Assessing land use and land management and the impacts on land degradation and conservation in Frienisberg (BE)

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Preface

The present master thesis has been written at the institute for geography of the University of Bern, in the year 2015/16. On behalf of the WOCAT mapping methodology, it aimed the mapping of land use and management as well as their impacts on land degradation and conservation technologies. The results illustrate the spatial understanding of processes, how they are perceived in the eyes of local stakeholders.

Fortunately, this master thesis is settled due to the collaboration and commitment of so many. First of all, I would like to thank my parents, my sister Anne, and my family for their unreserved support, patience, and understanding, as well as my friends for their listening and encouragements.

Then, I am grateful to the workshop participants Stefan Brunner, Hanspeter Lauper, Jürg Lauper, Mirjam Lazzini, Deborah Niggli, Nina Lauterburg, Andreas Chervet, Volker Prasuhn, and Hanspeter Liniger. Without their time and precious collaboration and pledge to the subjects this thesis would not have been possible.

Furthermore, I would like to extend my acknowledgment to the members of the academic community, to Nina Lauterburg for her great availability, reinforcements, and advises, to Dr. Hanspeter Liniger for the supervision, the profitable feedbacks, and for conducting the workshop with great sensitivity, to Kurt Gerber, Dr. Andreas Heinimann, and Pascal Bircher who offered me technical support, as well as my deep recognition to Mirjam Bühler for offering her time and giving me helpful criticisms.

Last but not least, thanks to Fela Kuti, Miriam Makeba, Robert Glasper, and many more, their moving spirit and work kept me going.

Notice: I am fully aware that the length of this master thesis exceeds the usual limits in terms of number of pages. In view of the complexity of the subject and extends of the problems it appeared necessary giving us the all the needed space, yet in the knowledge that it would be impossible to be fully inclusive, particularly with respect to the non-professional research partners. In fact, the creation and development of opportunities to craft closer relationships and trust, to share, to work together, and to find solutions have certainly only been partially achieved to return truly the voice of the practitioners. Close and long-term collaboration are needed exceeding the capabilities offered by one master thesis.

Summary

Rigorous research focusing mainly soil erosion by water including its drivers and impacts is carried out in the region Frienisberg since more than 10 years. Within the EU project named RECARE Frienisberg has been chosen as one of the 17 Study sites throughout Europe. This initiative has been established in order to search for effective soil degradation prevention and remediation solutions in Europe. Concentrating on soil erosion and compaction one PhD study and several master and bachelor studies are being carried out as part of the project in the same focal region.

While focusing mainly on agricultural land and forest, the goal of this study is the evaluation of various land-uses and distinct land management practices in order to appraise their impact on land degradation and ecosystem services. The final output of this study aims identifying and localising effective land degradation and conservation measures in relation to the corresponding land use systems (LUSs). Changes, trends, and impacts are observed and analysed over a ten-year period (2005-2015).

To accomplish the set objectives the *World Overview of Conservation, Approaches, and Technologies* (WOCAT) mapping methodology has been implemented, focussing on three tasks: First, the identification and categorization of the major land use systems. Second, the mapping of these defined systems in the study area Frienisberg. Finally, and based on the WOCAT Mapping Questionnaire (QM), the engagement of multi-stakeholder meetings.

The WOCAT QM tool has now been applied in several countries worldwide, yet never before in Switzerland. Thus, the useful and local implementation necessities further reflection and practice adapted to the Swiss agricultural landscape.

The three LUS *cropland*, *permanent grassland*, and *forest* have been identified and assessed according to the QM method. The surfaces used for crop production are qualified as **cropland**. Though different management practices can apply, conventional intensive ploughing is retained as reference technology on these lands. **Permanent grasslands** are surfaces under perennial (generally six years) grass cover and are used as meadows or pastures, whereas **forests** are land areas covered with trees or other woody vegetation.

The questionnaire data was collected in a one-day stakeholder workshop and in a meeting with the district forester. This collective reasoning led to the identification, for each LUS, of the major land degradation types and conservation measures, as well as their impacts on selected ecosystem services. The main land management practices/conservation measures on the LUS cropland are *extensive ploughing*, *intensive* and *extensive mulching*, *intensive* and *extensive strip sowing*, *intensive* and *extensive no-till*, as well as (bi-) annual *grass clover leys*: Plough tillage is a practice inverting soils with

a disk plough or mould-board consistent with one or two harrowing passes. Mulching refers to a non-inversion tillage practice leaving more than 30% of the crop residues on the soil surface. Since no-till and strip sowing practices allow the crop to be planted in a seedbed that has not been tilled (at least since the preceding crop), these technologies limit the soil disturbance to the strict necessary for the seed positioning. In the context of LUS cropland, *intensive* and *extensive* refer to crop rotations with, respectively without, root crops. Finally, grass clover leys are sown grasslands included in the crop rotation, which are generally maintained over a two-year period (sometimes the last one or three years). The latter conservation technology distinguishes itself in that it is present in all cultivation systems, i.e. in the reference technology and in all conservation technologies. The LUS permanent grassland is also subdivided in two management practices, *intensive* and *extensive*, distinguishing variables such as the frequency of mowing or drive-on, grassland species composition, or nutrient inputs influencing the ecological impact of the land management. Finally, the conservation practice *mixed forest,* advancing mixed stocks, represents the LUS forest at its best.

In terms of area trends, no significant shifts have happened during the last 10 years, only minor surface losses of LUS *cropland* were retained relating to the expansion of the settlement area. Nevertheless, these minimal changes may be partially biased by effective adaptation and mitigation measures. Individually, the farmers may take initiatives to compensate the surface losses on flatter areas by cultivating steeper zones. As a matter of precaution these assumptions are not explicitly reflected in the questionnaire outputs.

On *cropland* moderate increases in the land use intensity are highlighted over the last decade, reflecting particularly the ecological intensification intended by the direct payment system to increase production without increasing its' ecological impacts. The workshop participants fear that the practical implementation of the intensification incentive suggested for midlands, through the agricultural policy, appears to take a worrying turn, although the expert group's request for precaution applies also here. The future evolution of this trend may be influenced by market pressure, government policies, as well as by the farmers' personal conviction in the management practices they apply.

However, it is remarkable to notice how the vast range of conservation measures, practiced for some since the 1950s or 1990s, involved reducing the land management intensity during the second half of the 20th century. In terms of unconventional cultivation systems, by reference to *conventional, high-input ploughing*, Frienisberg can be considered as an "area of exploration", or "pioneering area", since more than 50% of the LUS *cropland* area is not being ploughed. Thus, considerable efforts were certainly made during the second half of the 20th century to reduce the land use intensity, which might explain why the trend values are so little over the observation

period 2005-2015. In order to truly convey the area and intensity trend all farmers in the study area should be questioned personally to explain their practices.

Despite Frienisberg's pioneering role when attending conservation management, all the LUSs in the area are prone to land degradation. It is easily understandable that LUS *cropland* is most affected by land degradation, while the occurring processes are surface erosion, compaction, and water degradation. Water degradation and surface erosion occur on slightly more than 10% of the surface area, though not in the same degree. While nearly no surface erosion or water degradation is observable on *flat* (slope gradient category (SGC): 0-3%) and *very steep* (SGC: >30%) parcels, *moderately* (SGC: 3-15%) sloped and *steep* (SGC: 15-30%) lands are perceivably degraded. Processes of compaction are particularly interesting since they affect indiscriminately all areas under cropland (100% of the LUS area) and all land management practices. Since drive-on and the use of heavy machinery are inseparably associated to today's agriculture the practitioners learn to cope with compaction. Unfortunately, the rate of compaction has been slightly increasing in the recent past, triggered by market pressure and flexibility, compelling sowing and harvesting periods, which may raise unexpected issues about production security and the maintenance of adequate soil structure, as well as about the impacts of extreme weather conditions.

The numerous unconventional cultivation systems emerging and establishing in Frienisberg over the last decades cover about 70% of the LUS *cropland* area, which is quite remarkable given the standards and practices in other parts of the country. And even more, since six out of eleven technologies are considered as highly effective, according to the classification they do "not only control the land degradation [i.e. soil erosion, compaction, and water degradation] problems appropriately, but even improve the situation compared to the situation before degradation occurred" (rated as high effectiveness, 4). Since most technologies have now been implemented during the 20th century, it is no particular surprise that the effectiveness trend of most technologies is not increasing anymore (rated as no change in effectiveness, 0), with the exception of *mulching int.* (rated as increase in effectiveness, 1). To some extent, this study leads to the reasoning, that conservation practices not only diminish, or in some cases even prevent, occurring land degradation processes, they can also be successful when encouraging ecosystems services, notably soil cover and structure. In some cases they even increase the farm income rate (e.g. *strip-sowing ext., ext. mulch* and *no-till ext.*), contribute to positive water quality results (e.g. *permanent grassland* and *ext. much*), or increase production while reducing the risk of crop failure (e.g. *ext. no-till*).

As with agricultural land, *forest* management required the implementation of conservation measures for it to become more viable. Woodlands have been managed for centuries and are thus far from their natural state. In pre-industrial ages, the lands were cleared without cause of concern. But since 1876, with the Forest Police Act, the Confederation realized the need to establish and maintain a minimal capital, and subsequently, the socio-cultural and ecological benefits of forest conservation become undeniable. Nowadays, nearly 80% of Frienisberg's LUS *forest* benefits from mixed stocks. Even if the conservation practice *mixed forest* is not specifically oriented to profit maximisation, through the positive effects on both land degradation and ecosystem services mixed stocks are established as the common practice. Through their well-developed root systems, supporting water infiltration and the improvement of the soil structure, mixed stocks mitigate and prevent water stresses during summer/dry spells as well as forest degradation caused by the additional impact of increasing pests/diseases. Long-term forest degradation may be prevented. Furthermore, *mixed forests* no not only make woodland management more resilient to hazardous markets, they make forests more enjoyable for leisure and great to watch.

Although when we look faithfully at the situation on the whole, the observed land degradation is not dramatic when compared to other regions of the world. Nevertheless, Frienisberg's land management (with particular emphasis on agricultural lands) cannot be regarded as totally *sustainable*, even though substantial efforts are made. Pushed by the practitioner's request for collective accountability and empowerment, calling for societal responsibility for what is happening in the fields, in the outlook the study suggests the emphasis on more community-based solutions, as proposed for instance by the movements of community supported agriculture, addressing sincerely some of the identified causes of land degradation. Aware that there may be a need to structural changes protecting all, farmlands and farmers as well as forests and foresters, from the roughness of free markets and global competition.

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Abbreviations

Agro-ecosystem (AES)

Bundesamt für Umwelt (BAFU)

Bundesamt für Landwirtschaft (BLW)

Centre for Development and Environment (CDE)

Community Supported Agriculture (CSA)

Desertification Mitigation and Remediation of Land (DESIRE)

Direct payments (DPs)

Digital Elevation Model (DEM)

Digital Terrain Model (DTM)

Driving forces, Pressures, States, Impacts, Responses (DPSIR)

Ecosystem Services (ESS)

European Environment Agency (EEA)

European Union (EU)

Food and Agriculture Organisation (FAO)

General Agreement on Tariffs and Trade (GATT)

Geographic Information System (GIS)

Integrated production (IP)

Intergovernmental Panel on Climate Change (IPCC)

Land Degradation Assessment in Drylands (LADA)

Land use and land cover (LULC)

Land Use System (LUS)

Mapping Questionnaire (QM)

Millennium Ecosystem Assessment (MEA)

Questionnaires on Technologies (QT)

Questionnaires on Approaches (QA)

Slope gradient category (SGC)

Soil and Water Conservation (SWC)

Soil organic matter (SOM)

Sustainable Land Management (SLM)

World Overview of Conservation Approaches and Technologies (WOCAT)

World Trade Organisation (WTO)

Dai diamanti non nasce niente

dal letame nascono i fior.

Fabrizio De André[1]

[1] De André, Fabrizio. "Via del campo". Volume I. Bluebeli Records, 1967. *„Nothing grows from diamonds, flowers grow from manure."* (Fedrigo 2016, free translation)

Part One

Introduction

1 Introduction

While stipulating the opening settings and drawing a contour of the main issues part, one aims a general introduction in the subject. Following a common overview of the production of food, the broader research project RECARE is presented, in which this master thesis fits in. Specifics on the relevance of this research lead to the elaboration of the study goal, the specific objectives, as well as the hypotheses and research questions. Finally, the chapter ends with the description of the RECARE project area and the confinement of the selected study area.

1.1 Structure of the thesis

The thesis will be structured in four main chapters titled as follows:

Part One Introduction
Part Two Methodology
Part Three Results and discussion
Part Four Synthesis and Outlooks

Subchapters have been introduced in order to facilitate reading and to provide more structure to the text. Part one contains the common introduction to the subject, references and a detailed description of the research goal and objectives, as well as a presentation and description of the area of interest. The theoretical background, the conceptual framework, the state of the art, as well as the WOCAT-tools are elaborated and clarified in part two. Part three offers space for listing and discussing the results, whereas the concluding synthesis, closing thoughts and observations regarding the theory, the methodology, and the results are exposed in the last section four.

1.2 General starting situation

The food and agriculture sector could record considerable successes over the past century as it could supply nourishment to a growing and richer world population (Godfray et al., 2010; Koohafkan, Altieri, & Gimenez, 2011). Generally, the total factor productivity increase of the agricultural sector surpasses the demographic expansion. As this continual population increase is expected to endure, an adaptation of the food production system to this swelling demand will become necessary. Over the past decades augmentations in food production were accomplished through the modernisation and intensification of the agro-industrial production system, primarily by using synthetic fertilisation, pesticides, large-scale irrigation, and high-yielding crop varieties (Koohafkan et al., 2011). Many studies already exposed the negative consequences of agricultural intensification for the land and its ecosystem services, by starting with the strong contribution of modern, high-input agriculture (e.g. synthetic fertilizers, intensive ploughing) to the increasing concentrations of atmospheric greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (Albrecht & Engel, 2009; Baah-Acheamfour, Carlyle, Bork, & Chang, 2014; Paustian, Six, Elliott, & Hunt, 2000). In a context of increasing awareness of climate changes and the environmental effects of using non-renewable resources, new solutions for land conservation seem indispensable. Additionally, combined global economic interests, property rights abuses, and asymmetric access to power and information cause environmental conditions to become critical and populations vulnerable (Adger, 2007). To face these requirements sustainable agricultural production systems are shaped (Godfray et al., 2010), in which context for instance agro-ecological production techniques and principles are advanced (de Schutter, 2010; Koohafkan et al., 2011).

Measurements, assessments, and documentation of the state of agriculture (in more general terms of the state of the land), as well as the extents and the effects of conservation practices are of value in these processes in movement. While committing to this study we may want to step into this breach.

1.3 Problematic and research gap

The region Frienisberg (BE), located in northwest part of the canton of Bern, Switzerland, is determined case-study site as part of the European research project *RECARE – Preventing and Remediating degradation of soils in Europe through Land Care* and therefore also identified as the focal area for this study. Based on the WOCAT mapping approach for the assessment, this research focuses on the evaluation of land use while illustrating land degradation (e.g. surface erosion, compaction) and conservation processes (e.g. agronomic measures such as mulching and minimum tillage), as well as ecosystem services.

Both natural and human-influenced systems are constantly subject to change. These inherent changes can be related to both global and local social, political, economic, and environmental changes. In life change is inevitable (Cabell & Oelofse, 2012). Ever-stable systems do not exist in practice (Kummer, Milestad, Leitgeb, & Vogl, 2012) and thus change shall rather be considered as the norm than the exception. In this perspective, learning to live with and to shape change

becomes a fundamental management strategy for agricultural systems (Folke, Berkes, & Colding, 2003).
Given the general topic *soil erosion by water* chosen by the RECARE project, the focus of this thesis is on agricultural land and forest land. The conventional, high-input agriculture requires field standardisation and homogeneity, originating potentially negative impacts on the ecosystems. This modern, technological agriculture strongly relies on synthetic fertiliser and heavy machinery (Godfray et al., 2010), wherein, through recurrent and intensive ploughing, fields are disrupted and spatially disconnected from their situation in the environmental setting (van Apeldoorn, Kok, Sonneveld, & Veldkamp, 2011). At larger scales, pushed by their economic viability, farming structures are subject to mechanisation and intensification. In order to enter food markets, common goods (i.e. living matter) are normalized, standardized, and products are labelled (Demeulenaere, 2013; Tordjman, 2008). Thus, no apparent reason requests any preferential treatment organic and conventional high-input management. Both are expected to induce land degradation, due to unadapted management, and consequently also to generate land conservation practices. Agriculture cannot be thought without the natural environment it evolves in, the need to preserve it seems undeniable (Bourguignon & Bourguignon, 2008).

Serious and rigorous research including long-term (more than ten years) erosion damage mapping and involving soil erosion and its on- and off-site effects has been, and still is, realised on selected areas in the region of Frienisberg (Prasuhn, 2011). That mapping method viewed as useful for the appraisal of erosion processes, stating the locations, reasons, and intensities as well as giving guidance for erosion-control. In the observed region, erosion is retained as a marginal problematic occurring on roughly 30% of the fields per year, controlled by different factors, such as weather conditions, crops and/or crop rotations, as well as soil tillage. Nevertheless, no broader and more inclusive illustration, embracing land use and degradation processes in their wide-ranging spectrum, has been done yet for the region. The geographic distribution, of land use and land management, within the landscape, as well as the expressions of land degradation and the responses to it, in terms of Sustainable Land Management (SLM) as well as Soil and Water Conservation (SWC), have not so far benefited from particular attention. Furthermore, no assessment illustrating the impacts of land use, land management, and land degradation on the land and on the related ecosystem services (ESS) has been done so far. Finally, the coverage and effectiveness of land conservation in controlling and reducing land degradation have barely been monitored. The present study intends to fill these gaps.

1.4 Relevance of the research

As already mentioned, this study is imbedded in the European RECARE-project, which relevance needs no further attention. Both land use and management are widely recognised as controlling factors in land degradation. The importance of understanding their drivers and impacts appears undeniable. Despite the fact that the WOCAT Mapping Questionnaire (QM) is recognised and accepted worldwide in fulfilling these purposes, no study based on the systematic application of the WOCAT QM has ever been made in Switzerland. The QM emerges and progresses as a partnership of WOCAT, LADA, and DESIRE, which combined result in participatory and integrated tools and methods for the assessment of land degradation and Sustainable Land Management (SLM) as well as improved decision support (CDE, 2012, p. 1). Given that the approach serves to draw and illustrate the current regional situation of the land management, as well as to picture causalities relating land use and degradation impacts, this research might represent an interesting support for further studies and/or practical implementation of conservation practices in Switzerland's midlands.
The land use map resulting from this exercise is considered as a useful contextualisation tool and might be valuable during further stakeholder workshops and participatory meetings, among others, as part of RECARE.

1.4.1 WOCAT-LADA-DESIRE

The following section provides a brief overview of the three branches of the questionnaire for mapping land degradation and sustainable land management WOCAT, LADA, and DESIRE (CDE, 2012, p. 1):

DESIRE (Desertification Mitigation and Remediation of Land) – *Local solutions for a global problem* emerges from the intention to give SLM measures a scientific basis free from error, thus a clear and understandable definition of indicators becomes necessary (www.desire-project.eu). Wherewith auspicious SLM strategies can be assessed and developed in cooperation with stakeholder groups. Furthermore, the tool permits the evaluation of SLM measures on regional scales and the diffusion of results, assessment and judgement support tools in appropriate formats allowing all significant stakeholders to enjoy the fruits of participation.

WOCAT (World Overview of Conservation Approaches and Technologies) – *Standard SLM knowledge management and decision support for up scaling of SLM* recognises the need of shaping and coordinating a worldwide network of SLM specialists (www.wocat.net). It emphases on the development of harmonized instruments and methods at local, regional, and domestic level in order to strengthen the organisation of knowledge and to support decision-making processes. The initiators assume the collective responsibility in working to manage this worldwide knowledge base on SLM and distributing the composed material by means of diverse channels. Management includes developing and enriching the competence of involved actors, through processes fostering research, training, and education. WOCAT strives to extend its' structure in order to become the standard platform wherein SLM practices and land degradation processes are assessed and reported.

LADA (Land Degradation Assessment in Drylands) – *basis for informed policy advice on land degradation at global, national and local level* takes special care of SLM and land degradation assessment in drylands from national to local scale (www.fao.org/nr/lada). The program puts efforts and determination on structuring competence and understanding in order to act in situations of land degradation. It aspires an integrated assessment of SLM and land degradation thus the elaboration of adequate tools and methods. To accomplish the assessment, LADA defines numerous indicators operating at various scales. As enclosing objective LADA tries to identify SLM and land degradation assessment methods at global level in order to create a worldwide standard for upcoming monitoring of land degradation.

1.4.2 RECARE project

In 2013, the European project titled RECARE has been established in order to search for effective soil degradation, prevention, and remediation solutions in Europe. By incorporating and advancing actively the understanding and experience of multiple actors and researchers, RECARE covers large series of soil threats in diverse biological, physical, and socio-economic milieus across Europe. RECARE emerged from the recognition that the available knowledge on soil threads in Europe is large, however fragmented and incomplete (www.recare-project.eu), thus the project initiators included a pioneering trans-disciplinary approach (Hadorn et al., 2008). The region Frienisberg (including the municipalities Seedorf (BE), Schüpfen, and Grossaffoltern) has been chosen as one of the 17 Study sites throughout Europe.

1.5 Goal and objectives

1.5.1 Study goal

The goal of this study is a spatial assessment of land use, land management, and land degradation as well as its impacts on ecosystem services on the base of the WOCAT participatory mapping method, in order to appraise the influence of land use and distinct land management practices on land degradation, land conservation, as well as on related ecosystem services. Within the agricultural land, particular attention is given to the assessment of a reference technology, namely *conventional or intensive, high-input ploughing*, as well as to other cultivation systems (e.g. no-tillage or mulching), referred to as conservation technologies of SLM practices, which are to be considered as emergent in response to the difficulties (e.g. occurring land degradation processes) encountered on lands under conventional, high-input ploughing.

1.5.2 Specific objectives

The objectives of this MSc study are pursuit to provide insight and contribute to the development and assemblage of knowledge on land degradation/conservation based on participatory methods and applied in the context of cropland, grassland, and forest management. The specific objectives of this study are listed as follows:

1. *Create a Land Use System (LUS) map including the major slope gradient categories*
2. *Establish the current state of land degradation in order to*
    a. *Identify type, severity and extent of land degradation,*
    b. *Identify drivers and impacts of land degradation,*
3. *Establish the current state of Sustainable Land Management (SLM) and Soil and Water Conservation (SWC) practices in the region of Frienisberg (BE) using the WOCAT Mapping Questionnaire (QM) in order to*
    a. *Identify type and extent of conservation measures/practices,*
    b. *Identify drivers and impacts of good land management practices*

Researchers notably form the University of Bern and Agroscope (FAL) studied the surroundings of Frienisberg (BE) largely over the past two decades. The study builds on very valuable knowledge and data and focuses on identifying both the degradation areas and the already implemented conservation practices with accurate precision. Leading to a better understanding of the effects of SLM initiatives, this process is conducted not only with the intention to identify problem areas and conservation successes but also eventually to fortify the need to shift towards more conservation practices and to pinpoint the good management while relating to ecosystem services.

1.5.3 Hypotheses and research questions

The research questions and hypotheses are expressed as follows:

Research questions

1. To what extent have the conservation practices been reducing and/or preventing *types, severity, and extent* of land degradation in Frienisberg?
2. Can so-called *bright spots*, locally adapted conservation technologies, be identified and encouraged in this pioneering region?

Hypotheses

i. On the base of the LUSs the land will encounter different types of degradation.
ii. The occurrence (*type*) and the strength (*severity* and *extent*) of land degradation will depend on the *land use system*, and, within the LUS *cropland*, on crop types (e.g. root crops), on the vegetation type (e.g. grade of soil cover), as well as on the land management (e.g. species selection, soil treatment, etc.).
iii. The various experts and stakeholders can assess and identify different types of land degradation, which are grounded on their knowledge related to the different land management practices applied in different fields within the well defined study area.
iv. Conservation practices significantly reduce land degradation. Land degradation cannot be completely avoided when referring to conservation technologies involving heavy, power-driven machinery.
v. The spread and effectiveness of conserving land management practices vary between different landscape categories (e.g. slope gradient categories).
vi. The long-term viability of high-input agriculture may be questionable given the importance of its impact on the land. Resolute community-based initiatives emphasising on structural transformations may be invited paths.

1.6 Area of interest: RECARE project area and study area

1.6.1 Valuation of the land

The surroundings of the village of Frienisberg (BE) have been selected as one out of 17 case study sites throughout Europe addressing different soil threats. This area is located in the Canton of Bern, Switzerland, between the cities of Biel/Bienne and Bern (approximately 20 kilometres northwest) (see Fig. 1). Enclosing three adjoined municipalities Seedorf (BE), Schüpfen, and Grossaffoltern the project area extends beyond the near vicinity of Frienisberg. The area of interest documented as part of this master thesis lies between those municipalities without covering them entirely, and sometimes extending beyond the boundaries (including areas belonging to Seedorf (BE), Schüpfen, Grossaffoltern, Lyss, Aarberg, Kappelen, Bargen (BE), Radelfingen, and Meikirch) principally in the East alongside the Aare River (Fig. 2 includes details of location).

