cover is slightly higher than at canola cover, probably because of different vegetation cover and its density. The increase in moisture content at the surface and 50mm is explained by the high organic matter content of the soil and also that it took more than an hour to experience the first runoff. This shows that water had enough time to infiltrate greater depth.

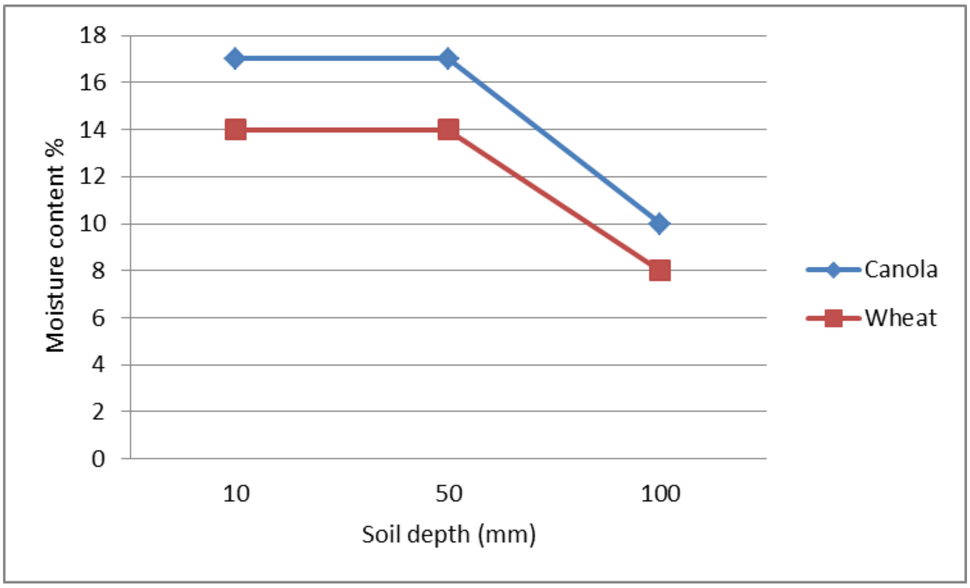


Figure 4.3 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 13 and 22

4.1.1.2Simulation 6 Gs 3.3(25) under canola and simulation 12 Gs 3.3(25) under wheat vegetation covers

Simulation 6 had the longest "time to run-off" of all the simulations under canola vegetation. The calculated infiltration curve for simulation 6 and 12 is illustrated in Figure 4.4

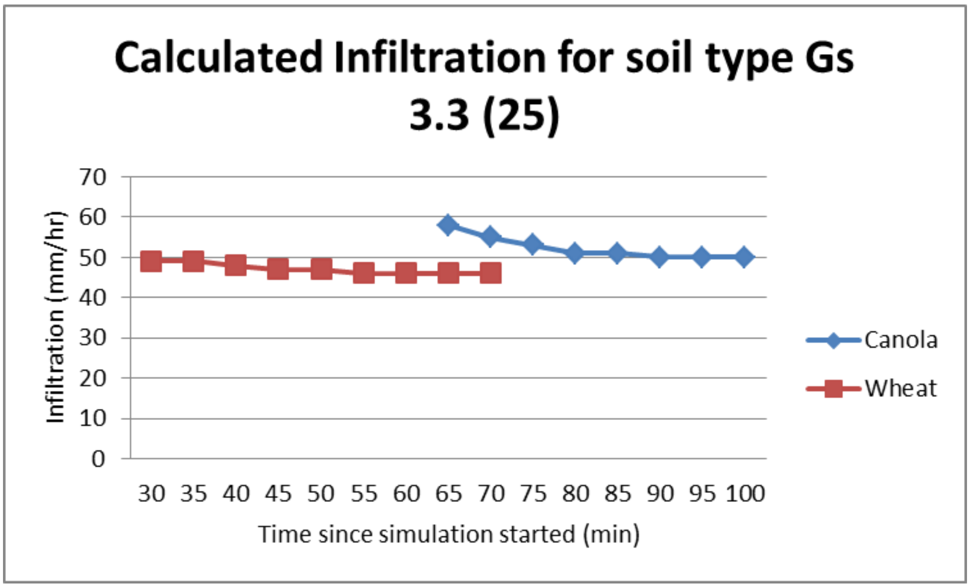


Figure 4.4 Indicates infiltration curve for simulations 6 and 12

Infiltration rates under canola vegetation cover varied between 58 mm/hr. initially, when run-off started, and 50 mm/hr. towards the end of the simulation. The first run-off for this simulation happened only after 1 hr. and 5 min and the entire simulation process lasted for 1 hr. and 30min.

Infiltration rates under wheat vegetation cover varied between 49 mm/hr. initially, when run-off started, and 46 mm/hr. towards the end of the simulation. The first run-off for this simulation happened only after 30 min and the entire simulation process lasted for 1 hr. and 10 min.

Simulation under canola vegetation cover was done on a south-facing slope of 20.00%. The soil type for this location was of the Glenrosa Form (Gs) and it had an organic content of 7.55g/l.

Simulation under canola vegetation cover was done on a south-facing slope of 19.11%. The soil type for this location was of the Glenrosa Form (Gs) and it had an organic content of 8.313g/l.

The moisture content decreased with depth from 19% at the surface, to a low value of 11% at a depth of 50mm, and then it increases to 13 at 100mm depth. This can be explained by the presence of a well-developed dry root system that left small tubes or tunnels in the ground, allowing the quick movement of water from surface downwards to accumulate at a depth of 100mm.

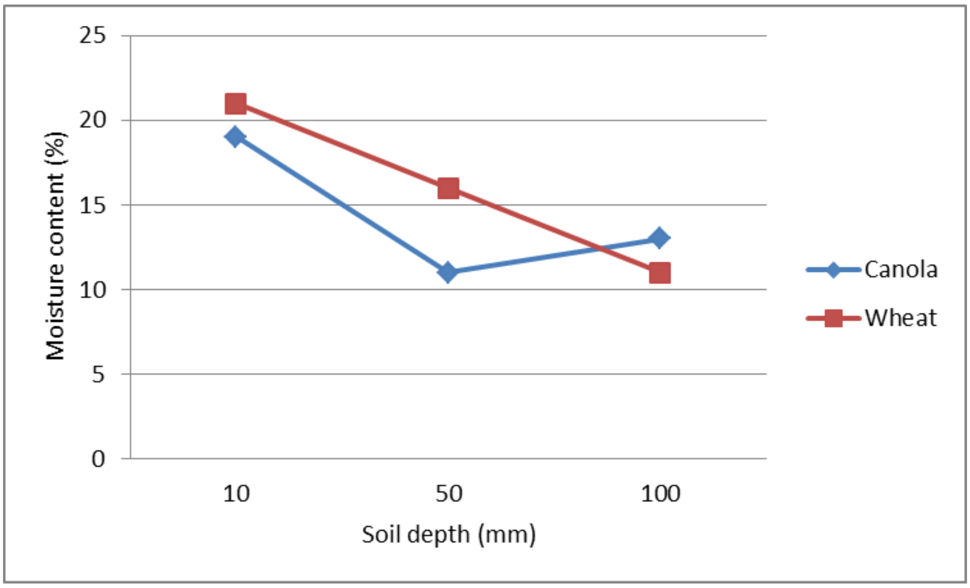


Figure 4.5 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 6 and 12

4.1.1.3 Simulation 17 Gs 2.3(33) under canola and simulation 24 Gs 2.3(33) under wheat vegetation covers

Simulation under canola vegetation cover was done on a north-facing slope, where the gradient was approximately 17.55% and the surface had a 70% cover of dry canola stems. The soil belongs to the Glenrosa Form (Gs) and had an organic matter content of 7.122g/l.

Simulation under wheat vegetation cover was done on a north-facing slope, where the gradient was approximately 17.32% and the surface had a 60% cover of dry canola stems. The soil belongs to the Glenrosa Form (Gs) and had an organic matter content of 7.332g/l. the calculated infiltration curve for these simulations is illustrated in Figure 4.6 below.

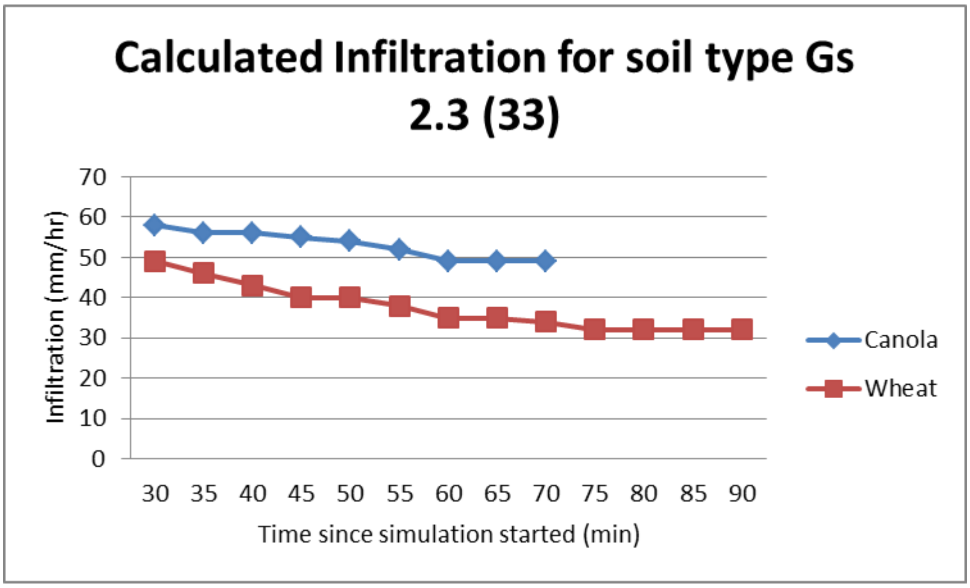


Figure 4.6 Indicates infiltration curve for simulations 17 and 24

The infiltration rate at the start of run-off after 30min of the simulation under canola vegetation cover was 58 mm/hr., dropping to 49 mm/hr. at the end of the simulation. The first run-off happened in the 30th min of simulation and the entire simulation process took 1 hr. and 10 min.

