Universität für Bodenkultur Wien
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HETEROGENEITY OF C - FACTORS IN VINEYARDS OF EASTERN AUSTRIA

Master thesis
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M.Sc.

submitted by:
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This master thesis forms an integral part of the ´Vinedivers´ project which aims to examine the impact of vineyard management on ecosystems and related ecosystem services.

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Abstract

Soil erosion control by means of soil conservation practices has gained importance in vineyard management of recent years. However, evaluation of soil erosion risk at regional scale remains difficult as little information is available on the heterogeneity of vineyard management and its effects on soil loss.

The viticulture fields of Eastern Austria are handled at a very small scale, thus land use management may vary greatly across neighbouring fields. Management practices range from keeping fallow soils to the perpetuation of a constant vegetated cover throughout the year. However, amount and intensity of soil cultivation do have influence on soil erosion susceptibility.

In a field research conducted over the time span of one year, different land use management systems were identified and dynamics of soil cover development were recorded for 6 different sites located in the regions around the villages of Göttlesbrunn and Purbach east of Vienna. By combining measured and modelled data individual soil cover parameters for every researched vineyard were predicted and transformed into soil loss using the well known C-Factor of the Revised Universal Soil Loss Equation (RUSLE). The effects of regional land use management forms and cultivation practices were compared and evaluated with regard to their respective erosion reduction potential.

An overall C-Factor of 0.06 was calculated for the entire study site while individual field plot C-Factors range from 0.01 to 0.38. Moreover, results indicated that a combination of reduced surface disturbance and increased vegetation cover fairly reduces the erodibility of soils.

The findings may be helpful for both, policy makers and farmers to translate the findings into practical implications for improving soil conservational measures in vineyard management.

Kurzfassung

Die Eindämmung von Erosion in Weingärten mit Hilfe von bodenkonservierenden Maßnahmen gewinnt zunehmend an Wichtigkeit. Die Bewertung von räumlich begrenzten Erosionsrisiken ist jedoch erschwert durch das Fehlen von Daten über spezifische Erosionseffekte heterogener Bewirtschaftungsweisen. Die Intensität der Bewirtschaftung sowie der Grad der Bodenbedeckung spielen eine zentrale Rolle bei der Kultivierung der kleinstrukturierten Weinparzellen im Osten Österreichs und reichen von einer offenen Bodenbewirtschaftung bis hin zur Beibehaltung einer konstanten Bodenbedeckung über das Jahr.

In der über den Zeitraum von einem Jahr durchgeführten Feldforschung wurden Bodenbedeckungsdynamiken von unterschiedlichen Bewirtschaftungsweisen für 6 verschiedene Gebiete im Raum Neusiedler See untersucht und aufgezeichnet. Im Anschluss daran wurden individuelle Bodenbedeckungsparameter bestimmt und mit Hilfe des bewährten C-Faktors der Revised Universal Soil Loss Equation (RUSLE) in gesonderte Bodenverlustraten umgerechnet. Zusätzlich wurden die Effekte regionaler Bewirtschaftungsweisen verglichen und hinsichtlich ihres Reduktionspotentials von Bodenerosion bewertet.

Ein C-Faktor von 0.06 für den gesamten Untersuchungsraum wurde berechnet, wobei einzelne Feldschläge C-Faktoren Werte von 0.01 bis 0.38 annehmen.

Die Ergebnisse zeigten, dass Häufigkeit und Intensität der Kultivierungsmaßnahmen einen Einfluss auf die Erodierbarkeit des Bodens haben. Eine Kombination aus geringer Bodenbearbeitungsintensität und erhöhter Bodenbedeckung kann Bodenerosion deutlich reduzieren.

Diese Masterarbeit soll einen Beitrag zu der aktuellen Debatte über die Auswirkungen von Bodenbedeckungsmanagement in semiariden Weinbau Ökosystemen leisten und Schlussfolgerungen für Entscheidungsträger und Weinbauern bei der Verbesserung von bodenkonservierenden Maßnahmen im Weinbau erleichtern.

1. Introduction

Soil erosion is widely recognized as being one of the most serious threats to cultivated soils all across the globe. The aim of soil conservation is to reduce erosion to an acceptable level equal or below the natural rate of soil formation. Although considerations regarding sustainable management toward a soil saving cultivation have increased in importance over the last years, yet most of the cultivation practices are targeted at two interrelated purposes: Obtaining maximum yield at the highest level of quality (Morgan, 2005).

Due to a combination of natural factors and farming practices vineyard agro-ecosystems form unique environmental contexts and are among the most attractive and diversified agricultural territories, high in biodiversity and associated ecosystem services. However, this state is threatened by intense soil cultivation practices and a low rate of surface vegetation cover, especially when field plots are located on steep slopes (Jackson, 2008).

Therefore, arable lands dedicated to vine cultivation belong to the most erosion-prone types of agricultural land in Europe (Lieskovský and Kenderessy, 2014). Soil erosion processes result from a combination of specific physiological and anthropogenic factors. The impact of climatic factors on soil erosion, however, can be controlled and vastly reduced by farmers through management activities, whereas the maintenance of a consolidated soil cover has proven to be a highly effective measure to prevent soil erosion at low costs (Renard et al.,1997).

1.1 Soil cover benefits and issues

Surface vegetation physically protects the soil by scattering raindrop energy and reducing runoff velocity, while roots and residues of plants act as mechanical barrier to soil and water movement, effectively helping to control soil erosion and associated leaching of nutrients (Mallory et al., 2011).

Moreover, vegetation cover substantially contributes to the fragile soil ecosystem. Below surface, root exudates balance chemical soil parameters and nourish soil micro-organisms which in turn physically bind and aggregate soil particles, thereby increasing soil structural stability and fertility (Renard et al. 2011). In addition to that, pedostructure is ameliorated through an enhanced formation of biologically-produced macro pores, subsequently expanding infiltration and water retention capacity. Besides, a controlled grass cover species protects vines from overgrowing, supressing undesired weeds in the immediate vicinity of the vine plant (Robačer et al., 2016)

In contrast to that, the absence of a consolidated surface cover can have detrimental effects on soil structure and stability. In case of erosive rain events, the loss of the anchoring function of roots can lead to interrelated onsite soil erosion processes like splash erosion, initial runoff formation, sediment losses and nutrient movement. If transported with runoff it can as well cause huge off-site damages like sediment and pesticide accumulation (Rodrigo Comino et al., 2016).

Due to high maintenance requirements of the vine crop, machine tracks between vine rows are frequently travelled on and are therefore affected by soil compaction, especially when driven on with heavy machinery. Moreover, a lack of vegetation cover leads to a deterioration of pedostructure, indicated by a decrease of soil porosity and shrinkage of large and middle-sized pores in lower soil horizons (Mallory et al., 2011; Eldon and Gershenson, 2015).

The individual choice for a certain type and degree of soil cover, however, is complex. Vine farmers face a perpetuated dilemma between the consideration of a sustainable form of soil cultivation and the competition of cover vegetation and cash crop in water and nutrients. Particularly intercropping systems in water-limited environments are disputed among vine growers because they appear to have significantly lower grape yields (Ruiz-Colmenero et al., 2011). On the other hand, the application of intercropping systems to vineyards can have several beneficiary effects on the soil-water balance. Vegetation cover as soil improvement technique, however, was first introduced in vineyards with wet climates as an "effort to reduce the moisture in the soil, and consequently the vigor of the vines" (Ruiz-Colmenero et al., 2011:211). Although cover crops show a high cumulative evapotranspiration, root uptake from lower layers considerably adds moisture to the top layers of soil, thereby also increasing the availability of water-soluble nutrients (Bodner, 2007). Some vine growers aware of that fact rely on a subtle water drainage effect, in which humidity stored in grass covered soil compartments is absorbed by the soil compartment of the vine crop (Ripoche et al., 2010).

However, the extent to which cover crops in vineyards influence water balance is controversial, largely unknown and therefore mostly based on vine growers´ belief (Ruiz-Colmenero et al., 2013). It remains difficult for vine growers to assess the short- and long term performance of an introduced or destroyed cover crop, as grapevine yield is determined both by immediate and delayed effects of the conditions resulting from the current and previous crop cycle (Ripoche et al., 2011).

1.2 Effects of tillage

In an arable agricultural system, the soils underneath row crops usually show a substantial susceptibility to erosion due to a high percentage of bare soils (Morgan, 2005). The case of row division in vineyards is not different from that.

Mechanical soil tillage operations in vineyards usually comprise ploughing, hoeing or rotavating. Every agronomic measure, however, differs in its specific effect on soil physical, chemical and biological properties. The magnitude of the impact on the soil-ecosystem, relies heavily on intrusion depths, tillage intensity and tillage frequency. In contrast to intensive tillage systems, soil conservational tillage is characterised by little intrusion depths, soft loosening and low turnover rates (Bauer et al., 2008).

The heterogeneities in choices of how row and interrow sections are operated largely depends on the land use management in practice. Land use regimes are also quite adaptive systems, as for instance periods of low precipitation may require vine growers to alter cover management practices, sometimes rapidly (Ripoche et al., 2011). Therefore, tillage operations usually reflect to some extent vine farmers´ choice as a response to changing climatic factors. Since grape production in quantity and quality is largely dependent on water availability, a natural greening is perceived to outcompete the vine crop in water and nutrient uptake if precipitation is low (Medrano et al., 2014).

In disregard to the potential advantages of surface cover, tillage appears yet to be a compelling option for vineyard farmers, as several benefits are identified with this particular form of soil cultivation. At the core of the field management strategies in use lies the regulation of both, nutrient and water availability.

Site-specific agronomic practices targeting the water balance of soil, however, range from mechanical to chemical weeding operations. Attention is drawn on preventing unproductive evaporation which is attributed to any kind of grass cover, especially under dry climatic conditions. If the management objective then pronounces a clean and weedless soil, farmers who are concerned with the undesirable effects of herbicide application may show a preference to mechanical tillage rather than to using chemical substances. Traditional management of vineyard soils has relied heavily on tillage aimed to reduce water competition by breaking up surface crusts in order to increase water infiltration, a benefit which is mostly rewarded to clean tilled soils due to increased soil surface areas (Ruiz-Colmenero et al., 2013).

As nutrient uptake is usually closely associated with plant available water, the breaking up of surface-sealing through a loosening of soil remains to be a viable option to induce an increased mineralisation rate (Bauer et al., 2008).

On the other hand, it has been shown that moderate water stress can be beneficial to bud fertility (Ripoche et al., 2011). Nevertheless, water stress should be limited during the vegetative phase to foster a suitable canopy development in order to ensure a satisfying assimilation rate (Ripoche et al., 2010).

In regard to soil type and climatic conditions, adverse effects of intense cultivation practices on soil-ecosystem are indicated by a degradation of soil physical and biological parameters (Lieskovský and Kenderessy, 2014). Ruiz-Colmenero et al., (2013) states, that the collapse of larger pores under the impact of cultivation largely offsets the infiltration benefits experienced in top soil layers. Following intensive tillage measures, the positive short term effects of mobilised nutrients and increased water infiltration rates are overcompensated by long-term adverse effects on soil fertility including a depletion of soil organic matter, diminished soil fauna and a degraded pedostructure. In a study on effects of tillage in Spanish semi-arid vineyards Ruiz-Colmenero et al. (2011) reported that beneficial effects of tillage were only temporary, because the change in soil structure in turn led to surface sealing and increased runoff.

1.3 Erosion Control in Austrian Vineyards

Due to beneficial economic and environmental conditions most of Austrian vineyards are located on slopes. These are the areas where soil loss poses a major threat, especially to the highly erodible loess terraces in vicinity of Danube River.

In Austria, the legislative background regarding soil protection is defined within the legislations of the 9 different provinces. For instance, the soil protection law of Lower Austria (https://www.ris.bka.gv.at/Dokumente/LgblNO/LRNI_2005025/LRNI_2005025.pdf) states the prevention of soil erosion as an objective target and several soil protection measurements are advised. However, there is no clear definition on tolerable soil loss and no legally binding erosion control rules whatsoever. Greater importance to soil protection in Austria is given through agricultural policies on a national level. With the entry of Austria into the European Union in 1995, the Austrian programme for a sustainable agriculture (ÖPUL) was launched. Among other arrangements, the programme offers farmers environmental contracts destined at combatting soil erosion in vineyards. Part of the protection measures to be implemented include terracing and/or the use of mulching systems or cover crops for at least 10 month per year (Strauss and Klaghofer, 2006).

Essential long-term field research regarding soil erosion in Austrian vineyards has been done in the 1970s, -80s and -90s by works of Klaghofer et al. (1990) on the use of waste compost as soil enhancement measure against water erosion, (Klaghofer and Strauss, 1993) on mulching under dry conditions and (Klaghofer and Bauer, 1982) on the effects of permanent grass cover on soil physical properties in irrigated vineyards.

1.4 Monitoring Soil Erosion

Little information is available about the determination of management effects on soil loss for vineyards at a regional scale. Monitoring soil erosion risk shall help to fill that knowledge gap and is moreover understood to be an important part of soil conservation practices.

As it is practically impossible to take measurements at every point in the landscape, monitoring is usually done with the help of erosion models, whereas USLE -the Universal Soil Loss Equation- (Wischmeier and Smith, 1978) and its revised version RUSLE (Renard et al., 1997) represent the most common ones. RUSLE estimates long-term average annual soil loss by sheet and rill erosion and reflects the on-site effects of management variations with the Cover Management Factor C.

C-factors are defined as the ratio of soil loss under a given vegetation cover and to what extent soil loss of an investigated field plot is different to that occurring under a worst-case management scenario with clean-tilled soil conditions (Alexandridis et al., 2015). Most commonly used in agriculture to describe the aboveground effects of crop rotations and different soil cultivation managements, RUSLE´s C-factor can as well be applied to viticulture land.

C-factors range from 1 for bare soil to as low as 0.001 for forest or dense shrub lands. Depending on site and crop specific proportion of the soil covered, farmed land shows intermediate C-factors. For instance, statistical data on C-factors for wheat range from 0.1 to 0.4, values for soy beans range from 0.2 to 0.5, whereas conventional tilled maize can take values of 0.5 to 0.9 (Morgan, 2005). However, studies on erosion risks of vineyards found C-Factors ranging from 0.2 to 0.6 (Jordan et al., 2005; Auerswald and Schwab, 1999; Novara et al., 2011; Lieskovský and Kenderessy, 2014).

So far, only a few studies have been carried out on C-factors for vine cultivation land and mostly rely on biophysical data derived from remote sensing techniques in combination with statistical data on agricultural crops and management practices (Panagos et al., 2015b; Vatandaşlar and Yavuz, 2017). Assessment of soil loss rates in these studies is usually done in a grid-cell resolution, which is a proper way to do research on a large scale. However, that methodological approach has shown to be unable to explain differences in soil loss rates due to land use management variances on a small scale.

1.5 Disposition of field study

In contrast to large scale estimation methods, this study tries to yield more verifiable data and determine exact parameters for modelling of soil loss rates at field resolution scale. This is done by a combination of modelled and measured data and constitutes of empirically determined data on soil cover degree and composition, which is fundamental to the RUSLE calculations of C-Factors.

The core of this study therefore lies at identifying relationships between predominant land use management forms in Eastern Austrian vineyards and their respective effect on soil loss expressed through the Cover Management factor C of RUSLE. On top of that, surface cover is highly variable both spatially and over time, therefore reflecting a high heterogeneity of C-Factors to which will be referred later in this thesis.

As detailed information on parameter calculation for soil erosion risk modelling in vineyards is rare in soil research, this work shall contribute to a better estimation of the risk assessment of erosion-prone soils. A successful comparison of different viticulture management practices could serve as an adequate data-base to develop general land management policies combating land degradation processes (Rodrigo Comino et al., 2016).

This Master thesis, however, forms an integral part of the EU funded ´Vinedivers´ programme (www.vinedivers.eu) which aims to analyse the implications of different management regimes in multifunctional viticulture agroecosystems and related ecosystem services. Emphasis is put on examining the impact of soil management on plant diversity, soil biota and pollinators, and the consequences for a variety of ecosystem services (VINEDIVERS, s.a.)

1.6 Objectives

This thesis aims to

i. Determine average annual C-factors of the RUSLE model on field- and regional scale for selected vineyard regions in Eastern Austria

ii. Determine the degree of heterogeneity of C-Factor for these regions

iii. Compare the effects of regional land use management forms and their respective management practices by showing to what extent soil loss can be reduced

1.7 Assumptions and Hypotheses

This study is based on the assumption, that modelling is necessary to build the bridge between measureable data and soil loss at regional scale and that the Cover Management Factor of the RUSLE erosion model is able to reflect the effects of management changes on soil erosion. A number of further assumptions have been made in the process which will be named and explained in the progress of this thesis.

