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Faculty of Agrobiology, Food and Natural Resources
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ASSESSMENT OF THE IMPACTS OF GEOTEXTILES ON THE GROWTH OF VEGETATION, SURFACE RUNOFF AND SOIL LOSS

USING RAINFALL SIMULATIONS ON SMALL SCALE PLOTS

Master's thesis
(Double Degree Programme)

Natural Resources Management and Ecological Engineering, BOKU

& Natural Resources and Environment, ČZU

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EINSCHÄTZUNG DER AUSWIRKUNGEN VON GEOTEXTILIEN AUF VEGETATIONSWACHSTUM, OBERFLÄCHENABFLUSS UND BODENABTRAG

Beregnungssimulationen auf kleinräumigen Versuchsflächen

Masterarbeit
zur Erlangung des akademischen Grades Diplomingenieurin und Master of Science

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A. Preface

This thesis is made as a completion of the master double degree education in Natural Resources Management and Ecological Engineering at University of Natural Resources and Life Sciences (BOKU) Vienna, Austria and Czech University of Life Sciences (CULS) Prague, Czech Republic. The thesis was done at BOKU at the Institute of Soil Bioengineering (IBLB) under the supervision of Prof. Dr. Florin Florineth and Dipl. Ing. Michael Obriejetan, and at CULS at the Faculty of Agrobiology, Food and Natural Resources under the supervision of Ing. Vít Penížek, Ph.D.

Several persons have contributed academically, practically and with support to this master thesis. I firstly like to thank my supervisors of the different universities who made it possible for me to do this thesis. Special thanks goes to Dipl. Ing. Michael Obriejetan for his time, valuable input and the big support throughout the entire period. Furthermore I would like to thank my friends Yuri Mimori, Christina Fernandez and Maria Kirchner for spending their time in correct reading and giving me some productive feedback.

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B. Abstract

Soil bioengineering measures are a special case of biotechnical stabilization which combine plants and non organic materials. In this context geotextiles play an important role in erosion and sedimentation control. Even though soil bioengineering and the use of geotextiles is widely scientifically accepted, available data to assess the influence of geotextiles on soil erosion are limited. Therefore in this research eight different scenarios were tested to assess the impacts of organic and inorganic geotextiles.

The focus was set on evaluating the influence on soil loss, surface runoff as well as the influences on the growth of vegetation. For the tests three different organic geotextiles and one inorganic geotextile (in three different ways) were in use ('BonTerra® Coir Netting', 'BonTerra® K Coir Fibre Blanket', 'BonTerra® R3D', 'MacMat® R', 'MacMat® R + Terravest K' and 'MacMat® R filled') and compared to the results of testing areas with only vegetation and bare soil. To determine soil loss and surface runoff a standardized rainfall simulator was used twice, in August 2012 and September 2012. The vegetational development was measured four times by measuring the above ground phytomass and the degree of vegetation cover.

In all scenarios vegetation was developing with accelerated growth in the second half during the period of observation. One exception was observed in the plots with the execution 'MacMat® R filled'. The highest influence in enhancing the growth of vegetation had the plots with the organic geotextile. Vegetation itself and the use of geotextile showed a high protective function against erosion compared to the reference plots with bare soil only. Once again the testing samples with 'MacMat® R filled' formed an exception. Considering the surface runoff the protective influence is lower compared to the result of soil loss reduction. 'BonTerra® Coir Netting' and 'BonTerra® Coir Fibre Blanket' showed a better water retention than the other scenarios.

Summarized had the organic materials the best impacts in enhancing the growth of vegetation and in reducing the surface runoff. Considering soil loss, vegetation alone has already a sufficient protective effect compared to bare soil. The geotextile MacMat® R showed in most points of interest no positive effects. The special application of MacMat® R filled with soil was according to soil loss and vegetation development unsatisfactory.

C. Kurzfasssung

Die Ingenieurbiologie beschreibt die Technik der Verwendung von Pflanzen für Sicherungsmaßnahmen. Dabei werden zu den Pflanzen auch unbelebte Materialien mitverwendet (FLORINETH, 2012). In diesem Zusammenhang spielen Geotextilien eine wichtige Rolle beim Erosionsschutz. Obwohl ingenieurbiologische Maßnahmen und die Verwendung von Geotextilien weit verbreitet und wissenschaftlich anerkannt sind, sind lediglich wenige Daten verfügbar, um den Einfluss von Geotextilien auf Bodenerosion zu beurteilen. Deshalb wurden in dieser Studie acht verschiedene Szenarien untersucht, um die Auswirkungen von organischen und anorganischen Geotextilien zu bewerten.

Als Schwerpunkt wurde der Einfluss auf den Bodenabtrag, Oberflächenabfluss sowie auf das Vegetationswachstum gesetzt. Für die verschiedenen Szenarien sind drei verschiedene organische Geotextilien und ein anorganisches Geotextil, in drei verschiedenen Anwendungsarten getestet worden (‚BonTerra® Kokosgewebe‘, ‚BonTerra® K Kokosmatte‘, ‚BonTerra® K R3D‘, ‚MacMat® R‘, ‚MacMat® R + Terravest K‘, ‚MacMat® R gefüllt‘). Diese wurden zudem mit Testflächen verglichen die rein aus Vegetation und ausschließlich aus nacktem Boden bestanden. Zur Bestimmung der Bodenerosion und des Oberflächenabflusses wurde ein standardisierter Beregnungssimulator eingesetzt und die Simulation zweimal durchgeführt, im August 2012 und im September 2012. Die Pflanzenentwicklung wurde in Summe vier Mal gemessen durch die Entnahme der oberirdischen Phytomasse und Bestimmung des Deckungsgrades.

In allen Versuchsflächen entwickelte sich die Vegetation positiv mit verstärktem Wachstum in der zweiten Hälfte des Beobachtungszeitraums. Eine Ausnahme wurde in den Flächen mit der Ausführung ‚MacMat® R gefüllt‘ beobachtet. Das größte Vegetationswachstum hatten die Versuchsflächen mit den organischen Geotextilien. Vegetation selbst und die Verwendung von Geotextilien zeigten eine hohe Schutzfunktion gegen Erosion im Vergleich zu den Referenzflächen mit nacktem Boden. Nur die Flächen mit ‚MacMat® R gefüllt‘ bildeten eine schlechte Ausnahme. Was den Oberflächenabfluss betrifft, ist der schützende Einfluss der Erosionsschutzmaßnahmen geringer im Vergleich zum Bodenabtrag. ‚BonTerra® Kokosgewebe‘ und ‚BonTerra® K Kokosmatte‘ zeigten eine bessere Wasserspeicherung verglichen mit den restlichen Aufbauten.

Zusammengefasst hatten die organischen Geotextilien bessere Einflüsse auf das Vegetationswachstum und die Verringerung des Oberflächenabflusses. Verglichen mit nacktem Boden hat Vegetation allein bereits eine ausreichende Schutzwirkung gegen Bodenerosion. Die Verwendung MacMat® R brachte in den meisten Untersuchungspunkten keine positive Wirkung. Die spezielle Anwendung MacMat® R gefüllt mit Bodenmaterial brachte bezogen auf Erosion und Vegetationswachstum unzureichende Ergebnisse.

1. Introduction

Degradation of soil by erosion is a serious environmental problem. In the temperate humid zone, water induced erosion is the main factor contributing to soil loss. As a consequence vegetation suffers from nutrient depletion and is hindered in growth and development. Additionally, sediments may settle in improper areas and can cause serious damages due to voluminous mass movements.

Various measures are employed to stabilize slopes. Vegetation is commonly used for erosion control systems and in soil bioengineering through hydrological and mechanical factors. The positive effects resulting from the use of vegetation cover on water-induced surface erosion have already been demonstrated by many specialized studies (ZHOU / SHANGGUAN, 2006; MARTIN et al., 2010; BARNI et al., 2007; BURRI et al., 2009; MATTIA et al., 2005; LOZANO-GARCIA et al., 2011). However, plants by itself may not be sufficient for proper soil protection. Especially newly constructed slopes, where vegetation development is at an early stage, can be highly vulnerable to soil erosion. In this case, it can be necessary to stabilize these newly constructed slopes with further measures until the vegetation is fully established. In successful soil bioengineering systems mechanical elements are supplemented with biological effects (interception of rainfall, root system) to stabilize surface near soil layers by achieving a „synergistic“ relationship between geotextiles and vegetation (NIGEL, 1987).

ZIEGLER and SUTHERLAND (1997) found that rolled erosion control systems respectively geotextiles can reduce surface runoff, enhance soil infiltration and decrease interrill sediment transport considerable. In the study of BHATTACHARYYA et al. (2010) all tested geotextiles reduced the runoff by 34% in average compared to bare soil. Despite the fact that geotextiles have soil conserving potential as explained above, its specific impact on soil erosion and runoff processes are not fully understood. For example, the few data that already exist in literature are based on different experimental designs because of the lack of a statistical framework. This makes the comparison of these studies and the assessment of the veritable impacts of geotextiles quite difficult. A few further comparative studies can be found in relevant scientific journals.

For determining the influences of vegetation and/or geotextiles on soil erosion, precipitation studies and rainfall simulation modeling have been conducted by using natural precipitation dating back to the beginning of the last century (KARL, 1980). However, the use of natural rainfall as single database bears several problems regarding to comparability of surface runoff or soil loss because of the complexity of rainfall events (rainfall intensity, duration etc.). During the last decades an increasing number of rainfall simulation studies were conducted using different rainfall simulators with the advantages of standardized stress forces as well as a good comparability of measuring results. This leads that most of the understanding of soil erosion processes is based on rainfall simulations.

1.1 Objectives and Questions

The objective of the thesis is to evaluate the effects of different types of geotextiles on soil loss, surface runoff as well as the influences on the growth of vegetation. It is therefore, essential to discover the nature of the geotextiles' influence on soil erosion processes and the manner in which they support vegetation growth. The thesis aims mainly to clarify the difference between particular geotextiles and the influences on the previously mentioned parameters. As outlines of the research following questions were formed:

1.1.1 Questionnaire

I: How do geotextiles affect vegetation development with regard to cover rates and biomass?

II: What kind of geotextiles have the biggest influences on surface runoff reduction?

III: What kind of geotextiles have the biggest influences on soil loss reduction?

2. Basics

2.1 Soil Erosion

Soil erosion is the removal of soil material due to wind or water and is related to climatic, pedological and anthropogenic processes. Soil erosion processes comprise different phases: mobilization, transport and sedimentation of soil particles.

Clearly, at present, soil erosion is no longer merely the consequence of a natural process. In other words, a distinction should be done between natural erosion and accelerated erosion, the latter being the result of human activities disturbing the natural conditions of the surface (BENNET, 1951).

The first mathematical approach to describe soil erosion by water used by Wischmeier and Smith (1965) is known as the Universal Soil Loss Equation (SCHMIDT, 2000).

2.1.1 Factors influencing erosion

The initiation of erosion and the amount of eroded material is closely linked to the erosivity of wind or rain and on the erodibility of the soil. This is dependent on local and environmental conditions of the individual slope. These are defined by the FLL Directive (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau e. V.) - Specific recommendations for greening process:

2.1.1.1 Slope angle, slope length and area

The erodibility of soil is influenced by the slope angle, slope length and the size of the area. It is expected that erosion is increasing with slope steepness, slope length and the area size because of increasing flowing velocities and increasing volume of runoff and a higher detaching ability of raindrops.

2.1.1.2 Land cover and roughness

The soil can be protected against erosion as long as there is a cover of vegetation, rocks, stones or mulch layers. In the case of vegetation cover, the plants need to be of a small height for an effective protection. Trees are not adequate in protecting soils because their leaves can collect the water of smaller raindrops and create later raindrops of a bigger size and higher detaching energy because of high falling velocities and high kinetic energy.

Soil surface roughness controls a lot of the transfer processes across the soil-atmosphere boundary e.g. infiltration, runoff, soil detachment, gas exchange, evaporation and heat flux (HUANG and BRADFORD, 1992 In: MAGUNDA et al., 1995). Surfaces with big stones are more stable than smooth surfaces because of a higher surface roughness. During a rainfall event the surface roughness is decreasing because of an occurring aggregate breakdown.

2.1.1.3 Soil cohesion

The type of soil also influences the soil erosion processes, some soils are more absorptive, whilst others less. Soils with big parts of silt and sand are very vulnerable to erosion. The soil`s property, more precisely its texture, is the most important factor for resistance. By contrast, the least resistant particles are silts and fine sands. Thus soils with a big silt content are highly erodible. According to RICHTER and NEGENDANK (1977) soils with a silt content of 40 - 60% are most erodible. EVANS (1980) showed that soils in terms of clay content are most susceptible with a content of 9 - 30% due to the presence of strong chemical bondings.

2.1.1.4 Climatic conditions

The differences of soil erosion are influenced by the amount of rainfall, daily inflow of water, storm addiction, risk of heavy rain, hail or snow falls and flooding. The ability of rain to detach soil is increasing with increasing amount of precipitation and intensity which needs to be bigger than the infiltration capacity of the soil. With increasing intensity also the raindrops get bigger and with that also the erosivity of the rain increases with the square of the rainfall intensity. For overland flow the rainfall intensity is the most important characteristic. The erosivity of a rainfall event is based on the kinetic energy and dependent of its intensity and duration. Further influencing factors in soil erosion is the erosivity of the eroding agent wind with respect to the wind frequency, wind speed and gustiness.

2.1.2 Processes and Mechanics of erosion

Soil erosion is a multi-phase process: first, the detachment of individual particles from the soil and second, the transport of detached particles by some erosive agents like water and wind. When transporting energy decreases, a third phase starts where the detached particles are deposited. The most important player in detaching the particles is rain splash where soil particles are thrown out from the surface by the energy of the raindrops and may be displaced up to several centimeters. The energy which causes soil erosion is divided into two different forms: potential and kinetic energy. The potential energy (PE) is the product of the difference of falling height (h), the mass of the raindrops (m) and acceleration of gravity (g) (MORGAN, 1979):

$$PE = m * g * h$$

The potential energy for erosion is transformed into kinetic energy (KE) responsible for motion. The energy is the product of the half of the mass (m) and the velocity (v) squared (MORGAN, 1979):

$$KE = \frac{1}{2} * m * \mathrm{v}^2$$

2.1.3 Raindrop impacts and soil detachment

Raindrops are potentially more erosive than overland flow. The main part of the energy of raindrops goes in detaching soil particles. The available energy for transporting the particles is less than in overland flow. The raindrops and their transferred energy have two effects: soil compaction and soil particle detachment. With the bounce of raindrops on the soil surface, soil aggregates are destroyed in a local area and particles are removed. Thus, raindrops have the effect of consolidation and dispersion on the soil surface. Usually, consolidation results in the surface crusting of a thickness of a few millimeters by initially removed particles transported into macropores and clogging them (MORGAN, 1979). By clogging the pores the infiltration rate is decreasing. Is the rainfall going on and the drops fall on a wet surface, the splash erosion first increases with the thickness of the water layer. After achieving a specific thickness the water layer plays a protective role, this water depth is approximately equal to the raindrop diameter (MORGAN, 1979).

The temporal rainsplash response on bare soil can be represented by a four phase model (ZIEGLER et al., 1996):

1. Aggregates are sheared off and removed from soil aggregates. The transport by rainsplash can be high if the kinetic energy is high.
2. Soil structural units are broken into parts.
3. Surface sealing and thereby decline in splash transport.

4. Splash transport is reduced because of the presence of the protective water layer. If the erosion of raindrops occurs evenly on the entire surface and removes a more or less uniform layer of soil particles, sheet erosion results.

2.1.4 Overland flow

Finally, the rain results in surface runoff and removes more particles due to higher flowing velocities in rills. Rills are formed due to the uneven removal of surface soil by streams of running water. Overland flow occurs on hillsides when the rainfall event is ongoing and the rainfall intensity is higher than the infiltration rate. Overland flow is hydraulically described by the Reynolds number (Re) respectively Froude number (F) as follows (MORGAN, 1979):

$$Re = \frac{v * r}{v}$$

$$F = \frac{v}{\sqrt{g * r}}$$

The hydraulic radius (r) is assumed to be equal to the flow depth. The kinematic viscosity of water is expressed as v. The Reynolds number can be seen as an index of the turbulence of flow. The higher the turbulences, the higher the erosivity of overland flow.

The most important factor of the erosive power of overland flow is the flow velocity. The flow needs to reach a specific velocity so that erosion can occur – this coherence is shown in the Hjulström diagram (see figure 1). For grains larger than 0,5 mm the critical velocity increases with grain size. For particles with a grain size smaller than 0,5 mm the critical velocity increases with decreasing grain size. Smaller particles are less easy removed because of the cohesiveness of clay minerals which comprises them. Already moving soil particles are easily transported and not deposited until the velocity is lower than the fall velocity threshold. This means, that less force is needed to keep the particles in motion than to detach them.

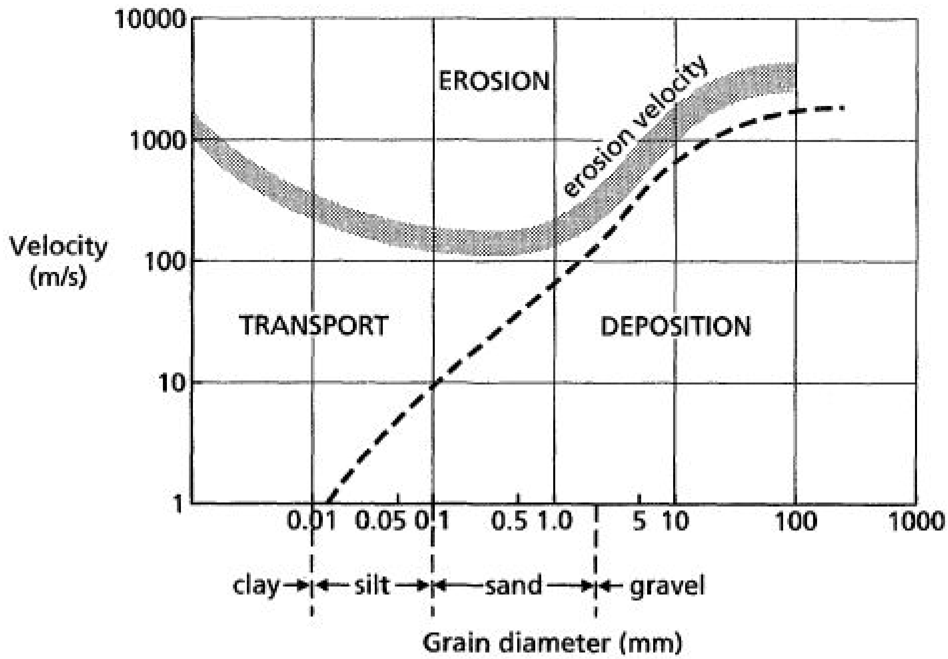

Figure 1 Critical water velocities for erosion, transport and deposition as function of particle size after HJULSTRÖM 1935 (http://www.answers.com, 15.06.2013)

The Hjulström diagram was developed for soil surfaces with uniform grain sizes. In practice, this sort of soil structure does not occur, therefore the actual velocities required to erode particles differ from the values shown in the diagram. At structural surfaces with different grain sizes the fine particles are protected by the larger ones and are not removed until the velocity is high enough for detaching the coarse particles.

According to HORTON (1945) overland flow is covering at least two-thirds of the hillsides in a drainage basin during the peak period of a rainfall event (DIAMOND / SHANLEY, 2003). The flow results from the rainfall intensity starting to be bigger than the infiltration rate/capacity. At the top of the slope is a part of undisturbed soil. With increasing distance from the top the flow becomes channeled and breaks up into uneven rills (< 10 cm), runse (< 30 cm) and latest in gullies (> 30 cm) (SCHEFFER et al., 2010).

2.1.4.1 Transport

The transport of particles is an interaction of removing and sedimentation. If the flow velocity reduces, the particles are matured. The transport of the soil particles also happens partly due to the splashing activity of raindrops as explained in section '2.1.3 Raindrop impacts and soil detachment'. The water spreads in all directions but at slopes the drops are wider spread down-slope than up-slope. The transport through raindrops is low, in most cases less than 1% from the overall amount of detached soil particles (RICHTER, 1998). More effective is the transport through surface flow. When the pores get blocked during the rainfall event and the infiltration capacity decreases, the water is first collected in pits at the surface. These pits are mostly able to store only 1 mm of the precipitation, the remaining water flows off on the surface. The flow itself is mainly undisturbed and would not have the force to keep the materials suspended, but with ongoing rainfall on the water layer some turbulences are created which disperse the fine particles. In rill erosion the water flows faster and creates the needed turbulences for removing soil particles by themselves. If the flow velocity is fast enough also bigger particles like stones can be removed and transported (RICHTER, 1998).

2.1.5 Infiltration

A further influencing factor is the infiltration of water into the soil. Infiltration is the process by which the water enters the soil and separates the applied water by precipitation into two hydrological components, surface runoff and subsurface recharge. The process is described by the equation of Kostiakov (1932) and Horton (1940) (DIAMOND / SHANLEY, 2003). Low vegetation cover results in lower infiltration rate because the direct energy of the raindrops reaches the bare surface and enhance surface sealing and crusting (EVANS, 1980). Reduction of infiltration rate causes increased overland flow and thereby increased surface erosion which results in higher soil and nutrient loss and a decrease in plant available soil water (KATO et al., 2009).

2.2 Erosion Protection Systems

Erosion control measures combine all systems with the aim to protect soil against soil loss by erosion processes. Effective protection from near-surface erosion can be achieved by purely technical measures, a stable and closed vegetation cover or by the combination of these protective factors.

2.2.1 Vegetation

The use of vegetation for slope stabilization dates back to ancient times and is still widely in use for erosion control systems in the present time. A stable vegetation layer can provide effective protection against surface near erosion by acting as a protective layer against the kinetic energy of raindrops (interception). This is the major role of vegetation, the kinetic energy is dissipated and thereby reduced. Also the hydrodynamic power of flowing water is diminished by vegetation. HUDSON and JACKSON (1959) have emphasized the role of plants by their experiments (MORGAN, 2005). The vegetation works as a buffer layer between atmosphere and soil as protection against the direct impacts of rainsplash erosion (MORGAN, 2005).

A second feature of vegetation is reinforcing the soil layer by the root system (RICHTER, 1998). The vegetation removes soil moisture by transpiring water. Therefore planted areas always have better water balance than non-planted areas. With these effects the soil moisture and pore pressure gets reduced and the resistance against erosion increases (MORGAN / RICKSON, 1995). Vegetated soils might have a better conductivity to infiltrate water than unvegetated soils and can reduce the erosive effects.