The infiltration rate at the start of run-off after 30min of the simulation under wheat vegetation cover was 49 mm/hr., dropping to 32 mm/hr. at the end of the simulation. The first run-off happened in the 30th min of simulation and the entire simulation process took 1 hr. and 30 min.

The moisture content decreased with depth from 9% at the surface, to a low value of 8% at a depth of 50mm, and then it increases to 10 at 100mm depth under 70% of canola vegetation cover. This can be explained by the presence of a well-developed dry root system that left small tubes or tunnels in the ground in both simulation sites, allowing the quick movement of water from surface downwards to accumulate at a depth of 100mm.

The moisture content directly under wheat vegetation cover varied between 9% at the surface and 7% at 100mm depth. Interestingly, the rate of decrease in the profile was more or less constant, showing that the soil was relatively uniform in the top 100mm beneath the wheat vegetation.

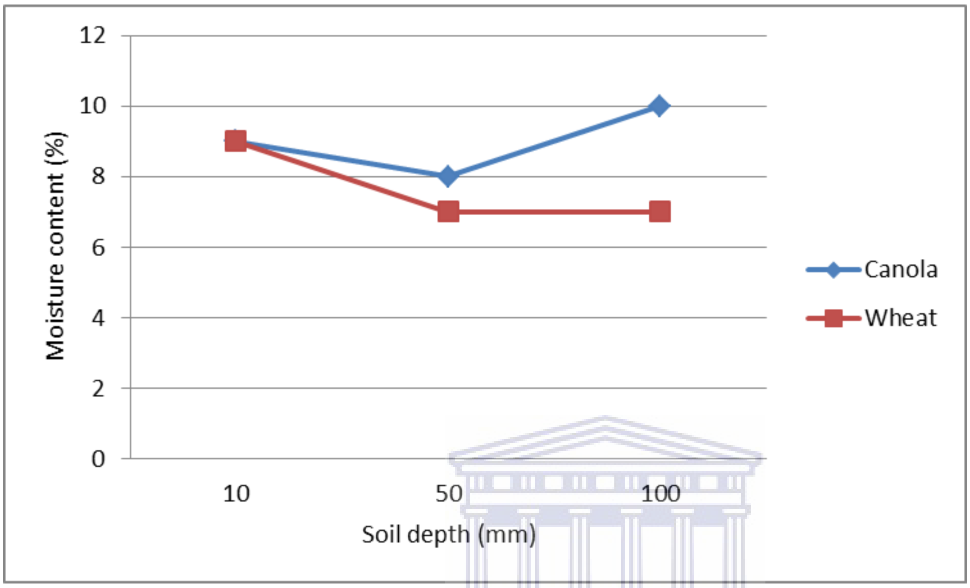


Figure 4.7 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 6 and 12

4.1.1.4 Simulation 2 Oa 2.4(5) under canola and simulation 4 Oa 2.4(5) under wheat vegetation covers

Simulation 2 and 4 were done on a north-facing slope with gradient of 17.14% and 17.23% respectively and the surface was covered by dry wheat and canola stems, because it was after the harvesting season.

The soil for these particular sites had an organic matter content of 6.432g/l and 7.373g/l respectively and was of the Oakland Form (Oa). The first run-off happened after 28 min for simulation 2 and 8 min for simulation 4. The simulation process lasted for approximately 1 hr. and 8 min for simulation 2 and 53 min for simulation 4.

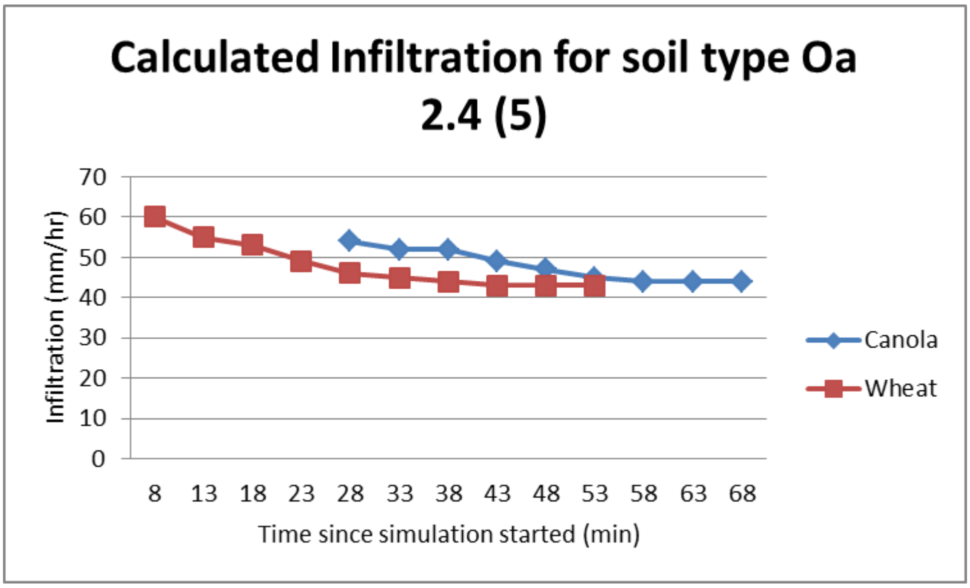


Figure 4.8 Indicates infiltration curve for simulations 2 and 4

The trend was a downward one as could have expected, but it fluctuated slightly under canola vegetation cover. The infiltration rate at the start of run-off was 54 mm/hr. and towards the end of the simulation, it was 44 mm/hr. the trend was a downward one under wheat vegetation cover as expected with the infiltration rate at the start of run-off being 60 mm/hr. and drops towards the end of simulation to 43 mm/hr. Both simulations had the same infiltration rate at the end of simulation process.

The distribution of moisture in the soil beneath a wheat and canola vegetation cover in the ring area of simulation 2 and 4 is illustrated in Figure. The curves indicates a general downward trend of decrease in moisture content, varying from 19% at the surface to 5% at 100mm for simulation 2 and 9% at the surface to 4% at 100mm for simulation 4. This could have been the result of soil composition and soil material arrangement in both simulation sites.

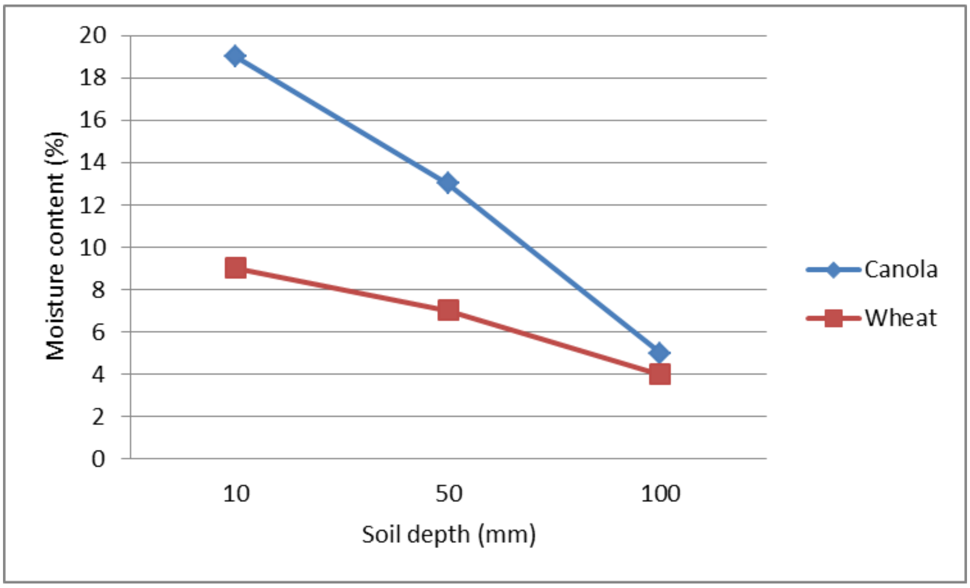


Figure 4.9 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 2 and 4

4.1.1.5 Simulation 8 Gs 3.5(21) under canola and simulation 5 Gs 3.5(21) under wheat vegetation covers

Simulation 8 and 5 are illustrated in Figure 4.10. Infiltration rates varied from an initial rate of 51 mm/hr. and 57 mm/hr. respectively when run-off started, to 41 mm/hr. at the end of both simulation site 8 and 5. Both simulation sites fall within category 1 for simulations with relatively high infiltration rate.

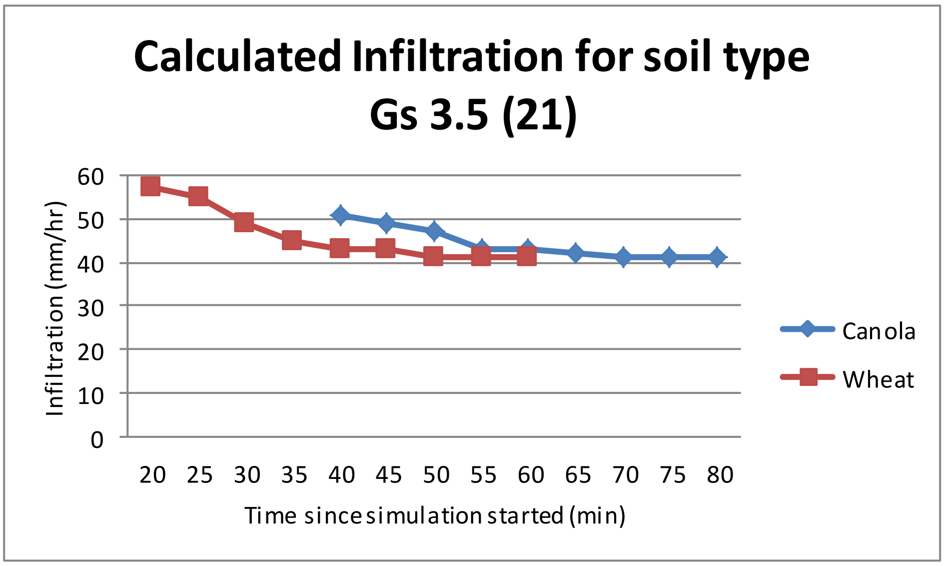


Figure 4.10 Indicates infiltration curve for simulations 5 and 8

These simulations were done on a south-facing slope of approximately 19.55% and 16.43 % respectively, where the soil was of Glenrosa Form (Gs) and had an organic matter content of 7.323g/l and 7.139g/l respectively. The micro topography of the soil surface within the ring was similar to that of the previous simulation site, except that smaller cracks were present.