Based on above named assumptions, the following hypotheses are defined for this research project

Hypothesis 1: Spatial heterogeneity of soil cover management

Variability in soil management of the vineyards of Eastern Austria expressed by soil cover is very high at local scale

Hypothesis 2: Heterogeneity of soil cover management during research period

Soil management of the vineyards of Eastern Austria expressed by soil cover highly varies between different observation periods in a year

Hypothesis 3: Heterogeneity of C-factors

Based on hypotheses 1 and 2, variability in soil management of the vineyards of Eastern Austria expressed by soil cover leads to a high heterogeneity of those factors that influence soil erosion through management

Hypothesis 4: Impact of cover management on C-factors

An increased soil cover show reduced C-factors while low soil coverage yields high C-factor values

1.8 Testing of Hypotheses

In order to examine the on-site consequences of erosion and compare the effects of different cultivation systems the following steps are to be taken:

i. identify the predominant land use forms in vineyards of Eastern Austria
ii. to qualify and quantify the respective soil cover and its development over investigation period
iii. to quantify the severity of soil erosion under different land use management systems based on the transfer of land use management systems into C-Factors (RUSLE)

2. Material and Methods

As in this study C-factors are calculated by combining measured and modelled data, the following part (Section 2.1 and 2.2) describes the design of the soil erosion model that was used to determine how soil loss rates respond to changes in cover management regimes.

After giving detailed information on geologic and socio-economic matters of the study site in Section 2.3, Section 2.4 will demonstrate the extraction of measured data in the conducted field experiment.

2.1 Soil Erosion Model

In general, soil erosion models should be able to predict soil loss rates under any given vegetation cover or a management scenario at different positions in the landscape over various spatial and time scales.

Basically there are three types of soil erosion models which can be distinguished by their specific design requirements. Physical and analogue models such as ´The Water Erosion Prediction Project (WEPP)´, ´the European Soil Erosion Model (EUROSEM)´ or simple sandbox models usually are event based and mostly run laboratory experiments that make use of mechanical or electrical systems to assume similitude between real world and model (Morgan, 2005).

Simplistic, thus universally applicable empirical soil erosion models like RUSLE, SLEMSA, or the Morgan and Finney method show high structural similarities in terms of mathematical descriptions of the processes involved and factors incorporated into the equations (Morgan, 2005). Differences within these models, however, refer to the temporal and spatial scale these models initially were designed for. For instance, as soil loss rates are usually expressed in relation to a standard unit plot, the specific adjustment of these standards represent the confined research conditions under which soil loss rates are predicted.

Suitable for the objectives of this thesis, however, are empirical soil erosion models that are based on identifying statistical significant factors through the use of observation and measurement. Furthermore, the model should eventually predict average annual soil loss rates and explain how components of the analysed system relate to changes within that period of time. Very few practical and reliable soil erosion models are able to do that.

Hence, the only soil erosion model coming into consideration for the purpose of this study was the empirically based RUSLE model. The Revised Universal Soil Loss Equation (RUSLE) is a well-known and effective tool to monitor soil erosion risks which enables both researchers and farmers to determine C-Factors for each viable land use management system (Alexandridis et al., 2015).

RUSLE is an improved version of the USLE –the Universal Soil Loss Equation- , a concept that had first been developed in the early 1940s when soil erosion became recognised as a problem. The early concept has been updated with additional research findings ever since (Morgan, 2005).

The fundamental idea in establishing the factor values composing RUSLE was the creation of a reference unit plot as base condition to which any given field plot can be adjusted and later be compared to. This conceptual plot consists of a land parcel 1.8 meters in width, 22.1 meters in length with a 9% slope and maintained in a clean-tilled fallow condition, thereby representing “a condition near the worst-case management” (Renard et al. 2011:138).

The USLE soil loss equation incorporates factors relating to climate, soil properties, topography, soil surface conditions and variations in surface management, whereas the C-factor plays a key role in computing the overall annual soil loss (Renard et.al, 1997).

Apart from rainfall erosivity expressed through the factor *R*, soil cover represents the major component changing substantially through the year (Renard et al., 2011). Moreover, soil cover management expressed through the C-factor is the only component that can be implicitly influenced by the field operator.

However, RUSLE input parameters does not specifically relate to viticulture systems, therefore a number of assumptions had to be undertaken in order to replace the parameters adjusted to regular croplands (Lieskovský and Kenderessy, 2014). Hence, RUSLE indications usually are given in US non-metric values, thus data has to be converted to SI metric values.

According to Renard et al. (1997), soil erosion processes on a given site result from a combination of specific physiological and anthropogenic factors, thus can be regarded as a function of climate, soil properties, topography, soil surface conditions and variations in surface management. The basic USLE soil loss equation derived from that specific function is:

$$A = K * P * R * L * S * C$$

(Renard et al., 1997)

A is the annual spatial average soil loss per unit area expressed in metric values with the unit ($t* ha^{-1}* y^{-1}$)

K (in $t* ha*h$) is the soil erodibility factor, a parameter that accounts for the response of a uniform plot to the process of soil detachment by raindrops and surface flow

P (a dimensionless coefficient) is the support practice factor, describing the effects of agricultural practices like contouring, strip-cropping or terracing

R (in $MJ*mm* ha^{-1}*h^{-1}*yr^{-1}$) is the rainfall-runoff erosivity factor,

L and *S* (both dimensionless coefficients) are the topography factors, namely slope length and steepness

C (a dimensionless coefficient) is the cover-management factor, defined as the rate of soil loss.

As the purpose of this thesis is to merely explore the heterogeneity of C-Factors in the vineyards of Eastern Austria, other factors than *C* and *R* do not contribute to the calculation of soil loss rates and will therefore not further be processed.

Soil erosion models simplify reality, therefore some assumptions were made to clearly define the boundaries within which the model operates. For instance, the RUSLE soil erosion model merely applies to the confined spaces of field parcels in between which no transfer of water or sediments occur. Moreover, in disregard of microclimatic variations shaped by elements of the landscape, rainfall erosivity factor *R* is equally applied to all fields within the study site.

2.2 Computation of C-Factors

According to the RUSLE handbook C-Factors are the outcome of the multiplication of the soil loss ratio (SLR) for a given time interval with their corresponding percentage of annual rainfall erosivity (EI). EI in this context is synonymous to factor *R* of the basic RUSLE equation (Renard et al., 1997).

As C-factors are most commonly used for arable land, calculations are usually done by splitting up the year into several periods in correspondence with the different stages of crop growth (Morgan, 2005).

In order to track changes in erosivity and plant morphology of viticulture lands best, C-factor calculations were done on a 15-day resolution instead.

$$C = (SLR_1 * EI_1 + SLR_2 * EI_2 + SLR_n * EI_n) / EI_t$$

(Renard et al., 1997)

C is the dimensionless rate of soil loss given as average annual crop value,

SLR_n (dimensionless) expresses soil loss rates at a given site for a given period, and

EI_n the rainfall erosivity for a given period in $MJ*mm* ha^{-1}*h^{-1}*yr^{-1}$,

C-values range between 0 and 1, where the reference value of 1 is assigned to a bare fallow unit plot with no vegetation cover. An increasing vegetation fairly reduces the C-Factor and results are given as a ratio compared to the loss of the defined conceptual reference plot.

2.2.1 Computation of Soil-Loss Ratio

$$SLR = PLU * CC * SC * SR * SM$$

(Renard et al., 1997)

The Cover management factor comprises five sub-factors that account for the specific effects of the respective management practice in use (Vatandaşlar and Yavuz, 2017).

These are prior land use (PLU), canopy cover (CC), surface cover (SC), surface roughness (SR) and soil moisture (SM). Above mentioned sub-factors include further variables, which will be explained step by step.

Soil loss ratios will be calculated on a field-scale for each vineyard section and each time interval individually. Along with indicators on soil quality, the significance of a protective herbaceous cover in preventing soil erosion is strongly reflected within the RUSLE model framework.

2.2.2 Canopy Cover Subfactor

The Canopy Cover Subfactor within the Universal Soil Loss Equation represents “the effectiveness of vegetative canopy in reducing the energy of rainfall striking the soil surface” (Renard et al. 1997: 157). Raindrops are intercepted by canopy and fractured into smaller drops hitting the canopy or lose their kinetic energy by travelling down the stem of the vine plant (Renard et al., 2011)

The canopy Cover effect is given as

$$CC = 1 - F_c * \exp(-0.1 * H)$$

(Renard et al., 1997)

CC is the dimensionless Canopy Cover Subfactor ranging from 0 to 1,

F_c is the fraction of land surface covered by canopy and

H is the average distance in feet of raindrop fall after striking the canopy.

A *CC* value of 1 expresses full exposure to elements inducing soil erosion processes. However, a higher portion of canopy cover F_c results in a higher protection rate, thus lower *CC* values.

Fc values are the result of soil cover image analysis, while the average raindrop fall height from canopy *H* had to be adjusted to local conditions. As a matter of fact, *H* was taken from literature and was set to 0.9 meters equalling 2.95 feet (Auerswald and Schwab, 1995).

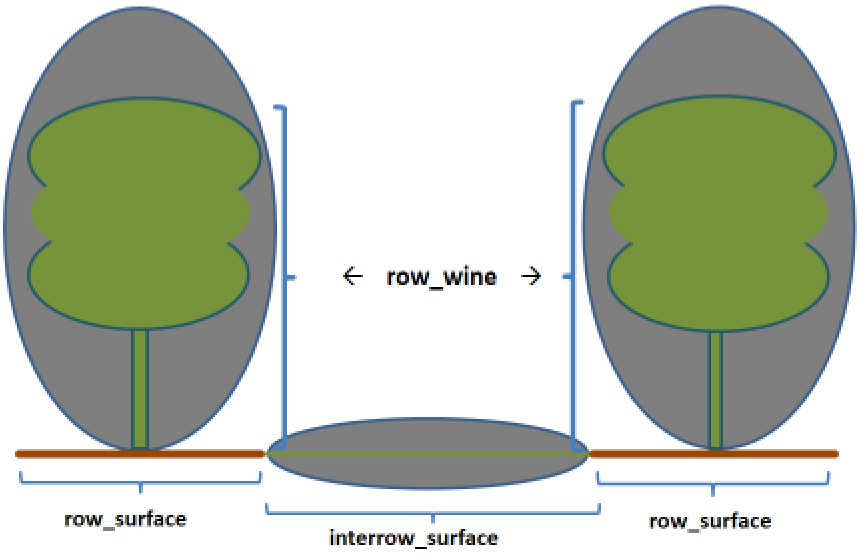


Figure 1. Section of vineyard for which a canopy cover value was calculated

As illustrated in Figure 1, CC values were calculated for all divisions of the vineyard, except for the row_surface section. Within the row section of vineyard, the protection of the overlying canopy was considered sufficient.

2.2.3 Surface Cover Subfactor

Surface cover affects erosion in two ways. On the one hand, it reduces the transport capacity of surface water by deposing runoff in ponded areas. Secondly, a closed surface cover decreases the exposed surface area susceptible to raindrop impact (Renard et al., 2011).

The effect of surface cover on soil erosion is given as:

$$SC = \exp * (-b*S_p*(0.24/R_u)^{0.08}$$

(Renard et al., 1997)

SC is the dimensionless surface cover Subfactor,

b is an empirical coefficient

S_p is the percentage of land area covered by surface cover, and

R_u is the Surface Roughness (in inch), as will be defined later

In order to have realistic outcomes from the surface cover sub-factor calculation, each vineyard section for which a SC value was calculated, had to be looked at distinctively (*Figure 2. Section of vineyard for which a surface cover value was calculated*). On account of this, b- and R_u values had to be assigned specifically and in accordance to the attributes of each vineyard division.

Assignation of b-values

According to Renard et al. (1997:159), b-values are empirically determined and indicate “the effectiveness of surface cover in reducing soil erosion”.

b-values for different agricultural lands range from 0.030 to 0.070 and reflect conditions from row crops with the highest share of bare soil until rangeland conditions with permanent grass cover (Renard et al., 1997)

In contrast to regular cropland management, the surface cover of vineyards is farmed in two partitions –the row_surface and the interrow_surface sections. Hence, also a distinction in the assignation of b values was needed.

The RUSLE handbook (Renard et al., 1997) suggests the use of a b-value of 0.035 for conditions under ´typical cropland erosion´. Hence, this value was applied to all vineyard sections frequently tilled. In contrast to that, a b-value of 0.039 assigned to ´rangeland condition´ was applied to all vineyard divisions with a nearly consolidated grass cover.

Assignation of R_u-values

Same as with *b*-values, different soil roughness factors had to be applied due to the distinctively farmed vineyard sections. R_u stands for surface roughness, which is a function of the surface random roughness defined as the "standard deviation of surface elevations across the slope" (Renard et al., 2011: 147). See a more detailed discussion on the surface roughness subfactor in the following section.

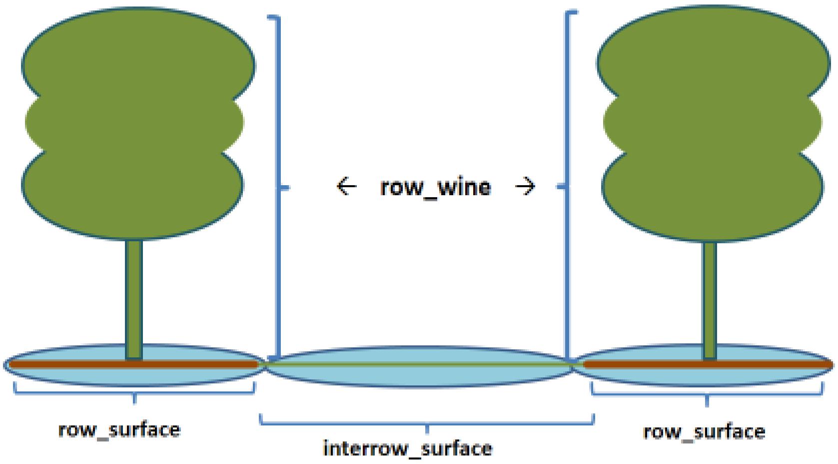


Figure 2. Section of vineyard for which a surface cover value was calculated

As illustrated in Figure 2 surface cover values were calculated for all surface sections of the vineyard marked with blue colour.

2.2.4 Surface Roughness Subfactor

Surface roughness has shown to affect soil erosion by water in different ways. During a rainfall event, the more roughness a soil attributes, the more sediment is trapped in depressions and barriers leading to a high infiltration rate and a decreased runoff velocity (Renard et al., 2011). Thus, if soils that are left rough and cloddy, they result in a lower erodibility. As mentioned above, surface roughness is defined as the “standard deviation of surface elevations across the slope” (Renard et al., 1997:160).

The effect of surface roughness (SR) on soil erosion is given as:

$$SR = \exp(-0.66 * (R_u - 0.24))$$

(Renard et al., 1997)

SR is the dimensionless Surface Roughness value,

R_u is the Surface Roughness (in inch)

The RUSLE approach of measuring the impact of soil roughness on erosion is done -equal to other subfactors- by setting a baseline condition of a clean-tilled unit plot. This conceptual plot is given the value 1, while an increased vegetative roughness fairly reduces soil erosion given as a ratio in reference to the RUSLE unit plot.

The RUSLE handbook (Renard et al., 1997) suggests the use of a soil roughness of 0.24 inch (6mm) for the standard unit plot with fine pulverised soil. This value was applied to all vineyard sections frequently tilled. Based on educated guess, a soil roughness of 0.65 inch was assigned to vineyard sections under permanent vegetation cover.

A set of further assumptions concerning the calculation of SR-factor were taken. Surface Roughness calculation usually contains a biomass adjustment variable that adds a roughness decay coefficient to express the smoothing out over time after tillage operation. Assuming that soil surface operations in vineyards are carried out intensively and in short intervals, no such decay coefficient was applied.

Since many field operations affect only a portion of the vineyard surface, each section of the vineyard has to be looked at specifically. Note, that R_u values used for computing subfactor SR values are the same as used in the calculation of surface cover subfactor.

2.2.5 Rainfall Erosivity

Soil Loss is closely related to rainfall, partly through the detachment of soil particles and formation of surface runoff (Ballabio et al., 2016). In order to initiate this kind of soil erosion processes the RUSLE model sets some criteria to express the erosive potential of precipitation.

Experimental data yielded that rainfall can be considered a single erosive storm event, in case the amount of precipitation exceeds 0.5 inch (12.7mm) in total or 0.25 inch (6.3mm) within 15 minutes (Renard et al., 1997). These are expressed in Factor R. Therefore, R is not only taking total amount of rainfall into consideration, it furthermore includes rainfall intensity, duration and seasonal distribution (Alexandridis et al., 2015).