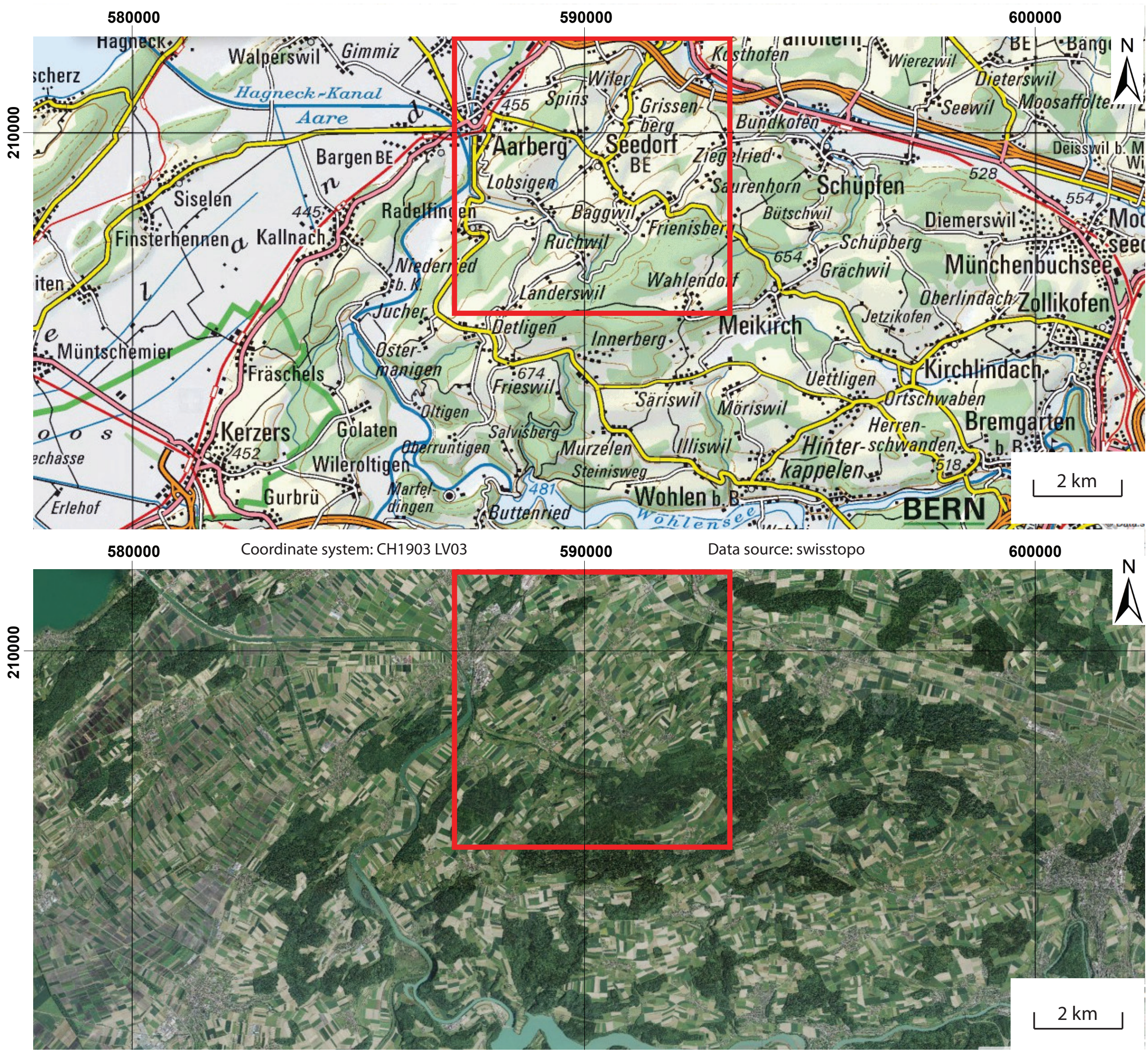

Fig. 1 Location of the study area Frienisberg (BE) (Illustration: Fedrigo 2016, Data source: © swisstopo)

Decisive factors defending a surface area reduction (with respect to the RECARE project area) were first the data availability, then, additionally, the availability of key actors and their readiness. Illustrating the area in question, Streit (2014) created an area pattern exemplifying an exact spatial grid of analysis, wherein the cropland and grassland surfaces are narrowed down to the accurateness of the practical cultivation plots (see section 2.4.5 for more details). The value of such precise grids is furthermore defensible by the characteristics of the areal distribution of

Switzerland's agricultural landscape: While referring to the analysis of the Swiss midland countryside both Gasser (2009) and Grob (2010) justify the use of a higher spatial resolution and a smaller scale. These characteristic patterns validate the assessment of a smaller area by comparison to the reference sizes usually expected by the WOCAT methodology. Additionally, Streit (2014) already justified the choice of this area of interest considered as representative for the surroundings. Trusting these judgements, the same area of interest is adopted. Furthermore, since the agricultural policy acts at national level (see section 1.6.3 for more details) and there is no usage and/or property right restriction that is systematically bond to the municipality, i.e. the agricultural leasing agreements and plot properties are not restricted/confined within municipal borders, the distinction of municipal boundaries is not necessarily required in the case of this study, although administrative borders are generally mentioned in the WOCAT procedure. Instead, agriculturalists own, inherit, buy, and lease patches that stretch over different municipalities, in which case the property and/or leasing covenant becomes determining factor, not the administrative borders.

The regional land use is typical for the Swiss midlands. Five major land use types are observable in the study area (Fig. 2), namely **cropland**, **grassland**, **forest**, **waters**, and **settlement area**. Out of these, cropping can be identified as a predominant land use characterising the region (see Fig. 10). The most spread agrarian system is mixed farming, joining cropland and livestock keeping. This uniform land use is regularly spatially disrupted by small settlement areas and waters bodies, as well as occasionally by forestlands. Frienisberg is also characterised by a wide range of **slopes** (see section 2.3.1.2), used for intensive and extensive crop production, and it's associated risks of land degradation. Vast research has been achieved within the area centring mainly on soil erosion and the related land uses (more details in section 2.6).

The agricultural surfaces account for the largest share of land area. Creating a checked pattern, as observable in Fig. 2, agricultural activities, joining **cropland** and **permanent grassland**, occupy nearly all the northern and central section of the study area. Thus, the surfaces affected by degradation processes due to mismanagement of farmland are potentially far-reaching. However, the region has been characterised by a remarkable diversification and conversion of the tillage practices between 1993/1997 and 2007: Even though ploughing remains a widespread soil tillage practice, ploughed surfaces were almost halved for the benefit of non-ploughed soils, mulching, and reduced tillage practices (Prasuhn, 2012). Furthermore, **forests** represent a significant part of the study zone. As noticeable in Fig. 2, most woodland is confined to the south of the research area, while smaller patches are distributed randomly all over the assessment zone.

Waters and **settlement areas** are not directly assessed as part of this study. In order to maintain consistency, the fact of their existence is recorded. Since the research focus of the RECARE project has been put principally on soil erosion by waters, it has been chosen to concentrate the efforts on the other land use types, although, the potential adverse effects of theses land uses are known. Water bodies and settlement areas are eventually investigated in terms of offsite effects and/or triggering factors when relating to other land uses.
In light of the homogeneity of land and the cultivated crops as well as the constraint study area surface no further distinction of the cropland, grassland, and woodland needs to be drawn other than the subdivisions provided by the **slope gradient categories** detailed in section 2.3.1.2.

Finally, illustrative precipitation values, retrieved from the long-term annual precipitation series, range between 1035 mm, for Seedorf (BE), and 1150 mm, for Frienisberg (Prasuhn, 2012).

Since many studies involving local actors have been performed throughout the years in the region we can benefit from the relations that built up, but with great sensitivity not to abuse the people's trust. So, this region seams an interesting area to start with for comparative research.

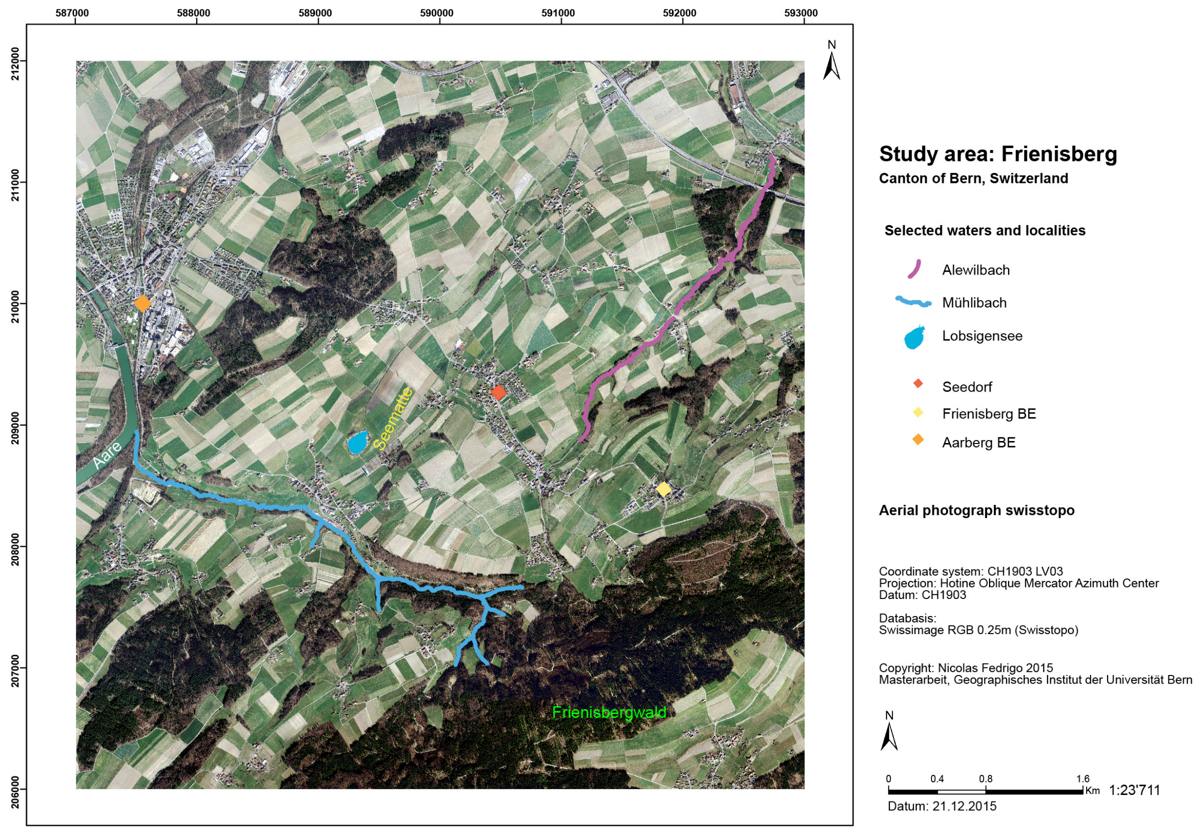

Fig. 2 Study area "Frienisberg (BE)" (Illustration: Fedrigo 2016, Data source: © swisstopo)

1.6.2 Soil properties

The aptitude maps illustrated in Fig. 3 are based on different physiographical units and features of the landscape characterised by bedrock, slope and hillside situation. While referring to the variable aptitude: cropland (Fig. 3, left) most of the area of interest is classified as *very good production* (*sehr gute Produktion* in German, red section) and *good production* (*gute Produktion* in German, green section), although nearly one fifth of the area is considered as *unsuitable* (*ungeeignet* in German) (Fig. 3 right, greyish section). By comparing with the areal picture and the digital elevation model (DEM) (described in section 2.4.2) it becomes visible that most of the land characterised by a steep slope gradient and qualified as *unsuitable* (grey section) is covered by forest. Selected steeper and *unsuitable* plots (e.g. nearby surface waters, see details of location in Fig. 2), which are not enclosed by forest, are managed as permanent grassland (comparing land-use map section in Fig. 13). Finally, two tiny areas one close-by lake Lobsigen, stretching North along the Seematte and identified as moorland/peat, and another on the northeast corner, are only *moderately* suitable for agricultural production (*mässige Produktion*) (yellow section).

Predominantly occurring soil types are identified as *Braunerde*, *Saure Braunerde*, *Parabraunerde*, *Kalkbraunerde, Cambisols* or *Brunic Arenosols* (see Annex Table 1 for more details) according to the WRB (USS Working Group WRB, 2015) and Luvisols (Ledermann et al., 2010).

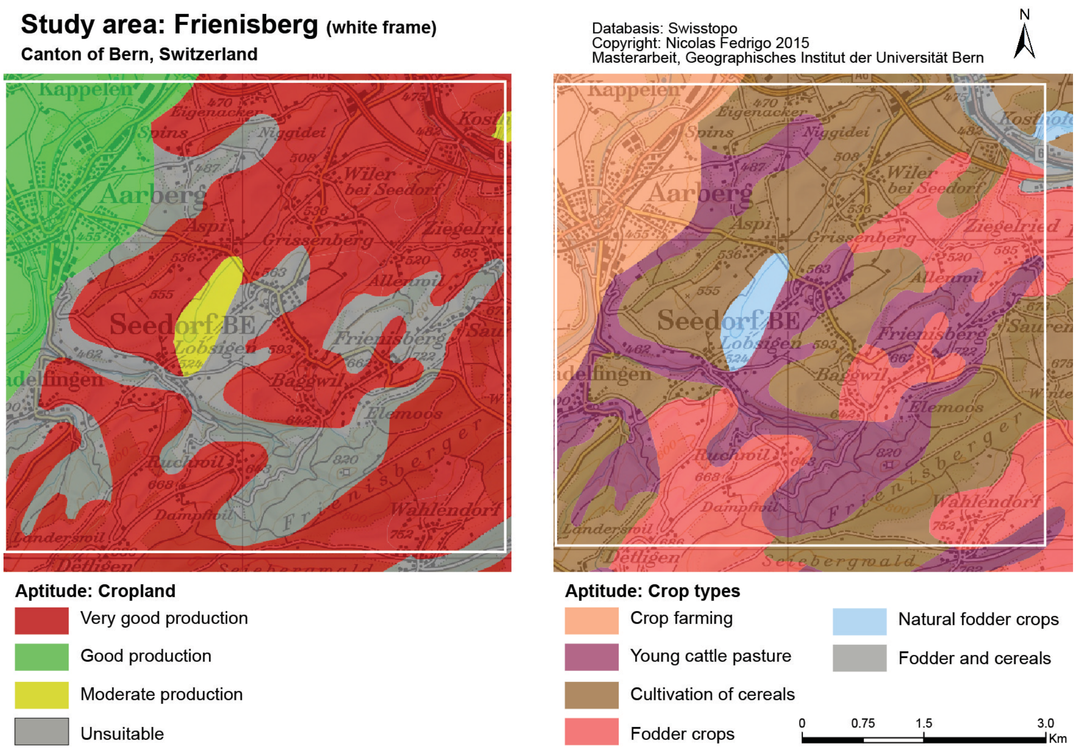

Fig. 3 Study area Friensiberg (BE) (white frame): Aptitude crop-types and cropland (Illustration: Fedrigo 2016, Data source: © swisstopo)

1.6.3 Agricultural policy

As the directives and payments are accounted by the Confederation, and thus the definition of margins, the leeway left to the Cantons and municipalities are only little. Ecological performances emerge from the farmers' willingness to contribute or from the choice to cooperate, wherefore the Canton or municipality only plays a secondary role in the location of the area of interest.

Since the agricultural reform in 1992, direct payments (DPs) constitute a central feature in Switzerland's agricultural policy (Bieri, Steppacher, & Moser, 1999; BLW, 2013). Up until then regulations of government subsidies where primary based on price and quantities. Since the revision of the agricultural law structural changes led to the introduction of general (compulsory) and ecological (voluntary) non-product dependent DPs (Popp, 2013). With the reform, ecological concerns are newly considered through economic incentives. Pure price support is no longer appropriate to achieve the goals of sustainable agriculture, including cultural landscape management and the conservation of natural resources. The agricultural policy 14/17 provides financial support to initiatives favouring extensive land use and farming practices. Specific ecological services, in which the participation is voluntary, are encouraged, maintained, and reinforced with ecological direct payments (*Ökologische Direktzahlungen* in German). In practical terms, by actively participating in these programs farmers receive amounts for ecological performances such as extensive meadows (*extensive Wiesen* in German) or wild flower fallow land (*Buntbrache* in German). Furthermore, the Confederation launched programs supporting the quality and the connectivity of ecological compensation areas (BLW, 2004), while the Canton of Bern introduced financial supports accompanying management practices intended to reduce the land use intensities and the related impacts on natural resources (Schwarz, Chervet, Sturny, Hofer, & Zuber, 2007).

Fostering sustainable and market oriented production the Swiss Confederation wants to ensure that agriculture contributes significantly in certifying a reliable supply to the population and the conservation of natural resources, while maintaining the cultural landscape and backing the decentralized settlement of the country (Agrarpolitik 2014-2017). According to its authorities and duties, the Swiss Confederation directs its actions so that the agriculture achieves its multi-functional obligations: General DPs include contributions related to the area, to roughage-consuming livestock, to livestock production under difficult conditions, and to hang posts, whereas contributions referring to ecological DPs relate to ecological compensation, extensive cereal and rapeseed cultivation, organic agriculture, and particularly animal-friendly husbandry as well as payments for summer pasturing. Furthermore, investment loans as well as retaining and operating aids can be entitled to the benefits of DPs.

Part Two

Methodology

2 Theoretical backgrounds

Experience made, and confirmed in the practical phase of this study while including multiple actors with different backgrounds, expertise, knowledge, or fields of application, clear and common definitions are necessary.

The most important definitions, methods, and concepts the research is built on are illustrated in the succeeding sections. The following chapter represents an attempt to form a concise and comprehensive presentation of the theoretical fundaments. The notion of land includes the natural resources soil, water, and vegetation, whereas the WOCAT-LADA-DESIR methodology involves the assessment of land degradation and conservation measures with regard to the resources mentioned, including moreover the ecosystem services. The theoretical sources underpinning the current research are acquired from the WOCAT methodology that is based on the DPSIR framework. Consequently, part two includes furthermore a section discussing the framework. Finally, the state of the art concludes the methodological chapter.

2.1 Terminology and Definitions

2.1.1 Sustainable Land Management

Sustainable Land Management (SLM) is a criterion of major importance for sustainable development (Liniger, van Lynden, Nachtergaele, Schwilch, & Biancalani, 2013). In this context SLM is defined as follows:

> "The use of land resources (including soils, water, animals and plants) for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (Liniger, van Lynden, Nachtergaele, et al., 2013, p. vi).

Agricultural intensification and the settlement on peripheral land areas increases pressure on croplands and forests, but also on meadows and pasture lands (Steiner, Herweg, & Dumanski, 2000). In face of the situation Steiner et al. (2000) suggest that rising food provisions need to be achieved through agricultural intensification other than the extension to additional land lots. Thus, SLM recommends this intensification to come along with paired ambitions of delivering socio-cultural, environmental, and economic openings, as well as care taking to the quality of the land resources.

However, in order for SLM to become effective, the need to develop operational and appropriate assessment and monitoring indicators and tools is recognised. The SLM terminology requires also clear definition for it to operate and thus, in the context of this research, it has been chosen to adopt the following definitions: The **land** is described as generally representing the natural resources, i.e. soil, plants/vegetation, water, and animals/living organisms (Liniger, Schwilch, et al., 2008, p. i), which are present in a confined spatial unit, the **land unit** (Hurni, 2000, p. 85). The on-ground action using appropriate technologies in the corresponding **land use system** (see section 2.3.1.1), considered as the elementary evaluation unit (Nachtergaele & Petri, 2007), is referred to as **management**, whereas **sustainable** calls for an implementation in all dimensions, i.e. ecological, social, economic, institutional, and political (Hurni, 2000, p. 85). Thus, when referring to what is sustainable the term 'appropriate' calls also for conformity to the three dimensions of sustainable development (as already intended in WCED, 1987), signifying that a techniques/practices ought to be ecologically, economic, and socio-culturally viable.
With the intention to assess SLM and to complement prior limited concepts, the *multi-level stakeholder approach to sustainable land management* is theorised, envisioning a guidance towards achievable, adequate, viable, and ecologically supportable local scale solutions (Hurni, 2000). "The ways and means used to realise SLM" are intended as an approach (Hurni, 2000, p. 86), wherein, the categories of people or institutions sharing a mutual interest in a portion of land are indicated as **stakeholders**. Hurni (2000) appreciates the broadness of a long-term sustainable land management to be expressed at **multiple levels**, as it invokes a variety of actors operating in different societal configurations, these **key actors** (further also referred to as **experts** or **expert group**) evolving on-site (e.g. farmers, residents, etc.) and off-site (e.g. scientists, professional researchers, administrators) are integrated in the assessment process, while former concepts and suggested technologies were trying to shorten the procedures by considering for instance land-users as the only actor category, an oversimplification leading to one-dimensional approaches evaluating the negative impacts on land.

In my understanding some limits, inherent to the application of this SLM definition in the context of this study, are worth noting. Practices will be further noticed as SLM/conservation technologies/practices without accomplishing – in my opinion – the notion of **sustainability** at its fullest. According to the Brundtland Report (1987) "sustainable global development requires that those who are more affluent adopt life-styles within the planet's ecological means – in their use of energy, for example" (WCED, 1987, p. 15). Since all conservation practices evaluate in this study rely in their functioning inherently and unconditionally on the consumption of non-renewable, fossil resources (be it for running machinery or for the reliance on synthetic inputs) none could be termed as long-term *sustainable* (or viable) technology, in its' strict sense, not least because of the global climate changes and the peaking of fossil energy (Mulligan, 2010). Even though it has been shown how conservation measures and organic farming may contribute in mitigating the greenhouse gas emissions also of Swiss farms (Schader et al., 2014), major long-term impacts, also associated with the consumption of fossil fuels, remain a source of concern. The environmental and social burden gets even heavier when addressing the food systems through all levels of the life cycle (Heller & Keoleian, 2003). In my understanding a technology cannot be qualified as *appropriate* and *sustainable*, or "viable" (WCED, 1987), at long-term, as long as it maintains its investment in fossil resources. It seems important to specify this understanding, which is relevant particularly when building up new perspectives.

However, in the interest of convenience, it has been decided to ensure consistency of the terminology used throughout the WOCAT methodology, thus not abandoning using the term "sustainable land management (SLM)".

2.1.2 Local participation and transdisciplinarity

Eventually this research emphasises on **participatory** and **multi-stakeholder** approaches, which are planned in an **actor-oriented** perspective. As presented in Hurni (2000), these methods can be embedded in a larger theoretical background structured on behalf of SLM perspectives, engaged in the attempt to catch the complexity of all operating factors, while emphasising on the potentials of multiple actors and scales, as well as pricing the local knowledge. The participation of multiple actors is expected to include more widespread information, although while highlighting the fact that common value-bases, including the belief in fundamentals such as learning, equity, empowerment and trust, are a prerequisite for the functioning (Reed, 2008).
In the attempt to capture the location specificity in its various forms and dimensions (social, physical, organizational, political, etc.) **transdisciplinary** research, as a joint work between science and society and thus based on the integration of various disciplines and actors, emerges and aims to produce new knowledge in collaborative learning processes (Angelstam et al., 2013). Grounded on the non-hierarchical exchange of observations, theories, and experiences the collaborative (multi-stakeholder representation) procedures can be introduced in all processes from knowledge production and learning to problem formulation. Evolving through the permanent effort and cooperation of researchers from distinctive scientific disciplines and non-scientific local stakeholder participation, transdisciplinary research is presented as a more holistic approach to understand and explain problems in complex social-ecological systems (Angelstam et al., 2013). Introduced as an antagonism to *applied* and *basic science* the authors reflect

transdisciplinary research as an **applied practice** prepared to find practical solutions to the world's problems. The LADA project, for instance, is quick to recognise the importance in creating multidisciplinary teams, involving land users, various experts, and district extension officers, for the sub-national and local assessment. Experiences made, it acknowledges the importance of producing real links with and within the districts under investigation, in order to ensure a better quality of the outputs, knowing that valid and equal participation, incorporating all stakeholders, is not always a tranquil task (Biancalani, Nachtergaele, Petri, & Bunning, 2013). Wide, diverse, and solid knowledge exists ramified among local actors, specialists, and the vast scientific community. Existing obstacles and difficulties mitigate the creation, diffusion, sharing, exchange, and access to information, experience, and encouraging techniques. Aware of the characteristics in knowledge involvement, the WOCAT-LADA initiative recognises the need to establish a tool for the integration and diffusion of SLM approaches and technologies among and between communities and actors. SLM practices often emerge and develop as an outcome of local traditional practices and progressive experimentation rather than only building upon scientific evidence (Berkes, Colding, & Folke, 2000). Recurrently SLM emerges in response to precarious conditions, however for countless reasons farmers' local and traditional knowledge is less weighted, e.g. in policy decisions (Stringer, Fleskens, Reed, Vente, & Zengin, 2014). Despite the fact that both field practitioners and scientific specialist have a wealth of knowledge and information about SLM, their complementarity seemed not yet to be perceived at its true value. Thus the call for transdisciplinary, participatory research seams unquestionable.