The distribution of moisture in the soil within the ring area directly under a wheat and canola vegetation cover, after completion of the simulations, is illustrated in Figure 4.11. It indicates a general downward trend of decrease in the moisture content dropping from 8% to 6% for simulation 8 and 9% to 7% for simulation 5. This is slightly lower than previous site, probably because of different soil type.

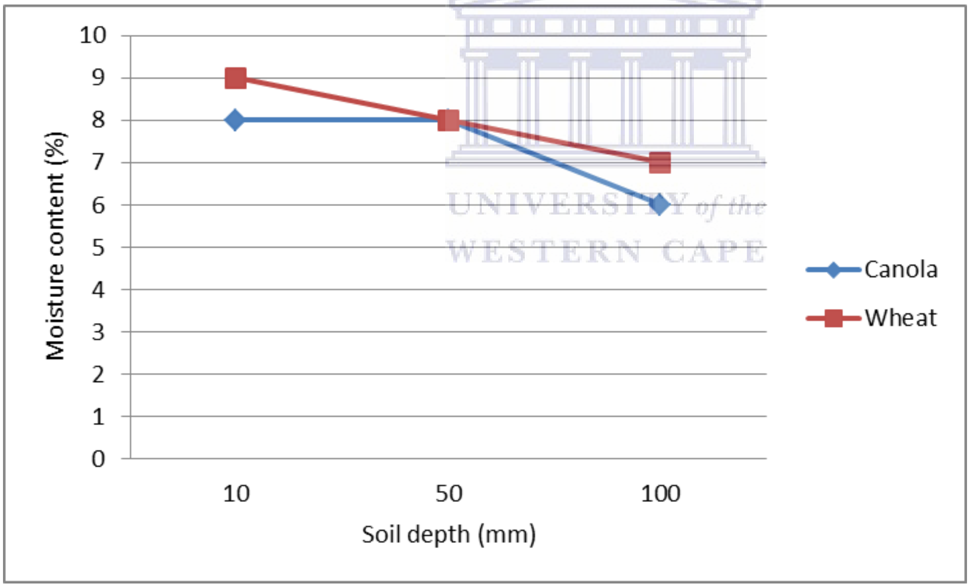


Figure 4.11 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 5 and 8

4.1.1.6 Simulation 1 Oa 2.2(4) under canola and simulation 3 Oa 2.2(4) under wheat vegetation covers

Simulation 1 had a total duration of 1 hr. and 5 min and run-off started after 20min while simulation 3 had a total duration of 1 hr. and 5 min and run-off started 15min. The calculated infiltration curves for these simulations are illustrated in Figure 4.12.

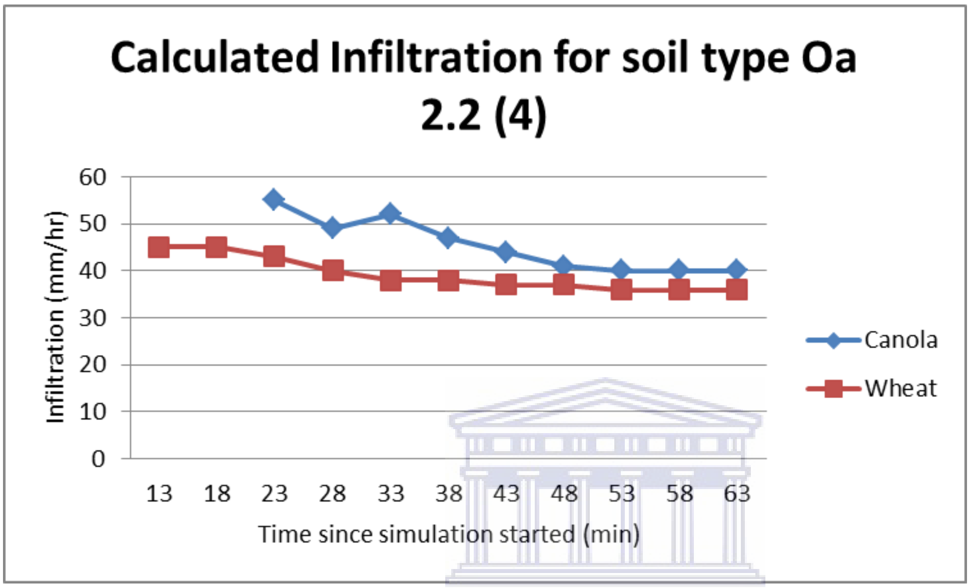


Figure 4.12 Indicates infiltration curve for simulations 1 and 3

The simulations were done on a north-facing slope with gradients of 18.11% and 20.21% respectively. The simulation sites had soils belonging to the Oakland (Oa), with organic matter content of 7.342g/l and 7.177g/l respectively. The surface simulation site 1 was covered by dry canola stems and dry wheat stems for simulation site 3, where the root systems of the already harvested crops were slightly better developed. Cracks of different dimensions were observed at simulation 1, this could be an explanation for slightly higher infiltration rate at site 1 than on simulation site 3. In this case, the factor that played the major role in different vegetation covers was the availability of cracks on simulation site 1 and vegetation density of wheat on simulation site 3.

At the beginning of run-off for simulation 1, the infiltration rate was 55 mm/hr. and at the end, it was 40 mm/hr. while simulation 3 had infiltration rate of 45 mm/hr. at the beginning of simulation and 36 mm/hr. at the end of simulation process. The distribution of moisture after completion of the simulation in the soil within the ring area is illustrated in Figure 4.13 below.

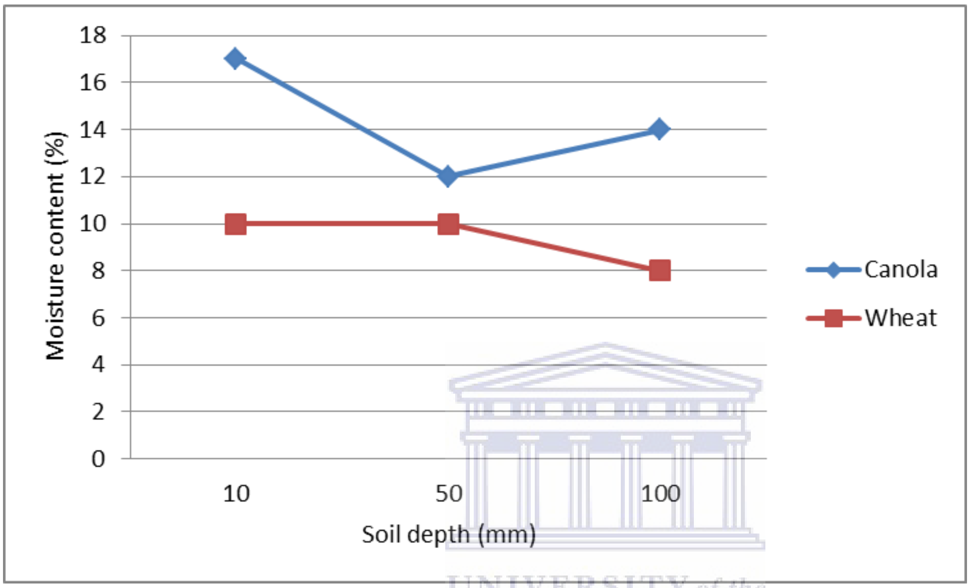


Figure 4.13 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 1 and 3

The moisture content decrease with depth from 17% at the surface to 12% at 50mm depth, then it increases to 14% at 100mm depth for simulation 1. This can be explained by the presence of a well-developed dry root system that left small tubes or tunnels in the ground, allowing the quick movement of water from the surface downwards to accumulate at a depth of 100mm, while moisture distribution in simulation 3 indicates general decrease in moisture content from 10% at the surface to 8% at 100mm depth.

4.1.1.7 Simulation 15 Gs 2.5 (27) under canola and simulation 19 Gs 2.5 (27) under wheat vegetation covers

These simulations were done on south-facing slope with a gradient of 16.23% and 18.14% respectively on soils of Glenrosa Form (Gs). The organic matter content of 7.133g/l for simulation 15 and 7.470g/l for simulation 27.

It has been widely reported in literature that roots can cause hydrological effects, when they increase surface roughness and soil permeability; they also increase the soils infiltration capacity (Poesen and Hooke, 1987). Cracks and the development of a visible micro topography were identified as the factors that allowed water to infiltrate into the soil with ease.

The calculated infiltration curve for simulation 15 and 19 is illustrated in Figure 4.14 below. Simulation 15 shows an infiltration rate of 54 mm/hr. at the start of simulation and 39 mm/hr. towards the end of simulation process, this simulation falls in category 2 (simulations with moderate infiltration rate between 20 mm/hr. to 39mm/hr.), while simulation 19 had infiltration rate of 56 mm/hr. at the start of simulation and 40 mm/hr. at the end of simulation process and it falls in category 1 for simulation with high infiltration rate. Run-off started after 20 min of simulation and lasted for 1 hr. in both simulations 15 and 19.

