Risk of Soil Erosion in the Context of Dynamic Changes in Land Use and Soil Protection Policies

MASTER THESIS

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ABSTRACT

Water-induced soil erosion has been identified as the major soil threat in the municipality of Michelhausen (Lower Austria) because of its negative impact on environment and agricultural yields. The erosion risk is interrelated with topographic and soil-physical preconditions as well as with farming practices, land use and the cropping systems and crop rotation.

Hence, the objective of this study was to (i) identify the effects of spatial variability, in particular the influence of topographic and soil-physical properties on the site-specific erosion risk, and (ii) to evaluate the relevant cropping practices in the municipality and their effect on soil erosion. The state of soil condition and soil degradation was connected with the existing soil conservation programmes and their state of implementation.

Current effects of spatial distribution were calculated in ArcGIS 9. The assessment of the crop-specific soil erosion risk and the influence of the applied soil conservation measures were carried out by the application of a fuzzy-logic approach. Qualitative methods from social sciences were used to identify the state of agricultural practices related to soil conservation policies. Effects of pre-defined land use scenarios on the soil vulnerability were assessed which allows defining the influence of management options for the future. The results were discussed in the context of foreseeable and expected developments and changes in soil conservation policies and land use.

The results show that the current soil conservation programmes do not adequately target the soil problems in Michelhausen, because the measures are neither accepted by farmers nor binding enough to have the necessary effect on the applied farming practices. The geological and soil-physical preconditions implicate a high site-specific erosion risk. However the modelling results show that differences in farming practices and cropping systems may cause differences in the potential risk for run-off. The possible benefits arising by changing the management options (e.g. tillage, application of cover crops) appear to be more promising than by changing the crop share.

ABSTRACT

Aufgrund der negativen Auswirkungen auf Umweltgüter und landwirtschaftliche Erträge stellt Wassererosion die größte Bodengefährdung in der Gemeinde Michelhausen (Niederösterreich) dar. Das vorhandene Erosionsrisiko wird durch die topographischen und bodenphysikalischen Gegebenheiten ebenso bedingt, wie durch die Landnutzung und die damit assoziierten Anbauverfahren und Fruchtartenverteilungen. Daher widmete sich die folgende Arbeit (i) der Ermittlung der räumlichen Verteilung des standortspezifischen Erosionsrisikos und (ii) der Untersuchung der Hauptanbauverfahren in der Gemeinde sowie der Bewertung der Fruchtarten hinsichtlich ihrer Schutzwirkung. Der Umsetzungsgrad der bestehenden Bodenschutzprogramme und -gesetze wurde mithilfe von Experteninterviews untersucht und mit den bestehenden Bodendegradationen in Verbindung gebracht.

Für die Berechung der räumlichen Verteilung des Erosionsrisikos wurde das Geoinformationssystem ArcGIS 9 verwendet. Die Bewertung des anbauspezifischen Erosionsrisikos wurde mit Hilfe eines auf Fuzzy-Logic basierten Ansatzes durchgeführt. Qualitative Methoden der Sozialforschung dienten der Identifikation des Umsetzungsgrades der vorhandenen Bodenschutzprogramme. Um zukünftige Entwicklungen abschätzen zu können, wurden Szenarien entwickelt, die im Zusammenhang mit relevanter Literatur diskutiert wurden.

Die Ergebnisse zeigten, dass die in den bestehenden Bodenschutzprogrammen enthaltenen Maßnahmen aufgrund von Akzeptanzschwellen bislang nicht zielführend umgesetzt werden konnten. Die geologischen und bodenphysikalischen Voraussetzungen in der Gemeinde bergen ein hohes potentielles standortspezifisches Erosionsrisiko, jedoch zeigen die Ergebnisse, dass eine Änderung der Anbauverfahren die tatsächliche Gefährdung stark positiv beeinflussen kann. Ein Wechsel der Anbauweise von konventioneller Bodenbearbeitung zu bodenschonenden Verfahren (wie reduzierte Bodenbearbeitung) erscheint vielversprechender als eine Änderung der Fruchtartenverteilung.

1. INTRODUCTION

1.1 BACKGROUND AND PROBLEM DEFINITION

Background

Soil erosion is a global problem because of its impact on environment and agricultural yields. On September 2006 the EU commission ratified three documents which establish the Soil Thematic Strategy in Europe (CEC 2006). These documents provide a common basis for comprehensive soil protection. The implementation of soil protection by statuary policies as well as new approaches in research shall support this process and ensure the sustainable use of soil in the EU-27 Member States. According to the EU Soil Thematic Strategy the greatest threats to soil in Europe comprise erosion (Figure 1), decline in organic matter, soil contamination, soil compaction, decline in soil biodiversity, salinisation as well as floods and landslides.

In January 2008 the Leibniz Centre for Agricultural Landscape Research (ZALF) in cooperation with the Humboldt-University of Berlin (HUB), the Institute for European Environmental Policy (IEEP) and 13 further subcontracting partners around Europe started a project that aims to reveal the relation between soil conservation practices and their ecological impacts, their acceptance by farmers and the appropriateness of policy measures based on a number of case studies in certain EU-27 countries (ZALF Tender J05/28/2007, 1). This Master Thesis was generated as part of the project SoCo (Soil Conservation and Policy Measures) that extends the EU study titled: "Sustainable Agriculture and Soil Conservation".

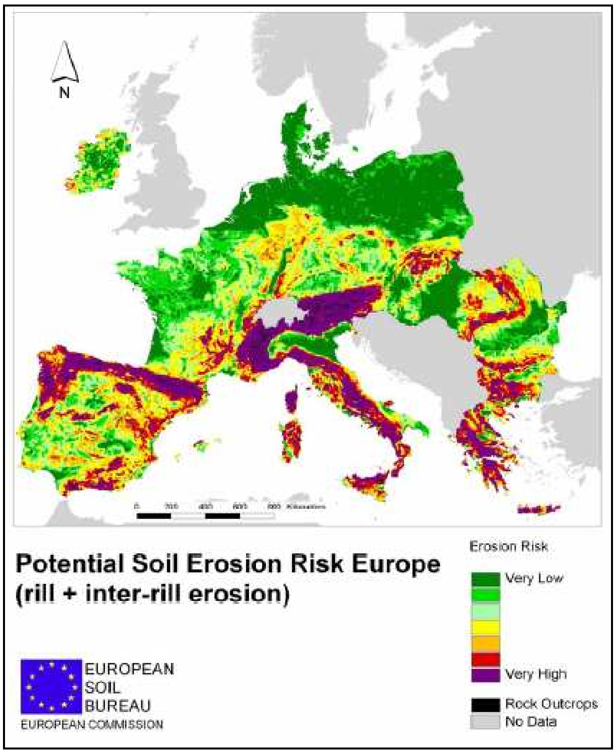


Figure 1 Potential Soil erosion risk in Europe. Based on the USLE (source: European Soil Bureau, 2001)

Problem definition

Soil erosion can be described as the movement of solid soil particles driven by water or wind. This process can be accelerated by human activities, in particular by several land management practices (Umweltbundesamt 2001, 65). In general the amount of newly formed soil corresponds roughly to the amount of soil that is removed by soil erosion. Agricultural land use can decrease the erosion risk by suitable cultivation practices or increase it, if the practices leave the soil unprotected and vulnerable. The case study region Michelhausen (Figure 2) was chosen because the area is highly affected by soil degradation in terms of water erosion. The first step to assess the risk of water erosion is to identify the main indicators of water erosion in the case study area.

Figure 2 The landscape is characterised by a number of soft hills and valleys covered with loess layers (source: Specht 2008)

The tertiary terraces and slopes are mainly not forested and covered with deep loess layers. The non-resistant loess combined with the high erosive marl and sandy subsoils lead on to run-off and erosion (IVFL 2002).

As soil erosion has already been identified as the major soil threat in the case study area (Michelhausen, Austria), the present Master Thesis provides an assessment of the crop-specific soil erosion risk and the influence of the applied soil conservation measures. Additionally, I developed scenarios for the future to explore the foreseeable changes of land use and their effects on soil erosion. The main attention will be directed at the measures of the Austrian Soil Conservation Programme ÖPUL and their impact on future soil erosion risk in the area.

General assumptions:

1. Soil erosion by water and wind is a natural process that has been significantly increased by human activity.
2. The current land use practices in the case study area lead to a high risk of soil erosion that is not sufficiently buffered by soil conservation activities.
3. The topography exerts influence on erosion, including the effect of steepness, slope form, lengths of uninterrupted non-dispositional overland flow and slope exposition (Bergsma et al. 1996, 55).
4. The erosion risk is interrelated with farming practices, land use and the cropping systems and crop rotation.
5. Changes in the agricultural policies have a strong impact on the current and future land use and therefore influence the erosion risk.

1.2 WATER-INDUCED SOIL EROSION

A wide variety of models to assess soil erosion are available. For this study a model-based approach was applied. The data sources that were used to estimate the erosion risk were calculated with the USLE. The model is designed to estimate long-term annual erosion rates on agricultural fields (Jones 2000, 11). As the existing maps and data inputs for this study used the USLE, this paragraph gives a brief overview on the equation. The basis for the assessment of soil erosion by water is the concept of the **Universal soil loss equation** which was developed by Wischmeier et al. in the 1950ies. The USLE was modified and extended over the years, and is still the most applied model in this context. Although the equation has many shortcomings and limitations (Jones 2000, 11), it is widely used because of its relative simplicity and robustness. The following formula predicts an estimation of the soil erosion with the version of the Wischmeier-formula (Wischmeier et al. 1978).

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

Where:

A= Long-term mean soil loss ($t \cdot ha^{-1} \cdot a^{-1}$)
K= Soil erodibility factor ($t \cdot h \cdot ha^{-1} \cdot N^{-1}$)
L= Slope length factor (dimensionless)
S= Slope incline factor (dimensionless)
C= Cropping management factor (dimensionless)
R= Rainfall and run-off erosivity factor ($N \cdot h^{-1}$)
P= Soil protection and conservation practice factor (dimensionless)

The R term represents the level of attacking forces while the remaining terms characterize the level of resisting forces (Emerstorfer 2008, 3). The calculation of the various factors (except K) is based on statistical analysis. The procedures that are used to estimate the single factors for the erosion risk assessment in the case study region are explained in detail in chapter 2.6.

Figure 3 shows the process of soil erosion by water which includes the detachment of particles as well as their transport and sedimentation.

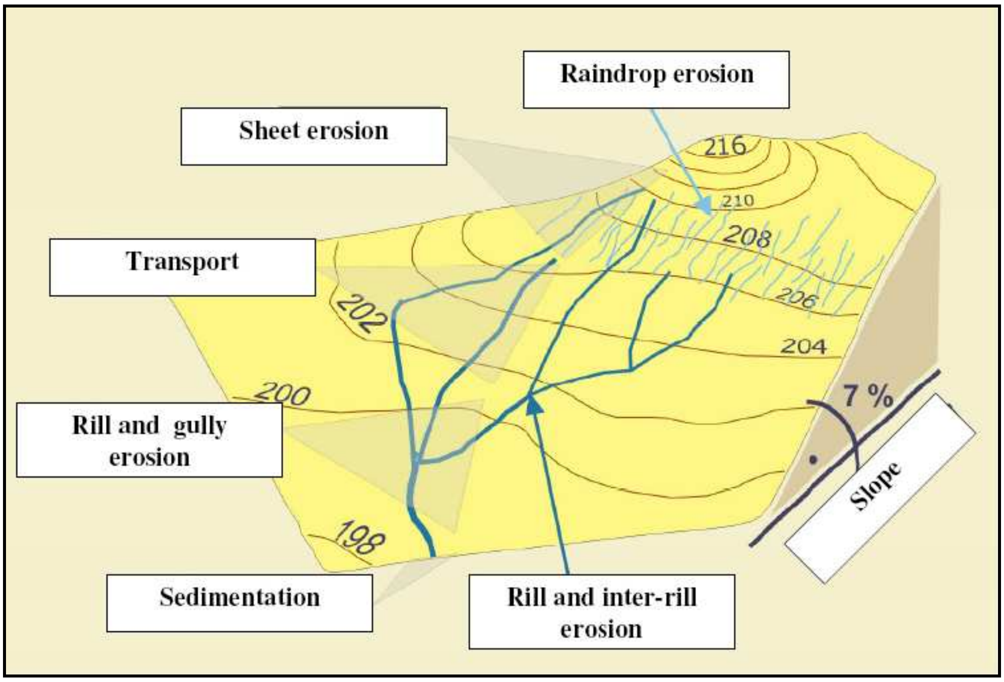


Figure 3 The erosion process: Types of soil erosion on an exposed slope (source: modified from Umweltbundesamt 2006)

As a result of erosive rainfalls or windstorms soil can be detached and transported. This process has impacts that are both on-site (where the soil is detached) and off-site (where it is deposited).

1.3 OBJECTIVES

The objective was to describe the current situation and the foreseeable developments in the case study area regarding general soil conditions, the soil erosion risk and soil conservation measures related to agricultural practices.

The following questions were to be answered:

- How is the case study area characterized regarding soil conditions and soil degradation?
- What are the key factors and the main driving forces for soil erosion in the case study area?
- Which policies and programmes are relevant regarding soil protection? What is their state of implementation?
- Which are the relevant cropping practices in the study area and how is their effect on soil erosion?

- What is the site-specific erosion risk and how is it distributed within the study area?
- What are the foreseeable consequences of a change of policies and measures in the study area?
- Are the current and the assumed future measures successful to prevent soil erosion or to decrease the soil erosion risk?

1.4 OUTLINE

Research for this thesis has been carried out in the eastern part of Austria (Michelhausen, Lower Austria). The research was performed in the framework of a multidisciplinary project at the Leibniz Centre for Agricultural Landscape Research (ZALF) with supervision of the University of Natural Resources and Applied Life Sciences, Vienna. The chapters of this thesis focus on different fields.

Chapter 2.1 provides a short characterization of the case study areas landscape and soil characteristics. It includes the selection criteria for the study area as well as descriptions of spatial and natural characteristics such as precipitation data and geological and soil-physical properties. The focus in chapter 2.2 is on legal framework conditions and policy targets for soil protection against erosion. It presents the general aims and principles of soil protection and the relevant laws that directly or indirectly contribute to prevent soil erosion. A description of the site visit as a qualitative method to investigate soil degradation and damages in the field is given in chapter 2.3. Chapter 2.4 comprises a depiction of the guided interview as a method to gather information on conservation measures and their state of implementation. The methodological framework to collect data on land use and farming practices in the study area is presented in chapter 2.5, which includes the interpretation of spatial data and the use of a semi-structured questionnaire. Chapter 2.6 provides the explanation of the methodological approach to assess the erosion risk under different land use scenarios. This includes the assessment of cropping systems with a fuzzy-logic instrument as well a GIS based assessment of sites and land use distribution.

Chapter 3.1 comprises a description of the specific soil degradation processes related to agricultural practices. The distribution of land use within the case study area is given in chapter 3.2. The most relevant farming practices were identified by analysing data of the questionnaire on cropping systems and soil conservation. Chapter 3.3 includes the identification of the most relevant soil conservation measures as well as an assessment of their implementation into practice. Chapter 3.4 presents the erosion risk in the area with varying management parameters while chapter 3.5 consists of literature- and expert-based assumptions about the effects under future land use scenarios and a discussion about the impacts of alternative land use options.

Summary and a general conclusion are given in chapter 4.

2. MATERIALS AND METHODS

2.1 LANDCSAPE AND SOIL CHARACTERISTICS OF THE STUDY AREA

Selection of the case study area

The case study area is the municipality Michelhausen in Lower Austria. It was selected together with the academic advisors from the Leibniz Centre for Agricultural Landscape Research (ZALF), the University of Natural Resources and Applied Life Sciences Vienna (BOKU) and the Chamber of Agriculture Tullnerfeld. The first step for the selection was an inspection of the soil erosion maps that are published in the Hydrological Atlas of Austria (Strauss 2007) to find possible case study areas. An important criterion for the selection was the areas' high potential for soil degradation caused by high intensity agriculture. From the whole range of potential study areas, those areas were identified, where the high soil erosion risk is attributable to the cropping practice and not preliminary caused by the topographic preconditions. Another important selection criterion was the participation of the municipality in the ELSA (European Land and Soil Alliance), which implies a general receptiveness to cooperation within the scope of soil protection. An imbedding of the working results into the regional planning community is in particular given by the stated interest of the Chamber of Agriculture in the scientific results. A further selection criterion was the availability of abundant data for the region as a result of several former research projects that have been conducted in the region. The size of the study area selected was due to two demands. On the one hand it had to be manageable to integrate detailed information of cropping systems and farming practices on the field level. On the other hand it was supposed to be large enough to allow statistical evaluation and the application of GIS analysis.

Spatial and natural characteristics

The study area Michelhausen is situated in the area of Tulln (Figure 4) in the southern part of the Tullnerfeld in the central part of Lower Austria. It is located 48°17' latitude and 15° 56' longitude. The total area under study is about 3090 ha.

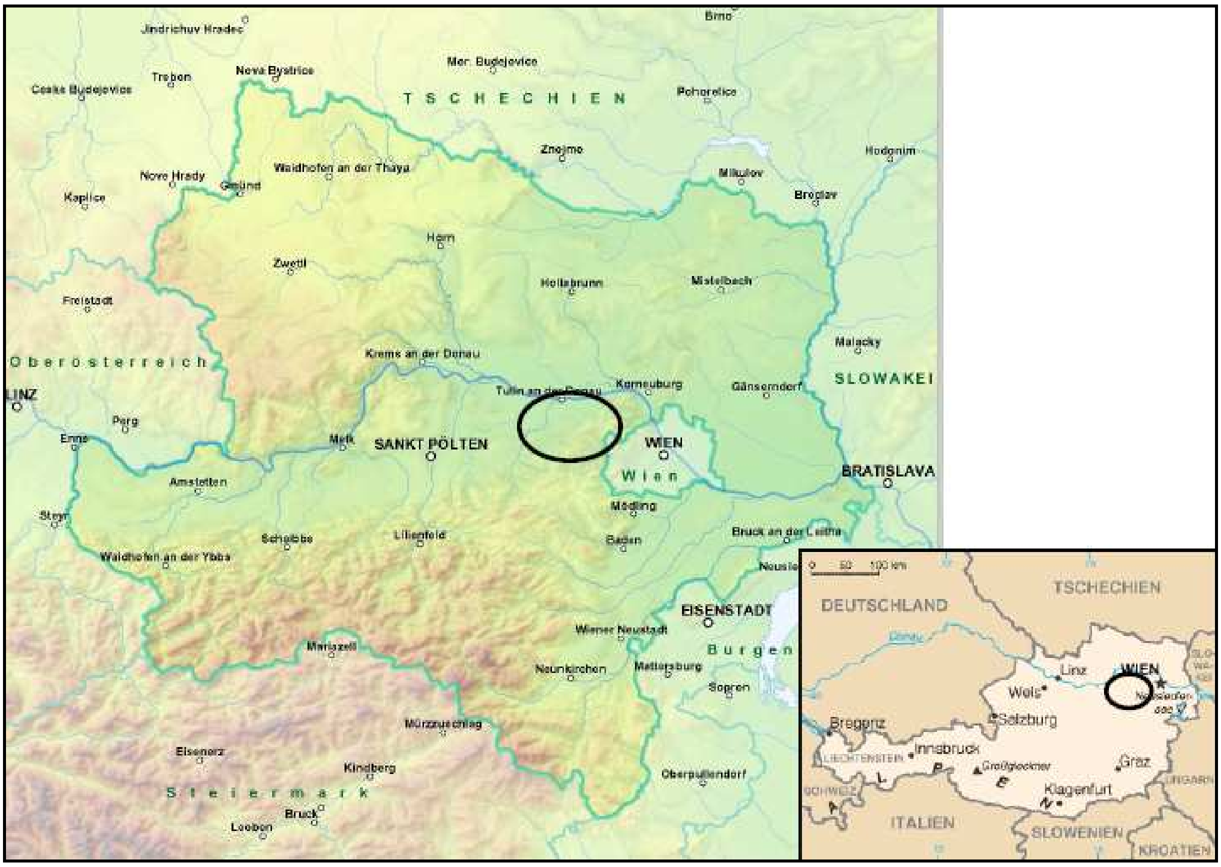


Figure 4 Location of the Case study area in Lower Austria (left) and Austria (right)
(source: NÖGIS Government of Lower Austria, Federation of survey and geoinformation 2007)

The topography is determined by the geological processes of the past. The eastern edge of the Alps ("Alpenostrand") once formed the shore of a tertiary ocean that invaded the Carpathian Basin. The Basin was formed when the connection between Alps and Carpathians were disrupted. Some remnants of the former connection remained as islands. The younger materials were deposited by water and wind. The layer of loess was removed by storms and solifluction.

These processes are visible in the Tullnerfeld, where the process formed asymmetric valleys on the clastic sediments of the Molasse-zone and the intramontaneaous basins (Figure 5).

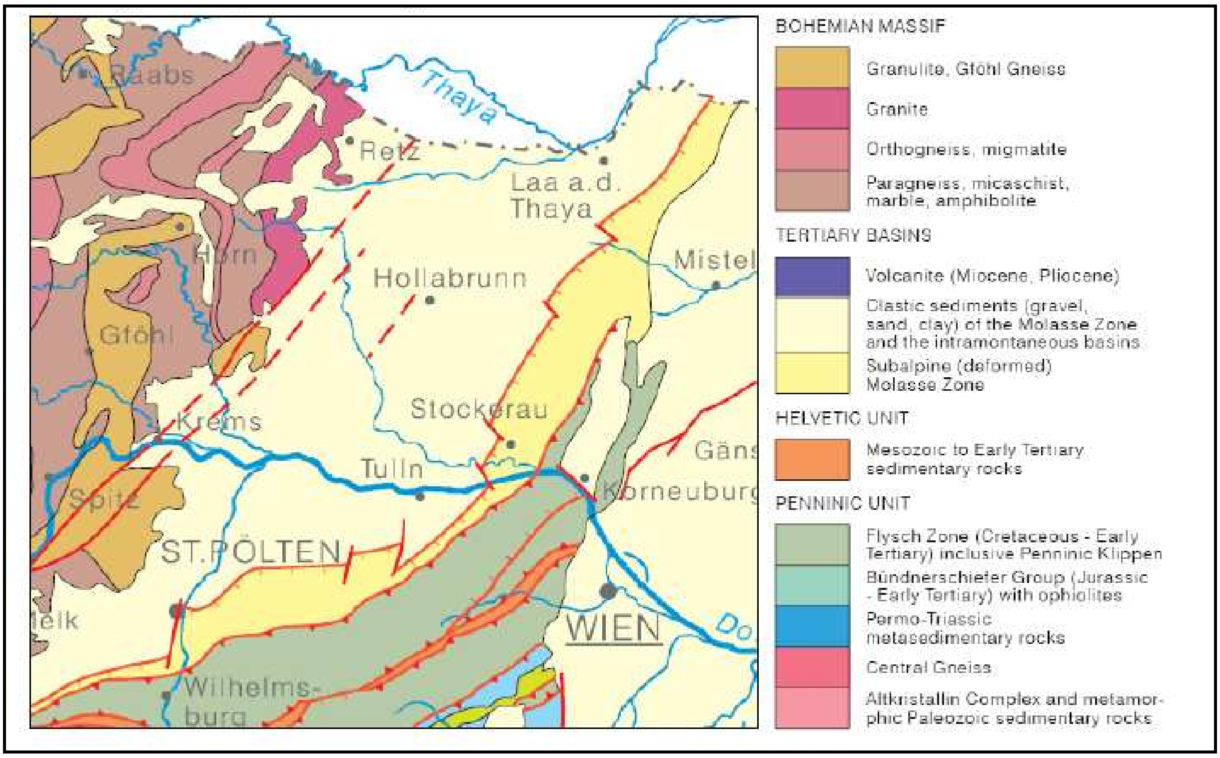


Figure 5 Geological map of Tullnerfeld and surroundings. The Carpathian Basin at the eastern edge of the alps (source: modified from Geological Survey of Austria Vienna, 1999)

The altitude is about 200m, which corresponds to the lower zone of the altitude belt. Due to the geological development the prevailing expositions are north and south.