In RUSLE, rainfall erosivity factor R for an individual storm is defined as

$$R = E * I_{30}$$

(Renard et al., 1997)

Where R has the unit ($MJ{*}mm\ {*}ha^{-1}{*}h^{-1}\ {*}yr^{-1}$),

E is the total storm energy for a given period with the unit $MJ{*}ha^{-1}$, and

I_{30} the maximum 30-min intensity of a storm event in $mm{*}h^{-1}$

Precipitation data for vineyards of Eastern Austria was taken directly from gauging station Neusiedl which was provided by ZAMG (2017) at a temporal resolution of 5 minutes to calculate rainfall erosivity records over a time period of 22 years. Individual storm events matching the above named criteria were manually selected and summed up in order to obtain viable R-values for the RUSLE equations.

Because of the low spatial variability and little distance between both study sites, a uniform R-value was assumed for all field parcels equally.

2.2.6 Prior Land Use Subfactor

The Prior Land Use Subfactor (PLU) in RUSLE expresses “the influence on soil erosion of subsurface residual effects from previous crops and (…) the effect of previous tillage practices on soil consolidation” (Renard et al., 1997:153). The PLU is therefore calculated as the product of soil consolidation and soil biomass effects.

The Prior Land Use effect is given as

$$PLU = C_f \; * C_b * \exp\left[(-c_{ur} * B_{ur}) + (c_{us} * B_{us} / C_f \, c_{uf})\right]$$

(Renard et al., 1997)

“*PLU* ranges from 0 to 1,

C_f is a surface-soil consolidation factor,

C_b represents the relative effectiveness of subsurface residue in consolidation,

B_{ur} is mass density of incorporated surface residue in the upper inch of soil,

C_{uf} represents the impact of soil consolidation on the effectiveness of incorporated residue, and c_{ur} and c_{us} are calibration coefficients indicating the impacts of subsurface residues” (Renard et al., 1997:154).

Interrow sections of vineyards vary greatly in surface management and differ from the RUSLE assumptions made for regular crop land. There is either no intervention at all, or field work operations intend to merely disturb the up to 5 cm deep top layer of soil in order to remove weeds.

Representing a permanent agricultural crop, viticulture systems assumingly experience no alterations in root masses in the row sections of the vineyard. Constant root masses are also assumed for the interrow sections as soils are barely overturned and transported down the slope.

Hence, in order to have realistic outcomes a PLU value of 1 was assigned to all researched vineyard plots, assuming no effects from previous field operations.

2.2.7 Soil Moisture Subfactor

Soil Moisture in general shows a substantial impact on infiltration and runoff capacity of agricultural soils (Renard et al., 1997).

According to (Renard et al., 2011) the soil moisture (SM) takes a value of between 0 and 1.

Prevalent in most instances is a SM factor of 1, reflecting a soil profile where there is “no substantial impact of soil moisture extraction by the vegetation on erosion” (Renard et al., 2011: 164). On the other hand, a SM value of 0 would represent a soil moisture condition near the wilting point.

Although soil moisture decreases substantially during growth period, replenishment of soil moisture in non-irrigated fields under semi-arid climates is substantial and light rainfall and storage of water in soils during winter season is considered sufficient to keep agricultural crops from reaching the wilting point (Renard et al., 1997).

Medrano et al. (2014) estimates a total water consumption of vineyards in a range of 300 to 700mm. Even in non-irrigated field plots such as the vineyards of Eastern Austria, precipitation of around 600 mm is considered high enough to keep moisture levels up, so no adjustments reducing the hypothetical SM factor value of 1 are being assumed for the purpose of this thesis.

2.3 Study Site

The starting point of the practical part of this master thesis was the selection of two study sites with six out of 16 research circles, each of a diameter of 750 metres. Position and dimension of these circles have been predetermined within the ´vinedivers´ programme because of the additional research done on pollinators.

Both study sites are situated near Lake Neusiedl, which is the largest lake in Austria and the second largest steppe lake in Central Europe with a total surface area of 285 km2 (Székely et al., 2009). The region is part of the Small Hungarian Plain and represents the westernmost extension of the Pannonian Basin.

Study Site One in `Leithagebirge´ region with research circles 02, 04 and 05 is located in the immediate vicinity west of Lake Neusiedl near the municipalities of Donnerskirchen and Purbach with an altitude of 129 meters above sea level.

Study Site Two in ´Carnuntum´ region with research circles 09, 10 and 11 is situated 15 km north of Lake Neusiedl near the municipality of Göttlesbrunn-Arbesthal with an altitude of 171 meters above sea level.

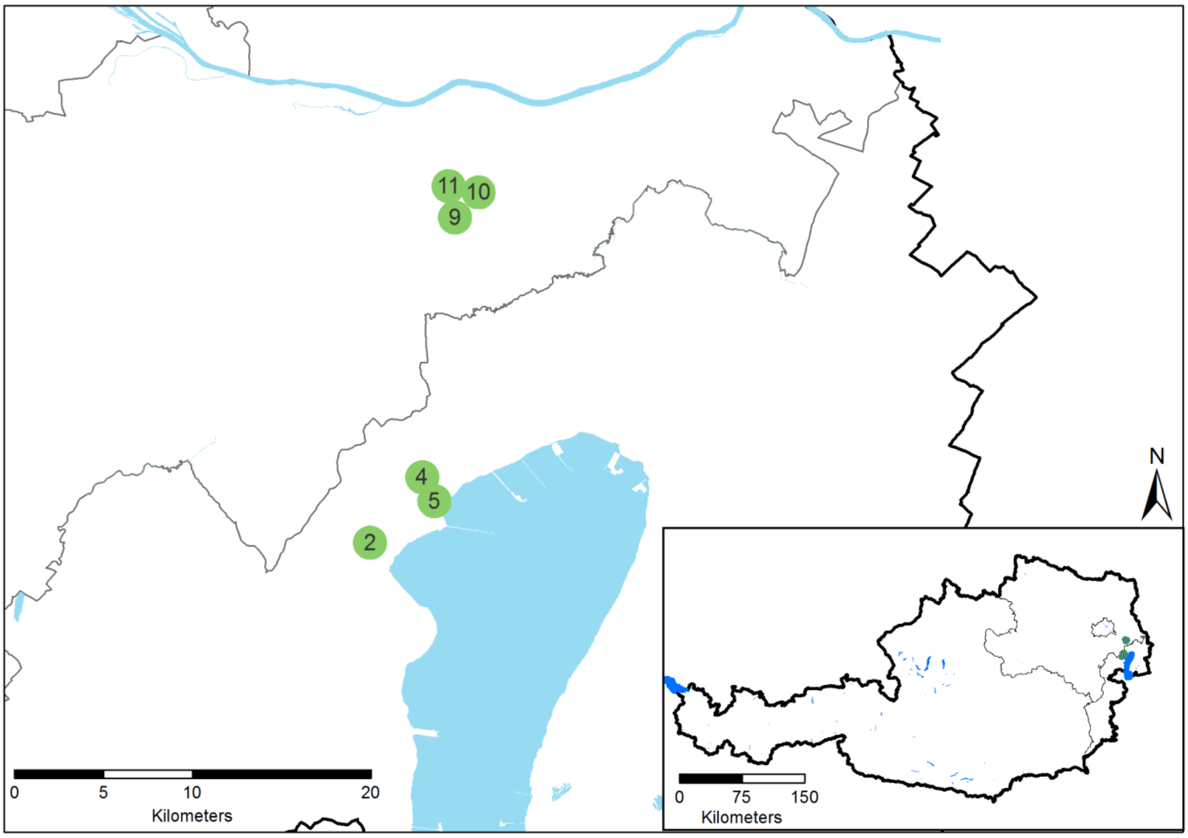


Figure 3. Location of study area

2.3.1 Geology and Pedology

Konkoly-Gyuró et al. (2010) defined several landform types, describing the main geomorphological relief features of the Neusiedlersee region. Specific landform types for both of the study sites range from ´Low terrace´ and ´Elevated terrace´ to ´Hilly area and hill´.

According to soil map of Austria´s Federal Forest Office, the soils of the Göttlesbrunn-Arbesthal study site are classified as deep chernosem. The soils of Donnerskirchen/Purbach study site are more heterogeneous and range from deep chernosem in lowlands to shallow brown calcareous soils in higher elevations, whereas hillside soils of little depths are classified rendzina (https://bfw.ac.at/rz/bfwcms2.web?dok=7066).

2.3.2 Climate

The region around Lake Neusiedl is characterised by a hot and dry Pannonian climate making it the warmest region in Austria with a total average number of 2002 sun hours per year (ZAMG, 2017). The climate of the region is dominated by the large body of water of Lake Neusiedl itself. Unlike typical Central European climates, temperatures in summer are moderate and there are two to three heavy rain periods. Taking into account the low probability of late frosts in spring and a prolonged summer, vegetation period in the region of Lake Neusiedl is extended up to 250 days (ZAMG, 2017). The combined effects create the ideal preconditions for vine cultivation.

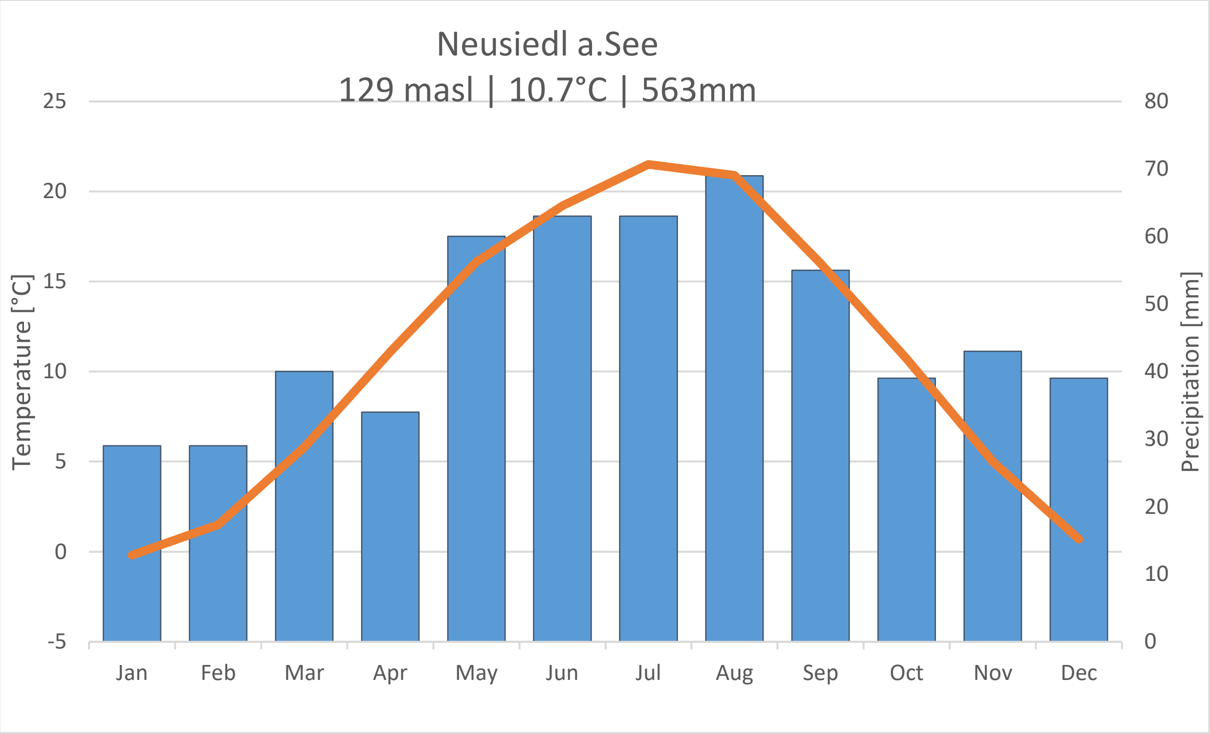


Figure 4. Climate graph Neusiedl/ See; adopted from ZAMG Austria´s Meteorological Institute

The climate diagram is calculated based on Meta data for the years 1981 to 2010 and shows the 30-years monthly mean average temperature and precipitation. 30-years total annual average precipitation and temperature for Neusiedl result 563 millimetres and 10.7°C, respectively (ZAMG, 2017)

Although all research circles lie within an air-line distance of approximately 20 kilometres, Study Sites One and Two are separated by the Leithagebirge (Leitha Mountains) - a 33 km long, <10 km wide, hilly landscape, dividing the Vienna Basin from the Neusiedlersee area (Székely et al., 2009).

Due to the different position in the geophysical landscape, macroclimatic factors influencing study site Two can be assumed slightly more continental than those of study site One. Nevertheless, climate data from gauging station Neusiedl were used for both study sites.

2.3.3 Rainfall Erosivity

Figures on rainfall erosivity was obtained directly from gauging station Neusiedl am See (http://www.zamg.ac.at/cms/de/klima/informationsportal-klimawandel/daten-download/klimamittel). Median results of a 22-years dataset are shown in ***Fehler! Verweisquelle konnte nicht gefunden werden.***.

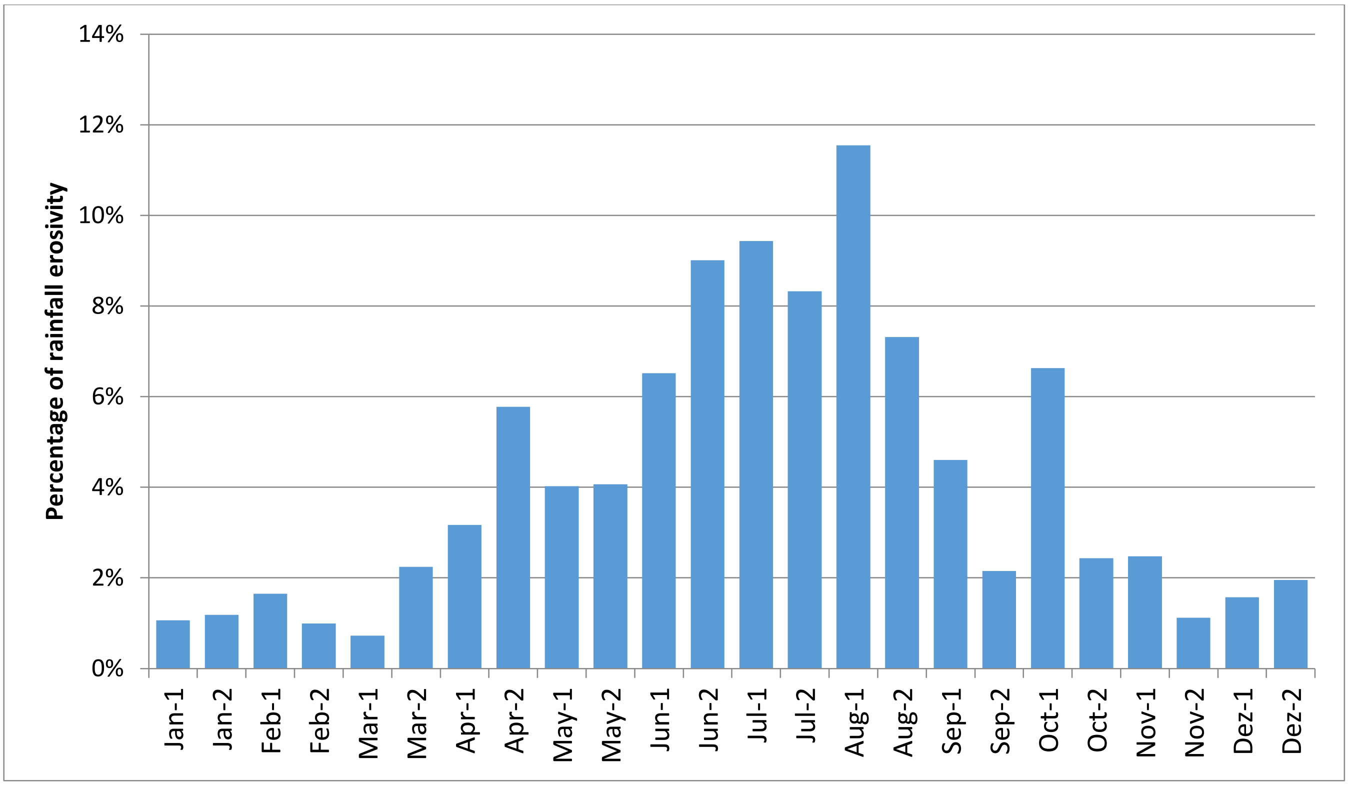


Figure 5. 15-day percentage of rainfall erosivity of station Neusiedl a.See

Over the 22 years of recording, an annual rainfall erosivity mean value of 70.9 MJ*mm *ha^{-1}*h^{-1} *yr^{-1} was calculated. Figures above show the relative share to total erosivity on a 15-day scale.