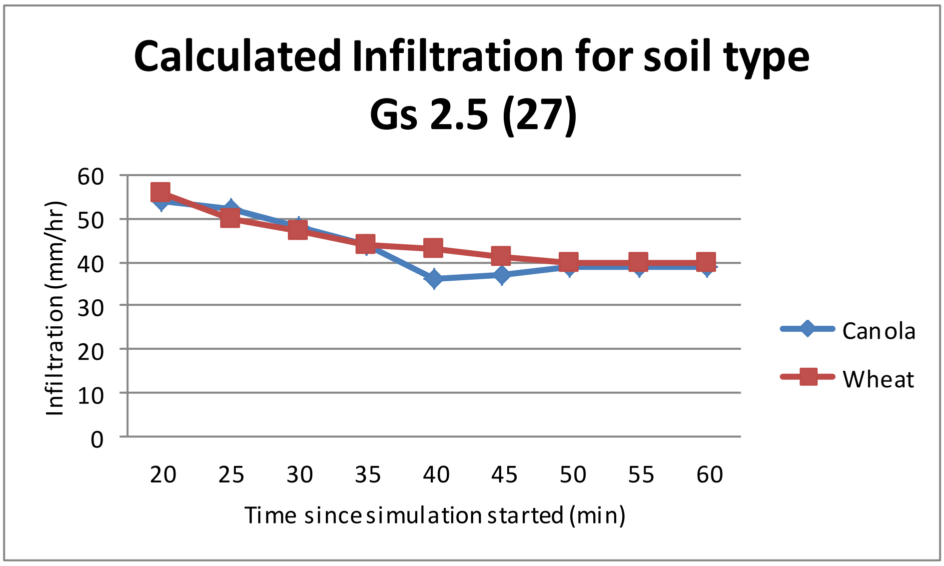


Figure 4.14 Indicates infiltration curve for simulations 15 and 19

The moisture content for the soils directly beneath a wheat and canola vegetation cover is shown in Figure 4.15. The moisture content ranged between approximately 13% at the surface and dropped to 5% at 50mm and then increases to 9% at 100mm depth for simulation 15. This can be explained by the availability of dry canola stems and well developed root system. Simulation 19 on the other hand indicates the general trend of decreasing moisture content of 8% at the surface to 6% at 100mm depth.

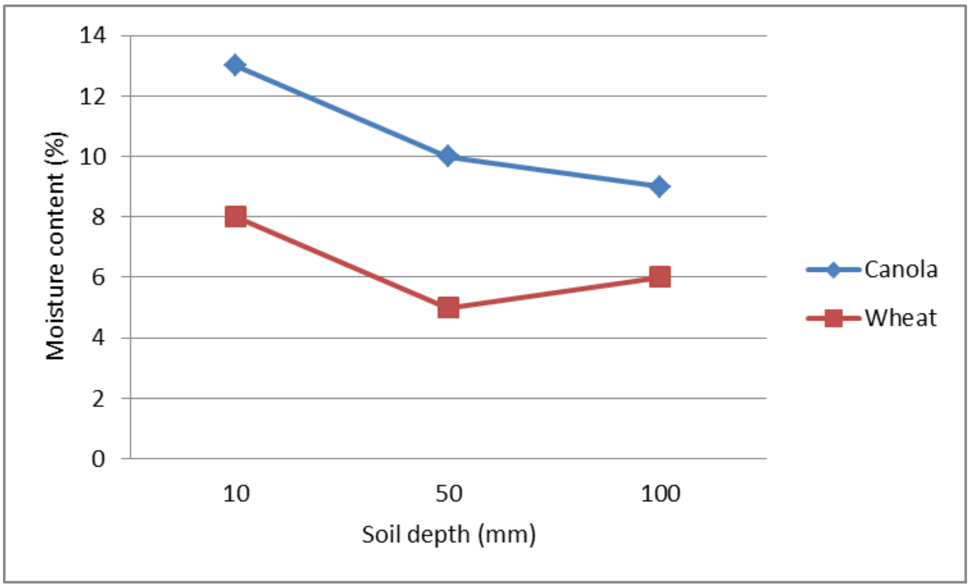


Figure 4.15 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 15 and 19

4.1.1.8 Simulation 20 Gs 3.3 (24) under canola and simulation 18 Gs 3.3 (24) under wheat vegetation covers

Simulation 20 and 18 are illustrated in Figure 4.16. Infiltration rates varied from an initial rate of 50 mm/hr. and when run-off started, to 36 mm/hr. at the end of simulation 20, this simulation falls in category 2 (simulations with moderate infiltration rate between 20 mm/hr. to 39mm/hr.) while simulation 18 had infiltration rate 53 mm/hr. at the beginning of simulation and dropped to 40 mm/hr. at the end of simulation process. Simulation 18 had relatively high infiltration rate compared to simulation 20 because of the present of cracks in simulation 18 that increased permeability of the soil and allowed water to infiltrate with ease.

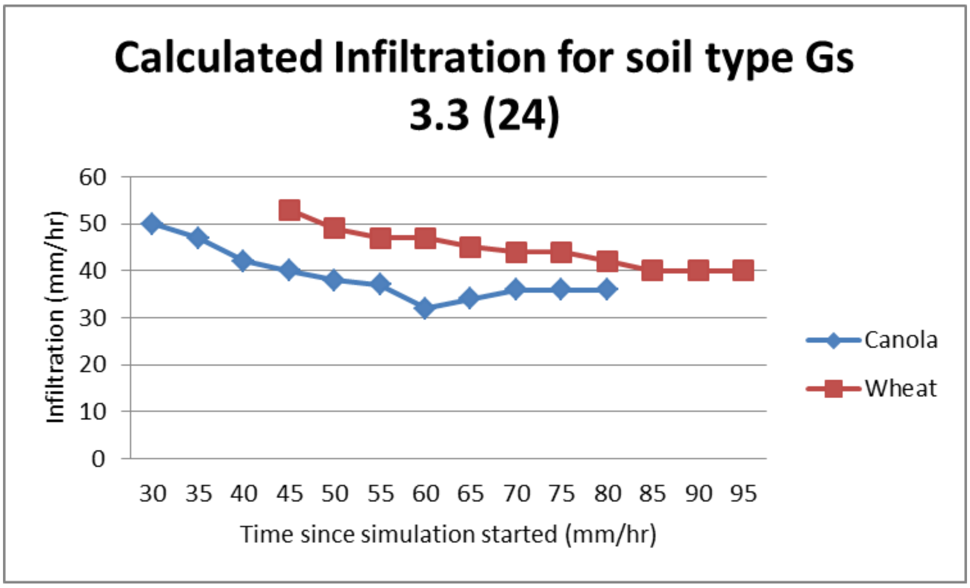


Figure 4.16 Indicates infiltration curve for simulations 20 and 18

These simulations were done on a south-facing slope of approximately 19.55% and 20.21 % respectively, where the soil was of Glenrosa Form (Gs) and had an organic matter content of 7.324g/l and 7.314g/l respectively. The micro topography of the soil surface within the ring was similar both simulation site, except that smaller cracks were present at simulation 18.

The distribution of moisture in the soil within the ring area directly under a wheat and canola vegetation cover, after completion of the simulations, is illustrated in Figure 4.17. It indicates a general downward trend of decrease in the moisture content dropping from 8% to 4% for simulation 20 and 9% to 8% for simulation 18. Simulation 18 is slightly lower than simulation site 18, probably because of different crop type and cracks present on the simulation site.

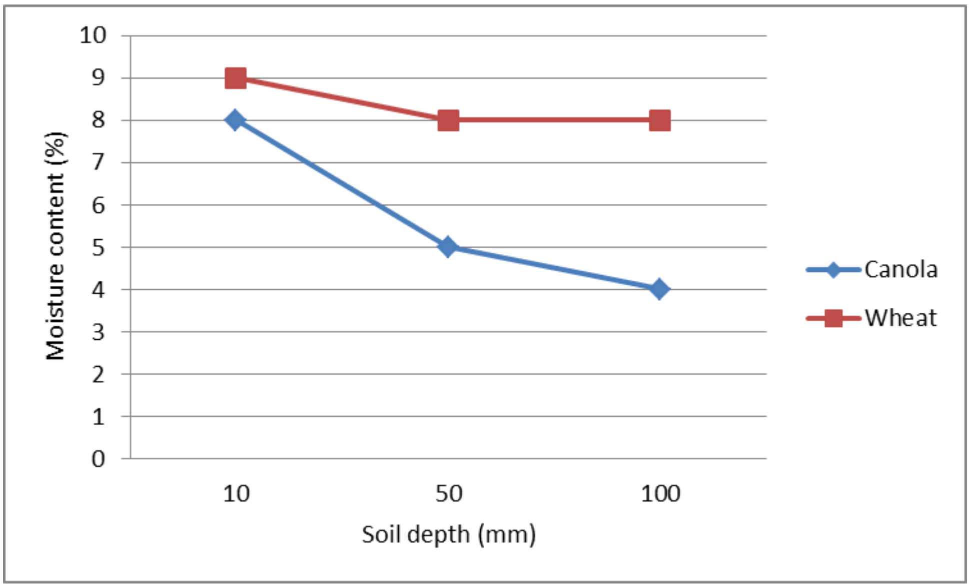


Figure 4.17 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 20 and 18

4.1.1.9 Simulation 14 Gs 2.5 (26) under canola and simulation 23 Gs 2.5 (26) under wheat vegetation covers

Simulation 14 and 23 were done on a north-facing slope with gradient of 18.14% and 15.13% respectively and the surface was covered by 30% dry wheat and canola stems, because it was after the harvesting season.

The soil for these particular sites had an organic matter content of 7.700g/l and 7.213g/l respectively and was of the Glenrosa Form (Gs). The first run-off started in 14 min for simulation 14 and 17 min for simulation 23. The simulation process lasted for approximately 1 hr. for simulation 14 and 1 hr. and 5 min for simulation 23. The calculated infiltration curves for these simulations are illustrated in Figure 4.18 below.