The Tullnerfeld in Lower Austria is characterized by a continental climate with a pannonian influence. Climate parameters are influenced by warm summers with a relatively dry period in late summer and moderate cold winters with comparatively sparse snow. The dry summer periods are aggravated by frequently occurring south-east winds. The average annual temperature is about 9.5° C.

The mean annual precipitation increases from north-west to south-east, with values ranging around 606 in the annual mean from 1961 to 1990 (eBOD 2008), which is among the lowest values in Austria.

Table 1 shows the monthly precipitation which is represented by the data from eight climatic stations in the Tullnerfeld as published by Cepuder et al. (2002).

Table 1 Precipitation data of eight weather stations in the Tullnerfeld in mm (source: Cepuder et al., 2002)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1989	9	13	22	108	89	113	63	86	62	26	23	7	621
1990	2	44	40	78	48	73	69	14	72	38	45	33	556
1991	6	14	24	19	116	50	80	65	21	10	67	44	516
1992	11	15	62	37	21	96	41	38	56	43	61	24	505
1993	26	30	14	14	27	74	91	86	29	51	30	40	512
1994	26	6	36	73	69	42	38	36	15	38	51	27	457
1995	18	34	39	57	48	103	57	85	104	10	38	60	653
1996	35	19	13	84	110	93	48	68	89	61	27	22	669
1997	15	14	70	30	64	51	214	36	23	33	55	46	651
Mean	16	21	36	56	66	77	78	57	52	34	44	34	571
Variance	117	151	401	1054	1146	655	2911	718	1036	293	244	247	

Water deficiency becomes noticeable as a limiting factor for the agricultural production in the area. Inversely, the region is affected by infrequent intense rain events, which often result in run-off. Zonal vegetation consists of thermophilous *Quercus* forests with *Quercus robur*, *Quercus petraea* or *Carpinus betulus*.

Land use patterns and agriculture

The Tullnerfeld is deemed to be one of the most fertile agricultural areas in Austria. The land use classification of CORINE Landcover in Table 2 shows that out of the total area, 2547 ha is agricultural land, which represents 78% of the whole area. 265 ha are associated with agriculture as far as they are heterogeneous agricultural patterns or agricultural areas with natural vegetation. 6% are forest or wood, the rest, 8% of the area, have settlements.

Table 2 Distribution of land use in Michelhausen in ha and percentage. Classification after CLC 2000 (source: CORINE Landcover 2000)

CORINE Code	Name	Area in ha	Area in %
211	Agriculture without irrigation	2547	78
242	Heterogeneous agricultural patterns	63	2
243	Agricultural area with natural vegetation	193	6
311	Decidous forest	202	6
112	Urban area	250	8

The whole case study area (municipality of Michelhausen) comprises 3090 ha and is subdivided into the districts of Rust, Atzelsdorf, Pixendorf, Michelhausen, Streithofen, Spital, Mitterndorf and Michelndorf. The distribution of land use within Michelhausen after the classification of CORINE Landcover is given in Figure 6.

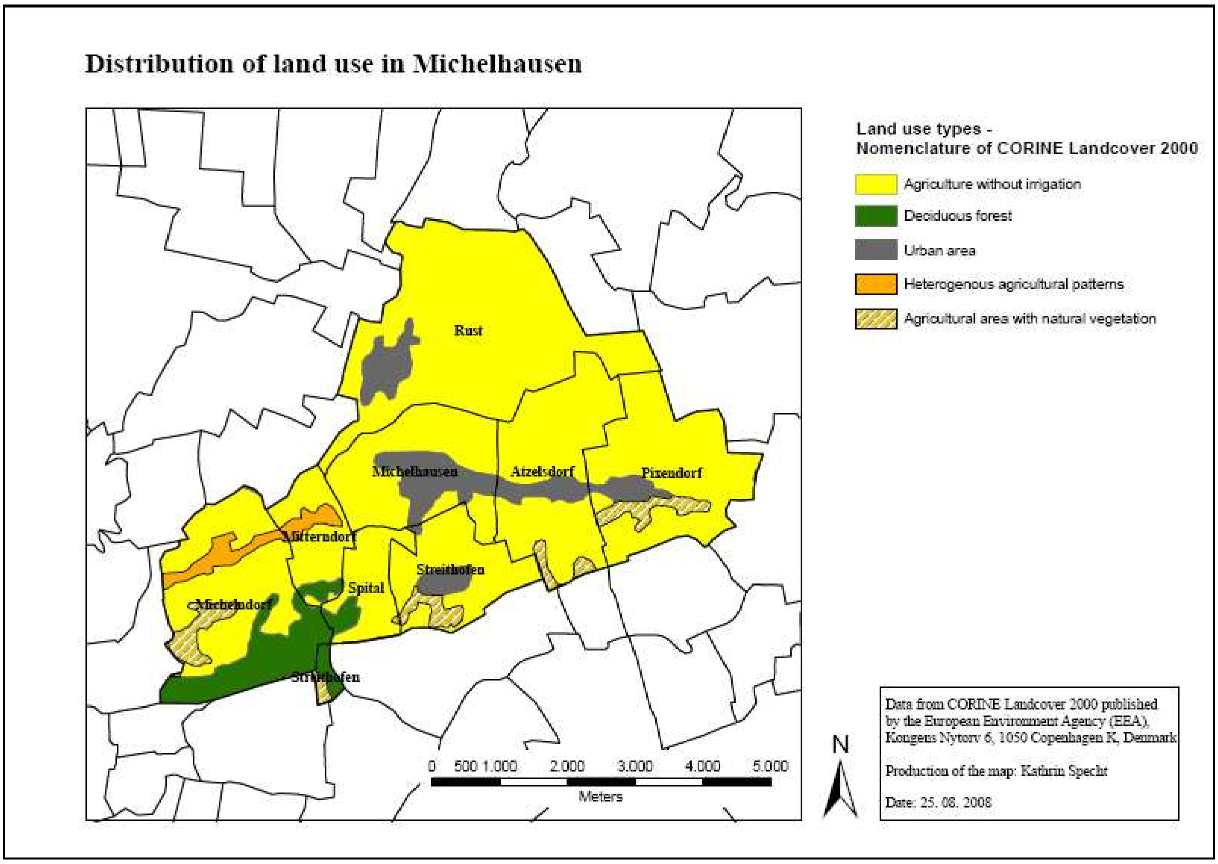


Figure 6 Distribution of land use after CORINE Landcover 2000
(source: Data from CORINE Landcover 2000, map by Kathrin Specht 2008)

On the scale of CORINE Landcover the land use category “agriculture without irrigation” is not further divided. To explain why the agricultural land use is certainly one of the key factors for on-site erosion risk, it needs a closer look at the distribution of crops and farming practices within the agriculturally used area.

The aerial photo of the area shows the parcelling of the arable land (Figure 7). Land consolidation and the beginning of more machinery-based farming started in Michelhausen in the 1960s. These intensification processes had a significant influence on the appearance and structure of the landscape. Small scale plots were merged into large agricultural fields. Small hedges, trees and shrubs, growing at the edges of the fields were removed.

The density of hedges as visible in the aerial photo is less than 1000m/km². Wind breaks and edges that could interrupt the sediment flows and surface run-off have been removed from the landscape during the past 50 years.

Figure 7 Land use patterns in the area of Streithofen (village on the right side) and Spital (source: eBOD 2008)

Soil properties and soil vulnerability

The information on soil types in Michelhausen was gathered using data from the digital soil maps of Lower Austria. The Austrian Digital Soil Map (eBOD 2008) is a free web GIS that provides spatial information of agricultural soils including soil forms and soil profiles. It is under the organisation of the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW).

The soil types in eBOD were classified using the Austrian Soil Classification. After reducing the occurring soil types to the four most relevant, they were reclassified after the Reference Base for Soil Resources (IUSS 2007). The range of soil types in the area includes Mollic, Eutric and Calcaric Cambisols on marl and loess in the southern part. The northern part is characterized by Gleyic, Luvic, Calcaric, Siltic and Haplic Pheozems and Mollic Gleysols and Gleysols (Figure 8). The Gleysols are not listed in the table, as these areas are used as grassland and not for crop production.

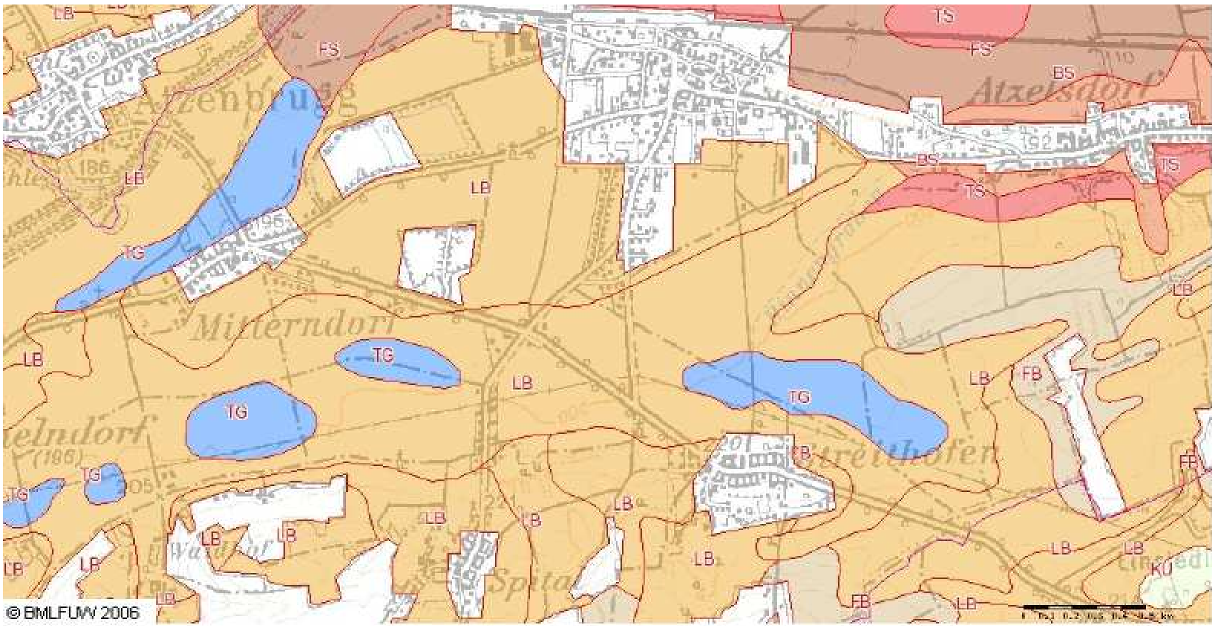


Figure 8 Soil map of Mitterndorf and Streithofen (municipality of Michelhausen). LB: Mollic, Eutric Cambisols on loess; FB: Mollic, Eutric and Calcaric Cambisols on marl; TS: Gleyic, Luvic, Calcaric and Haplic Pheozems; FS: Mollic Gleysols (source: eBOD 2008)

The soils in the study area (Table 3) are mainly Cambisols on loess, marl or sandy limestone (approximately 80 %). The loess soils are especially prone for soil erosion by water; therefore protection against soil erosion is an environmental priority in the hills of Michelhausen.

Table 3 Main soil uits in the municipality of Michelhausen : Cambisols (source: eBOD 2008)

IUSS (2007) classification	**Mollic/Eutric Cambisols on marl**	**Mollic/Eutric/Calcaric Cambisols on loess**
Austrian Soil Classification	entkalkte Lockersediment-Braunerde aus tief aufgemürbtem Mergel	kalkhaltige Lockersediment-Braunerde aus Löß
Short term (soil map)	FB	LB
Approximate share of the soil type in the area	10%	70%
Site and position	Flat to hilly sites on ridges, lowlands and on slopes	Flat to hilly sites on ridges, lowlands and on slopes
Soil type and parent material	Cambisols from marl	Calcaric Cambisols from loess
Soil moisture conditions	Good water relation; high retention capacity, medium permeability	Medium dry; medium retention capacity, medium permeability
Soil texture	Ap loamy Silt, Loam or silty Loam Bv Loam or silty Loam C silty Loam, partially low content of stones	Ap/ Bv/ C loamy Silt or sandy Silt; partially silty Loam
Humus content	Ap medium humus content; Mull	Ap medium humus content; Mull
Lime content	Ap Bv deficient in lime or lime free C very calcaric	medium calcaric to very calcaric

IUSS (2007) classification	Mollic/Eutric Cambisols on marl	Mollic/Eutric/Calcaric Cambisols on loess
Chemical reaction	Low acid to neutral	Neutral to alcaline
Vulnerabiliy to soil erosion	Medium vulnerability to run-off on slopes; partially medium vulnerability to wind erosion	Medium vulnerability to run-off (on steep slopes high vulnerability to run-off)
Machinability	Machining complicated by stickyness and formation of clods	Good machinability
Natural soil value	High value arable land	High value arable land

In the northern part of Michelhausen (Table 4) Gleyic, Luvic, Calcaric, Siltic and Haplic Pheozems and Mollic Gleysols/ Gleyic Pheozems occupy approximately 20 % of the whole region. Pheozems and Gleysols are fertile soils that are used for growing a wide variety of crops.

Table 4 Main soil units in Michelhausen: Pheozems and Gleysols (source: eBOD 2008)

IUSS (2007) classification	Siltic/Luvic/Calcaric/Haplic Pheozems	Mollic Gleysols/ Gleyic Pheozems
Austrian Soil Classification	Tschernosem aus Löß oder lößähnlichem Feinsediment	Feuchtschwarzerde aus feinem Schwemmaterial
Short term (soil map)	TS	FS
Approximate share of the soil type in the area	10%	10%
Site and position	Flat to hilly sites on ridges, lowlands and on slopes	Lowlands
Soil type and parent material	Pheozems from loess	Gleysols/ Pheozems from fine sediments
Soil moisture conditions	Dry; medium retention capacity, medium permeability	Good water relation; high retention capacity, medium permeability; medium influence by ground water
Distribution of soil contents	A1p A2 sandy Loam or loamy Silt C sandy Loam or loamy Sand	A1p A2 Acg loamy Silt or sandy Loam
Humus content	A1p medium humus content; Mull A2 low humus content C Mull	A1p medium humus content; Mull A2 medium to low humus content or low humus content; Mull Acg low humus content
Lime content	Calcaric or medium calcaric	Calcaric or very calcaric
Chemical reaction	Neutral or alkaline	Neutral
Vulnerabiliy to soil erosion	Medium vulnerability to wind erosion	Medium vulnerability to wind erosion; low vulnerability to run-off
Machinability	Good machinability	Good machinability
Natural soil value	High value arable land	High value arable land

2. 2 SOIL PROTECTION TARGETS AND LEGAL FRAMEWORK

General aims of soil protection

Soils play a central role at the interface of atmosphere, hydrosphere, geosphere and biosphere. Blum (2002, 1-8) defines six main functions of soils, which comprise ecological functions as well as the technical, industrial and socioeconomic dimension of soil and land.

These functions are:

- Production of biomass: This function, which states the basis of human and animal life, ensures the production of food, renewable energy, fodder and raw materials;
- Filtering, buffering and transformation: These capacities are limited and vary according to the specific soil conditions. Soils influence the interrelation between the atmosphere, the groundwater and the plant cover through mechanical filtration, physical or chemical absorption and precipitation on its inner surfaces or microbiological and biochemical mineralisation and metabolisation of organic compounds;
- Biological habitat and gene reserve;
- Physical basis for technical, industrial and socio-economic structures and their development (e.g. housing, transport, industrial premises etc.);
- Source of raw materials (e.g. clay, sand, gravel, minerals) and energy;
- Geogenic and cultural heritage.

Soils contain more species in number and quantity than all other above-ground biota together, therefore they are a main basis of biodiversity, and they are largely not renewable.

Due to the central role of soils sustainable soil management is the first step towards sustainable use of natural resources (Blum 2002, 1). The aim of soil protection is to maintain or even improve the different functions of soil.

Policy targets for soil protection

Referring to the Sixth State of the Environment Report (Umweltbundesamt 2001, 289-307), policy targets are proclaimed on different administrative levels.

As soil erosion is a problem in the whole European Union (Table 5) at EU level the “Environmental Action Programme for the Protection of Nature and Biodiversity” focuses on the prevention of soil erosion.

Table 5 Estimation of water erosion on a European level: Approximation of the area affected by soil degradation in M ha (source: European Soil Bureau, 2001)

Water erosion	Light	Moderate	Strong	Extreme	Total
Loss of topsoil	18.9	64.7	9.2	-	92.8
Terrain deformation	2.5	16.3	0.6	2.4	21.8
Total:	21.4	81.0	9.8	2.4	114.5 (52.3%)

The EU specifies the good agricultural practices in its Common Agricultural Policy (CAP), which includes soil protection measures that are obligatory under the Cross Compliance scheme (CC) in order to receive the EU area payments. Additionally, the European Union provides financial incentives to improve the agricultural use of soils in Europe. It is left to the member states to implement the practices on a national level within their agri-environmental programmes.

The “Soil Protection Protocol of the Alpine Convention”, which has been ratified by Austria, contains soil-relevant targets as the containment of soil erosion in particular by the application of soil protecting agricultural and commercial procedures. In key target 11 of the “Austrian Sustainability Strategy”, targets for the protection of soil are formulated. The “Rural Development Programme 2007-2013” aims *“to permit practising a sustainable, competitive and multifunctional agriculture and forestry in well-functioning, vital rural areas”* (RDP 2007). Agri-environmental measures as ÖPUL are part of this “second pillar” of the Common Agricultural Policy (CAP).

Legal framework conditions

The protection of soils is defined in different soil protection laws. Beside the “Command and Control Policies” (CCP), that include national laws and regulations, the Federal Provinces of Austria are responsible for soil protection legislation. The Province of Lower Austria has an own specific soil protection act at their command.

Conservation agriculture encompasses a set of agricultural practices based on three principles (FAO 2008 in: ZALF J05/28/2007, 23):

1. Minimal soil disturbance
2. Permanent soil cover
3. Diversified crop rotations

These principles can also be implemented through Incentive Based Measures (IBM), that indirectly influence farmer’s behaviour by providing financial incentives for environmentally friendly practices (ZALF Tender J05/28/2007, 5).

Soils are protected by laws that are directly aimed at soil erosion:

- Soil Protection Law of Lower Austria LGB1 (Niederösterreichisches Bodenschutzgesetz)
- Minimum soil cover (Mindestanforderungen an die Bodenbedeckung) BGBL. II Nr. 474/2004 (INVEKOS- Umsetzungs- Verordnung 2008)
- Protection of permanent pastures (Schutz von Dauergrünland) (BGBL. II Nr. 474/2004 (INVEKOS- Umsetzungs- Verordnung 2008)
- Standards for crop rotations where applicable (Standards für Fruchtfolgen) BGBL. II Nr. 474/2004 (INVEKOS- Umsetzungs- Verordnung 2008)

Soils are protected by laws that indirectly contribute to prevent soil erosion:

- Forestry Law 1975, as amended on BGBl. I Nr. 55/2007 (Forstgesetz 1975, in der Fassung BGBl. I Nr. 55/2007)

Soils are protected by further agri-environmental programmes or projects:

- „Agri-Environmental Programme” for the promotion of an environmentally compatible, extensive agriculture which preserves natural areas of living (ÖPUL- Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft)
- ELSA- European Land and Soil Alliance (Europäisches Bodenbündnis)

2.3 INVESTIGATION OF SOIL DEGRADATION AND DAMAGES

Site visit

To investigate the state of soil degradation and the severity of current damages a site visit was chosen as a qualitative method. The on-site visit is a way of getting an overview of land use and production systems. It can be used for identifying the cause and effect of relationships among topography, soils, natural vegetation, cultivation, and other production activities (FAO 2008). The side visit is supposed to last two to three hours. A local expert guides the walk and explains the key characteristics of visible features.

The site visits in Michelhausen took place on the 23. June 2008 (between 10 a.m. and 5 p.m.) and consisted of two sessions with different focuses. The first part lasted approximately two hours and was guided by two local experts. The visited sites were chosen by DI Meyer from the Chamber of Agriculture. The main focuses were on-site erosion damages and gullies on the agricultural field. The experts explanations were facilitated by asking questions about the details and by making own observations.

The second site visit took approximately four hours and was accompanied by DI Wieshammer-Zivkovic, a soil expert from the BOKU and local from the Tullnerfeld. The focus of this visit was to get an overview on the soil properties and the applied cropping practices. It comprised a detailed look on the field crops as well as short dialogues with farmers. After the walk was finished, the participants discussed and recorded the information and data collected. During the visits, photographs were taken to document the key information. The results influenced the whole thesis but are mainly presented into chapter 3.1 (Description of soil degradation and damages).

2.4 CONSERVATION MEASURES AND THEIR IMPLEMENTATION INTO PRACTICE

Guided interview

The guided interview is a qualitative method that is commonly applied in social sciences. It is used to gather information about the opinions of a particular person in order to gain qualitative insights into a problem. A questionnaire is developed in advance but is only used as a guideline for the interview. However, the conversation between interviewer and interviewee does not have to follow it strictly. Wording and order of the questions can be varied, following the outline of topics or issues to be covered. According to Sewell (2008) the major advantage is that the data are more systematic and comprehensive than in the informal conversational interview, while the tone of the interview remains conversational and informal. To increase the validity of the outcomes the results should be brought into a process of verification, for example by cross checking the statements with other interview partners.