In Frienisberg, scientists from the University of Bern, Agroscope (FAL) and practitioners have been working together over decades. The cooperation led to the establishment of networks of trustworthy actors and close (research) partnerships.

2.1.3 Land degradation

The following sections introduce and discuss the content related to the notions of land **degradation**. The LADA involvement in the land degradation discussion has been significant, when showing the necessity to incorporate the time period over which the degradation processes strike as an assessment variable. Considering that nearly every land would be considered as degraded if referring to its original natural state, land degradation is therewith put in its local context. Human-caused degradation and its impacts on food production must be assessed in this local context and shared with all stakeholders and local actors (Oldeman, 1998). The location specificity recognises the role that beneficiaries or stakeholders play pondering that, on a given status, the land can be considered as *good* or *bad* depending on the applied value system or the envisioned use of the land (Nachtergaele, Biancalani, Bunning, & George, 2010). The time variable is one major dimension in which land degradation operates, wherewith the process are theorised as a compulsive development of multi-annual land cover activity (Mialhe et al., 2015).

Various definitions of land degradation exist (we may retain the third one):

- LADA defines land degradation as: *"The reduction in the capacity of the land to provide ecosystem goods and services and assure its functions over a period of time for its beneficiaries."* (Bunning, McDonagh, & Rioux, 2011b, p. 31).
- UNEP defines land degradation as: *"a long-term loss of ecosystem function and service, caused by disturbances from which the system cannot recover unaided"* (UN Environment Programme, 2007, p. 92).
- Whereas the WOCAT definition of degraded land is: "*land that, due to natural processes or human activity, is no longer able to sustain properly an economic function and/or the original ecological function*" (Liniger & Critchley, 2007, p. 18).

Degradation disturbs and lowers permanently or temporarily the productivity of the land as well as numerous further ecosystem services it provides. It is widely recognised that there is an urgent need for both local and global action against land degradation. In the outcome document adopted at the *Rio+20 UN Conference on Sustainable Development* held in Rio de Janeiro, Brazil, in June 2012, articles 205-209 refer to *Desertification, land degradation and drought* (United Nations, 2012). The urgency of action, to prevent and reduce land degradation, is mentioned, as well as the will to achieve a *"land-degradation neutral world"* (art. 206).
Mainly initiated by natural processes, and potentially accelerated by human activities and changing climates, land degradation leads to the qualitative and quantitative reduction of both land resources and related ecosystem services (Bunning, McDonagh, & Rioux, 2011a). Qualified as developments affecting soil properties, land degradation processes can be grouped into three broad categories, namely physical, chemical, and biological degradation (Liniger, van Lynden, Nachtergaele, & Schwilch, 2008; Liniger, van Lynden, Nachtergaele, et al., 2013). Characteristics and particularities distinguishing each group are briefly outlined in the sections below.

2.1.3.1 Physical degradation

Physical soil degradation is mainly characterised by soil erosion and compaction processes, expressed through actions such as surface crusting and sealing, loss of topsoil structure, sub-soil compaction, reduced soil rooting depth, and loss of fines (erosion of clay and silts). The loss of bio-productive functions, waterlogging, and the subsidence of organic soils are also included in this section (Bunning et al., 2011a; Liniger, van Lynden, Nachtergaele, et al., 2013).

Soil erosion is conveniently explained as replying to the increasing and accumulative stresses applied on the land, both by a growing world population and by the desertion of wide regions of previously productive land (e.g. resulting from erosion, alkalinisation and/or salinization). Globally, in terms of severity and regularity, the spatial variability of soil erosion is substantial. Social, political, economic, and institutional factors influence its' geographical and temporal parameters (Morgan, 2005).

Soil erosion is one major expression of physical and mechanical soil strain. Occurring in two phases, it starts with the secondment of discrete soil elements from the soil mass and is followed by the soil transport through erosive agents (e.g. flowing water and wind). Eventually, the erosion stops once the remaining energy becomes insufficient for carrying the mobilised particles (Morgan, 2005). Exposed soils are weakened and once they are loosened, their particles are easily removable by transporting agents. Both biochemical and mechanical (e.g. alternating wetting-drying, freezing-thawing) weathering processes disrupt the soils. Raindrops splattering (rainsplash) on bare soils are the most significant isolating agent, displaced particles being moved over many centimetres. Transporting agents can be categorised in two major entities opposing *spatially extensive and homogenous displacement*, caused by rainsplash, to *channelled water flows*, expressed in forms of rill erosion or its larger associate gully erosion. Another driver gathering and transferring the material on the land surface is expressed as the transport by mass movements: water disturbs the soil inertia by changing its strength (Morgan, 2005).

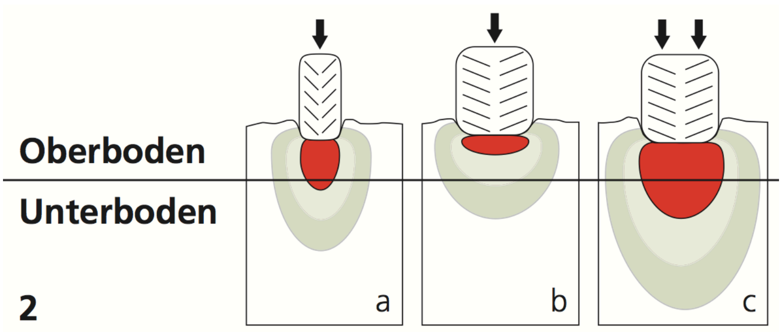

Fig. 4 Effects of the tyre width and wheel load on the top- and subsoil (Source: Marbot et al., 2014)

Second types of physical land degradation are confined in **soil compaction** processes. Animal hooves, farm machinery, and impacting raindrops are the principal factors causing crusting and sealing. The use of heavy machinery and wheelers, accentuated by the frequent passages, lead to internal transformations of the soil structure, such as the compression of soil cavities. If combined with excessive tillage or recurrent ploughing at a persistent depth these thoroughgoing physical stresses that can reach subsoil depths and high levels of compaction.

The soil functioning and the state of its' quality can be identified or evaluated when assessing the soil structure, demonstrating the faculty of the soil to sustain plant and animal live this indicator is of central influence. Variables such as the soil pore system (Pagliai, Vignozzi, & Pellegrini, 2004) and the aggregate stability (Six, Elliott, & Paustian, 2000) appear to be indicators for the soil structure.

In general terms, soil compaction occurs when the soil pressure exceeds the soil strength (Marbot, Fischler, & Küng, 2014). Anthropogenic pressure on the soil can be confined when reducing the wheel load (machine and load weight) and raising the contact area (tyre type, pressure, width and volume, single or twin formation (tyres), and axis type). It is of primary importance to avoid subsoil compaction. As shown in Fig. 4 both the wheel load (arrows) and the tyre width induce and vary the soil pressure (red). The wheel load remains a critical factor even though the tire width might mitigate the pressure exerted, wherefore high loads are fundamentally risky. Soil strength is a force that counteracts compaction. The primary factors acting on the soil strength are the soil moisture, the soil type, and the soil structure. The higher the soil moisture content, the lower the soil strength, thus the danger of soil compaction rises with increasing soil moisture. It is therefore draw attention on moist fields that should not be driven on for at least three days after intensive rainfalls (Marbot et al., 2014). Furthermore, the soil types are characterised by the texture and weight, wherewith light and/or sandy soils are less exposed to compaction than heavy, loamy ones.

Finally, a well-developed soil structure, characterised by small soil particles and comprised by active living organisms and pore water availability, decimates compaction. The soil organisms subsist due to root and crop residues as well as organic manure. Tillage practices induce soil loosening and the weakening of its' structure (Bronick & Lal, 2005; Holland, 2004). Thus, in Switzerland, most agricultural lands are at risk of compaction. Applying adequate cultivation methods (e.g. no-tillage, conservation tillage) may prevent this degradation processes from happening (Armengot, Berner, Blanco-Moreno, Mäder, & Sans, 2015; Holland, 2004; Siegrist, Schaub, Pfiffner, & Mäder, 1998).

2.1.3.2 Chemical degradation

The second soil deterioration category assessed in this study is qualified as **chemical degradation**. This expression of soil degradation does not discuss recurrent oscillations of soil chemical settings in agricultural systems of relative stability, nor does it refer to steady transformations in the chemical configuration resulting from soil building processes (Oldeman, 1994), but rather articulate processes of unfavourable soil developments: e.g. progression of soil reaction or pH, fertility regression, quantitative decline in reserves and availability of soil and plant nutrients, or the capability to unplug toxic complexes and diminish extreme accumulations of salts in the root area (Lal, Iivari, & Kimble, 2003). The chemical processes underpinning this deterioration are e.g. organic matter decline, acidification, salinization, or soil pollution (Bunning et al., 2011a; Liniger & Critchley, 2007).

Nowadays, large amounts of pollutants reach the earth and enter the soil. Many processes and sources can lead to land contamination, e.g. washout of airborne pollutants and particle setting, mineral and farm manure, chemical pesticides, or the use and improper waste deposition. Presently, the impacts of such pollutants are not known at all, or only incompletely known. The substances accumulate somewhat in the soil where they affect the soil life and its' fertility. While certain elements leave the soil to reach the **water** or the air, others enter the food chain via comestible plants and the water cycle (BAFU, 2007). The investigations carried out so far point to the recognition that there are no uncontaminated soils left in Switzerland. According to BAFU (2007) problematic stresses are generally linked to particular and imbalanced uses (e.g. viticulture), close exposure to significant sources of pollutions (e.g. roads), or mismanaged processing of soil excavations. Fortunately, only low pollutant contents could be registered outside the actual pressured key areas. In most agricultural and forest areas the soil fertility is still guaranteed in the long term, provided that the stresses do not increase further (BAFU, 2007).

2.1.3.3 Biological degradation

Finally, the degradation of soil biological properties is systematised by processes such as the reduction, in terms of quantity and activity, of symbiotic and valuable soil organisms (e.g. earthworms, mycorrhiza, bacteria, rhizobia) as well as the loss of their related functions, or in contrast, the increase (also in terms of quantities and activity) of damaging soil organisms (e.g. parasitic weeds, nematodes) as well as the losses associated to pest and/or diseases (Bunning et al., 2011a).

Biological degradation includes stresses exercised by pathogens or non-indigenous, which have been consciously introduced as well as genetically modified living organisms (GMOs). Even though the risk of biological soil contamination stays moderate, it is nonetheless quite real. A global market, thus globally distributed commodities introduce stowaway species in new environments. These living organisms represent a threat to soil fertility and health (BAFU, 2007). The structural evolution of Switzerland's farming system, notably hiring contractors and the increasing community tolerance for GMOs (the current moratorium ends in 2017, what is the situation going to be after?), at least for scientific trials (Nausch, Sautter, Broer, & Schmidt, 2015), contributes to increasing risks related to biological contaminations.

Soil degradation, expressed through physical, biological, and chemical degradation processes, and the related causal effects on the environment are an issue of increasing importance since the 1930s and will persist as critical concern throughout the 21st century. According to the MEA worldwide 15% of the soils are degraded by the early nineties, whereof 38% only to a light degree and 62% to a moderate or strong degree (BLW, 2008). For this study the assessment of land degradation is focussing on anthropogenic causes, notwithstanding naturally driven causes are not excluded nor are they contested. Concisely defined, soil degradation is the soil quality deterioration triggered by anthropogenic mismanagement. This quality decline occurs through the temporal interaction of the tree processes presented previously. Degradation can be irreversible and permanent. Nevertheless, slightly or temporarily degraded soil might be restored through changes in land use and management, including SLM practices and conservation measures (Lal et al., 2003). This mapping practice directs precisely the evaluation potential of the soil, or the land, resilience, meaning the restoration or recovery capacity of the land, termed for instance in environment balance capacity and biomass productivity, through appropriate management. Special emphasis it put on agricultural land, comprehending ploughed cropland (reference technology), permanent grassland, and other cultivation methods, out of concern for the cohesion, referred to as conservation technologies (e.g. no-tillage).

2.1.4 Ecosystem services (ESS)

According to MEA (2005a) ecosystems are the systemic fundamentals of life on earth. Besides its need for water, food, shelter, clean air, and comparative constancy in climatic conditions, anthropological biology relies on integral watersheds, climate regulation, genetic assortment, and species complementarity. The health and well-being are highly impacted when stressing food-production systems, freshwater sources, or climate regulation, since they rely on the services provided by the ecosystems (MEA, 2005a). The yields from agriculture, for instance, are one of the crucial ecosystem services humanity relies on (MEA, 2005c), in order to maintain them it is important to assure the long-term sustainability of social-ecological systems.

In its most concise definition **ecosystem services (ESS)** are “the benefits people obtain from ecosystems” (MEA, 2005b, p. 1). These, as well as their constituents water, soil, nutrients, and organism, are central and vital to human health and safety. Fluctuations in those services can disturb revenue, livelihoods, local population movements, as well as eventually political conflicts, which, while affecting physical and economic security, or social relations, may impact on human

health and safety (MEA, 2005b). In other words, ESS can be qualified as the procedures through which the environment generates assets used by humans, such as water, food, clean are, etc. Various elementary services untaken by biodiversity (e.g. carbon sequestration, pest regulation, pollination, or nutrient steering) uphold for instance farming efficiency (FAO, 2015).
Selected from the Millennium Ecosystem Assessment (MEA), the WOCAT QM assesses the impacts on ESS according to the following categories (Liniger, van Lynden, et al., 2008, p. E 14):

- Productive services
- Ecological services
- Socio-cultural services/human well-being and indicators

Productive services are to be understood as including the *provisioning services*, namely the essential requirements (e.g. water, food, fibre, genetic resources, etc.). The second category entitled ecological services and incorporating the water, soil, and climate services, combines both the *supporting* and the *regulating* services, whereas the third group defines the *cultural* services outlining the immaterial components accompanying the context of human life (FAO, 2015).

2.2 DPSIR framework

In the late 1990s the European Environment Agency (EEA) adopted the DPSIR (Driving forces, Pressures, States, Impacts, and Responses) framework to describe the interactions between the environment and society (Smeets & Weterings, 1999). National and international institutions such as the UNEP or the Swiss Agency for the Environment (BAFU) refer to this conceptual framework, which is a simple and useful tool for the illustration of complex and multi-layered environmental concerns such as land degradation. Research on land degradation steers towards solution-finding processes and remedies against land degradation, with the DPSIR scheme different methodical perspectives can be connected to particular forms of answers (Andersson, Brogaard, & Olsson, 2011). Representing the referential framework within the WOCAT approach, the current study is also sustained by this theoretical background.

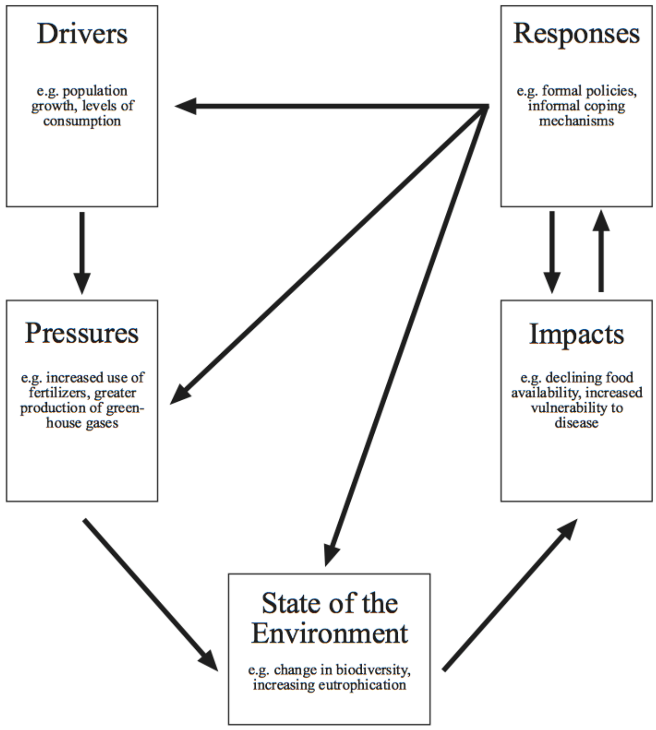

Fig. 5 The DPSIR framework visualising the flow of causes and effects for a certain environmental issue as represented in Carr et al. (2007)

The DPSIR framework emerged as an extension of the Pressure-State-Response (PSR) framework, developed by the Organization for Economic Co-operation and Development (OECD), and of the Driving-Force-State-Response (DSR) framework, proposed by the UN Commission on Sustainable Development. Practically, it arose as a response to gaps in the two former frameworks (Carr et al., 2007). While the PSR only focused on anthropogenic pressures and responses, none of the two frameworks (PSR and DSR) could address the incentives underlying the responses to alterations in the state of the environment nor did they comprise a category focussing on the causal motives for the pressures. The DPSIR framework establishes as a tool seizing the relevance and significance of the broad assortment of environmental indicators in use. It is intended to support the structure and analysis of the indicators as well as to relate the inter-connections between the environment and society (Smeets & Weterings, 1999).

The acronym DPSIR stands for the five components constituting the framework (Carr et al., 2007, p. 545):

- ***Driving forces*** *(or* ***Drivers****) refer to fundamental social processes, such as the distribution of wealth, which shape the human activities that have a direct impact on the environment.*
- ***Pressures*** *are both the specific human activities that result from driving forces which impact the environment, such as the resource extraction necessary to fuel the automobile fleet (…), and the natural processes that have a similar impact on the environment, such as volcanoes and solar radiation.*

- ***State*** *is the condition of the environment. This condition, under current conceptualizations, is not static, but is meant to reflect current environmental trends as well.*
- ***Impacts*** *are the ways in which changes in state influence human well-being.*
- ***Responses*** *generally refer to institutional efforts to address changes in state, as prioritized by impacts.*

The DPSIR, as well as its forerunners, is intended to identify suitable indicators to measure and evaluate environmental problems. DPSIR is planned for the classification and the distribution of information related to precise environmental challenges. Additionally, the framework allows to assess the efficiency of the diverse responses that were crafted (Carr et al., 2007).

In other words the framework gives an edifice for organising the required indicators allowing advice on environmental value and on the subsequent effect of the political actions made (or to be made) to the policy makers (Kristensen, 2004).

As illustrated in Fig. 5, the **driving forces** trigger and induce causal reactions in the chain of elements (Kristensen, 2004): These **drivers** (e.g. human activities) induce **pressures** (e.g. pollution, waste, resource use, emissions) on the **states** (biological, physical, and chemical) of the environment, which **impact** on the quality of the environments (e.g. in terms of ecosystems health, human wellbeing and functions). These causal links can generate **responses**, expressed in terms of societal and political actions, which can address any element of the series (i.e. from drivers to impacts). As it is displayed in Fig. 5 the **responses** assume a central role in structuring the causalities (illustrated by the arrows), which can be created with the four other components of the framework. Since land degradation is comprised in the **state** compartment, the focus is put on that section and on its interactions with the **responses** section. As mentioned previously the **state** describes the environmental situation. The indicators used for monitoring pronounce noticeable alterations in the environmental dynamics and functions relating sustainable development (Bowen & Riley, 2003). The **state** of the environment, such as the value of the different environmental compartments (e.g. soil, water, air) related to the roles they accomplish, is disturbed as a consequence of the exerted **pressures** (Kristensen, 2004). The delivery of satisfactory settings for health, resources accessibility, and biodiversity might be compromised as soon as the **state** of the environment changes (Smeets & Weterings, 1999). The **pressures** compartment is inevitably included in this thesis since the different land-uses suggest this category.

Referring to a certain area by inventorying Driving forces, Pressures, States, Impacts, and Responses, the description of land degradation and SLM is pursuit by the DPSIR mapping (Liniger, van Lynden, Nachtergaele, et al., 2013).

2.3 WOCAT Mapping Questionnaire (QM)

WOCAT emerges also in a context of conscious awareness of the social, environmental, and economic issues related to land degradation and it is concerned by the search for adapted and viable solutions. In this process, WOCAT believes and invests in the strength and the necessity of **knowledge sharing**. Specialists (comprising for instance land users, project managers, agricultural advisors, government agents, etc.) continually produce valuable and vast knowledge and savoir-faire related to good land management (Schwilch et al., 2011). Recognizing the lacking distribution and exchange of this specialized knowledge, the WOCAT-network initiators conceptualise the project, inter alia, with the scope of providing experts with the appropriate **structures** and **tools** favouring a visually supported sharing of their precious comprehension. To facilitate and efficiently organise the extra-regional **exchange of local accomplishments** and expertise in land management, a globally acceptable categorization system for SWC-SLM technologies and approaches is required (Liniger et al., 2002). WOCAT conceptualized three questionnaires and one database system to document the characteristics of each important feature of the conservation technologies and approaches. As a complement to the Questionnaires on Technologies (QT) and on Approaches (QA) (both not used in this study), the **Mapping Questionnaire** (QM) represents the geographical perspective for research. Emphasising on the centrality of the land use, the joined questionnaires offer a broad overview of SLM-SWC activities in the defined geographical area, e.g. country or region (Liniger, van Lynden, et al., 2008; G. W. J. van Lynden, Liniger, & Schwilch, 2002). The WOCAT QM guidelines (Liniger, van Lynden, et al., 2008) represent the basis for the methodology applied in this study. The central elements are briefly discussed in the following section.

The QM suggests an extensive choice of variables (i.e. degradation types, conservation groups and measures, impacts on ESS, etc.) offering a more in-depth, comprehensive, and transparent sharing of information and practice (detailed in sections 2.3.4, 2.3.5, and 2.3.6). Encouraged by the will to create a complementary map to the FAO LADA project, which is particularly concerned by the hot spots (problem areas), through its QM WOCAT wishes to identify **conservation successes**, so-called **bright spots** (Liniger & Critchley, 2007, p. 10). To do so conservation techniques and approaches, and SLM practices are globally assessed, but in diffuse (local or regional) and inclusive processes soliciting local stakeholders and their situation-specific knowledge.

Determined to assess both biophysical and socio-economic parameters, the **QM** offers tools for broad and intelligible know-how documentation, monitoring, and evaluation. The spatial assessment is processed while following three fundamentals: First of all, the principal **land use systems** (LUSs) are identified and categorised. Then, the revealed LUSs are mapped in the treating phase of the **base map**. In a third step supported by the base map, the QM is completed during the **stakeholder meetings** and/or **expert interviews**: Based on the information obtained from a mixture of sources, supported by the QM and the GIS-database, the consulted experts systematise and register the data. More detailed information to the LUS and base map are described in the following section 2.3.1, while the stakeholder participation is discussed in section 2.5.

For consistency with other documents the mapping methodology focuses, for each LUS and within a predefined spatial unit (the management unit) on three aspects (Liniger, van Lynden, Biancalani, Mekdaschi-Studer, et al., 2013): (i) Enclosed **area** and **intensity trends** (LUS trends), (ii) **Types**, **degree**, **causes**, and **impacts** of land degradation, and (iii) Implemented conservation practices (SLM **technologies**), their **range**, **effectiveness**, and **effects** (also on ESS). This process helps in identifying and illustrating the **spatial spread** and the features of land management, while relating them to different **land-use types** (Schwilch, Hessel, & Verzandvoort, 2012). The QM outcomes represent dissemination channels to simplify the transfer of experience, although, to ensure a certain degree of uniformity, a certain number of points need to be considered while implementing this method (Liniger, van Lynden, et al., 2008): Include both **fruitful** and **unsuccessful** examples in the map and the documentation; evaluate the current situation from a **historical perspective**, reaching at least ten years back in time; and include conservation and land degradation **experts** (with scientific data) as well as **land users** (with specialized knowledge) with **diverse qualifications and experiences** to reply to the questionnaires.

The QM pays also notice on both **direct** and **indirect** (socio-economic) **causes** of degradation processes (Liniger, van Lynden, et al., 2008) and serves for the appraisal of whether there is a need for **remediation** or **conservation** strategies, i.e. evaluation of whether there is need to repair or to inhibit land degradation, and as a basis for the identification of appropriate **areas for investment**, suggesting, for each option, the **impacts on ESS** (Liniger, van Lynden, Biancalani, Mekdaschi-Studer, et al., 2013; Schwilch et al., 2012). The methodology offers a harmonised and standardised knowledge management system and builds a corner stone for **informed decision-making** on various scales (Liniger & Schwilch, 2002; G. W. J. van Lynden et al., 2002) by pledging the **assured involvement** of different actors.

2.3.1 Defining the base map: land use system (LUS) and slope category

The characterisation of following categories is necessary to the application of the QM.

2.3.1.1 Land use system (LUS)

The **land use system** is the elementary spatial unit of evaluation (Nachtergaele & Petri, 2007) and serves as primary unit to illustrate the base map, since the WOCAT mapping system founds on the **land use**, which is considered as one of the main drivers for both land degradation and land conservation measures (Nachtergaele & Petri, 2007). As defined by the IPCC **land use** is:

> "*The total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). The social and economic purposes for which land is managed (e.g. grazing, timber extraction, conservation)*" (IPCC, 2000, p. 21).