Organic matter, roots, their growth and decay, earthworms and termites are important factors to guarantee a good pore system of the soil and result in a higher hydraulic conductivity, and a better ability to take in water. Roots and root remnants bind the soil particles and form mechanical barriers for water and soil. Furthermore, they improve the subsurface flow in creating pathways for the water and the infiltration capacity is increasing (MERZ et al., 2009).

Some other effects are hydraulically based for instance, roughness and flow velocity. The increasing roughness due to dense vegetation cover controls the speed of the generated runoff and is also important for dissipating the energy of wind. A fine root mat close to the surface protects the soil like a mulch mat from soil erosion (MORGAN / RICKSON, 1995). For an effective erosion control the vegetation growth should be regularly spaced out and not clumped. Hence, tussocky and tufted species need to be avoided for erosion control. To achieve the maximum effect of vegetation the following must be provided (MORGAN / RICKSON, 1995):

- a dense uniform cover close to ground surface (> 70%);
- a dense laterally-spreading root system;

If vegetation is used for erosion control, a variety of different vegetation species is preferable in order to allow failure of some species. The vegetation should be selected in such a way that naturally occurring vegetation is replicated. Native species help to retain the local ecology and are better adapted to grow in their local environment (MORGAN / RICKSON, 1995).

2.2.2 Geotextiles

Geosynthetical erosion control is the use of natural and synthetical materials, and a combination of both as erosion protection. They are permeable textiles used in conjunction with soil, foundation, rock, earth or any geotechnical engineering-related material (NIGEL, 1987). The use of adjuvants combined with so-called bioengineering methods is used primarily for water storage and as mechanical protection near the surface. Geotextiles imitate the properties of vegetation and affect the amount of surface runoff and the ability of water to transport soil particles (MORGAN / RICKSON, 1995). Geotextiles provide immediate protection of soil and seeds so that the latter have a better chance for germination and vegetation therefore, a greater chance for development (ZIEGLER / SUTHERLAND, 1997). It is argued that once the vegetation cover is established, the geotextiles become redundant.

Immediate geomorphological benefits of geotextiles (ZIEGLER / SUTHERLAND, 1997):

- they reduce the direct impacts of raindrops and wind;
- they enhance the water infiltration into the soil, increase thereby the soil moisture and reduce the surface runoff;
- are a rough surface cover and reduce by their roughness the overland flow velocities;

Geotextiles have been used since 1926 but their importance became greatly recognised decades later, between 1970 to 1980 (NIGEL, 1987). Though the use of geotextiles is very versatile, their main role is for soil protection against erosion. Additionally, geotextiles are also in use for filtration, road sub-base separators, reinforcing soils in embankments and retaining walls. The basic functions of geotextiles are described by NIGEL (1987) and the German Road and Transportation Research Association (FGSV, 2005) which creates international guidelines for the use of geotextiles:

- Separation – they prevent mixing of soil particles of different layers;
- Reinforcement – they have specific strength to hold the soil mass together;
- Filtration – they enhance the development of a natural filter and must hold back soil particles;
- Drainage – they act as filter, by protecting some other drainage medium, also called fluid transmission;
- Sealing – of basins and ditches;

- Protection – against erosion;

A big variety of products is available for this purposes with respect to the individual application, particular protection objective and the specific location. Additionally to economic and safety considerations increasingly, ecological, aesthetic and socio-economic aspects play an important role.

2.2.2.1 Classification according to ECTC

The *Erosion Control Technology Council (ECTC)* is an organization consisting of a wide range of manufacturers, professionals and agencies that deal with erosion protection and has developed a classification system. A scheme of the RECP classification by ECTC is attached in the Appendix.

The ECTC system is characterized by the subdivision into three main classes:

- Rolled Erosion Control Products (RECPs)
- Hydraulic Erosion Control Products (HECPS)
- Sediment Retention Fiber Rolls (SRFRs)

A further differentiation of the RECP's is possible with the focus on production technology, function and durability. The differentiation includes the following types (ECTC, 2007):

- Mulch Control Nettings (MCN) respectively Erosion Control Nettings (ECN)
- Open-Weave Textiles (OWT)
- Erosion-Control Blankets (ECB)
- Turf Reinforcement Mats (TRM)

2.2.2.2 Non-RECP´s for stabilizing slopes

Besides RECP's many other technical systems are available. A majority of these systems is designed for permanent erosion protection and is as TRM's mostly made of plastic, steel or combinations of the materials. In addition to protective functions, these systems are often able to take on several functions of geotextiles at the same time such as drainage or reinforcement. Depending on the application, these technical systems are combined with different planting techniques.

2.2.2.3 Application

Geotextiles are usually available in rolls and installed on the surface using different anchoring techniques. The geotextiles need to be flexible to allow an installation closely to the surface and stay in direct contact with the soil. The close soil contact is the main factor for a proper stabilization of slopes. For the application of geotextiles on a slope are numerous ways possible. Depending on the system, soil conditions and terrain, the installing of geotextiles is mostly done with pegs or anchors made of wood, steel or plastic see figure 2.

Figure 2 Standard mounting materials for RECP’s (www.ectc.org/guidelines.asp, 18.06.2013)

3. Materials and methods

To answer the questionnaire formulated in the beginning, it was necessary to create a method to determine the impacts of the use of different geotextiles. First of all the method to measure the impacts of different geotextiles on surface runoff and soil loss was defined. In the following sequences the method and all the materials used are described in detail.

3.1 Study area

The experimental garden of the Institute of Soil Bioengineering (IBLB) at BOKU University was selected to carry out the practical experiments. It is located in Essling (Vienna, Austria) and is constantly maintained by institute employees respectively landscape gardeners.

Figure 3 Experimental garden Essling, VIENNA (www.de.wikipedia.org/wiki/Wien, 22.04.2013)

3.2 Materials

3.2.1 Rainfall simulator

For the study a fully standardized rainfall simulator - type LUW - from Eijkelkamp Agrisearch Equipment was used (see figure 4 and figure 5). The advantages of this simulator are flexibility, standardization in stress loads respectively reproducibility and existing experience values as described in literature (see SULAIMAN et al., 1990; MARTIN et al., 2010; LOZANO-GARCIA, 2011; SMETS / POESEN, 2009; KATO et al., 2009; MARQUES et al., 2007; MAGUNDA et al., 1997; ZIEGLER et al., 1996; ZIEGLER / SUTHERLAND, 1997). The rainfall simulator bears a lot of advantages for fulfilling the desired requirements in this study.

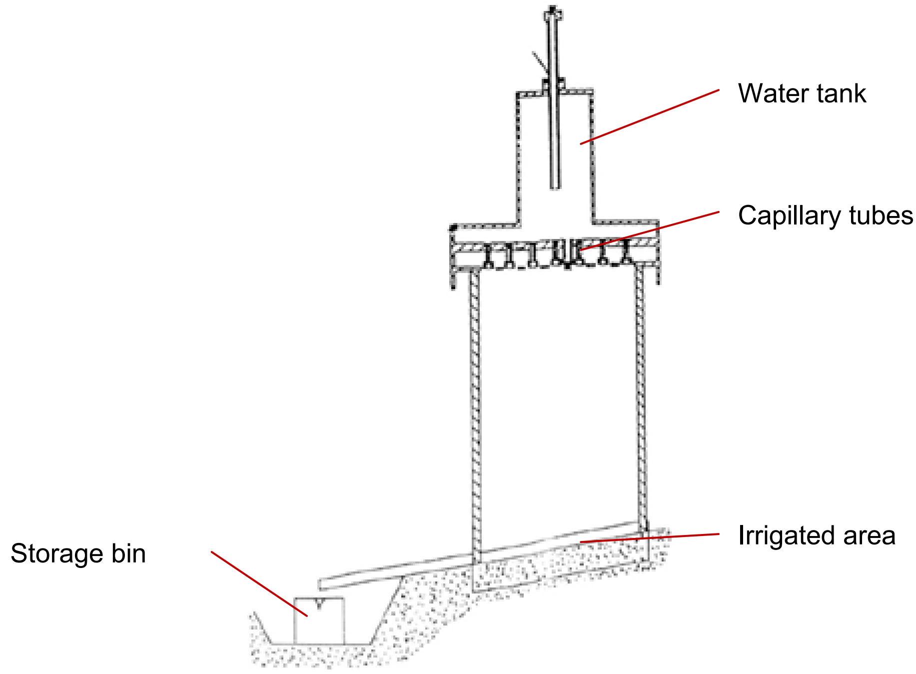

Figure 4 Scheme of rainfall simulator (LOZANO-GARCIA et al. 2011)

The rainfall simulator is small and therefore very handy to transport and easily installed on different study sites without considerable expenditure. This key feature allows either the use in the field or in the laboratory and supplies highly standardized data with a good reproducibility and comparability.

Figure 5 Rainfall simulator (09.05.2012, Essling, VIENNA)

The rainfall simulator irrigates an area of 25 x 25 cm (625 cm^2) and spreads the water through 49 capillary tubes. The water is stored in a tank with a capacity of 2,3 liters. The tubes are on average 400 mm above the irrigated testing plots. The generated drops through the tubes reach a diameter size of 5,9 mm whereas the rainfall intensity is quantified with 6 mm/min. Due to the high rainfall intensity and big raindrops the short falling distance and small kinetic energy per raindrop is compensated (MARTIN et al., 2010). The simulator has to be calibrated to correspond to the manufacturer´s specification (see Appendix).

3.2.2 Base frame construction

To simulate conditions on a slope the sowing pans with the installed plots (see further details in section ‘3.2.3 Sowing pans’) were tipped for the rainfall simulation. To guarantee the same conditions for all implementations a construction was built on which the pans were supplied. The construction generates a slope of 30° and delivers an easy implementation of the rainfall simulation and comparable results. For the construction spruce wood was used. Covering the construction with self adhesive foil should protect the wood and extend its service life. A scheme with dimension specification of the construction is shown in figure 6.

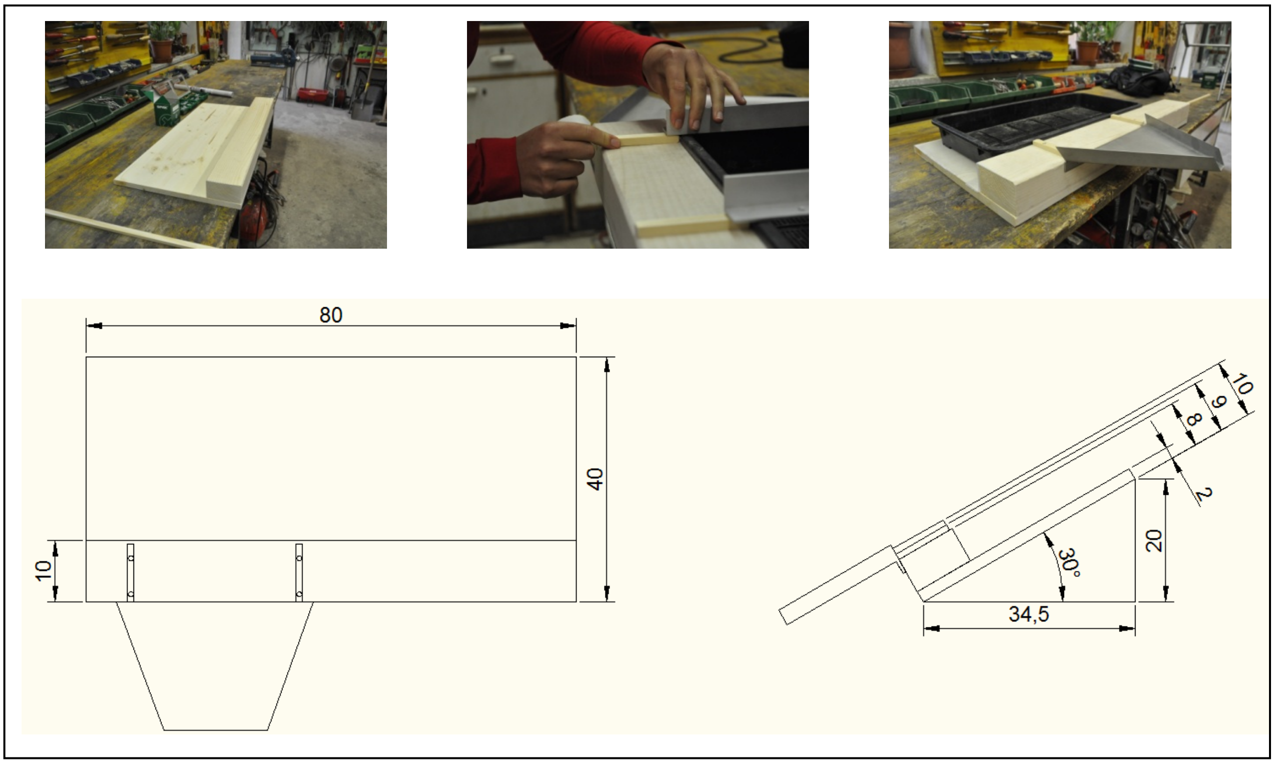

Figure 6 Base frame construction for rainfall simulations (13.07.2012 Essling, VIENNA)

3.2.3 Sowing pans

The different scenarios were finally built up in the so-called sowing pans. With the sowing pans it was possible to construct all set ups on a small space. It was possible to do all the construction work without the use of heavy machines in a time saving working process. Furthermore this kind of setup is very keen and provides high flexibility. Due to its transportability a change in place for implementing the rainfall simulation may be performed quite simple. The pans are made out of polystyrene and are perforated in the bottom so that the plant roots are not hindered in reaching subsoil area (see figure 7).

With the outer dimension of 57 cm x 27 cm x 5,4 cm it was possible to do two simulation runs at each pan which therefore, makes the random sample survey higher.

Figure 7 Sowing pans (09.05.2012 Essling, VIENNA)

3.2.4 Soil characteristics

The sowing pans were filled with a soil mixture available from the experimental garden Essling. The soil was roughly determined by using finger test to guarantee that the soil characteristics meet the actual ASTM (American Society for Testing and Materials) D 5268 standards for topsoil used for landscaping purposes and geotextile performance testing (http://www.astm.org/ABOUT/overview.html, 30.10.2013). The ASTM is a globally recognized leader in the development and delivery of international voluntary consensus standards. The standard specifications for topsoil are as follows:

Table 1 ASTM D 5268 specification for topsoil (ASTM D 5268 standards)

Compositional Category	**Percentage**
Total sample	
Deleterious material (rock, gravel, slag, cinder, roots, sod)	max. 5
Soil fractions	
Organic material	2 – 20
Sand content	20 – 60
Silt and clay content	35 – 70
pH	5 – 7

Soils usually consist of more than one soil separate. With the proportion of the different soil separates the exact soil texture can be determined by a mechanical analysis in the laboratory (PLASTER, 2011). The results of the soil type determination is illustrated in the following table, whereas all values are inside the required limits of the ASTM thresholds.

Table 2 Soil texture (2012 Essling, VIENNA)

Soil fraction	Percent
Sand (0,05 - 2 mm)	57,78
Silt (0,002 - 0,05mm)	35,59
Clay (< 0,002mm)	6,63

If the values of sand, silt and clay amount are transferred to the soil triangle, the soil textural class can be determined. The point of the intersection of the lines inward from each specific point names the soil texture class, in our case it is sandy loam. This soil texture class indicates a mixture of all three particle sizes but sand is most influential. The following graphic illustrates the structure of the soil triangle with designated soil classes and indicator for the used specific material:

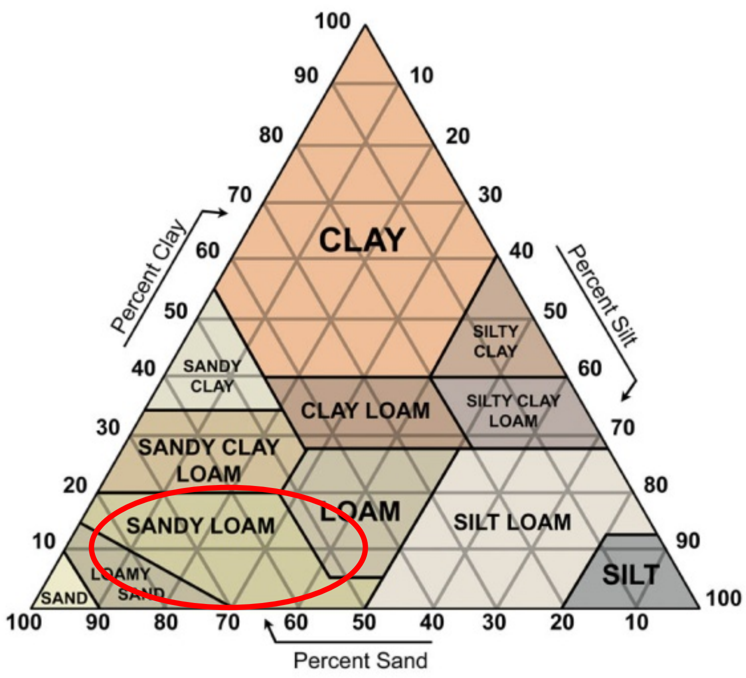

Figure 8 Soil triangle including the used soil texture class (www.lowbird.com/all/view/2013/03/soilsensor-soiltriangle-large, 23.04.2012)

Further the soil pH-value, carbonate content and soil organic matter were measured to determine the specific soil characteristics. The pH-value of the soil is related to plant nutrition and is part of the most soil-plant relations. In addition to that it is valuable to know about soil acidity because of its major influence on nutrient uptake, root growth and controlling the activity of micro-organisms. Many nutrients like Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur are best available at a neutral (pH = 7,0) respectively near neutral pH value (PLASTER, 2011). The measured soil pH-value gives information about the active pH (in solution) and the total acidity of the soil (including active and exchangeable acidity). In our sample the soil pH is near neutral (see table 3).

Table 3 Soil characteristics (2012 Essling, Vienna)

Parameter	Value	Annotation
pH		
Exchangeable acidity	7,04	Alkaline
Active acidity	6,96	Neutral
Carbonat content	3,1%	Slightly carbonate contained
Humus (organic matter)	3,278%	

The amount of organic matter is another considerable parameter especially if we consider soil erosion. Soil organic matter can cause clumping of soil particles and enhances the formation of soil aggregates. The proportion of humus is relatively small with 3,278 %. Regarding to the contained carbonate the results showed its low level with 3,1 %.

3.2.5 Geotextiles

All together four different types were in use. Three scenarios were built up with natural geotextiles and three with one specific synthetic geotextile in different executions (for more details see section '3.3.1 Technical execution'). In table 4 an overview about the characteristics and differences is displayed.

Table 4 Characteristics of used geotextiles (2012 Essling, VIENNA)

	MacMat® R	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D
Material	Steel wire; PP geomat	100% coir fibre	100 % coir fibre matrix ; JUTE-thread	100 % coir fibre matrix; PP grid
Mesh size [mm x mm]	Steel wire: 60 x 80; PP geomat: 90% void space	25 x 30	20 x 20	PP-Nets: 20 x 20; Grid mesh: 15 x 12
Surface cover [%]	Not specified	35	100	100
Dry weight [g/m²]	ca. 800	400	350 – 400	350 – 400
Characteristics	Stiff, deformable	Flexible, deformable	Flexible, deformable	Flexible, deformable

3.2.5.1 MacMat® R

Figure 9 MacMat® R geotextile – turf reinforcement mat (TRM) (15.05.2012, Essling VIENNA)

MacMat® R is a double drilled metal net in combination with a three dimensional polymere mazy clutch as displayed in figure 9. This type of geotextile can be used on long and steep slopes to improve the shear strength of the soil. The material is produced for application purposes where permanent erosion protection is aimed. This product is UV stable and non-degradable. MacMat® R solutions protect the soil surface by immediate protection of exposed areas from direct effects of wind and rainfall impact, protecting seeded topsoil from washing out before vegetation has established, creating an environment that enhances the growth of vegetation through the mat, reinforcing the root system of plants, further binding the soil surface and increasing shear resistance of the surface. By the three dimensional polymere turf reinforcement mat the surface roughness is higher and reduces therefore, the velocity and volume of run-off flow by increasing water (www.maccaferri-northamerica.com/macmat.aspx, 25.02.2013).

3.2.5.2 BonTerra® Coir Netting

Figure 10 BonTerra® Coir Netting (15.05.2012, Essling VIENNA)

BonTerra® Coir Netting is a woven system of coir fibre. The netting is a tool for protection against erosion and to promote the growth of vegetation. The mat has a durability of 1 to 5 years (depending on environmental characteristics, vegetation development, activity of microorganisms, …) and is recommended for slope inclinations up to 1:2 which is equivalent to 27° respectively 51 % (www.bonterra.de, 25.02.2013).

3.2.5.3 BonTerra® K Coir Fibre Blanket

Figure 11 BonTerra® K Coir Fibre Blanket (15.05.2012, Essling VIENNA)

BonTerra® K Coir Fibre Blankets are 100% untreated coir fibre stitched with polypropylene or jute netting. This type of erosion control product is a special solution for slopes and supplies instant full surface cover. The mat has a durability of 3 to 5 years and is suitable for slopes with an inclination up to 2:3 which is equivalent to 34° respectively 67,5 %. It can also be used for steeper slopes where high stress loads are expected high velocity of water runoff and severe erosion forces (www.bonterra.de, 25.02.2013).

3.2.5.4 BonTerra® R3D

Figure 12 BonTerra® R3D (15.05.2012, Essling VIENNA)

The BonTerra® R3D blanket is a 100% coconut fibre stitched on one side with a three-dimensional polypropylene (PP) grid. This type of mat is used as an erosion control blanket and provides a long term erosion control of 3 to 5 years due to mulching effects. It can store water and acts as protection against dry conditions due to the reduction of evaporation. This can improve germination rates and protects the seeds from being transported. BonTerra® R3D is applied in critical erosion control areas and for long term establishment of vegetation and stabilization (www.bonterra.de, 25.02.2013).