Interview preparation and procedure

In order to prepare for the interview and to design the outline for the questionnaire a short literature review was carried out. As the aim of the interview was to investigate the state of policy implementation and soil conservation in the municipality, I generated an overview of the most important programmes. A list of available soil conservation measures was compiled as well, to be evaluated by the interviewee.

The current state of soil protection in the area (cf. chapter 3.3) was mainly derived from the interview with DI Josef Meyer from the Chamber of Agriculture Tullnerfeld. The interview was carried out at the 23.06.2008 starting at 8 a.m. in the office of DI Meyer in the main building of the Chamber of Agriculture in Tulln, Lower Austria.

The interview started with some general questions about the region and changed into more detailed questions on the current situation of farming systems and management practices. The last part of the interview focussed on agricultural and environmental policies and their state of implementation. A copy of the complete questionnaire is included in the Annex A-1.

At the end of the interview Mr. Meyer stated a large interest in the proceedings of the study and approved the publication of his statements. He consented to provide further information or answer additional questions that might arise at a later date. To gather additional information, brochures, maps, and other explanatory materials were collected in the Chamber of Agriculture. The notes that were taken during the interview were written down as full descriptions on the next day. The results are mainly presented in chapter 3.2 and chapter 3.3.

2.5 ANALYSIS OF LAND USE AND FARMING PRACTICES

Spatial data interpretation

To get a first impression of the distribution of land use and the spatial organisation aerial images were used. I received the data from the Federal State of Lower Austria that runs a web service (NÖGis) where the directorate of survey and geo-information provides maps and data for the free download. The data is in the spatial reference of the Bundesmeldenetz, Meridianstreifen 34 (BMN34). In addition, digital orthophotos were ordered for a small fee. The aerial photos help to understand the parcelling of the land and provide information on land use patterns and landscape structures such as the density of hedges.

Data from CORINE Land Cover (CLC 2000) was used to quantify the share of different land uses on the scale of the municipality. The GIS data of CLC 2000 were ordered from the Ministry of Environment.

Semi-structured questionnaire

To identify the most relevant farming practices and their impact on soil degradation in the case study area, a semi-structured questionnaire was used, that was designed in the SoCo-project (Soil Conservation and Policy Measures) that extends the EU study titled: "Sustainable Agriculture and Soil Conservation" at the ZALF in 2008. This questionnaire was developed as an excel spreadsheet and has been directly filled with the expertise of DI Josef Meyer from the Chamber of Agriculture Tullnerfeld, data from Statistic Austria and the AMA. To cross-check the collected data and to fill data gaps, some farmers of Spital and Streithofen were consulted for short telephone interviews on certain management issues. The aim was to gather detailed information on farming practices, soil conservation measures and the links between certain practices and soil degradation types.

The complete questionnaire is included in the Annex A-1. The results are mainly presented in chapter 3.2 (Analysis of land use and farming practices).

2.6 SIMULATION OF EROSION RISK UNDER DIFFERENT LAND USE AND MANAGEMENT SCENARIOS

Background of the fuzzy approach and the GIS- simulation

Field experiments help to get the basic quantitative knowledge about the interaction of process factors. For a larger scaled assessment of the erosion risk and the spatial distribution, the application of erosion models has a higher significance (Strauss 2007). The use of models enables to calculate the impact of the single factors as well as the effects of different protection measures. *"As models are abstractions of reality, results of a model should not be interpreted as precise predictions of what will happen, but rather as indicators of the direction in which, and the degree to which a system will or may change"* (Zander 2003, 128).

Figure 9 shows the areal risk for soil loss by water. I generated the map using the GIS-database from the Hydrological Atlas of Austria (Strauss 2007).

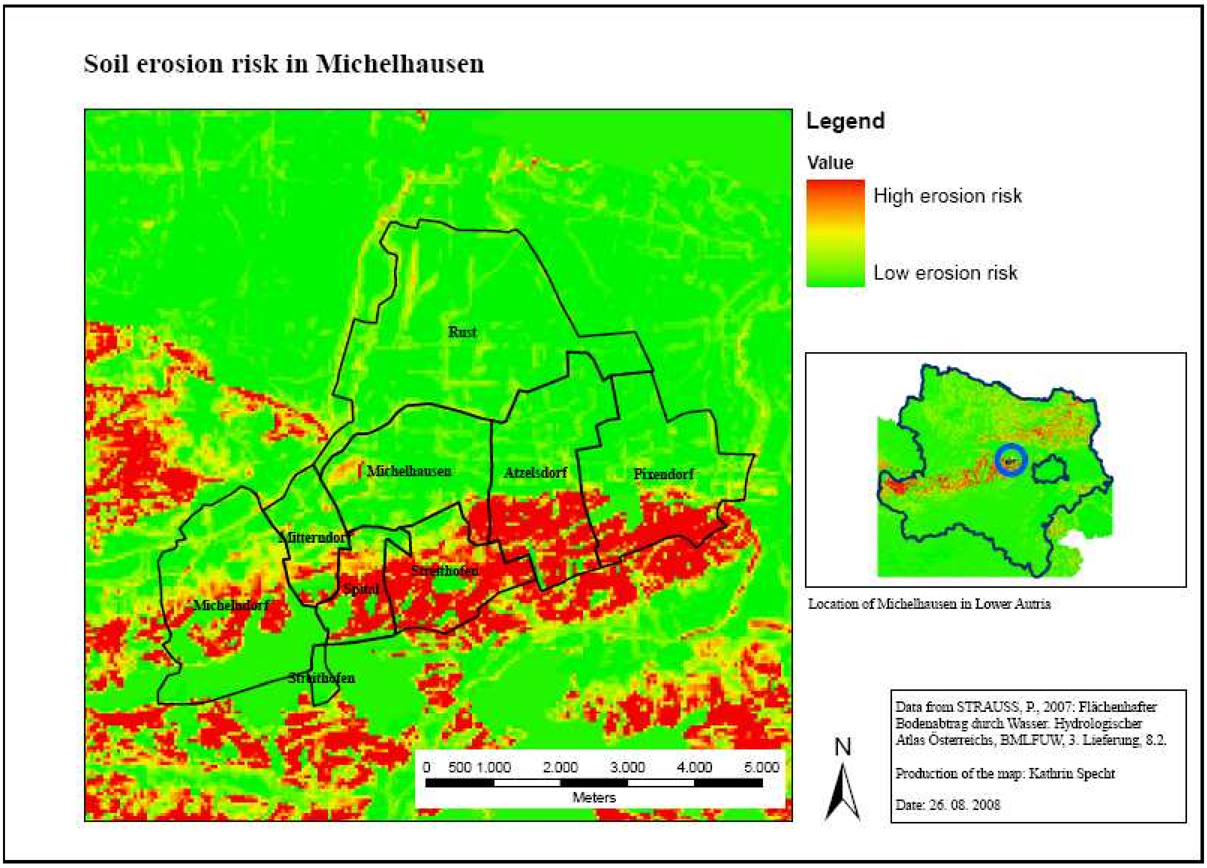


Figure 9 Spatial distribution of the erosion risk within the study area. Soil loss values were found to increase from north to south (source: Data from Strauss 2007, map by Kathrin Specht 2008)

Soil loss values were found to increase from north to south. The increase of erosion risk is largely owing to the topography, namely the LS factor, which indicates that the vulnerability to soil erosion in the northern parts of Michelhausen is rather low. Therefore the areas of Spital and Streithofen in the southern part of the municipality were selected for a closer and detailed consideration.

The overview on factors that influence soil erosion in Figure 10 shows the input of site- and crop-specific factors on the erosion risk. Site characteristics are only determining the potential erosion risk.

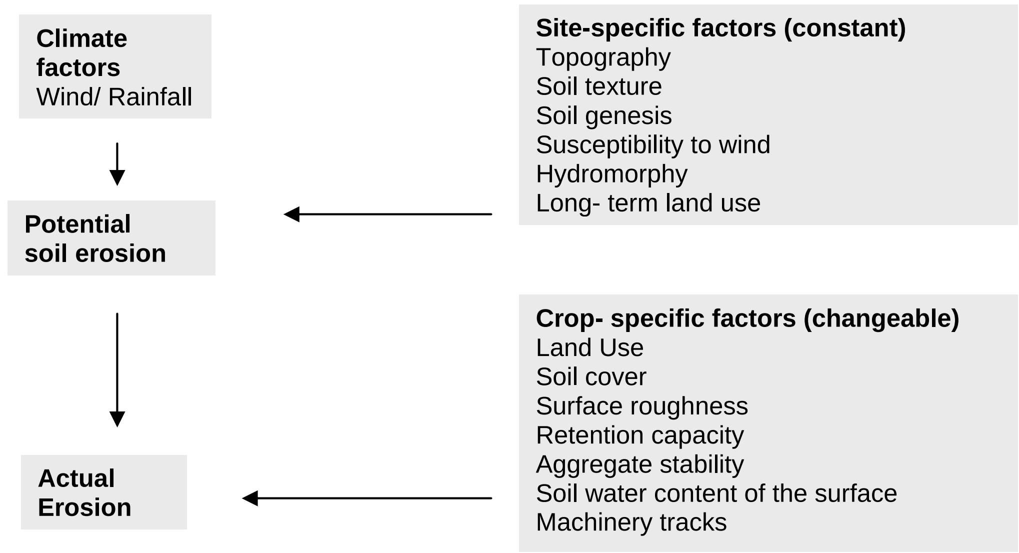


Figure 10 Factors that cause and influence soil erosion: Constant factors only determine the potential erosion risk while the actual erosion risk is influenced by changeable factors (source: MLUR, 2002)

The aim of the GIS-based simulation was to show the distribution of the actual erosion risk on a constant site. The application of models is characterised by some limitations. Theoretical reflections on the techniques and distinctions between the many types of models are covered by other authors (Kächele 2001; Zander 2003; Schuler 2007) and will not be a subject of the discussions in this thesis.

Risk assessment procedure and data basis

Assessing the erosion risk is divided into three steps:

1. Assessment of cropping systems
2. Assessment of site characteristics and
3. Assessment of possible combinations of cropping systems and site characteristics.

Table 6 shows the data basis for the main steps of the risk simulation under different land use and management scenarios.

Table 6 Data input for the main steps of the risk assessment for crops and sites

Assessment of	Type of data	Source
Crop-specific risk	Share of crops within the municipality Michelhausen	STATISTIK Austria 2008 (Annex B-1)
Crop-specific risk	Cropping systems of the main crops in the municipality Michelhausen	Questionnaire Q1 (Annex A-1)
Crop-specific risk	IGA values = rule based indices for the assessment of farming practices	SoCo-CS fuzzy-logic approach (Sattler 2008)
Site-specific risk	K-values (USLE) for Lower Austria (GIS database)	Database for the Hydrological Atlas of Austria (Strauss 2007)
Site-specific risk	LS-values (USLE) for Lower Austria (GIS database)	Database for the Hydrological Atlas of Austria (Strauss 2007)
Site-specific risk	Site Sensitivity map	Generated from K- and LS-values

Assessment of the crop-specific erosion risk (fuzzy logic approach)

Assuming, that the cropping systems and farming practices highly influence the potential and actual soil erosion risk, the crop-specific erosion risk was simulated using the IGA (Index of Goal Achievement) values. The IGA are indices that are calculated with the given information of cropping systems and farming practices. Basic processes that are indicated in the calculation are soil cover, tillage system and the number of crossings. The values are carried out by applying a rule-based assessment that is using a fuzzy logic approach (Figure 11). According to Salski (1998) fuzzy approaches are particularly useful for processing uncertain or imprecise environmental data with not sharply defined boundaries.

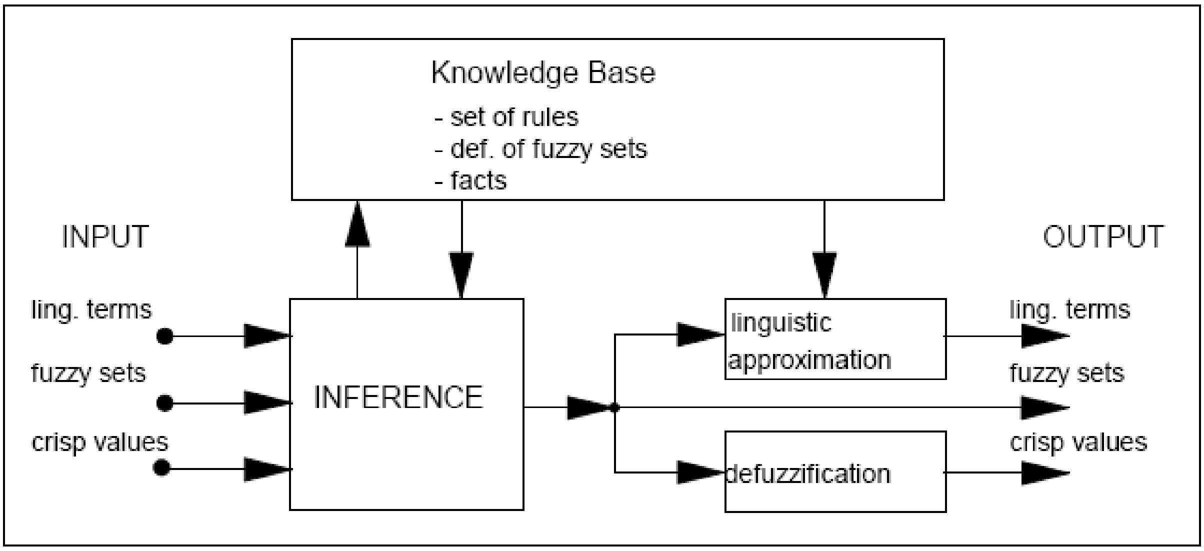


Figure 11 Information flow in the fuzzy model (source: Salski 1998)

The main part of the fuzzy model is the knowledge base. This knowledge can be represented by a set of linguistic rules in the "IF- THEN" form.

Example: **IF "soil cover summer" is "low" and**
"soil cover winter" is "high"
THEN "soil cover" is "medium".

The variables (soil cover summer, soil cover winter) are linguistic variables. The terms "low", "high" etc. are defined in the form of fuzzy sets. It should be noted that the formulation of these linguistic rules and the definition of fuzzy sets have a subjective character (Salski 1998, 2).

For the estimation of the potential soil erosion, some parameters are considered to play the major role (Table 7). In view of water-induced soil erosion the soil cover by plants (1) is one key factor. Seeding without tillage, or with reduced tillage systems (2) help to avoid erosive conditions of the seedbed. A further considerable influence is given by catch crops (3) as undersown crops or intercrops. Another possibility to protect the soil from water erosion is a reduction of the machine tracks (4).

Table 7 Assessment parameters for the crop specific erosion risk: plant-specific soil cover, tillage, catch crops and the number of crossings are considered being the most important parameters

No	Input Name	Description	Unit	Min	Max	source
1	CoverS	Crop-specific soil coverage (during summer and during winter season)	[-]	1	3	Crop classification after Frielinghaus et al. 1998, p. 32 (Annex C-1)
2	TillCatch	Tillage systems (conventional, reduced, zero)	[-]	0	1	Classification after Deumlich (pers. comm.) (Annex C-2)
3	CoverW	Catch crops (intercrops, undersown crops)	[-]	1	3	Crop classification after Frielinghaus et al. 1998, p. 32 (Annex C-1)
4	Crossings	Number of crossings	[count]	0	20	Questionnaire (Q1) data (Annex A-1)

The estimation of the soil cover is developed with a classification system of Frielinghaus et al. (1998) (Annex C-1). The classification of the cultures is based on field experiments that were run in the east of Germany. The estimation of the soil cover includes the speed of plant growth and the degree of soil cover in different periods of growth. For the winter crops the sowing date is taken into consideration, as it influences the length of the period without sufficient soil cover. For the assessment of the cropping systems the tillage practice is taken into account (conventional/ zero tillage) as well as the application of catch crops. For the impact of different tillage types a classification of Deumlich (2001) is used (Annex C-2). The last input factor is the numbers of crossings; the more crossings occur in the winter time the lower is the value. A very detailed description of this method can be found in Sattler (2008, 95-114). Table 8 shows the calculation for the example "reduced tillage". With a change in “Tillage” (0.5 to 0.8) the outcome changes.

Table 8 The indices of goal achievement (IGA) are generated by varying the cropping systems input parameters; for this example the input for tillage was changed from conventional (0.5) to reduced tillage (0.8)

Crop	Soil Cover Summer	Conventional Tillage	Reduced tillage	Soil Cover Winter	IGA Conventional tillage	IGA Reduced tillage
Maize - Grain	2.5	0.5	0.8	3	0.267	0.438
Soft wheat, winter - Grain	1	0.5	0.8	2	0.608	0.666
Beet, sugar – Fodder	2.5	0.5	0.8	3	0.267	0.438
Maize, Fodder - Silage	2.5	0.5	0.8	3	0.267	0.438
Barley, winter - Grain	1	0.5	0.8	1	0.735	0.789
Pea – Fodder	1.5	0.5	0.8	3	0.393	0.507
Sunflower – Grain	2.5	0.5	0.8	3	0.246	0.411

The final step was to define three crop specific risk-classes. The values range from 0 to 1 where "0" represents the maximum risk and "1" low or no risk. The degree of goal achievement allows formulation of positive/negative statements on an ordinal scale (Zander 2003, 139); indicating whether a farming practice performs better or worse than another. To define the breaks of classes an equal interval was chosen. This classification scheme allows mapping of continuous data. The break values are as follows: first interval: 0-0.33/ second interval: 0.33-0.66/ third interval: 0.66-1 (Table 9).

Table 9 Classification scheme of crop-specific risk classes

Crop-specific risk classes		
Break values	**Risk**	**Class**
0-0.33	High	1
0.33-0.66	Medium	2
0.66-1	Low	3

Table 8 shows that for maize the values changed from 0.267 (with conventional tillage) to 0.438 (with reduced tillage). As the value break is at 0.33 the assessment of the farming practice maize changed the risk class from "high risk" to "medium risk" with a change in "tillage".
The outcome is presented in chapter 3.4.

Comparison of conservation measures

To compare the effects on soil conservation, the available measures were combined with the land use and evaluated as single measures and in possible combinations. For the assessment of the farming practices the parameters tillage/ no tillage and application of undersown crops/ intercrops were considered. The efficiency of measures is rated in the following order: no tillage > undersown crops > intercrops (Sattler 2008, 101).
Table 10 shows the possible combinations of soil conservation measures and the classification of the potential erosion risk. The possible management options allow the differentiation of two tillage types (reduced tillage or conventional) and the application of undersown crops and/ or intercrops.

The crop-specific erosion risk for the current land use and farming practices (status quo) is represented by management option No. 5 (Table 10).

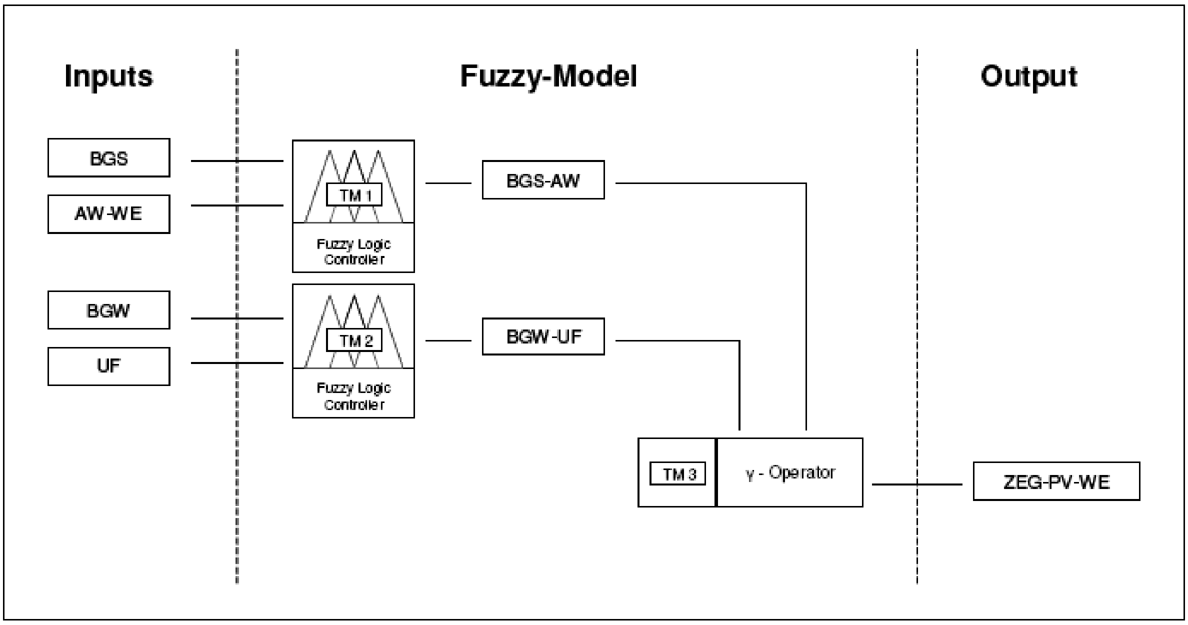
Table 10 Assessment of different measures of tillage and soil cover and their possible combinations (source: based on the classification scheme of Deumlich 2001; Sattler 2008)

Management options /Measures			
No.	**Tillage type**	**Undersown crops (UC)/ intercrops (IC)**	**Input value**
1	Reduced tillage	UC + IC	1
2	Reduced tillage	UC or IC	0.9/0.8
3	Reduced tillage	no	0.7
4	Conventional	UC + IC	0.6
5	Conventional	UC or IC	0.4/0.5
6	Conventional	no	0

The closer the assessment reaches the value of 1, the higher is the measures ability to prevent erosion. Figure 12 shows the model for the assessment of the farming practices. An overview on the detailed single parts of the model functions can be found in Sattler (2008).

The inputs for the soil cover summer (BGS) and soil cover winter (BGW) (Frielinghaus 1995, 34) can be found in Annex C-1. For the comparison of measures the input values for conservation measures (AW-WE) are varied. Using the fuzzy-based approach, the "Input value" is the cropping system/conservation measure (AW-WE) value in the model (Figure 12). The UF value (number of crossings) was adapted to the combination of measures.