Wherewith **land cover** is:

> "*The observed physical and biological cover of the Earth's land as vegetation or man-made feature*" (IPCC, 2000, p. 21).

The anthropogenic on-land interventions (i.e. the different land use types) accent on actions that directly disturb the state of the land and have an effect on merchandises and services. The joined **land management** (referred to in section 2.1.1) practices and the **land use** can be termed as **land use system (LUS).**

Since the LUSs are developed and build on the distinct land uses, the evidence on land degradation and conservation practices can be implemented into these mapping categories. Even though a global land use system map already exists, there is a need to improve and adjust it at national or regional levels in order to offer appropriate national, respectively regional, units to describe and evaluate land degradation and conservation. Combined with chosen administrative units and other subdivisions (e.g. slope gradient categories), the LUS units enhance the understanding and the appraisal of land conservation practices and degradation, notably with regard to tendencies and variations in time (Liniger, van Lynden, et al., 2008).

Selecting various land use types is an important pace in the land assessment. Since characteristic properties, transpiring the land use types, induce or inhibit land degradation, some land use types are more susceptible to land degradation, or to some expressions of land degradation, than others. As described through the section 2.3.1.2, in this study the LUSs are further subdivided in slope gradient categories.

2.3.1.2 Slope gradient categories (SGC)

To describe the global terrain slope (Fig. 6) IIASA/FAO uses eight slope gradient classes (IIASA/FAO, 2012). Based on the slope pattern of the area of interest retrieved from the DEM (swissALTI^{3D})[2], four SGC are retained for the classification, reaching from *flat* to *very steep*. Careful reflection and analysis of the extracted slope values, corroborated by the group of experts during the multi-stakeholder meeting, led to the conclusion that in the present case no information of substantial value is lost while reducing the number of classes from eight to four.

Following gradient categories subdivide the area according to the slope classes *flat* (0-3%), *moderate* (3-15%), *steep* (15-30%), and *very steep* (>30%). These subdivisions are representative for the slope matrices in the area of interest, characterising concise and clear patterns with regard to the information reported.

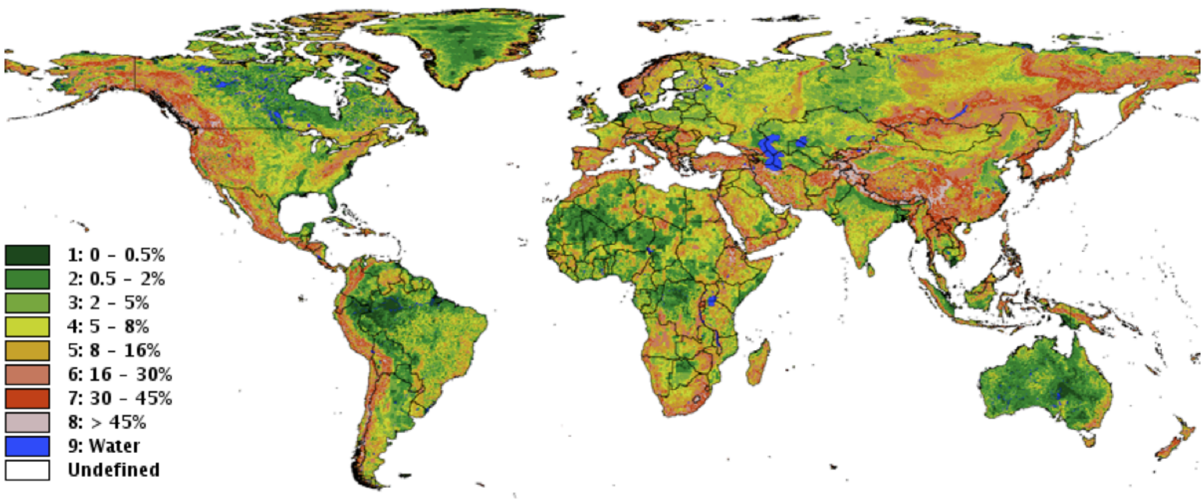

Fig. 6: Median global terrain slope as used by IIASA/FAO (2012)

2.3.1.3 The base map

The mapping process starts with the establishment of a base map, involving closed polygons, that provides a ground to the questionnaire (Liniger, van Lynden, et al., 2008) and functions as visual information support for the stakeholder workshops, the individual discussions, and eventually for the field observations. Based on existing data (e.g. LIE and BOF[3] and LANDKULT[4]) following land use types could be identified, localized, and mapped for the region: **cropland**, **permanent grassland**, **forested areas**, **waters**, as well as **settlements** (urban areas, roads, etc.). After

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[2] swissALTI3D © Bundesamt für Landestopographie swisstopo
[3] Amtliche Vermessung Reduziert AVR © Amt für Geoinformation des Kantons Bern
[4] Landwirtschaftliche Kulturen © Amt für Landwirtschaft und Natur des Kantons Bern

extensive study and numerous attempts to refine the land units, the land use systems are defined in accordance to the land use types.

Subsequently, considering the hilly terrain shaping the regional landscape, the LUSs *cropland*, *permanent grassland*, and *forest* are further subdivided with respect to the **slope gradient category** (four slope classes, in percentage) creating eleven distinct **mapping units**. The slope categories are basically defined according to FAO, used in WOCAT, but modified, grouped, and regrouped according to the stakeholder perception, which categories they perceive as relevant to distinguish and assess separately (Table 1). The skeleton of the these units builds on Streit's master thesis, wherein he realised an exact spatial grid of analysis narrowed down the accurateness of cultivation plots (Streit, 2014). Since *grass clover leys* (which have also been spatially identified by Streit, 2014) are not permanent on selected patches they are not assessed as an individual LUS but incorporated in the LUS *cropland*. Grass clover ley represents (bi-) annual vegetation cover aiming land regeneration, generally included in the crop rotation (see section 3.4.1).

Illustrating the base map, the **mapping units** highlight an area pattern by combining the land use type and the slope gradient. The slope parameter is primarily involved for reappraisal and validation, thus to confirm the importance of slopes in land degradation processes and the incorporation of slope gradients in the conception of land conservation measures in agro-ecosystems.

2.3.2 Organising the LUSs

The following section introduces concisely the LUSs, how they are structured, isolated and assesses on the field:

2.3.2.1 Agricultural land:

The land qualified as *agricultural land* (*landwirtschaftliche Nutzfläche* in German) is assigned to a farm and available to the managers all year round. In accordance with *Article 14, LBV* this category includes (agridea, 2014):

LUS Cropland

Croplands (*offene Ackerflächen* in German) are cultivated areas enclosing one-year field crops, vegetables, and berry plantations as well as one-year aromatic and medicinal plants. Strips sown in wildflowers, rotational fallow land, and agricultural land edges are included in this category.

The current wording *cropland* raises the question of the land management: Various management methods are practiced in Frienisberg, although according to the questionnaire structure one reference technology will be assessed as such: *conventional or intensive, high-input ploughing* (see section 2.3.3.1).

LUS Permanent grassland

Areas permanently under grass/permanent grasslands are described as agricultural areas permanently sheltered with grasses and herbs grown outside summering areas. Grasslands (meadows and pastures) that are maintained over more than six years can be qualified as *permanent*: While permanent grass clover leys/meadows are mown and harvested for fodder at least once a year, permanent pastures are lands belonging to a year-round farm and are exclusively used as pastureland.

In the context of this thesis, all categories of *permanent* grassland (i.e. meadows and pastures) shall be understood as referring to the LUS *permanent grassland*. More specific characteristics of LUS *permanent grassland* are discussed in section 2.3.3.2.

2.3.2.2 Wooden areas:

LUS Forest

Forests are wide areas covered with tress and wooden vegetation that represent an angular stone in the environment. They do not only act as natural regulators they also play a central role in human activities. Forests furnish vast and valuable assets to humankind: maintain the diversity of species (biodiversity), clean the air, filter precipitation, act as a carbon sink (storing carbon dioxide in trees and in the soil), produce timber, offer spaces for recreational activities, protect against natural hazards, as well as induce payed labour forces (Bundesamt für Umwelt BAFU, 2010).

Unlike agricultural surfaces, forests are not, or only to a very limited extent, supported by government payments. As a matter of fact, forest management is a highly challenging activity since woodlands must be economically profitable, environmentally beneficial, and remain recreational and relaxation areas. Sustainability is a key issue in the forest management, so the timber-harvesting rate should not exceed the wood-growing rate Only this specific attention guarantees the permanent maintenance of the forest functions, such as resources, protection, recreation, and habitat (Bundesamt für Umwelt BAFU, 2010). Location factors such as soil and climatic conditions influence the vegetation types in which the forest grows. 32% (1.31 million ha) of the Swiss territory is covered by forest (Bundesamt für Umwelt BAFU, 2010) and none of it is deprived of human influence. With the exception of the three last primeval forests (e.g. Forêt vierge de Derborence[5], in the Canton of Valais) all woodlands have been used for a long time with varying degrees of intensity, so that they became part of the cultural landscape.

Areas with hedges, wooden banks and field shrubs

Hedges and *wooden banks* are mainly enclosed and narrow (only few meters wide) wooden strips. They are generally constituted of indigenous shrubs, perennials, and small threes in accordance with the location. *Field shrubs* are extensively arranged groups constituted of indigenous shrubs and location specific threes. Although the *areas with hedges, wooden banks, and field shrubs* are not implemented and organised within the LUS forest, it appears appropriated to mention the presence. This vegetation became inherent part of Switzerland's agricultural landscape and is privileged by the agricultural policy and assisted by direct payments.

2.3.2.3 Others:

LUS Settlement area

Urban or *settlement areas* are zones characterised by high human population density and extended human-built structures relatively to its surrounding areas. One major village, Aarberg (see Fig. 2 for details of location), is situated in the western part of the area of interest. Further, small villages spread randomly over the whole research perimeter. The on-land and off-site effects of the settlement areas can be evaluated while assessing other LUSs.

LUS Waters

No major plane *water bodies* are situated in our area of interest. A tiny lake (Lobsigensee; see Fig. 2 for details of location) is located in the centre of the focal zone and on the western edge the river Aare flows through Aarberg and extends northwards for about two kilometres. Other small rivers run through and shape the landscape. The anthropogenic influence on surface waters is very important as no river kept its natural flow. However, since RECARE focuses on soil erosion by water no specific questionnaire, assessing water bodies, is completed. The on-land and off-site effects of land degradation on water bodies are evaluated while assessing other LUSs.

[5] http://www.derborence.ch/flore/foret-vierge/, page visited on 26 May 2015.

Illustration 1 Study area Frienisberg (BE): Grass clover ley with lake Lobsigen in the background (Data source: © Fedrigo 2016)

The selected LUSs are presented in Table 1. Therein they can be directly related to the **slope gradient category** (subdivision) and to the according mapping unit.

Mapping unit	Land use system	Slope gradient category	
1	Cropland	0-3%	1
2	Cropland	3-15%	2
3	Cropland	15-30%	3
4	Cropland	>30%	4
5	Permanent grassland	0-3%	1
6	Permanent grassland	3-15%	2
7	Permanent grassland	15-30%	3
8	Permanent grassland	> 30%	4
9	Forest	3-15%	2
10	Forest	15-30%	3
11	Forest	> 30%	4
12 (not assessed)	Waters	none	-
13 (not assessed)	Settlement	none	-

Table 1 Study area Frienisberg (BE): Overview Land use systems (LUS), slope gradients categories, and mapping units

2.3.3 Land management practices organised per LUS

The following sections are devoted to the description of the land management technologies implemented on each LUS. Since the major conservation practices have been identified at early stage in the elaboration process of this study, and confirmed during the QM assessment, it has been chosen to describe the conservation technologies in that section, succeeding the description of the land use systems.

2.3.3.1 LUS cropland

Various management practices appear in the study area Frienisberg (BE) on the LUS *cropland*. According to the methodological and structural pattern of this thesis, one cultivation system is qualified as reference technology, namely *conventional, intensive, or high-input ploughing*. The other cultivation systems (no-tillage, mulch, and strip sowing) need to be qualified as conservation technologies and are documented as such in part 3. Both the reference system and the conservation practices are studied, measured, and assessed as intended by the WOCAT QM.

2.3.3.1.1 Reference technology: "conventional"/intensive/high-input ploughing

In the context of this research, the reference technology *intensive, high-input ploughing* comprises all ploughed surfaces that include **root crops** (e.g. potatoes, sugar beets) into the crop rotations. This is mainly due to the fact that according to the farmers' personal beliefs, or the physical variability and situation specificity of the local land, the ploughing technology cannot be considered as a stable and homogenous practical action throughout the study area.

Generally, "conventional" cultivation systems involve annual deep topsoil loosening with the plough. Simultaneously, the remains of the preliminary and/or intermediate crops and the weeds are incorporated into the soil. The ploughing process leaves an arable surface free from residual materials, a requirement for the appropriate operation of seeding technologies, such as seed drill (*Drillsaat* in German) or wide sowing (*Breitsaat* in German). The seedbed preparation follows the basic tillage and prepares the upper soil layer for sowing or planting. The processing depth is uniform and homogenous, clods are crushed, the soil surface is levelled out, and the soil underneath the seed placement horizon is reconsolidated for the desired seed-soil contact. Ploughing and tillage tools can be differentiated between passive (pulled) and active (rotating or oscillating) instruments. Considering that each individual implement has different working effects, they can be joined as tool combinations. Therewith the seedbed preparation might require fewer processes or tracks and could become labour saving (Landwirtschaftskammer Nordrhein-Westfalen, 2015).

Illustration 2 Study area Frienisberg (BE): Ploughed cropland (Data source: © Fedrigo 2016)

In order to understand the development of the reference technology the historical agrarian context must be briefly explained:

The terminology "conventional", which is in this case also understood as "intensive" or "high external input", refers to this cultivation system describing, transforming, reshaping, as well as industrialising the agricultural landscape strappingly since the 1950s. It does not only describe the strong intensification of the agricultural production systems, caused by increasing mechanisation and the massive use of agricultural inputs permitting a high labour productivity, but also a gradual specialisation of the agricultural systems (e.g. separating spatially crop production from animal farming). On-farm species diversity gradually decreased, cash-crops became one major criteria orienting the production, and the use of pesticides, herbicides, and synthetic fertilisers firmly increased to level out the effects of condensed crop rotation periods (De Raymond & Goulet, 2014; Meynard et al., 2014). Incorporating heavy machinery, tow cars, and tools the industrialised agriculture increases stresses and loads (firm increasing degree of interventions and use of power take-off-driven machines and higher axle loads) too which the land is exposed to, damaging progressively the soil structure until the destruction is irreversible. These stresses might induce various consequences such as physical soil compaction, accumulations of mud, surface erosion, as well as leaching of nutrients and additives (Schwarz, Chervet, Hofer, Sturny, & Zuber, 2007).

2.3.3.1.2 Conservation technology: Extensive ploughing

Extensive ploughing excludes **root crops**, while intensive ploughing comprises them. With this cultivation technique a first trial is taken towards more attentive agricultural practice. Certainly, during the harvesting process root crops, such as potatoes and beets, require strong physical intervention affecting the soil structure deeply. While avoiding these additional stresses *extensive ploughing* reduces the vulnerability of the land.

2.3.3.1.3 Conservation technologies: intensive and extensive mulching

Mulching or minimum tillage refers to the conservation technologies in which the main crop is sown in the crop residues of the previous crop (www.ohnepflug.de). In line with the workshop participants, two general types of mulching, reflecting the land use intensity, are sustained in the QM assessment, namely *intensive* and *extensive mulch*. While *intensive mulch* comprises **root crops**, *extensive mulch* excludes them. More detailed and technical subdivisions of the cultivation systems would have required the involvement of a great number of practitioners, which was impossible in light of the local availability.

Illustration 3 Mulched sugar beet on cropland (Data source: © Prasuhn[6])

In *mulch* farming, rapidly growing crops, the catch crop or undersow, can be grown between succeeding plantings of primary crops. The crop mulch, e.g. biomass from the cash crop or straw from the previous crop, covers the soil surface before and after sowing protecting it, inter alia, from erosion and mud silting (Prasuhn, 2012). Mulched land requires between 30 and 70% of the soil surface to be covered by crop residues. These rests of preceding crops can either be used as mulching material and remain on the soil surface or be incorporated superficially (ANNA, 2010a). Usually the mulching practice induces the application of reduced tillage techniques, i.e. cultivation practices implying, if at all, the use of non-turning tillage tools (e.g. grubber, disk harrow) for soil loosening. Depending on the farmers needs loosening can be deep or shallow.
Mulching techniques are subdivided in mulching with subsoiler (mole plough) and mulching with shallow tillage. The latter implies only superficial tillage above (< 5cm) or just underneath (5-10 cm) seeding depth, whereas the use of a subsoiler induces soil loosening and breaching up as far

[6] „Zuckerrüben Mulchsaat001" by Volker Prasuhn. Licenced under CC BY-SA 3.0 via Commons - https://commons.wikimedia.org/wiki/File:Zuckerr%C3%BCben_Mulchsaat001.JPG#/media/File:Zuckerr%C3%BCben_Mulchsaat001.JPG, retrieved October 1, 2015.

as the plough pan level (> 25 cm). Mulching with subsoiler is recommended when the nature of the soil causes major restrictions on the seeding technology. The crop root penetration can be obstructed by compacted soils with unfavourable soil structures. First the grubber is used to break up the soil structure. Then the crop residues and the soil are loosened and mixed up with coulters (different coulters produce different results). A surface tillage can apply eventually to process and level the topsoil (ANNA, 2010c). On the other hand shallow tillage involves the superficial incorporation of pre- or inter-crop residuals (mulched topsoil) wherein the sowing is done. This labour expresses mainly in forms of stubble cultivation, fostering straw decomposition, germination of volunteer grains and weeds, as well as disease prevention, and eventually seedbed preparation. Factors such as soil type, climatic conditions, as well as cultivated crops or crop rotations determine the actual practical choice. Seedbed preparations are discouraged on plots subject to erosion (ANNA, 2010b), thus mulching without seedbed preparation can largely contribute to erosion control and soil structure stabilization. In these cases, to combat well-developed weeds that are difficult to eliminate after emergence, some practitioners chose a non-selective herbicide (e.g. glyphosate) before or immediately following sowing.

2.3.3.1.4 Conservation technologies: intensive and extensive no-tillage

No-tillage systems are presented as soil-conserving techniques maintaining long-lasting soil fertility and structure. As par of this study, in line with the workshop participants, two general types of no-tillage, reflecting the land use intensity, are sustained in the QM assessment, namely *intensive* and *extensive no-till*. While *intensive no-till* comprises **root crops**, *extensive no-till* excludes them. More detailed and technical subdivisions of the cultivation systems would have required the involvement of a great number of practitioners, which was impossible in light of the local availability.

No-till systems emerge as a consequence of the rising awareness recognizing the need to converge towards a less disturbing agriculture, requiring the enforcement of physical soil protection. While abandoning the plough, the seeds are deposited directly in the raw ground covered with plants and/or plant residues without prior tillage (Fachstelle Bodenschutz, 2013), at least since the previous crop harvest (Prasuhn, 2012). Croplands under enduring no-tillage practice redevelop stronger and more stable topsoil structures. Eventually, the soils are enlivened and revitalised, whereas the damages in the subsoil microstructure are slowly resorbed (Busari, Kukal, Kaur, Bhatt, & Dulazi, 2015).

No-till is recognized as a separated cultivation system and not only a sowing technique (www.no-till.ch). Using specific disks, chisels or cross-slot saw-coulters to place the seed, only a slit is

opened in the ground and closed right after. Auxiliaries, such as (micro)-nutrients, can be introduced simultaneously in the soil. The permanent renunciation of soil disturbance, reduced mechanical soil stresses, permanent soil cover, improved water conservation, as well as nitrogen- and energy-efficiency have a part in the success of long-standing, uninterrupted no-tillage-system (Chervet et al., 2007; Sturny et al., 2007), although the benefits are not always recognised (Maltas, Charles, Jeangros, & Sinaj, 2013). While endorsing valuable functions for the land, cover crops are a distinctive feature of no-tillage systems, encouraging soil fertility building processes, underpinning nitrate leaching, rising the soil organic matter content, acting as erosion control measure, lowering soil temperature, providing effective weed control, and improving soil water infiltration and storage (Derpsch, 2002). However, abandoning mechanical soil disturbance for weed control many farmers do also use non-selective herbicides in no-till farming systems.
According to Prasuhn (2012), out of the technologies observable in the study region, only no-till meets the three preconditions for "conservation tillage", namely the soil organic matter cover (>30%) must be maintained year-round, the soil disturbance by tillage minimized (<25% of the cropped area), as well as the crop rotation, sequences and associations (at least three different crops) diversified (Kassam, Friedrich, Shaxson, & Pretty, 2009, in Prasuhn, 2012).

Glyphosate is a highly effective herbicide, also in Switzerland widely used in the agriculture, private gardens, and for maintenance of banks along the communication channels (national and cantonal roads, railway tracks). In 2007, it has been qualified as a "valuable tool that should remain fully accessible to our [Switzerland's] agriculture" (Delabays & Bohren, 2007, p. 338). Nowadays it is used worldwide in over 750 distinctive products for various applications (agriculture, forestry, urban, and home). In march 2015, this synthetic pesticide and active ingredient in the *Roundup* herbicide synthesised by Monsanto since the 1970s, is declared as "probably carcinogenic to humans" by the International Agency for Research on Cancer (IARC; Lyon, France) of the WHO (Guyton et al., 2015, p. 491). With its most recent agricultural policy the Swiss Confederation provides indirect subsidies for glyphosate since it founds programs encouraging the application of no-tillage technologies.

2.3.3.1.5 Conservation technologies: intensive and extensive strip-sowing

Emerging in the 1990s, *strip sowing* (*Streifensaat* in German) is rapidly considered as technically and economically practicable, while reducing soil and nutrient leaching into groundwater, when compared to ploughing methods. As par of this study, in line with the workshop participants, two general types of strip sowing, reflecting the land use intensity, are sustained in the QM assessment, namely *intensive* and *extensive strip sowing*. While *intensive strip sowing* comprises **root crops**, *extensive strip sowing* excludes them. More detailed and technical subdivisions of the cultivation systems would have required the involvement of a great number of practitioners, which was impossible in light of the local availability.

Strip sowing emerges as an intermediate technique between conventional ploughing and conservation agriculture. Maximum 30 cm wide strips (in which the seeds will be sown) are cut into an intermediate culture or a field by combining till and drill actions. The soil is loosened just below the plough pan limit with leading cultivator tines (Fachstelle Bodenschutz, 2013). It has been recognised that the technology contributes in the effort of conserving soil structure and reducing erosion risk, although effective and consistent weed control is determining (Bohren, Ammon, Dubois, & Streit, 2002). In the research area this technology is primarily used for planting maize into grass-clover sods (Prasuhn, 2012).

The spreading of no-tillage, mulching, and strip sowing technologies is encouraged by the soil support programme (*Förderprogramm Boden* in German) of the canton of Bern.

Comparative research at Inforama Rüti

Since 1994, the two farming systems no-tillage and "conventional" ploughing are compared at the Inforama Rüti in Zollikofen (BE), on a medium-weight, deep, and basic moist brown earth (Chervet et al., 2006). This faintly humic grimy loam is a profound soil and rich in nutrients (Sturny et al., 2007). The two techniques are studied measuring decisive parameters for the maintenance of a valuable land for food and fodder production. Parameters reaching from physical soil properties, moisture content, pest management, nitrogen fertilization and yield, to the ecological balance sheet are assessed and compared on permanent observation plots. After a seven-year testing period at the Inforama "Rütti" results indicate that uninterrupted no-tillage systems can be presented as worthwhile alternatives to conventional ploughing. The authors consider no-till agriculture as being arrived at a stadium of practical maturity, producing a biologically active soil with a stable structure and thus load-bearing capacity, reducing erosion risk and achieving a favourable ecological balance sheet. The yields harvested on the test plots where slightly higher in no-tillage systems compared to conventional ploughing, obtained through higher and continuously renewed soil moisture as well as higher nitrogen efficiency (Sturny et al., 2007).

Illustration 4 Strip sowed maize on cropland (Data source: © Prasuhn[7])

[7] „Mais Streifenfrässaat009" von Volker Prasuhn. Lizenziert unter CC BY-SA 3.0 über Wikimedia Commons -

2.3.3.1.6 Conservation technology: grass clover ley

Annual or biennial grass clover leys (*Kunstwiese* in German) are included in crop rotation cycles. They represent sown grassland areas maintained for at least one vegetation period (one growing season). Grass-clover leys have various purposes reaching from a viable and equilibrated nitrogen supply, over to weed and erosion control, as well as humus enrichment and increasing the biological activity in soils. Information on these fluctuating surfaces is not available from any register. Data for specific vegetation periods can be extracted from the analysis of aerial photographs, wherewith parcels can be identified and spatially localised (Streit, 2014). According to Streit's calculations, in Frienisberg *annual/biennial grass clover leys* represent nearly 20% of the agricultural land area. This land management practice applies to all cultivation systems (including all conservation technologies) and is generally a partaking step in rotational cropping systems. They are of inseparable nature for integrated production (IP) and conservation agriculture and call therefore for attention and characterisation. Temporary *grass clover leys* might be confused with permanent grasslands. Their (bi)-annual characteristic discriminates them clearly form permanent grassland, which maintain a perennial/permanent grass cover (*permanent* implying at least six-year-lasting vegetation). This differentiation is hardly feasible through simple on-field observation. Prior local field knowledge including its history becomes therefore a prerequisite for the mapping process (importance of the multi-stakeholder approach and of quality databases).