3.3 Methods

3.3.1 Technical execution

The previously described geotextiles were used to build up six different scenarios. To assess the influences of the geotextiles also experimental plots called 'dry seeding' (vegetation only) and 'reference plots' without any erosion reducing measurement were made. At the end we came up with eight different scenarios and 64 plots in sum for having a sufficient number of samples. In the following table a layout plan of the different plots is displayed:

Table 5 Characteristics of used geotextiles [1] (2012 Essling, VIENNA)

<table>
<tr><td colspan="4">
Reference</td><td colspan="4">
BonTerra® Coir Netting</td><td colspan="4">
BonTerra® K Coir Fibre Blanket</td><td colspan="4">
BonTerra® R3D</td></tr>
<tr><td>61</td><td>64</td><td>62</td><td>56</td><td>27</td><td>48</td><td>31</td><td>40</td><td>23</td><td>32</td><td>22</td><td>24</td><td>14</td><td>16</td><td>16</td><td>8</td></tr>
<tr><td>64</td><td>63</td><td>59</td><td>55</td><td>26</td><td>47</td><td>30</td><td>39</td><td>18</td><td>31</td><td>17</td><td>23</td><td>10</td><td>15</td><td>11</td><td>7</td></tr>
<tr><td>60</td><td>62</td><td>57</td><td>54</td><td>29</td><td>46</td><td>32</td><td>38</td><td>21</td><td>30</td><td>24</td><td>22</td><td>13</td><td>14</td><td>15</td><td>6</td></tr>
<tr><td>58</td><td>61</td><td>63</td><td>53</td><td>28</td><td>45</td><td>25</td><td>37</td><td>20</td><td>29</td><td>19</td><td>21</td><td>9</td><td>13</td><td>12</td><td>5</td></tr>
<tr><td>56</td><td>60</td><td>49</td><td>52</td><td>46</td><td>44</td><td>47</td><td>36</td><td>40</td><td>28</td><td>38</td><td>20</td><td>8</td><td>12</td><td>7</td><td>4</td></tr>
<tr><td>54</td><td>59</td><td>50</td><td>51</td><td>42</td><td>43</td><td>48</td><td>35</td><td>33</td><td>27</td><td>34</td><td>19</td><td>1</td><td>11</td><td>5</td><td>3</td></tr>
<tr><td>51</td><td>58</td><td>53</td><td>50</td><td>43</td><td>42</td><td>44</td><td>34</td><td>39</td><td>26</td><td>37</td><td>18</td><td>4</td><td>10</td><td>3</td><td>2</td></tr>
<tr><td>55</td><td>57</td><td>52</td><td>49</td><td>41</td><td>41</td><td>45</td><td>33</td><td>35</td><td>25</td><td>36</td><td>17</td><td>2</td><td>9</td><td>6</td><td>1</td></tr>
<tr><td colspan="4">MacMat® R filled with soil
</td><td colspan="4">MacMat® R + Terravest K
</td><td colspan="4">MacMat® R
</td><td colspan="4">Dry seeding
</td></tr>
</table>

3.3.2 Preparation and filling of testing plots

Before using the soil to fill up the pans, the big coarse particles were removed. This was accomplished by using a coarse meshed sieve. The pre-treated soil was used to fill the sowing pans on which the different samples were built.

[1] black: plot number, gray: picture number

The typical density of cultivated mineral soils at plowed horizon for moderate to heavy texture are at a range between 0,8 and 1,4 g/cm³ and for light texture between 1,4 and 1,7 g/cm³ (ROWELL, 1994). For this project the value of 1,3 g/cm³ was chosen to minimize too strong soil subsidence. The required volume of soil for each box can be calculated by using the following formula:

$$Filling\ weight = \frac{Volume}{Density}$$

As result 10,8 kg of topsoil was needed for each sowing pan to reach the appointed density value. To prevent the soil from gushing through the holes a piece of garden fleece was placed in the bottom of each pan before the soil was filled in. For the fixation of the geotextiles on the top of the sowing pans, holes were made just below the edge to fix the geotextiles later with cable strips. In the following pictures the different working steps of filling the sowing pans are displayed:

Figure 13 Preparation and filling of testing plots (11.05.2012, Essling VIENNA)

3.3.3 Seed mixture – weighing

As seeds for the planting, a seed mixture of BOKU university was used. The seed mixture is a proven assortment of drought resistant species for dry regions. The amount of seeds is expressed in g/m^2.

The selection of the quantity highly depends on quality of seeds, mixture of species and also on local site conditions. Based on the external factors and personal experiences we have chosen a quantity of 10 g/ m^2 what results in a total amount of 1,8 g for each sowing pan. Details about the seed mixture and the portion of each species is listed in the Appendix. The different seeds of the single species where weighed in the laboratory and packed in boxes and envelopes as illustrated in the following pictures:

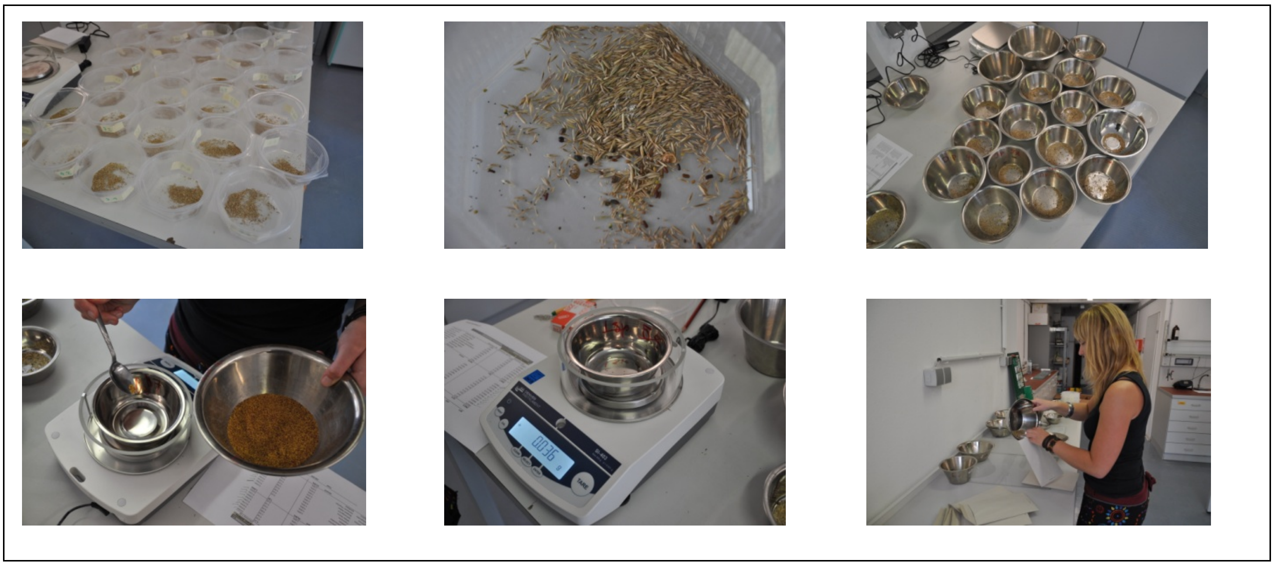

Figure 14 Weighing and packing of seeds (10.05.2012, BOKU VIENNA)

3.3.4 Installation of geotextiles and seeding

End of May 2012 the plots were completed. First of all the geotextiles were fitted to the size of the sowing pans. For the embodiments with ‘BonTerra®’, ‘MacMat® R’ and ‘MacMat® R + Terravest K’ the upper part of the soil was first bulked with a rake. Then the seeds spread equally over the area using dry seeding method. Finally the geotextiles were placed on top and fixed with cable straps (see pictures below):

Figure 15 Sowing and installation of geotextiles (18.05.2012, 22.05.2012 Essling, VIENNA)

For the executions with ‘MacMat® R + Terravest K’ an organic glue of the company Terravest was used as an additional protection of the seeds against erosion. Glues can bind or stabilize the soil particles and seeds. Usually the binders are used in a suspension with water (MORGAN / RICKSON, 1995). Terravest K binder is an organic soil stabilizer based on special liquid polymer combined with auxiliaries. The binder needs to be diluted in water and then spread over the surface. The compounds of the binder react with oxygen within a few hours after application and an insoluble network is formed. The effects are a fixation of the seeds and soil amendments on the surface (http://www.sw-duenger.de, 26.02.2012). The necessary amount of binder was calculated by following the manufacturers specifications. The amount of binder in one watering can was 90 g what results in an amount of 11,25 g per each plot. Detailed calculation and the datasheet of the Terravest K binder can be found in the Appendix. Finally the water diluted Terravest K binder was equally distributed over the eight plots, see following pictures:

Figure 16 Spreading of Terravest K binder over the testing plots (22.05.2012 Essling, VIENNA)

For the plots with the execution ‘MacMat® R filled’ the upper part of the soil was removed first. A 1 cm layer for refilling was assumed and the volume from the soil to be removed calculated what resulted in an amount of 2 kg. After removing the soil the MacMat® R turf reinforcement mat was placed on the sowing pan and fixed with cable straps. In this case the seeding mixture was spread equally by dry seeding method after installing the geotextile on the top. Afterwards the geotextilec entanglement was filled with the previous removed soil and compacted carefully by hand, the working steps are displayed in the pictures below:

Figure 17 Sowing and filling of the set ups MacMat® R filled (22.05.2012 Essling, VIENNA)

3.3.5 Implementation of rainfall simulation

Two rainfall simulation experiments were implemented 11 respectively 17 weeks after sowing. Before starting the rainfall simulation the phytomass of each plot was cut on a height of 5 cm. For this experiment the cutting was necessary so that the raindrops can reach the soil in the short precipitation duration. Also in other studies this method was found (for example in MERZ et al. (2009)).

Figure 18 Rainfall simulation (18.09.2012 Essling, VIENNA)

For each scenario two pans were used and irrigated once on each half of the pan. This resulted in an overall amount of four rainfall simulations for each execution. The rainfall simulation was done under dry soil condition (no rain during the days before) to ensure similar conditions regarding to the soil moisture. The plots were pre-wetted with a soil wetting jar (a tool that is part of the rainfall simulator). For a comparison of the soil moisture conditions and to determine the changes, the volumetric soil moisture was measured with a Time Domain Reflectrometry Sensor (TDR). The pans were placed on the previously built construction and each testing field was irrigated for a duration of 3 minutes.

Figure 19 Working steps of implementation of rainfall simulation (18.09.2012 Essling, VIENNA)

The created runoff from the pans was collected after every minute on the lower side of each test plot and stored in closeable bins and transported to the laboratory. As an additional information the runoff starting time during each simulation was noted.

3.3.6 Measured parameters

3.3.6.1 Vegetation development

The vegetation characteristics of each plot were recorded at different stages during the growing period (06.06.2012, 03.07.2012, 06.08.2012, 18.09.2012). At the first review a severe infestation of pest plants was observed. The pest plants were removed manually by hand before the phytomass of the plots was mown. The biomass was cut on a height of 5 cm above ground and collected. The cutting is also important for the development of a sufficient vegetation cover. All herbaceous plants should be cut at least once to remove invading plants and to decrease the possibility of uneven growth (MORGAN / RICKSON, 1995).

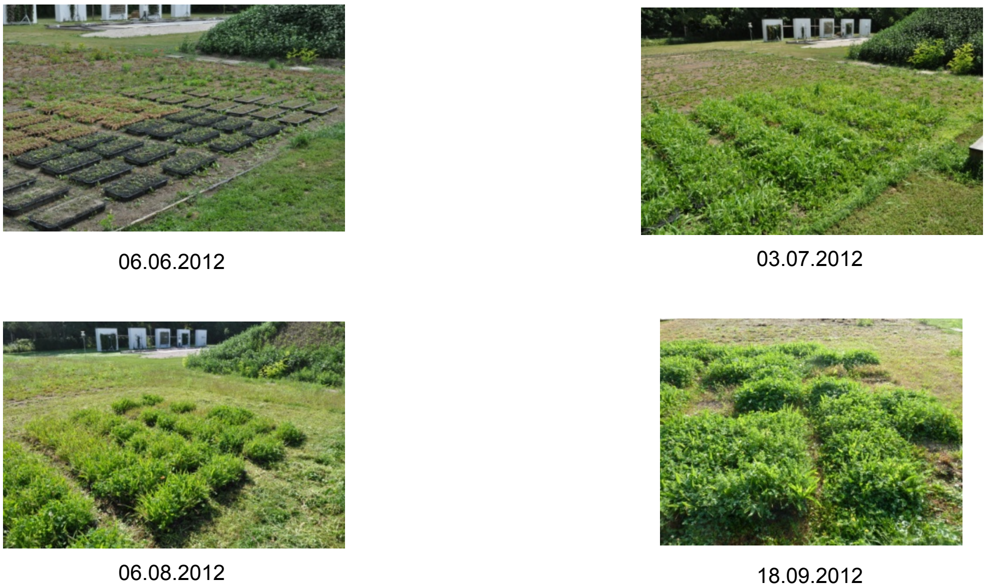

Figure 20 Impressions of vegetation development (22.05.2012 Essling, VIENNA)

With recording the development of vegetation the influence of geotextiles on growing characteristics of the plants can be determined. The development of vegetation was measured in two different ways as described in the following sequences.

3.3.6.1.1 Biomass

The total biomass of each plot was collected in envelopes and brought to the laboratory for drying. The biomass was dried in an oven at 70°C until the oven-dry mass was reached. Afterwards the biomass was weighed and recorded for further statistical analysis.

Figure 21 Maintenance cut and preparation of biomass (18.09.2012 Essling, VIENNA, 21.06.2012 BOKU, VIENNA)

3.3.6.1.2 Vegetation cover

At the same dates (see sequence above) the evolution was recorded optically by taking high resolution pictures of each testing plot. The pictures were taken before and after the maintenance cut and analysed by using Photoshop to determine the degree of vegetation cover. Afterwards the data were transferred to a statistical evaluation software (SPSS) and assessed.

3.3.6.2 Surface runoff

The surface runoff collected in buckets was measured in the laboratory by using measuring cylinders with a resolution of 10 ml. After measuring the runoff amounts, the liquids with the contained soil particles were filled in metal bowls and put into an oven for drying. The drying was done at different temperatures, depending on the available time (90°C, 160°C, 200°C, 210°C, 250°C).

Figure 22 Drying of runoff samples (14.11.2012 BOKU, VIENNA)

3.3.6.3 Soil loss

The interrill soil loss [g/0,0625 m^2] was measured by weighing the dried soil samples. The amount of sediments in the collected runoff provides information about the soil`s erodibility as well as the effect of the different soil erosion control measures. The soil loss is considered quantitatively. For the samples of the first simulation the remaining soil particles were removed using a ‘scraping out technique’ by using different tools like spoon, knife, etc. Then the soil was weight with a precision scale.

Figure 23 Scratching out and weighing of soil losses (14.11.2012 BOKU,VIENNA)

For the second implementation another, less time-consuming, technique was used. The empty metal bowls were weighed before using. Afterwards the bowls were filled with the runoff sample with the contained soil loss and oven dried. After the samples were completely dry, the bowls were removed from the oven and left to cool. Finally the bowls were weighed with the soil samples inside and the difference to the previously measured weight was calculated. Although the bowls were cooled it was necessary to put a glass layer between the bowl and the scale to avoid misrepresentations due to minimal temperature changes. To ensure the comparability of method one and method two an adequate number of bowls was treated in both ways. The results showed no essential impacts, therefore the directly measured data were used for the statistical analysis.

3.3.6.4 Runoff initiation – starting time

The runoff initiation is a very important feature in soil erosion. It determines the time required for water to start running down the soil surface. The runoff initiation also controls soil detachment rates and sediment transport. The earlier the runoff starts, the higher is the amount of the water volume and the time for transporting soil particles. The different executions should delay the runoff initiation in different intensities.

Vegetation can delay the starting time by enhancing the infiltration rate by roots, interception by above ground parts or increasing the roughness of the soil surface by stems and near surface roots. Also geotextiles have positive influences on the runoff initiation. Depending on the material they might have water absorbing capacities and the starting time is delayed until this capacity is exceeded. Also the surface roughness is increased by most of the geotextiles and soil particles are held back by the geotextile structure. Geotextiles with a high degree of coverage might also have better delaying capacity than geotextiles with lower coverage. For each irrigated plot the starting time was recorded and later transferred to SPSS and statistically analysed.

3.3.6.5 Plant effects on sediment and runoff reductions

As the different impacts can be determined quantitatively also some qualitative measures are possible. For the determination of the impacts of the plants on soil erosion the differences between planted pans and the reference pans were compared. According to the formulas of ZHOU and SHANNUAN (2006) the total effects of the plant impacts on the reduction of soil loss and runoff reduction can be calculated as follows:

$$CRp = \frac{Rf - Rp}{Rf} * 100\%$$

$$CSp = \frac{Sf - Sp}{Sf} * 100\%$$

CS_p, CR_p … contribution to sediment and runoff reduction [%]

S_f, R_f … sediment and runoff in fallow pans [g]

S_p, R_p … sediment and runoff in planted pans [g]

3.3.6.6 Infiltration rate

The infiltration rate is another crucial parameter for soil erosion processes. As described in chapter ‘2 Basics’ soil erosion starts when the rainfall intensity exceeds the infiltration capacity. For the infiltration rate the rainfall intensity must be calculated with following equation:

$$I = \frac{D}{A}$$

I …. Rainfall intensity [mm*min^{-1}]

D … Rainfall depth [l]

A … Irrigated Area [m^2]

Following ZHOU and SHANGGUAN (2006) the rainfall intensity can be calculated with next equation:

$$i = I * cos\theta - \frac{R}{t * A}$$

i … infiltration rate [mm*min^{-1}]

I … rainfall intensity [mm*min^{-1}]

θ … slope [°]

R … collected runoff in the ith bucket [mm^3]

t … sampling time [min]

A … area of the soil flume [mm^2]

3.3.6.7 Saturation discharge coefficient

With the saturation discharge coefficient the part of the precipitation which results in surface runoff is shown at constant infiltration. The saturation discharge coefficient was calculated as additional information to the quantitative surface runoff data. The formula of the saturation discharge coefficient was formed by Markart et al. (2004):

$$\psi t = \frac{Qt}{Nt}$$

ψ_t…saturation discharge coefficient at time t [-]

Q_t…surface runoff at time t [l]

N_t…precipitation at time t [l]

t…time with constant infiltration [s]

3.3.7 Laboratory soil analysis

As previously mentioned soil samples were taken to prove the accordance of the used soil with the ASTM D 5268 standards for topsoil used in erosion and sediment control testing's (see also section '3.2.4 Soil characteristics). The analysis was conducted by using a conventional sedimentation analysis for soil property determination in the laboratory. For all laboratory analysis the soil was sieved with a 2 mm mesh sieve in advance.

3.3.7.1 pH value

For determining the soil pH value the electrometric method with a pH gauge was used. For the exchangeable acidity a soil sample with KCl and for the active acidity, soil samples were mixed with H_2O. Afterwards the pH can be measured with an electrode.

Figure 24 Soil-pH measurement (14.11.2012 CULS, PRAGUE)

The different ranges and their declaration are displayed in table 6.

Table 6 Definition of pH values (Department of soil sciences CULS, PRAGUE, n. d.)

pH KCl (exchangeable acidity)	
Strongly acid	< 4,5
Acid	4,5 - 5,5
Slightly acid	5,5 - 6,5
Neutral	6,5 - 7,2
Alkaline	> 7,2
pH H_2O (active acidity)	
Strongly acid	< 4,9
Acid	4,9 - 5,9
Slightly acid	5,9 - 6,9
Neutral	6,9 - 7,1
Slightly alkaline	7,1 - 8
Alkaline	8 - 9,4
Strongly alkaline	> 9,4

3.3.7.2 Soil texture

The soil particle size distribution has large impacts on the hydraulic properties of the soil. Soil particles smaller than 2 mm are divided into three texture groups – sand, silt and clay.

Table 7 Definition of soil particle size (Department of soil sciences CULS, PRAGUE, n. d.)

Soil fraction	Grain size [mm]
Sand	0,05 - 2
Silt	0,002 - 0,05
Clay	< 0,002

The soil texture respectively the soil particle size was measured by a sedimentation method. All measurements were performed during one single sedimentation process, the different particles with different size settle down at different speeds. Depending on the reduction of particles moving in the solution the density is decreasing. This decrease is measureable with a special hydrometer (see figure 25).

Figure 25 Soil-texture measurement (14.11.2012 CULS, PRAGUE)

3.3.7.3 Organic content

For the organic content in the soil 0,2 g respectively 0,35 g of the prepared soil sample were weighed and filled into two different glass beaker. After that a 10 ml chromo-sulfuric mixture was added. In one extra beaker also 10 ml chromo-sulfuric mixture was put without soil as a reference sample. After heating the samples, they were rinsed with distilled water and the organic content can be determined with a potentiometric titration measurement.

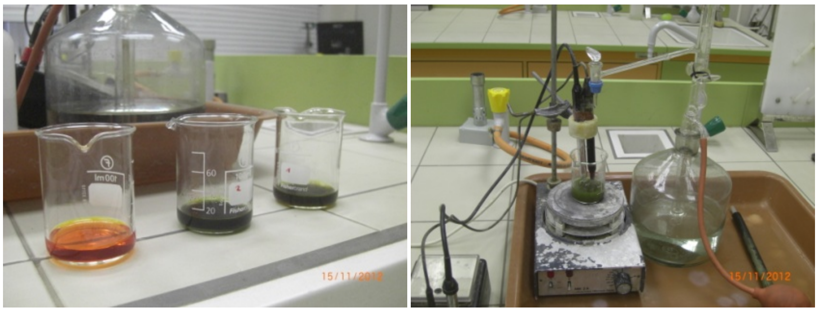

Figure 26 Soil organic content measurement (14.11.2012 CULS, PRAGUE)

The carbonate content value can be calculated according to the following equations:

$$f = 40/a$$

$$C = (12 - 0{,}3 * S * f) * 100/N$$

$$\%\ of\ humus = C * 1{,}724$$

f...factor Mohr’s salt

a...consumption for a blank sample

S...consumption [ml]

N...weight of the sample [mg]

3.3.7.4 Carbonate content

The content of carbonate was determined in two different ways. First half-quantitatively to determine if carbonate is contained and if further analysis are necessary. A small amount of soil was put in a petri-dish and mixed with a 10 % HCl solution. The following reaction provides a rough estimation about the carbonate content. The reactions and its associated magnitude of the carbonate content are defined as follows (Department of soil sciences CULS, PRAGUE, n. d.):

- Very weak reaction, only hearable: < 0,5 % carbonate
- Weak reaction, hardly visible: 0,5 – 2 % carbonate
- Clear reaction, not long lasting: 2 – 5 % carbonate
- Strong reaction, not long lasting: 5 – 10 % carbonate
- Very strong reaction, long lasting: > 10 % carbonate

In our case the reaction was clearly visible and hearable but not long lasting. Therefore a further measurement was done to determine the exact value of carbonate content.