UF value adaption: **No tillage (-1)**
No tillage/ no intercrops (-2)
Undersown crops (+1)



BGS **= Soil cover summer**
AW-WE **= Cropping system/conservation measures**
BGS-AW **= 1. result**
BGW **= Soil cover winter**
UF **= Number of crossings winter**
BGW-UF **= 2. result**
ZEG-PV-WE **= Index of goal achievement: farming practice – soil erosion water**

Figure 12 Model "WE-PV" for the assessment of farming practices and their effect on soil erosion by water (source: Sattler 2008)

The model allows comparing the efficiency of the applied and possible alternative farming practices. The results are presented in chapter 3.4. The complete table with the outputs of the fuzzy model can be found in Annex C-3.

Simulation of erosion risk with varying crop shares

Using the results of the interviews and literature reviews soil land use and conservation scenarios were developed. The aim was to identify opportunities for soil conservation within the process of land use changes to reduce soil losses. The results are presented in three scenarios, which are described below. All scenarios are based on the presumption that the total area of agricultural used land remains the same.

I. The current situation of land use and farming practices (2008)

II. Intensification of land use (e.g. fodder/ energy crops)

III. Soil conservation/ extensification of land use (e.g. strengthening of ÖPUL and/or its implementation)

The land use distribution of the 2008 situation (scenario I) is characterised by a high share of maize. It represents more than 34 % of the crops in the area which corresponds to 1047ha out of the total 2547ha of arable land (Maize-fodder/ silage, Maize corn-cob and Maize grain are grouped together). Another 25 % is represented by the winter crops (winter wheat and winter barley).The rest are sugar beets (9.6 %) and smaller percentage (2-3 %) of vegetables, peas and sunflowers. The production system used in the analysed part of the municipality is conventional without exceptions.

Scenario II was based on the assumption that the share of high intense crops is growing (+10 %) on the costs of the other crops. Due to an assumed reduction of agri-environmental payments this scenario aims to increase productivity. The yield increase is to be achieved by a narrowing of the crop rotation. In this scenario, the demand of maize (for energy and fodder) and the world market price of maize remain high. The distribution of crops changes while the farming practices stay the same as in the status quo.

In scenario III the land use distribution changes towards soil-conservation practices. The scenario was based on the assumption that the share of winter crops is growing on the cost of maize. As a reaction on high income losses through erosion damages caused by heavy rainstorms, the farmers start to make use of the Chambers services that are directly aimed at preventing soil erosion. The ÖPUL becomes stronger and offers more financial support to the farmers.

By combining the cropping scenarios with the sites, the scenarios for the status quo are developed for a worst case, where maize and other row crops are allowed on slopes and highly sensitive sites and a best case where the high erosive crops are grown on sites of low sensitivity.

In a further step conservation measures are added to the scenarios as well. Additional conservation measures include zero tillage and the application of under crops and intercrops.

Data base for the site assessment

The data from the Hydrological Atlas of Austria (Strauss 2007) served as input for the site assessment. The original dataset included the R-, C-, K and LS values for Lower Austria as used for the Universal Soil Loss Equation (cf. chapter 1.3). The calculation of the single factors was based on a raster calculation in ArcGIS 9.2 with a grid cell size of 10*10m. Due to missing data the P factor was fixed at P= 1 and therefore not taken into account.

<u>Rainfall factor (R)</u>

The R-factor, which is determined by the precipitation, is a statistical calculation from the annual summation of rainfall kinetic energy of a storm times its maximum 30-minutes intensity (Morgan 1999). Precipitation is the driving force for soil erosion by crushing aggregates, preparing transportable particles and initiating surface run-off that transports dissolved material and detaches further particles.

The database for the calculation of the R-term was the average annual precipitation of the years 1960 to 1990, which are available with a resolution of 7.5*7.5m for Austria in the dataset of the Hydrological Atlas of Austria (Strauss 2007). The R-factor in the Tullnerfeld ranges from 51 to 57 (Figure 13). Almost 60 % of the erosive rainfalls occur in the months April to August.

<u>Cropping management factor (C)</u>

Soil cover and crop rotation on erosive sides including catch crops and cover crops helps to mitigate the risk of soil erosion. A permanent cover of the soil surface with covering crops or crop residues reduces the soil loss during the winter.

For the calculation of the C-term the data of CORINE Landcover was taken into account to differentiate between forest, settlement, agriculture, etc. Within the group of agricultural areas the share of crops within the agricultural area was evaluated (Strauss 2007). The different crops vary regarding their potential erosion risk depending on the time of soil cover and the applied cropping practices. This factor varies locally and incorporates effects of tillage management, type of crop, seasonal distribution, crop rotation and crop yield level.

Depending on the distribution of crops within the municipality (Statistik Austria 2001) one C-value was generated for the whole area of the municipality. In Michelhausen it is 0.316. The equation and further explanations can be found in Strauss (2006b, 7- 10). Figure 13 shows the R- and K-values for Michelhausen.

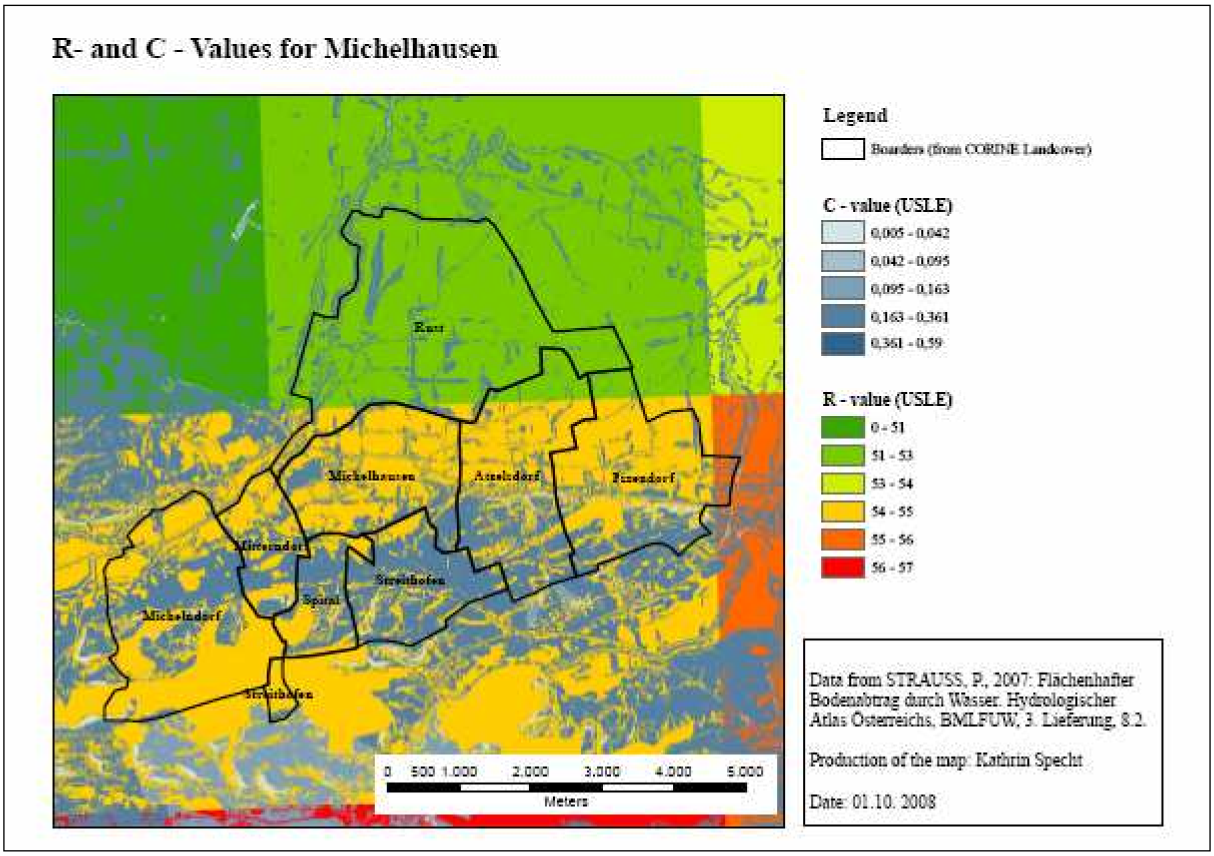


Figure 13 The R value ranges from 51 to 55 while the C-values for Michelhausen are nearly constant (source: Strauss 2007)

The map of R- and C-values shows, that these values are almost constant over the area: Range of R-value= 51- 54; C-value= 0.316.

Soil erodibility factor (K)

Soil erodibility (K) indicates the susceptibility of soils to the different types of erosion. It is calculated on the basis of texture, structure, permeability and organic matter. High proportion of sand and silt and low organic matter content increases the erodibility. The soil texture influences the water retention capacity as well as the stability of the soil.

The calculation of the K is based on the Soil Map of Austria, which is available as a digital dataset (Figure 14). A summary of the method for the generation of the Soil Map of Austria can be found in Schneider (2001).

The K-factor quantifies the cohesive character of a soil type and its resistance to dislodging and transport due to raindrop impact and overland flow shear forces. A higher content of sand and silt increases the vulnerability to soil erosion. A higher content of clay means a stronger cohesion, which makes the soil more stable against precipitation but also leads to a higher rate of surface run-off. Organic matter decreases the erodibility because it reduces the risk of soil detachment and increases the infiltration.

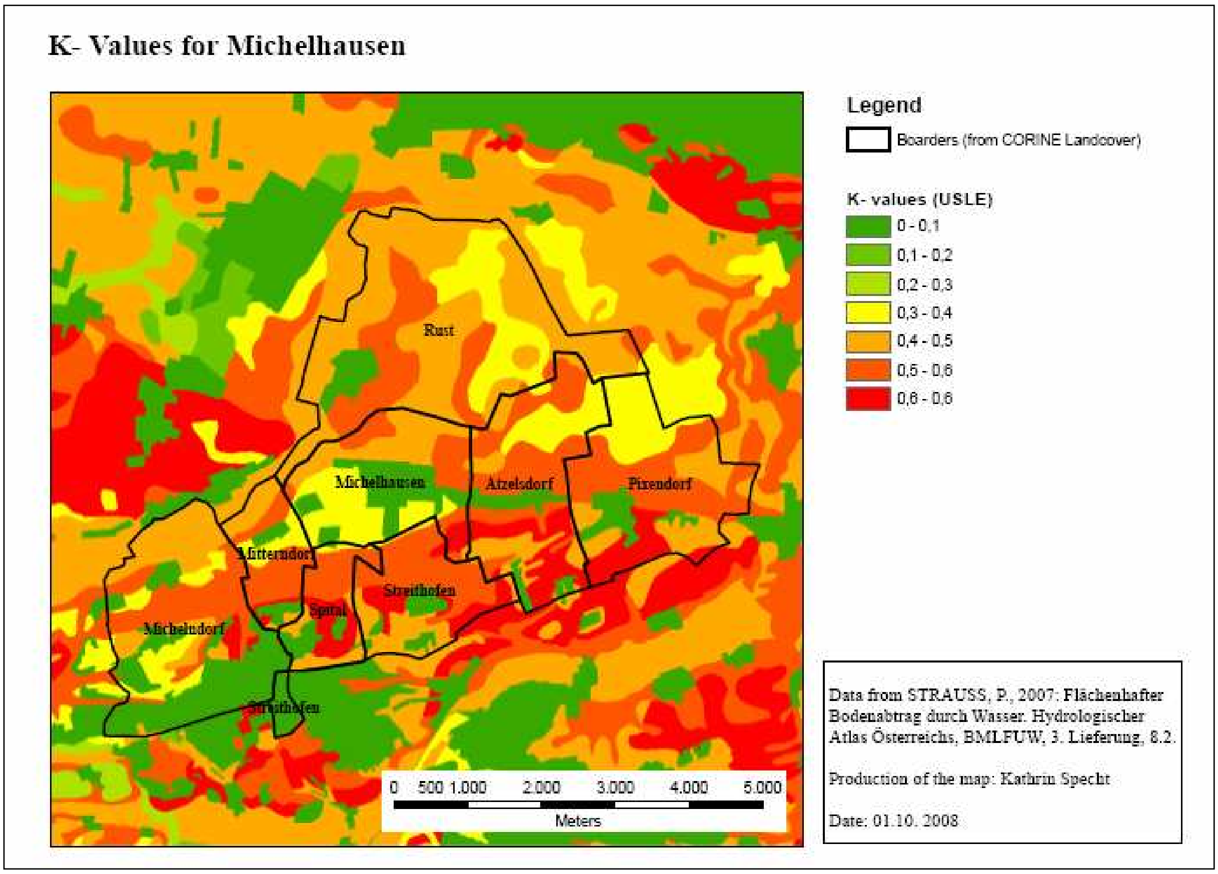


Figure 14 K values for Michelhausen indicating the susceptibility of the soils (source: Strauss 2007)

<u>Topography factor (LS)</u>

The slope lengths (L) and the slope steepness (S) are usually considered together. The soil loss increases with an accumulation of run-off by longer slope or increasing steepness. The database for the calculation of the L- and S-term was a digital elevation model (DEM) with a resolution of 10*10m. The algorithmic of Jenson and Domingue (1988), which is implemented in the GIS-system, was used for the creation of the dataset for the Hydrological Atlas of Austria. Strauss (2006b, 11- 13) discusses the advantages and disadvantages of this method.

Assessment of the site-specific risk (Intersection of LS- and K-values)

Slope length and steepness and the soil properties are considered to be the most important parameters to assess the vulnerability of the site. As the R-factor is nearly constant over the whole study area (Figure 13) and the P-factor was set to 1 those parameters are not taken into account. All calculations were performed using the Geographic Information System ArcGIS 9.2. The assessment includes two main steps:

1. Generating of a site-sensitivity-map regarding soil and topographic preconditions by intersecting LS-values (USLE) und K-values (USLE);
2. Classification of the LS*K values into three sensitivity classes.

For the first step the LS and K-values from the database for the Hydrological Atlas of Austria (Strauss 2007) were imported to the map and clipped with the boarders of the municipality. To make the data compatible for the calculation the floating point raster datasets were converted to shape files. The floating point raster were transformed to integer raster by using the Spatial Analyst Tools > Math > Int.

The next step was to convert the integer raster to the shapefiles geometry type using Conversion Tools > From Raster to Polygon. The result was the original floating point raster values in the attribute table of an integer raster dataset.

The final step was to connect the two layers and combine the values of LS and K. This was performed using the Spatial analyst > Join and Relate > Join data by spatial location. The outcome was a dataset with the combined attributes of both datasets.

Corresponding to the crop risk, the aim was to define three classes for high, medium or low sensitive sites. To ensure easy handling of the produced data, which ranged from 0 to 0.07, the values were multiplied with 100. Therefore the range of values lsk*100 is from 0 to 7. The classes are divided by finding the median and using the natural breaks (Table 11). This classification scheme that is included in ArcGIS 9.2 (Properties > Classify) associates data where there are jumps in values, and pairs them in the same break value.

Table 11 Classification scheme for the site-specific risk classes

Break values	**Site-specific risk**	**Class**
5 -7	High risk	**1**
2 -5	Medium risk	**2**
0 -2	Low risk	**3**

Natural breaks are good for taking care of outliers, which could otherwise set the whole scheme off balance. The sensitivity corresponds to the site-specific erosion risk. The results of the assessment are shown in chapter 3.4.

3. RESULTS AND DISCUSSION

3.1 DESCRIPTION OF SOIL DEGRADATION AND DAMAGES

Damages due to soil erosion

On-site damages due to soil erosion are caused by loss of nutrients, decline of organic matter and structural deterioration (Steiner 1996, 19). The decline in productivity depends mainly on the quality of soil and the crop planted. The fields in Michelhausen are characterised by very deep soils (Cambisols > 100cm) with a high content of loamy silt, sandy loam, silty loam and loam from deep loess layers (cf. Table 3) that are vulnerable for run-off.

Referring to the geological and soil-physical preconditions, the landscape can be described as a number of soft hills and valleys covered with loess layers. Agricultural products are grown in the valleys as well as on the top of the hills and on the slopes. The high water retention capacity of the loess makes it ideal for agriculture but on the same time it can be eroded very easy. Usually the erosive rainfalls occur during the summer but in the year 2008 the region was affected by heavy rainstorms in spring and early summer coinciding with the period of less soil cover. On many fields in the area arable topsoil was carried off (Figure 15) with simultaneous formation of rills, which reduces the land suitable for production.

Figure 15 On-site erosion damages on a field with sugar beet. The fertile soil was removed from the upper slope and deposited downstream (source: Kathrin Specht 2008)

During the erosive rainfalls in the early summer 2008 large gullies were formed on the fields located on the slopes (Figure 16). The depth of the gullies is only limited by the depth of the underlying rock layer. They have a depth of up to three meters and are therefore much too deep to be levelled by tillage, which makes it an irreversible damage. Whilst these peak flows from the intense rainfall, tons of the highly fertile soil were removed from the agricultural field and deposited in lower parts of the landscape.

Figure 16 This gully in Pixendorf (eastern part of the municipality Michelhausen) is a highly visible form of soil erosion that affects soil productivity and restricts the land use (source: Kathrin Specht 2008)

Another crucial aspect, especially concerning the yield and the productivity, are the negative effects on the existing plants and the plant quality (LUNG 2002, 14). Some of these impacts are visible such as the uprooting of plants or the destruction of plants that are broken under the energy of mud flows. Plants and fruits are injured or contaminated with soil material.

The uncovering of plant roots increases the vulnerability of the plants and the stability of larger plants is reduced (Figure 17). Invisible damages are the covering or the removal of seeds. The loss of top soil means at the same time a reduction of the soil that is available for plant growing. The necessary regeneration of the field means additional costs for the owner.

Figure 17 Visible on-site damages on the plants in Pixendorf (Michelhausen). Uncovered plant roots of maize and sun flowers (source: Kathrin Specht 2008)

Off-site damages occur downstream, where sedimentation harms field tracks, roads and residential areas (Figure 18) or outlet ditches, irrigation, drainage systems and water reservoirs. In addition water turbidity and nutrient and pesticide entry damage the aquatic ecosystem (Steiner 1996, 20). Soil eroded from the gullied area causes siltation of waterways, roads, reservoirs and sewers. The heavy rainfall event in April 2008 resulted in large mudflows on the streets and field tracks, which means a considerable damage to the infrastructure.

Figure 18 Off-site damages due to soil erosion in residential areas and on field tracks in Tullnerfeld after erosive rainfalls in spring (source: Rosner 2003)

3.2 ANALYSIS OF LAND USE AND FARMING PRACTICES

Analysis of statistical data

Statistical data from the Statistic Austria was used to get an indication of the crop-distribution within the study area.

Figure 19 shows that maize represents more than 34 % of the crops in the area which corresponds to 1047ha out of the total 2547ha of arable land (Maize-fodder/silage, Maize corn-cob and Maize grain are grouped together). Another 25% is represented by the winter crops (winter wheat and winter barley).The rest are sugar beets (9.6 %) and smaller amounts (2-3 %) of vegetables, peas and sunflowers. Crops that are grown on less than 30ha are not diagrammed in the figure. The full list can be found in Annex B-1.

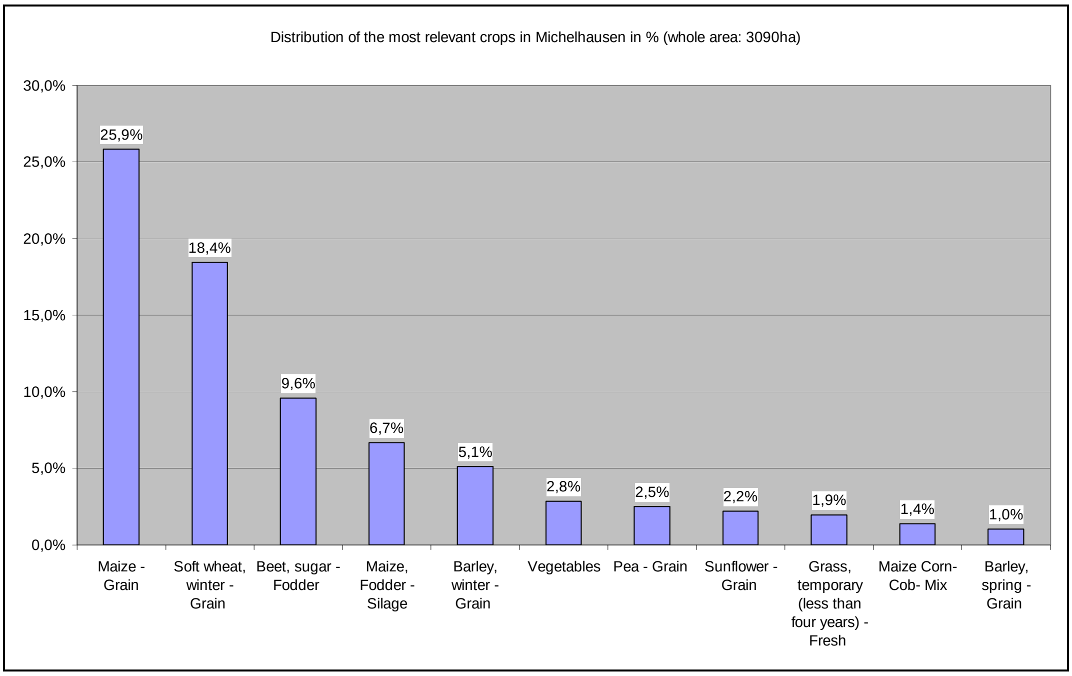


Figure 19 Most relevant crops in Michelhausen. The crop share is dominated by maize. All crops with > 30ha are diagrammed (source: generated from Statistik Austria 2008)

Results of the survey on farming practices

The following chapter presents the results of the survey on farming practices (Annex A-1 and A-2). The main crops that are grown in the area of Michelhausen are maize, winter wheat, sugar beet, winter barley, pea and sunflowers. According to the farmers the production system in the regarded part of the municipality is conventional without exceptions. Farmers mentioned that there have been some organic farmers in the area, who returned to conventional farming a few years ago. In general, the tillage type is conventional ploughing. Only in scattered instances farmers try to avoid tilling. The ploughs have a usual working depth of 25cm and combined with other machinery uses there are up to 10 crossings within the field per year. There are no irrigation or drainage systems in the area. On the farm level the single fields are very small compared to the European average, the average field size in Michelhausen is 1 to 1.5ha. From the whole range of soil affecting measures, the most relevant is the cultivation of winter cover crops, which is applied in 80% of the fields in the municipality. Despite the winter crops all crops have a relatively short cropping period (130 to 160 days) and a long period with less than 80 % soil cover. Referring to the fact that most of the crops are planted in the calendar weeks 13 to 17 the time with less than 80 % soil cover coincides with the period of heavy rainstorm events.

There is also some minor livestock production (bovine) in Michelhausen used for meat production that is virtually irrelevant compared to crop production.