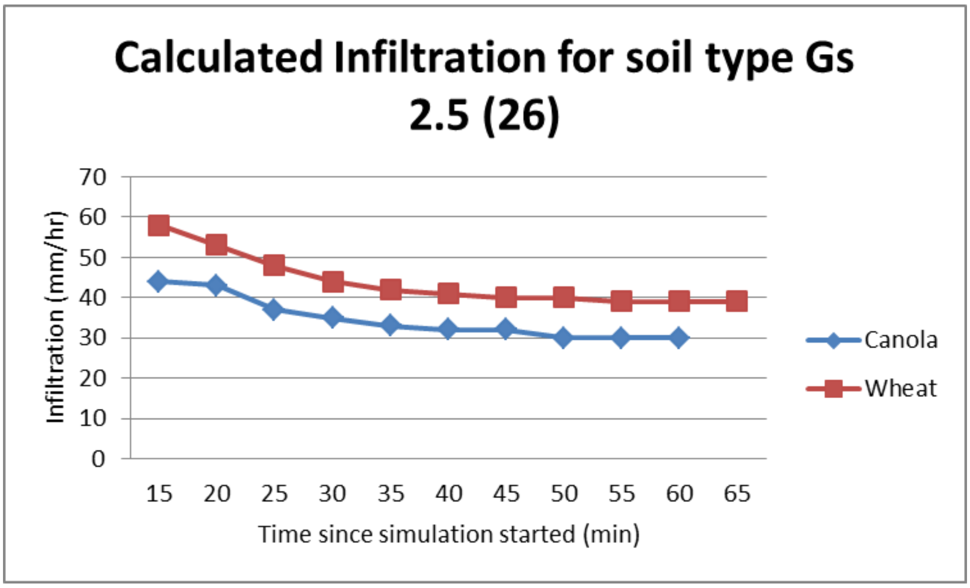


Figure 4.18 Indicates infiltration curve for simulations 14 and 23

The infiltration rate ranged between 44 mm/hr. at the start of run-off and 30 mm/hr. at the end of the simulation 14 while simulation 23 had infiltration rate of 58 mm/hr. at the start of run-off and 39 mm/hr. at the end of the simulation. Both simulations falls in category of moderate infiltration rate (between 20 mm/hr. to 39 mm/hr.).

The vertical distribution of moisture beneath wheat and canola vegetation covers in the ring area is illustrated in Figure 4.19. Here the moisture content decreased smoothly from 12% to 5% for simulation 14 and 14% to 8% for simulation 23. It seems that, because of the steeper slope (18.14%) and the low vegetation density, water drained away quite quickly, allowing little time to infiltrate to greater depth.

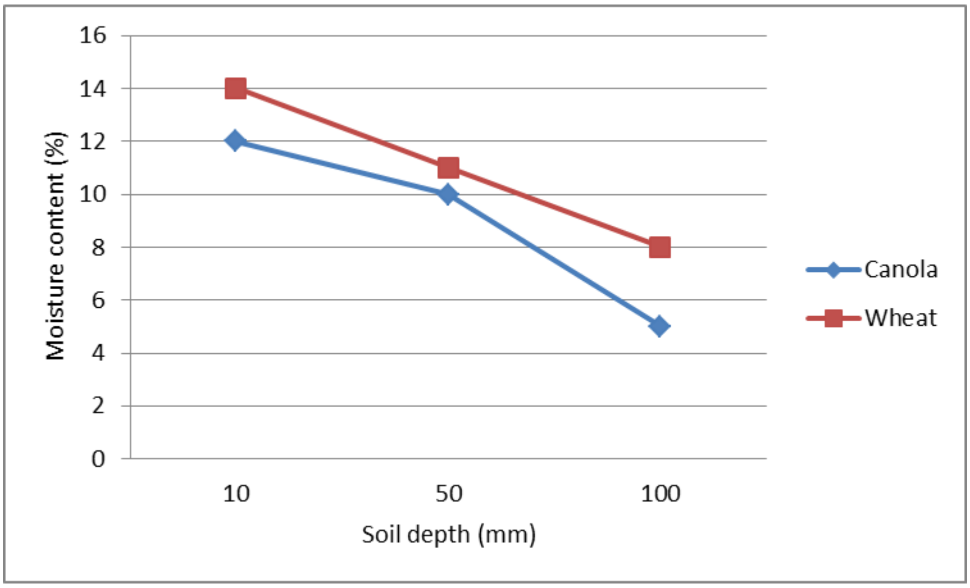


Figure 4.19 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 14 and 23

4.1.1.10 Simulation 7 Oa 2.4(7) under canola and simulation 10 Oa 2.4(7) under wheat vegetation covers

Simulation 7 and 10 are illustrated in Figure. Infiltration rates varied from an initial rate of 56 mm/hr. and when run-off started, to 31 mm/hr. at the end of simulation 7, this simulation falls in category 2 (simulations with moderate infiltration rate between 20 mm/hr. to 39mm/hr.) while simulation 10 had infiltration rate 52 mm/hr. at the beginning of simulation and dropped to 47 mm/hr. at the end of simulation process. Simulation 10 had relatively high infiltration rate compared to simulation 7 because of the present of cracks in simulation 10 that increased permeability of the soil and allowed water to infiltrate with ease.

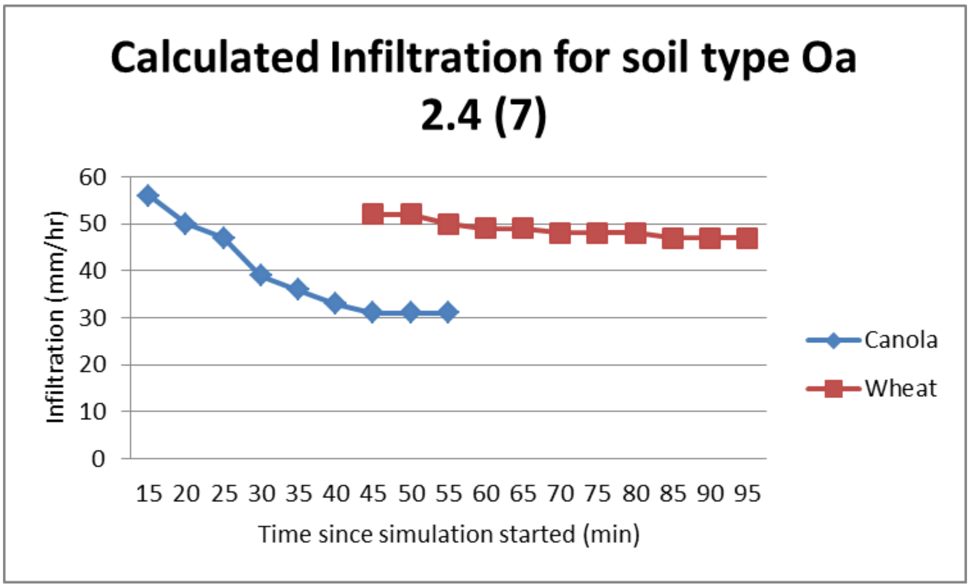


Figure 4.20 Indicates infiltration curve for simulations 7 and 10

The moisture content generally decreased from approximately 5% at the surface to 2% at 100mm depth for simulation 7, while simulation 10, moisture content decreased from approximately 10 % at the surface, decreased to 7% at 50mm depth, then increases to 8% at 100mm depth. This could have been because of the cracks observed in the ring area.

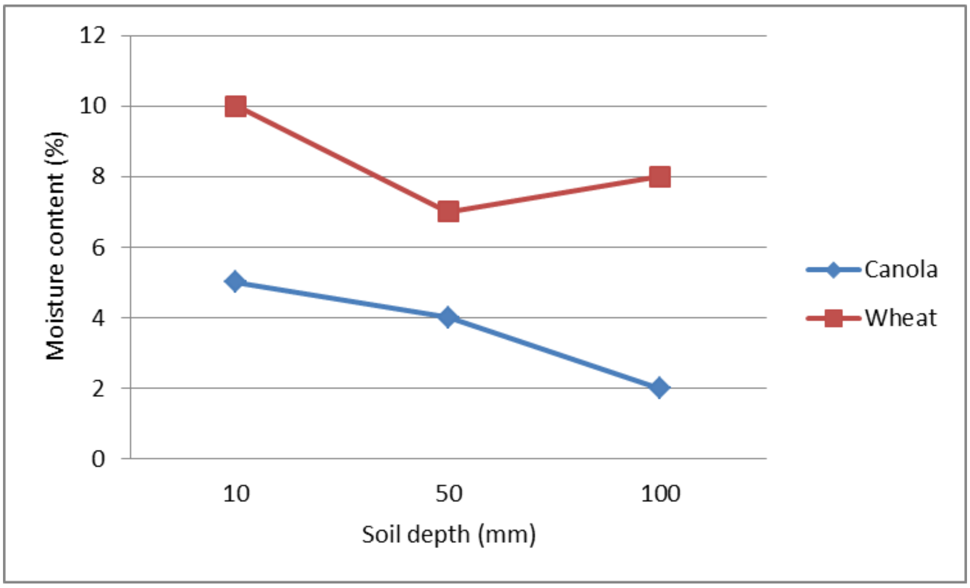


Figure 4.21 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 7 and 10

4.1.1.11 Simulation 9 Gs 2.3 (32) under canola and simulation 21 Gs 2.3 (32) under wheat vegetation covers

Simulation 9 and 21 are illustrated in Figure 4.22. Infiltration rates varied from an initial rate of 56 mm/hr. when run-off started, to 23 mm/hr. at the end of simulation 9, while simulation 21 had infiltration rate of 43 mm/hr. at the beginning of the simulation and 28 mm/hr. at the end of simulation process.