This measurement is called quantitatively determination by using a tool created by the CULS soil sciences laboratory similar to the Scheibler-equipment.

10 g of the soil sample were put into a measuring cylinder and mixed with a 10% HCl solution. The measuring cylinder was closed properly with the rubber plug which is connected to the pipes of the equipment. Due to the development of gas the level of water in the pipes changes, with removing the air from the pipes the water in both needs to become to the same level. The shown value is the actual value of the carbonate content of the soil.

Figure 27 Soil carbonate content measurement (14.11.2012 CULS, PRAGUE)

The different ranges and their declaration are displayed in table 8.

Table 8 Definition of carbonate values (Department of soil sciences CULS, PRAGUE, n. d.)

Carbonate in %	Description
0	Without carbon
<0,5	Very poorly carbonate contained
0,5-2	Poorly carbonate contained
2-10	Carbonate contained
2-4	Slightly carbonate contained
4-7	Middle carbonate contained
7-10	Strong carbonate contained
10-25	Rich in carbonate
25-50	Very rich in carbonate
>50	Extremely rich in carbonate

4. Results and analysis

In this chapter all the collected data are analysed and discussed. All statistical analyses of the data were performed using SPSS 20 for Windows and determined using analysis of variance (ANOVA) followed by the Tukey post-hoc test. Whenever some significant differences between each analysed class have been previously verified, a post-hoc test is used to find additional information about these differences. As significance level an alpha-value of 0,05 was defined whereas the results have been evaluated by the following criteria:

- a > 0.05 (> 5 %) → not significant
- α = 0.01 to 0.05 (1 to 5 %) → significant
- α = 0.001 to 0.01 (0.1 to 1 %) → high significant
- α ≤ 0.001 (≤ 0.1 %) → highly significant

4.1 Soil loss

4.1.1 Soil loss – sample type

As expected the reference plots without vegetation and erosion control products show the highest amount of sediment loss concentrations. Therefore, in figure 28 the data of the reference plots are excluded to show the difference between the remaining executions. The results are expressed in grams in table 9.

Table 9 Soil loss considered quantitatively, mean values [g] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest K	MacMat® R filled	Reference
August	0,30	0,18	0,11	0,15	0,16	0,21	0,28	8,41
September	0,47	0,37	0,34	0,40	0,38	0,37	1,38	17,79
Total	0,39	0,27	0,23	0,28	0,27	0,29	0,83	13,10

According to all the data, the ANOVA analysis shows highly significant differences (α ≤ 0,001) between the different plots. For detailed analysis the differences within the implementation dates were considered. Consequently, this resulted in a high significant difference of α = 0,004 between the executions.

According to table 9 the lowest and thereby best value in the first date resulted from the use of 'BonTerra® K Coir Fibre Blanket' and had therefore, the highest significant difference α = 0,008 compared to 'Dry seeding' with the highest soil loss rates. Also 'BonTerra® R3D', 'MacMat® R' and 'BonTerra® Coir Netting' had a very low amount of soil loss and showed a significant difference to 'Dry seeding' (α > 0,01). The executions 'MacMat® R + Terravest K' and 'MacMat® R filled' had the highest amount in soil loss and therefore the lowest effect in soil retention. In the second measurement the overall differences between all groups were significant with α = 0,002. Exclusively the 'MacMat® R filled' variant show significantly high difference compared to the other plots, which did not reveal significant difference between each other. Also in the second date the 'BonTerra® K Coir Fibre Blanket' had the best soil retention. Furthermore 'BonTerra® Coir Netting', 'MacMat® R + Terravest K' and 'MacMat® R' showed good values. The soil loss of 'BonTerra® R3D' and 'Dry seeding is slightly higher compared to the already mentioned scenarios. As in the first date the execution 'MacMat® R filled' showed the highest loss in soil particles also in the second date.

The average of the two dates indicates 'BonTerra® K Coir Fibre Blanket' as the material with the lowest soil loss and best retention capacity. The scenarios 'BonTerra® Coir Netting', 'MacMat® R' and 'BonTerra® R3D' also had low values in soil loss. The amount was slightly higher for 'Dry seeding'. 'MacMat® R filled' showed a very high value in soil loss compared to the other scenarios (see table 9).

For all executions the total soil loss increased from date 1 to date 2. The highest increase showed the variant 'MacMat® R filled' with almost 400 % more soil loss in the second date. The lowest increase show the variants with vegetation only (58 %), also a lower increase compared to the other variants had 'MacMat® R+ Terravest K' (80 %).

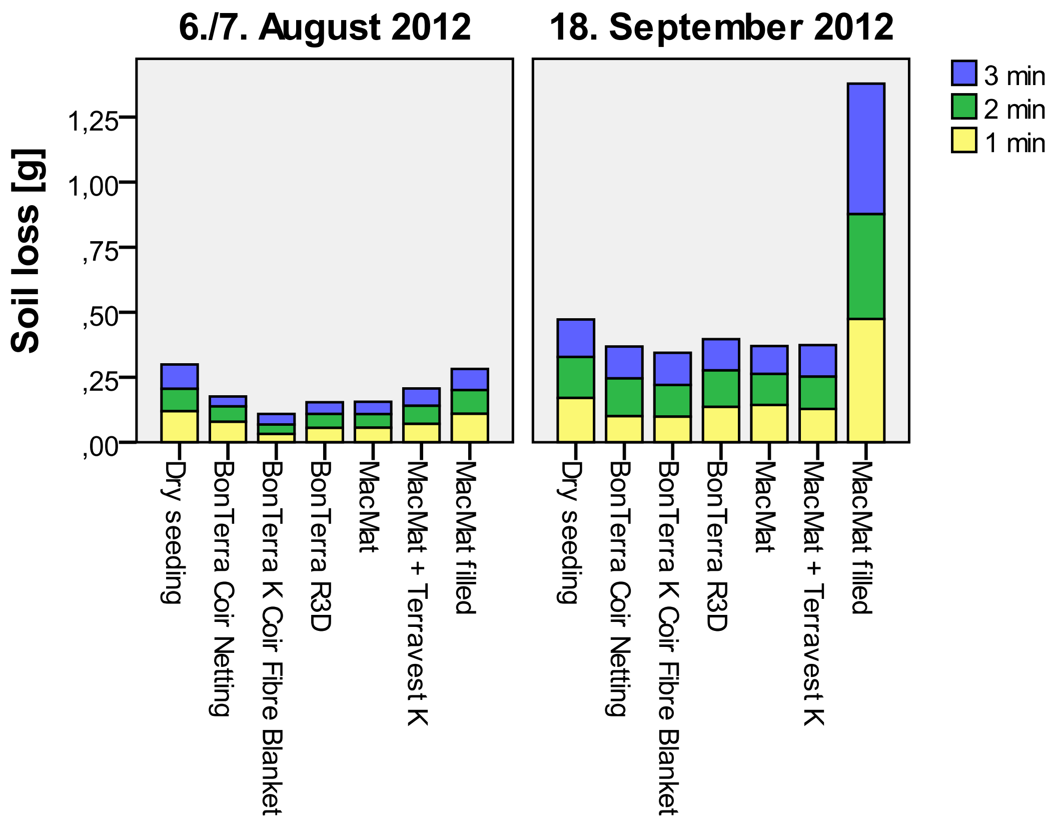

Figure 28 Soil loss considered quantitatively, mean values [g] (without bare soil) (2012 Essling, VIENNA)

The duration of the precipitation did not significantly affect the changes in soil loss. No significant difference is shown in the amount of soil loss regarding the minute-values. Soil loss slightly decreased from 1 min to 2 min and to 3 min in most cases. Only the plots with 'BonTerra® K Coir Fibre Blanket' and 'BonTerra® Coir Netting' showed an increase within the duration of the simulation.

4.1.2 Soil loss – organic vs. synthetic

In order to determine whether organic or synthetic geotextiles were more effective, the collected data were combined and categorised according to different classes of materials.

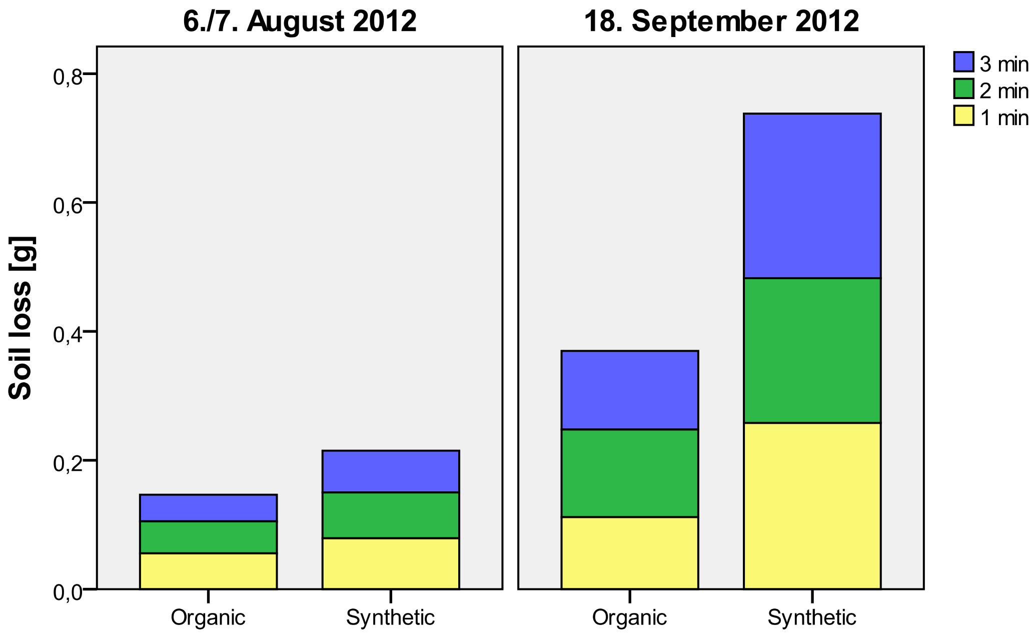

Figure 29 Soil loss considered quantitatively organic vs. synthetic, mean values [g] (2012 Essling, VIENNA)

Figure 29 clearly shows that the executions under usage of organic geotextiles had lower soil losses and therefore better ability to reduce soil erosion. The mean values of the classes are displayed in table 10. Following the ANOVA calculation, it was found that the difference is significant in both implementations. In date 1 the difference is rather high with α = 0,017 and in date 2 significant with α = 0,047. In both measures, and in total, the organic materials show lower values of soil loss and thus a more positive influence on the erodibility of the soil (see table 10).

Table 10 Soil loss considered quantitatively organic vs. synthetic, mean values [g] (2012 Essling, VIENNA)

	Organic	Synthetic
6./7. August 2012	0,15	0,22
18. September 2012	0,37	0,71
Total	0,26	0,46

Overall the organic geotextiles showed a 80% lower value of soil loss (in average) than the synthetic geotextiles. According the development of date 1 to date 2 had the synthetic materials a bigger increase in soil loss of 230 %, the organic materials had an increase of 152 %.

4.1.3 Soil loss – 'Dry seeding' vs. 'Reference'

As a further investigation, two more classes were compared to each other ('Dry Seeding' and 'Reference').

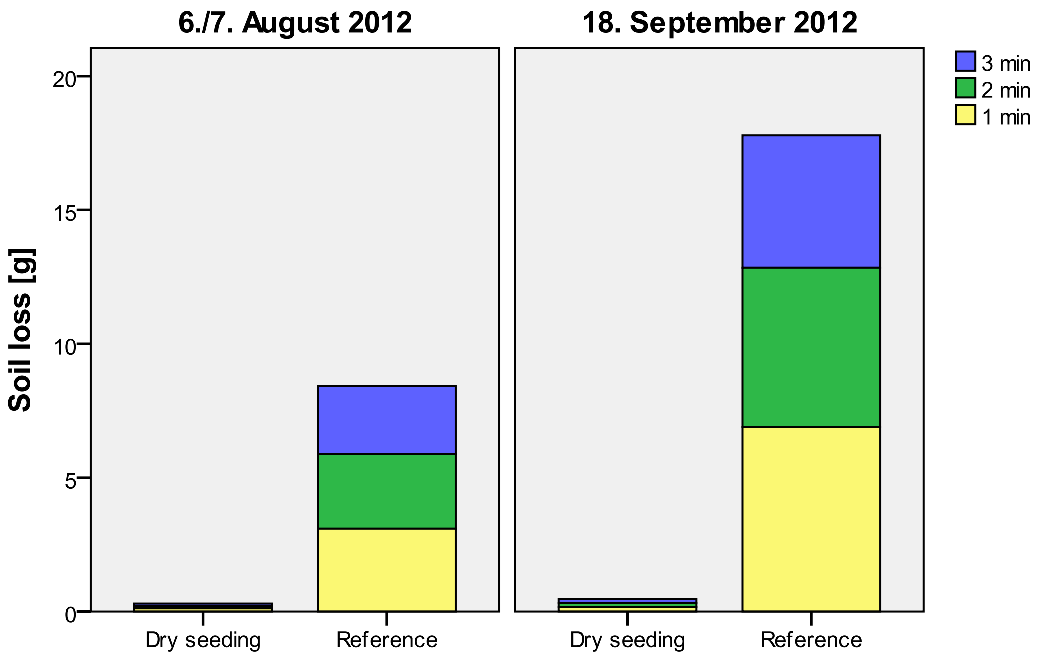

Figure 30 Soil loss considered quantitatively 'Dry seeding' vs. 'Reference', mean values [g] (2012 Essling, VIENNA)

According to figure 30, 'Dry seeding' plots had much lower value in soil loss, suggesting positive influence in reducing soil erosion due to the plants impact.

Table 11 Soil loss considered quantitatively – 'Dry seeding' vs. 'Reference', mean values [g] (2012 Essling, VIENNA)

	Dry seeding	Reference
6./7. August 2012	0,30	8,42
18. September 2012	0,48	17,79
Total	0,39	13,10

In both measures the dry seeding plots have lower soil loss and therefore, a definitely better potential for minimizing soil loss (see table 11). The soil loss of the 'Reference' plots is clearly higher than the soil loss of the 'Dry seeding' plots and had also a higher increasing of date 1 to date 2 ('Reference': 112 %, 'Dry seeding': 58 %).

4.2 Water losses

4.2.1 Runoff – sample type

The runoff rates are analysed quantitatively in this section. In table 12 the mean amount of surface runoff is displayed in millilitres. According to ANOVA analysis there was no significant difference in surface runoff at date 1. At date 2 the ANOVA shows a significant difference between 'Dry seeding' and 'BonTerra® Coir Netting' (α = 0,027) and a highly significant difference between 'Dry seeding' and 'BonTerra® K Coir Fibre Blanket' (α ≤ 0,001). In other words, 'BonTerra® K Coir Fibre Blanket' had the best retention capacity regarding to the surface runoff and also 'BonTerra® Coir Netting' showed a good water retention capacity with lower values in comparison to the other variants. By contrast, 'Dry seeding' had the highest value and thereby the highest water losses. The value of 'BonTerra® K Coir Fibre Blanket' had also significant differences to 'BonTerra® R3D' (α = 0,014), 'Reference' (α = 0,017), 'MacMat® R' (α = 0,027) and 'MacMat® R + Terravest K' (α = 0,045). Only the 'MacMat® R filled' had no significant differences and therefore also positive influences on the surface runoff.

Table 12 Runoff considered quantitatively, mean values [ml] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest K	MacMat® R filled	Reference
August	642,50	686,25	601,25	681,25	737,50	713,75	591,25	761,25
September	773,75	558,75	478,75	711,25	693,75	680,00	583,75	706,25
Total	708,13	622,50	540,00	696,25	715,63	696,88	587,50	733,75

Regarding to table 12 had the execution 'MacMat® R filled' the best water retention capacity in date one. Also 'BonTerra® K Coir Fibre Blanket' and 'Dry seeding' showed a lower amount in surface runoff. The values of the scenarios 'BonTerra® R3D' and 'BonTerra® Coir Netting' is clearly higher and therefore not as good as the previously mentioned. Very high water loss had 'MacMat® R' and 'MacMat® R + Terravest K'. The 'Reference' plots had the highest surface runoff. In the second date the picture changed slightly. 'BonTerra® K Coir Fibre Blanket' changed to the one with the lowest water loss and 'MacMat® R filled' shifted to place two. Also 'BonTerra® Coir Netting' had a good water retention in date two. The other scenarios showed less good results with the ranking 'MacMat® R + Terravest K', 'MacMat® R', 'Reference', 'BonTerra® R3D' and 'Dry seeding'.

In total 'BonTerra® K Coir Fibre Blanket' had the best ability in retaining water, also 'MacMat® R filled' shows good results. 'BonTerra® Coir Netting', 'BonTerra® R3D' and 'MacMat® R + Terravest K' are in the middle field. The least good effect resulted from the execution 'Dry seeding' and the 'Reference' plots (see values table 12).

Also considered was the development between the two simulation phases. 'MacMat® R', 'BonTerra® R3D' and 'Dry seeding' show an increase in surface runoff, indicating that their ability to retain water is limited. This is true especially with the dry seeding, which had an increased surface runoff by more than 20 %. By contrast, for the remaining executions the surface runoff decreased. The 'BonTerra® Coir Netting' and the 'BonTerra® K Coir Fibre Blanket' made a great improvement, with a very significant decrease in surface runoff (by 18 % and 20 %) indicating their high potential for water retention.

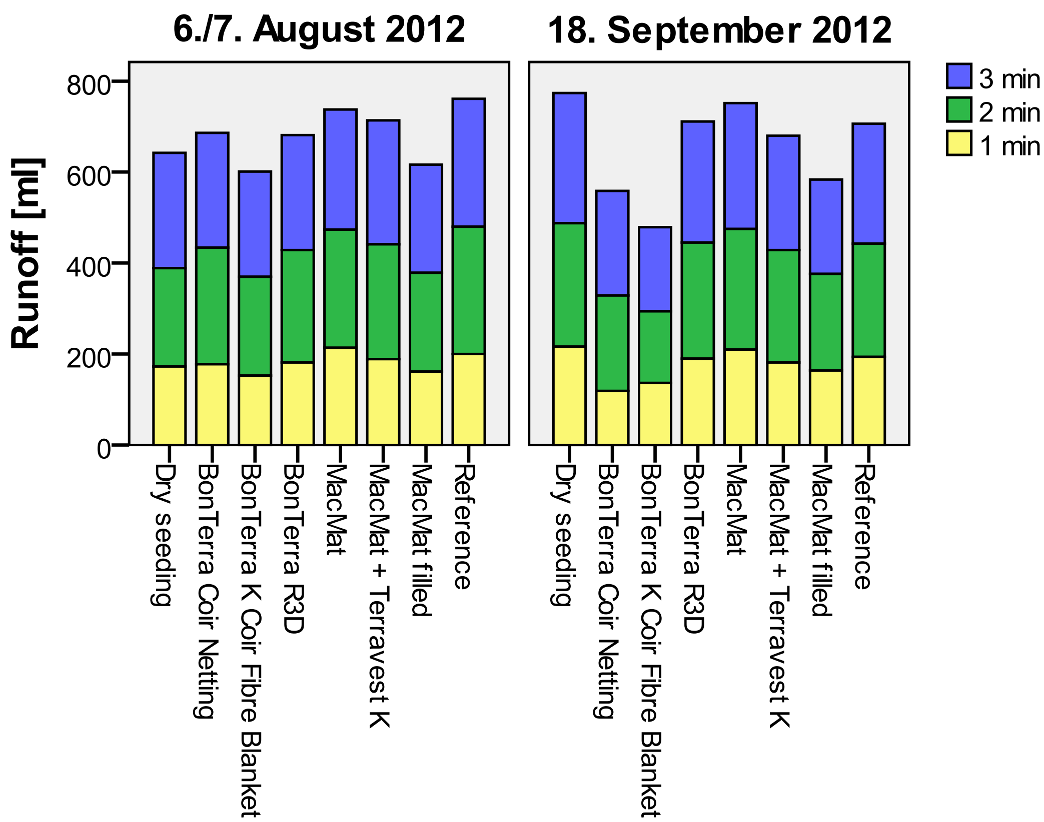

Figure 31 Runoff considered quantitatively, mean values [ml] (2012 Essling, VIENNA)

During the rainfall simulation are no significant differences observable within the different minutes. The significance level in all cases is > 0,05. The amount of surface runoff slightly increases from 1 min to 2 min and to 3 min. Within minute 1 the increase is higher than in the following two minutes. This is the result of an increasing saturation of the soil during the rainfall simulation. This characteristic development can be observed with regard to the date of implementation as well as the sample type.

4.2.2 Runoff – organic vs. synthetic

The effect of using organic and synthetic materials were compared in detail in order to understand the impact of these different types of geotextiles.

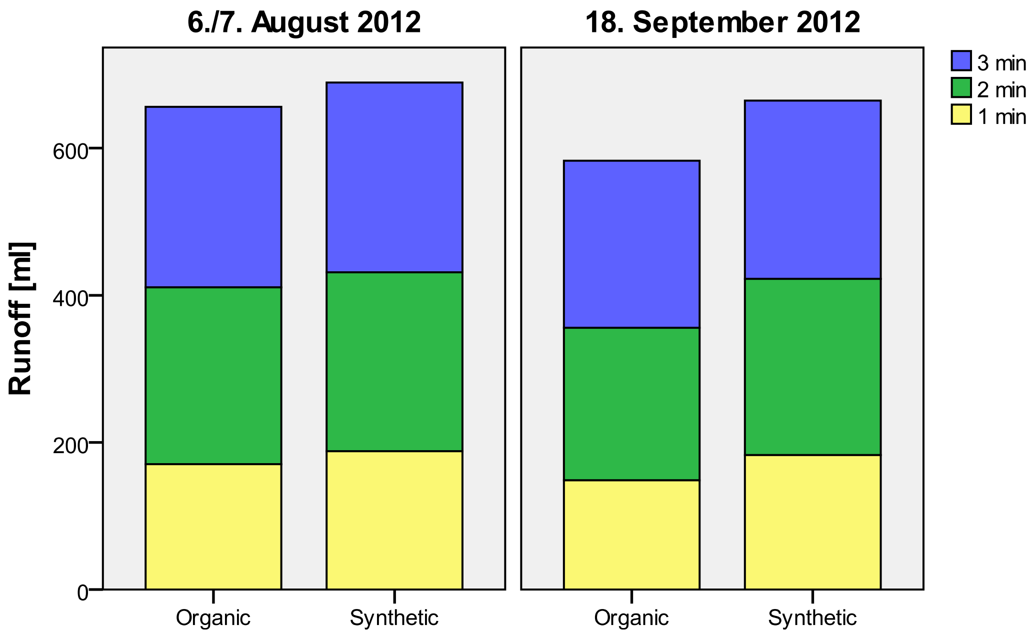

Figure 32 Runoff considered quantitatively organic vs. synthetic, mean values [ml] (2012 Essling, VIENNA)

As shown in figure 32 the differences between the executions with organic compared to the executions with synthetic materials are low. By ANOVA analysis it was found that in both implementations (date 1: $\alpha = 0{,}556$, date 2: $\alpha = 0{,}151$) the differences were not significant.