Rainfall erosivity follows the typical course with low intense rains in winter and highly erosive rain events in summer period.

Winter and spring months November to April account for 24% of total erosivity, whereas the 3 summer month June, July and August represent more than half (52%) of total erosivity. Highest R-factors were observed in August (11.5%).

2.3.4 Local Viticulture and Farm Structure

In 2015, Austria´s area of farmland dedicated to vine totaled 45440 ha, while the average acreage of a vineyard sized 3.2 ha (BMLFUW, 2016).

Land ownership of agricultural land in the region of Lake Neusiedl is highly fractured. Due to complex intergenerational land succession legislations, farmers inherit merely scattered pieces of land. Therefore, the choice of vine varieties and field cultivation vary tremendously, even across neighbouring fields.

A broad spectrum of red vine (`Balufränkisch´, `Zweigelt´) and white vine varieties (´Gewürztraminer´, ´Chardonnay´ ´Sauvignon blanc´) were found (Stas and Kalin, 2008). Referring to the whole scope in heterogeneity of vine species is beyond the limits of this thesis, thus had to be disregarded in the C-Factor calculation process.

The emphasis of research lies on investigating the characteristics of different Land Use Management systems, not on identifying differences in cultivar management.

2.4 Methodological Approach of Field Research

The field study was conducted during 7 months from June until December 2016. Each of the six circles researched on has been visited once a month, except for November because no change in land use management in that period of the year was assumed.

Over that time period, the characteristics of 1215 field plots were examined using data manipulation procedure of a Geographic Information System (ArcMap 10.2) and a cadastral map to mark every parcel investigated. All field plots are located within the research circles indicated on *Figure 3*.

Out of the initial 1215 parcels, a number of 144 (12%) were marked ´not available´. These were either not found, did not match the cadastral map, or else were assigned to a land use management category for which only discontinuous data existed.

Total surface area of the remaining 1071 field plots was 275.8 ha, while median field sizes range at only 0.19 ha.

The chosen type of field research enabled the ability to monitor the site conditions by observing the farmers´ individual decisions for a certain type of land use management. The main elements investigated were

- Parcel-bound land use management form and its continuance over time
- Development of soil cover in each of the examined land use management systems
- Width of the row- and interrow sections of every researched vineyard parcel

In order to investigate above named factors influencing C-factor calculation, a 5-step approach as line of action was adopted

- Partitionimg of vineyard into distinctive management zones
- Determining the management width of row- and interrow sections for every parcel
- On-site manual classification of land use management systems
- On-site acquisition of sample images to determine soil cover
- Off-site image classification to obtain exact figures on the amount and proportion of surface cover

2.4.1 Partitioning of vineyard into functional zones

A virtual split up of the vineyard field area was necessary in order to refer to differences in management and soil cover development, separately. Three operational systems within one vineyard were identified. The divisions are

- The grapevine plant itself, further named ´**row_vine** ´
- The cultivated area below vine plant, further named ´**row_surface**´
- The cultivated area between the rows, further named ´**interrow_surface**´

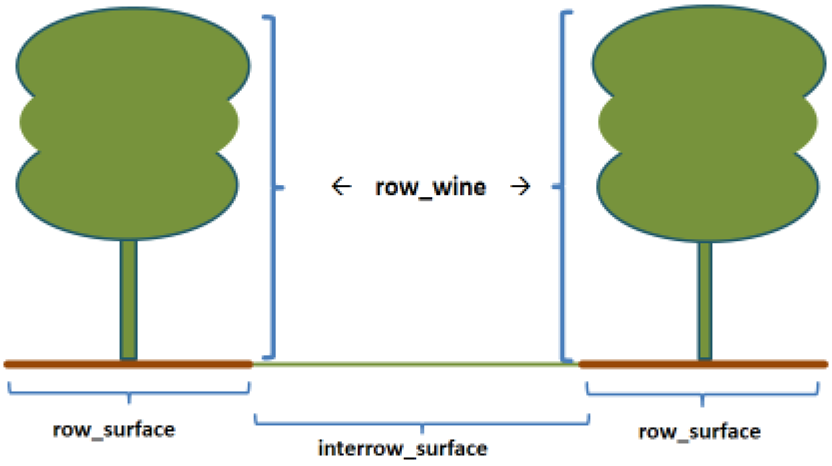


Figure 6. Functional zones in vineyard management

2.4.2 Measuring Management width

As every vineyard is managed independently, the width of row- and interrow sections differ greatly even across neighbouring fields. Precise calculations of field-scale C-factors take the dimension of every single vineyard section into account, therefore the widths of the row and interrow sections had to be measured. Widths were obtained by walking the properties with a simple yard stick. As the number of field parcels to be measured by hand would have exceeded practical feasibility, measurement results partly rely on taking educated guess.

2.4.3 Manual Classification of Land Use Management Categories

In a third step, an on-site manual classification system was developed in order to distinguish different soil cultivating regimes. Therefore, a set of six categories was created to reflect the local conditions of Eastern Austrian viticulture lands. In practice, basically three prevailing land use systems were found.

These are strip vegetation, alternated greening and frequent tilling systems. They all differ in surface cover management of both row_surface and interrow_surface sections.

Conversely, canopy management of the vine plant was assumed to be same for all categories.

The nomination of the different Land Use Management Categories, further named LUMC, was done using a combination of capital letters and indices.

A capital letter was assigned to distinguish the type of ´**interrow_surface**´ cultivation.

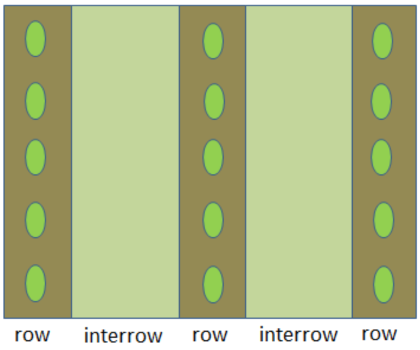
- ´A´ for intercropping systems with a high portion of vegetation cover between the vine rows
- ´C´ for alternated greening systems, with one strip high in vegetation cover and every neighbouring strip tilled bare open
- ´D´ for traditional tilling systems with frequently tilled bare soils

An index was added to express the estimated extent to which the ´**row_surface**´ area is vegetated

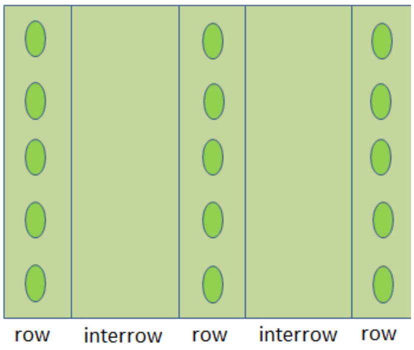
- ´1´ for an estimated soil cover of less than 50%
- ´2´ for an estimated soil cover of more than 50%

Illustration of Land Use Management Categories (LUMC)

Land Use Management Category
A1



Land Use Management Category
A2



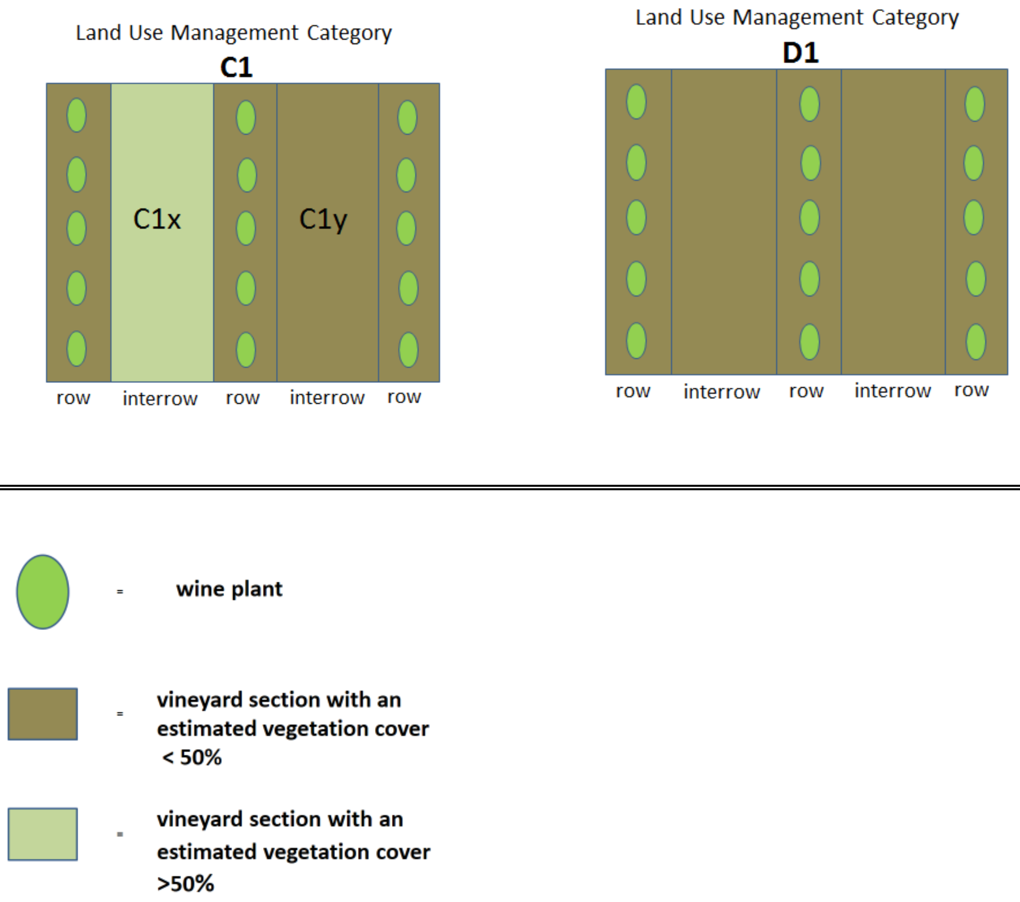


Figure 7. Land Use Management Categories (LUMC)

Note that due to facilitation of the C-factor calculation process, LUMC C1 had to be split up into C1x –the interrow strip with higher ground cover –and C1y, the section with lower ground cover, respectively.

LUMCs C2 and D2 existed at the beginning of the field research, but have been excluded later in the process due to lack of continuous data.

The on-site procedural approach was to assign individual land use management categories to any available field plot in the same way.

The course of action was to spot a single field parcel and locate it on the cadastral map. Subsequently, the portion of soil cover was estimated by taking educated guess. Eventually, above mentioned classification system was applied and listed continuously.

Figure 8. Land use management category A1

Figure 9. Land use management category A2

Figure 10. Land use management category C1

Figure 11. Land use management category D1

2.4.4 Soil Cover Image Classification

As vegetation cover plays a major role to minimise soil loss rates, emphasis was put on obtaining exact figures on the vegetation cover present on the study site. The build-up of a sufficient database is crucial in ensuring that measurements are not biased by extreme events or by human error.

Given the large number of sample images to be classified, it was advisable to adhere to an automated image classification method which is both quick and accurate in measuring the degree of residue and vegetation cover. As common manual image analyses simply rely on taking educated guess or using a predetermined grid system they have shown to be either too subjective or else time consuming, thus they had to be excluded from choice.

The most practicable method for the purpose of this thesis was the `entangled random forest´, a rather new and promising method that combines the usage of camera hardware with a computed, pixel-wise image analysis software (Riegler-Nurscher et al., 2016).

Image Acquisition

Image acquisition was done with Panasonic TZ61, a GPS compatible camera at an 18.1 Megapixel standard. Shots were taken from the top of ladder at an average height of approximately 2.2 meters.

A representative spot was picked and a set of 12 photos was taken to picture every single land use management category in each of the research circles. In order to have consistent data, the procedure was repeated 1-3 times at comparable spots across the cadastral map.

Hence, during the seven month of field research a data base consisting of 3220 images was build-up for further vegetation cover analysis.

Image Processing

The sample images taken during field research had to be processed in order to obtain results on the composition of soil cover and residues. The Software associated to the `entangled random forest´ method was ´SoilCoverClassifier´. It classifies individual pixels into soil, living plants, biofilm, dead residues and stones. *Figure 12* shows an example of a soil cover image of a random interrow section taken on-site (left) and its classification result (right).

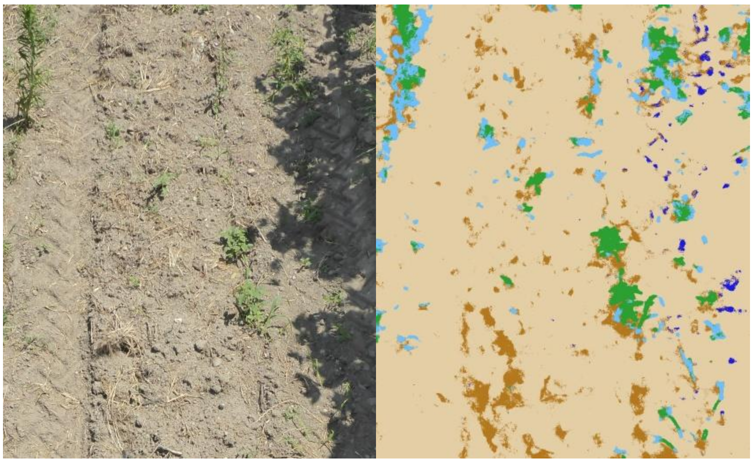


Figure 12. Soil patch image (left); Classification result (right)

3. Results

In the previous chapter it was explained how the field research has been carried out and how the RUSLE soil erosion model has been modified to match local field conditions. The processing of the obtained data resulted in detailed figures on soil cover of the existent land use management.

The following chapter will now present and interpret these findings. Section 3.1 contains information on local land allotment and vine growers´ preferential Land Use Management forms, whereas Section 3.2 shows and interprets the outcome of soil cover image analyses while Section 3.3 eventually presents the results of C-factors calculations.

3.1 Local Design of Land Use Management

3.1.1 Land Allotment

GIS data of the 1071 field plots figured a total surface area of 275.8 ha, while field sizes ranged from only a few hundred square-meters to maximum field sizes of about 2.3 ha. See an overview of land allotment according to study site and research circle in *Table 1*.

Table 1. Land allotment

		Study site 1 – Donnerskirchen/Purbach			Study site 2 – Göttlesbrunn Arbesthal		
Circle number		2	4	5	9	10	11
Number of field parcels		276	128	164	81	301	121
Total surface area in ha		60.0	29.4	29.3	31.4	93.5	31.8
Total surface area in ha		275.8					
Field parcel sizes in ha	25% Quartile	0.12	0.11	0.09	0.19	0.12	0.11
	Median	0.19	0.18	0.14	0.26	0.19	0.21

	75% Quartile	0.26	0.27	0.24	0.49	0.33	0.31

Field sizes in Study site 1 were smaller than in Study site 2. The reason for that may relate to differences in land inheritance practices. In ´Burgenland´ district, farm premises usually are split up equally among the land heirs, leading to a fracturation of land ownership over the generations. As Study site 1 is located in the political district `Burgenland´, land ownership is handled at a much smaller scale than in the political district `Niederösterreich` where study site 2 is located.

3.1.2 Management Width

One main element investigated during field research was measuring the widths of the row- and interrow sections of every single vineyard parcel. Measurement results show that average vineyard management divides the plot into nearly one quarter of row and three quarters of interrow respectively.

Table 2. Parcel management widths

Data is given in cm		Study site 1 – Donnerskirchen/Purbach			Study site 2 – Göttlesbrunn Arbesthal		
Circle number		2	4	5	9	10	11
Interrow section	25% Quartile	210	150	182.5	160	150	170
	Median	225	180	200	190	160	190
	75% Quartile	230	200	225	200	190	200
	SD	39.2	30.3	26.9	27.0	34.6	32.9
Row section	25% Quartile	42	60	60	80	60	60
	Median	50	80	60	100	80	80

	75% Quartile	60	80	80	100	90	100
	SD	24.0	18.7	22.0	17.3	20.0	23.2
Total management width	25% Quartile	256.5	230	250	260	210	250
	Median	275	250	280	270	240	260
	75% Quartile	298.75	260	290	280	270	290

3.1.3 Predominant Land Use Management

A main concern of the field study was to monitor the prevalent vineyard cultivation regimes and observe its development over research time by recording vine farmers´ individual decisions for a certain type of land use management.