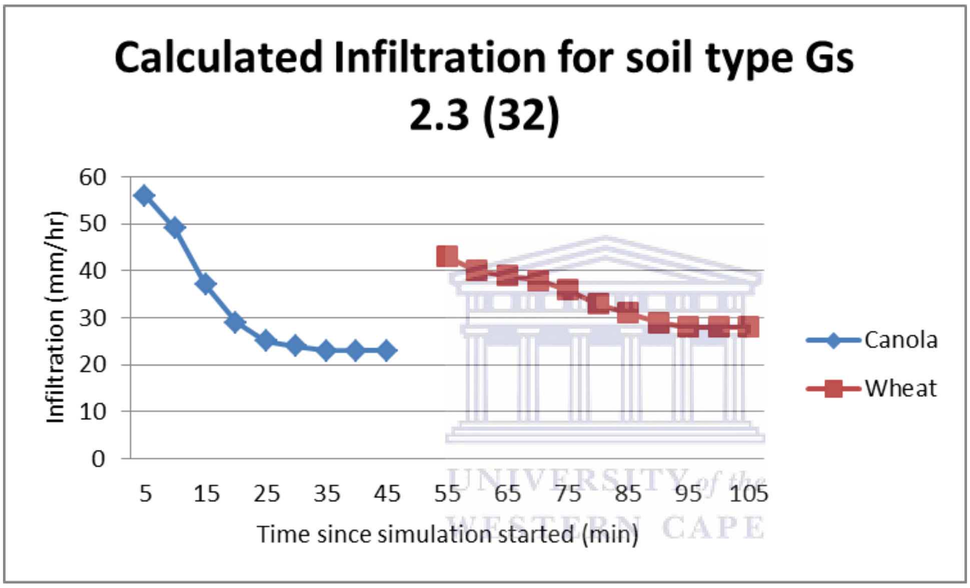


Figure 4.22 Indicates infiltration curve for simulations 9 and 21

Figure 4.23 indicates an evenly decreasing distribution of the moisture content at both simulation sites. It is clear that a large percentage of the moisture was concentrated at the surface, where materials such as clay were present. At the surface the moisture content was approximately 13%, decreasing to approximately 5% at a depth of 100mm for simulation 9 and decreased from approximately 12% at the surface to 5% at 100mm depth for simulation 21.

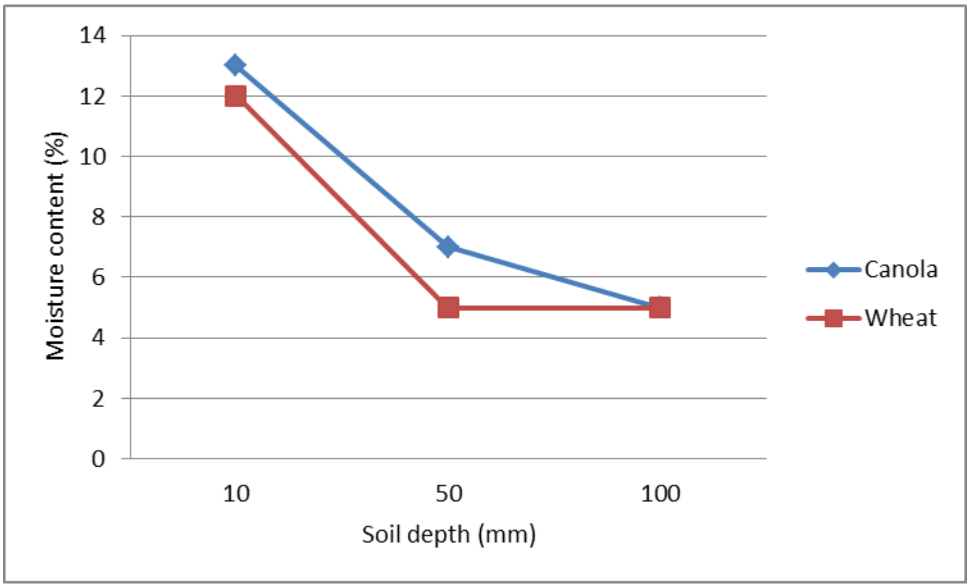


Figure 4.23 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 9 and 21

4.1.1.12 Simulation 11 Ms 1.3 (19) under canola and simulation 16 Ms 1.3 (19) under wheat vegetation covers

Simulations in the sites fall under category showing low infiltration rates (less than 20mm/hr.). The time to run-off during the simulations varied between 51 mm/hr. at the start of the simulation to 6 mm/hr. at the end of simulation process for simulation 11 while simulation 16 varied between 42 mm/hr. at the beginning of the simulation to 20 mm/hr. at the end of simulation.

The surface was covered by wheat and canola stems (15%) that remained after harvesting. The first run-off happened in the 3rd min of simulation and the entire simulation took 43 min for simulation 11 while simulation 16 experienced first run-offs in the 15th min of simulation and the entire simulation lasted for 55 min.

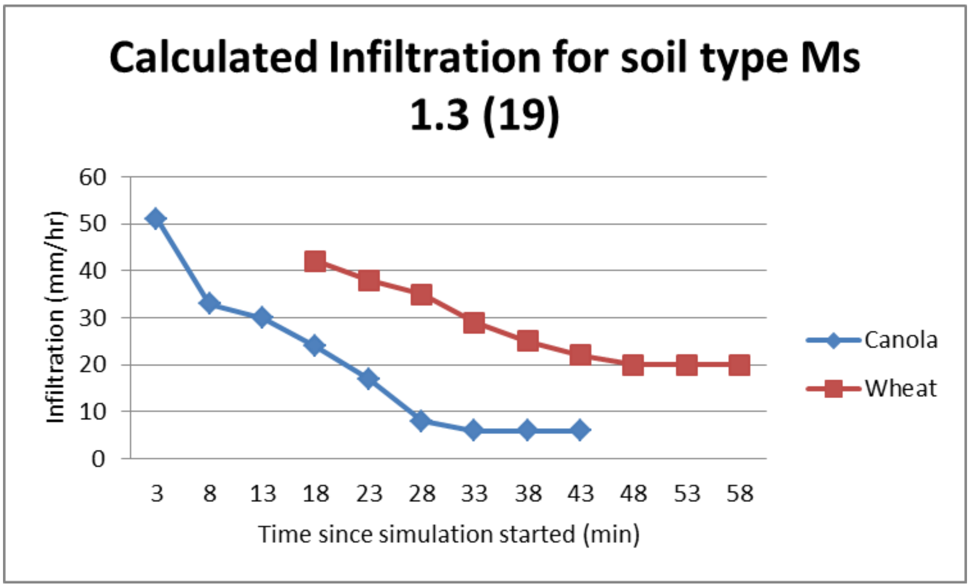


Figure 4.24 Indicates infiltration curve for simulations 11 and 16

The vertical distribution of moisture within the ring area is illustrated in Figure 4.25 below. The moisture content decreased sharply from 7% at the surface to 1% at 100mm depth for simulation 11. It is clear that water only really infiltrated the upper soil horizon, resulting in the relative short time to run-off of approximately 3 min. the clear influence of the canola roots, allowing water to infiltrates (whereas the opposite applies where roots are absent), was well illustrated in simulation 11.

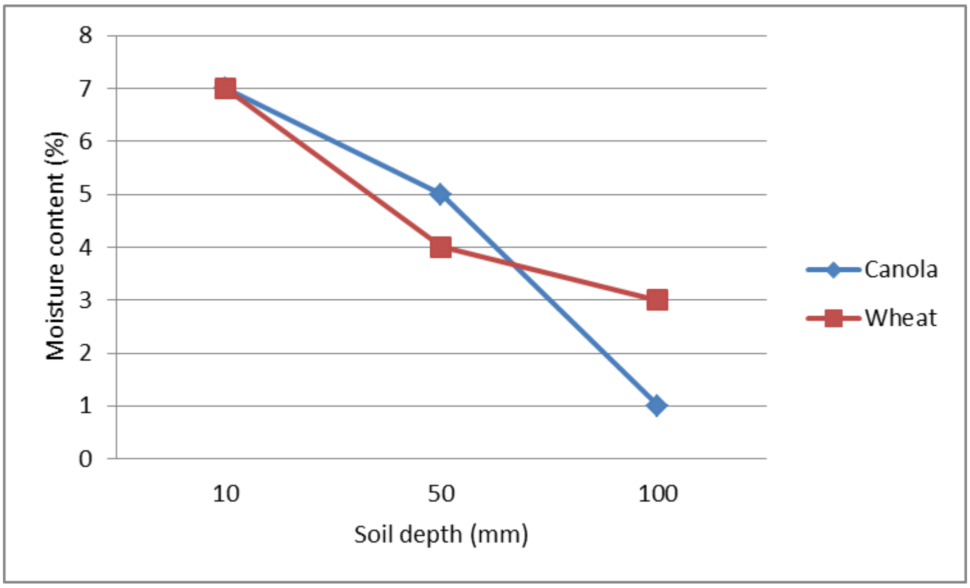


Figure 4.25 Indicates vertical distribution of moisture in the soil directly under wheat and canola row within the ring area of simulation 11 and 16

4.2 Evaluation of run-off

To understand the effects of individual vegetation patches and surface micro topography on run-off at the slope scale, new properties, patterns and processes that are observed at the broader scale have to be taken into consideration. For example, the presence of interrows, and concentration of flow in these, significantly affects the measurement of run-off at the slope scale (Roels, 1984).

The principal environmental issues associated with run-off are the impacts to surface water, groundwater and soil through transport of water pollutants. Ultimately, these consequences results in human health risks, ecosystem disturbance.

The aim of studying the run-off was to answer the question of how the different soil type and vegetation type could influence infiltration rate and run-off. This section gives an overview of run-off characteristics in the Langgewens catchment. The methodology used was discussed in detail earlier in chapter 3 and will not be repeated here. Table 4.3 shows a summary of the simulation results obtained.

Table 4.3 shows a summary of the simulation results obtained.