2.3.3.2 LUS permanent grassland

Permanent grassland is per se perceived as a land conservation technique on agricultural lands. Its value appears undeniable to Switzerland's agricultural landscape, just as well as grass clover leys. Different management practices clustering under the concealment of permanent grasslands can be identified, notably *meadows* and *pastures*. Although sometimes hardly visible to the untrained eye these categories can be further subdivided reflecting the intensities of the land use, i.e. *intensive* and *extensive* management.

In line with the workshop participants, only two permanent grassland types, reflecting the land use intensity, are sustained in the assessment, namely **intensive** and **extensive permanent grassland**. Since permanent grassland meets at the same time the LUS and SLM practice criteria, the various dimensions of permanent grassland can be considered as conservation technologies relating to the agricultural land as an entity.

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https://commons.wikimedia.org/wiki/File:Mais_Streifenfr%C3%A4ssaat009.jpg#/media/File:Mais_Streifenfr%C3%A4ssaat009.jpg, retrieved October 1, 2015.

2.3.3.2.1 Intensive permanent grassland

Based on the data LANDKULT (discussed in section 2.4.4) *intensive permanent grassland* includes the following two categories indiscriminately (description based on: pro natura, 2015):

Intensive meadow: Intensively used meadows represent nowadays the most common type of grassland in Switzerland (typical examples are ray or orchard grassy meadows). These areas thrive less than 20 plant species per are. They are mown between four and six times a year, mostly the harvest is used to produce silage for animal feed. Animal manure or synthetic fertilizers are regularly disseminated on the land plots, wherefore they grow on very nutrient-rich soils.

Intensive pasture: Intensive pastures are frequently fertilized, as well as evenly grazed by brewers, while additional revitalizing cuts might apply occasionally. Comparable to intensive meadows, this management practice does not favour abundant species diversity (of both plants and animals).

Illustration 5 Study area Frienisberg (BE): Intensive meadow (Data source: © Fedrigo 2016)

2.3.3.2.2 Extensive permanent grassland

Based on the data LANDKULT (discussed in section 2.4.4) *extensive permanent grassland* includes the following three categories indiscriminately (description based on: pro natura, 2015):

Low intensity or extensive meadow: While low intensity or extensive meadows were the most common grassland type in Switzerland only a few decades back they became rare nowadays. These surfaces account between 20 and 35 plant species per are. The two most prominent examples for this category are made of golden oatgrass and tall oatgrass. Animal manure is not at all, or only to a very limited extent, used on these meadows. The practice implies mowing up to two or three times per year.

Extensive meadow: Extensive meadows create Switzerland's most species-rich grasslands. On such surfaces over 50 different plant species are to be found per are. This management technique implies no fertilizers and rare mowing, maximally twice a year.

Illustration 6 Study area Frienisberg (BE): Extensive meadow (Data source: © Fedrigo 2016)

Extensive pasture: Structured, very diverse extensive pastures are often found on sloped and sunny situations. These surfaces are not fertilized and only grazed once to three times a year over a limited period. In comparison to intensive pastures the trampling damage can be lowered. Altering the over- and under-use of land patches provides an interesting location-mix for a wide range of plant species and small animals.

2.3.3.3 LUS forest

Only one conservation technology applies on LUS *forest* and is intended as described in the following paragraph:

2.3.3.3.1 Mixed forest

According to the National forest inventory (NFI), mixed stand (here *mixed forest*) is defined as follows: "Stand consisting of at least two tree species both with an ecologically important share", while the stand is demarcated as a share of "broadleaves and conifers cover" extending over "at least 10% each of the basal area". This is in contrast with the pure stand: "consisting of a single tree species or with an ecologically marginal mixture of other tree species" (Brändli & Speich 2007)[8].

2.3.4 LUS area trend and land use intensity trend

Changes in LUS area and land use intensity are discussed in addition to the assessment of land degradation and conservation technologies. Spatial changes in land use and variations in land use

[8] The definition is taken from the *Swiss NFI glossary and dictionary*: Brändli, U.-B.; Speich, S., 2007: Swiss NFI glossary and dictionary. [Published online 27.06.2007]. Available from World Wide Web http://www.lfi.ch/glossar/glossar-en.php. Birmensdorf, Swiss Federal Research Institute WSL. (Page visited on 9 January 2016).

intensities are estimated as potential factors leading to land degradation/conservation, thus they become determining in the assessment.
First of all, this **trend analysis** implies the estimation of the spatial variation of the **LUS area** (increasing or decreasing area) within the retained mapping units. It goes without saying that the increase of one or several LUS goes with the decrease of another (or others). While considering changes in a historical perspective (including a 10 year observation period; in this case between 2005-2015) outstanding years can be averaged in the evaluation process.

Changes in area of the LUS (direct drivers[9])		**Changes in land use intensity (direct drivers)**	
-2	Area coverage is rapidly decreasing in size, i.e. > 10% of that specific LUS area/10 years	**-2**	A major decrease in land use intensity, e.g. from mechanisation to manual labour, or a large reduction of external inputs.
-1	Area coverage is slowly decreasing in size, i.e. < 10% of the LUS area/10 years	**-1**	A moderate decrease in land use intensity, e.g. a slight reduction of external inputs.
0	Area coverage remains stable	**0**	No major changes in inputs, management level, etc.
1	Area coverage is slowly increasing in size, i.e. < 10% of the LUS area/10 years	**1**	Moderate increase, e.g. a switch from no or low external inputs to some fertilizers/pesticides; switch from manual labour to animal traction.
2	Area coverage is rapidly increasing in size; i.e. > 10% of the LUS area/10 years	**2**	Major increase: e.g. from manual labour to mechanisation, from low external inputs to high external inputs, etc.

Table 2 Area trend and land use intensity trends as provided by the WOCAT QM (Illustration: Fedrigo 2016, Data source: Liniger, van Lynden, et al., 2008, p. E4)

Secondly, changes in the **land use intensity** are estimated. In crop-based systems intensity changes are articulated in terms of input modification, management level, or organisation of harvests, whereas in grazing plots they are more probably expressed in terms of functional changes such as the introduction of rotational grazing and fencing (Liniger, van Lynden, et al., 2008). Figures ranging from 2 to -2 are used to express increasing, respectively decreasing, trends according to Table 2 (Liniger, van Lynden, et al., 2008, p. E4).

2.3.5 Land degradation assessment

The third step, following the trend analysis, involves the particular appraisal of the land degradation. This procedure allows a concrete expression of the current state of the land. According to the QM each LUS is assessed with regard to the variables (first column) listed in Table 3[10]. The polysemous nature of the concepts of land degradation and thus the importance of clear definitions could be experienced during the workshop session. Well-defined terms are an essential precondition, which should ideally be defined in a participatory process including all key-actors.

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[9] Refers to the indicators within the DIPSR framework, c.f. section 2.2
[10] See Annex p. 144 for the translated materials (German) used during the stakeholder workshop/meeting

<table>
<tr><td>Types of land degradation
(State indicators[11])</td><td colspan="2">W: Soil erosion by water:
Wt: Loss of topsoil/surface erosion
Wg: Gully erosion
Wm: Mass movements/landslides
Wr: Riverbank erosion
Wc: Costal erosion
Wo: Offsite degradation effects
E: Soil erosion by wind
Et: Loss of topsoil
Ed: Deflation and deposition
Eo: Offsite degradation effects
B: Biological degradation
Bc: Reduction of vegetation cover
Bh: Loss of habitats
Bq: Quality/biomass decline
Bf: Detrimental effects of fires
Bs: Quality and species composition / diversity decline
Bl: Loss of soil life
Bp: Increases of pests/diseases</td><td colspan="2">C: Chemical soil deterioration:
Cn: Fertility decline and reduced organic matter content
Ca: Acidification
Cp: Soil pollution
Cs: Salinization/alkanisation
P: Physical soil deterioration
Pc: Compaction
Pk: Sealing and crusting
Pw: Waterlogging
Ps: Subsidence of organic soils, settling of soil
Pu: Loss of bio-productive functions due to other activities
H: Water degradation
Ha: Aridification
Hs: Changes in quantity of surface water
Hg: Changes in groundwater/aquifer level
Hp: Decline of surface water quality
Hq: Decline of groundwater quality
Hw: Reduction of the buffering capacity of wetland areas</td></tr>
<tr><td>Extent (in % of LUS)
(State indicator)</td><td colspan="4">Extent of the degradation type: Area percentage of mapping unit.</td></tr>
<tr><td>Degree of land degradation
(State indicator)</td><td colspan="2">1: Light
2: Moderate</td><td colspan="2">3: Strong
4: Extreme</td></tr>
<tr><td>Rate of degradation
(State indicator)</td><td>Increasing degradation:
3: rapidly
2: moderately
1: slowly</td><td colspan="2">0: no change in degradation</td><td>Decreasing degradation:
- 3: rapidly
- 2: moderately
- 1: slowly</td></tr>
<tr><td>Direct causes of degradation
(Direct pressure indicators)</td><td colspan="2">s: Soil management
c: Crop and rangeland management
f: Deforestation and removal of natural forest
e: Over-exploitation of veg. for domestic use
g: Overgrazing
i: Industrial activities and mining</td><td colspan="2">u: Urbanisation and infrastructure development
p: Discharges
q: Release of industrial airborne pollutants
w: Disturbance of the water cycle
o: Over-abstraction/excessive withdrawal of water
n: Natural causes</td></tr>
<tr><td>Indirect causes
(Indirect pressure indicators)</td><td colspan="2">p: Population pressure
c: Consumption pattern and individual demand
t: Land tenure
h: Poverty
l: Labour Availability</td><td colspan="2">r: Inputs and infrastructure
e: Education, awareness raising, access to knowledge
w: War and conflicts
g: Governance, institutions, and politics
o: Others</td></tr>
<tr><td>Impacts on ecosystem services
(Impact indicators)</td><td colspan="4">P: Productive services
E: Ecological services and indicators
S: Socio-cultural services/human well-being and indicators</td></tr>
<tr><td>Impact level
(Impact indicator)</td><td colspan="2">Positive impact:
3: high positive
2: negative impact
1: low positive</td><td colspan="2">Negative impact:
- 3: high negative
- 2: negative impact
- 1: low negative</td></tr>
</table>

Table 3 Overview of the land degradation assessment as provided by the WOCAT QM (Illustration: Fedrigo 2016, Data source: Liniger, van Lynden, et al., 2008, pp. E6–E15)

2.3.6 Land conservation assessment

The fourth step focuses on the spatial expression of conservation processes. It offers a geographical overview of the conservation practices within the area of interest. According to the QM the assessment of each LUS includes the investigation of following parameters by reference to the applied technology: determination of the reasons for the use (making reference to a **conservation group** and **conservation measure**), identification of the **purpose addressed** by

[11] Refers to the indicators within the DIPSR framework, c.f. section 2.2

the technology, estimation of the **extent** and qualification of the **degradation types addressed**, as well as the **effectiveness**, the **effectiveness trends**, and the **impacts on ecosystem services**.

Name of the Technology	(No local names)	
Conservation groups	**CA**: Conservation agriculture / Mulching **MN**: Manuring/composting/nutrient management **RO**: Rotational systems **VS**: Vegetative strips/cover **AF**: Agroforestry **AP**: Afforestation and forest protection **RH**: Gully control/rehabilitation **TR**: Terraces **GR**: Grazing land management **WH**: Water harvesting	**SA**: Groundwater/water use efficiency **WQ**: Water quality improvements **SD**: Sand dune stabilization **CB**: Costal bank protection **PR**: Protection against natural hazards **SC**: Storm water control, road runoff **WM**: Waste management **CO**: Conservation of natural biodiversity **OT**: Other
Conservation measures	**A**: Agronomic **V**: Vegetative	**S**: Structural **M**: Management
Purpose addressed by the SLM Technologies	**P**: Prevention **M**: Mitigation	**R**: Rehabilitation
Extent of the SLM Technology	Indicated as an area percentage of the mapping unit	
Degradation addressed	Specify the degradation types addressed by the SLM Technology according the types listed in Table 3	
Effectiveness of SLM Technologies	**1**: Low **2**: Moderate	**3**: High **4**: Very high
Effectiveness trend of SLM Technologies	**1:** Increasing effectiveness **0:** no change in effectiveness **-1:** decrease in effectiveness	
Impact on ecosystem services (Impact indicators)	**P**: Productive services **E**: Ecological services and indicators **S**: Socio-cultural services/human well-being and indicators	
Level of impact	**Negative impact:** **-3**: High negative **-2**: Negative impact **-1**: Low negative impact	**Positive impact:** **3**: High positive **2**: Positive impact **1**: Low positive
Period of implementation	Indicate since what year the technology has been implemented	

Table 4 Overview of the land conservation assessment as provided by the WOCAT QM (Illustration: Fedrigo 2015, Data source: Liniger, van Lynden, et al., 2008, pp. E16–E23)

2.4 Data basis

According to the objectives set in chapter 1.5 the data is chosen in order to create a detailed and precise land-use map, adapted to the regional and local context of Switzerland's agricultural landscape. In a view to maintain coherence, the national triangulation network LV03 (reference framework) is used for all geographical data.

2.4.1 Aerial photographs

The structure of Switzerland's farming system resides noticeably in small farms. Therefore it involves datasets with a high spatial resolution. Various entities and institutions produce aerial or satellite imagery/photographs and make them available for commercial use. Nevertheless, high-resolution imagery remains related to great expenses.

Various Federal Offices of the Swiss Confederation produce large quantities of data concealing the whole country area in more or less regular grids. The land-use statistics (*Arealstatistik*) provide point information on land-use and land-cover (LULC) in a 100x100 meter grid (map.geo.admin.ch). Even though the number of farms in activity diminished over the last decades (decreasing form over 70'500 farms to 56'600 between 2000 and 2012) small farms are still dominant in the agricultural landscape: the average utilised agricultural area reached 18.6 ha per farm in 2012 (Bundesamt für Statistik BFS, 2014). In such agricultural disposals only limited information, useful to the purpose of this thesis, can be derived from a one-hectare data grid.

The Federal Office of Topography swisstopo, further referred to as swisstopo, produces high-resolution aerial pictures (SWISSIMAGE) covering nearly the country area surface. These images reveal the territory with a high areal resolution (0.5 meters), thus they are a remarkable data source for the purpose of this study. Hence the aerial photographs serve as root information to the production of the base map. For research purpose swisstopo delivers aerial series free of charge to the Institute of Geography of the University of Bern.

The SWISSIMAGE photographs cover the complete surface of the state territory. The pictures are subdivided in 4375 by 3000 m tiles corresponding to 1/16 of the 1:25'000 domestic map. The quad-tree standard operates for the division and numbering of the tiles. Geometric and radiometric values are of pronounced significance for the use of an orthophotograph, as well as the moment (year, date) when the imagery is recorded (swisstopo, 2007). The tiles Lyss 1146-31, -32, -33, and -34 cover the area of interest. For each tile the flight years are fixed, wherewith it becomes manageable to analyse, combine, and compare images from different years (here 2004 and 2011). Finally, while comparing images reaching back to the early 2000s tendencies such as area trends can also be included.

2.4.2 Digital elevation/terrain model ("Digitales Höhenmodell")[12]

Besides the aerial photographs a digital elevation model (DEM) is introduced as additional dataset for the production of the base map. Established on its' predecessor product, the DHM25, swisstopo creates a high resolution digital terrain model (DTM) swissALTI^{3D} describing the surface of Switzerland and Lichtenstein deprived of vegetation and infrastructure/development (swisstopo, 2014). The series structuring the dataset are renewed in a six-year cycle and can be

[12] Digitales Höhenmodell (DHM) LIDAR Rohdaten des Kantons Bern © Amt für Wald des Kantons Bern ; swissALTI3D © Bundesamt für Landestopographie swisstopo

ordered from the toposhop[13]. As presented by swissALTI^{3D} the DTM is a digital raster dataset or a xyz-file, with a regular grid, disposing a mesh width of 2m, 5m, or 10m, wherein an altitudinal value is attributed to each element compiling the dataset. Various sources assemble the elevation records contained in the swissALTI^{3D}. Alpine chronicles ranging over 2000 meters above mean sea level (mamsl) are generated through stereo correlation, whereas lowland data is recovered from laser measuring points (swisstopo, 2014). These disparities in the database and in the survey methods lead to an absence of uniform accuracy within the swissALTI^{3D}. Corresponding to accuracy values for both situation and altitude in the lowlands (below 2000 mamsl) a precision reaching approximately 50 can be obtained, where as in the alpine regions (above 2000 mamsl) it extends within 100 cm.

Sectoral slope values are calculated and extracted from the raster dataset swissALTI^{3D} within the field zones (discussed in chapter 2.4.5). The esri ArcGIS-tool *Zonal Statistics (Spatial Analyst)* is used for the statistical calculation enclosing the slope gradient in the field grids.

2.4.3 "Amtliche Vermessung reduziert"[14] AVR (Official measurements)

The concise version of the official measurements (AVR) is a geoproduct created by the Department for geographic information of the Canton of Bern (Amt für Geoinformation des Kantons Bern). Covering the whole area of the Canton of Bern, it contains the most accurate data on land and soil available (Zeltner, Muchenberger, Droz, & Brawand, 2010). Because of its accuracy and its timeliness, this data is a valuable product for the purpose of this study. It permits high precision and truthful fragmentation of the fields as well as a detailed evaluation of individual parcels of land. Enclosed in the procedure of official measurement precise surveys of the earth's surface are made. The AVR dataset contains assorted information such as the property boundary points, the ground height, and the type of land cover, e.g. buildings or roads, but also fields, meadows, and waters (swisstopo, 2012). Various products, such as the digital terrain model (*Digitales Terrainmodell*), the AV basic plan (*Basisplan der amtlichen Vermessung*), and the cadastre (*Grundbuch*), establish on these official measurements, but also Geographic Information Systems (GISs), the national geodata infrastructure, and maps.

The data contained in the AVR is based on the coordinates and on the height systems of the Swiss land survey. Since 1903 the convex globe is epitomised on a two-dimensional surface by reason of a conformal, oblique cylinder projection. By unwinding the cylinders' surface both the

[13] http://www.toposhop.admin.ch/de/shop/products/height/alti3D_1, retrieved on 26 May 2015.

[14] Amtliche Vermessung Reduziert (AVR) © Amt für Geoinformation des Kantons Bern (http://www.apps.be.ch/geo)

earth latitudes and longitudes are projected on a rectangular plane coordinate system (swisstopo, 2012). Willing to involve new, satellite-based technologies swisstopo demarcates the highly precise land survey LV95 (*Landesvermessung 1995*), including Global Navigation Satellite System (GNSS) techniques facilitating the access to the European reference system and data exchanges reaching beyond national boundaries (swisstopo, 2006). In LV95 the ancient origins x_0 = 200'000 m and y_0 = 600'000 m are replaced by the denomination North and East related to new origins: N_0 = 1'200'000.00 m and E_0 = 2'600'000.00 m. So as to avoid confusion the numerical values have also been extended. Even though not the whole territory has been retained in the official measurements yet, the available data covers roughly two thirds of the surface.

The current state of measurements can be called up on the Internet at www.geometa.ch. For the study perimeter this online map confirms the existing standard of quality "digital LV03" (y = 587'000 to 593'000, x = 206'000 to 212'000), which is therefore used for this study.

The environment is continuously changing. In order to guarantee the correctness and precision of ever-changing settings, official measurements require permanent (*laufende Nachführung* in German) and periodical (*periodische Nachführung* in German) renewal and re-evaluation. The final dataset results from the combination of various on-land and aerial methods and procedures, such as terrestrial recordings, levelling, GNSS, photogrammetry, and laser scanning, consenting precise measurements (swisstopo, 2006). Points of reference (fix points and boarder points) are arranged for backups, to ensure systematic accuracy of the measurements, and for actual on-field demarcations.

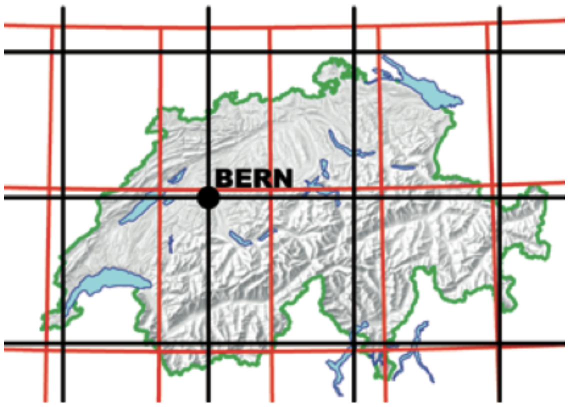

Fig. 7 Swiss coordinate system; Geographic reference system (red) and Swiss projection system (black). In: swisstopo (2006)

2.4.4 Agricultural crops (LANDKULT)[15]

Since May 2015 and in accordance with the Department for geographic information of the Canton of Bern, the geoproduct *LANDKULT Landwirtschaftliche Kulturen* (agricultural crops) is publicly accessible. This dataset includes the geographic location of the spatially registered crops on the basis of the contribution year (areas and trees). The first status report is created at the end of the contribution year, following the ordinary opposition period, and published at the

[15] Landwirtschaftliche Kulturen © Amt für Landwirtschaft und Natur des Kantons Bern, Abteilung Direktzahlungen

beginning of the following year, whereas the second status report is produced in the summer of the following year. The product LANDKULT contains various elements related to the direct payments. The layers *Dauerkulturen (DK)* (permanent cultures in English) and *Ökoelemente, Flächen (ÖEFL)* (eco-elements, areas in English) are of particular interest to fulfil the purpose of this study, emphasising on permanent grasslands, and other permanent cultures, wherein symptoms of degradation are marginal, possibly negligible. The layer ÖEFL contains areas such as extensively used meadows and pastures, rotational fallow, or wildflower strips. DK, however, contain inter alia permanent meadows, horticultural outdoor crops, or permanent pastures. The information contained in these layers could be narrowed down, keeping only permanent ecological surfaces appealing to the denominator permanent grassland (c.f. section 2.3.2).

2.4.5 Field grid: cultivation plots on LUS cropland

In his master thesis, Streit (2014) experiences the conception of an automated classification system. From the spectral information of the aerial photographs the author creates texture layers and performs object-based analysis with the geographic information system eCognition. Therefrom, a subdivision of the aerial image into segments, representing the single fields, or cultivation plots, is made in order to distinguish open farmland (cropland) from grass clover ley and from permanent grassland. Willing to obtain the cultivation plot accuracy Streit (2014) extracts the information from the AVR and combines it with the spectral information derived from the aerial photographs. Based on the data from the cadastral survey (AVR) the agricultural area can be subdivided using the land cover layer (*BOF Bodendeckung* in German). The BOF layer distinguishes land cover 26 categories, one of which contains arable, meadow, pasture (referred to as ART8). This layer is of major interest for this work, excluding herewith in the first instance buildings, roads, rocks, forests, and waters. Distinguishing particular crop plants (or more broadly the land cover), each polygon, as part of the agricultural land area, characterises a particular cultivation plot. Streit (2014) encounters some particularities in the plot border demarcations: High contrasting fields, which border correspond to the property plots, were identified easily and the lines matched well with the plot patterns observable on the aerial photographs. Whereas more homogenous cultivation plots are recurrently subdivided in two or more plots, while the aerial pictures show clearly the recurrence of one crop plant type (or management practice). These erroneous margins are easily identifiable given their frayed line path. Once cross-referenced with the slope gradients, the surfaces are gathered to the LUS and the irregularities can be considered as marginal. Finally, artefacts such as cast shadows sometimes disturb the accuracy of distinct cultivation plots. These misstatements are of minor importance, since they will not be fastidious in the fulfilment of the thesis, there is no need for further discussion.

2.5 Actor participation

Offering a substitute to formal research practices theories of participatory research and planning emerge primary between the 1970s and the 1980s (Ericson, 2006). They act as a counterbalance to top-down, centralised approaches. The underlying thoughts of participatory methods are the incorporation of local perspectives and knowledge, facilitating the empowerment of local populations. Solutions emerging from their integration in research and planning are expected to be longer lasting and more appropriate to the local context (Ericson, 2006).