In practice, basically four prevailing land use systems were found. These are strip vegetation (A1), fully consolidated (A2), alternated greening (C1) and frequent tilling systems (D1). They all differ in surface cover management of both row_surface and interrow_surface sections.

An overview of land use managements´ median annual share of total surface area according to research circle and study site is given in Table 3 and Table 4 while Figure 13 shows the combined result of both study sites. The dynamics in land use management over time is outlined in *Figure 14*.

Table 3. Land use management categories, median annual share of total surface area according to research circle

		Study site 1 – Donnerskirchen/Purbach			Study site 2 – Göttlesbrunn Arbesthal		
	Circle number	2	4	5	9	10	11
LUMC share in % of total surface area	A1	79.8	67.8	59.6	40.6	38.5	45.5
	A2	13.5	27.4	32.2	34.8	29.2	36.6
	C1	5.6	3.6	3.0	7.0	10.3	5.4
	D1	0.9	4.6	4.6	17.6	21.6	11.4
	Other LUMC	0.2	1.1	0.6	0.1	0.4	1.2

Table 4. Land use management categories, median annual share of total surface area according to study site

		Study site 1 – Donnerskirchen/Purbach	Study site 2 – Göttlesbrunn Arbesthal
LUMC share in % of total surface area	A1	69.1	41.5
	A2	24.4	33.5
	C1	4.1	7.6
	D1	1.9	16.9
	Other LUMC	0.6	0.6

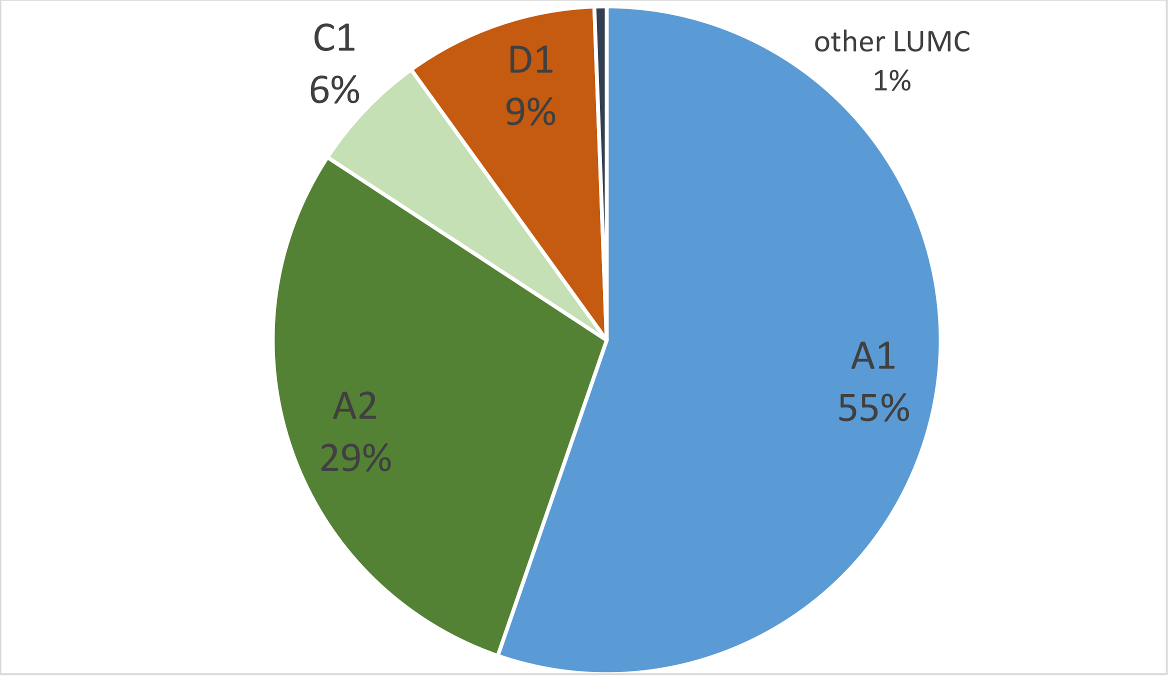


Figure 13. LUMC´s median annual share in % of total surface area covered; both study sites combined

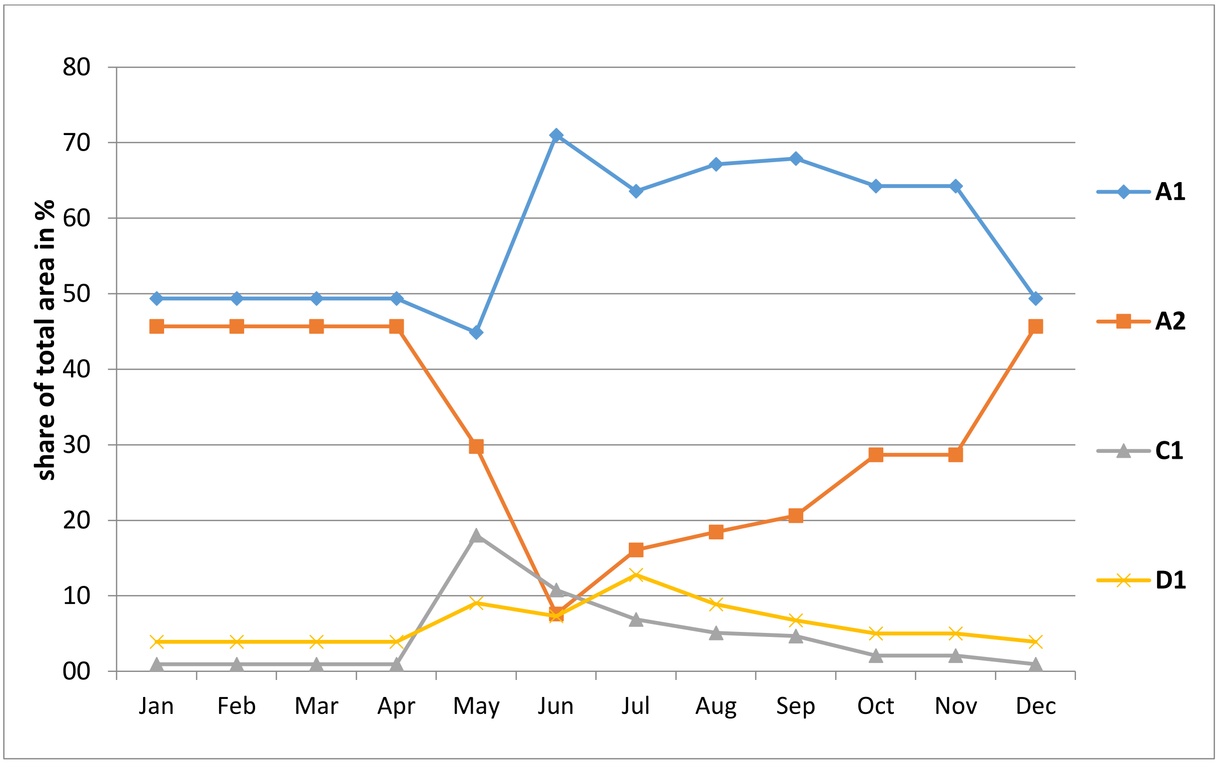


Figure 14. Predominant regional land use management systems over time

The results show that throughout the year of investigation, the major part of total surface area was either managed by strip cultivation with row_surface section tilled (A1) or consisted of fully consolidated row- and interrow_surface sections (A2). Therefore, LUMCs A1 and A2 together dominated in the researched surface area with an annual mean share of 84% (see *Figure 13*).

If results of LUMC´s total share of surface area are compared between the two Study sites, differences in soil management regimes are clearly visible (*Table 4*). Farmers of Study site 2 show a higher tendency towards a D1 open soil management practices at the expense of LUMC A1. Reasons for that behavioural pattern may source in greater concerns of plant-crop competition in water resources and nutrients or simply relate to peer pressures resulting in an alignment of soil management among neighbouring farmers preserving the traditional way of soil cultivation in vineyards. However, an increased use of the grassy LUMC A2 in Study site 2 compared to Study site 1 states that land use management is both debated and divers among vine growers of the same region.

In May, a majority of vine growers break up winter grass cover of row_vine section leading to an increase in share of A1 at the expense of LUMC A2. Open row surfaces of A1 are mostly kept until autumn. Starting in June, the total share of vineyards managed with LUMC A2 constantly increases, probably due to favourable climatic conditions in summer season 2016.

Alternated greening systems (C1) as well as frequent tilling systems with open bare soils (D1) play a minor role in the vineyards of Eastern Austria. Together, they comprise an overall mean share of merely 15% of total surface area.

LUMCs C2 and D2 existed by the beginning of the field research but were excluded later in the calculation process due to lack of continuous data as the year advanced.

If predominant LUMC data is combined with the findings on the average widths of vineyard, a total green covered surface area of 74.5% can be posted. These figures show that the vine farmers of Lake Neusiedl put emphasis on maintaining a high degree of soil cover.

Furthermore, the continuance of vine growers retaining one single land use management system over the year was investigated. Numbers show, that out of the 1071 field plots 289 (27%) were maintained in the same cultivation form, out of which 84% were strip cultivated with A1, 37% with consolidated vegetation cover (A2) and merely 8% of clean-tilled D1. These figures show that fluctuation of land use management is high as in more than two thirds of field plots soil cultivation system has been altered at least once a year. However, among those vine growers who stick to one single form of soil cultivation, LUMC A1 was the most predominant.

A potential reason for the popularity of LUMC A1 lies within its balance between the protection function of a grass covered interrow section and open soils in immediate vicinity of the vine plant avoiding water and nutrient competition.

3.2 Soil Cover Development

The sample images of field research processed by ´SoilCoverClassifier´ Software classified individual pixels into 5 main components: soil, life organic matter, biofilm, dead residues and stones.

Life organic matter and biofilm is defined as any kind of living material, whereas dead residues mostly consist of the remainder of pruning or trimming activities or the remnants of mechanical and chemical weeding operations.

´Ground Cover´ in this respect is synonymous for ´Soil Cover´ and refers to the sum of the cumulated portions of life and dead organic matter, biofilm and stones, hence, to all of which a certain function in protecting bare soil is attributed. The individual proportion itself is variable and its composition does not play a significant role in soil protection.

Table 5 lists the results of the ground cover readings according to LUMC and vineyard section. Ground cover development dynamics will be discussed later within this chapter. However, data was insufficient to be separated according to research circle or study site.

Table 5. Ground cover portions in % over time (coloured), number of measurements (N) and standard deviation (SD)

LUMC		May	June	July	August	September	October	December
A1	row_vine		91	96	96	96	88	
	N		7	9	15	16	15	
	SD		0.19	0.04	0.07	0.06	0.10	
	row_surface	50	41	47	54	45	23	34
	N	12	8	9	15	16	15	17
	SD	0.18	0.16	0.14	0.16	0.23	0.23	0.22
	interrow_surface	95	94	84	89	85	89	66
	N	15	8	9	15	16	15	17
	SD	0.12	0.10	0.19	0.20	0.19	0.20	0.19
A2	row_vine		98	99	98	96	98	
	N		4	8	13	11	13	
	SD		0.02	0.01	0.02	0.07	0.02	

	row_surface	90	90	94	87	89	87	57
	N	15	4	8	13	11	13	16
	SD	0.08	0.11	0.03	0.15	0.20	0.15	0.17
	interrow_surface	98	82	92	81	97	81	79
	N	14	4	8	13	11	13	16
	SD	0.05	0.10	0.07	0.13	0.19	0.13	0.16
C1	row_vine		88	99	97	94	97	
	N		7	7	7	4	7	
	SD		0.08	0.02	0.05	0.02	0.05	
	row_surface	54	41	71	49	49	49	25
	N	11	7	7	7	4	7	2
	SD	0.24	0.17	0.09	0.20	0.14	0.20	0.14
	interrowX_surface	99	95	87	85	86	85	64
	N	13	7	7	7	4	7	2
	SD	0.06	0.13	0.07	0.09	0.07	0.09	0.05
	interrowY_surface	16	6	20	27	34	27	23
	N	11	7	7	7	4	7	2
	SD	0.26	0.10	0.12	0.14	0.17	0.14	0.19
D1	row_vine		87	96	86	88	86	
	N		5	5	5	4	5	
	SD		0.08	0.05	0.06	0.18	0.06	
	row_surface	41	27	44	21	38	21	24
	N	7	5	5	5	4	5	3
	SD	0.22	0.12	0.11	0.10	0.25	0.10	0.10
	interrow_surface	41	8	16	14	15	14	20
	N	7	5	5	5	4	5	3
	SD	0.22	0.06	0.08	0.12	0.15	0.12	0.08

The digit seen in section ´Number of measurements (N)´ combines figures of both Study sites and represents the actual number of spots where a) photos were taken and b) were selected to be eligible for further processing with image analysis software. As it can be seen in *Table 5*, N is relatively numerous for measurements of the predominant LUMCs A1 and A2. Due to little encounter of eligible spots for measurement extraction of LUMCs C1 and D1 in the field, ´N´ gets scarcer as the season advances.

3.2.1 Ground Cover for Row_Vine_Section

As for this thesis ´row_wine´ is defined as the aboveground parts of the grapevine plant itself, ground cover in this respect relates to all wooden and leafy parts of the vine canopy.

Figure 15 shows the output data for row_wine section yielded by image analyses. The course of the graph can be explained with the development of soil cover portions with the factors determining the portion of ground cover, which basically are the grapevine´s annual growth cycle and canopy management operations.

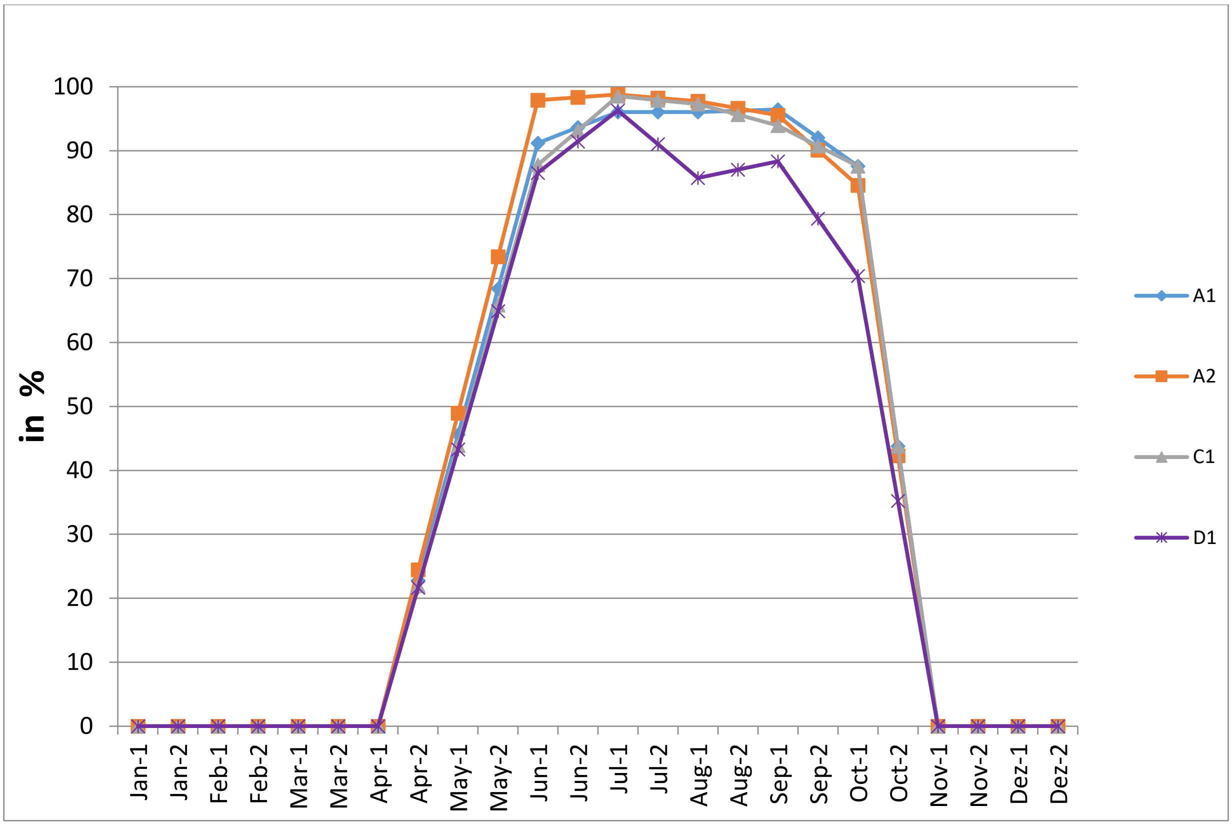


Figure 15. Ground cover development for row_vine section according to LUMC

Grapevine´s annual growth cycle

This graph basically depicts the life of wine plant over the year. Crucial for the initialisation process of developing leaf tissue is an average soil temperature of 8 to 10 degrees Celsius, kept over a period of several weeks (Bauer et al., 2008). Shoot development begins with bud break in spring and ends with leaf fall in autumn.