Soil map, grid number and crop type	Gradient of simulation area (%)	Time to run-off (min)	Simulation period (min)	Run-off (mm/hr.)
Oa 2.2(4) Canola	18.11	20	65	20 L
Oa 2.4(5) Canola	17.14	28	68	16 L
Sw 2.5(16) Canola	18.23	51	105	9 L
Gs 3.5(21) Canola	19.55	40	80	19 L
Gs 3.3(25) Canola	20.00	65	98	10 L
Gs 2.3 (33) Canola	17.55	30	70	11 L
Ms 1.3 (19) Canola	18.21	3	45	54 H
Gs 2.3 (32) Canola	18.11	6	45	37 M
Oa 2.4(7)	16.21			

Canola		15	55	29 M
Gs 2.5 (26) Canola	15.13	15	59	30 M
Gs 2.5 (27) Canola	16.23	20	60	21 L
Gs 3.3 (24) Canola	17.23	30	80	19 L
Oa 2.4(5) Wheat	19.13	8	55	17 L
Oa 2.4(7) Wheat	18.34	43	93	13 L
Sw 2.4(16) Wheat	16.43	90	135	8 L
Gs 3.5(21) Wheat	20.21	20	60	19 L
Gs 3.3 (24) Wheat	19.11	45	95	20 L
Gs 3.3(25) Wheat	18.14	29	70	14 L
Gs 2.5 (27) Wheat	18.13	20	60	20 L

Ms 1.3 (19) Wheat	**17.11**	**15**	**55**	**40 H**
Gs 2.3 (32) Wheat	**20.21**	**52**	**107**	**32 M**
Oa 2.2(4) Wheat	**18.14**	**13**	**63**	**24 M**
Gs 2.5 (26) Wheat	**17.23**	**17**	**63**	**21 L**
Gs 2.3 (33) Wheat	**16.212**	**31**	**90**	**28 M**

H (high run-off) = > 40mm/hr.

M (Moderate run-off) =22 to 39 mm/hr.

L (Low run-off) = < 22 mm/hr.

Considering the run-off data of the above table, one could divide it into three categories: the high run-off category, moderate category and the low category.

Because the infiltration was calculated using the difference between the incoming simulated rainfall and the measured run-off as indicated earlier in this chapter, there was an inverse relationship between run-off and infiltration. When run-off was low, the infiltration was high and vice versa. As a result the high run-off category included the category with relatively low infiltration rate, Mispah soil Form under both wheat and canola vegetation cover. The simulations were done on steeper north facing slopes (>15%). It is clear that these simulations had been expected to have high run-off because of their relatively steep gradient

(>15%). Both simulations experienced quick run-off as their time to first run-off was 3 min and 15 min respectively. This clearly indicates that water did not have enough time to infiltrate the greater depth. Another factor that played a major role is the density of the vegetation cover on simulation sites; both simulation sites had a surface with 20% and 30% vegetation density. In theory it is expected that run-off will be high on soils with low vegetation density.

The moderate run-off category conversely consisted of six simulations; all simulations were done on steep slope gradient (>15%) and simulation site 7 was covered with 30% of canola vegetation where cracks and animal openings were observed. Simulation site 14 was covered with 50% of wheat vegetation and no cracks were observed at this simulation site. Surprisingly both sites produced moderate run-off, despite of different vegetation density at each simulation site. It is clear that other factors might have played a role in this case.

The low run-off category comprised 15 simulations, simulations were done on a steep slope gradient, south facing simulation area where vegetation density was more than 60% and cracks were also observed at all simulation sites. It was expected that all simulations will have high run-off because of their relatively steep slope> 15%. However all simulation had the lowest run-off, although they had been expected to have high run-off, because of their higher gradients. A number of factors could be expected to play a major role in influencing the run-off. Soil type is one of these and this aspect was very important in this study, because it gave the structural pattern where the cracks that play a major role. The soil type with low or high organic matter content influences the vegetation growth and the development of the root system and the vegetation roots conversely influence infiltration and therefore run-off. The other factors that influence run-off is the micro topography, which influences run-off in the way that water collects in depressions created by the micro topography over a period until it overcomes the height of the micro topography and eventually starts the motion of run-off.

4.3 Evaluation of particle mobilisation

Particles smaller than 65um in size are subject to mobilisation, if storm rainfall occurs (Poesen and Hooke, 1987). Fine particles, when washed away as a results of a rainfall event, can pollute water resource and causes siltation.

The simulation site gradient was measured to evaluate its influence in sediment movement during rainfall simulation. The rainfall simulator that was used to generate artificial rainfall was discussed in chapter 3. Each simulation was done on different soil type under wheat and canola vegetation cover to evaluate the wetting front after rainfall simulation.

Run-off generated by the simulator described in Chapter 3 was sampled on a 5 min interval for the analysis of its suspended load. Throughout the experiments, mobilised sediments were greater in the first sample than in the last sample. Table 4.4 and 4.5 lists the different parameters that played major roles in the mobilisation of sediments.

Table 4.4 lists the different parameters that played major roles in the mobilisation of sediments under canola vegetation cover.

Simulations	**Oa 2.2(4)**	**Oa 2.4(5)**	**Sw 2.5(16)**	**Gs 3.5(21)**	**Gs 3.3(25)**	**Gs 2.3 (33)**	**Ms 1.3 (19)**	**Gs 2.3 (32)**	**Oa 2.4(7)**	**Gs 2.5 (26)**	**Gs 2.5 (27)**	**Gs 3.3 (24)**
Gradient %	18.11	17.14	18.23	19.55	20.00	17.55	18.21	18.11	16.21	15.13	16.23	17.23
Vegetation cover %	50	45	65	50	55	40	15	20	30	35	30	35
Organic Matter content	7.342	6.432	7.150	7.232	7.555	7.122	6.321	7.382	7.364	7.700	7.133	7.324
Infiltration	55	54	60	51	58	58	43	46	56	44	54	50

start												
End (mm/hr.)	40	44	51	41	50	49	6	23	31	30	39	36
Mobilised sediments start (g/l)	35	15	19	32	19	34	31	20	25	18	13	20
Mobilised sediment end (g/l)	11	8	11	17	11	22	6	9	14	5	4	6
Time to first run-off (min)	20	28	51	40	65	30	3	6	15	15	20	30
Simulation length	65	68	105	80	98	70	45	45	55	60	60	80

Table 4.5 lists the different parameters that played major roles in the mobilisation of sediments under wheat vegetation cover.

Simulations	**Oa 2.2(4)**	**Oa 2.4(5)**	**Sw 2.5(16)**	**Gs 3.5(21)**	**Gs 3.3(25)**	**Gs 2.3 (33)**	**Ms 1.3 (19)**	**Gs 2.3 (32)**	**Oa 2.4(7)**	**Gs 2.5 (26)**	**Gs 2.5 (27)**	**Gs 3.3 (24)**
Gradient %	19.13	18.34	16.43	20.21	19.11	18.14	18.13	17.11	20.21	18.14	17.23	16.212
Vegetation cover %	50	55	55	50	50	50	20	20	15	15	15	15
Organic Matter content	7.373	7.233	7.609	7.139	7.314	8.313	7.470	7.243	7.328	7.177	7.213	7.332
Infiltration start	45	60	55	57	49	49	42	43	52	58	56	53
End (mm/hr.)	36	43	52	41	46	32	20	28	47	39	40	40
Mobilised sediments start (g/l)	23	31	18	17	29	27	18	27	20	21	18	21

Mobilised sediment end (g/l)	**10**	**11**	**7**	**5**	**11**	**12**	**8**	**13**	**6**	**15**	**4**	**12**
Time to first run-off (min)	**13**	**8**	**90**	**20**	**30**	**30**	**15**	**52**	**43**	**17**	**20**	**45**
Simulation length (min)	**63**	**53**	**135**	**60**	**70**	**91**	**55**	**107**	**93**	**60**	**60**	**95**

Comparing the values of mobilised sediments for all simulations, one might suggest that in many of the simulations the sediment yield might have been influenced by the soil type and crop type.

Table 4.4 shows that the mobilised sediments generally decreased from the first to the last sample in each simulations, whereas vegetation types were different and fluctuated.

The above observation of higher amounts of mobilised sediments at the beginning of a rainfall event seems to correlate with the seasonal pattern of sediment transport to a river catchment. As soon as the rain starts, the river turns muddy because of sediment load, and when rain continues over time, the river becomes clear again. These results agree with those of Pitt, 1995 who investigated sediment transport by water from agricultural catchment in the Central Belgium.

Sediment mobilisation at simulations with the highest and the lowest infiltration rate is illustrated in Figure 4.26 below.

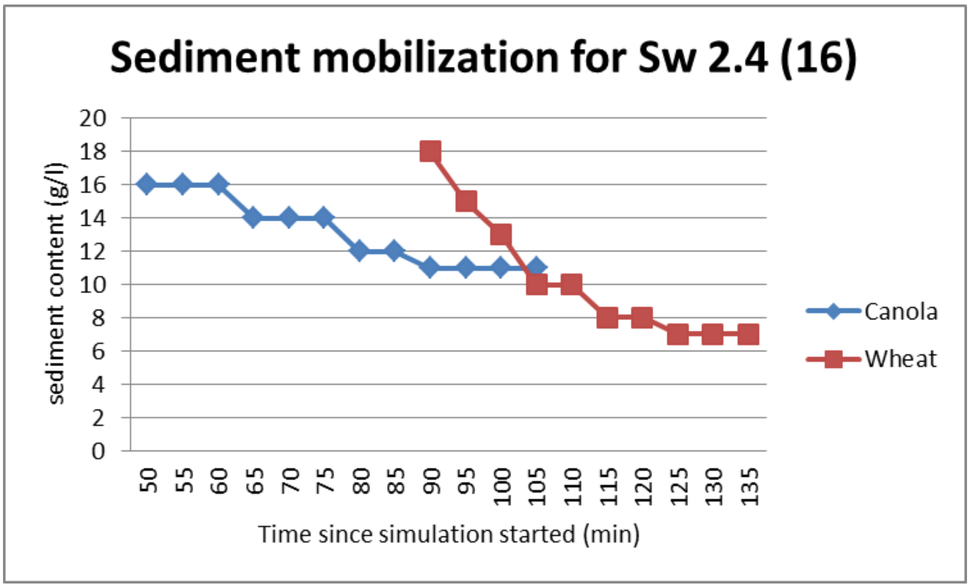


Figure 4.26 Indicates sediment content for simulations with the highest infiltration rate

It is clear from these two Figures (4.26 and 4.27) that simulations with relatively high infiltration rate had low sediment mobility compared to the ones with lower infiltration rate. A number of factors could be expected to a play a major role in influencing the sediment mobilisation. The time to run-off is one of the factors that contributed to low sediment mobilisation for simulation 13 and 22, because water had enough time to infiltrate greater depth and as a results low run-off was generated mobilising low sediment particles.