Establishing in a perspective of social change, the model of *action-research* is certainly the first milestone posed with the intention to better anchor research in practice (Anadón & Savoie-Zajc, 2007; Couture et al., 2007). It has been developed in order to foster the understanding of peoples' actions and eventually to modify them, as well as to acquire prejudice reduction and increase democratic behaviour. Focusing on change, *action-research* joins practitioners and researchers to produce it, considering systemic changes only achievable through the active engagement of small groups of people (Anadón & Savoie-Zajc, 2007). Although the historical roots of this research structure are predominantly in the educational field and in the sociology, the author points the concern of scientists to link research and action in order to provoke radical changes in society (Ander-Egg, 2003 in Anadón & Savoie-Zajc, 2007). In processes emerging therefrom researchers can be considered as intellectual activists committed to the interests of the popular movement and action-research as a process of political action and an area of social participation. Aiming the discovery of social and systemic inequalities and the emancipation and empowerment of populations through knowledge sharing generated within research processes, the critical paradigm founds the perspective of the action-research (Anadón & Savoie-Zajc, 2007).

By now, as exposed in Couture et al. (2007), research based on participatory processes is subject to polysemy. Various terminologies are being used, and equally as many attempts are started to define **participation**. The common idea recurring in most approaches is the intent to strengthen links between theory and practice, taking into account the voice of practitioners and local actors in the production of a certain knowledge related to their practice (Couture, Bednarz, & Barry, 2007), while considering that participatory research is done with the practitioners rather than about them (Desgagné, 2007). Participatory research is commonly based on on-field complexity and on the recognition that adaptations involving different expertise need to emerge from it. Creating research partnerships materializes as a precondition, increasing the significance of research involvement to sustainable development (Wiesmann, Hurni, Ott, & Zingerli, 2011). Hence the responsibility for determining sustainability and multifaceted society-environment concerns would not only be that of individual actor groups (Herweg et al., 2010), e.g. the scientists. Thus, by combining system, target, and transformation knowledge, **transdisciplinarity** aims to link the scientific world as well as society and science, and appeals on how to arrange and systematize collective knowledge creation and social learning practices at the edges that lie between science and society (Wiesmann et al., 2011). Ideally, local actor involvement is achieved all-over the process of the study, by involving the research partners in the characterization of the terminology, the elaboration of the research questions, as well as the choice of the methodology and procedure (Herweg et al., 2010).

In practice, research termed as "participative" implies the involvement of the local population, e.g. in conservation programs, though it can appear in many forms ranging from simple, passive participation to the complete commitment to the cause (Couture et al., 2007). The WOCAT QM envisages the involvement of participatory approaches through the production of qualitative data emerging from **discussions** and **workshops** embracing land users, decision-makers, scientific experts, etc. (Schwilch et al., 2012), and sustained by documents, studies, and analyses (Liniger, van Lynden, Biancalani, Mekdaschi-Studer, et al., 2013). It has been broadly recognised that notwithstanding their scientific viability and efficiency, acknowledged SLM technologies only succeed and are fruitfully implemented by agriculturalists or land superiors once various hurdles are overcome, notably cultural norms, local traditions, profitability, risk, etc. (Stringer et al., 2014). By favouring local interaction and exchanges, **stakeholder workshops** may either help to anticipate such difficulties or to prevent them from happening. Organised in order to induce mutual interactions and knowledge sharing such exchange boards can also act as a springboard and extend the disposable knowledge as well as empower the local ability for decision-making (Mendoza & Prabhu, 2000).

Participatory processes attempt to challenge the legitimacy of the knowledge and the contributors. However, emerging from different stakeholders, it seems sensible to bear in mind, while interpreting the outcomes, that the results reveal somehow the discrete importance various actors give to one or the other landscape (Mialhe et al., 2015). Even though the extents of subjective biases are weakened, through the participation of multiple land users and professional researchers, they cannot be avoided entirely and are therefore accepted as probable prejudice.

2.5.1 Stakeholder workshop

For this study, a multi-stakeholder expert group engages the regional situational analysis in a workshop environment based on the QM. The emerging data is produced through a process of participatory assessment and agreement, based on the vast personal, private, and professional experience of the participants and their knowledge of the region. Obviously this study does not pretend accomplishing thorough understanding, although it provides a grounded insight into the region and how it is perceived and felt while including the local actors. The outcomes may serve as support in further steps of the transdisciplinary RECARE project, organised by other contributing researchers in which key actors are involved.

The organisers' role is to take care of the good organisation of the workshop and to create favourable structures for the meeting making people feel comfortable and their knowledge recognized and valued. It remains important to avoid creating the impression of abusing their availability, considering that these local research partners, and experts in the fields of investigation, contribute on a voluntary basis, hence doing it with conviction and belief.

The foregoing is not intended to be a stamp of legitimacy but only a way to outline and bring clarity to the source of the data provided.

2.5.1.1 Stakeholder workshop held on September 4, 2015

The one-day workshop held on September 4, 2015 at the restaurant Hirschen in Frienisberg is a central component of this study. This multi-actor involvement is one key component in assembling and generating knowledge and data used in this study. Regrouping assorted players active in the region and exploring the specific objectives exposed in section 1.5.2 on behalf of the WOCAT QM (questionnaire provided by: Liniger, van Lynden, et al., 2008), it is an integral part of this research process.

First of all, this research is lucky to insert in an existing network of shared commitment and in a region where research partnership and trust could be established over the past two decades between local stakeholders and the professional research communities from the University of Bern and Agroscope (FAL). It seems of prior importance not to unbalance the established mutual confidence and respect between on-field actors and off-field scientists when introducing an additional research proposal. The data formation and acquisition performed in this study would not have been possible without the devotion and participation of convinced stakeholders dedicated to the cause, as well as the trust and relationship they share.

Hence, supported by a solid partnership, a complementary, experienced, and specialized **research team** is formed for the **one-day stakeholder workshop** on the commitment for adapted and viable development of the region.

Illustration 7 Multi-stakeholder workshop held on September 4, 2015 at the Restaurant Hirschen in Frienisberg (BE) (Source: © Hanspeter Liniger)

Stakeholder narrative	Name
Farmers	
Conventional farmer, contractor, and representative of the association SWISS NO-TILL	Hanspeter Lauper
Conventional farmer and member of the local council (municipality of Seedorf BE)	Jürg Lauper
Organic farmer and entrepreneur	Stefan Brunner
Forest representative	
District forester Seedorf (BE)	Rudolf Schweizer
Researchers	
Researcher at the Swiss centre of excellence for agricultural research Agroscope; head of the division water protection/pollution control	Volker Prasuhn
Researcher at the Office of agriculture and nature (LANAT), specialist department for soil protection of Canton Bern	Andreas Chervet
Senior research scientist at the CDE, University of Bern and coordinator of WOCAT	Hanspeter Liniger
Research Associate at the CDE, University of Bern. Thematic cluster: Natural resources and Ecosystem Services	Nina Lauterburg
MSc Student at the CDE, University of Bern and trainee at the specialist department for soil protection of Canton Bern	Mirjam Lazzini
BSc Student at the University of Bern	Deborah Niggli

Table 5 Overview of the key-actors involved in completing the WOCAT QM to document and evaluate land degradation and land conservation in Frienisberg (BE) (Illustration: Fedrigo 2016).

The constituted research group embraces relevant land-users and local stakeholders, including farmers, agricultural contractors, representatives of the no-till association SWISS NO-TILL and officials of the commune, as well as federal and cantonal soil and water conservation experts. All part-taking experts had shown their interest for the RECARE study in the past and already attended meetings as part of that broader research project. More than twenty people where originally contacted by mail, email, and telephone, a suitable date could finally be set for one meeting regrouping about ten people. The workshop participants, who are the major contributors to this research, are mentioned by name in Table 5, they completed the questionnaire in a process of participatory assessment and agreement.

Structured on behalf of the WOCAT mapping questionnaire, the workshop was planned and thoughtfully structured to be a one-day meeting and it proceeded as follows:
The meeting has been scheduled at 9 a.m. at the Restaurant Hirschen in Frienisberg, which is located within the study area, where the research group could easily access. First contacts can be established while sharing a coffee and waiting that all participating partners have joined and are installed. After what, a short introduction takes us through the day. Each subject is presented, as well as the assessment procedure and the criteria of selection and evaluation, so that the expert group arrives at a common understanding, as well as the agreement is established on consistent definitions and cohesion in the approach. On the basis of this, the evaluation can then be conducted on behalf of the leaflet constituted for the purpose gathering the essence of the WOCAT QM translated in German (included in Annex 2). A printed version of the base map (combining Fig. 11, Fig. 12, and Fig. 13) and the German leaflet are distributed to each participant as a visual support for the discussion. In addition to these printed documents the base map (included in Annex Fig. 2) and the evaluation grids are projected from the computer with the beamer.
Then, the validity of the pre-established land uses and slope gradient categories (determined by the workshop organisers) is discussed, negotiated, and modified taking into account the different opinions of the local stakeholders involved. Only when the agreement is found, on the distinct land use types and slope classes, all the steps of the assessment are carried out for the entire study region.
In the interests of brevity, clarity, convenience, and consistency, all aspects of land use, land degradation, and impacts on ecosystem services (QM step 2 and step 3) are discussed area-wide, but by differentiating the land use types and the slope gradient categories. To become familiar with the questionnaire, the assessment addresses first the LUS *permanent grassland* in which all aspects on land degradation and impacts on ESS are discussed one after another and for each slope gradient category separately: i.e. starting with LUS *permanent grassland* slope gradient category 0-3%; then LUS *permanent grassland* slope gradient category 3-15%, etc.). After examining and documenting the LUS *permanent grassland* this process is repeated for the LUS *cropland* (the stakeholder workshop outputs are included in Annex 4). This way of doing results in great discussions and debates that are extended until approximately twelve o'clock. Informal, individual

debriefings held during the lunch break, draw an encouraging overall picture of the first workshop half-day.

The second half-day of the workshop focuses on the evaluation of land conservation and the impacts on ESS (step 4 of the QM) as well as on the expert recommendations (step 5 of the QM). The pre-established list of conservation technologies (determined by the workshop organisers) is discussed and validated by the working group before analysis commences. In conformity with the approach used for steps 2 and 3, land conservation is assessed separately by land use type (*cropland* and *permanent grassland*) and slope steepness. In addition, contrary to what was made for land degradation, the four slope categories are reduced to two broader slope gradient classes (*>15%* and *<15%* slope steepness) when discussing the extent of the conservation technologies on LUS *cropland*. In the light of the significant number of conservation technologies on LUS *cropland*, the evaluation procedure must be systematic, functional and efficacious: The questionnaire variables (extent, effectiveness and -trend, etc.; see Annex 2: "Schritt 4" for more details) are assessed one after the other and it is at this stage, while discussing each variable, that all conservation technologies are evaluated and documented in a spreadsheet (documented sheet included in Annex 4). As scheduled, the workshop ends at 5 p.m. with a debriefing, after which the research partners are invited to enjoy a drink. This gives me the opportunity to express my sincere thanks for their participation in, and contribution to, the workshop.

The success of this consultative and cooperative approach is based on the contributors' willingness to listen and to understand the complexity of the processes and actors involved in the region, as well as on the know how to call and conduct a meeting in order to captivate participants' attention on the agenda. I should like here to express my recognition to Hanspeter Liniger who conducted the meeting with great sensitivity. His long-standing partnership with the local stakeholders, as well as his knowledge and experience on the WOCAT method, and his flexibility in referring to the participants facilitate the exchanges and allow the success of this workshop day.

The stakeholder meeting (held on September 4, 2015) was decisive in producing valuable and adequate information and making it accessible all stakeholders as well as eventually to an even larger audience. In order to eliminate uncertainties and little shortcomings informal exchanges were conducted.

The assessment of the LUS *forest* is based on the experience gained during the stakeholder workshop. It was made in consultation with the district forester on September 14, 2015 and also supported by the WOCAT mapping questionnaire, the German leaflet, and the printed version of the base map.

Illustration 8 Group of experts involved in the stakeholder workshop on Septembre 4, 2015 in Frienisberg (BE). Missing: Mirjam Lazzini, who is taking the photograph, and Stefan Brunner (Source: © Hanspeter Liniger)

2.5.2 Field observations

Field observations are additional tools in the procedure of assessing land degradation and conservation, as they may be valuable for both the identification of degradation processes and as a calibration or validation method. Workshops might want to be kept in a restrained and calm environment favouring the understanding and an inclusive participation of all actors. Nevertheless, unplanned and impulsive fieldtrips with the survey participants can be envisaged, encouraged, and acutely valuable, as spontaneous information can emerge in-situ elicited by the context itself (e.g. observations, reflections, remarks, explanations, etc.).

The circumstance in which this study is made, considering both the players involved and the small study area, does not particularly request the inclusion of collective field observations, the study area being relatively small and the expert group very well acquainted with the region, its situation and its development. The majority of the participants work on the ground on a daily basis and are totally aware of the existing processes. While the land users walk the fields every day, the professional researcher and soil and water conservation experts have been doing research in the study region for many years. However, I have walked the land to observe and absorb the spirit of the place.

2.6 State of the knowledge

The following section emphases on the literature review. While some notions have already been introduced in sections 2.1 and 2.5 (while discussing actor participation), a brief overview of the notions of **soil** and **land** is given in this section before focusing on documents and publications relating to the local and regional context of Frienisberg.

2.6.1 Opening remarks

In ancient times bridges had already been built between life and soils. The Latin word **Homo** for the human species is derived from **humus** (Bourguignon & Bourguignon, 2008; Hillel, 2003), where as a close literal meaning of the two biblical figures Adam and Eve is **soil** and **life**, from the Hebrew words *adama* and *Hava* (Hillel, 2003), finally in the Inca mythology *Pachamama*, meaning “Mother earth” (Eviatar, 2006), is the sovereign, the fertility goodness determining over planting and harvesting (Graves, 2001; Kemper Columbus, 2004). Following these tight bonds between life and soils, the necessity for protecting soils appears undoubtable.

Soils represent the essence of life (Bourguignon & Bourguignon, 2008; Gobat, Aragno, Mathey, Collectif, & Bally, 2010; McNeill & Winiwarter, 2004) and the basis of its establishment within the ecosphere (Scheffer et al., 2010). There is no need to discuss this topic at too much length. Through their physical, chemical, and biological characteristics soils control and disclose many ecological processes and are therefore considered as one of the most important sections composing the ecosystem (Gobat et al., 2010), regrettably the least comprehended (McNeill & Winiwarter, 2004). Innumerable factors relate to the soil and many of them influencing its’ quality reach far beyond the soils’ defined space (Bouma, 2002). The used wording **land**, land quality, and by extension land degradation become common custom, since the opinion of land degradation is widened over the decades, starting from the limited concept of production to an ampler conception embracing broadly the provided goods and services. The focus is thus extended from the only soil to the ecosystem as an entity (Nachtergaele et al., 2010). Various authors do not explicitly distinguish the terminology (soil degradation or land degradation) what might lead to confusion. It appears important to make it clear that this study regards both terms as equal. A land of quality is a sine qua non for sustainable agricultural production. Soils, water, and air are of important relevance for habitat, regulation, and production functions and thus precious goods and the most worthy of protection (Scheffer et al., 2010). The enhancement and conservation of the land components, through the reappropriation of natural cycles within agricultural structures, are significant constituents of a strategy leading towards a more sustainable agriculture (Barrios, 2007; Fukuoka, 1989; Robin, 2012).

Initiatives for land protection

Through the adoption of the *European Soil Charter* United Nations' (UN) *Resolution (72) 19* in 1972 the Committee of Ministers deliberates soils as part of humanities' most valuable assets (Council of Europe, 1972). Although UN resolutions are mostly considered as non-binding this adoption may anyway lead to a soil conservation perspective. Sensible to the emerging risks of land degradation in terms of yield and land surface losses (in both countries of the *Global South* and the *industrial North*) the 21st Session of the FAO Conference (November 1981) approved the *World Soil Charter* (Food and Agriculture Organisation of the United Nations (FAO), 1982). This document sets a number of principles for the use, the productivity improvement, and the conservation of the global land resources for upcoming generations. Through the Rio Earth Summit 1992 desertification, climate change, and the loss of biodiversity have been recognised as the utmost defies to sustainable development. Building on this statement the *United Nations Convention to Combat Desertification (UNCCD)* has been approved in 1996. Even though soil protection is not an explicit goal of any European Union (EU) legislation up to now, some legislations mention it as a resulting objective (SoCo Project Team, 2009): Two EU environmental directives are referred to as ambitioning the improvement of soil quality, specifically the *Nitrates Directive (91/676/EEC)* and the *Water Framework Directive (2000/60/EC)*.

The 2012 European Commission Report *The State of Soil in Europe* beholds an acceleration of soil degradation processes throughout Europe (G. van Lynden, Ritsema, & Hessel, 2014). While the intensification of land use and the deforestation for agricultural production enhanced the stress exerted on soils (McNeill & Winiwarter, 2004) land degradation represents a danger to society, the habitat, and the economy. The 68th UN General Assembly declares 2015 as the International Year of Soils (IYS) recognizing the fundamental essence of soils as a natural but limited resource for crop production, ecosystem functions and food security (United Nations, 2014).

Worldwide land degradation endangers soils, water, native vegetation, but also cultivated crops (Liniger & Schwilch, 2002). The spread, enforcement, and belief in agro-technology titled *Green Revolution* (Khush, 2001), engages the development of irrigation infrastructure and the generalisation of high-yielding varieties, hybridized seeds, synthetic fertilizers, and pesticides in the farming communities (Koohafkan et al., 2011; Robin, 2012). Nowadays, intensive agro-systems using technical inputs such as soil tillage and the spread of fertiliser and pesticide are considered practices adjusting soil structure, nutrient stream, as well as pest and disease control (Barrios, 2007; Dale & Polasky, 2007). In this context of intensive, high-input, and technological agriculture land degradation is a topic of major importance, as it has strong repercussions on both the environment (e.g. soil or biodiversity loss) and the agricultural productivity, there is no need to dwell on the impacts (Benton, Vickery, & Wilson, 2003). The main degradation processes contributing to the declines of fertile agricultural land and ecosystem services, as well as making the land lose its' ability to sustain suitably its primary ecological and/or an economic function are presented as "vegetation degradation, water degradation, soil degradation, climate deterioration, and losses to urban/industrial development" (Liniger & Critchley, 2007, p. 18). Human-induced impacts such as soil erosion or urbanisation are expected with increasing tendency alongside the ongoing climate changes. Consequently, soil conservation techniques such as terracing, use of grass strips, contour ploughing, no-tillage, and soil treatments have been widely studied, and an abundant literature is already available on these subjects (Liniger & Critchley, 2007). The EU project RECONDES has for instance been developed with the intention to produce an integrated spatial strategy for erosion control while using vegetation as land degradation management method (Hooke & Sandercock, 2012), proposals and suggestions are produced for the operation of the strategy. While natural processes and human activity can lead to land degradation, fitting to the political visibility society has varying outlooks on different properties of land degradation (UN Environment Programme, 2007).

The case-specificity and polysemous nature of land degradation seems obvious since, among other things, the concepts are constructed on socio-culturally and economically embedded ideas of *quality* and *productivity* (Warren, 2002). Standardization and normalisation procedures are questionable since they inherently induce the necessity to consider certain parameters as constancies, such as, among others, relief, climate, parent material, vegetation and organisms, but also the social context, land management, economic viability or time (Bojórquez-Tapia, Cruz-Bello, & Luna-González, 2013). However, the necessity to create standardised methodologies for the assessment and the illustration of land degradation, as well as the responses to it, could be established (Liniger, van Lynden, Biancalani, Lindeque, et al., 2013). In this respect, WOCAT recognizes the potentiality of maps and includes them next to the assessment of SLM technologies and approaches. By emphasising on land degradation, conservation technologies, and ecosystem services the QM is a tool assembling, creating, and visually representing the knowledge convenient for addressing land management appropriately. Thus, maps are not only a valuable and useful communication tool to initiate discussions, they are also powerful contributors to evidence-based policy making (Hauck et al., 2013), as they might serve as visual support to plan conservation related activities (e.g. in the context of nature and biodiversity) and to underline the benefits of conservation measures. Beyond their geographic perspective the products resulting from mapping processes can be beneficial and suitable for different purposes. While assessing the potential benefits for decision-making processes, Hauck et al. (2013) deduce that mapping ecosystem services allows the identification and framing of related problems, e.g. the assessment of conceivable divergences between ecosystem services and other land uses (Hauck et al., 2013).

Both topics SLM (section 2.1.1) and SWC are and have been research subjects over several years and by a vast number of scientists and practitioners. A high number of scientific publications have evaluated the range and grade of land degradation throughout Europe. Abundant research has also been done on single soil/land threads (e.g. soil organic matter decline, compaction, salinization, landslides, or erosion), which became subject to many reviews. Both the broad scientific community and numerous national and major international institutions acknowledge the scientific fundamentals of those topics (Hurni, Giger, & Meyer, 2006) so that there is therefore no further need to prove their scientific applicability. Consequently, the following section 2.6.2 will only focus its attention on local subjects and published documents that are relevant for the present research areas.

2.6.2 The Swiss context

The *Centre of Development and Environment* (CDE) at the University of Bern has conducted many studies assessing land and soil quality in Switzerland. Focusing mainly on soil erosion, the region of Frienisberg has been studied and mapped over various years (Prasuhn, 2011). An interesting referential is the erosion damage research accomplished by Ledermann et al. (2008) showing the current state in the three study sites (Frienisberg, Estavayer-le-Lac, and Oberaargau). The damage mapping approach is considered as the appropriate methodology to assess rill erosion. The resulting maps showing an overview of on-site erosion damage, including its temporal implications, are a useful support to picture the interactions occurring between human activity and the soil (Ledermann et al., 2008). As an outcome, linear erosion (including both small and large rills) represents between 62 and 85% of the total soil loss in the three study areas, whereas wind erosion characterises only a minimal problem.

The region Frienisberg has also been chosen as test area while evaluating the legal regulations concerning SWC, introduced in 1993 (Prasuhn & Weisskopf, 2003). These regulations are embedded in the re-positioning of Switzerland's agricultural policy, wherein direct payments are allocated to the farmers to compensate for ecological attainments. In their research Prasuhn & Weisskopf (2003) focus on soil erosion using simultaneously both methods model calculations (assessment of mean long-term soil erosion risk) and erosion damage mapping (regular estimation of soil losses). The mapping results published in Prasuhn & Weisskopf (2003) illustrate the positive effects of conservation measures to counter and prevent soil erosion. The authors recognise the effects of soil conservation tillage systems, protecting fields from erosion, and regulated crop rotations, since barely any erosion could be evaluated in areas with direct seeding and reduced tillage systems with mulch cover in contrast to recurrent and intense soils losses in ploughed fields. The damage mapping method permits the assessment of valuable information such as the in-field analysis of causalities, the valuation of special cases (e.g. road inflows, subsurface exfiltration flows, etc.) (Prasuhn & Weisskopf, 2003), and the identification of off-site damages associated with soil erosion (e.g. for the assessment of phosphorous pollution of surface water) (Ledermann et al., 2008; Prasuhn & Weisskopf, 2003). Reflecting certain circumstances the authors mention the need for specific measures against linear erosion, e.g. grassed waterways since the vegetation cover can act as an important agent mitigating soil loss. The outcomes of the test fields revealed the main damages occurring in periods of low vegetation cover and shortly after cultivation (Ledermann et al., 2008), *"during vegetation period of spring crops"* and *"when the fields were planted with winter cereals"* (Prasuhn, 2011, p. 37). Nevertheless, in an extended perspective, the Swiss Plateau is only locally affected by soil erosion processes, since physical activities affect between 10 and 40% of the agricultural land (Ledermann et al., 2008; Prasuhn, 2011).

Furthermore, the high resolution erosion risk map of Switzerland illustrates the agricultural areas potentially affected by soil erosion (Gisler, Liniger, & Prasuhn, 2011). Gisler et al. (2011) identify the topology of the terrain as major influencing factor for the erosion risk. They state that the potential risk of erosion can be related to factors as the presence or absence of depressions (*Geländemulden* in German), concave or convex slopes, banks and hedges, or the direction of the water flow. However, as a concluding thought, Gisler et al. (2011) suggest some precaution to the user interpreting the map, since areas might be qualified at high risk of erosion, while in reality the farmers have already adapted their cultivation practice (e.g. conservation soil cultivation, areas of permanent grassland, etc.), and on the other hand some areas can be qualified as not endangered by erosion, when in fact erosion processes occur (caused by high inflow of external water, outflow of slope water, defective drainage, etc.). In such configurations experts' knowledge (farmers, scientists, land users, etc.) and participation become important and can reveal themselves determining. Most soil erosion research and modelling is still based on results from test plots as large-scale field studies are not fully considered as scientific by a range of researchers (Prasuhn, 2011). A 10-year field survey (1998-2007) assessing soil erosion in 203 fields around Frienisberg (max. 10km between the five study areas) is presented in Prasuhn (2011). The author divulges the importance of long-term studies minimising the bias that might result from *"low frequency high magnitude effects"* (Prasuhn, 2011, p. 34). Most of the identified rill-depths reached only a few centimetres and the erosion mainly occurred just after the sowing or seedbed preparation. The difficulty in determining reliably the sedimentation areas is foregrounded. He argued that an important part of the eroded soil volume had been diffused on the fields, concentrated on the field border, or distributed beyond these edges, whereof some of it might have reached surrounding water bodies. Over a ten-year period the author detected erosion damage on approximately 30% of the fields. He accredits the absence of erosion (observed on 24 of the 203 fields) to a valuable soil structure and enough soil cover, obtained thanks to favourable site properties (relief, soil), crop rotations, conservation tillage, and the presence of temporary grass-clover leys. Finally, Prasuhn (2011) emphasises on the subsequent off-site damages that could be detected in 72% of the studied cases. In Switzerland erosion damage mapping has now an extended tradition. Numerous conducted studies lead to raising attentiveness to the concern and the institution of many legal regulations diminishing the soil erosion range in the country (Prasuhn, 2011; Prasuhn & Weisskopf, 2003). Even though the current study is targeting land degradation in a broader perspective than only focusing on erosion damage and soil loss, the information generated in these studies as well as the existing long-standing relationships and trustful networks between the different stakeholders present and active in the region are qualified as highly valuable and a great advantage.