An overview of the typical cropping systems modified from the questionnaire on farming practices (Annex A-1) and their characteristics in Michelhausen is given in Table 12.

Table 12 Typical cropping systems and their characteristics: Farming practices in Michelhausen are characterised by conventional farming with ploughing

Crop	Maize - Grain	Soft wheat, winter - Grain	Beet, sugar - Fodder	Maize, Fodder Silage	Barley, winter - Grain	Pea - Grain	Sunflower - Grain
Production orientation	Conventional	Conventional	Conventional	Conventional	Conventional	Conventional	Conventional
Farm type	Arable farm	Arable farm	Arable farm	Arable farm	Arable farm	Arable farm	Arable farm
Tillage type	Ploughing	Ploughing	Ploughing	Ploughing	Ploughing	Ploughing	Ploughing
Irrigation type	No irrigation	No irrigation	No irrigation	No irrigation	No irrigation	No irrigation	No irrigation

One of the most important indicators for the vulnerability of the soil to run-off is the soil cover. Figure 20 shows the soil cover in the month of May for the main crops in Michelhausen: maize, winter wheat and sugar beet.

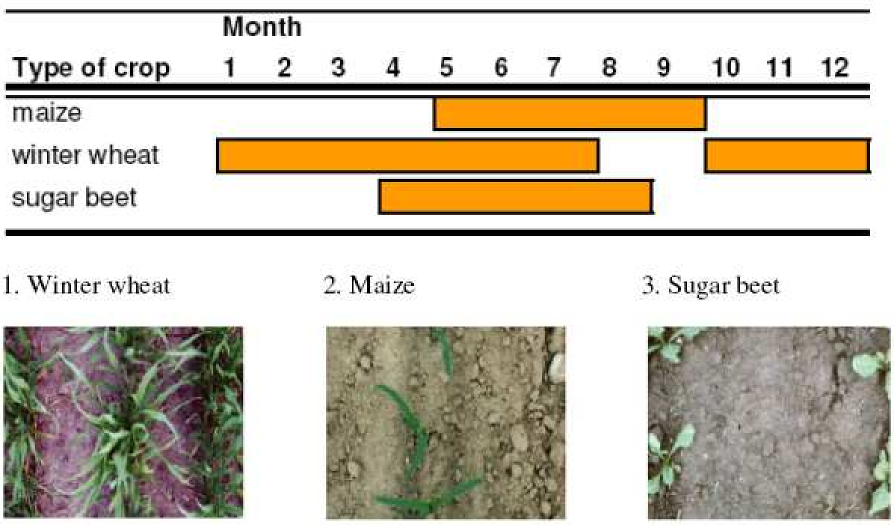


Figure 20 Soil cover during the year (graph) and in the month of May (photos) for the main crops in Michelhausen (source: MLUR, 2002 and questionnaire on farming practices)

3. 3 STATE OF SOIL PROTECTION IN THE REGION AND IN THE MUNICIPALITY

Source and impact oriented conservation measures

There is a variety of conservation measures that are theoretically available and are applicable on the agricultural sites in the case study region.

Soil protection measures can be divided in source- and impact-oriented measures. Source-oriented measures aim at reducing the potential erosion risk at the place where it starts. It includes measures that reduce the kinetic energy of falling raindrops and the flow velocity of surface run-off. For agricultural sites all measures can be considered as source oriented, that maintain the infiltration capacity of soils or protect the soil through a permanent or semi-permanent vegetation cover. Contour ploughing or the maintenance of linear landscape elements belong to the source-oriented measures as well as a correct choice of land use respecting the principles of land capability and soil suitability (CEC Task Group 4.1, 6).

Impact-oriented measures aim at reducing or interrupting the transport of detached material to other protected areas such as surface water bodies, infrastructure, housing areas, edging agricultural fields or nature reserves. Impact-oriented measures include all kind of natural barriers, retention areas or dams that diminish the amount of sediment being transported. Measures like grass buffer strips or soil retaining vegetation also contribute to the prevention of soil erosion downstream, by controlling both, velocity and amount of run-off. The more upstream in the catchments the measures are located the more source-oriented they are, whilst the more downstream the more impact-oriented (CEC Task Group 4.1, 7). Source- and impact-oriented measures are very closely linked. In general, source-oriented measures are more preventive conducts while impact-oriented measures are defence or mitigation actions. To reduce the risks of on- and off-site damages, prevention and source-oriented measures are considered the more effective in the long term.

Design of soil conservation measures in ÖPUL 2007

The following measures to reduce erosion are open for economic support to the farmers (Agrarmarkt Austria AMA, 2007) in Lower Austria. For some ÖPUL measures, protection against soil erosion is a side-effect of actions tackling other environmental problems. Table 13 lists up the measures associated with cropping systems and aiming to prevent soil erosion according to their description in ÖPUL 2007 or that include one of the above mentioned soil protection measures.

Table 13 ÖPUL measures (source: modified after ÖPUL 2007)

Measure No.	Measure	Explanation	Euro/ha
7	Integrated production of certain crops	Reduction of the intensity of land use by diversification of crop rotations that are dominated by cereals and maize.	150
18	Eco- points (Ökopunkte)	Protection of the cultural landscape and landscape elements by rewarding extensification of land use. Up to 12 points per ha are possible for “soil cover”.	10.70 per point
19	Planting of intercrops	Protection of the soil from wind and water erosion and rise in biodiversity by planting of winter freezing (mustard, oil radish, pea, phacelia, clover) or perennial green manure.	130- 190
20	Mulch- and direct seeeding	Reduction of nutrient loss and soil erosion by omission of ploughing in combination with the planting of green manure.	40
22	Preventive soil and water protection	Reduction of eluviation and run-off by planting of green manure and biological farming.	25- 40
24	Planting of under seeds with maize	Protection against soil erosion with maize by undersown crops (grass or mixtures of grass and legumes).	50

ÖPUL is considered being the most important agri-environmental policy measures since the entry of Austria into the European Union. In the context of the EU-regulations all European Union member states are requested to implement agri-environmental measures. Austria translated this EU regulation into the ÖPUL program, which is adapted by 70 % of all agriculture and silvicultural enterprises. But the high participation is not only explained by the high environmental awareness of the farmers. It is also due to the Austrian agricultural policy, which embedded the ÖPUL into a system of financial incentives. The agricultural payments are an important component of the rural income. With the accession to the EU, the Agrarmarkt Austria (AMA) was originated to execute the entire assignment and control of all subsidies. The administrative authorities were already familiar with the implementation of agri-environmental measures before the introduction of the ÖPUL as well as the farmers, who already experienced that these kinds of incentives can make a noticeable contribution to the income. According to Sinabell (2004) these factors facilitated both, the implementation and acceptance of new measures. This explains the smooth continuation of existing programs since the financial participation of the European Union clearly extended the available budget.

Results of the interview on the current state of soil protection

During the last years there has been a change of mind concerning the importance of soil protection in the region, which had a positive impact on the implementation of protection programmes. As a consequence of increasing problems in the context of soil erosion, local actors gave more priority to soil conservation and the issue of soil erosion has gained in importance. According to Mr. Meyer from the Chamber of Agriculture the public interest has increased, which means a serious advance in the steady progress. Broader acceptance and the awareness of the problem lead on to discussion processes. Especially in the field of conservation tillage a growing interest has been noticed by the administrative and advising authorities.

The execution of the ÖPUL- measures is based on the regulations of the Integrated Administration and Control System INVEKOS (Integriertes Verwaltungs- und Kontrollsystem). In the name of the Federal Ministry of Agriculture, Forestry, Environment and Water Management (BMLFUW) the AMA (Agrarmarkt Austria) is entrusted with the acceptance of the ÖPUL- applications, their control and the payment of the dues.

On the level of implementation and monitoring of laws, Mr. Meyer still recognises some weaknesses. The competent authority for compliance of the laws is primarily the AMA, but only 1 % of the whole area is controlled by random samples. In connection with the conservation areas the Agricultural District Office (Agrarbezirksbehörde) has a supervisory function as well. The control of the Soil Protection Law of Lower Austria is in the jurisdiction of the district administration, but they start legal proceedings only as a consequence of a complaint to the administration office. Mr. Meyer regrets that not all laws are actually executed.

One of the major objectives in the municipality Michelhausen is to support the “Good Agricultural Practice”. A main focus of the future should be on the field of prevention and measures of precaution (source oriented measures). Therefore, the Chamber of Agriculture provides an extensive consultation service, but unfortunately the farmers do not make enough use of it as yet. Some information services are directly aimed at preventing soil erosion such as advisory programmes on catch cropping or special events that deal with the subject of water erosion at the municipal level. The programmes are well-concerted to the various conditions and problems in the different municipalities. In addition, there are thematically comprehensive events, for example about the Cross Compliance or proper fertilization. A forthcoming project on climate change is prepared at the moment on the initiative of the Chamber of Agriculture.

The municipality Michelhausen is also a very active member of the ELSA and is associated in numerous networks in the field of research. There are experimental plots of the University of Natural Resources and Applied Life Sciences, Vienna, and the School of Agriculture Tulln.

In the budgetary policy of the municipalities soil protection is treated as a subordinated subject. To Mr. Meyers regret, soil conservation has no priority in the distribution of the budget. Although it finds the public approval, it is not the most promising programme of the local politicians who bid for votes.

Available and applied measures in the study area

The description of the available and applied conservation measures contains an estimation of their effects (adapted from Frielinghaus 2005) and a short statement about their implementation into practice which I derived from interviews with Mr. Meyer and three farmers from Michelhausen. Frielinghaus et al (2005, 354-362) divide the different types of conservation measures into three complexes, which are measures of

- Infrastructure;
- Soil covering/ Conservation management and
- Conservation tillage.

The tables 14-16 are extended by the submitted measures of ÖPUL 2007 (Agrarmarkt Austria 2007). This includes the farming practices and conservation measures that are available in ÖPUL 2007 (cf. Table 13).

Table 14 Infrastructure measures

Effects	Implementation
<u>Arrangement/ rearrangement of the field shape</u> Rearrangement of fields can help to mitigate the damaging effect of transportation traffic on the fields. The orientation of fields perpendicular to the wind direction reduces the wind erosion.	This measure is generally assumed to have a high efficiency, but is not applied in Michelhausen, because of the very small-scaled property situation. It can only be considered as a long term measure in the context of future land consolidation.
<u>Alteration of land use type</u> By adaption of land use to soil erodibility, erosion can be highly mitigated. Measures include protecting crops instead of erosion-enhancing spring crops, specific inclusion of perennial forage, permanent grassland as well as setting aside farmland or afforestation (Frielinghaus 2001, 355)	There are no comprehensive programmes for the whole municipality for the use or restriction of certain land for certain crops. This takes only place on single farm level.
<u>Construction of farm roads and country roads</u> The construction of roads and field tracks can decrease accumulation effects. They can route the water off from traffic lines or reduce the frequency of crossings if they are perpendicular to the direction of water flow and winds. Traffic routes can be lined by wind breaks.	Unfortunately, in the distribution of the budget it has no priority. It is important for the municipality but not the most promising programme for the local politicians.
<u>Filtering edges, shelter-belts and wind-breaks around endangered fields</u> Wind breaks and edges interrupt the sediment flows and surface run-off and function as filters to protect water and edging biotopes.	This measure is only applied in the context of land consolidations.

Table 15 Best management practices

Effects	Implementation
Selection of covering crops Winter cereals and perennial forage crops help to protect the soil surface by increasing the time of cover. They should be increased on the expense of broadstanding row crops (corn, sugar beets, potatoes, winter rape, sun flower).	Concerning this measure, there is an inverse progress. The price and therefore the yields of maize and sunflowers are high and the incentives do not compensate the income loss for the growing of alternative crops. The maximum content of maize-growing is restricted on 75 %.
Planting of catch crops The planting of winter-freezing green manure helps to increase the content of organic matter and therefore enhances the structure stabilization and the surface roughness during the erosive winter season.	The minimum is done, that is paid through the ÖPUL programme. This is the most used measure in the area.
Undersown crops Cropping of grass or undersown crops with winter cereals and cropping clover or clover/ grass mixtures with maize increases the surface cover during autumn and winter season.	This measure is only used to a small extent, but there are strong political ambitions from the Chamber of Agriculture to promote this practice.
Site-dependent soil tillage and cultivation Tillage and cultivation during wet field conditions should be avoided as well as wheel tracks before the winter season and in the early spring time to reduce soil sealing and crusting.	Farmers and experts are aware of the importance of this measure, but in many cases it is ignored. It is not part of a certain programme and therefore difficult to control.
Extensification by set-aside and rotation of fallows Extensification of intensively used agricultural land helps to regenerate the soil functions.	Tendentially the agricultural use in Michelhausen is rather intensified than extensified.

Table 16 Conservation tillage

Effects	Implementation
Mulch-seeding: Seeding into the soil surface covered with crop residues (frozen catch crops, harvest residues left at the surface or mixed into the upper soil layer) extends the soil cover, reduces the impacts of raindrops and wind, increases the infiltration, the soil structure stability and soil retention capacity. Direct seeding/ zero tillage Seeding with special machinery without tillage into stubble of corn, stubble of cereals or residues of catch crops helps to avoid erosive conditions of the seedbed.	Mulch-seeding, direct seeding or zero-tillage are not used in Michelhausen. The main reasons for non-application is the purchase of new machinery and higher management needs. The farmers fear the high investment in new equipment. Up to now there is not enough interest from the farmers to build cooperation for a shared investment. Even though it can also be used as a mean of cost reduction. There are some political ambitions from the chamber to promote conservation tillage as a common practice.

Effects	Implementation
Contour farming The cultivation should be adapted to the relief, rectangular to the inclination, tracks of cultivation function as barriers against surface run-off.	This „Good Management“- principle is sometimes ignored by the farmers, which can have a negative effect for the farmers in case of water-induced erosion damages. The insurances are not paying the damage if the crops were grown parallel to the inclination.

3.4 SITE- AND CROP-SPECIFIC RISK

Results of the assessment on the crop-specific erosion risk

The crop-specific erosion risk is the outcome from the rule-based assessment for the whole study area (municipality Michelhausen; 3090ha). The fuzzy-values that correlates the crops of Michelhausen with their associated potential erosion risks are based on the soil protecting attributes of the crops (after Frielinghaus et al. 1995; Annex C-1) and the available farming practices (source: Questionnaire on cropping systems and farming practices; Annex A-1).

The result of the crop assessment for the seven main crops in Michelhausen with changing management options is given in Table 17. The horizontal line shows the six variants of management options while the available crops appear on the vertical line. The indices of goal achievement (IGA) are the final output values for the risk of soil erosion by water (model output 3: ZEG-PV-WE). The full table with the intermediate results is given in Annex C-3. The management option No. 5 (conventional with intercrops) represents the status quo for the municipality of Michelhausen. It is obvious that the indices decrease steadily from management option 1 to 6.

Table 17 Indices of goal achievement (IGA) towards the goal: protection against water erosion, for the seven main crops in Michelhausen, 0=no goal achievement/ 1=highest goal achievement

Crop	**IGA values Management options/ Measure No.**					
	1	**2**	**3**	**4**	**5**	**6**
Tillage Type	**Reduced**	**Reduced**	**Reduced**	**Ploughing**	**Ploughing**	**Ploughing**
Undersown crops (UC)/ Intercrops (IC)	**UC +IC**	**IC or UC**	**no**	**UC +IC**	**IC or UC**	**no**
Maize - Grain	0.515	0.438	0.411	0.333	0.267	0.154
Soft wheat, winter - Grain	0.749	0.666	0.629	0.608	0.608	0.495
Beet, sugar - Fodder	0.515	0.438	0.411	0.333	0.267	0.154
Maize, Fodder - Silage	0.515	0.438	0.411	0.333	0.267	0.154
Barley, winter - Grain	0.864	0.789	0.755	0.735	0.735	0.629
Pea - Fodder	0.579	0.507	0.477	0.399	0.393	0.282
Sunflower - Grain	0.483	0.411	0.386	0.310	0.246	0.138

Based on the outcomes that are illustrated in the Table 18, the main crops of the municipality can be divided into low- medium- and high-risk crops. However, the potential soil erosion risk does not only depend on the crop-specific qualities (such as soil cover in summer/ soil cover in winter). It is mainly determined by the cropping practices and the application of measures.

Table 18 Crop-specific erosion risk indices for the seven main crops in Michelhausen grouped into three risk classes. Red= High risk/ yellow=Medium risk/ green=Low risk

Crop	**Risk classes Management options/ Measure No.**					
	1	**2**	**3**	**4**	**5**	**6**
Tillage Type	**Reduced**	**Reduced**	**Reduced**	**Ploughing**	**Ploughing**	**Ploughing**
Undersown crops (UC)/ Intercrops (IC)	**UC +IC**	**IC or UC**	**no**	**UC +IC**	**IC or UC**	**no**
Maize - Grain	0.515	0.438	0.411	0.333	0.267	0.154
Soft wheat, winter - Grain	0.749	0.666	0.629	0.608	0.608	0.495
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Maize, Fodder - Silage	0.515	0.438	0.411	0.333	0.267	0.154
Barley, winter - Grain	0.864	0.789	0.755	0.735	0.735	0.629
Pea - Fodder	0.579	0.507	0.477	0.399	0.393	0.282
Sunflower - Grain	0.483	0.411	0.386	0.310	0.246	0.138

Considering the distribution of land use and farming practices in Michelhausen (cf. chapter 3.2) the result of the crop-assessment answers the former expectations that the current land use practices lead to a high risk of erosion. For the management option No.5 that represents the status quo in Michelhausen, four of the seven main crops are classed with high risk (maize-grain/ fodder, sugar beet and sun flower), which connotes a high crop related risk for more than the half of the whole agricultural area. Two crops were evaluated with a medium risk (winter wheat and pea) while for one crop (winter barley) the assessment estimated a low risk.

Results of the assessment on the site-specific risk for the southern part of the municipality

For the evaluation of sites the southern part of the municipality (Streithofen; Spital) was selected for a more detailed consideration. The site specific erosion risk is the outcome from the intersection of LS- and K-values of the USLE (cf. chapter 2.6). Figure 21 shows the result of the site assessment.

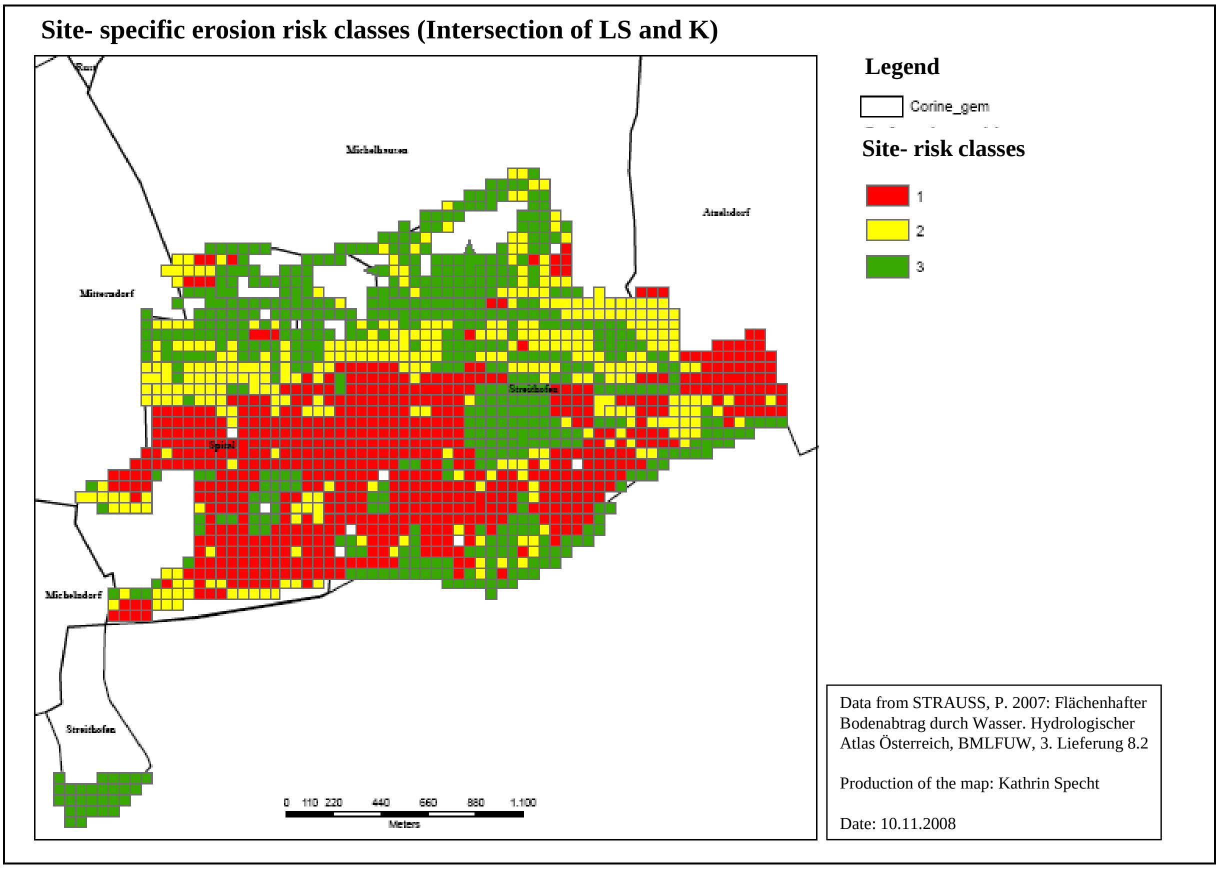


Figure 21 Site-specific erosion risk classes for the southern part of Michelhausen (Spital; Streithofen) as emerged from the intersection of USLE values LS and K. 1= High sensitivity/ 2=Medium sensitivity/ 3=Low sensitivity (data source: Strauss 2007 and CLC 2000)

The share of risk classes (Table 19) shows that there is a share of 23 % that can be classified with medium risk. 40 % of the area has a high site-sensitivity (Figure 22) which is mainly referable to the slope steepness in these areas. 37 % of the sites are found to have low site-sensitivity and therefore a low potential site-specific erosion risk.

Table 19 illustrates the distribution of the site specific erosion risk within the municipality and its areal and percentage share.