Hence, according to local climatic conditions, the start of biomass production was set to 15th of April, whereas the beginning of winter dormancy was set to November 1st (Bauer et al., 2008).

Maximum vegetation cover rapidly increases to its maximum extent of nearly 100% by the beginning of June. This is basically valid for all of the different land use management categories, with the exception of a slightly less covered canopy of LUMC D1. Assumingly vine growers that make use of a more stringent Land Use Management Category also show a higher tendency to clip and trim vine canopy more often.

Stabilising at high levels during the summer months, canopy cover gradually decreases until end of October. After grape harvest with beginning of leaf fall, canopy cover plunges to level zero with the vine plant entering the stage of winter dormancy.

Although red and white vine cultivar varieties show slightly deferred vegetation stages and differences in canopy management, no individual growth cycle adjustments were assumed in the process.

Canopy Management Operations in ´row_vine´ Section

Traditionally, canopy management of the vine plant involves pruning and training systems. Pruning is the selective removal of canes, shoots or any wooden part of vine plant considered unnecessary, whereas training systems refer to foliage alterations like hedging and trimming which intend to secure a full exposure of leaves and fruits to light and air (Jackson, 2008). Temperature and light conditions do have direct influence on the yield/quality ratio. By providing an optimal berry microclimate along with a well-balanced leaf area per fruit, yield and quality of wine can be manipulated best (Bauer et al., 2008).

Pruning is normally done in winter time, but partial shoot removal as well as clipping off young and weak shoots are usually timed right after grapevine plant enters early growth stages in late spring and early summer (Jackson, 2008). However, trimming the vine plant´s top as well as cutting off other undesired shoots and excess leaves are activities which are performed several times a year if considered necessary. After flowering around end of June until Mid of July, excess berries are thinned out as a measurement to boost the ripening of the remaining ones (Bauer et al., 2008). Approaching the end of season, an operation usually done is thinning, which comprises the removal of whole parts of flower and fruit clusters. Canopy Management during the growth cycle of grapevine plant ends with the vine plant entering the stage of winter dormancy.

All of the above named field operations contribute to ground cover by altering the portion of living vegetation and deposing dead material in the immediate vicinity of the grapevine plant. To what extent residues remain on site after field work is a decision made by vine growers, as there is machinery to remove the remainder.

3.2.2 Ground Cover for Row_Surface_Section

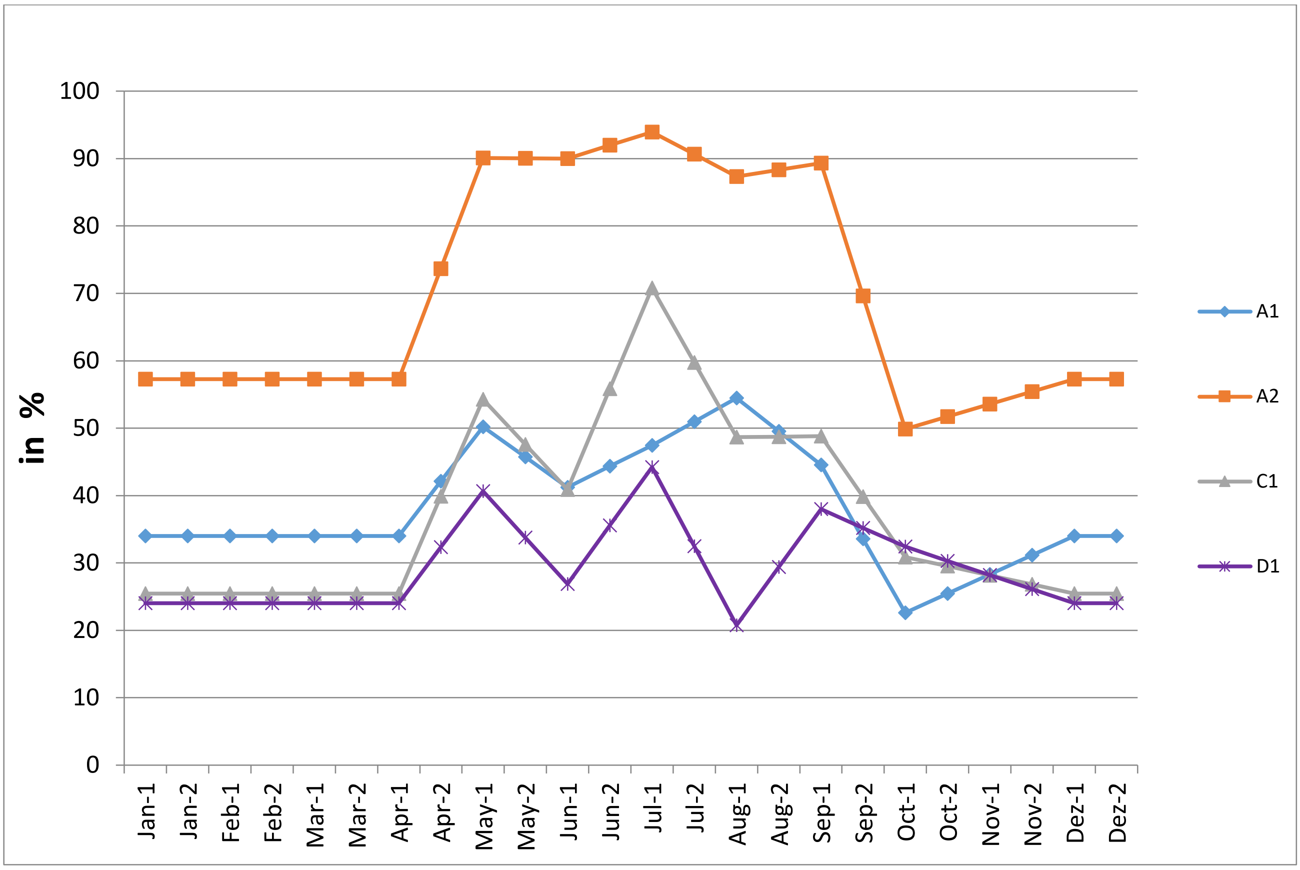


Figure 16. Ground cover development for row_surface according to LUMC

No measurements were taken in the month of January, February, March, April and November. By definition, ground cover values for the winter period December to March are fixed to the ground cover values observed in December, as no vegetation development within that period is assumed.

After completion of winter dormancy in early April, surface vegetation quickly increases. As LUMC A2 is considered a management form of little interference, ground cover values in the row section are kept stable at elevated levels of around 90% until the end of vegetation cycle in early September.

In contrast to that, LUMCs A1, C1 and D1 with open soils in row section of the vineyards are characterised by strong interference. Ground cover development of these LUMCs show a more gradual rise and reach lower top levels than their consolidated counterparts. LUMCs A1, C1 and D1 substantially oscillate during summer, reflecting the different tillage operations carried out in the vicinity of the wine plant. To some extent the remainder of dead organic material from canopy management operations contribute to the portion of surface cover in the row_surface section.

However, LUMC D1 takes ground cover values from 20% to 45% before gradually decreasing to winter levels of about 25%, whereas LUMC C1 pretty much follows the same course, just that ground cover values fluctuate from 24% to as much as 71% before entering winter dormancy at a value of 25%. LUMC A1, however, can take ground cover values from 22% to 55% before stabilising at a surface cover of 34% by the end of the season.

Tillage operations usually reflect the farmer´s adaption to alterations of climatic factors. If precipitation is low, natural greening competes with the vine crop for water and/or nutrients. Since grape production in quantity and quality is largely dependent on water availability, vine growers making use of LUMCs A1, C1, D1 show a quick response to water scarce periods by applying mechanical and chemical weeding (Medrano et al., 2014).

Notably, although occasionally dwelling at low levels, ground cover values of LUMCs A1, C1 and D1 hardly drop below 20%.

In order to assort and combine the findings, aggregated annual ground cover values were calculated. LUMCs A1, C1 and D1 together merge in an average annual ground cover level of 30%, while contrastingly LUMC A2 results in an annual average value of 57%.

On top of that, an average annual value for the combined ground covers of row_surface and row_vine was calculated in order to have a realistic outcome of the actual protective effect of the maximum vegetation cover present in the row division of the vineyard throughout the year. Results yielded values of 65% annual ground cover for LUMC A2, while figures of 42% annual ground cover were found for LUMCs A1, C1, and D1.

3.2.3 Ground Cover for Interrow_Surface_Section

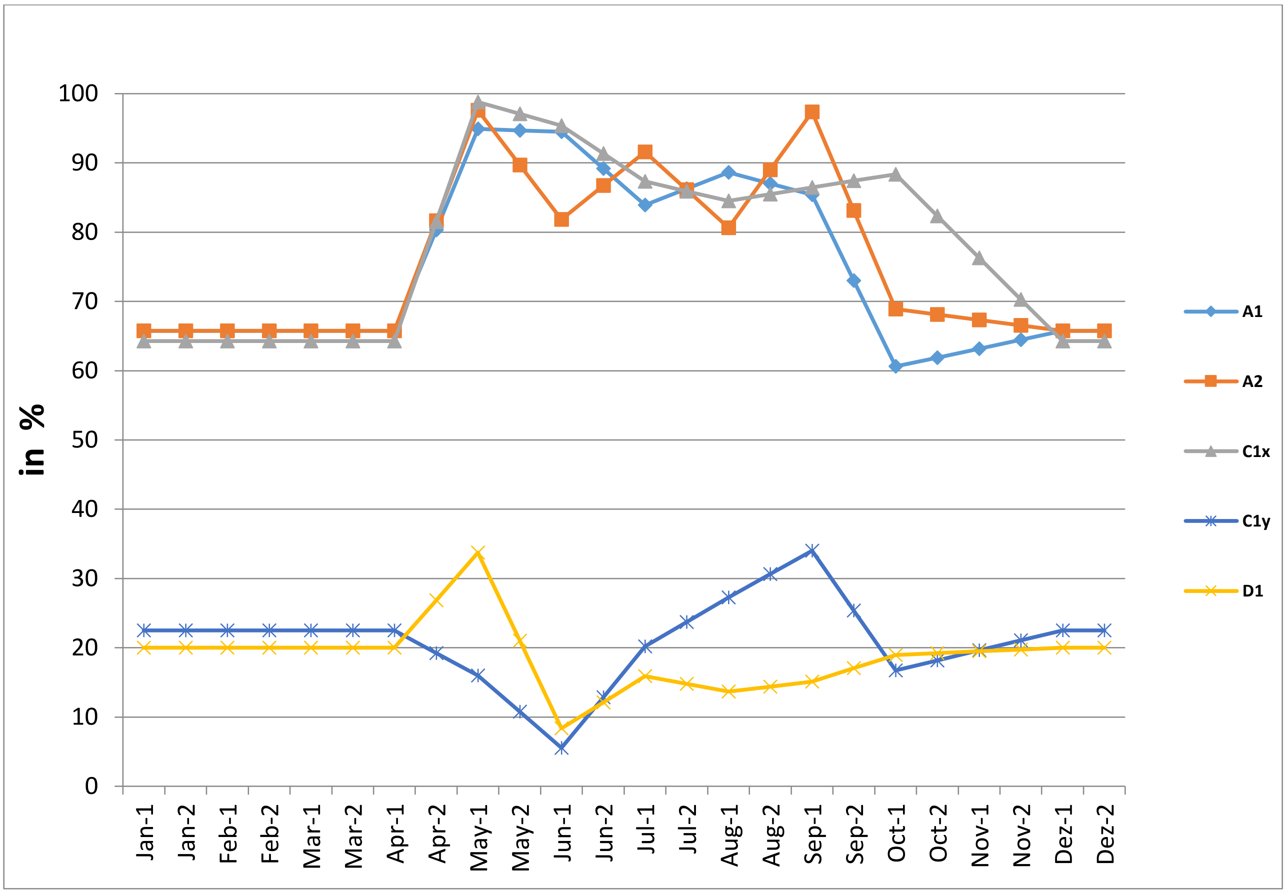


Figure 17. Ground cover development for interrow_surface according to LUMC

No measurements were taken in the month of January, February, March, April and November. By definition, ground cover values for the winter period December to March are fixed to the ground cover values observed in December, as no vegetation development within that period is assumed.

Simultaneously to the vegetation of row_surface section, the grass cover of the interrow section instantly begins development in early April, starting from a relatively high ground cover value of around 65%. Vegetation of the interrow sections of LUMCs A1, A2 and C1x grows fast, reaching consolidation levels of above 90% in May. Due to little interference levels are maintained high until early September before gradually decreasing to a winter cover of around 65%.

Although notably fluctuating, ground cover values of bare tilled interrow sections of LUMCs C1y and D1 are maintained at relatively low degrees. Levels oscillate from 5% to 35%, representing soil cultivation activities in the vegetation period before stabilising at a winter value of around 20%.

The interrow sections of LUMCs A1, A2 and C1x together account for an average annual ground cover of 69%, whereas LUMCs C1y and D1 together show an average annual value of merely 21% ground cover.

3.3 C – Factor Results

Table 6. Overview of C-Factors at field scale according to LUMC

	A1	A2	C1		D1
			C1x	C1y	
Interrow section	0.01	0.01	0.01	0.33	0.38
Row section	0.11	0.03	0.11		0.16
Combined C-Factor	0.04	0.02	0.14		0.27

Table 6 shows an overview of the C-Factors calculated according to LUMC and section within the vineyard, while ***Fehler! Ungültiger Eigenverweis auf Textmarke.*** lists the C-Factor results according to research circle and study site and include a final C-Factor for both of the study sites combined.

As can be seen in this table, C-Factors increase with higher portions of open soil represented by the respective LUMCs. The findings will be discussed individually later within this chapter.

Table 7. Overview of C-Factors according to research circle and study site

	Study site 1 – Donnerskirchen/Purbach			Study site 2 – Göttlesbrunn Arbesthal		
Circle number	2	4	5	9	10	11
C-Factor of circle	0.08	0.07	0.1	0.05	0.04	0.05

C-Factor of study site	0.08	0.05
Overall C-Factor of both study sites combined: **0.06**		

3.3.1 C-Factors of Land Use Management Categories

Individual C-Factors according to LUMC were calculated combining respective row and interrow section of the vineyard.

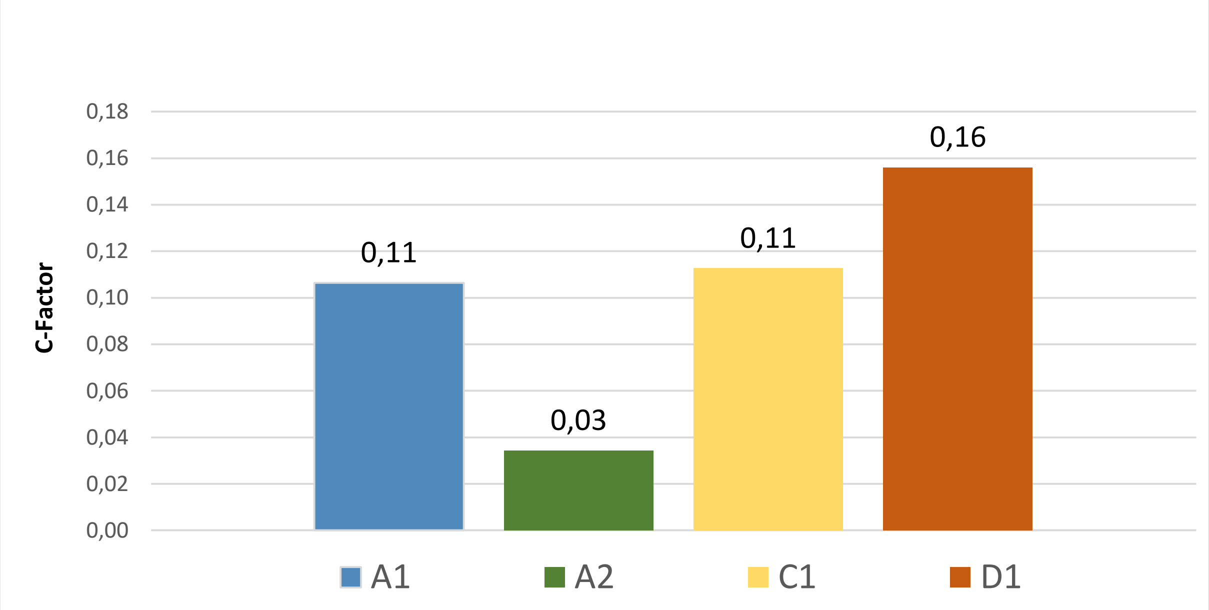


Figure 18. Individual C-Factors for row_surface section according to LUMC

In row section, highest C-factors were found for the traditional tillage systems D1 (0.16), followed by LUMC C1 (0.11) and A1 (0.11). Lowest C-Factor was found for LUMC A2 (0.03). LUMC A2 therefore provides the highest grade of protection from soil erosion, reducing soil erosion by 97% in comparison to the bare tilled unit plot as cited in Renard (1997). Both of the row sections of LUMCs C1 and A1 account for a reduction of 89% in soil erosion risk, while the lowest protection rate can be assigned to LUMC D1.