Table 13 Runoff considered quantitatively, mean values [ml] (2012 Essling, VIENNA)

	Organic	Synthetic
6./7. August 2012	656,25	680,83
18. September 2012	582,92	652,50
Total	619,58	666,67

When comparing the mean values the organic variants show a better water retention capacity than the synthetic materials (refer to values in table 13). For both executions the surface runoff decreased from date 1 to date 2. This is indicative of the increasing water retention capacity. The decrease of about 11 % was definitely higher in the executions with organic plots than the increase of the synthetic plots with about 4 %.

4.2.3 Runoff – 'Dry seeding' vs. 'Reference'

Furthermore the 'Dry seeding' and 'Reference' plots were combined into classes and compared regarding to runoff amount.

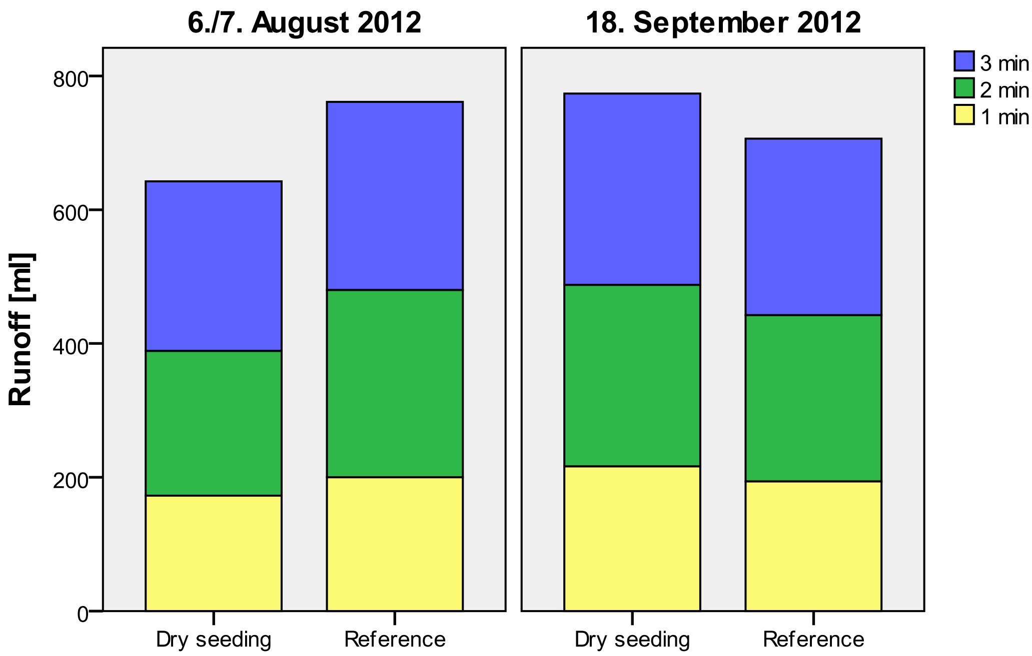

Figure 33 Runoff considered quantitatively 'Dry seeding' vs. 'Reference', mean values [ml] (2012 Essling, VIENNA)

The comparison of 'Dry seeding' vs. 'Reference' shows a significant difference at date 1 (α = 0,034). The 'Dry seeding' plots in the first implementation had a better reduction in surface runoff. At date 2 the diversity was reduced and no significant differences observable (α = 0,182).

Table 14 Runoff considered quantitatively Dry seeding vs. Reference, mean values [ml] (2012 Essling, VIENNA)

	Dry seeding	**Reference**
6./7. August 2012	642,50	761,25
18. September 2012	773,75	706,25
Total mean	708,13	733,75

At date 1 the water retention capacity was clearly higher for the executions with ‘Dry seeding’, while at date 2 this was the other way around but the ‘Reference’ plots showed a positive development regarding surface runoff (see values in table 14). The ‘Dry seeding’ plots had a negative development by showing a growth of water losses about 20 %. Despite this, the ‘Reference’ plots showed a decrease of water losses about 7% and therefore state positive influence in reducing the surface runoff. The surface runoff is in total 3,6 % lower at the ‘Dry seeding’ plots than at the ‘Reference’ plots.

4.3 Saturation discharge coefficient

The saturation discharge coefficient is the rate of discharged water on the surface and similar to the results showed in the previous section. The results of saturation discharge coefficient should further illuminate the relative effectiveness of the various geotextiles used. The mean values of the saturation discharge coefficient are displayed in table 15.

Table 15 Saturation discharge coefficient, mean values [-] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest	MacMat® R filled	Reference
August	0,53	0,58	0,51	0,57	0,64	0,60	0,50	0,64
September	0,66	0,48	0,41	0,60	0,61	0,58	0,50	0,63
Total	0,59	0,53	0,46	0,59	0,63	0,59	0,50	0,63

According to the total mean, ‘BonTerra® K Coir Fibre Blanket’ had the lowest saturation discharge coefficient and therefore the best retention capacity. In fact, compared to both ‘BonTerra® R3D’ ($\alpha = 0{,}025$) and ‘Dry seeding’ ($\alpha = 0{,}017$) a significant difference is noticeable. The ‘MacMat® R’ plots and ‘Reference’ plots ($\alpha \leq 0{,}001$) showed highly significant differences from ‘BonTerra® K Coir Fibre Blanket’ and thereby the lowest retention capacity.

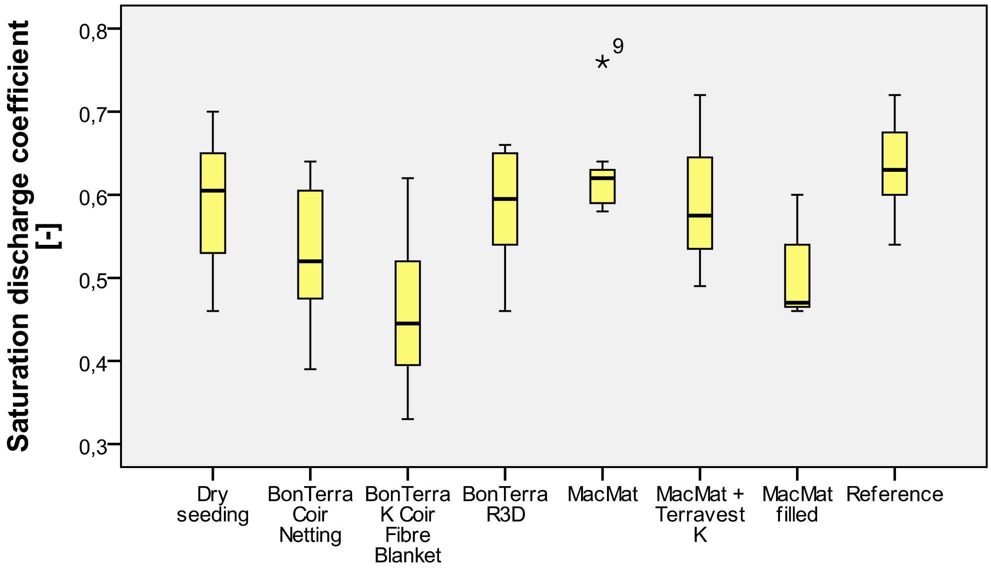

Figure 34 Saturation discharge coefficient total, mean values [-] (2012 Essling, VIENNA)

If the dates are considered separately the results are different. At date 1 there are no significant differences between the executions. 'MacMat® R filled' had the lowest and 'BonTerra® K Coir Fibre Blanket' the second lowest saturation discharge coefficient. 'Reference' and 'MacMat® R' had the highest value, indicating their lowest retention capacity. At date 2 the results are similar to the results of the data in total. The 'BonTerra® K Coir Fibre Blanket' showed the highest retention capacity, no significant differences are observable to 'BonTerra® Coir Netting' with the second lowest discharge and 'MacMat® R filled' with the third lowest discharge. All other executions had clearly higher discharge rates and therefore significant differences. 'Dry seeding': $\alpha = 0{,}017$; 'BonTerra® R3D': $\alpha = 0{,}025$; 'MacMat® R': $\alpha \leq 0{,}001$; 'MacMat® R + Terravest K': $\alpha = 0{,}019$; 'Reference': $\alpha \leq 0{,}001$.

4.4 Infiltration rate

In this section the infiltration rate is analysed to shed some information about the change in infiltration of water into the soil. Therefore this analysis is based on the differentiation of the three precipitation stages (1 min, 2 min and 3 min).

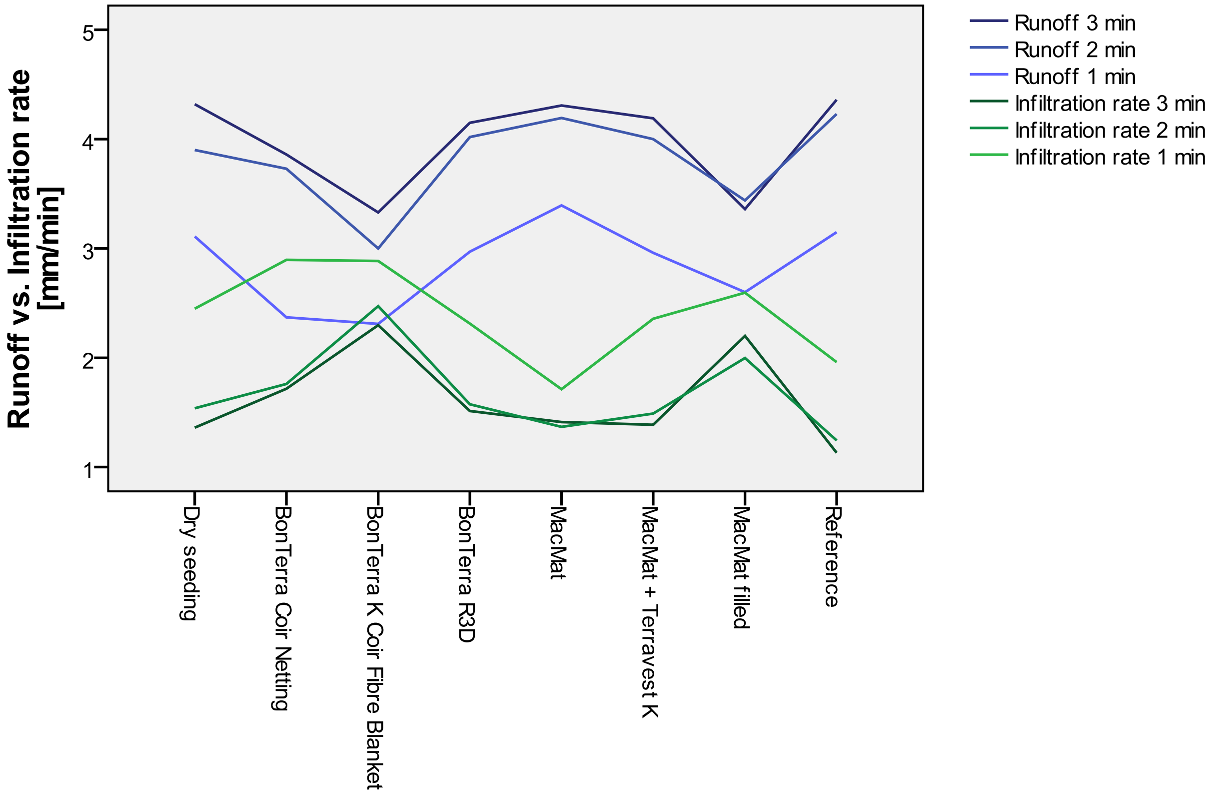

Figure 35 Saturation discharge coefficient total, mean values [-] (2012 Essling, VIENNA)

During the first minute, period from the start of rainfall to initiation of runoff, the highest infiltration rates could be determined. Within the second and third minute the infiltration rate is clearly lower. Between second and third minute the difference is not significant. The differences between the executions within the groups are highly significant in the first and third minute ($\alpha \leq 0{,}001$), in the second minute the differences are lower ($\alpha = 0{,}112$).

Table 16 Infiltration rate, mean values [mm/min] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest	MacMat® R filled	Reference
August								
1 min	2,75	2,56	2,69	2,33	1,53	2,38	2,75	2,13
2 min	2,15	1,44	2,06	1,65	1,35	1,40	1,92	1,64
3 min	1,72	1,50	1,91	1,68	1,29	1,22	2,11	1,57
September								
1 min	2,15	3,23	3,09	2,29	1,83	2,33	2,44	1,78
2 min	0,93	2,08	2,88	1,50	2,47	1,58	2,07	1,32
3 min	1,00	1,93	2,69	1,35	1,51	1,56	2,29	1,11
Total								
1 min	2,45	2,90	2,89	2,31	1,68	2,36	2,60	1,96
2 min	1,54	1,76	2,47	1,57	1,91	1,49	2,00	1,24
3 min	1,36	1,72	2,30	1,51	1,40	1,39	2,20	1,13

According to table 16 had the scenarios of ‘BonTerra® K Coir Fibre Blanket’ and ‘BonTerra® Coir Netting’ very high infiltration rates in the first minute. The rate was of course decreasing after the first minute but was still high compared to the others. The decrease of ‘BonTerra® K Coir Fibre Blanket’ was lower. Also a very good rate showed ‘MacMat® R filled’ and ‘Dry seeding’, whilst the infiltration rate of ‘MacMat® R filled’ was better over the irrigated time and therefore decreasing less. The plots ‘BonTerra® R3D’ and ‘Reference’ are both in the middle field of the amount of infiltration with a medium decrease of the rate. And the lowest value showed the scenario ‘MacMat® R’ with a very poor infiltration rate from the beginning but a smaller decrease of the infiltration rate compared to the other scenarios.

Considering the dates separately, at date 1 there were no significant difference verifiable between the groups within the minutes. At date 2 the infiltration rates are more variable. Within the first minute a high significant difference was observed ($\alpha = 0{,}008$). In the second minute the variation is smaller and no significant difference is shown ($\alpha = 0{,}116$). Within the third minute the highest variation between the groups is shown with highly significant differences (α ≤ 0,001). Please also refer to the mean values in table 16.

4.5 Plant impacts on soil loss (CSp [%]) and surface runoff (CRp [%])

The plant impacts on soil loss are shown in table 18. For this calculation it was differentiated between the Reference plots and the executions with erosion reducing measures respectively all plots with vegetation.

Table 17 Plant impacts in reduction of soil loss (CS_p), mean values [%] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest	MacMat® R filled
August	96,45	97,91	98,70	98,17	98,15	97,54	96,65
September	97,34	97,93	98,06	97,77	97,67	97,90	92,25

The soil loss (CSp [%]) is significantly reduced by the vegetation, the measurements show values between min. 92,25 % and max. 98,7 % (see table 17). Between the different plots are no significant differences. According to the ANOVA analysis the significance level in all cases is α > 0,05.

In table 18 the plant impact in reduction of surface runoff are displayed. Just like in the soil loss analysis, the reference plots were compared with the other executions with erosion reducing measures respectively with vegetation.

Table 18 Plant impacts in reduction of surface runoff (CR_p), mean values [%] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest	MacMat® R filled
August	15,60	9,85	21,02	10,51	3,12	6,24	22,33
September	-9,56	20,88	32,21	-0,71	-7,16	3,72	17,35

When considering the values of surface runoff reduction(CRp [%]) the results are different. The amount of runoff reduction is with values of maximum 32 % much less than the reduction of soil loss. For ‘Dry seeding’, ‘BonTerra® R3D’ and ‘MacMat® R’ there is a reduction in surface runoff traceable compared to the bare soil plots during the first rainfall simulation. In the second rainfall simulation the surface runoff was higher for all of them compared to the bare soil. For 'MacMat® R + Terravest K binder' and 'MacMat® R filled' also a reduction of the positive impact of vegetation is observable between the two measurements, but the vegetation has still reducing influences on the surface runoff. The two setups with a positive development between the two implementations are 'BonTerra® K Coir Fibre Blanket' and 'BonTerra® Coir Netting'. In both cases, the surface runoff is significantly reduced, indicating a positive protective development. 'BonTerra® K Coir Fibre Blanket', which already showed good reduction potential during the first rainfall simulation, had also the best value in the second one.

4.6 Vegetation

4.6.1 Biomass

The biomass was taken four times as described in section '3.3.6.1 Vegetation development'. The obtained data were statistically analysed using the mean values for each different execution.

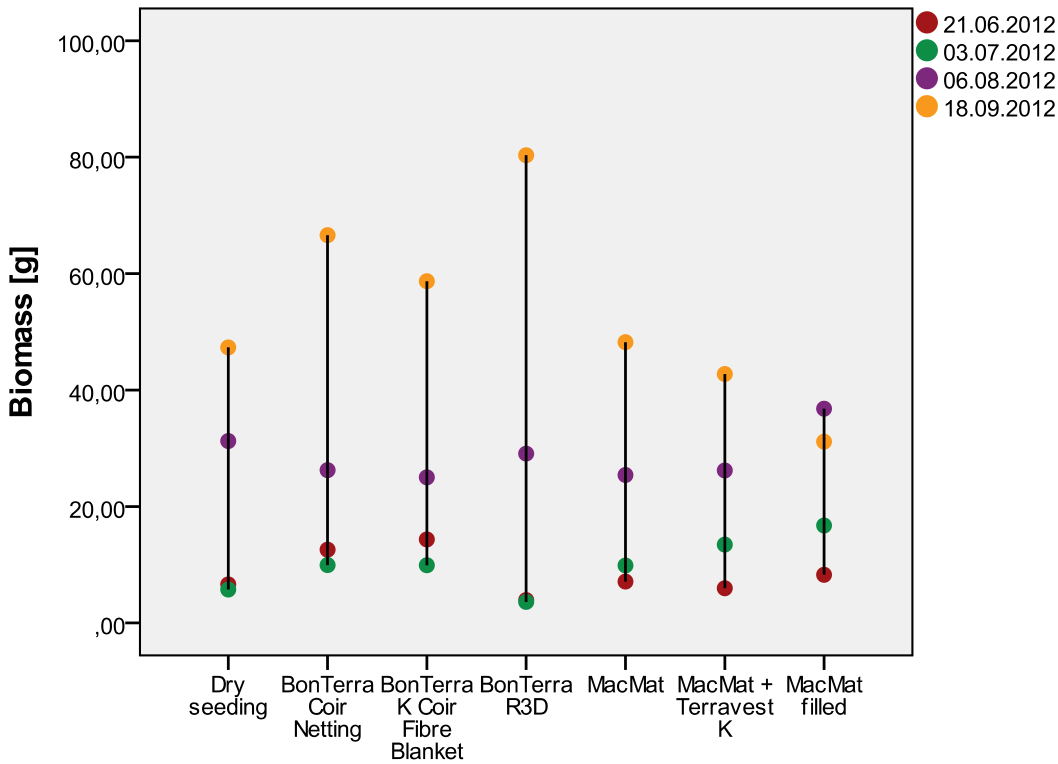

Figure 36 Biomass development, mean values [g] (2012 Essling, VIENNA)

Three 'BonTerra® R3D' plots were excluded of the calculation of the mean values due to their poor growth. The poor growth was caused during the first acquisition date by uplifting of the plots, which resulted in the destruction of the plant roots. The mean values and the percentage growth are shown in table 19.

Table 19 Biomass development, mean values [g] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest	MacMat® R filled
21.06.2012	6,64	12,56	13,93	6,66	7,59	5,80	8,74
03.07.2012	5,48	10,35	11,07	3,57	10,03	13,04	15,09
06.08.2012	26,76	24,04	24,04	27,11	25,14	25,50	33,94
18.09.2012	47,33	66,60	58,70	80,33	48,23	42,75	31,14

In the first acquisition date ‘BonTerra® Coir Netting’ and ‘BonTerra® K Coir Fibre Blanket’ had the highest values. Likewise, ANOVA analysis showed a highly significant difference to all other executions. The other executions are all on the same comparable level. The ‘MacMat® R + Terravest K’ had the lowest biomass rates.

‘BonTerra® R3D’ had the lowest quantity of biomass in the second data acquisition. Analysis showed difference to all other executions except ‘Dry seeding’ which verifies the low amount of biomass of only vegetation. Within the other executions there was no significant difference measureable. ‘MacMat® R + Terravest K’ and ‘MacMat® R filled’ had the highest amounts in biomass production. The biomass showed a decrease in ‘Dry seeding’, ‘BonTerra® Coir Netting’ and ‘BonTerra® K Coir Fibre Blanket’ about 20%. The ‘BonTerra® R3D’ had an extreme reduction about 46%. All plots with MacMat® R geotextiles showed an increase of biomass. ‘MacMat® R’ with about 32% the lowest and ‘MacMat® R + Terravest K’ and ‘MacMat® R filled’ a similar growth with more than 124%.

In the third measurement a significant increase in all scenarios was observed. In all plots the increase of biomass was 100% or more. The highest increase was in the dry seeding plots. Between the different executions no significant differences were observed.

At the fourth and last measurement, again a high increase in almost all plots was observed in this stage. The plots with BonTerra® geotextiles had a higher increase than in the stage before. For all other executions the increase was lower and the executions ‘MacMat® R’ filled have even a decrease of biomass in the last stage. ‘MacMat® R filled’ also had the lowest value of all executions in this stage and was therefore the only one with a recognizable significant difference of α = 0,043 to 'BonTerra® Coir Netting' which had the highest amount of biomass. All other setups did not show significant difference among each other. BonTerra® plots showed the highest amount of biomass in this data acquisition and a significant difference compared to all the other executions.

4.6.1.1 Classes – 'Dry seeding', organic, synthetic

For a better understanding the different executions were categorized into three different classes: 'Dry seeding', organic and synthetic.