Table 19 Site-specific erosion risk: Share of risk classes in the area of Streithofen and Spital

Site specific erosion risk	Share of risk classes	
	raster	percentage
High =1	647	40%
Medium =2	366	23%
Low =3	597	37%

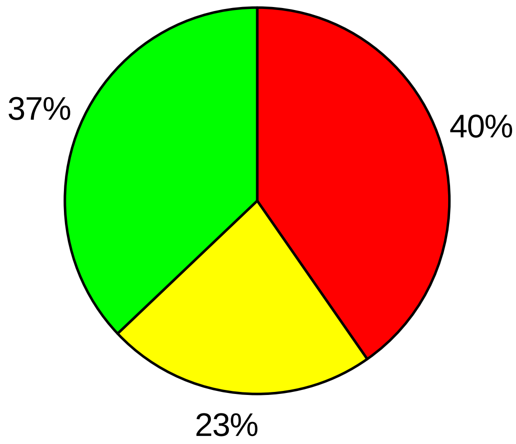


Figure 22 Risk values and their share in percentage

3.5 EROSION RISK IN THE CONTEXT OF CHANGING LAND USE AND POLICIES

Erosion risk with varying parameters

The available data on site-specific erosion risk, distribution of crops and crop-specific erosion risk that was compiled in the preceding chapters (cf. chapters 3.1 to chapter 3.4) serves as a basis for the development of scenarios to foresee possible future land use and farming practices. Primarily, the modelling results are presented. Subsequently, the outcomes are related to the interview results and other relevant literature. Finally, the impact of changing crop rotation will be compared to the impact of changing management option. For the construction of those scenarios the most important parameters are varied. Based on the current land use (status quo) the inputs are modified:

- First parameter to be modified: crop rotation/ crop share
- Second parameter to be modified: management options

The procedure presented here assumes that the actual size of agricultural area is neither extended nor narrowed.

Impact of the crop share - modelling results

The following calculations illustrate the influences of the crop share on the erosion risk in the area. The first scenario (scenario I) uses the current land use. In the first variation (scenario II) the composition of crops is intensified. The crop rotation is changed in favour of intensive crops (+10 %) on the extent of less intensive crops. For the second variation (scenario III) an extensification of land use is assumed and the share of maize is reduced by 10 % to the extent of more extensive crops.

1) STATUS QUO

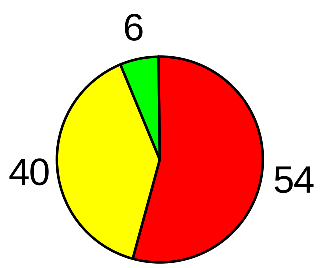
- Current land use

Table 20 presents the share of crops within the municipality of Michelhausen (in ha and percentage) as derived from data of Statistik Austria (2008). Each of the seven main crops is connected with a certain crop-specific risk class that was calculated with the fuzzy approach for goal achievement.

For the current land use, four of the seven main crops are associated with a high crop-specific erosion risk (maize-grain/fodder, sugar beet and sun flower), which stands for more than half (54 %) of the whole agricultural area. Two crops were assessed with a medium risk (winter wheat and pea) which represents a share of 40 % of the available area, while for one crop (winter barley with a share of 6 %) the assessment reached a low risk.

Table 20 STATUS QUO: each of the seven main crops in Michelhausen is associated with a crop-specific risk class. The share of crops for the current land use is shown in ha and percentage

Crop	area/ha	Risk Class	%	Share of risk classes in %
Maize - Grain	799	High	31	
Soft wheat, winter - Grain	570	Medium	22	
Beet, sugar - Fodder	296	High	12	
Maize, Fodder - Silage	206	High	8	
Barley, winter - Grain	158	Low	6	
Pea - Fodder	78	Medium	3	
Sunflower - Grain	68	High	3	
Others	372	Medium	15	



2) INTENSIFICATION

- Same farming practices, intensification of crop rotation

In this first modification (scenario II) the share of maize was raised at the expense of alternative crops. The rationale for this assumption is the expected rising demand of maize and sugar beet for energy and fodder and the stable or increasing world market price, which will be discussed subsequently. Maize and sugar beet are associated with a high crop-specific erosion risk for the actual farming practices. Therefore, the overall risk rises in interdependency with the increase of those two crops (Figure 23).

The negative impact of the crop-specific risk in the study area is directly correlated to the amount of maize and sugar beet, if the farming practices remain the same.

3) CONSERVATION

- Same farming practices, extensification of crop rotation

For scenario III the share of maize is reduced by 10%. This is based on the assumption that the crop distribution changes towards more soil-conserving crop rotations. The instruments for soil protection become stronger and policy programs offer more financial support to farmers who cultivate crops, that are associated with a lower crop-specific erosion risk. The comparison of the scenario III with the status quo (Figure 23) illustrates, that the share of high risk crops decreases from 1369 to 1114ha for the extensification of crop rotations, even if the farming practices remain the same.

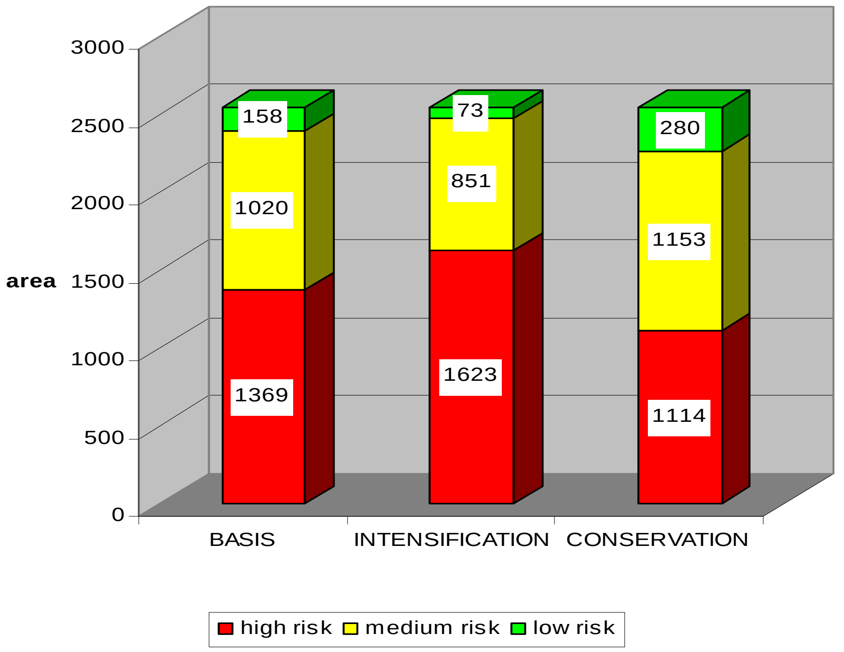


Figure 23 Comparison of the overall erosion risk for three variants of crop distribution; the increase of the potential erosion risk is directly correlated with the increase of row crops

The bar chart on the influence of crop distribution (Figure 23) shows that the increase of the potential erosion risk is directly correlated with the increase of row crops. With the current land use situation the share of highly erosive crops is already 54 %. In the southern part of the municipality at least 40 % of the area is classified with high site-specific erosion, which signifies that the share of high-erosive crops can not be raised without causing the inevitable overlapping of highly erosive crops with highly erosive sites. In view of the fact that there are crop rotations as well, it is (even for the current situation) impossible to avoid the use of highly risk sites for cultivating highly risk crops. Keeping the share of highly erosive crops within a certain limit (e.g. 50 %, half of the agricultural area) could be defined as a policy aim for those areas that are characterized by a high share of erosive sites.

Discussion on the modelling results related to changing demands in agriculture

The scenarios are connected to the actual trends in agriculture and discussed by interpreting the results of the previous chapter and relating it to relevant literature (Sinabell 2004; Umweltbundesamt 2005; Umweltbundesamt 2007; UN Department for economic and social affairs 2007).

Figure 23 shows, that the change of land use towards a reduction of high risk crops (scenario III-CONSERVATION) could be a way to reduce the potential erosion risk. However, the trend in agriculture is developing conversely. Measures that are applied to counteract the adverse effects can slow down the process of intensification. According to Umweltbundesamt (2007a) even the ÖPUL is not strong enough to stop the increasing intensity of agricultural land use. Statistical data (Statistik Austria 2008) illustrates how the yields of agricultural products are constantly increasing since the 1950s. This was reached by the steady industrialization of agriculture. In the field of crop farming the intensification has been mainly achieved by the cultivation of high yield crops. The rising intensification of the agriculture that goes with the use of heavy machinery, bigger field units and the narrowing of crop rotation is connected with a high negative impact on the soil.

With the entry to the European Union, the product prices were adapted to the lower EU price level. For bridging the economic losses, the Austrian farmers were supported with compensatory payments that have been reduced gradually since 1999 (Sinabell 2004). The economic pressure on the farmers and their decisions remains very serious. According to Umweltbundesamt (2007, 90) the Austrian Action Plan for Biomass promotes the increase of biomass production from agriculture and forestry to meet the requirements of future energy production. As a consequence, the demand of biomass for biogas production is to be developed intensively (Table 21).

Table 21 Demand of biomass for energy production for the year 2004 and scenarios for the future demand in Peta- Joule (PJ) (source: Umweltbundesamt 2007a)

	2004	2010	2020
		Biomass- energy for combined heat and power	
Biomass (Biogas)	1	6,8	9
Biomass (Biofuel)	0,2	1,2	1,3
		Biomass- energy for fuel	
Biomass (Biogas)	0	3	35
Biomass (Biofuel)	0	31	37
		Total demand	
Biomass (Biogas)	1	9,8	44
Biomass (Biofuel)	0,2	32,2	38,3

Schumacher (2008) predicts a rising demand of products from agriculture for biofuel and bioethanol production and even connects this assumption with the tendentially increasing prices for energy crops. Figure 24 shows the development of prices for energy crops from 2002 to 2009.

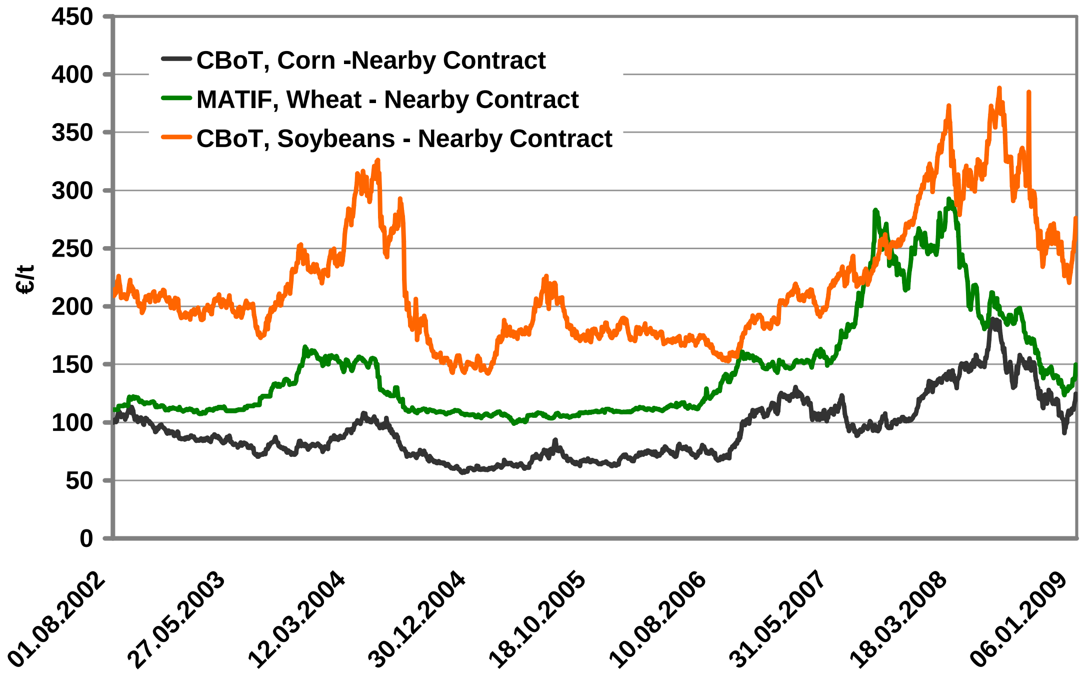


Figure 24 Development of prices for wheat, maize and soy beans from 01/2002 to 01/2009 (source: Schumacher 2009)

A facility is currently under construction, which aims at producing around 200.000 m^3 of bioethanol. Starting from autumn 2007, the input products to be processed are mostly wheat, but also maize and sugar beet syrup (UN 2007, 13). The rising need of biomass for renewable energy is supposed to be one of the key drivers for the intensification of agricultural production. Beside the expected and well-known negative impacts of intensive agriculture the expansion of areas for renewable sources of energy and renewable raw materials is politically intended. The UN (2007) states in the SD report that *"Austria has set itself ambitious targets in terms of energetic use and use of biomass from agriculture. A number of facilities have already been erected, and new ones are being added constantly, that allow processing of biomass from agricultural production into fuels."*

These trends indicate the intensification of the future crop production. As the demand of energy crops will increase, it is highly important to combine the future production with accompanying measures. Against the background of intensification, it is a must-do to maintain the agricultural land in good conditions for ensuring future productivity and soil protection. Even with a share of 54 % of maize, sugar beet and sunflower the upper limit of intensification has not been reached yet for the study area. Assuming that the cultivation of those "mainstream" crops is not reduced but enlarged in the future, there are still some measures available that could have a positive influence on the over-all erosion risk. These measures and the impact of farming practices and management options are presented and discussed in the following chapter.

Impact of farming practices and management options- modelling results

The results of the fuzzy-based calculation show, how the farming practices (including management options and measures) can influence the effect of certain crops on the erosion risk. The overview table (Table 22) includes the assessment for the status quo (management option No.5) and five further combinations of tillage systems and measures. The values represent the varying effect of the specific crops, depending on the type of cultivation. The risk is based on the soil protecting attributes of the crops (after Frielinghaus et al. 1995, Annex C-1).

Table 22 shows the results for the distribution of the crop-specific risk classes using different tillage types and measures for extended soil cover. For the farming practices 1-3 "reduced tillage" is assumed as tillage type. The farming practices 4-6 use "conventional ploughing" as tillage type. The first management option combines reduced tillage with intercrops and undersown crops (1). The second alternative uses either intercrops or undersown crops (2), while the third option provides no measure of soil cover at all (3). The next three options assume conventional ploughing as tillage system. For these farming practices, ploughing is combined with intercrops and undersown crops (4). The management option (5) uses conventional ploughing in combination with whether intercrops or undersown crops (currently applied in Michelhausen). The last alternative uses conventional ploughing without any measures (6).

Table 22 Crop specific erosion risk classes for different tillage types (reduced; ploughing) and measures of soil cover (undersown crops; intercrops)

Crop	**Risk classes Management options/ Measure No.**					
	1	**2**	**3**	**4**	**5**	**6**
Tillage Type	**Reduced**	**Reduced**	**Reduced**	**Ploughing**	**Ploughing**	**Ploughing**
Undersown crops (UC)/ Intercrops (IC)	**UC +IC**	**IC or UC**	**no**	**UC +IC**	**IC or UC**	**no**
Maize - Grain	0.515	0.438	0.411	0.333	0.267	0.154
Soft wheat, winter - Grain	0.749	0.666	0.629	0.608	0.608	0.495
Beet, sugar - Fodder	0.515	0.438	0.411	0.333	0.267	0.154
Maize, Fodder - Silage	0.515	0.438	0.411	0.333	0.267	0.154
Barley, winter - Grain	0.864	0.789	0.755	0.735	0.735	0.629
Pea - Fodder	0.579	0.507	0.477	0.399	0.393	0.282
Sunflower - Grain	0.483	0.411	0.386	0.310	0.246	0.138

Maize, sugar beet and sun flower remain highly erosive crops as long as the tillage system is conventional, even when further measures for extended soil cover are applied. This can be explained by the general low soil protecting attributes of the plants (soil cover, process of growth). As a model output, winter wheat is deemed to be highly soil protective in combination with reduced tillage systems but remains in the range "medium" if cultivated with less efficient farming practices for soil protection. The assessment of pea results in “medium” values for every practice except the variant that implies no measures at all. Winter barley appears to be highly soil protective even without reducing the tillage, which is explained by the fast plant growth and the high degree of soil cover during summer and winter.

Figure 25 shows the effect of the crop-induced erosion risk related to the current situation of crop distribution within the area (Michelhausen).

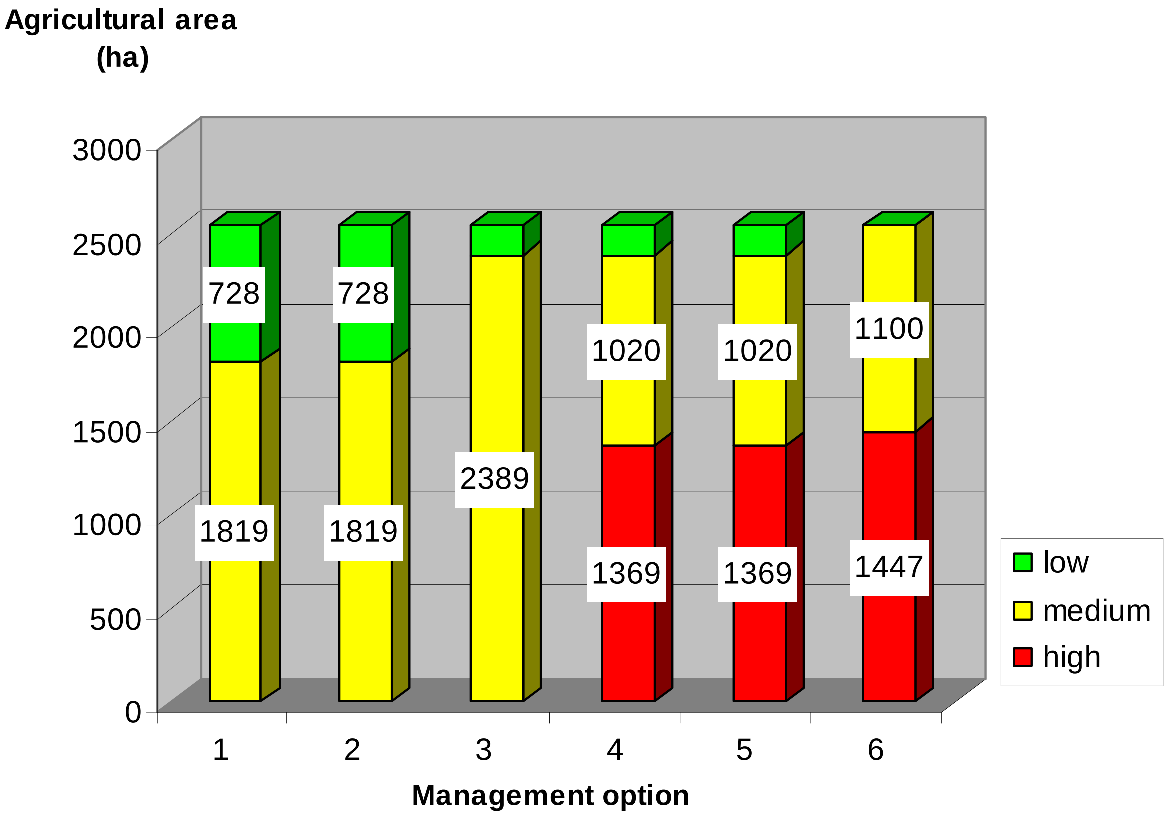


Figure 25 Potential crop-induced erosion risk in ha of the whole agricultural area; changing the management options has a highly positive effect on the overall distribution of the erosion risk

The model output appears to be the same for the application of intercrops *and* undersown crops as for the application of either intercrops *or* undersown crops. This applies for conventional and reduced tillage systems. The bar chart (Figure 25) shows no distinction of effects if intercrops and undersown crops are combined. The basic trend is an increase of the crop-specific risk from one to six, while the classes stay constant between option one and two and between option four and five. Intercrops and undersown crops appear to be as efficient as individual measures as they are in combination. This is explained by the division into classes: the abstracting of the real values obliterates the fine differences. The illustration leads to an underestimation of the individual measures. A more detailed examination about the influence of the individual measures on the potential crop-specific risk is given in Figure 26.

The x-axis of the graph shows the six management options, while the arithmetic mean of the indices of goal achievement (IGA) appears on the y-axis.

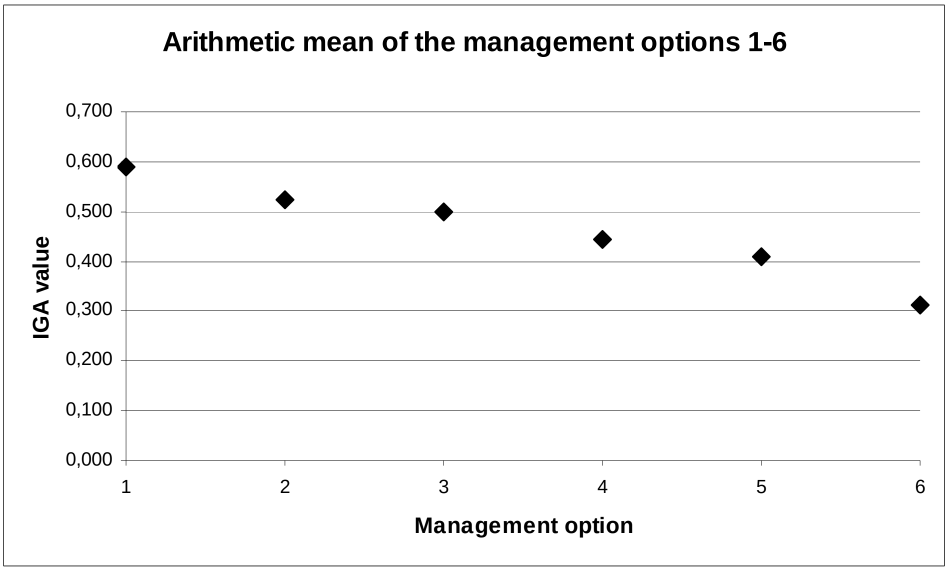


Figure 26 Arithmetic mean of the IGA values for the six management options decreasing constantly from 1 to 6

It is evident that the soil protective factor of the cropping system declines steadily. There is a significant decline between management option one and two and a slight downturn between four and five. The model documents a difference of cropping-management options in terms of the protection against soil erosion.

Comparing the modelling results of the crop-share scenarios (Figure 23) with those of the different management options (Figure 25) it can be concluded, that the application of measures (primarily reduced tillage) has a higher impact on the overall crop-specific erosion risk than their actual share. Therefore the potential benefits arising by changing the management options are more promising than by changing the crop share. As the comparison of measures shows the high influence of the tillage system on the crop-specific erosion risk, the following discussion focuses on the application of mulch- and direct seeding as a mean to control soil erosion.

Discussion on the modelling results in the context of the interview and further literature

The results of the survey and interview on farming practices showed that ploughing is area-wide used as tillage system for the preparation of the seedbed in the case study area (Michelhausen). The advantages and disadvantages of alternative tillage systems are discussed in the context of the interview and relevant literature (Kächele et al. 2001; Rosner 2003; Klik 2008).