For the interrow_surface section the following results were calculated.

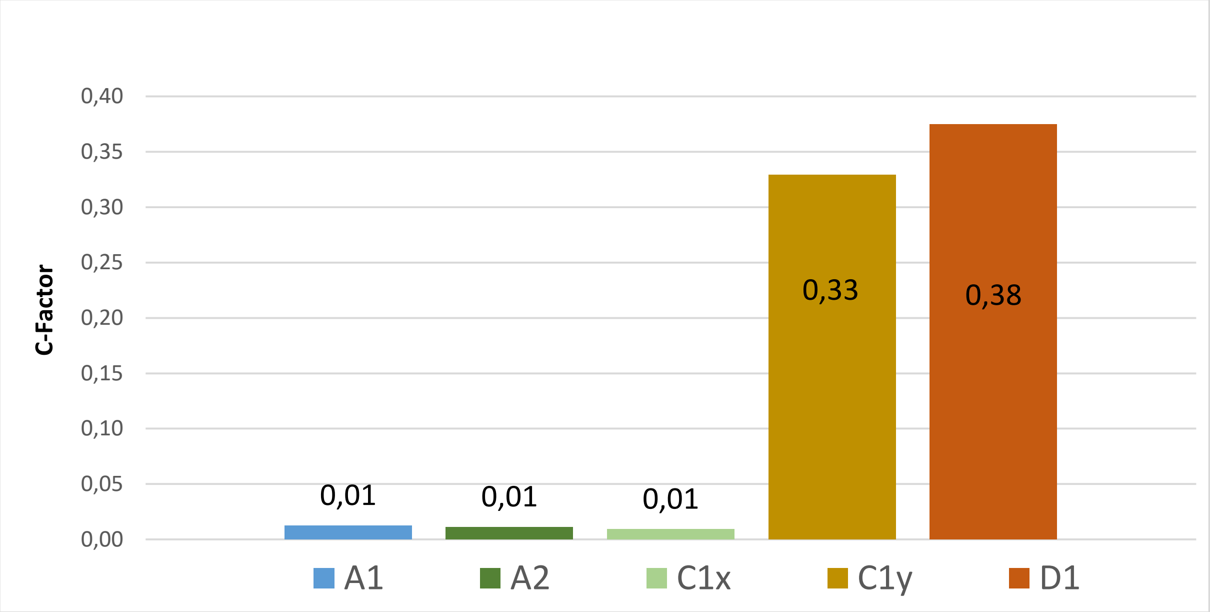


Figure 19. Individual C-Factors for interrow_surface section according to LUMC

In interrow section, highest C-factors were found for the traditional tillage system D1 (0.38) and the bare soil part of LUMC C1y (0.33), whereas LUMCs A1, A2 and the grass covered part of LUMC C1x equally result in a C-Factor of 0.01. Highest protection from soil erosion by water can therefore be assigned to LUMCs A1, A2 and C1x, reducing soil erosion risk by a notable 99%. The soils of LUMCs D1 and C1y offer less but still significant protection, reducing soil erosion by 67% (C1y) and 62% (D1), respectively.

3.3.2 Combined C-Factors

Combined C-Factors applied to local field conditions merge the findings of the individually assigned C-Factors with the measured row/interrow sizes.

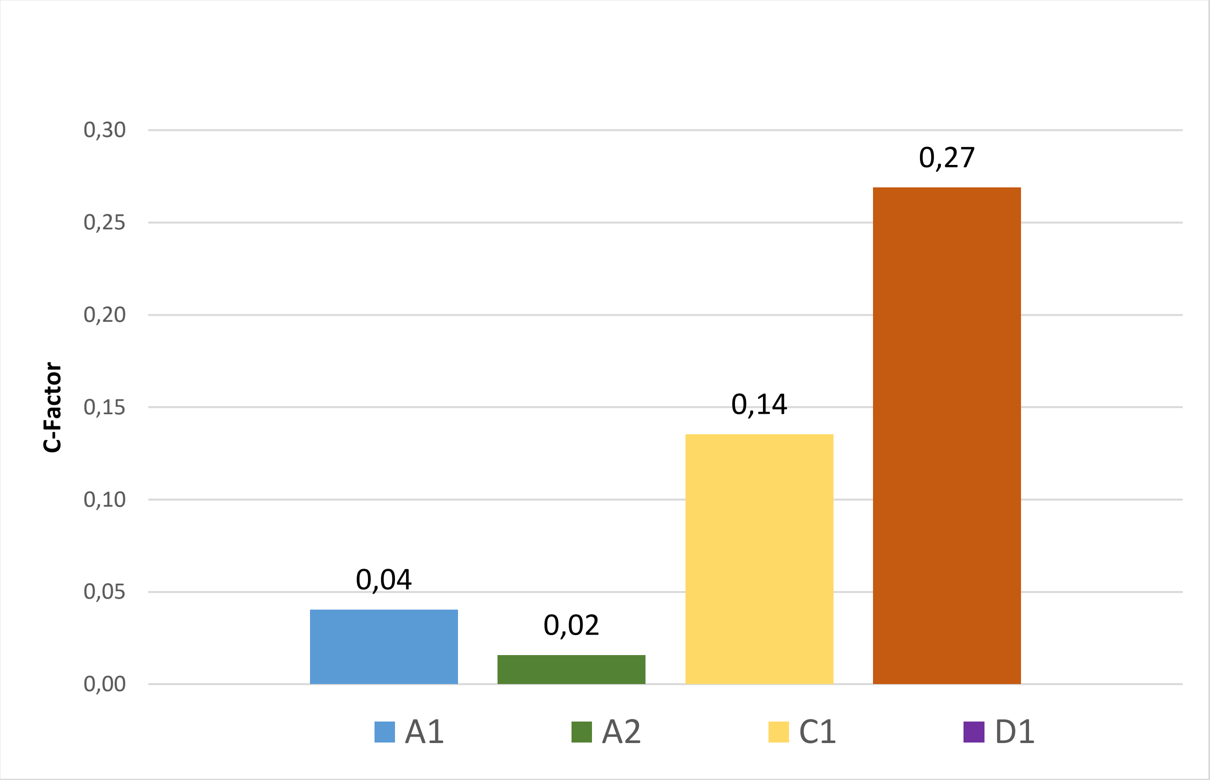


Figure 20. Combined C-Factors according to LUMC

Due to a consolidated herbaceous protective cover throughout the vegetation period, lowest C-Factors were calculated for LUMC A2 (0.02), offering the best management option in terms of protecting soils from erosion by water. In comparison to the standard unit plot as cited in Renard (1997), soil loss is reduced by 98%.

The most frequent LUMC in use was strip cultivation system A1 with tilled row_surface section. Results show a relatively low C-value of 0.04 and a corresponding high soil loss reduction of 96%.

Due to lack of conservation practices and a predominance of low surface cover, bare soils of the traditional tillage systems are most exposed to erosive events during summer. Hence, highest C-factors were calculated for LUMC D1 (0.27), with an respective value of 73% reduction of soil loss compared to the bare tilled unit plot as cited in Renard (1997). However, LUMC D1 accounts for a 13-fold soil erosion risk compared to LUMC A2.

The alternated greening management system of LUMC C1 (0.14), however, shows both an intermediate C-value of 0.14 and a corresponding reduction in soil loss of 86% compared to standard unit plot.

The following *Figure 21* shows the C-Factor gain of every LUMC on a 15-day scale.

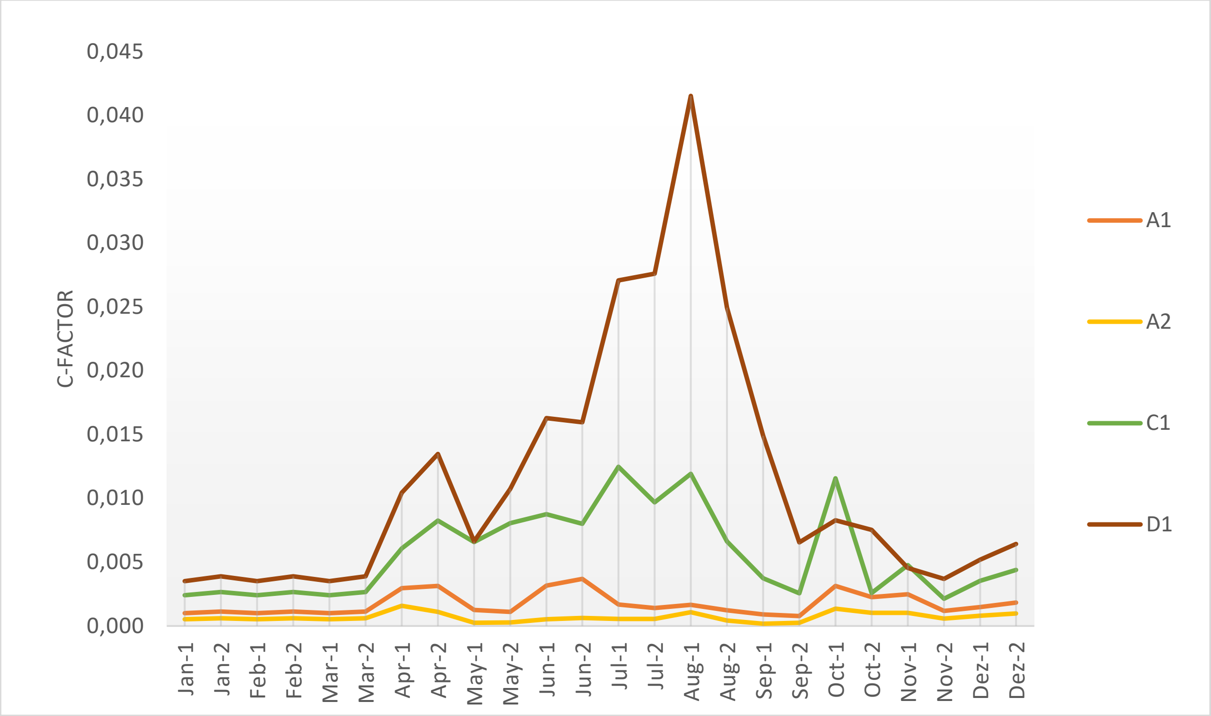


Figure 21. 15-day gain of C-Factor over time according to LUMC

As every LUMC´s composition of ground cover, management widths and soil roughness is different, so are the specific gains in C-Factor, summing up to the final C-Factor values figured in *Table 6*.

Starting on March, LUMC D1 shows highest gains in C-Factor until early August. This sharp increase might be due to the impact of high rainfall erosivities on the bare soils of LUMC D1. As rainfall erosivity values steadily drop by the end of August, C-Factor gains decrease almost parallel to the course of rainfall erosivity. The case for the well protected LUMCs A1 and A2 is much different from that. C-Factor gains remain at low levels throughout the year, reflecting the buffering potential of covered soil against erosive events. LUMC C1 again shows an intermediate development. The unusual spikes (e.g. C1 in October-1 and November-1) might be explained by the low number and unusualness of measurements of C1 by that time.

3.3.3 Annual C-Factors at Field-Scale

As it has been shown before, an average field size of just 0.19 ha reveals that ownership in the investigated agricultural land in the Neusiedlersee region is highly fractured and fields are handled at small-scale. Therefore field operation choices and corresponding soil cover rates vary tremendously on a regional scale, as well as individual choices of the land use management form to be implemented as the season advances.

Study site 1 showed a 1.6-fold higher C-Factor than study site 2 which may be explained by the higher portion of open soil LUMCs C1 and D1, significantly increasing soil erosion risk due to the lack of surface cover.