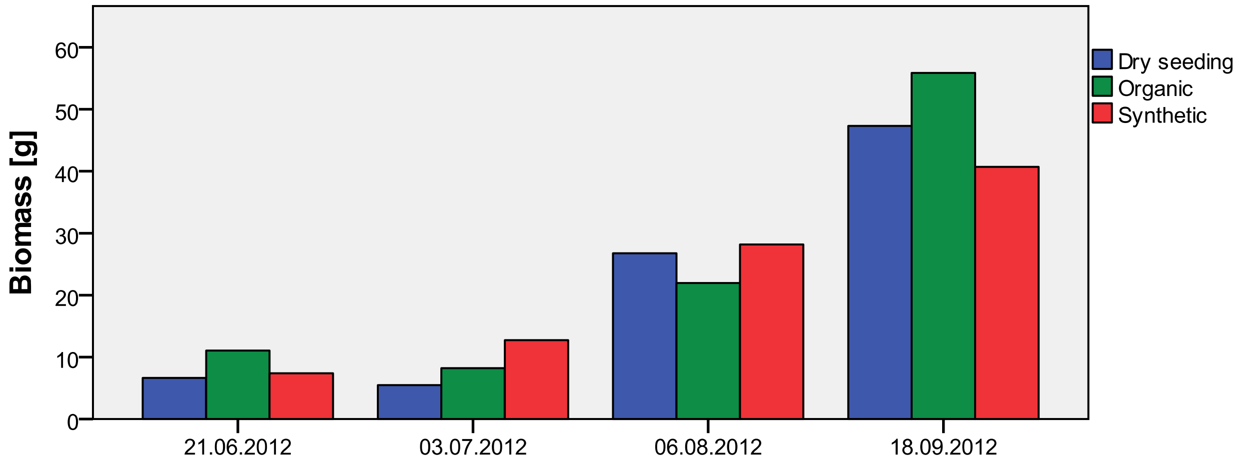

Figure 37 Biomass development – classes, mean values [g] (2012 Essling, VIENNA)

The measurements at the first two dates and the last date show a highly significant difference between the different classes (α ≤ 0,001). In the third date no significant differences could be observed between the analysed classes.

Table 20 Biomass development – classes, mean values (2012 Essling, VIENNA)

	Dry seeding	Organic	Synthetic
21.06.2012	6,64	11,05	7,38
03.07.2012	5,48	9,01	12,72
06.08.2012	26,76	24,77	28,19
18.09.2012	47,33	66,19	40,71

The organic geotextiles had the best biomass growth in the first measurement with significant differences to the synthetic plots (α = 0,04) and also to 'Dry seeding' (α = 0,01) with the lowest amount of biomass.

In the second measurement the synthetic plots had highly significant (α ≤ 0,001) difference from 'Dry seeding' with the lowest value. Organic plots and synthetic plots had no significant difference (α > 0,05). Accordingly, observing the trend, only the plots with synthetic geotextiles had positive growth of 73 % in the amount of biomass, whereas the amount of the plots with organic geotextiles and plots with vegetation only were both decreasing with a percentage decrease of 18 %.

In the third stage all plots had a positive development although increase of biomass was clearly lower in the plots with synthetic materials (percentage growth 122 %) and 'Dry seeding' plots (percentage growth 175 %) than the growth of the plots with organic materials (percentage growth almost 400 %). When comparing these three groups among each other, no significant differences can be detected. The executions with organic geotextiles had the highest amount of biomass production whilst the amount of the plots with synthetic geotextiles was the lowest.

The synthetic materials had the lowest value in the most recent measurement although in the preceding dates they showed the best values. Therefore, a highly significant difference to the plots with organic geotextiles with the highest results was observed (α ≤ 0,000) in the last date. They also had a significant difference (α = 0,014) to the plots with vegetation only ('Dry seeding'). The trend shows that the amount of biomass of all executions was increasing but the executions with organic geotextiles had the highest percentage growth of 168 % ('Dry seeding': 77%; Synthetic materials: 45 %).

4.6.2 Degree of vegetation cover

The degree of vegetation cover was photographed on four different occasions as described in section '3.3.6.1 Vegetation development'. The degree of vegetation cover was calculated using Adobe Photoshop.

Table 21 Degree of vegetation cover, mean values [%] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest K	MacMat® R filled
21.06.2012	10,73	11,86	16,33	14,04	15,33	13,35	3,77
03.07.2012	66,83	77,11	69,39	57,18	73,99	70,58	39,63
06.08.2012	66,70	57,95	49,20	61,45	51,55	75,45	43,10
18.09.2012	90,35	92,30	91,95	90,25	90,50	90,50	88,20

Between the groups a highly significant difference (α ≤ 0,001) was observed in the first date. ‘BonTerra® K Coir Fibre Blanket’ had the highest amount of vegetation cover. ‘BonTerra® R3D’, ‘MacMat® R’ and ‘MacMat® R + Terravest K’ had similar values and therefore no significant differences. By contrast, with ‘BonTerra® Coir Netting’ a significant difference was observed with α = 0,012. ‘Dry seeding’ and ‘MacMat® R filled’ show highly significant difference with α ≤ 0,001 what indicates the lowest amount of vegetation cover. The vegetation cover of ‘MacMat® R filled’ was 77 % lower than the vegetation cover of ‘BonTerra® K Coir Fibre Blanket’.

In the second measurement the difference between the groups were highly significant (α ≤ 0,001). The degree of vegetation cover was again the lowest of ‘MacMat® R filled’ and showed a highly significant difference to all other executions, expressed in percent had ‘MacMat® R filled’ 49 % less vegetation cover than the one with the highest amount in this stage which was ‘BonTerra® Coir Netting’. This one had the best amount of vegetation cover in this date and a highly significant difference to ‘BonTerra® R3D’ (α ≤ 0,001) which had a relatively low amount of vegetation cover in comparison to the other executions. Also ‘BonTerra® R3D’ shows a significant difference to ‘Dry seeding’ with the third lowest vegetation cover (α = 0,048). All the other executions are at a comparable level. The percentage growth between the first and the second measurements were massive for all plots with values of 300-900 %.

In the third measurement a significant difference between the groups (α = 0,013) was observed. The variety between the plots was lower than in the dates before and the plot with the highest amount of vegetation cover changed to ‘MacMat® R + Terravest K binder’. The only significant difference is observable with ‘MacMat® R filled’ with again the lowest amount (α = 0,012) but the difference to the highest result decreased with an amount of 30 % less vegetation cover than ‘MacMat® R + Terravest K’. The development was different from the second to the third date. Only three executions showed an increase of coverage of around 8 % (‘BonTerra® R3D’, ‘MacMat® R + Terravest K’ and ‘MacMat® R filled’), three plots showed even a decrease of vegetation cover of around 28 % (‘BonTerra® Coir Netting’, ‘BonTerra® K Coir Fibre Blanket’ and ‘BonTerra® R3D’) and ‘Dry seeding’ remained at the same level.

After longer growing period in the fourth date, vegetation cover had equalized to the level observed in the last measurement. Between the different plots are no significant differences noticeable. The percentage growth was positive again in all cases. The growth of ‘MacMat® R + Terravest K’ was with 20 % the lowest, ‘MacMat® R filled’ had caught up with a high growth of more than 100 %.

4.7 Runoff starting time

The starting time of all plots was transferred to SPSS and the mean value calculated for each execution. The results are displayed in table 22. Initially, potential differences occurring within the same date were analysed. At date 1 the ANOVA testing showed significant difference at a level of α = 0,016 between ‘BonTerra® Coir Netting’ with the best retention capacity of 13,25 sec and the ‘Reference’ plots with the smallest retention capacity of 4,75 sec. All other significance levels exceeded α = 0,05 which indicates non-significant differences. Only ‘MacMat® R’ had a lower retention capacity in comparison to other plots.

At date 2 the analysis showed that the ‘Reference’ plots differ significantly compared to all other executions. The ‘Reference’ plots showed highly significant difference (α < 0,001) to ‘Dry seeding’, ‘BonTerra® Coir Netting’, ‘BonTerra® K Coir Fibre Blanket’ and ‘BonTerra® R3D’. The difference to ‘MacMat® R’ and ‘MacMat® R +Terravest K’ is highly significant (α = 0,001). Compared with ‘MacMat® R filled’ the difference is significant (α = 0,024), the lower retention capacity ‘MacMat® R filled’ can also be seen in the high significant difference to ‘BonTerra® K Coir Fibre Blanket’ (with the biggest delay) of α = 0,001. Also ‘MacMat® R’ (α = 0,018), ‘MacMat® R + Terravest K’ (α = 0,013) and ‘BonTerra® R3D’ (α=0,043) have significant difference compared to ‘BonTerra® K Coir Fibre Blanket’ in the second implementation. Only ‘Dry seeding’ and ‘BonTerra® Coir Netting’ showed no significant difference.

Table 22 Runoff starting time, mean values [sec] (2012 Essling, VIENNA)

	Dry seeding	BonTerra® Coir Netting	BonTerra® K Coir Fibre Blanket	BonTerra® R3D	MacMat® R	MacMat® R + Terravest K	MacMat® R filled	Reference
August	12,50	13,25	11,67	10,50	7,50	11,25	12,50	4,75
September	15,75	17,25	21,25	14,75	14,00	13,75	11,50	4,50

If we consider the differences in percent between the different implementation it is obvious that two executions had positive effects on the development on date 1 to date

2. ‘BonTerra® K Coir Fibre Blanket’ with 82 % and ‘MacMat® R’ with 87 % developed very well which is attributable to a good vegetational growth between the two dates (see also section 4.6). Also ‘MacMat® R + Terravest K’, ‘Dry seeding’, ‘BonTerra® Coir Netting’ and ‘BonTerra® R3D’ had positive influence and therefore an increase in retention capacity. Only ‘MacMat® R filled’ and the ‘Reference’ plots had decreased in retention capacity. For ‘MacMat® R filled’ this can also be seen in the vegetational development which showed a decreasing value from date 1 to date 2.

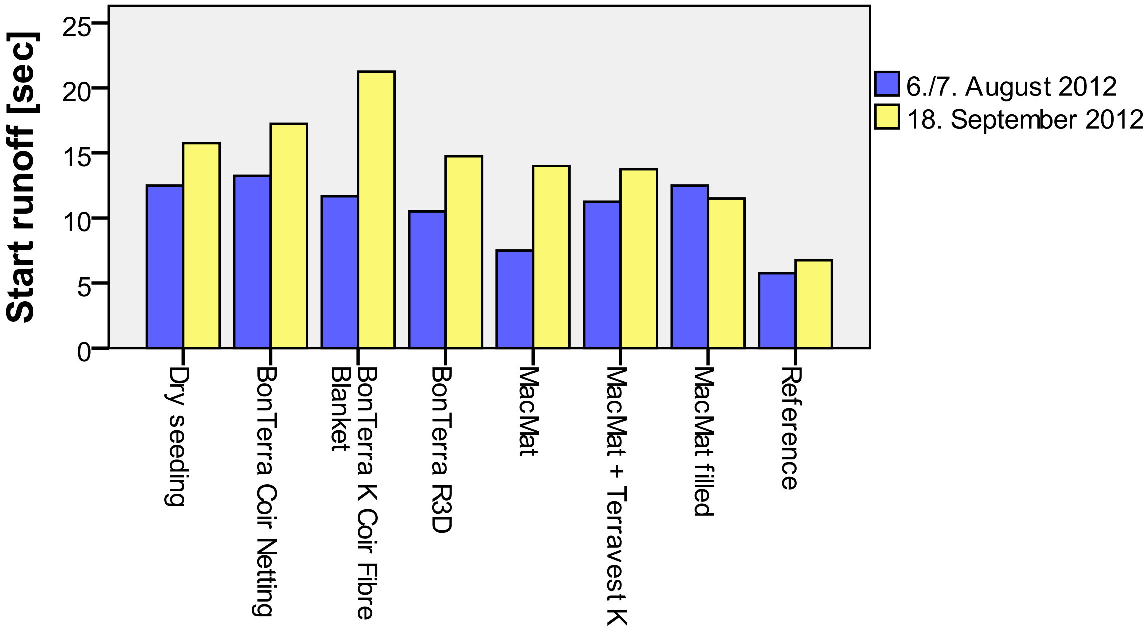

Figure 38 Runoff starting time, mean values [sec] (2012 Essling, VIENNA)

4.8 Discussion

4.8.1 Soil loss

As also reported by ZIEGLER / SUTHERLAND (1997) and BHATTACHARYYA et al. (2010) had all geotextile variants positive effects in reducing soil loss compared to the non geotextile variant – except 'MacMat® R filled' in date two. The plots with only vegetation decreased the soil loss by a value of 96% in average in both dates, compared to the reference plots with bare soil though the plots with vegetation only had the highest soil loss of all scenarios with erosion reducing measures. Only the variant 'MacMat® R filled' was an exception and showed a very high soil loss compared to all other scenarios. This can be explained by loose soil particles in the polypropylene wire mesh which are easily washed out and faster transported by overland flow. All other variants had similar values in soil loss but slightly better than plots with vegetation only. The best performance in both dates had 'BonTerra® K Coir Fibre Blanket' with a 63 % respectively 75 % lower amount of soil loss compared to the one with the worst performance in each date (date one: 'Dry seeding'; date two: 'MacMat® R filled'). Contrary to other researches, e. g. BHATTACHARYYA et al. (2010), was the soil loss rate increasing from the first implementation date to the second one although the vegetation cover was higher in the second date.

The results classified into organic and synthetic geotextiles showed that the organic materials had in both dates a lower value in soil loss, in total 44% lower. The increase of soil loss (from date one to date two) was much higher for the synthetic materials what is a result of the high soil loss values of the 'MacMat® R filled' plots.

4.8.2 Surface runoff

Considered the surface runoff is no clear trend visible. The results are rather diverse within the different groups. In date one is no specific tendency observable, the highest water loss had the plots with bare soil with 28% more surface runoff in average compared to the plots with the best retention capacity 'MacMat® R filled' and 'BonTerra® K Coir Fibre Blanket'. Also BHATTACHARYYA et al. (2010) found no definite trends in the runoff volume same as well as ZIEGLER and SUTHERLAND (1997) who indicated that natural and synthetic materials have similar effects in reducing surface runoff. After the second data acquisition 'BonTerra® K Coir Fibre Blanket' was revealed as the product with the best water retention capacity, the plots with only vegetation had the lowest effect on reducing surface runoff. According to increase and decrease of the values no apparent trend can be seen, only that the results are clearly more divers in date two than they were in date one. The plots with ‘BonTerra® K Coir Fibre Blanket’ and ‘BonTerra® Coir Netting’ had the best water retention in the second rainfall simulation and also the highest decrease of water losses. The lower runoff rates of the Coir Fibre is attributed to the better water absorbency of the natural materials. A very high increase of water losses and also the worst value in the second implementation had the plots with vegetation only. Summarized to classes had the organic geotextiles in both measurements better water retention capacities compared to the synthetic geotextiles. Perhaps due to some impermeable and hydrophobic characteristics of the geotextiles and a lower ability to sorb water on the impermeable PP wire mesh.

4.8.3 Vegetation

In all plots the development of the vegetation was positive, in the first stage (first two acquisition dates) the development was nearly similar and only a minor difference observed. In the third date ‘MacMat® R’ had the highest peak in amount of biomass with 33,5% more compared to the other plots. In the second data acquisition the image has changed, all plots with BonTerra® products had a high growth of biomass with 68% more than the plots with MacMat® R and 45 % more than the plots with vegetation only. This shows that the organic geotextiles had a significant higher positive development in biomass after a longer growing period. Considered the percentage growth it is noticeable that the executions ‘BonTerra® Coir Netting’ and ‘BonTerra® K Coir Fibre Blanket’ had the most desirable influence and a continuous increase. Between date 2 and date 3 all set ups had a high increase. Also between date 3 and date 4 the biomass was clearly decreasing in most scenarios only for the plots ‘Dry seeding’ the increase was lower. And for ‘MacMat® R filled’ the biomass amount was even decreasing between date 3 and date 4. This contributes that the oraganic materials have a more positive influence in enhancing the growth of plants compared to ‘MacMat® R’ and ‘Dry seeding’. Out of the three organic materials the ranking is ‘BonTerra® R3D’, ‘BonTerra® Coir Netting’ and ‘BonTerra® K Coir Fibre Blanket’.

The influence of the different used material on the degree of vegetation cover was clearly different in the very beginning. At the first date of measuring the execution ‘MacMat® R filled’ had the lowest degree of vegetation cover of only 4 %. All other variants were on the same level, but the best influence in enhancing growth in the beginning had 'BonTerra® K Coir Fibre Blanket' with a degree of vegetation cover of more than 16 %. In the second and third measuring the vegetation cover became equal in all plots. Only 'MacMat® R filled' was an exception again with in average 71 % less in the second date and 37 % less than the other variants. The poor development of 'MacMat® R filled' can be explained by the covering of the seeds by soil. In the last measurement the different scenarios have aligned each others. All had an increase again and also 'MacMat® R filled' has caught up. For all scenarios the degree of vegetation cover was in this date around 90 %.

4.8.4 Runoff starting time

Regarding runoff starting time all erosion reducing measures had a positive effect and therefore an increase in the delay of the runoff starting time. 'BonTerra® Coir Netting' showed best retention capacity in first date with almost three times higher value than the reference plots with the lowest runoff starting time. The higher delay is assumed by the high sorbing capacity of the coir material. Also ZIEGLER and SUTHERLAND (1997) reported a significant delay in runoff starting time and increased infiltration of RECS treatments. Between the different plots with erosion reducing measures only minor differences were observed. According to the development between implementation one and two all plots had an increase in runoff starting time except 'MacMat® R filled' and the reference plots with bare soil. The result of 'MacMat® R filled' can be explained with the lower vegetation cover and loose soil particles on top. The best retention capacity in the second date had 'BonTerra® K Coir Fibre Blanket' with almost five times more than the reference plots. All BonTerra plots had in average a 36 % higher value than the MacMat® R plots and a 13 % higher value than the plots with vegetation only.

4.8.5 Saturation discharge coefficient (SDC)

In the first date were no significant differences observed between the eight different scenarios. After the 4 weeks more in growth of vegetation 'BonTerra® K Coir Fibre Blanket' had the lowest saturation discharge coefficient in total and thereby the best capacity in water retention. The SDC of 'BonTerra® K Coir Fibre Blanket' is 37 % lower than the SDC of the reference plots with the highest saturation discharge coefficient. This circumstance can be explained by the amount of vegetation cover which was highest at the plots with 'BonTerra® K Coir Fibre Blanket'. But also 'MacMat® R filled' had a good value of SDC and therefore a good water retention capacity. This scenario stayed at the same value and therefore it is assumed that the vegetation had compared to the other materials no influence on the SDC in this case. Most appropriate for a lower saturation discharge coefficient are the materials ‘BonTerra® Coir Netting’, ‘BonTerra® K Coir Fibre Blanket’ and MacMat® R fulfilled with soil. Only vegetation is no proper protection to keep the saturation discharge coefficient low as well as ‘BonTerra® R3D’ and ‘MacMat® R + Terravest K’.

4.8.6 Infiltration rate

As explained in section (BASICS) is the infiltration rate of the soil decreasing after time, this was true for all scenarios. The infiltration rate is a counterpart to the saturation discharge coefficient and therefore the results are similar. Highest infiltration into the soil was observed in the plots with ‘BonTerra® Coir Netting’ and ‘BonTerra® K Coir Fibre Blanket’. The step of decreasing the infiltration rate was of ‘BonTerra® K Coir Netting’ much lower than of ‘BonTerra® Coir Netting’. An explanation for that can be the high water absorbing capacity of the Fibre Blanket. Similar to the Fibre Blanket are the results of plots with ‘MacMat® R filled’, it is assumed that this is a result of loose soil particles and bigger pores in the soil compared to the other plots because of the soil material filled in the polypropylene mesh. The lowest infiltration rate was observed at the plots with MacMat® R in the first stage of irrigation, but the decrease of the infiltration rate was proportionally low. Further interesting is that the ‘BonTerra® R3D’ and ‘MacMat® R + Terravest K’ had both an infiltration rate in the upper mid-field in the beginning but a big loss in infiltration rate after the first minute.

4.8.7 Plant impacts on soil loss and surface runoff

Regarding soil loss all soil erosion reducing measures had very high positive influence. The soil loss was in all cases reduced by more than 90 % compared to the Reference plots. Within the different measures are no significant differences in reducing soil loss. As conclusion can be said that vegetation only is already a sufficient protection against erosion. Regarding surface runoff the results vary greatly. As also said in the section surface runoff had ‘BonTerra® K Coir Fibre Blanket’ the best water retention capacity and also an increase of retention from the first to the second measurement. The reasons are the same as mentioned before. Also good reducing of surface runoff compared to bare soil showed the plot with ‘MacMat® R filled’, although an decrease was observed from first to second measurement, this can be explained by the decrease of vegetation. In the first date all scenarios showed a decrease of surface runoff compared to bare soil. In the second measurement ‘Dry seeding’ and ‘MacMat® R’ had even a higher water loss than the reference plots with over 7 % more.

5. Conclusion and Outlook

In the following section the previously discussed parameters are summarized to give a clear indication of the best scenario for specific purposes. Therefore the results were compared between each other's and are illustrated in table 24. The table provides information about the differences between the diverse scenarios with the positive and less positive influences on the different measured parameters. The evaluation should help to determine which geotextile is the best for certain application with respect to different points of interest. Therefore the scenarios are only compared between each other and not compared to bare soil.