Beside the positive effects of ploughing (loosening and aerating, bringing up more nutrients to the surface, destruction of weeds, displacing residues of previous crops in lower soil layers, quicker warming of the soil in spring) the creation of the fine seedbed is the major variable that indices soil erosion. Resulting from the interview, the cultivation of catch crops during the winter is most commonly applied in Michelhausen, while tillage practices that reduce soil erosion problems (e.g.

mulch/direct seeding) are only applied to a slight extent. A study on behalf of Umweltbundesamt (2005) investigated the efficiency of intercrops as a measure to minimize soil erosion. The financial support of intercrops was an innovation in ÖPUL 2000. The results of this study show that the measure can efficiently decrease soil erosion. Nevertheless, the report pointed out that this measure should not be applied as a single measure and recommended combinations with other measures. Mulch- or direct seeding is suggested to accompany the cultivation of intercrops (Umweltbundesamt 2005, 58).

The Austrian Chamber of Agriculture promoted the implementation of conservation tillage as a common practice during the last years, but without considerable success. However, these measures of conservation tillage are the ones that offer the most promising opportunity to farmers to combat erosion without requiring too many changes regarding the production systems.

To investigate the effects of conventional tillage with ploughing compared to mulch seeding and direct seeding, field experiments were run in Pixendorf (Michelhausen) by the University of Natural Resources and Applied Life Sciences Vienna from 1994 to 2005 and by the Chamber of Agriculture from 1994 to 2006 (Table 23). The experiments' main objectives were to compare the amount of loss of soil, nutrients and organic matter in three tillage systems (conventional/ mulch-seeding/ direct seeding) as well as the influence of different tillage systems on the yield. Table 23 illustrates the effect of different tillage systems compared to conventional ploughing on run-off and soil loss.

Table 23 Effects of conventional tillage with ploughing compared to mulch seeding and direct seeding on experimental plots in Pixendorf (Tullnerfeld)(source: Klik 2000b)

Reduction effects	**Tillage type**		
	conventional	**Mulch seeding**	**Direct seeding**
Soil loss in t/ha	6.5	2.07	1.14
Reduction		68 %	82 %
Loss of C- organic matter in kg/ha	50.5	15.1	13.23
Reduction		70 %	74 %
Run-off in mm	21.4	20.94	19.73

The average soil loss dropped from 6.50 t/ ha/ year (conventional tillage) to 2.07 t/ ha/ year with conservation tillage in cover crops and to 1.14 t/ ha/ year with direct drilling systems.

A positive side-effect of the alternative practice is the reduction of nitrogen loss from 9.9 (conventional) to 3.9 (mulch seeding) respectively 2.7 kg/ ha (direct seeding) and the reduced loss of phosphorus from 5.2 to 1.5 respectively 0.9 kg/ ha.

One reason for the non-use of alternative tillage systems, which is often mentioned by farmers, is the decrease of productivity and thereby a reduction of yields and income. Table 24 shows the influence of different tillage systems on the average yield of the cropping product.

Table 24 Effects of different tillage systems on the average yield on experimental plots in Lower Austria 1994-2006 (Rosner 2008)

Cultivation method/ tillage system	**Mistelbach**	**Phyra**	**Pixendorf**
Conventional Grubber- Plough	100	100	100
Grubber without green manure	100	91	99
Grubber with natural vegetation	97	87	102
Grubber – Mulch seeding 1kg Phacelia tanacetifolia + 8kg buckwheat + 3kg clover A + 3kg clover B + 2kg yellow mustard + 2kg oil radish	96	103	98
Grubber – Mulch seeding 7kg Lathyrus + 11kg Vicia+ 3.7 kg buckwheat +1kg clover A+ 1kg clover B + 0.4kg yellow mustard	93	110	103
Grubber- Direct Seeding 7kg Phacelia tanacetifolia + 3kg yellow mustard	90	106	101
Grubber- Direct Seeding 80kg green rye	89	95	95
Grubber- Direct Seeding 120kg summer barley	97	108	108

The results (Rosner 2008) show that the application of reduced tillage systems does not implicitly lead to an income loss. For the experimental plot "Pixendorf" that is located within the municipality of Michelhausen, the yields even increased by the tillage reduction in four out of seven instances.

There are some difficulties related to the application of reduced tillage regarding the increase of pests (appearance of bromegrass, fusarium, snails or mice). An overview on the main problems and strategies (Frielinghaus 2002) to control them is added in Annex D-1.

A further reason for the non-application of reduced tillage, which is frequently mentioned by farmers are the high investment costs. However, there are several studies (Peter 2001; Rosner 2003) that compare the required machinery investment costs to the estimated annual cost savings. Conservation tillage has been recognized by farmers in other areas to be a valid mean to reduce costs for labour and machinery (Kächele et al. 2001, 115).

These estimations show that there are potential savings to be made by switching from conventional tillage systems to reduced tillage systems. These savings are private benefits, which can be recognised by the individual farmer.

Rosner et al. (2003) specify the further potential benefits for switching to reduced tillage systems:

- Lowering of production costs
- Fewer passes- less work time- less soil compaction
- Increased productivity
- Reduction of fuel consumption
- Lower machinery use
- Increased humus content
- Improved water retention
- Higher yields

Therefore, it is necessary to continue informing the farmers that they can benefit by switching the tillage system. The Chamber of Agriculture and further soil related actors in the municipality should encourage farmers to integrate these benefits into the calculations.

Discussion on the spatial distribution of erosion risk and the designation of risk areas

The accumulative effects of site-risk and crop-risk are given in Table 25. The combination of site-assessment and farming systems helps to define, whether the land use and farming practices are appropriate for a site or if it needs some improvement. For those fields where the combination of both site and crop risk leads to risk class "low" the measures of precaution are sufficient. For areas which are assessed with "medium", the applied measures are not sufficiently protecting the soil against erosion in some respects. This might even affect sites, where the initial situation is calculated with a low sensitivity if it is combined with highly erosive crops. Concerning an estimation of "high" risk for the combination of crops and sites, the measures of precaution are not adequate.

Table 25 Accumulative effects of farming practices and site sensitivities
(source: modified after Frielinghaus et al. 2002, 37)

Site sensitivity	**Crop-specific erosion risk**		
	Low [3]	**Medium** [2]	**High** [1]
Low [3]	Low [6]	Low [5]	Medium [4]
Medium [2]	Low [5]	Medium [4]	High [3]
High [1]	Medium [4]	High [3]	High [2]

If “high” or “medium” risk crops are combined with sensitive sites, the soil is extremely endangered in view of soil erosion. In this case the farming practices need to be changed. This comprises two possibilities: a change towards soil-conserving practices or to the cultivation of alternative cropping systems. For the municipality of Michelhausen it can be concluded that from the seven main crops only winter barley would be adequate to be grown on the steeper slopes to reach at least an aggregate of "medium" vulnerability. As winter wheat in combination with reduced tillage systems reaches a low risk value as well, this is an acceptable alternative.

The classification (Table 25) illustrates the limitation of the sites which restricts the intensity of crop production. In the case study area this natural limitation is determined by even two factors. The first natural constraint is due to the topography and the relative steepness of slopes, the second factor are the physical soil properties. For the medium-erosive sites and fields the production of row crops requires a high degree of management to obtain acceptable erosion rates. If maize, sugar beet and sunflowers are not taken out of the crop rotation for these sites; accompanying measures need to be established to increase the cover of the soil surface. Winter cover crops should be planted and undersown crops or intercrops need to be added to the farming practice. Maize, sunflower and sugar beet can be planted on low-risk sites with gently sloping or level fields. It would still be wise to use additional soil protective measures on these fields to avoid soil degradation.

To estimate the erosion risk on the single-farm level the scale needed to be adapted to a smaller level (parcels or fields). A more detailed inspection had to be carried out, if the aim was to give concrete advices to farmers on the single-farm level. However, the general issue is clear: a site with a higher sensitivity can not be cultivated with high-erosive crops if the aim was soil conservation.

The results of the site assessment for the south of Michelhausen show, that there is a high degree of disparity regarding the site-specific risk within the municipality. The sensitivity of sites varies substantially in the hilly area even within the very small-scaled municipal territory. The design of this assessment for the accumulative effects of crops and sites is rather general and can therefore only give a rough overview on the characteristics of the interaction between site-specific parameters and the applied farming practices.

Regarding the identification of erosion risk zones, the JRC (Eckelmann et al. 2006) is working on a comprehensive programme which is supposed to cover the whole European Union. In 2006 the JRC published a paper with the name *"Common Criteria for Risk Area Identification according to Soil Threats"*. This study presents an overview of common criteria to identify risk areas (Eckelmann et al. 2006, 1), including a chapter on soil erosion. For Europe as a whole a 1km grid is considered to be an appropriate resolution. However, the soil erosion risk is apparently influenced to a high amount by the agricultural land use and varies on a very small scale. The question rises, if the designation of risk areas is an adequate means to protect sensitive sites. The potential erosion risk in Austria is generally high due to its topographic preconditions. However, the actual erosion risk is mainly determined by insufficient conservation measures. The intersection of sites and cropping systems shows, that with regard to soil erosion it does not need a special program like the titling of a whole area with "EU risk area", which is based on spatial data that does not distinguish between the many types of cropping practices. On the one hand the small-scaled variation of erosion risk would not be tackled. On the other hand it leads to an underestimation of the impact of land use. Instead of a time-consuming and expensive designation, the affected areas need the support of concrete measures that can be taken together as "good soil conservation practices". For the case study area the most important practices to be promoted are the adaptation of farming to the topography and the application of reduced tillage systems.

The identification of risk areas is used as an instrument for the comprehensive categorisation of potentially endangered areas. But on a long-term basis, the dimension of soil erosion is determined by specific management practices, which are not covered by this approach.

Soil related actors in the study area

The ÖPUL program that is part of the second pillar of the European CAP could be extended by measures that offer financial support to farmers when cultivating and tilling steep slopes in loess areas (or on other vulnerable soils).

Reflecting the results, it is apparent, that the specific problems in the context of soil erosion belong to different responsibilities. For the municipality of Michelhausen the only measure that is implemented satisfactory is the use of catch crops and green manure in autumn and winter. In view of further measures the policies needs to be improved. Schuler (2008) explains how agricultural policies influence the potential and actual risk for soil erosion in agricultural regions by changing the economic conditions of crop-production. *"Agri-environmental policies are a commonly used tool for controlling soil erosion and supporting soil conservation measures. Prices of inputs and outputs, regulations and incentives can change, which is forcing or encouraging farmers to adopt new crop rotations"* (Schuler 2008, 2). It is necessary to find out how a change of policies and measures could improve the future situation and on which level these changes might take place. The main policy-makers in the case study area and their sphere of influence are discussed below.

<u>1. The Federal Ministry of Agriculture, Forestry, Environment and Water Management</u>

The BMLFUW is responsible for the all-European orientation and the harmonisation of the agricultural policy within the framework of the Common Agricultural Policy of the European Union (UN, 1). The ministry provides instruments of command and control and is responsible for the contents of the ÖPUL, which gives incentives to the farmers for soil conservation practices. If the interest was to place special emphasis on measures to prevent soil erosion, this would be the level of implementation. As the gross margin of maize and sunflowers is high and the incentives do not compensate the income loss for the growing of alternative crops, there is a strong need for either an increase of payments given for alternative crops or a legislation that regulates the application of "best management practices" or conservation tillage by law. The ministry must have a clear position how the potential of biomass as an energy source should be developed without threatening the soil. Incentives should be only given to those forms of bio-energy which provide the overall highest environmental benefits.

2. The government of the Province Lower Austria

This institution is responsible for the implementation of support measures for agriculture. The policies of the province government contain legislative approaches. Their legislations can support the "good practice" and encourage the municipalities to give more priority to local measures that prevent soil erosion when discussing the use of the municipality's budget. Furthermore the government exerts influence on the design of the ÖPUL programme. For example "Ecopoints" is a specific feature of the Province Lower Austria. It provides the opportunity to integrate the promotion of soil protecting measures (primarily application of reduced tillage systems) into the ÖPUL programme. The adoption of soil conservation measures on “high risk crops” should be an objective of a policy measure.

3. The Austrian Chamber of Agriculture

The chamber *"focuses clearly on farm advice and tasks delegated by the national and regional governments, as well as the representation of interests, in particular vis-à-vis all Austrian institutions and at European level"* (UN, 2). They should proceed to provide programs that aim at spreading knowledge about erosion avoiding practices in agriculture and support farmers who are interested in soil conservation measures. The chamber could encourage the municipalities to discuss the adaption of land use to soil erodibility and think about concepts for the reallocation of highly erosive crops. They can also contribute to linking farmers to one another to establish a basis for future networks that can share the investment in new machinery.

4. The government of the municipality

The municipality's government should give more priority to soil protecting measures and inform the farmers and inhabitants about the reasons for these priorities and how they benefit from it. Generally, this topic deserves more attention on the local level in the future. If missing machinery was the constraint, there could be a joint acquisition within a machinery ring. This network could also be helpful to enable interested farmers to affiliate with other interested farmers to build up cooperation.

The institutions on higher administrative and political levels determine the framework for area-wide soil control of soil erosion while the main priority of soil protection should be localised on the level of regions and municipalities. The government or government-associated actors should push the development of incentives and programmes that support soil protecting measures and give economic support to conservation farming practices while the regional actors should encourage the land owners and land users and put the measures into practice. The concrete planning can not be top down because the measures are realised on the basis of specific preconditions and needs. The region or the municipality is usually the unit, where the most detailed knowledge and data about soil conditions is available and the flexibility to react on dynamic changes is higher.

4. CONCLUSIONS

The Loess soils in Michelhausen (mainly Cambisols on loess, marl or sandy limestone) are especially prone for soil erosion by water. Formation of rills and gullies on the fields are a highly visible form of these erosion processes in the municipality, inducing on- and off-site damages. The occurrence of soil erosion problems mainly derives from three factors: the type of cultivated crops, the applied tillage systems and the disregarding of topographic limitations. An additional key factor is the incidence of erosive rainfalls in spring and early summer coinciding with the period of less soil cover.

Agricultural soil conservation in the case study area is based on two pillars. The first pillar comprises mandatory measures such as the Soil Protection Law of Lower Austria. Farmers have to comply with these regulations otherwise they face sanctions. The second pillar contains incentive-based measures such as the agri-environmental scheme ÖPUL, which offers economic support to farmers for several soil protection measures. From the range of measures only the planting of winter cover crops is sufficiently applied in the case study area. The fuzzy-approach revealed that certain crops are associated with the existence of soil degradation problems in the study area (maize, sugar beet and sun flower) and that from the seven main crops only winter barley would be adequate to be grown on the steeper slopes.

The geological and soil-physical preconditions implicate a high site-specific risk for soil erosion that increases within the municipality from north to south. The degree of erosion risk largely determines how the various farming practices should be used. The identification of European risk areas is planned as an instrument for the comprehensive categorisation of potentially endangered areas based on spatial data; however the small-scaled variation of erosion risk would not be tackled in this approach. Furthermore the dimension of soil erosion is determined by specific management practices, which can not be covered by large-scaled assessments.

The rising need of biomass for energy production is supposed to be one of the key drivers for the further intensification of agricultural production. As the foreseeable development implies an increasing demand of crops with a high crop-specific erosion risk, it is highly important to combine the future production with accompanying measures. The study shows that even for the same site, differences in farming practices and cropping systems may cause differences in the potential risk for run-off. The model results show that potential benefits arising by changing the management options (e.g. tillage, application of cover crops) are more promising than by changing the crop share.

The findings presented in this thesis can be used as a basis for discussing a conception of measures that combines the properties of site and management options. As the assessment for the crop-specific risk has already been developed, the existing data basis can also be used for comparable areas with relatively small additional effort. The modelling results for the scenarios can be used for negotiation within the next planning processes to provide information on effects of various alternatives - not presenting a final answer but a range of land use and management options with their associated risks.

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8. ANNEX

8.1 ANNEX A – MATERIALS ON EXPERT SURVEYS AND INTERVIEWS

Annex A – 1 Questionnaire on farming practices

Part 1: General part (contact information)
Part 2: Assessment of soil conservation measures and farming practices in dependence on crop production

Questionnaire on farming practices and soil conservation/ degradation

Please fill in for your standard procedures and for those that might not be standard but you would propose.
If there are perennuals in your region please use three columns for planting, growing and mature period (for detailed description se

Part C-1: Cropping systems questions								
Serial number		1	2	3	4	5	6	7
Crop		Maize - Grain	Soft wheat, winter - Grain	Beet, sugar - Fodder	Maize, Fodder - Silage ()	Barley, winter - Grain	Pea - Grain	Sunflower - Grain
Production orientation		conventional	conventional	conventional	conventional	conventional	conventional	conventional
Farm type		arable farm	arable farm	arable farm	arable farm	arable farm	arable farm	arable farm
Tillage type		ploughing	ploughing	ploughing	ploughing	ploughing	ploughing	ploughing
Irrigation type		no irrigation	no irrigation	no irrigation	no irrigation	no irrigation	no irrigation	no irrigation
Which of the soil quality classes described in part B are used for this crop?		2	2	2	2	1	1	2
Description	Unit							
Calendar week of planting / seeding (does not refer to perennials!)	[Calendar Week]	17	41	14	17	37	13	13
Row distance for perennials	[cm]	75		40	75			
Number of plants per hectare	[ ]	65000		90.000	65000			
Average yield	[t/ha]	9	6	66	49	6	3,2	2,7
Yield of by-coproduct (important if by-product gives more than 100% of revenues)	[t/ha]						255	
Crop protection applications in one farming period	[ ]							1
Amount of nitrogen (N) per hectare in one farming period (pure nutrient)	[kg/ha]	130	120	100	150	110	60	50
Number of nitrogen-split applications	[ ]	2	3	1	1	2	1	
Amount of phosphorus (P_2O_5) per hectare in one farming period (pure nutrient)	[kg/ha]	85	55	85	90	55	65	65
Number of phosphorus-split applications	[ ]	1	1	1	1	1	1	
Amount of potassium (K_2O) per hectare in one farming period (pure nutrient)	[kg/ha]	200	80	320	225	80	100	200
Number of potassium-split applications	[ ]	1	1	1	1	1	1	
Frequency of irrigation	[days/farming period]	0	0	0	0	0	0	0
Amount of irrigation water per hectare in one farming period	[m³/ha]	0	0	0	0	0	0	0
Average selling price of the crop per ton (reference year 2006 if possible)	[EUR/t]	233	267	48	255	226	233	487
Price of by-product (important if by-product gives more than 100% of revenues)	[EUR/t]							
Revenue= Price * yield	[EUR/ha]	2097	1602	3168	12495	1356	745,6	1314,9
Costs of the fertilizers per hectare per farming period	[EUR/ha]	354	321	396	183	253	87	243
Costs of crop protection measures per hectare per farming period	[EUR/ha]	69	121	218	69	97	75	70
Costs of seeds (incl. planting material e.g. potatoes!) + insurances (hail e.g.) + drying costs, per farming period	[EUR/ha]	639	141	581	347	148	292	218
Variable machinery costs for the entire cultivation method	[EUR/ha]	416	281	451	452	271	266	290
= Costs of fertilizer + Costs of crop protection + machinery costs + other variable Costs	[EUR/ha]	1062	583	1195	599	498	454	531
= Total revenues - sum of variable Costs	[EUR/ha]	1035	1019	1973	11896	858	291,6	783,9
Number of working hours per hectare per farming period	[h/ha]	15-23	15-23	15-23	15-23	15-23	15-23	15-23

Part 3: Soil conservation related questions

Part C-2: Soil conservation related questions								
How long is the cropping period (seeding/planting to harvest)?	[days]	161	280	147	161	308	133	154
What is the time period with less than 80% soil cover?	[days]	60	150	50	60	165	50	50
Does the time period with less than 80% soil cover usually coincide with a period of heavy rainstorm events?		yes	no	yes	yes	no	yes	yes
Is the crop combined with other crops?		yes: intercrops - annual	yes: intercrops - annual	yes: intercrops - annual	yes: intercrops - annual	yes: intercrops - annual	yes: intercrops - annual	yes: intercrops - annual
If yes, which other crops?		winter cover crops (often mustard)	winter cover crops (often mustard)	winter cover crops (often mustard)	winter cover crops (often mustard)	winter cover crops (often mustard)	winter cover crops (often mustard)	winter cover crops (often mustard)
Is liquid manure generally used for this crop?		no	no	no	no	no	no	no
If yes, what is the average amount of liquid manure used per hectare in one farming period?	[m³/ha]							
What is the usual number of applications of liquid manure in one farming period?	[ ]							
Is solid manure generally used for this crop?		yes	yes	no	yes	no	no	no
If yes, what is the average amount of solid manure per hectare in one farming period?	[kg/ha]							
What is the number of applications of solid manure in one farming period?	[ ]							
What kind of machinery is usually used?		plough	plough	plough	plough	plough	plough	plough
What is a usual working depth of tilling/ploughing machinery?	[cm]	25	25	25	25	25	15-25	25
How many crossings/tracks within the field are there per year?	[ ]	8	10	8	8	10	8	10

Annex A – 2 Interview on Conservation measures and their state of implementation

Interview guideline for the interview with DI Meyer on soil conservation measures, policies and cropping practices in Michelhausen

Farm organisation

- Farms – how many?
  - How many farmers own land in Michelhausen?
  - If possible: Names and addresses for personal contact to farmers
- Full-time/part-time farmers?
- Existing cooperations (machines, marketing, etc.)
- How many people work in agriculture?

Property rights/ legal organisation of farms

- Family farms? Companies?
- Typical land use patterns (shape and size of parcels)

Questions about the region

- Which drainage system is used in your region?
- What is the average field size?
- What irrigation methods are usually used?
- Are there gras strips?
- Are there hedges? If yes, what is the density of hedges.? [m/km²]

Land use

- Estimated share: Forest, agriculture fields, pasture, settlements, etc.

Livestock and pastures

- Type of cattle

Questions fo each type (sheep, bovine, pig, etc.)

- Production (meat, milk, etc.)
- Typical land use
  - For pastures:
    - How long are the animals on the pasture land (month/year)
- Usual livestock units

Do the animals influence the soil properties/ soil conditions in the area? What could be improved?

Cropping sytems

- Which are the main crops and crop rotations?
  - Cropping systems?