In addition to the peer-reviewed publications, previous bachelor and master thesis issued by the CDE and the University of Bern have studied land degradation in the Swiss Plateau. These represent an additional useful state of the art literature for this study. One document of particular interest is Constantin Streit's master thesis published in 2014. Willing to contribute with additional information to the review of the erosion risk map, the author describes the feasibility of automated classification characterising effective agricultural areas based on aerial images (Streit, 2014). The tree investigated study sites, whereof one is covering the region of Frienisberg, are situated in the canton of Bern. Streit understands the importance of land cover in the evaluation of the erosion risk. He managed the creation of an automated tool distinguishing croplands from grass clover leys as well as from permanent grasslands. Discriminating (bi)-annual grass clover ley from permanent grassland is necessary, since grass clover leys being comprised in crop rotation cycles whereas the latter (permanent grasslands) maintain a perennial grass cover for at least six years. The present master thesis assumes Streit's (2014) classification as a thematic layer to build on while constituting the base map. A second interesting document is Christine Hauert's master thesis, wherein she compared the humus content of no-till and conventionally tilled agricultural fields, in both regions Oberaargau and Frienisberg (Hauert, 2007). She also measured physical properties such as the water infiltration, determined the grain texture and soil structure, and estimated the vegetation cover in each patch. With regard to the long term, soils under conservation agriculture (no-tillage) will develop better soil properties than conventionally tilled soils. Although the difference between the two soil treatments where more pronounced in the Oberaargau than in Frienisberg.

In his master thesis, Urs Grob applied methods of visual field observation in the region of Oberaargau (Swiss Plateau), for the mapping and the evaluation of land degradation as well as SLM practices on agricultural fields. Grob (2010) based his approach on the WOCAT/LADA methodology; wherefore he had to establish and adapt the method in order for it to become suitable to the spatial partitioning of the regional farmland. He also had to review and check the land degradation indicators for their applicability in this context. Grob made one major methodological adaptation in the mapping process when substituting the experts' participation by visual field observations, wherefore he used a higher spatial resolution (Grob, 2010). The amendments made to the approach induced the creation of a suitable and adapted catalogue. Grob (2010) focused on the assessment of two main land use types: grassland and agricultural land. He attributes the land use systems *grassland/grass clover ley* and *pasture and grass clover ley* to the land type grassland, whereas *no-tillage*, *mulching*, and *conventional ploughing* to the agricultural land. He confirmed that the various land use types are subject to degradation in different manners, grassland being less affected by land degradation processes than agricultural land. While the differences in the extent of land degradation are negligible between no-tillage and mulching techniques, these two conservation methods reduce the land degradation potential compared to conventional ploughing methods. Even though conservation agriculture does not entirely prevent land degradation (Grob, 2010), many authors consider no-tillage agriculture as a possible base for sustainable agriculture, creating inter alia significantly lower erosion charges (Chervet, Ramseier, Sturny, & Tschannen, 2005; Montgomery, 2007, 2007), with erosion values that may be close to soil production rates (Montgomery, 2007). In her master's thesis Judith Gasser has also proposed an adaptation of the WOCAT/LADA mapping Questionnaire to the small scale agricultural patterns of the Swiss Plateau (Gasser, 2009). Further, her method differs from the one used in this study as she decided to exclude interviews with farmers, soil and water experts, or other stakeholders, while focusing the data collection on pure and intense fieldwork. Here study area – Murist – is located in the East of Yverdon-les-Bains in an exclave of the canton of Fribourg, in vicinity of Lake Neuchatel. Both Gasser (2009) and Grob (2010) justify the use of a higher spatial resolution and a smaller scale by the characteristics of the areal distribution of the Swiss agricultural landscape.

Finally, the master thesis presented by Michael Chisholm, and the follow up project realised by Simon Gisler, both assessing soil erosion on agricultural cropland in the Swiss Plateau operating the GIS-Tool AVErosion for ArcView 3.x., also contain valuable information. Chisholm (2008) identified the tool as adequately structured and useful for the long-term prediction of the rates of soil loss. He argues that this high-resolution assessment allows identifying the strong variation of the relative erosion risk within small spatial areas and he recognises the relief (principally the slope) as being one major influencing factor for soil erosion on agricultural land (Chisholm, 2008). Even though the tendency that the AVErosion tool overestimates erosion can be confirmed in the follow up study (Gisler, 2009), the assumption that the C-factor (land cover and land management) weights in local soil erosion processes can be re-established and confirmed, as it had been mentioned in Chisholm (2008).

Part Three

Results and discussion

3 Results and discussion

The following part three shows the data assembled and produced according to the purpose of the present master thesis. It illustrates and discusses the results obtained through the WOCAT QM with regard to LUS changes, land degradation, and land conservation measures.
The multi-stakeholder meeting held on September 4, 2015 at the Restaurant Hirschen in Frienisberg (BE) to assess the LUSs *cropland* and *permanent grassland* and the consultation held on September 14, 2015 with the district forester to assess LUS *forest* allowed us to gather sufficient valuable and adequate information eliminating the need for additional personal interviews, with the exception of some informal exchanges.
The WOCAT assessment focuses on the land use systems *permanent grassland*, *cropland*, and *forest*, combined with the four major slope categories (Table 7). The LUSs *settlement* and *water bodies* have been disregarded as such in the appraisal, though related to land degradation they are considered when referring to other LUS. For the purposes of coherence they are included in the report, along with other types of land degradation perceivable in the region.

3.1 Valuation of the land

In the context of this study the municipal boundaries are of minor interest, there is no usage and/or property right restriction that is systematically bond to the municipality, i.e. the agricultural leasing agreements and plot properties are not restricted or confined within municipal borders, which makes this distinction not necessarily required. Instead, agriculturalists own, inherit, buy, and lease patches that stretch over different municipalities, in which case the property and/or leasing covenant becomes determining factor, not the administrative borders. Since conservation practices recurrently emerge from personal initiatives, face-to-face exchanges, and through observations made on neighbouring fields, the focus is put on the practitioners and the key local actors, which in daily practice, guided by ideological view, work their land according to their convictions.

In accordance with the LUSs, the area of interest is subdivided conferring to the spatial proportions detailed in Table 6 and illustrated in Fig. 8 and Fig. 10.

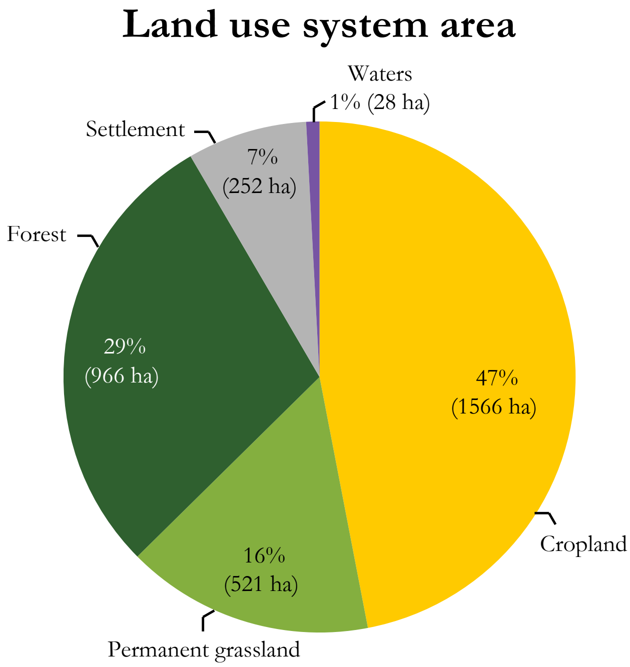

Fig. 8 Study area Frienisberg (BE): Relative (in %) and absolute (in ha) spatial extent of each land use system (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern)

The LUS **cropland** accounts for the largest share of land area, covering approximately 47% of the study zone (see Fig. 8), and 75% of the agricultural land (see Fig. 9). As illustrated by Fig. 12 and Fig. 13 agricultural activities occupy particularly the northern and central sections of the study area. While most LUS *cropland* parcels belong to the *moderately sloped* areas (77 % of the cropland area), much less are located on *flat* (12.7 % of the cropland area) and *steep* (9.3 % of the cropland area) lands, and only very few are on *very sloped* (1.0 % of the cropland area) terrains (Fig. 9), alongside the Mülibach (see Fig. 2). According to the workshop participants, the latter category might even be inexistent, its' appearance in the map may be related to inaccuracies in the dataset. Although, since the croplands are manly situated on *moderately* sloped patches (extending over 36% of the total study area), the surfaces affected degradation processes due to mismanagement of farmland are potentially far-reaching (see Table 6 or section 3.3.2).

The LUS **permanent grassland** is the second system belonging to the agricultural land (comprising roughly 25% of these surfaces, as shown in Table 22) while it extends over 16% of the area of interest (see Fig. 8). It is quickly detectable in Fig. 12 and Fig. 13 how the two LUSs are complementary (see also section 3.3): Most *permanent grassland* parcels are located either on more or less inclined terrains or in the vicinity of surface water bodies. Unlike *cropland* areas, *permanent grassland* patches are frequently confined on *moderately* (43.36 % of the permanent grassland area) and *sloped* (46.22 % of the cropland area) lands. Some remaining grassland areas are on *extremely* (7.8 % of the permanent grassland area) sloped terrains, whereas they are barely detectable on *flat* (2.62 % of the permanent grassland area) patches (see Fig. 9).

The agricultural lands, joining LUS *cropland* and LUS *permanent grassland*, extend over roughly 62% of the area of interest (Table 6). The necessity to generate interest in adequate management of these areas seems thus undeniable.

Land use system	**LUS area (in % of total area)**	**LUS area (ha)**	**Slope category (%) and steepness**		**Area (in % of total study area)**	**Area extent (%) per LUS**	**Surface area (ha)**
Cropland	47.0	1'565.6	0-3%	Flat	6.0	12.7	198.8
			3-15%	Moderate	36.2	77.0	1205.1
			15-30%	Steep	4.4	9.3	146.0
			>30%	Very steep	0.5	1.0	15.6
Permanent grassland	15.6	520.8	0-3%	Flat	0.4	2.6	13.6
			3-15%	Moderate	6.8	43.4	225.8
			15-30%	Steep	7.2	46.2	240.8
			>30%	Very steep	1.2	7.8	40.6
Forest	29.0	966.4	0-3%	Flat	-	-	-
			3-15%	Moderate	10.8	37.2	359.4
			15-30%	Steep	12.1	41.8	403.5
			>30%	Very steep	6.1	21.1	203.6
Waters	0.8	27.8	No distinction -		0.8	100	27.8
Settlement	7.6	252.3	No distinction-		7.6	100	252.3
Total	100	3'333.04	-	-	100	-	3'333.0

Table 6 Study area Frienisberg (BE): Surface area (in % and ha) for each LUS and slope category according to FAO and modified through the stakeholder workshop (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern)

The **forest** cover dominates approximately 30% of the area. As clearly illustrated in Fig. 11 most woodland is confined to the south of the study area, while smaller patches are distributed randomly all over the assessment zone. Since there is no woodland on *flat* patches, almost 63% of the forest area belongs to the gradient categories *sloped* and *extremely sloped*, whereas the remaining 37% is accountable to the *moderately* sloped land. Since no apparent need to subdivide the land any further has been mentioned, the whole forest surfaces is evaluated as an entity even though the forest patches are disseminated within the survey area.

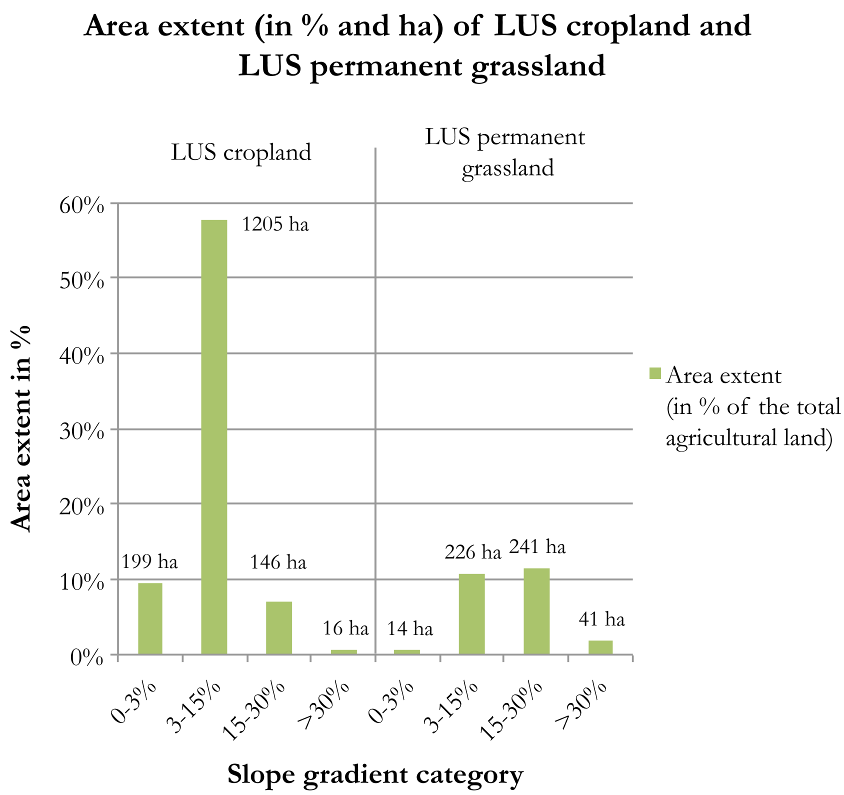

Fig. 9 Study area Frienisberg (BE): Area extent (in % and ha) of LUS cropland (75% of the agricultural land) and LUS permanent grassland (25% of the agricultural land) according to the slope gradient categories and relative to the total agricultural land area. Combining both LUSs, the total surface of the agricultural land covers 62% (2086.47 ha) of the total study area (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern, data in Table 22).

Apart from the land use categories mentioned above, the study area is furthermore expressed in terms of **slope gradient categories (SGC)**. Frienisberg is a hilly area principally characterized by cropland, woods, and small settlements. While observing the LUSs *cropland*, *permanent grassland*, and *forest*, the *flat* and *very steep* parcels are relatively few (respectively 6.4% and 7.8% of the total study area) compared to *moderately sloped* and *sloped* lands (respectively 53.7% and 23.7% of the total area) (see Table 7). The missing 8.4% refer to waters and settlement areas and will not be discussed any further. Most of the steeper land patches are located in the southern section of the research area (see Fig. 11 and Fig. 13), where they extend alongside the Mülibach (river) up to the Frienisberger Wald (see Fig. 2). Further isolated sections, mostly covered by forestland, extend alongside the Alewilbach (see Fig. 2) in the northeast of the area (see Fig. 11).

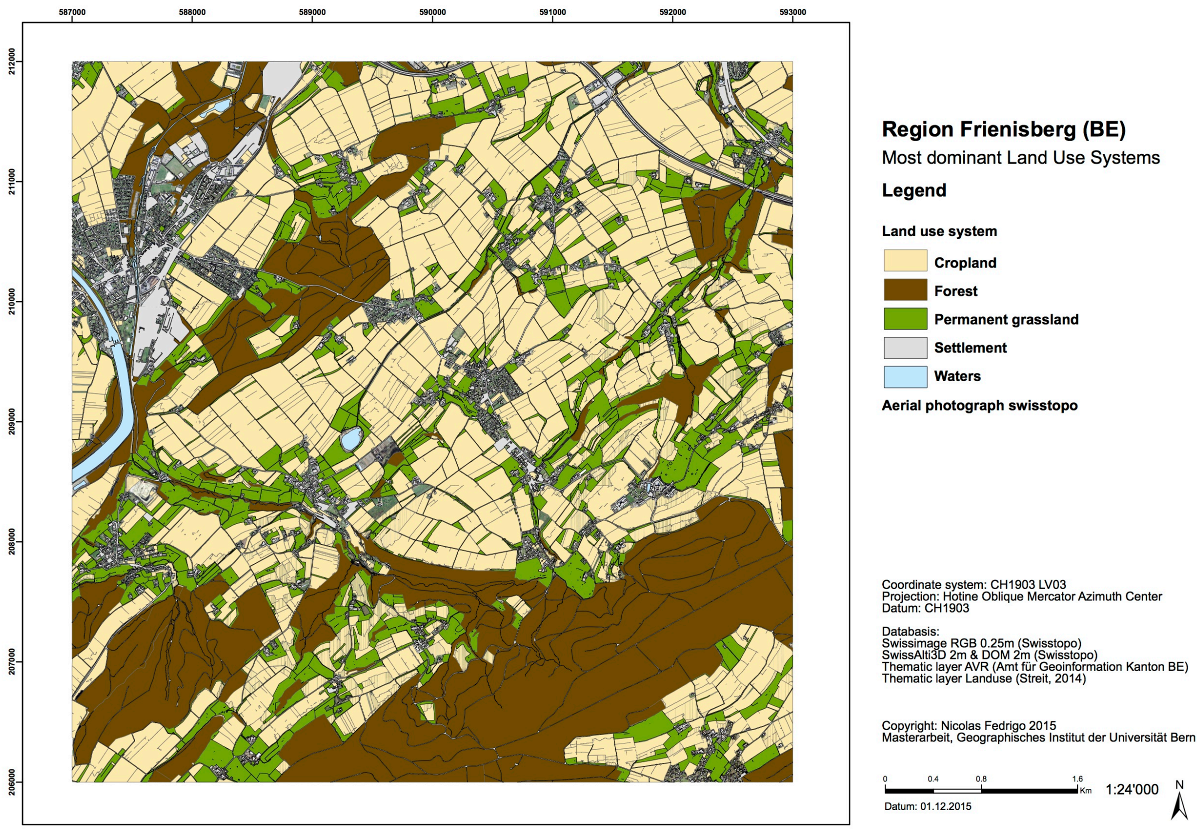

Fig. 10 Study area Frienisberg (BE): Spatial distribution of the existing land use system (Fedrigo 2016)

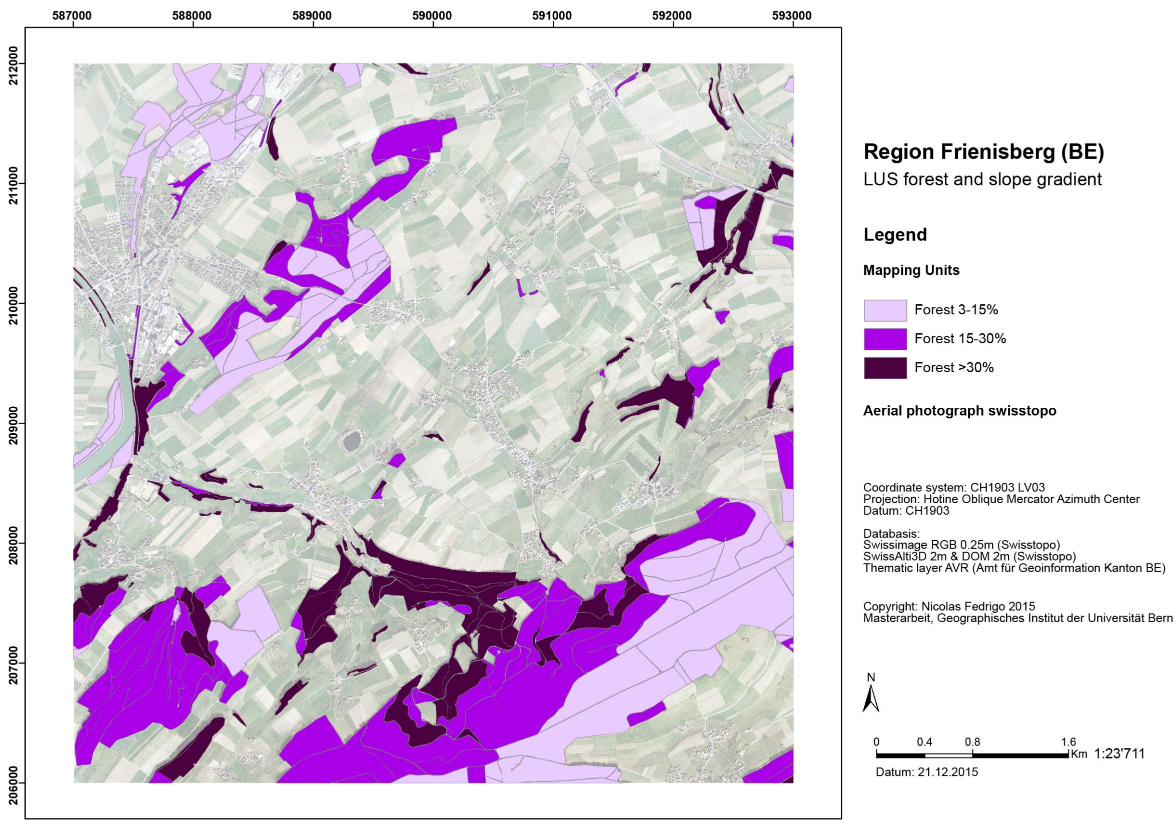

Fig. 11 Study area Frienisberg (BE): Regional base map section illustrating LUS forest and the slope gradient categories (Fedrigo 2016)

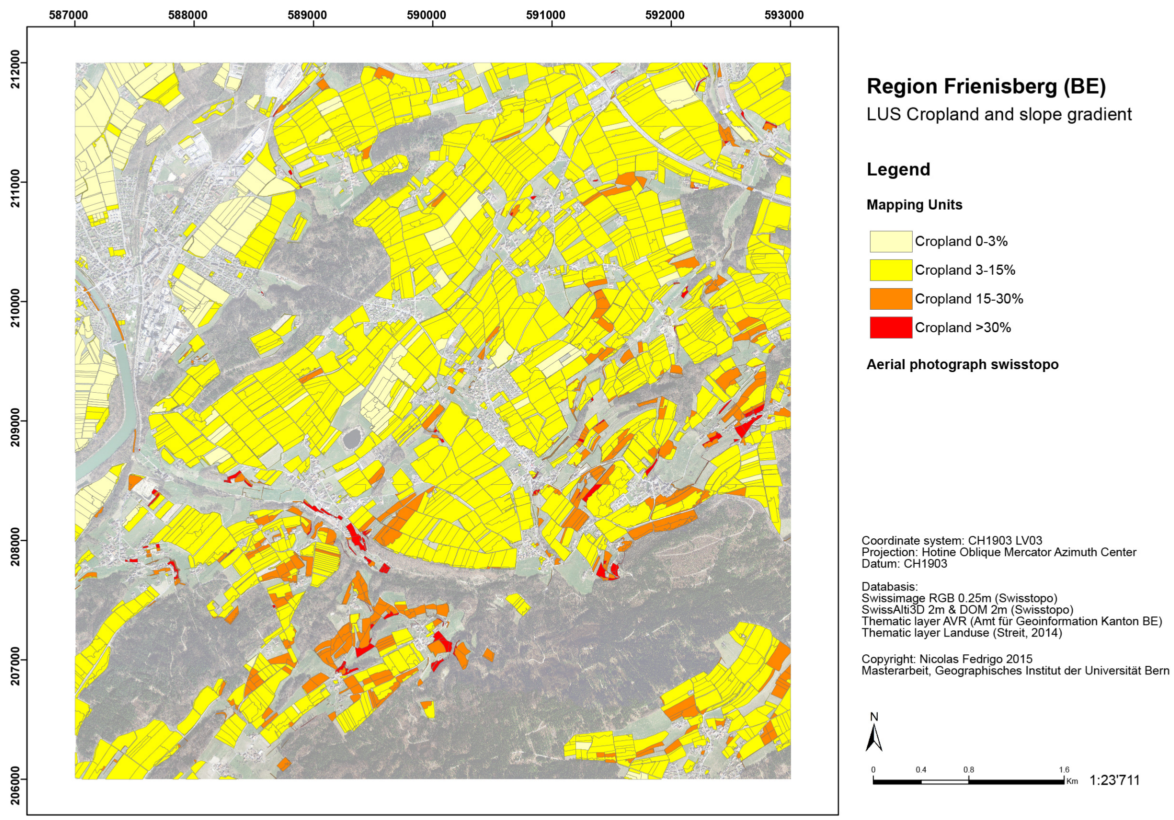

Fig. 12 Study area Frienisberg (BE): Regional base map section illustrating LUS cropland and the slope gradient categories (Fedrigo 2016)