Table 23 Runoff starting time, mean values [sec] (2012 Essling, VIENNA)[1]

Scenario	Soil loss		Surface runoff		Saturation discharge coefficient		Infiltration rate		Runoff starting time		Biomass
	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	Aug.	Sept.	total
	total		total		total		total		total		
Dry seeding	-	-	+ -	- -	+ -	- -	+ +	-	+	+ -	+ -
	-		- -		+ -		+ -		+		
BonTerra® Coir Netting	+	+	+ -	+ +	-	+ +	+ -	+ +	+ +	+	+
	+		+ -		+		+ +		+ +		
BonTerra® K Coir Fibre Bl.	+ +	+ +	+	+ +	+ +	+ +	+	+ +	+ -	+ +	+ +
	+ +		+ +		+ +		+ +		+		
BonTerra® R3D	+	+ -	+ -	-	+ -	+ -	-	-	-	+ -	+
	+ -		-		+ -		-		+ -		
MacMat® R	+	+ -	- -	-	- -	-	- -	- -	- -	+ -	+ -
	+		- -		- -		- -		-		
MacMat® R + Terravest K	+ -	+	-	+ -	-	+ -	-	+ -	+ -	-	-
	+ -		-		+ -		+ -		-		
MacMat® R filled	-	- -	+ +	+	+ +	+	+ +	+	+	- -	- -
	- -		+		+ +		+		-		

BonTerra® K Coir Fibre Blanket is highly recommended to use for surface protection and has big positive influences for a big variety of parameters. In all points of interest

[1] + +: Very good; +: Good; +-: Neutral; -: Poor; - -: Very poor;

the results of BonTerra® K Coir Fibre Blanket are highly satisfactory. Similar are the results BonTerra® Coir Netting. This geotextile also shows very good outcomes in all points of interest and has only minor differences to BonTerra® K Coir Fibre Blanket. Also the material BonTerra® R3D showed good or rather neutral results. For surface runoff and infiltration rate BonTerra® R3D showed even a poor result. Very diverse are the finings regard to the use of MacMat® R. The scenarios with only MacMat® R revealed very poor results in many investigation points (surface runoff, SDC, infiltration rate, runoff starting time). Only the values of soil loss and vegetation development are neutral. The 'MacMat® R filled' is contrary to that. The vegetation development and also the soil loss where had been the worst outturn of all scenarios. Also the runoff starting time is less good. But surface runoff, saturation discharge coefficient and infiltration rate are very good in this type of application. Very interesting is the influencing effect of the organic glue. The Terravest K was affecting the surface protection and vegetation development positive and showed an equal influence on all parameters. All findings resulted as neutral with no extraordinary peaks as with MacMat® R alone or MacMat® R fulfilled with soil.

Also the 'Dry seeding' showed some interesting results. Although it was mentioned before that vegetation alone has a sufficient protective function against erosion, the effects compared to the other scenarios were poor. For all other points of interest the effects of vegetation alone is in the whole neutral to poor.

It can be said in summary that vegetation alone enhance protection against soil erosion. However, to guarantee good soil protection it is advisable to install geotextiles. Highly recommended is the use of BonTerra® K Coir Fibre Blanket and also BonTerra® Coir Netting. Despite significant shortcomings I still recommend the use of BonTerra® R3D because it had positive impacts on the growth of vegetation. Contrary to the organic material the geotextile MacMat® R should only be applied if it is combined with an organic glue.

The done research with the previously discussed data is the first one of this kind at the Institute of Soil Bioengineering (IBLB). Due to this fact the development of the method and the establishment of the experimental plots was a big part. During the research it was noted that a few data, which would be of a special interest, were not considered. I would recommend to take account the plant roots with their length, thickness and root area ratio in further studies. Also of interest would be a determination of soil volume and soil density to find out the water storage capacity of the soil. Furthermore it may be useful to observe the weather conditions during the days before the rainfall simulations. This may give some more information about the different amounts of soil loss.

Another fact not considered in this research is the influence of the geotextiles only without vegetation. For that some additional plots are advisable to find out the individual influences of the different materials regarding to the specific physical properties alone without vegetation. Thus a conclusion can be drawn about the impacts of vegetation combined with geotextiles.

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7. Figures

8. Tables

9. Appendix

9.1 Layout plan

Initial situation

Plot Nr. Picture Nr.

Bare soil				BonTerra coconut netting				BonTerra mesh/net combo				BonTerra R3D			
61	64	62	56	27	48	31	40	23	32	22	24	14	16	16	8
64	63	59	55	26	47	30	39	18	31	17	23	10	15	11	7
60	62	57	54	29	46	32	38	21	30	24	22	13	14	15	6
58	61	63	53	28	45	25	37	20	29	19	21	9	13	12	5
56	60	49	52	46	44	47	36	40	28	38	20	8	12	7	4
54	59	50	51	42	43	48	35	33	27	34	19	1	11	5	3
51	58	53	50	43	42	44	34	39	26	37	18	4	10	3	2
55	57	52	49	41	41	45	33	35	25	36	17	2	9	6	1
MacMat filled				MacMat + Terravest binder				MacMat				Dry seeding			

Hill

Cottage

1. Rainfall simulation 06.08.2012

Bare soil				BonTerra coconut netting				BonTerra mesh/net combo				BonTerra R3D			
61	64	62	56	27	48	31	40	23	32	22	24	14	16	16	8
64	63	59	55	26	47	30	39	18	31	17	23	10	15	11	7
60	62	57	54	29	46	32	38	21	30	24	22	13	14	15	6
58	61	63	53	28	45	25	37	20	29	19	21	9	13	12	5
56	60	49	52	46	44	47	36	40	28	38	20	8	12	7	4
54	59	50	51	42	43	48	35	33	27	34	19	1	11	5	3
51	58	53	50	43	42	44	34	39	26	37	18	4	10	3	2
55	57	52	49	41	41	45	33	35	25	36	17	2	9	6	1
MacMat filled				MacMat + Terravest binder				MacMat				Dry seeding			

Hill

← irrigated plots

Cottage

2. Rainfall simulation 18.09.2012

Bare soil				BonTerra coconut netting				BonTerra mesh/net combo				BonTerra R3D			
		62	56			31	40	23	32	22	24	14	16	16	8
		59	55	26	47	30	39	18	31	17	23	10	15	11	7
60	62	57	54	29	46					24	22				
58	61	63	53	28	45	25	37			19	21	9	13	12	5
56	60	49	52	46	44	47	36					8	12	7	4
54	59	50	51	42	43	48	35	33	27	34	19	1	11	5	3
51	58	53	50	43	42	44	34	39	26	37	18	4	10		
								35	25	36	17	2	9		
MacMat filled				MacMat + Terravest binder				MacMat				Dry seeding			

Hill

Cottage

9.2 Seed mixture

Table 24 Seeding material (BOKU Vienna, n. d.)

No.	Denotation latin	Denotation english	Mixture [%]	Mixture for 1 m^2[g]	Mixture for 0,18 m^2
1	*Bromus erectus*	Upright bromegrass	2,00%	0,20	0,0360
2	*Bromus inermis*	Awnless bromegrass	2,00%	0,20	0,0360
3	*Festuca ovina*	Sheep's fescue	35,00%	3,50	0,6300
4	*Festuca nigrescens*	Chewing's fescue	15,00%	1,50	0,2700
5	*Festuca rubra rubra*	Red fescue	8,00%	0,80	0,1440
6	*Festuca valesiaca*	Wallis fescue	2,00%	0,20	0,0360
7	*Lolium perenne*	English raygrass	5,00%	0,50	0,0900
8	*Poa compressa*	Flattened meadow grass	7,00%	0,70	0,1260
9	*Poa pratensis*	Common meadow grass	2,00%	0,20	0,0360
		Total	**78,00%**	**7,80**	**1,4040**
10	*Achillea millefolium*	Yarrow	2,00%	0,20	0,0360
11	*Anthyllis vulneraria*	Common kidneyvetch	2,00%	0,20	0,0360
12	*Coronilla varia*	Axseed (crown vetch)	4,00%	0,40	0,0720
13	*Lathyrus pratensis*	Meadow vetchling	1,00%	0,10	0,0180
14	*Lotus corniculatus*	Birdsfoot trefoil	4,00%	0,40	0,0720
15	*Medicago lupulina*	Blackweed	2,00%	0,20	0,0360
16	*Onobrychis viciifolia*	Sainfoin	2,00%	0,20	0,0360
17	*Papaver rhoeas*	Field poppy	0,10%	0,01	0,0018
18	*Plantago lanceolata*	Buckhorn	1,90%	0,19	0,0342
19	*Salvia nemorosa*	Woodland sage	0,50%	0,05	0,0090
20	*Thymus pulegioides*	Broad-leaved thyme	0,50%	0,05	0,0090
21	*Trifolium repens*	White clover	2,00%	0,20	0,0360
		Total	**22,00%**	**2,20**	**0,3960**
		Total	**100,00%**	**10,0**	**1,80**

9.3 ECTC Standard Specifications for RECP's – permanent / temporary

Erosion Control Technology Council

Rolled Erosion Control Products Specification Chart

June 2006

Table 2. *RECP Specification*

For applications where vegetation alone will not sustain expected flow conditions and/or provide sufficient long-term erosion protection.

Rolled Erosion Control - Permanent					
Permanent[1] - All categories of TRMs must have a minimum thickness of 0.25 inches (6.35 mm) per ASTM D 6525 and U.V. stability of 80% per ASTM D 4355 (500 hours exposure).					
Type	Product Description	Material Composition	Slope Applications Maximum Gradient (H:V)	Channel Applications Maximum Shear Stress [4, 5]	Minimum Tensile Strength [1, 2]
5.A	Turf Reinforcement Mat	Turf Reinforcement Mat (TRM) – A rolled erosion control product composed of non-degradable synthetic fibers, filaments, nets, wire mesh and/or other elements, processed into a permanent, three-dimensional matrix of sufficient thickness. TRMs, which may be supplemented with degradable components, are designed to impart immediate erosion protection, enhance vegetation establishment and provide long-term functionality by permanently reinforcing vegetation during and after maturation. Note: TRMs are typically used in hydraulic applications, such as high flow ditches and channels, steep slopes, stream banks, and shorelines, where erosive forces may exceed the limits of natural, unreinforced vegetation or in areas where limited vegetation establishment is anticipated.	0.5:1 (H:V)	6.0 lbs/ft[2] (288 Pa)	125 lbs/ft (1.82 kN/m)
5.B	Turf Reinforcement Mat		0.5:1 (H:V)	8.0 lbs/ft[2] (384 Pa)	150 lbs/ft (2.19 kN/m)
5.C	Turf Reinforcement Mat		0.5:1 (H:V)	10.0 lbs/ft[2] (480 Pa)	175 lbs/ft (2.55 kN/m)

[1] For TRMs containing degradable components, all property values must be obtained on the non-degradable portion of the matting alone.

[2] Minimum Average Roll Values, machine direction only for tensile strength determination using ASTM D6818 (Supersedes Mod. ASTM D5035 for RECPs)

[3] Field conditions with high loading and/or high survivability requirements may warrant the use of a TRM with a tensile strength of 44 kN/m (3,000 lb/ft) or greater.

[4] Required minimum shear stress TRM (fully vegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in.) soil loss) during a 30-minute flow event in large scale testing.

[5] Acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

EROSION CONTROL TECHNOLOGY COUNCIL — WWW.ECTC.ORG

Erosion Control Technology Council

Rolled Erosion Control Products Specification Chart

Table 1. RECP Specification *June 2006*

Rolled Erosion Control—Temporary

ULTRA SHORT-TERM — Typical 3 month functional longevity.

			Slope Applications *		Channel	
Type	Product Description	Material Composition	Maximum Gradient	C Factor 2, 5	Max. Shear Stress 3, 4, 6	Minimum Tensile Strength 1
1.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	0.25 lbs/ft² (12 Pa)	5 lbs/ft (0.073 kN/m)
1.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked and/or chemically adhered together to form a RECP.	4:1 (H:V)	≤ 0.10 @ 4:1	0.5 lbs/ft² (24 Pa)	5 lbs/ft (0.073 kN/m)
1.C	Single-net Erosion Control Blankets & Open Weave Textiles	Processed degradable natural and/or polymer fibers mechanically bound together by a single rapidly degrading, synthetic or natural fiber netting or an open weave textile of processed rapidly degrading natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	≤ 0.15 @ 3:1	1.5 lbs/ft² (72 Pa)	50 lbs/ft (0.73 kN/m)
1.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.	2:1 (H:V)	≤ 0.20 @ 2:1	1.75 lbs/ft² (84 Pa)	75 lbs/ft (1.09 kN/m)

SHORT-TERM — Typical 12 month functional longevity.

			Slope Applications *		Channel Applications *	
Type	Product Description	Material Composition	Maximum Gradient	C Factor 2, 5	Max. Shear Stress 3, 4, 6	Minimum Tensile Strength 1
2.A	Mulch Control Nets	A photodegradable synthetic mesh or woven biodegradable natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	0.25 lbs/ft² (12 Pa)	5 lbs/ft (0.073 kN/m)
2.B	Netless Rolled Erosion Control Blankets	Natural and/or polymer fibers mechanically interlocked and/or chemically adhered together to form a RECP.	4:1 (H:V)	≤ 0.10 @ 4:1	0.5 lbs/ft² (24 Pa)	5 lbs/ft (0.073 kN/m)
2.C	Single-net Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed degradable natural or polymer fibers mechanically bound together by a single degradable synthetic or natural fiber netting to form a continuous matrix or an open weave textile composed of processed degradable natural or polymer yarns or twines woven into a continuous matrix.	3:1 (H:V)	≤ 0.15 @ 3:1	1.5 lbs/ft² (72 Pa)	50 lbs/ft (0.73 kN/m)
2.D	Double-net Erosion Control Blankets	Processed degradable natural and/or polymer fibers mechanically bound together between two rapidly degrading, synthetic or natural fiber nettings.	2:1 (H:V)	≤ 0.20 @ 2:1	1.75 lbs/ft² (84 Pa)	75 lbs/ft (1.09 kN/m)

Erosion Control Technology Council

Rolled Erosion Control Products Specification Chart

Table 1. RECP Specification *June 2006*

Education and Standardization for a Growing Industry

Rolled Erosion Control—Temporary

EXTENDED-TERM – Typical 24 month functional longevity.

			Slope Applications *		Channel Applications *	
Type	Product Description	Material Composition	Maximum Gradient	C Factor [2, 5]	Max. Shear Stress [3, 4, 6]	Minimum Tensile Strength [1]
3.A	Mulch Control Nets	A slow degrading synthetic mesh or woven natural fiber netting.	5:1 (H:V)	≤ 0.10 @ 5:1	0.25 lbs/ft² (12 Pa)	25 lbs/ft (0.073 kN/m)
3.B	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or	1.5:1 (H:V)	≤ 0.25 @ 1.5:1	2.00 lbs/ft² (96 Pa)	100 lbs/ft (1.45 kN/m)

LONG-TERM – Typical 36 month functional longevity.

			Slope Applications *		Channel Applications *	
Type	Product Description	Material Composition	Maximum Gradient	C Factor [2, 5]	Max. Shear Stress [3, 4, 6]	Minimum Tensile Strength [1]
4	Erosion Control Blankets & Open Weave Textiles	An erosion control blanket composed of processed slow degrading natural or polymer fibers mechanically bound together between two slow degrading synthetic or natural fiber nettings to form a continuous matrix or an open weave textile composed of processed slow degrading natural or polymer yarns or twines woven into a continuous matrix.	1:1 (H:V)	≤ 0.25 @ 1:1	2.25 lbs/ft² (108 Pa)	125 lbs/ft (1.82 kN/m)

* "C" factor and shear stress for Types 1.A., 2.A and 3.A mulch control nettings must be obtained with netting used in conjunction with pre-applied mulch material.

[1] Minimum Average Roll Values, Machine direction using ECTC Mod. ASTM D 5035.

[2] "C" Factor calculated as ratio of soil loss from RECP protected slope (tested at specified or greater gradient, h:v) to ratio of soil loss from unprotected (control) plot in large-scale testing.

[3] Required minimum shear stress RECP (unvegetated) can sustain without physical damage or excess erosion (> 12.7 mm (0.5 in) soil loss) during a 30-minute flow event in large-scale testing.

[4] The permissible shear stress levels established for each performance category are based on historical experience with products characterized by Manning's roughness coefficients in the range of 0.01 - 0.05.

[5] Acceptable large-scale test methods may include ASTM D6459, or other independent testing deemed acceptable by the engineer.

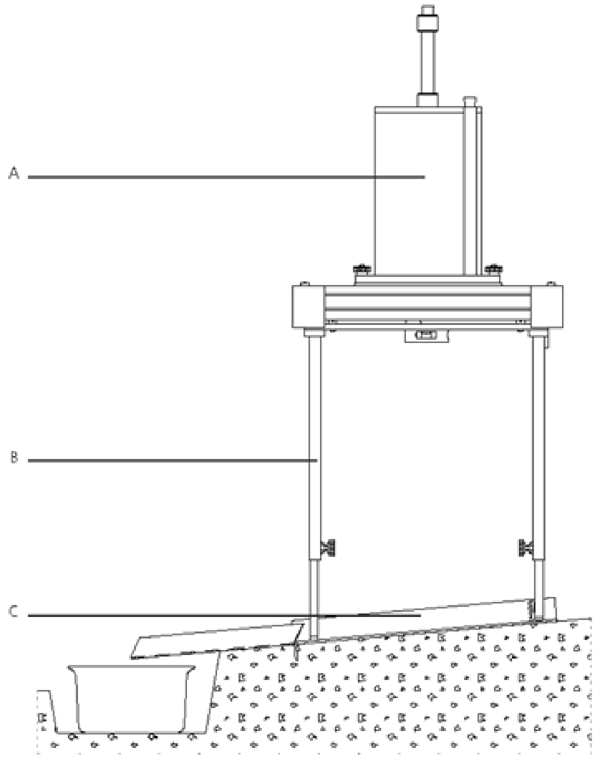
[6] Per the engineers discretion. Recommended acceptable large-scale testing protocol may include ASTM D6460, or other independent testing deemed acceptable by the engineer.

9.4 Datasheets

9.4.1 Eijkelkamp rainfall simulator

OPERATING INSTRUCTIONS

09.06 RAINFALL SIMULATOR



Contents

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 1 M1.09.06.E

On these operating instructions

☞ **If the text follows a mark (as shown on the left), this means that an important instruction follows.**

⚠ **If the text follows a mark (as shown on the left), this means that an important warning follows relating to danger to the user or damage to the apparatus.**

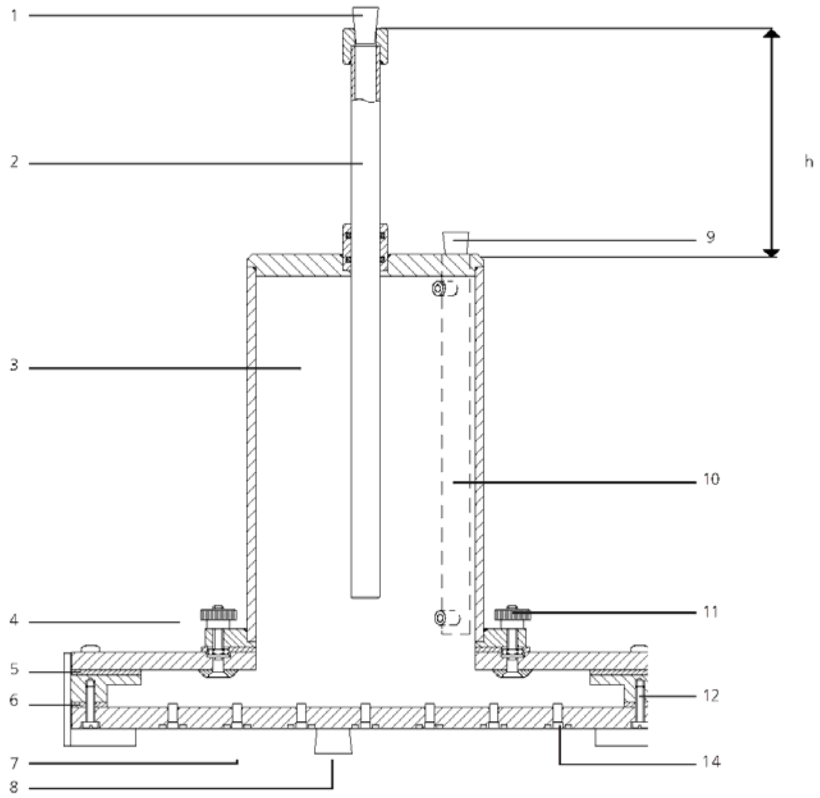
1 Description

With the rainfall simulator, one measures the runoff and soil loss generated by a standardised rainshower on a plot with standard surface area. The duration, intensity and kinetic energy of the shower are such that a high sensitivity of the test results for differences in soil properties is obtained.

1.1 Rainfall simulator

Essentially the rainfall simulator consists of three parts (see figure page 1):

- ❒ A sprinkler (A) with a built-in pressure regulator for the production of the standard rain shower.
- ❒ An adjustable support (B) for the sprinkler.
- ❒ An aluminium ground frame (C), which is placed on the soil and prevents the lateral movement of water from the test plot to the surrounding soil.



2

Sprinkler
The sprinkler (A) consists of a calibrated cylindrical reservoir (3) with a capacity of approximately 2300 ml, which is in open connection with the sprinkling head. The waterlevel can be read on the reading pipe (10) which is closed using a plug (9). Water is released from the sprinkling head through 49 capillaries (14). The pressure head and the length and the inner diameter of the capillaries determine the release rate. The pressure head on the capillaries can be increased or decreased by moving the aeration tube (2) upward or downward. The magnitude of this pressure head regulation is sufficient to correct for influence of the viscosity of the water used on the discharge rate of the capillaries. It is meant to control the intensity of the required standard shower. The lower ends of the capillaries are fitted with a short piece of tubing (7). The inner and outer diameters of this tubing control the drop size and the drop frequency. The sprinkler can be filled through the filling opening, which is normally closed with a plug (8).

Adjustable support
The adjustable support (B) is used for positioning and levelling the sprinkler. Two levels (16) and four knobs (18) are used to level the support (B) on which the sprinkler is placed. The stainless steel adjustable legs (17) are positioned on the ground frame (C).

Ground frame
The aluminium ground frame (C) is fixed on the soil using four large nails. The frame is meant to prevent the lateral movement of water from the testplot to the surrounding soil.

A gutter (19) is installed on the down stream site of the plot for the collection of the runoff and sediment in the sample collection box (20).

1.2 Accessories

Soil wetting jar
The soil-wetting jar, a plastic box with perforated lid, is used to wet the plot area before sampling.

Water storage tank
With use of a tube, the water storage tank (21) with contents of 20 liter can be connected to the sprinklers' filling opening. By doing so, the sprinkler can be filled with water.

Sample collection box
Sample material is collected in the plastic sample box with contents of 2 liter.

Sample bucket
The plastic sample box is used to store and transport the sample material.

Transport case
The rainfall simulator and accessories can be stored or transported in the aluminium transport case (22). The transport case is equipped with two grips, a hinge, and two locks on which the yellow brass padlock can be fitted.