Only answer this for your standard. If too difficult please give a suggestion where the answers might be found

1. Cropping systems (fertilization, irrigation, costs)

- Production orientation (conventional, organic, conventinal with reduced tillage, etc.)
- tillage (ploughing, reduced, mulch seeding, etc.)
- irrigation type
- soil quality
- Calendar week of planting / seeding (does not refer to perennials!)
- Row distance for perennials
- Number of plants per hectare
- Average yield
- Yield of by-coproduct (important if by-product gives more than 100% of revenues)
- Crop protection applications in one farming period
- Frequency of irrigation
- Amount of irrigation water per hectare in one farming period
- Average selling price of the crop per ton (reference year 2006 if possible)
- Price of by-product (important if by-product gives more than 100% of revenues)
- Number of working hours per hectare per farming period

2. Soil conservation related questions

- How long is the cropping period (seeding/planting to harvest)? [days]
- What is the time period with less than 80% soil cover? [days]
- Does the time period with less than 80% soil cover usually coincide with a period of heavy rainstorm events?
- Is the crop combined with other crops? If yes, which other crops?
- Is liquid manure generally used for this crop? If yes, what is the average amount of liquid manure used per hectare in one farming period? [m^3/ha]
- What is the usual number of applications of liquid manure in one farming period?
- Is solid manure generally used for this crop? If yes, what is the average amount of solid manure per hectare in one farming period?[kg/ha]
- What is the number of applications of solid manure in one farming period?
- What kind of machinery is usually used?
- What is a usual working depth of tilling/ploughing machinery? [cm]
- How many crossings/tracks within the field are there per year?
- Which conservation measures would you suggest for this crop?

Soil threats

(= soil erosion water, soil erosion wind, decline in organic matter, negative carbon balance, diffuse contamination, compaction, salinisation, acidification, decrease of water-retention capacity, off-site damages e.g. to water bodies, infrastructure)

- Which soil threats occur in Michelhausen and why?
- Spatial distribution and time (where, when, etc.)

Soil protection EU/national/local

- Which european, national, lower austrian laws are relevant?
    - Why?
- How is their implementation into practice?

Estimation of soil protection measures
What are their effects, problems, acceptance, state of implementation, etc.?

- Arrangement/ rearrangement of the field shape
- Rearrangement of tracks and roads
- Filtering edges, shelter-belts and wind-breaks around endangered fields and at water
- Selection of covering crops
- Planting of catch crops
- Undersown crops
- Site-dependent soil tillage and cultivation
- Extensification by set-aside and rotation of fallows
- Mulch-seeding:
- Direct seeding/ zero tillage
- Contour farming

Political framework/ future scenarios

- Influence of national/ lower austrian laws on the farming practices?
- Influence of ÖPUL on the farming practices?
- How will the land use develop?
    - Decrease of certain land use types/crops? Increase?
    - Intensification? Extensification?
    - Fodder – Energy crops?
- Influence of EU support?

Soil protection in the region/municipality

- Administration – who controlls the soil protection
- Implementation of laws and control
- Consultation services for farmers?
- Cooperations with scientific institutions?
- What is planned for the future? Development of soil conservation?

Final

- Are there other additional aspects that have not been mentioned yet? Other important information about the topic?

8.2 ANNEX B LAND USE STATISTICS

Annex B -1 Share of crops in Michelhausen

Fruchtart	Fruchtart Name Q1 (englisch)	Fläche/ha	Anteil an der Gesamtfläche in %
Körnermais	Maize - Grain	799	25,9%
Winterweichweizen	Soft wheat, winter - Grain	570	18,4%
Zuckerrüben	Beet, sugar - Fodder	296	9,6%
Silomais	Maize, Fodder - Silage	206	6,7%
Wintergerste	Barley, winter - Grain	158	5,1%
Feldgemüse	Vegetables	88	2,8%
Körnerebsen	Pea - Grain	78	2,5%
Sonnenblumen	Sunflower - Grain	68	2,2%
Blühfläche	Grass, temporary (less than four years) - Fresh	60	1,9%
Mais Corn- Cob Mix	Maize Corn- Cob Mix	42	1,4%
Sommergerste	Barley, spring - Grain	32	1,0%
Wintertriticale	Triticale - Grain	28	0,9%
Mähwiese	Grassland	26	0,8%
Grünbrache	Set aside	24	0,8%
Erdbeeren	Strawberry - Fruit	22	0,7%
Winterraps	Rape - Grain	22	0,7%
Stärkeindustriekartoffeln (inkl. Spritkartoffeln)	Potato - Root	17	0,6%
Wein	Grape, wine	16	0,5%
sonstige Ackerflächen	others	16	0,5%

8.3 ANNEX C ASSESSMENT OF THE CROP-SPECIFIC EROSION RISK

Annex C – 1 Table: Soil cover crop classification after Frielinghaus (1995)

Assessment of crops regarding their soil protecting attributes

	Bewertungskriterien					
	Geschwindigkeit der Pflanzen-entwicklung	Grad der Bedeckung (Standraum-verteilung)	Bedeckung während des Sommerhalbj. (1.4. bis 30.9.)	Bedeckung während des Winterhalbj. (1.10 bis 31.3.)	Technologisch bedingte Zeit-spanne o. Boden-bedeckung	Gesamtbe-wertung
Teil I						
Fruchtarten						
Dauerbegrünung	1	1	1	1		1
Mehrjährige Futterpflanzen Luzerne, Kleegras (Hauptnutzungsjahr)	1	1	1	1		1
Wintergerste	1	1	1	1		1
Winterweizen						
Aussaat vor 1. Oktober	2	1	1	2		1,5
Aussaat nach 10. Oktober	3	1	1,5	3		2,5
Winterroggen Aussaat vor 1. Oktober	1,5	1	1	1		1
Aussaat nach 10. Oktober	2	1	1	2		1,5
Winterraps	1,5	1,5	1,5	1,5		1,5
Sommergerste	1,5	1	2	3		2
Kartoffeln	2,5	2,5	2,5	3		3
Zuckerrüben	3	2	2,5	3		3
Lupine	1,5	2	1,5	3		2
Öllein/Faserlein	2,5	1	2,5	3		2,5
Mais	3	3	2,5	3		3
Sonnenblumen	3	3	2,5	3		3
(Zwischenfrüchte)						
(Ölrettich)	1,5	2	-	1,5		2
(Phacelia)	1	1,5	-	1,5		1,5
(Senf)	1	1,5	-	1,5		1,5
(Getreidestoppel)	1	1	-	1		1
(Getreidestoppel mit Einsaaten)	1	1	-	1		1
Brache	3	3	3	3		3
Teil II						
Anbaufolgen						
Dauerbegrünung/Mehrjähriger Futterbau	1	1	1	1	1	1
Mais - Winterweizen - Sommergerste	2,5	2	2	2,5	2,5	2,5
Winterraps - Winterroggen- Ackerfutter (Leguminosen) - Winterroggen - Wintergerste	2	1,5	1,5	1,5	2	2
Winterraps - Winterweizen - Ackerfutter (Grasgemisch/ Herbstaussaat) - Wintergerste	2	1	1	1,5	1,5	1,5
Zuckerrüben - Winter-weizen - Wintergerste	2,5	2	2	2,5	2,5	2,5

Teil III

Erhöhte Bodenbedeckung Anbaufolgen						
Wintergerste - Senf (abfrierend) Mais (Mulchsaat)-Winterweizen - Winterroggen mit Untersaat	1,5	1	1,5	1,5	1,5	1,5
Wintergerste - Senf (abfrierend) Zuckerrüben (Mulchsaat) - Winterweizen - Wintergerste	2	1	1,5	2	1,5	2
Winterraps - Winterroggen mit Gras-Untersaat - Winterroggen - Wintergerste	1,5	1,5	1	1	1	1
Winterraps - Winterroggen - Ackerfutter (Grasgemisch/ Herbstaussaat) - Winterroggen- Wintergerste	2	1,5	1,5	1,5	1,5	1,5
Winterraps - Winterroggen - Ackerfutter (Gerstgras/Früh- jahrsaussaat) - Winterroggen - Wintergerste	1,5	1,5	1,5	1,5	2	1,5
Winterraps - Winterweizen - Ackerfutter (Grasgemisch/ Herbstaussaat) - Wintergerste	2	1	1	1,5	1,5	1,5
gelb (1) blau (2) rot (3)	schnell mäßig langsam	hoch mäßig niedrig	hoher Schutz geringer Schutz kein Schutz	hoher Schutz geringer Schutz kein Schutz	ohne mäßig lang	ausreichender Schutz geringer Schutz unzureichender Schutz

Annex C – 2 Table : Tillage classification after Deumlich (2001)

Anbauweise	Bewertung*
pfluglos und Untersaat und Zwischenfrucht	1
pfluglos und Untersaat	0,9
pfluglos und Zwischenfrucht	0,8
pfluglos, keine Untersaat oder Zwischenfrucht	0,7
Untersaat und Zwischenfrucht	0,6
nur Untersaat	0,5
nur Zwischenfrucht	0,4
weder pfluglos, noch Untersaat, noch Zwischenfrucht	0

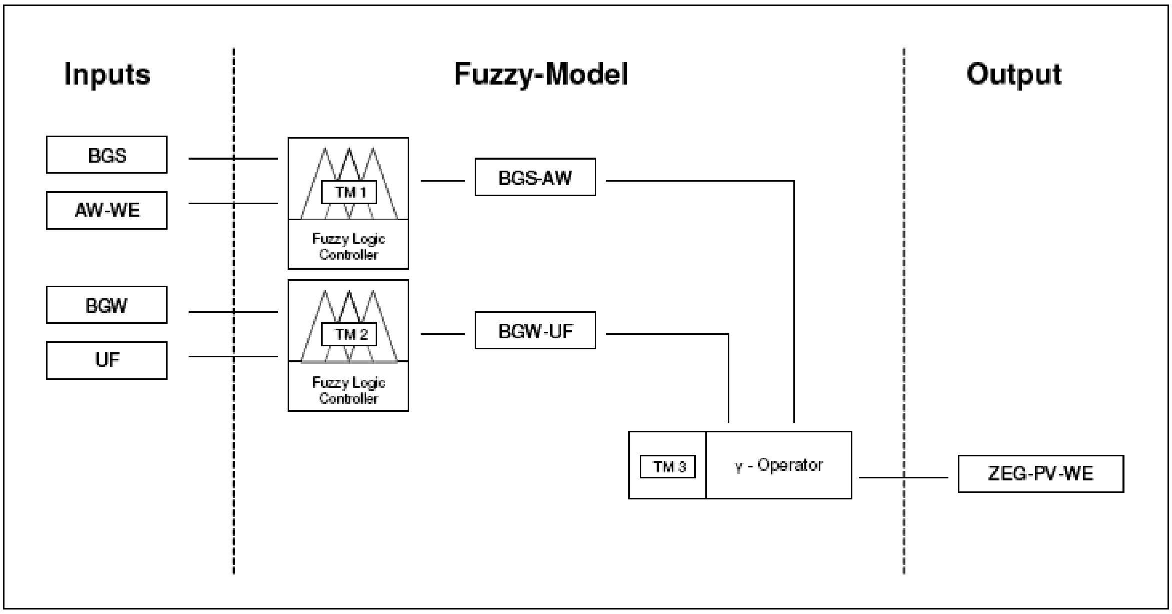
*0 = ungünstig; 1 = günstig

Annex C – 3 Assessment of cropping systems for the indicator water erosion after Sattler (2008)

Part 1: Fuzzy model input parameters

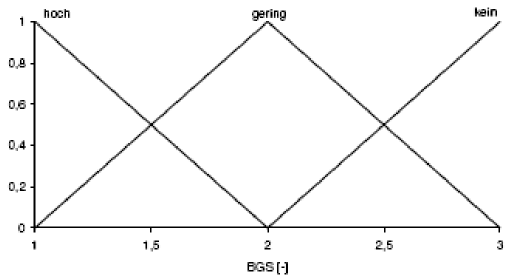
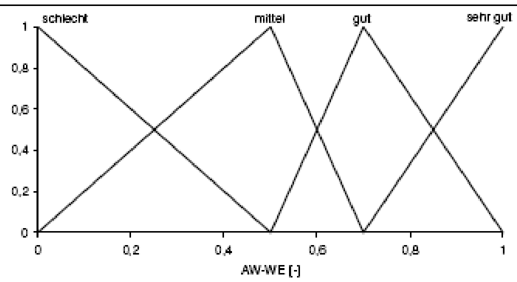
Nr.	Bewertungsparameter [Einheit]	Kürzel
	Sommererosion:	
1	Bodenbedeckung im Sommerhalbjahr [-]	BGS
2	Bewertete Anbauweise Wassererosion [-]	AW-WE
	Wintererosion:	
3	Bodenbedeckung im Winterhalbjahr [-]	BGW
4	Anzahl Überfahrungen im Winterhalbjahr [n]	UF

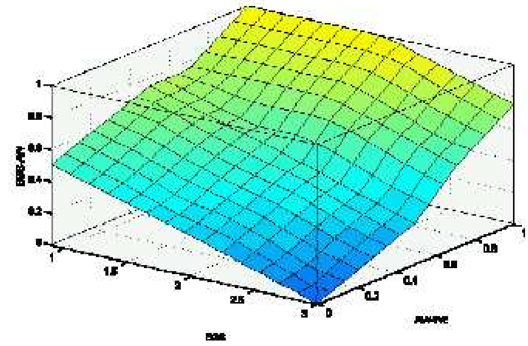
Part 2: Fuzzy model “WE-PV” for the indicator water erosion



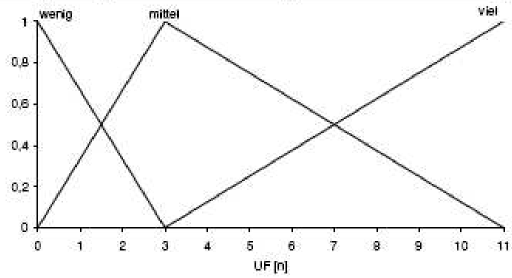
BGS = **Soil cover summer**
AW-WE = **Cropping system/conservation measures**
BGS-AW = **1. result**
BGW = **Soil cover winter**
UF = **Number of crossings winter**
BGW-UF = **2. result**
ZEG-PV-WE = **Index of goal achievement: farming practice – soil erosion water**

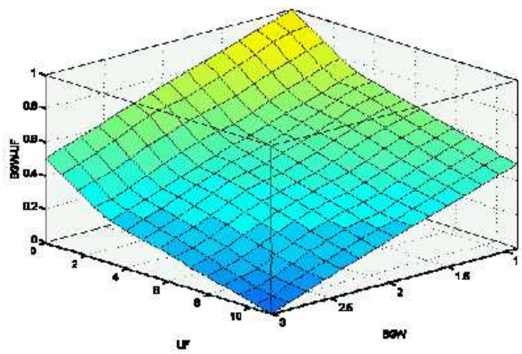
Part 3: Fuzzy model “WE-PV”- Details

Bewertungsparameter	Beschreibung	Zugehörigkeitsfunktionen (grafische Darstellung)
TM 1 (Sommererosion)		
Input 1:	Bewertete Bodenbedeckung im Sommerhalbjahr	
Kürzel [Einheit]:	BGS [-]	
Wertebereich:	[1 ... 3]	
Datenherkunft:	Frielinghaus et al. 1998	
Algorithmus:	hoch >... > keine	
Zugehörigkeitsfunktion:	Typ: Dreieck	
hoch	(1 1 2)	
gering	(1 2 3)	
keine	(2 3 3)	
Input 2:	Bewertete Anbauweise Wassererosion	
Kürzel [Einheit]:	AW-WE [-]	
Wertebereich:	[0 ... 1]	
Datenherkunft:	MODAM	
Algorithmus:	sehr gut > ... > schlecht	
Zugehörigkeitsfunktion:	Typ: Dreieck	
schlecht	(0 0 0,5)	
mittel	(0 0,5 0,7)	
gut	(0,5 0,7 1)	
sehr gut	(0,7 1 1)	
Output 1:	BGS-AW	(wie Output X, siehe Anhang B - 1)

Regelwerk zur Verknüpfung von Input 1 und 2				**Oberflächendiagramm**
Nr.	Wenn BGS ist	Und AW-WE ist	Dann BGS-AW ist	
1	*kein*	*schlecht*	*sehr schlecht*	
2	*kein*	*mitel*	*schlecht*	
3	*kein*	*gut*	*mittel*	
4	*kein*	*sehr gut*	*gut*	
5	*gering*	*schlecht*	*schlecht*	
6	*gering*	*mitel*	*mittel*	
7	*gering*	*gut*	*gut*	
8	*gering*	*sehr gut*	*sehr gut*	
9	*hoch*	*schlecht*	*mittel*	
10	*hoch*	*mitel*	*gut*	
11	*hoch*	*gut*	*gut*	
12	*hoch*	*sehr gut*	*sehr gut*	

Bewertungsparameter	**Beschreibung**	**Zugehörigkeitsfunktionen (grafische Darstellung)**
TM 2 (Wintererosion)		
Input 3:	Bodenbedeckung im Winterhalbjahr	(wie Input 1 (BGS), siehe TM 1)
Kürzel [Einheit]:	BGW [-]	

Bewertungsparameter	**Beschreibung**	**Zugehörigkeitsfunktionen (grafische Darstellung)**
Input 4:	Anzahl Überfahrungen im Winterhalbjahr	
Kürzel [Einheit]:	UF [n]	
Wertebereich:	[0 ... 11]	
Datenherkunft:	MODAM	
Algorithmus:	wenig > ... > viel	
Zugehörigkeitsfunktion:	Typ: Dreieck	
wenig	(0 0 3)	
mittel	(0 3 11)	
viel	(3 11 11)	
Output 2:	BGW-UF	(wie Output X, wie in Anhang B - 1)

Regelwerk zur Verknüpfung von Input 3 und 4				**Oberflächendiagramm**
Nr.	Wenn BGW ist	Und UF ist	Dann BGW-UF ist	
1	*kein*	*viel*	*sehr schlecht*	
2	*kein*	*mittel*	*schlecht*	
3	*kein*	*wenig*	*mittel*	
4	*gering*	*viel*	*schlecht*	
5	*gering*	*mittel*	*mittel*	
6	*gering*	*wenig*	*gut*	
7	*hoch*	*viel*	*mittel*	
8	*hoch*	*mittel*	*gut*	
9	*hoch*	*wenig*	*sehr gut*	

TM 3	
Verknüpfung von Output 1 und Output 2 über γ-Operator:	**γ = 0,7, siehe Formel** (1)
Output 3 (Endergebnis):	ZEG-PV-WE

Part 4: Table Fuzzy model "WE-PV" output

CaseStudyID	SerialNumber	CoverS	TillCatch	CoverW	Crossings	out1	out2	out3
9	1	2,5	0,5	3	8	0,375	0,176471	0,266941
9	2	1	0,5	2	10	0,727273	0,397059	0,607506
9	3	2,5	0,5	3	8	0,375	0,176471	0,266941
9	4	2,5	0,5	3	8	0,375	0,176471	0,266941
9	5	1	0,5	1	10	0,727273	0,631356	0,735155
9	6	1,5	0,5	3	8	0,613636	0,176471	0,392594
9	7	2,5	0,5	3	10	0,375	0,147059	0,245992
9	8	2,5	0,8	3	8	0,7	0,176471	0,437788
9	9	1	0,8	2	10	0,833333	0,397059	0,666356
9	10	2,5	0,8	3	8	0,7	0,176471	0,437788
9	11	2,5	0,8	3	8	0,7	0,176471	0,437788
9	12	1	0,8	1	10	0,833333	0,631356	0,788953
9	13	1,5	0,8	3	8	0,833333	0,176471	0,507417
9	14	2,5	0,8	3	10	0,7	0,147059	0,41108
9	15	2,5	0,6	3	8	0,5	0,176471	0,33295
9	16	1	0,6	2	10	0,727273	0,397059	0,607506
9	17	2,5	0,6	3	8	0,5	0,176471	0,33295
9	18	2,5	0,6	3	8	0,5	0,176471	0,33295
9	19	1	0,6	1	10	0,727273	0,631356	0,735155
9	20	1,5	0,6	3	8	0,625	0,176471	0,398546
9	21	2,5	0,6	3	10	0,5	0,147059	0,30969
9	22	2,5	0,7	3	7	0,625	0,191176	0,410509
9	23	1	0,7	2	9	0,75	0,411765	0,628864
9	24	2,5	0,7	3	7	0,625	0,191176	0,410509
9	25	2,5	0,7	3	7	0,625	0,191176	0,410509
9	26	1	0,7	1	9	0,75	0,647727	0,754935
9	27	1,5	0,7	3	7	0,75	0,191176	0,476729
9	28	2,5	0,7	3	9	0,625	0,161765	0,386106
9	29	2,5	1	3	9	0,875	0,161765	0,514777
9	30	1	1	2	11	1	0,382353	0,749444
9	31	2,5	1	3	9	0,875	0,161765	0,514777
9	32	2,5	1	3	9	0,875	0,161765	0,514777
9	33	1	1	1	11	1	0,615169	0,864367
9	34	1,5	1	3	9	1	0,161765	0,578982
9	35	2,5	1	3	11	0,875	0,132353	0,483306
9	36	2,5	0,1	3	8	0,166667	0,176471	0,154221
9	37	1	0,1	2	10	0,527778	0,397059	0,494908
9	38	2,5	0,1	3	8	0,166667	0,176471	0,154221
9	39	2,5	0,1	3	8	0,166667	0,176471	0,154221
9	40	1	0,1	1	10	0,527778	0,631356	0,629033
9	41	1,5	0,1	3	8	0,403061	0,176471	0,281812
9	42	2,5	0,1	3	10	0,166667	0,147059	0,13793

8.4 ANNEX D REDUCED TILLAGE: PROBLEMS AND SOLUTION STRATEGIES

Annex D – 1 Problems and solutions for brome grass, fusarium, snails and mice (shortened form; after Frielinghaus 2002)

Brome grass

- controlling of the fields
- cleaning of the harvester before changing to other fields
- preventive application of grass-herbicides
- controlling of brome grass nests with a non-selective herbicide before the seed formation
- controlling of field edges (e.g. mulching of field edges to block the spreading of brome grass from the edge to the fields)

Fusarium head blight

- cultivation of winter wheat types which are less susceptible, especially if maize was the previous crop
- avoiding the storage of wheat
- shreddering and mulching of maize-residues
- cultivation of summer crops and "break crops" after maize (bees, potatoes, peas)
- decrease of maize in the crop rotation
- planting wheat with less density of plants to avoid the favourable micro climate

Snails

- even distribution and chaffing of straw
- switching between summer- and winter crops
- liming before winter wheat or triticale
- rolling after the preparation of the seedbed to remove holes
- controlling of snails by further measures (e.g. snail foil)

Mice

- support of natural enemies (raptors)
- application of a grubber (>15cm)
- even distribution of straw and attentive residue management
- diversified crop rotation with switching between summer- and winter crops