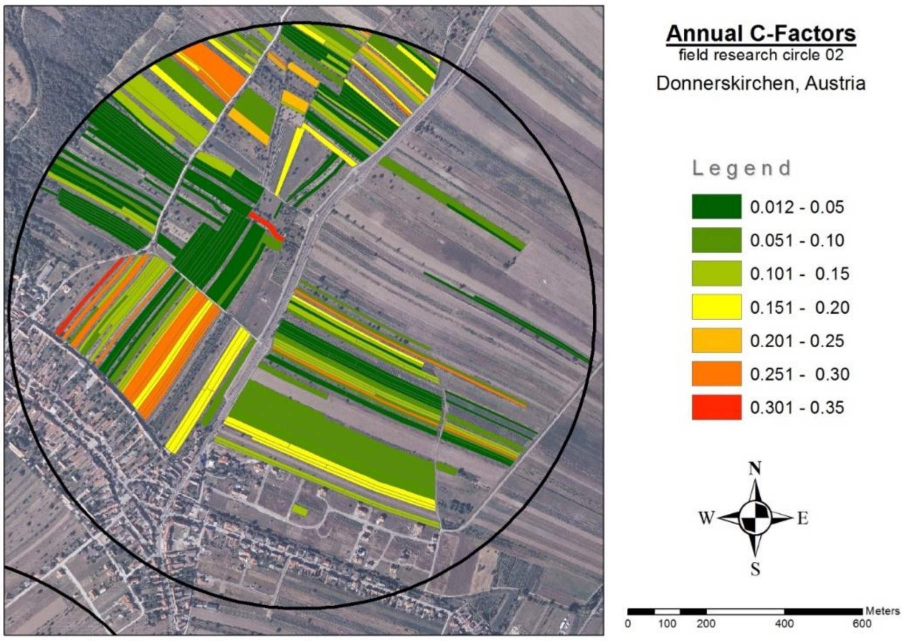


Figure 22. Annual C-Factors of research circle 02

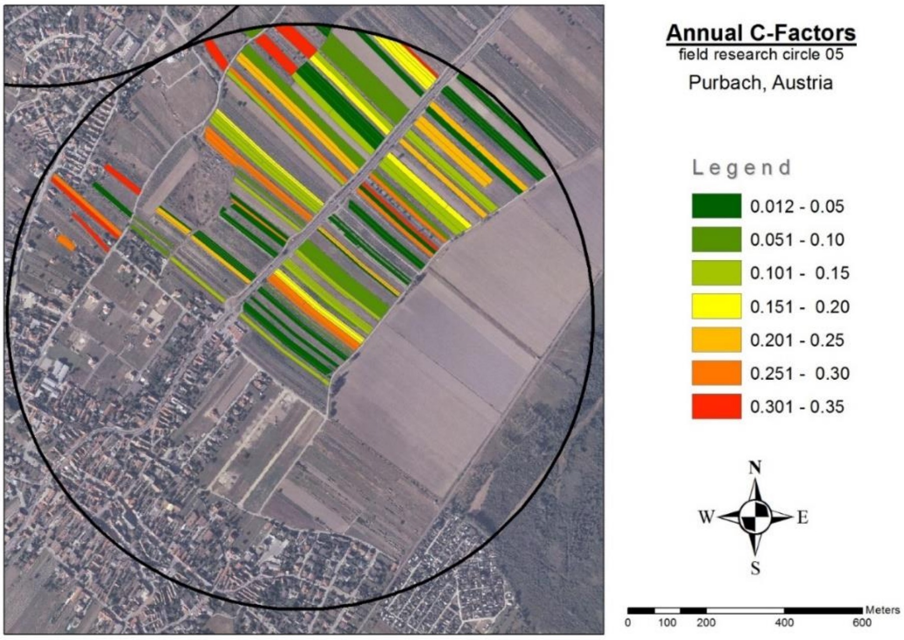


Figure 23. Annual C-Factors of research circle 05

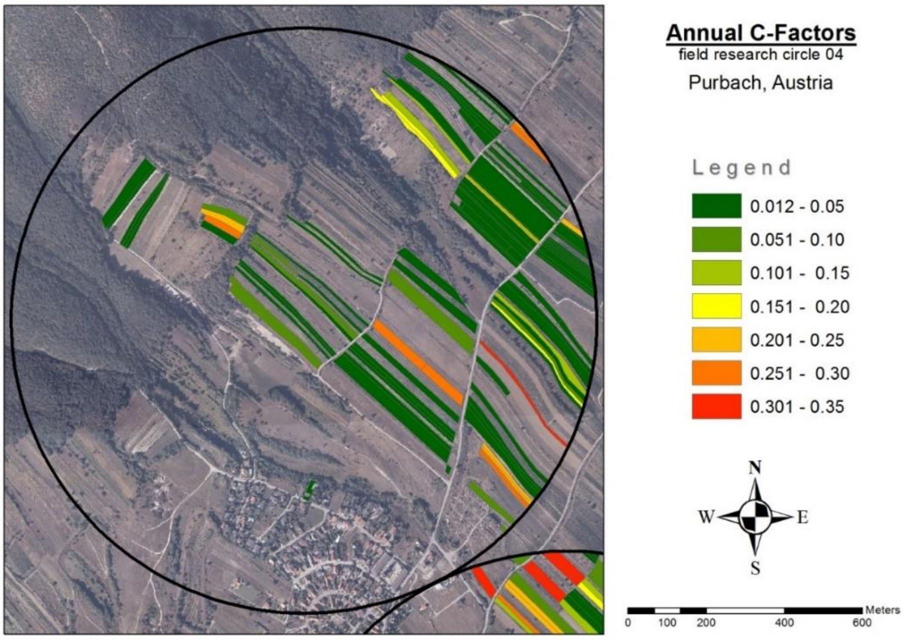


Figure 24. Annual C-Factors of research circle 04

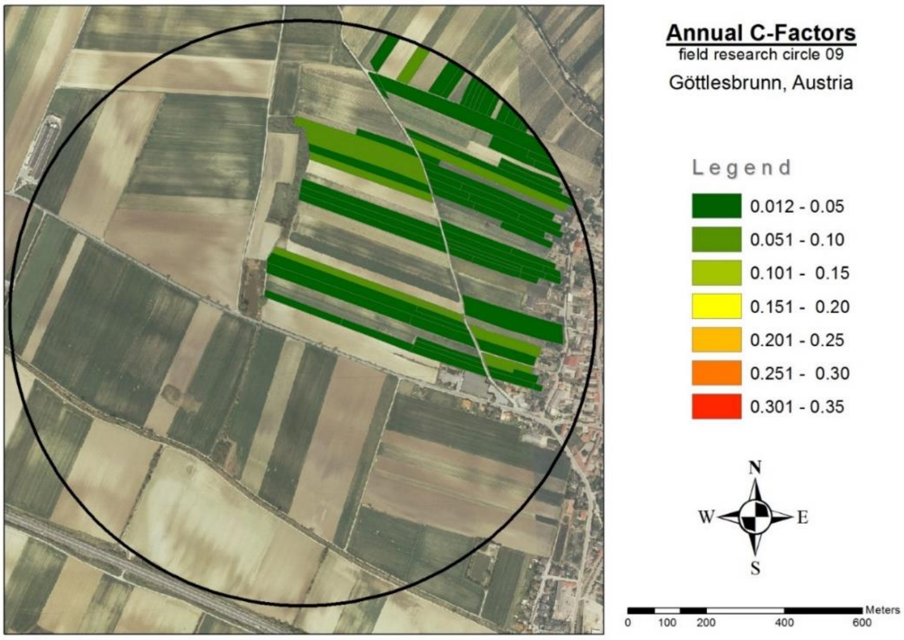


Figure 25. Annual C-Factors of research circle 09

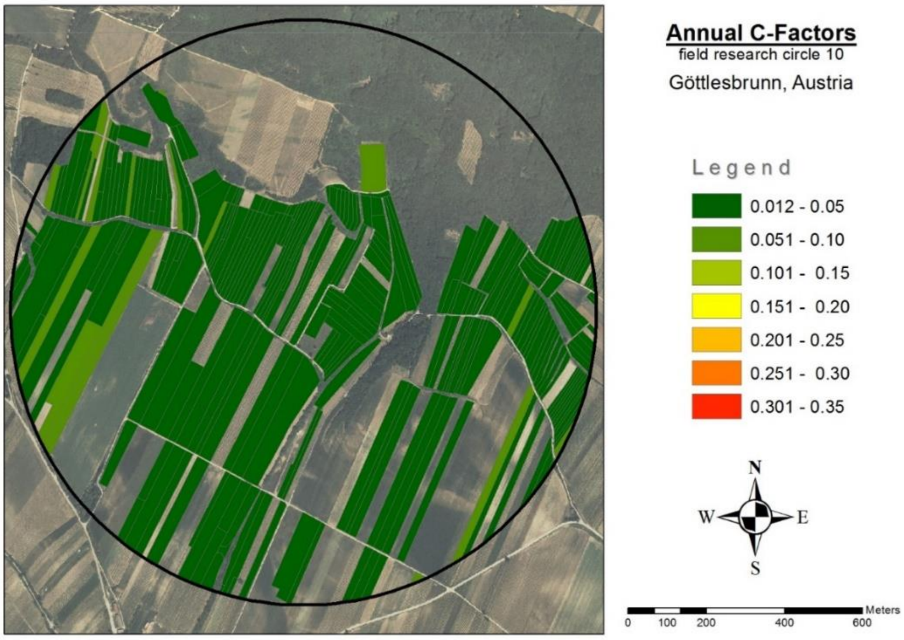


Figure 26. Annual C-Factors of research circle 10

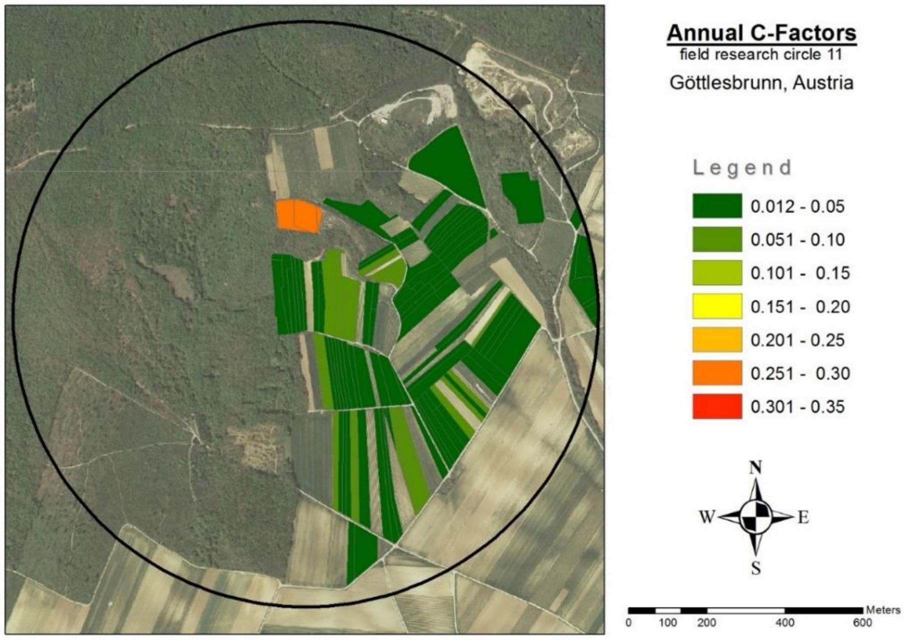


Figure 27. Annual C-Factors of research circle 11

Eventually, an overall C-Factor of 0.06 was calculated for all 1071 field plots of the study site.

4. **Discussion**

Sources of Error

During the experimental part of the research, several difficulties and potential sources of errors were encountered. A potential source of error involves the material in use. Cadastre plan was not up to date and difficult to read on the field, causing occasional misinterpretation of LUMC observations.

Likewise, accuracy of image analysis software occasionally was affected by unsuitable light conditions during image collection. Due to the large size of dataset, ground cover image analysis results could only be reviewed randomly. As a consequence, distorted results of 15 images had to be replaced by manual assessment.

Another potential source of error concerns the soil erosion model itself. The exactness of the computed C-Factor values strongly relies on the precision of the model input parameters. Little information is available on determining b-values of the surface cover subfactor ´SC´ as well as on moisture subfactor ´SM´. Subfactors might not have been properly modelled, thus potentially leading to slightly disfigured C-Factor results. However, as part of the necessity to simplify the erosion model, emphasis must be put on processes which are assumed to have the greatest influence on the output, while those with little effect are being ignored (Morgan, 2005).

However, the significance of stand-alone C-Factors as an informative value can be criticized, as figures on soil quality and slope steepness are excluded from the calculation and soil loss ratios are merely given in relation to the standard unit plot as cited in Renard (1997).

Despite these facts, the model represents a useful tool for assessing the impact of different management scenarios on soil loss. Nevertheless, the accuracy of the RUSLE model can be further increased, if data was available at finer scales and confirmed by long term research (Morgan, 2005)

Comparison to C-Factors found by other authors

So far, only few studies have been carried out on determining C-Factors of vineyards. For instance, Novara et al. (2011) quantified soil erosion in Sicilian vineyards in a 9-years study, relating a reduction in soil loss by 39.65 to 69.8 per cent to the effects of different cover crops. Figures translated into respective C-factor values would range from 0.3 to 0.6.

By using a WATEM/SEDEM soil erosion model, Jordan et al. (2005) found a grid cell based C-Factor of 0.5 for the vineyards of Balaton region, which is located within a 140 kilometres air-line distance southeast of Lake Neusiedl.

A study on soil erosion risk in the vineyards of southern Germany carried out by Auerswald and Schwab (1999). Due to deficits in soil protection measures it revealed a relatively high cover management factor of 0.59 for bare, frequently disturbed soils. However, by implementing different mulching systems a significant reduction capacity was assessed, potentially decreasing C-Factors of the mentioned study site. Highest reduction was assigned to permanent grass cover (0.03) while bark mulch (0.06) and straw mulch (0.12) resulted in slightly increased C-Factors. An elevated C-Factor of 0.46 was calculated for autumn/winter part-time greening management system,

In comparison to the findings of the studies on soil erosion in vineyards mentioned above, the present study yielded significantly lower C-factors. On the one hand, the reasons for that may relate to different configurations of the studies. For example, Auerswald and Schwab (1999) use a distinct calculation procedure with value-adopted variables.

In order to be able to compare several studies, the use of different types of input data has to be aligned. For instance, the findings on C-Factors of the studies carried out by Panagos et al. (2015b) or Vatandaşlar and Yavuz (2017) rely on biophysical input data derived from remote sensing techniques in combination with statistical data on agricultural crops and management practices. Hence, methodology and scale of these studies are in contrast to the field-scale procedure of this thesis, yet using the same soil erosion model. Therefore, as the simplistic RUSLE framework barely limits the temporal and spatial study range, researchers may have different focuses which hampers the comparability of studies.

On the other hand, the low C-Factor outcomes of the present study expressing a low erosion risk, however, may be frankly due to a moderate rainfall erosivity in conjunction with good agricultural farming practices indicated by the perpetuation of a generally high soil cover portion throughout the year. Hence, vine growers of Eastern Austria show a high concern for soil erosion issues and actively control erosion through the application of soil conserving practices. Figures showed that 91% of all interrow sections and nearly one third of all row sections are maintained with a consolidated soil cover over the year. Compared to dry farmed Spanish vineyards of which an estimated 75% use frequent tillage systems, C-factor results of local climates can thus be expected considerably lower than their Mediterranean counterparts (Ruiz-Colmenero et al., 2011)

5. **Conclusion**

The objective of the present study was to provide scientific contribution to the current knowledge about impacts of soil cover management in the semi-arid vineyard environments of Eastern Austria.

Four different vineyard management approaches were tested for their effectiveness to prevent soil erosion by water. The foundation of the field study was a detailed assessment of the development of soil cover within each of the distinctive land use management systems. With the help of GIS and the RUSLE soil erosion model, the acquired dataset was used to predict a specific soil loss parameter for every single vineyard of the study area over the time period of one year.

This study was able to reflect the significance of the protective effects of herbaceous cover by demonstrating that the maintenance of a vegetative cover in vineyards can vastly reduce soil losses from erosion. Results revealed that traditional tillage systems with practically bare soils showed a 14-fold increased erosion risk in comparison to the best rated management option with nearly consolidated grass covers. In terms of soil erosion risk, land use management systems relying on frequent tillage can therefore be considered as a worst case management scenario.

The major part of vine growers in Lake Neusiedl region switched between the different soil cover management systems, effectually manipulating soil cover dynamics. The predominant soil management system in the vineyards of Eastern Austria, however, was strip cultivation.

Strip cultivation systems adopt a convenient 2-fold soil loss compared to conservational management, whereas an intermediate C-Factor was calculated for alternated greening soil management. With regard to total surface area covered, alternated greening systems were of minor importance in practice.

Notably, nearly 75% of total surface area of the researched field parcels embrace high portions of soil cover summing an annual average of 68%. The remaining 25% of surface area still hold a considerable annual average soil cover portion of 26%.

The high share of conservational managed vineyard allotments of Eastern Austria explain the comparably low overall C-Factor of 0.06, which has been calculated for the entire study site. These figures, however, may distract from the fact, that punctual soil erosion occurs especially at the open soils in immediate vicinity of the vine plant, as nearly 70% of vineyards keep an open row division. However, soil erosion mitigation should be among the primary concerns of vine growers. Soil erosion risk factors such as rainfall erosivity, soil erodibility, slope length and steepness depend on natural endowments and can hardly be modified. On the contrary, a soil erosion risk factor that can be easily altered by policy makers and farmers at reasonable costs is the expansion of on-site surface cover. A direct correlation between soil erosion parameters and soil cover portions have been confirmed in this thesis.

The positive effect of cover crops especially in case of highly erosive events during summer has been proven (Lieskovský and Kenderessy, 2014). Nevertheless, farmers have to deal with climatic variations and resource offsets in practice. Due to an observed reduction in vine water potential as a consequence of water consumption by the cover crop, some vine growers habitually respond with tillage (Mallory et al., 2011).

However, tillage operations in amount and intensity could be reduced, if knowledge on cover crop management for water limited environments is expanded.

Notwithstanding, there is a need to reduce the number of estates with bare soils in full exposure to the elements. Erosion of soil as a non-renewable resource is a huge problem on a global scale and cannot be solved through single field operations alone. Broader erosion control measures such as terracing or the use of agro-forestry systems may need to be considered a viable option.

The aim of erosion control techniques in farming should break the cycle of the processes that lead to soil loss (Ruiz-Colmenero et al., 2011).

The implementation of soil conservational measures will not only reduce soil erosion by water, it also improves soil quality and fertility by preventing the loss of nutrients while preserving soil organic carbon along with priceless beneficial effects to biodiversity in vineyard ecosystems (Panagos et al., 2015a).

The improvements of the above mentioned soil conditions would ultimately benefit the vines themselves (Ruiz-Colmenero et al., 2013).

Hypothesis 1: Spatial heterogeneity of soil cover management

Variability in soil management of the vineyards of Eastern Austria expressed by soil cover is very high at local scale.

Hypothesis 1 can be confirmed, since land ownership in the region of Lake Neusiedl is highly fractured. Fields are handled at small scale. The average size of a vine parcel merely figures

0.19 ha, therefore, land use management and corresponding soil cover portions vary greatly, even among neighbouring fields.

Hypothesis 2: Heterogeneity of soil cover management over time

Soil management of the vineyards of Eastern Austria expressed by soil cover highly varies between different observation periods in a year.

Hypothesis 2 can be confirmed. Due to field management operations in response to climatic factors, soil cover rates notably fluctuate throughout the entire vegetation period. However, soil tillage in immediate vicinity of the vine plant is carried out in higher frequencies than operations in interrow divisions of the vineyard.

Hypothesis 3: Heterogeneity of C-factors

Based on hypotheses 1 and 2, variability in soil management of the vineyards of Eastern Austria expressed by soil cover leads to a high heterogeneity of those factors that influence soil erosion through management

Hypothesis 3 can be confirmed. As interpreted in the course of this thesis, the factors that mainly account for soil erosion through management basically are soil roughness and degree of soil cover. Great alternations of soil cover rates were observed, even within the same land use management categories

Hypothesis 4: Impact of cover management on C-factors

An increased soil cover shows reduced C-factors while low soil coverage yield high C-factor values.

Hypothesis 4 can be confirmed. Results indicated that a combination of reduced surface disturbance and increased vegetation cover lead to greater soil loss rates on an annual term. The C-Factor and associated soil loss rates can therefore be vastly influenced by management practices.

6. References

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7. Appendix

7.1 Figures

7.2 Tables

8. Affirmation

I certify, that the master thesis was written by me, not using sources and tools other than quoted and without use of any other illegitimate support.

Furthermore, I confirm that I have not submitted this master thesis either nationally or internationally in any form.

Vienna, 06.10.2017,

Tobias Thielke