2 Technical specifications

Transport case	Outside dimensions:	60 x 48 x 40 cm
Sprinkler	Dimensions:	330 x 330 mm
Capillair	Length:	10 mm ± 1 mm
	Diameter:	0.6 mm ±0.08 mm
	Material:	Glass
Adjustable support	Two waterlevels included,	dimension: 305 x 305 mm
Ground frame	Aluminium	Dimension: 345 x 320 mm
Soil wetting jar	Diameter:	14 cm, height: 5.5 cm
Sample collection box	Contents:	2 liter
Sample bucket	Contents:	1.2 liter
Magnitude of rain simulation	18 mm	
Duration of rain simulation	3 min.	
Intensity of rain simulation	6 mm/min	
Fall height of drops	average 400 mm	
Diameter of drops	5.9 mm	
Mass of drops	0.106 g	
Number of capillary tubes	49	
Kinetic energy of rain	4 J m^{-2} mm^{-1}	
Kinetic energy of rain shower	72 J m^{-2}	
Surface area of test plot	0.0625 m^2	
Slope of test plot	Max. 40%	

3 Safety instructions

⚠ **Adjustment of the adjustable support has to be done before placing the sprinkler.**

⚠ **Only use the water storage tank (21) for transporting clean water.**

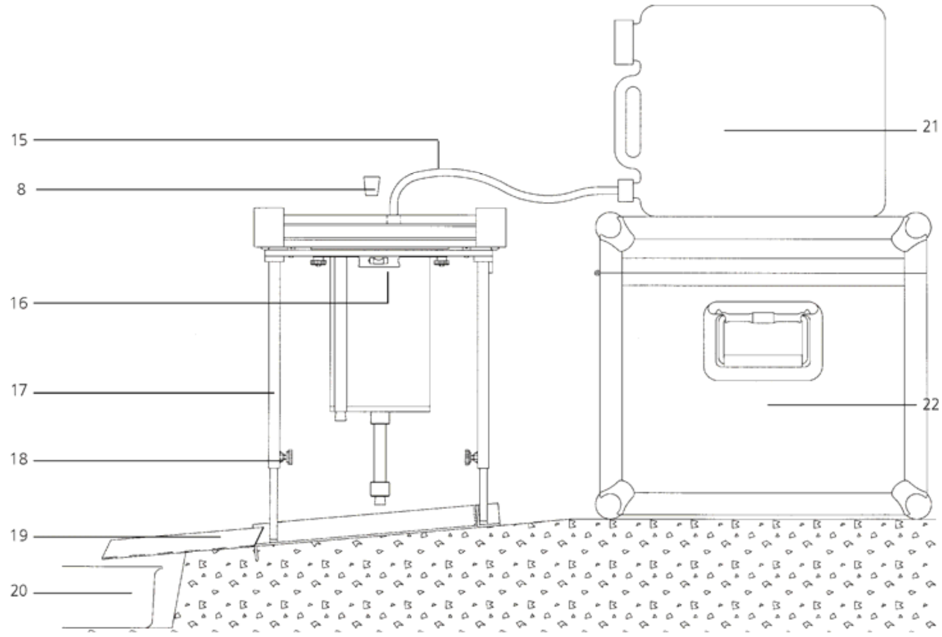
4 Calibration

To gain representative measurements the required discharge rate is 375 ml per minute. The discharge rate is related to the water-temperature. Therefore and because of possible clogged capillaries it's necessary to check if all capillaries are clear and to calibrate the sprinkler before use on the plot field. Follow the next procedure:

☞ **A plot can only be used once. Therefore do not calibrate or test the sprinkler on the plot.**

1. Install the ground frame (C) using the four nails.
2. Install the adjustable support (B) on the ground frame (C). Use the two levels (16) and four knobs (18) to level the support (B).
3. Close the aeration pipe (2) with a plug (1).
4. The sprinkler is placed upside down on the support.
5. Remove the plug (8) out of the filling opening.
6. Use the water storage tank (21) to fill the sprinkler with water. Connect the water storage tank tube (15) to the water storage tank (21). Install the water storage tank (21) uphill on top of the transport case (22), above the sprinkler.
7. Connect the tube (15) to the sprinklers' filling opening as soon as the water starts to flow. If the water doesn't flow, suck the tube while holding the end of the tube below the water storage tanks till water starts to flow.
8. The tube can be disconnected, as the sprinkler is filled and all the air has escaped through the capillaries. The waterflow can be stopped by moving the tube above the water storage tank (21).
9. After filling the sprinkler, note the water temperature and put the plug (8) in the filling opening.

4



10. Turn the sprinkler around to its sprinkling position on the support.
11. Adjust the rainfall intensity using the aeration pipe (2). The distance (h, see figure page 2) between the reservoir and the upper side of the aeration pipe has to be set depending on the measured water temperature. For a **rough indication of the correct setting**, the following formula can be used.

    h = 100 mm – 0.65 * temperature (°C)

    Value 100 mm is the starting position of the aeration tube at the beginning of the calibration (closest to the required 375 ml/min). Value 0.65 is an average factor for the correction of the temperature, 1 degree difference equals approx. 4 ml/min in the final result.
    The formula has to do with the viscosity of the water. The viscosity of the water depends on the temperature of the water, so this can influence the intensity of the shower. Before use, you always have to calibrate to 375 ml/minute. At 10 °C the viscosity is higher, so the aeration pipe must be placed a little bit higher (>h). At 40 °C, the water has a lower viscosity, so therefore the pipe must be placed a little bit lower. At the Wageningen University and Research Centre they tested with the following results:

Water temp.	Shower	h*
10 °C	350 ml/min-1	10 cm
20 °C	375 ml/min-1	9 cm
40 °C	450 ml/min-1	8 cm

    h* = top reservoir (3) - top aeration pipe (2)

    In practice you better ignore the formula. One should always test and calibrate in order to get 375 ml/min (all depending on the temperature of the water).

12. Note the water level in the reservoir.
13. Check if the stopwatch works properly and reset.
14. Removing the plug (1) from the aeration pipe (2) starts the simulation. Start the stopwatch.
15. After three minutes, stop the simulation by placing the plug (1) on the aeration pipe (2).
16. Note the water level in the reservoir. If the water level has decreased 375 ml in 1 minute, the sprinkler is calibrated correctly (outflow = 375 ml/min). Note the distance (h) at this setting. If not calibrated correctly, repeat step 11-16 and re-adjust the aeration pipe (2). If the distance (h) is increased, the quantity of sprinkled water per minute will increase.

5

5 Installation

1. Select the soil plot area.

☞ **Leave the soil plot unimpaired.**

2. Install the ground frame (C) using the four nails. A waterproof connection between the soil and the ground frame (C) can be made using clay.
3. Fill the soil wetting jar with water and place the lid.
4. At the bottom of the slope, a small trench is made, in which the sample collection box for the collection of runoff and soil-loss is placed.
5. Install the gutter so that all of the runoff and soil-loss will flow in the sample collection box. Clay can be used to provide a waterproof connection between the gutter and the soil plot. Be carefull no added clay will rinse in the sample collection box (20).
6. Install the adjustable support on the ground frame. Use the two levels (16) and four knobs (18) to install the support level to the desired height.

6 The use

1. If not already done, fill the sprinkler and turn the sprinkler around to its sprinkling position on the support (B).
2. Ascertain that the ground frame (C), gutter (19) and sample collection box (20) are in place.
3. Note the water level in the reservoir (3).
4. Check if the stopwatch works properly and reset.
5. Removing the plug (1) from the aeration pipe (2) starts the simulation. Start the stopwatch.
6. During the simulation, move the sprinkling head sideways in all horizontal directions, to make sure that the drops emerging from the capillaries are equally and randomly distributed over the test plot. This can be done by hand, as the sprinkling head slides easily on the upper rim of the support over predetermined distances.
7. After three minutes, place the plug (1) in the aeration pipe (2) to stop the simulation.
8. Sediment left behind in the gutter (19) is added to the contents of the sample collection box (20) with the aid of a wiper.
9. Put al the material left in the sample collection box (20) in the sample bucket. Now the material can be transported easily to the laboratory, where the amounts of runoff and sediment are determined by weighing and drying.
10. Note the water level in the reservoir (3).
11. Before storage or transportation, all parts have to be clean.

7 Application

The rainfall-simulator can be used in the field as well as in the laboratory.
The results obtained allow to compare different soil types and crusts on:

1. Erodibility
2. Runnoff (as a percentage of total simulated rain)

8 Troubleshooting

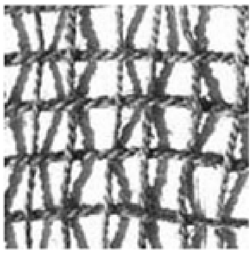
- ❑ In case of windy circumstances, it is possible the wind affects the simulation. To prevent this, in most cases it is sufficient to place yourself between the frame and the wind direction.

6

9 Maintenance

- Cleaning the sprinkler has to be done thoroughly since clogged up capillaries may cause the simulation to be useless. Clean the capillaries thoroughly with the supplied 0.5-mm drill or a needle.
- Before storage or transportation, all parts have to be clean.
- For replacing the round sealing (4), remove the four nuts (11) and the reservoir (3), replace the round sealing (4) and reasseble the sprinkler using the four nuts (11).
- For replacing sealing (5), remove the eight screws (12), the reservoir and assembled sprinkler part. Replace the sealing. Reassemble the sprinkler using the eight screws (12).
- For replacing sealing (6) remove the eight screws (13) and the assembled sprinkler part. Replace the sealing. Reassemble the sprinkler using the eight screws (13).

9.4.2 BonTerra® Coir Netting



Technical Data

BonTerra® Coir Netting 400g/m^2

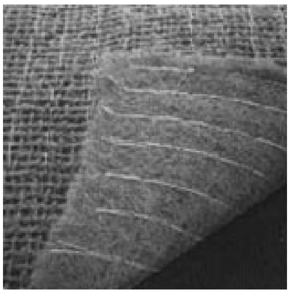
BonTerra ® Coir Netting 400g / m² is a flat canvas fabric made of 100% pure coconut double twist with a mesh size of 25 x 30 mm.

Composition of coconut fiber:
Approx. 46% lignin
45% cellulose, hemicellulose 0.15-0.25%
from 5.25 to 6% water
3.5% pectin
ash
wax

Recommended use:
Inclinations of 1:3 - 1:2
3 - 5 years

Weights / Measures:
BonTerra ® coconut fabric 400 g / m² can be supplied in rolls of 1 m, 2 m, 3 m and 4 m wide x 50m long or pressed in bales. Other dimensions and specifications on request.

9.4.3 BonTerra® K Coir Fibre Blanket



TECHNICAL DATA

BONTERRA KCN4 Special Blanket
With Top Coir Netting 400 g

BONTERRA KCN7 Special Blanket consists on a 350 – 400 g/m² coir blanket stitched on the upper side with a coir netting 400 g/m², on the lower side with a PP net or Jute net. The stitching thread is PP or Jute.

Analysis of Coir Fibre:
Approximately as follows :
46 % lignins, 44 % cellulose, 0.25 % hemicellulose, 5.25 % water, 4.5 % pections, ash, wax.

Material Content:
100 % pure coir fibre
PP or Jute Thread (see Technical Data BONTERRA K enclosed)
PP or Jute Netting (see Technical Data BONTERRA K enclosed)
Coir Netting HY 400 g (see Technical Data enclosed)

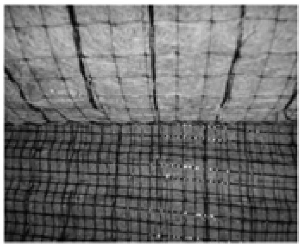
Dimensions 1 roll:
2 m x 25 m
Diam. 60 – 65 cm
Weight: approx. 38 kg

Durability:
3 – 5 years

Applications:
Shoreline Protection
Drainage Ditches
Severe Slopes

BonTerra blankets are produced in accordance with the ISO quality system management.

9.4.4 BonTerra® R3D



Technical Data

BonTerra® K R3D
100 % Coir Blanket re-enforced with a high-strength, Three-dimensional PP Grid

Blanket Construction
BonTerra® K R3D Blanket consists of a 100 % coconut fibre matrix stitched on the upper side with a high-strength permanent three-dimensional PP Grid. The coconut fibre matrix provides instant erosion control and mulching effect/evaporation protection. The high-strength permanent three-dimensional PP Grid ensures effective long-term seed and soil protection.

Materials:
350 – 400 g/m² 100 % coir fibre matrix
Black PP-Nets on top and bottom, mesh size 20 mm x 20 mm
Black three-dimensional, high-strength, corrugated PP Grid
Grid mesh size: 15 mm x 12 mm

Roll Dimensions
2 m x 30 m
Diameter approx. 75cm
Weight one roll approx. 30kg

Tensile Strength (ASTM D 4595)

Dry	Wet
MD: 5,5 kN/m	MD: 4,4 kN/m
TD: 11,5 kN/m	TD: 9,6 kN/m

Application:
Critical erosion control areas
Long term establishment and stabilization of vegetated areas
Shore protection

Customs Tariff No. : 4602 1991 900
BonTerra® Blankets are produced in accordance with ISO 9001 Quality Management.

9.4.5 MacMat® R

MACCAFERRI

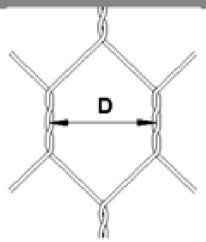
TECHNICAL DATA SHEET

UK / TDS / MR / PG622 / Rev: 08, July 07

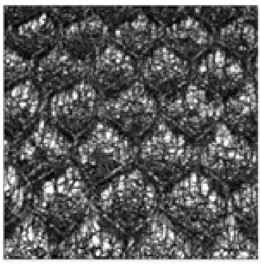
MACMAT-R

PVC GALFAN GALVANISED 6 / 2.2

SPECIFICATIONS	
PROPERTIES	
Type	Double twist hexagonal woven steel wire mesh onto which a 3D geomat matrix is extruded
Mesh Type	6 x 8
Mesh Wire	2.2mm diameter (BS EN 10218-2 & BS EN 10223-3)
Selvedge Wire	2.7mm diameter (BS EN 10218-2 & BS EN 10223-3)
Corrosion Protection	Galfan galvanised (95% Zinc + 5% Aluminium Alloy + Mischmetals) coated to BS EN 10244-2 Class A (230 g/m^2) with an extruded grey PVC coating of mean wall thickness of 0.5mm
Geomat Type	A three dimensional geomat of entangled polypropylene monofilaments, heat bonded at contact points, 10mm thick with a void space of 90%.
Roll Size / Weight	2m x 25m (Roll Weight = 90 kg (Nominal))
Jointing	All joints and connections shall be formed with continuous 2.2mm PVC Galfan coated lacing wire and/ or high tensile 3mm diameter Stainless Steel 'C' rings.
BBA Approval	Maccaferri hexagonal wire mesh is BBA certified for up to 120 years design life. Agrément Certificate No. 95/3141



D = 60mm (Nominal)



All units are supplied with sufficient lacing wire for standard installation.
Maccaferri reserves the right to alter specifications of its products without notice.
Please contact us for the most up to date specifications.

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Web: www.maccaferri.ie

Oxford, Perth, Belfast

9.4.6 Terravest K binder

Kategorie:	**Nassansaat**	**Hydroseeding**
Name/Typ/Attribut:	***TERRAVEST K (Bodenfestiger)***	***TERRAVEST K (Bodenfestiger)***
Sprache:		
Berschreibung:	Die Grundlage von TERRAVEST K ist ein spezielles, flüssiges Polymer, kombiniert mit Hilfsstoffen, wie Netzmitteln, Trocknungsbeschleunigern und Entschäumern. Nach Emulgierung in Wasser wird TERRAVEST K durch Versprühen auf die zu schützenden Böden aufgebracht und dringt je nach Saugfähigkeit des Bodensubstrates bis zu 20 mm tief in die Oberfläche ein. Nach Aufbringen von TERRAVEST K tritt eine Reaktion mit Luftsauerstoff ein; es bildet sich innerhalb einiger Stunden ein festes, wasserunlösliches Netzwerk. Dadurch werden alle benetzten Partikel, wie Sandkörner, Dünger, Saatgut und andere Stoffe, an der Oberfläche fixiert. Die Bodenoberfläche wird durch ausgehärtetes TERRAVEST K nicht versiegelt. Die Saugfähigkeit des Bodens bleibt durch den Netzcharakter der Verfestigung für Niederschlagswasser voll erhalten. Keimung und Pflanzenwuchs werden nicht beeinträchtigt.	TERRAVEST K is based on a special liquid polymer combined with auxiliaries such as wetting agents, driers (accelerating oxygen uptake) and defoaming agents. TERRAVEST K is emulsified in water and then spray-applied to the surface to be protected where it penetrates up to 20 mm in depth, depending on the absorbency of the soil substrate.After its application, TERRAVEST K reacts with atmospheric oxygen and within a few hours a firm, water-insoluble network is formed. As a result all wet particles such as sand grains, fertilizer, seed and other materials become bound to the surface.The cured TERRAVEST K does not seal the surface of the soil, indeed the soil absorbency for rain is fully maintained by the open matrix-like character of its bound (stabilized) structure. Germination and plat growth remain unimpaired.
Inhaltsstoffe:	Polybutadien	Polybutadien
Spurenelemente:	- keine Angaben -	- no value -
pH-Wert:	- keine Angaben -	- no value -
Ausbringung:	Immer, außer bei Bodenfrost, Starkregen und Schneebelag	All time, but not: during heavy rainfall, when snow on the ground with frost in the soil
Aufwandmengen:	einmalig 10 bis 25 g/m² je nach Bodenzustand, Böschungsneigung, Witterungsverhältnissen und Oberflächenstruktur.	One time 10 to 30 g/m² depending on soil structure and composition as well as on slope steepness and risk of high rainfall and danger of erosion.
Einsatzbereiche:	Nassansaat Ingenieurbiologie Böschungssicherung Schutz vor Winderosionen	Hydroseeding Bioengineering Erosion control Dust control
Aggregatzustand:	[liquid] Flüssiges Konzentrat	[liquid] Dark brown liquid concentrate. density: 0,91 g/m³
Gebindegröße:	51 x 20 kg Kunststoffkanister auf Einwegpalette 900 kg Kunststofftank Einweg	51 x 20 kg non-returnable containers on a one way pallet 900 kg one way tank

9.4.6.1 Quantity calculation Terravest K binder

Table 25 Quantity calculation Terravest K binder (2012 Essling, VIENNA)

Parameter	Value
Area total [m²]	1,231
Amount of binder [g/m²]	15
Amount of binder [ml/m²]	16,35
Water for dilution [l/m²]	2
Size of watering can [l]	12
Binder total [g]	18,468
Binder total [ml]	20,13012
Water for dilution total [l]	2,4624
Mixture total [l]	2,48
Watering cans total [Stk]	0,206878
Binder per watering can [g]	89,27

9.5 Working diary

Table 26 Working diary (2012 Essling, VIENNA)

Date	Activity
04.04.2012	Pre-experiments – Tanking of soil sample (spade) and irrigation with watering can;
27.04.2012	Pre-experiments of calibration of rainfall simulator in BOKU laboratory;
02.05.2012	Start of clearing of the test fields;
07.05.2012	Finishing of clearing of the test fields;
09.05.2009	Pre-experiments of rainfall simulation respectively sowing pans with geotextiles; determination of fixing method of geotextiles on sowing pans -> 10 bore holes for 10 cable straps; fleece as protection necessary;
10.05.2012	Weighing and mixing of seeds and packing (BOKU Laboratory);
11.05.2012	Filling of sowing pans with soil and fleece;
15.05.2012	Finishing of filling of sowing pans; Cutting of geotextiles; Mowing;
18.05.2012	Seeding and installation of geotextiles (BonTerra®, Bare soil); weighing of sowing pans; Watering;
21.05.2012	Start determining of soil moisture content (--> dry oven) (BOKU laboratory);
22.05.2012	Seeding and installation of remnant set ups (MacMat® R, MacMat® R + terravest K binder, MacMat® R filled, Dry seeding), Watering;
24.05.2012	New location of set ups; Installation of automatic irrigation; Documentation of development;
06.06.2012	Weeding of pest plants (*Amaranthus spec.*); Documentation of development; Irrigation;
22.06.2012	Test implementations with rainfall simulator (Boku laboratory);
27.06.2012	Determining of dry weight (biomass) (BOKU laboratory);
03.07.2012	Documentation of development; Mowing of vegetation around test plots; Mowing of biomass in h=5cm; Drying of biomass in dry oven (70°C) (BOKU laboratory);
13.07.2012	Building of construction for standardized rainfall simulation; Pre-tests of construction;
17.07.2012	Inspection with FF, PdP
06.08.2012	Finishing of construction; Mowing of vegetation around test plots; Mowing of biomass in h=5cm; 1. rainfallsimulation;
07.08.2012	Finishing of rainfall simulation (2 remnant sowing pans); First measurements of surface runoff and positioning of samples in dry oven (160°C);
28.08.2012	Measuring of surface runoff and positioning of samples in dry oven (160°C);
29.-31.08.2012	Weighing of dry mass; Further measuring of surface runoff and positioning of samples in dry oven (160°C);
18.09.2012	2. rainfall simulation; Measuring of surface runoff and positioning of samples in dry oven (160°C);
19.09.2012	Weighing of dry mass; (Difference of shell weights); Measuring of surface runoff and positioning of samples in dry oven (160°C);
20.09.2012	Weighing of dry mass (Difference of shell weights);
14.11.2012	Determination of soil pH in CULS laboratory
15.11.2012	Determination of humus content in CULS laboratory
19.11.2012	Beginning of determination of soil texture and determination of carbonate content in CULS laboratory
20.11.2012	Finishing of determination of soil texture in CULS laboratory

10. Curriculum Vitae

SILVIA STOCKINGER B. Sc.

Born on 10.09.1987, in Oberndorf

Austrian

EDUCATION

2011 – now	**University of Life Sciences Vienna** Master study Natural Resources Management and Ecological Engineering
2008 – 2011	**University of Salzburg** Bachelor study Geography. Certificated August 2011
2007 – 2008	**University of Leoben** Bachelor study Applied Geosciences
2001 –2006	**HTBLA Braunau** Branch of study Electrical Engineering; Specialization Information Technology. Matura: 13.06.2006
1997 – 2001	HS Eggelsberg
1996 - 1997	VS Eggelsberg
1993 - 1996	VS Ach

EMPLOYMENT EXPERIENCE

August 2006 – August 2011	**Bernecker + Rainer Industrie-Elektronik GmbH**, Eggelsberg

SKILLS AND ACHIEVEMENTS

German	Mother tongue
English	Very good
PC	MS Office, Corel Draw, Frame Maker, ArcGis, SPSS

HOBBIES AND INTERESTS

Participation of the culture association inn.drei.viertel
Hiking, climbing, Hoop dance

Eggelsberg, 30.10.2013

11. STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources and that I have explicitly marked all material which has been quoted either literally or by content from the used sources.

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date   (signature)