It is also evident from the Figures (4.26 and 4.27) that the mobilised sediments generally decreased from the first to the last sample in each simulations.

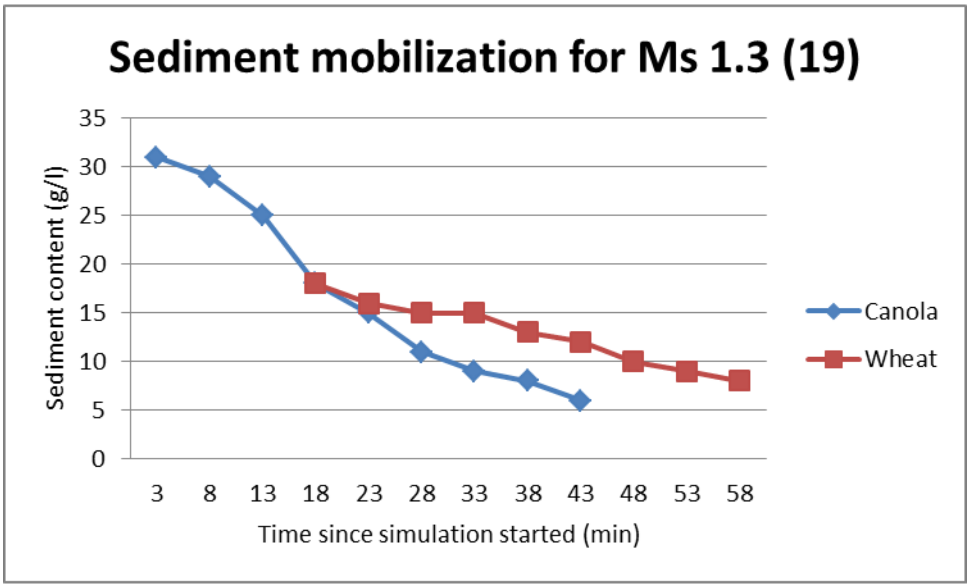


Figure 4.27 Indicates sediment content for simulations with the lowest infiltration rate

CHAPTER FIVE: DISCUSSION

Twenty four simulation experiments (12 simulations under canola fields and 12 under wheat fields) were grouped into two categories, simulations with high infiltration rate ranging between 40 to 60mm/hr. (Category 1) and low infiltration rate ranging between 0 to 39mm/hr. (Category 2).

From the infiltration curves and moisture distribution curves shown earlier, it is clear that the vertical movement of water through the top soil was largely governed by a well-developed soil structure, organic matter content and vegetation covers. This was further enhanced by the presence of mainly dry root systems of canola and wheat that formed small tubes along which water could infiltrate. It seems that the water was usually concentrated in the depressions of the micro topography, before being channelled downward by the above mentioned factors.

It was also evident that type of vegetation cover was one of the factors that affected infiltration rate as simulations with highest infiltration was observed at simulation under wheat vegetation cover while simulation with lowest infiltration rate was observed at simulation under canola vegetation cover. Vegetation density was the major factor in this case as soils with high vegetation density experience or produces low run-off as vegetation intercept the precipitation. Simulations conducted under wheat had more vegetation density than canola and as a result they had relatively high infiltration rate compared to simulation conducted under canola vegetation.

Considering the results, one might conclude that the decayed root systems from the canola and wheat vegetation covers, soil cracks, slope orientation, and soil composition, all played a major role in influencing the ability of the soil to absorb the simulated rainfall.

Because the infiltration was calculated using the difference between the incoming simulated rainfall and the measured run-off as indicated earlier in this chapter, there was an inverse relationship between run-off and infiltration. When run-off was low, the infiltration was high and vice versa. As a result the high run-off category included the category with relatively low infiltration rate, Mispah soil Form under both wheat and canola vegetation cover.

It was expected that all simulations will have high run-off because of their relatively steep slope> 15%. However most simulation had the lowest run-off, although they had been expected to have high run-off, because of their higher gradients. A number of factors could be expected to play a major role in influencing the run-off. Soil type is one of these and this aspect was very important in this study, because it gave the structural pattern where the cracks that play a major role. The soil type with low or high organic matter content influences the vegetation growth and the development of the root system and the vegetation roots conversely influence infiltration and therefore run-off. The other factors that influence run-off is the micro topography, which influences run-off in the way that water collects in depressions created by the micro topography over a period until it overcomes the height of the micro topography and eventually starts the motion of run-off.

Sediment mobilisation using rainfall simulation was evaluated on a small-scale catchment in the Langgewens experimental farm. Factors that governed sediment mobilisation within the ring area are micro topography within the ring area, the slope gradient and vegetation covers.

From the above analyses, vegetation cover played a pivotal role and it must be maintained at all times. It is advisable that the farmers must leave a crop residual cover behind after the annual harvest and not expose the land surface in bare form for too long as this will generate more run-off and increase sediment mobilisation. The analyses showed that wheat crop protects the soil from rain drop impact, thus reduces erosion or sediment mobilisation than on canola crop.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The importance of raindrop impact, infiltration and runoff in detaching soil particles that may be transported by overland flow has been often studied and documented. The majority of these investigations has relied on statistical multivariate analyses and has produced a number of different equations relating sediment detachment to parameters such as drop circumference, hill slope angle, and kinetic energy. In this paper, three primary water parameters (infiltration, runoff and sediment content) were selected as conventional indicators of pollution load with the aim of determining whether sediments in the Berg River are generated from agricultural activities.

The rainfall simulation events were shown to raise the sediment content count presumably by detaching sediments from surfaces and transporting this via storm water systems and into the Berg River. The study captured the 'first flush' effect for sediment mobilization in category 2 simulations (simulation with low infiltration rate) but this was not observed in the case of simulations in category 1 (simulations with high infiltration rate).

As was expected, Sediment content decreased with increasing runoff. This is mainly because elevated sediment mobilization levels are associated with the first flush that occurs during or soon after a rainfall event, but thereafter it was expected that the load will decrease with increasing dilution from further precipitation. The major factors that influenced sediment mobilisation are firmly believed to be the micro topography within the ring area, slope gradient, vegetation cover and rainfall intensity, these findings answers the research questions (Which factors plays a role during sediment mobilisation and how will sediment mobility be influenced?) and (Whether or not agricultural activities at Langgewens Experimental Farm contributes sediments into the Berg River?).

While some researchers noted that sediments are washed out more frequently in large quantities during wet conditions compared to dry weather conditions, this study was unable to establish such refinement.

As was expected, runoff rate was lower under wheat vegetation cover compared to canola vegetation cover because wheat vegetation cover is densely populated than canola, therefore wheat vegetation cover and residue cover protected the soil from the harmful effects of raindrops and soil erosion. It was demonstrated that high run-offf production was linked to the local soil properties, organic matter content, moisture content and type of vegetation cover. The same factors that influenced infiltration also played a major role in determining run-off, namely micro topography, root systems, soil cracks dimensions and hydraulic conductivity, these results answers the research question (Which factors play the main role during the infiltration process and how will this influence the depth of infiltration).

The vegetation cover also has a significant effect on the flow. Because the hydraulic roughness depends on slope, hill slopes with less vegetation will convey flow more efficiently (Jagals et al., 1995). Decreases in vegetation covers therefore result in higher rates of sediment detachment and quicker hydrological response times.

Both canola and wheat vegetation covers experienced high infiltration rates under Swartland soil form and low infiltration rates under Mispah soil form. These results prove that Swartland soil forms have a high water holding capacity than Mispah soil forms and also answers the research question (How will the different soil types and infiltration rates influence runoff?).

The answers for the research questions were achieved, the study showed that agricultural activities contribute sediments into the Berg River Catchment due to rainfall first flush. The study also showed that infiltration rate is higher under wheat vegetation covers than under canola vegetation covers due to vegetation cover density. More than 80% of simulations at Langgewens experimental farm had high infiltration rate. This finding shows that soil erosion is not a threat in the study area and that crop residue, vegetation covers and method of ploughing probably played an important role.

6.2 Recommendations

It is recommended that more wheat crops be planted on the experimental farm since this type of crop increases the infiltration rate because of its density. Fertilizers should be applied during the dry season when there is no rainfall. Fertilizers increases organic matter of the soil and by so doing it minimises run-off and increases infiltration. Crops should not be irrigated during the winter season because the study area and the whole Western Cape experience their rainfall during winter season. The irrigation system (furrow irrigation) that is being used currently in the study area should be changed to either sprinklers or centre pivot irrigation system.

CHAPTER 7: BIBLIOGRAPHY

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APPENDICES

7.2 Appendices

Pictures of simulation areas under both canola and wheat vegetation cover

Figure 7.1 Gs 21 canola land cover during summer

Figure 7.2 Gs 24 canola land cover during summer

Figure 7.3 Gs 32 canola land cover during summer

Figure 7.4 Gs 31 canola land cover during summer

Figure 7.5 Sw 16 canola land cover during summer

Figure 7.6 Oa 5 canola land cover during summer

Figure 7.7 Gs 25 canola land cover during summer

Figure 7.8 Gs 26 canola land cover during summer

Figure 7.9 Ms 19 canola land cover during summer

Figure 7.10 Gs 21 wheat land cover during summer

Figure 7.11 Gs 32 wheat land cover during summer

Figure 7.12 Rock fragments of Gs 25 wheat land cover during summer

Figure 7.13 Gs 27 wheat land cover during summer

Figure 7.14 Gs 32 wheat land cover during summer

Figure 7.15 Rock fragments at Gs 32 wheat land cover during summer

Figure 7.16 Gs 33 wheat land cover during summer

Figure 7.17 Ms 19 wheat land cover during summer

Figure 7.18 Gs 24 wheat land cover during summer


Figure 7.19 Oa 4 wheat land cover during summer


Figure 7.20 Oa 5 wheat land cover during summer


Figure 7.21 Gs 26 wheat land cover during summer

Figure 7.22 Sw 16 wheat land cover during summer

Figure 7.23 Oa 7 wheat land cover during summer

Figure7.24 Canola land cover during winter

Figure7.24 Wheat land cover during winter