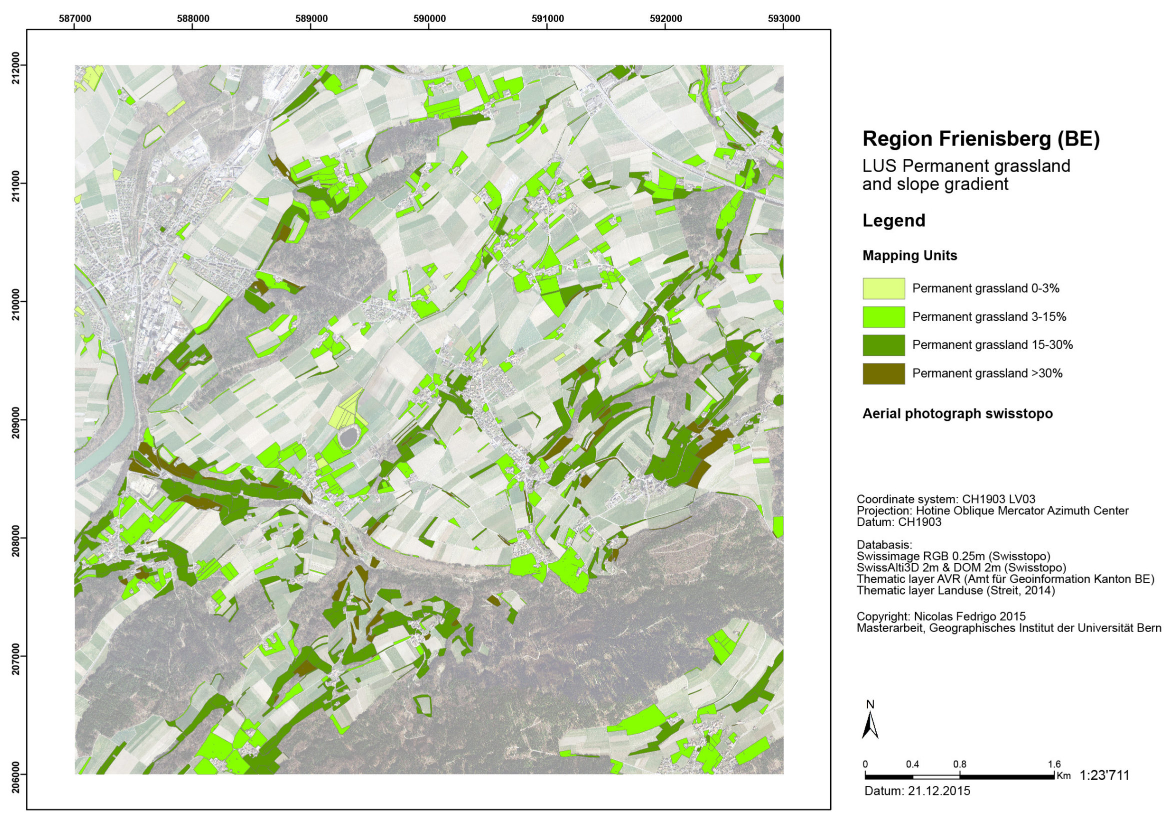

Fig. 13 Study area Frienisberg (BE): Regional base map section illustrating LUS permanent grassland and the slope gradient categories (Fedrigo 2016)

Some arrangements were introduced to the slope categories during the stakeholder workshop[16]: Originally, and according to FAO standards, the evenest category had been planned including slope gradients between 0 and 8% steepness. During the workshop expert group clearly state the necessity to separate the **flat** parcels (SGC: 0-3%) from the parcels with **moderate** slope gradients (SGC: 3-15%). For the mean of practical field experience (e.g. from a machinery perspective) and several readings taken in the region, clear differences become visible between the two slope categories in terms of degradation processes or types, as well as their occurrence, shape, and intensity, though from a strict machinery perspective the land users would even consider 20% steepness as the upper border for the evenest category. In terms of surface erosion, first soil movements already appear at slope values nearby 2-3% and alter rapidly with increasing gradients. Thus, with the knowledge that major changes in surface erosion processes already occur on fields sloping between 3 and 8%, and with regard to the slope categories used in crop rotation surfaces (*Fruchtfolgeflächen* in German), the limiting values are as shown in Table 7. In order to maintain consistency, the slope gradient categories apply also to LUS *forest*.

Slope gradient category	Area extent (in %)	Area (in ha)
0-3%	6.4	212.5
3-15%	53.7	1790.3
15-30%	23.7	790.3
>30%	7.8	259.8
TOTAL	**91.6**	**3052.9**

Table 7 Study area Frienisberg (BE): Study area fragmentation according to the slope gradient categories. The missing 8.4% surfaces designated as LUS water and LUS settlement areas. (Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern).

3.2 Land use system (LUS) trends

3.2.1 LUS area trends

Referring to the data available in Switzerland's Land Use Statistics (*Arealstatistik* in German) moderate area changes occurred in the region over the last two decades. Based on data gathered in 2004 (the most recent records available) the coverage areas evolved as listed in Table 8 (BFS, 2015) – the selected municipalities and district provide an illustrative guidance. According to the workshop results, in certain circumstances slight changes in land use area occurred over the observation period 2005-2015 (see Fig. 14).

[16] Multi-stakeholder Workshop, held on September 2, 2015, in Frienisberg (BE)

Representing the Land Use Statistics, Table 8 illustrates how the spatial distribution of the land uses has been changing during the past decades: According to the QM classifications[17] (please refer to: Liniger, van Lynden, et al., 2008, p. E4) the LUS *cropland* area coverage has been "slowly decreasing in size, i.e. < 10% of the LUS area/10 years" (rated as slowly decreasing, -1) over past decades for the benefit of *settlement area* that "is slowly increasing in size, i.e. < 10% of the LUS area/10 years" (rated as slowly increasing, 1). Similar tendencies are assumed in the workshop results (Fig. 14) and "**overbuilding**" (*Überbauung* in German), i.e. the expansion of settlement areas, is identified as major cause and anthropogenic action causing these area changes.

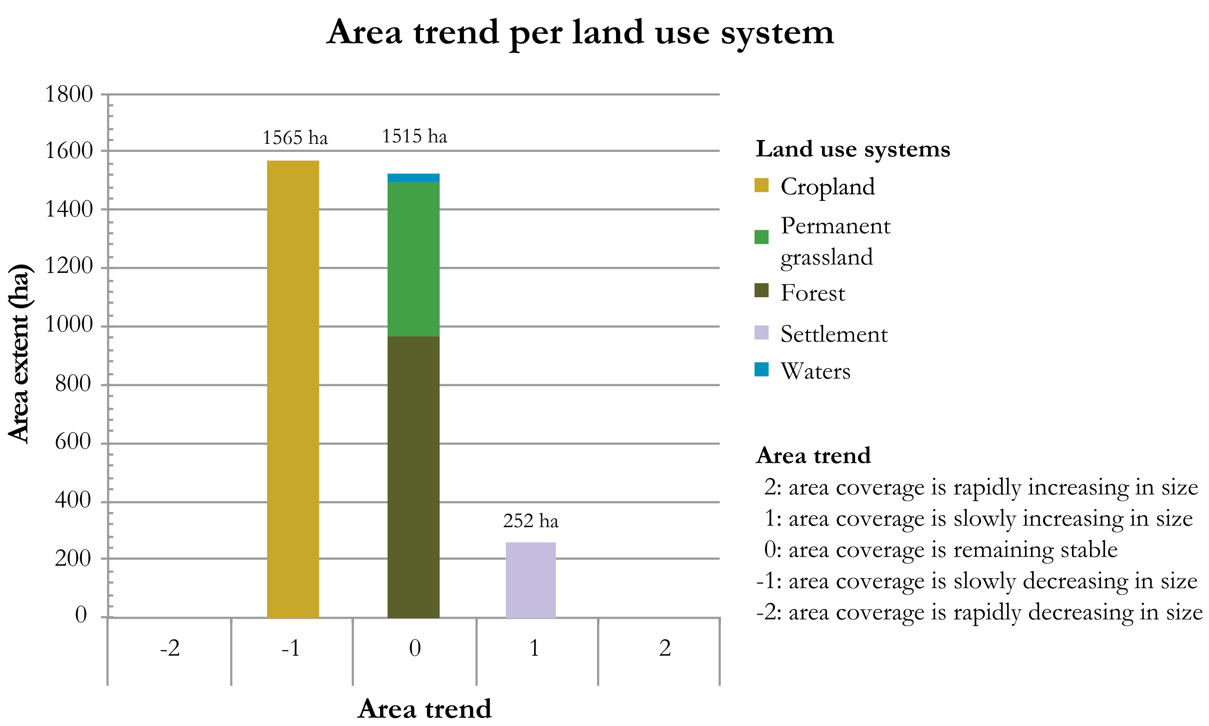

Fig. 14 Study area Frienisberg (BE): Area trend for each LUS based on a ten-year (2005-2015) observation period (Illustration: Fedrigo 2016 based on De Maddalena (2011), Data source: WOCAT QM)

As underlining example, including the whole district Seeland, the area coverage of the settlement increased by 8% (from 3'552 to 3'844 ha) during the periods ranging between 1992/97 and 2004, whereas during the same periods the agricultural surface area decreased by 2% (from 20'254 to 19'983 ha). Illustrations demonstrating the area values from selected municipalities, Schüpfen and

[17] In accordance with the definitions, categories, and rated classifcations listed in the WOCAT Mapping Questionnaire (QM) (Liniger, van Lynden, Nachtergaele, & Schwilch, 2008). Readers are advised that for future quotes and references to any definition/category/classification the QM source Liniger et al. (2008) will not be repeated though it is understood as such.

Seedorf BE, can be extracted from Table 8 below, whereas more exhaustive data including all municipalities concerned by the study area is given in Annex Table 4.

	Settlement area			Agricultural area			Forest area		
Reference period	**1992 /97**	**2004**	**Area trend %**	**1992/ 97**	**2004**	**Area trend %**	**1992 /97**	**2004**	**Area trend %**
Seeland	3552	3844	8.22	20254	19983	-1.34	8839	8806	-0.37
Schüpfen	201	213	5.97	1119	1105	-1.25	655	652	-0.46
Seedorf (BE)	154	161	4.55	1250	1248	-0.16	680	679	-0.15

Table 8 Area coverage of the district (*Bezirk* in German) Seeland and the municipalities (*Gemeinde* in German) Schüpfen and Seedorf (BE). The land surface values are given in ha and the surface area change (from 1992/97 to 2004) in % (Data source: BFS, 2015).

For the selected LUS some districts reveal only very little surface changes in area coverage: e.g. Seedorf (BE) only lost 0.16% (-2 ha) of agricultural surface between 1992/97 and 2004. Processes of adaptation engaged by the farmers (prior to the assessment period 2005-2015) may have contributed in maintaining the area losses at minimal values. While flatter areas (in the valley) were converted to new uses and credited to the *settlement area*, farmers were conducted and started cultivating closer to the limits of their lands, including steeper land patches (D. Niggli, 2015a), balancing thus the losses provoked by the decreasing area coverage. However, conflicting opinions regarding the area extent, the coverage, and the evolution of all observable LUSs are mentioned during the stakeholder workshop. When individual perceptions hit on statistical discernments, or when personal interests guide the sense of judgement, diverging views arise. With respect to the LUS *forest* the workshop participants perceive an increasing area trend whereas the forester states for a status quo.

Even though these disagreements are only marginal, they are worth mentioning as they touch some fragility of the used method and subtleties in the interpretation of statistical values. When working with qualitative data we basically operate in a different state of consciousness. Through individual, subjective perceptions each observation of time becomes relative. Nevertheless, the consciousness of appearing incoherencies in the constructed and discussed results puts the data interpretation into perspective.

LUS	Slope category	LUS area trend	LUS intensity trend
Cropland	0-3%	-1	1
	3-15%	-1	1
	15-30%	-1	1
	>30%	-1	1
(Grass clover ley)	0-3%	-1	1
	3-15%	-1	1
	15-30%	-1	1
	>30%	-1	1
Permanent grassland	0-3%	0	0
	3-15%	0	0
	15-30%	0	0
	>30%	0	0
Forest	3-15%	0	0
	15-30%	0	0
	>30%	0	0
Waters	n.a.	0	0
Settlement	n.a.	1	0

Table 9 Study area Frienisberg (BE): Area and intensity trend for each LUS based on a ten-year (2005-2015) observation period (Data source: WOCAT QM)

No particular distinctions between the slope categories are visible in the LUS area trends (stakeholder workshop outcomes are presented in Table 9). However, the experts perceive slightly diverging tendencies in the surface evolution. As mentioned, *flat* and *moderately sloped* lands (SGC: 0-3% and 3-15%) might have been subject to land use conversion in the past, agricultural lands where rehabilitated to settlement areas. Willing to compensate these area losses, the cultivation of steeper land patches became eventually necessary. The direct payment system gives financial supports according to the area size, thus hillside locations may be reconsidered for cropping also to increase the farm size (D. Niggli, 2015a). In practice, in order to receive additional payments land users may be tempted to cultivate sloped terrains (this may include plots belonging to the slope gradient categories 15-30% and >30%), thus converting them into *cropland*. These variations are not listed in Table 9 as the expert group clearly mentions this information based on assumptions. To give more certainty to the statements it is recommended by the expert group to interview additional farmers and landlords. The analysis of aerial photographs may also provide additional insight on surface changes, although this requires technical equipment that is not generally available for everyone.

3.2.2 Land use intensity trends

Considering the evolution of the crop rotations and the increasing cultivation of vegetables in the region the workshop participants believe that only the *cropland* (Fig. 15), and by extension it implies also the *grass clover ley*, is qualified by the QM category: “moderate increase of land use intensity” (rated as moderate increase, 1). While throughout the past ten years, no significant changes in the land use intensity have been identified in the LUS *forest* or *permanent grassland*, as with the other land use categories *settlement* and *waters* (rated as no major changes in inputs, management level, etc., 0). According to the stakeholder workshop, key changes to Frienisberg's land management intensities occurred in the second part of the 20th century with the development of some of the conservation technologies on LUS *cropland*, notably *strip sowing* and *no-tillage* in the 1990's, as well as *intensive mulching* in the 1950/60's, while previous changes had already occurred (or have always existed), especially *extensive ploughing* and *mulching* (19th century). Both *intensive* and *extensive permanent grassland* (LUS *permanent grassland*), as well as *mixed forests* (LUS *forest*) are also ancient practices dating back to the 19th century.

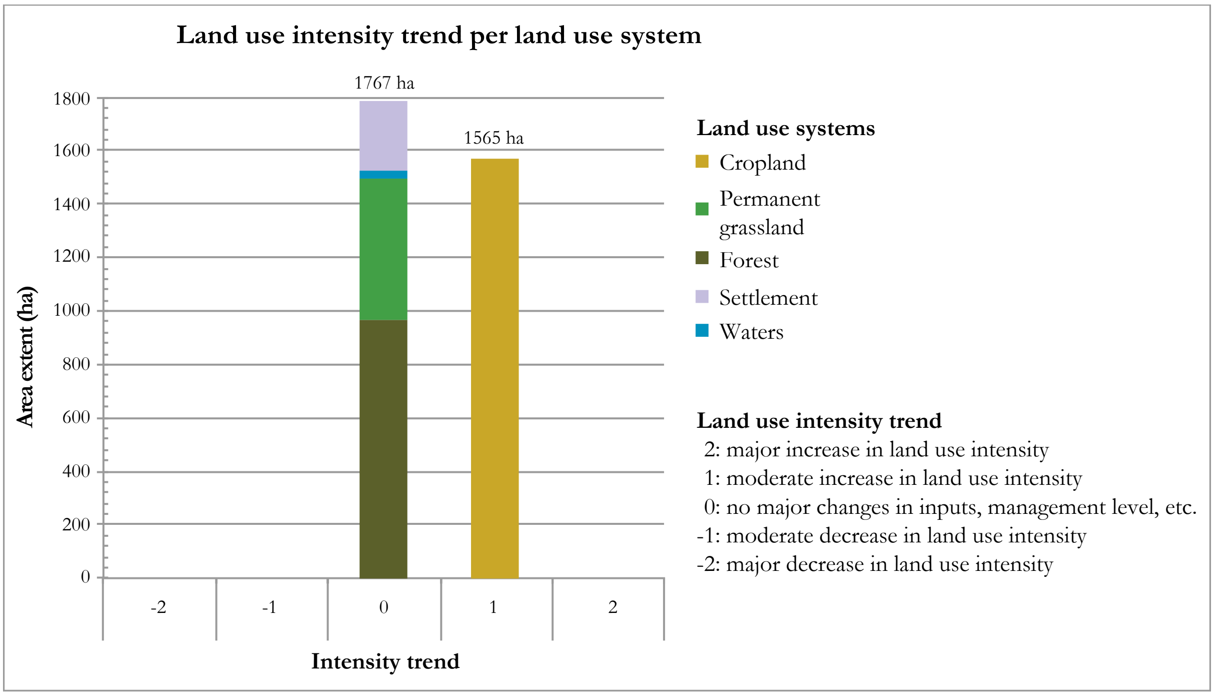

Fig. 15 Study area Frienisberg (BE): Land use intensity trend for each LUS based on a ten-year (2005-2015) observation period (Illustration: Fedrigo 2016 based on De Maddalena (2011), Data source: WOCAT QM)

Referring to LUS *cropland*, when including indicators such as the evolution of the tillage techniques, the building knowledge concerning fertilizers (even though there is no major evolution regarding fertilizers in the area of interest) and pesticides use (targeted and limited use respecting human health and the environment), as well as the initiated national and cantonal conservation and support programs, a decrease in the land use intensity would be expectable. Yet, in Frienisberg (and in a broader perspective Switzerland's midlands), many farms, principally the parcels with *flat* (0-3%) and *moderate* (3-15%) gradients, are likewise subject to ecological intensification programs, intended to increase production without increasing its' ecological impacts (Haas, 2014). These parcels represent potentially vast surfaces, covering roughly 90%

(1’404 ha) of the LUS *cropland* area (40% of the total area of interest, see Table 6). According to the stakeholder workshop these encouragements led, in recent years, most probably to an intensification that cannot be considered as ecological. As mentioned, the financial support provided by the direct payment system may encourage farmers to cultivate hillside locations with the intention to expand the farm size. Thus, the cultivation of more vulnerable lands (D. Niggli, 2015a) may also be understood as a process of intensification.

Furthermore, it was noted in particular by the expert group that some conservation practices, which intended to reduce the land use intensity, possibly already lost some of their significance, e.g. *no-tillage*: Relying mostly still on the use of non-selective herbicides some farmers refuse to adopt this technology, while others cannot support the high investment-costs related to the conversion to another cultivation system. However, with regulated crop rotations *intensive mulching* still has a potential for increasing effectiveness (see section 3.4.1.3) and may thus, eventually, extend further.
According to the land users, the LUS intensification trend might be strengthened by a general intensification of the crop rotations hustled by the economic/market pressures: It turns out that the planned crop rotations are not respected and the fallow periods shortened (e.g. by limiting the grass clover ley period to one year rather than two). Nevertheless, according to the expert group such generalizing statements need to be taken very cautiously, as emerging intensification processes are eventually directly depending on the land users personal convictions and on their management practice, which is known as varying. In order to obtain more reliable information and to give certainty to these statements it is recommended to involve all farmers working in the region personally and to question them about their tillage practices, crop rotations, etc.
The promotion and the financial support of extensification programs commanded by the agricultural policy, might lead, among other things, to the conversion of cropland to permanent grassland. However, on several occasions we were brought to conclude that the agriculturalists want to remain and to be perceived as smallholders and producers rather than to be pressured to become landscape conservationists.

3.3 Land degradation per land use system

In the following sections each LUS is considered by taking account of the land degradation types, the most important of which are discussed in more detail in sections 3.3.2, 3.3.3, and 3.3.4.

3.3.1 Recognizing degradation types for all LUSs

Regardless of the LUS, various degradation types could be observed in the area of interest during the last decade (listed in Table 10), the nomenclature is based upon Liniger et al. (2008, pp. E6-E8).

These degradation types do not appear in the same intensity, rate, or degree, nor do they apply to all land use systems. In Table 10 the main degradation types (*italic*) can be distinguished from secondary types (normal). While some forms of the latter might appear occasionally as a single process, others emerge sometimes in association with a main degradation type, in which case they would create a combination. The most important information retained in relation to secondary degradation types will be briefly explained in each section of the concerned LUS.

• **Soil erosion by water**: **Wt**: *Loss of topsoil / Surface erosion* **Wm**: Mass movements/landslides **Wo**: Offsite degradation effects • **Chemical degradation**: **Ca**: Acidification **Cp**: Soil pollution **Cs**: Salinization • **Physical soil deterioration**: **Pc**: *Compaction* **Pk**: Sealing	**Pw**: Waterlogging **Ps**: Subsidence of organic soils **Pu**: Loss of bio-productive functions due to other activities • **Water degradation** **Ha**: Aridification **Hs**: *Change in quantity of surface water* **Hq**: *Change in groundwater/aquifer level* • **Biological degradation** **Bs**: Quality and species composition **Bp**: *Increases of pests / diseases*

Table 10 Study area Frienisberg (BE): All land degradation types observed in the study area including all LUSs and slope gradient categories (Data source: WOCAT QM, Terminology based on: Liniger et al. (2008, pp. E6-E8))

Four degradation types are identified as subjects of major concern as they truly affect the ecological, social, and economic stability of the region:

- LUS *permanent grassland* and *cropland* are subject to following degradation types:
  - **Pc**: Compaction
  - **Wt**: Loss of topsoil/surface erosion
  - **Hs** and/or **Hq**: Change in quantity of surface water and/or changes in groundwater
- Whereas *forests* are principally affected by to the combined action of:
  - **Ha - Bp**: Aridification (Ha) and increase of pests / diseases (Bp)

<u>Note</u>: Before proceeding further with the results it appears appropriate to clarify a meaningful term, which has taken importance in the course of the conversations on agricultural land during

the stakeholder workshop: **headland**[18] (*Vorgewende* in German). The headland is to be understood as the strip of land on each side of the farming plot with a width of 5-10 meters (representing approximately 10% of the plot area, according to the stakeholder workshop) persistently used for turning with farm instruments/machinery. While trying to reduce crop damage at its lowest level, it is also the first sector to be harvested. Knowingly the soil on headlands is subject to greater land degradation intensities, illustrating more particularly the impacts of repeated drive-on. These strips of land require special interest particularly in terms of compaction (see sections 3.3.3.1 and 3.3.2.2). In succeeding tables and graphic illustrations the variable **land management** includes the clear distinction between areas *on headland* and *in-plot* (meaning not on headland), when opportune and desirable.

3.3.2 Degradation on cropland

On LUS *cropland* **compaction**, **surface erosion**, and **water degradation** have been qualified as the most important degradation types (in terms of weighted extent and degree). Even though they frequently appear in combination and/or in parallel, their expressions, developments, and impacts are being evaluated separately in the following sections.

3.3.2.1 Wt: Loss of topsoil/surface erosion

Erosion by water has been studied for many years in the Frienisberg area (Prasuhn, 2011). With a view to maintaining coherence in the categories the **intensity** classification has been assumed, it states (Prasuhn & Fischler, 2007):

- **Light** erosion: < 2t/ha/yr.
- **Moderate** erosion: 2-4t/ha/yr.
- **Strong** erosion: 4-10t/ha/yr.
- **Extreme** erosion: >10t/ha/yr.

Processes of loss of topsoil/surface erosion affect roughly 11% of the LUS *cropland*. In other studies describing the area the **extent** of cropland affected by surface erosion varies between 10 and 40% (Ledermann et al., 2008; Prasuhn, 2011). While 7.5**%** of the area in question is only slightly affected by surface erosion/loss of topsoil (rated as light degradation, 1), 2.5% is moderately/strongly concerned (rated as moderate-strong degradation, 2-3), and 1% is extremely damaged (rated as extreme degradation, 4) (see Table 11 for stakeholder workshop outcomes).

[18] Headland (or turnrow) as defined by https://en.wikipedia.org/wiki/Headland_%28agriculture%29, accessed September 17, 2015.

As detailed in Table 11, surface erosion principally occurs on cultivation plots with *moderate* (SGC: 3-15%) and *steep* (SGC: 15-30%) slopes. 12% of the parcels with *moderate* slope gradients are affected by surface erosion (the degree category of surface erosion is light on 9% of the lands, whereas it is moderate/strong on 3%) and only 8% of the *steep* parcels (degree category: light on 6% of the slope category and moderate/strong on 2%). In addition 1% of the total cropland area is extremely affected by surface erosion (extent and degree shown in Fig. 16).

Surface erosion strongly depends on the specific situation and context (site specificity, weather conditions, etc.). It is not an area-wide process, but rather a problem affecting some fields per year and, generally, it does not disturb repeatedly the same fields (Prasuhn, 2011).

<table>
<tr><th rowspan="2">c) Degree</th><th colspan="2">b) Extent %</th><th rowspan="2">Slope gradient</th><th rowspan="2">d) Rate</th><th rowspan="2">e) Direct causes</th><th rowspan="2">f) Indirect causes</th><th rowspan="2">g) Impact on ESS</th></tr>
<tr><th>% of slope category</th><th>% of LUS</th></tr>
<tr><td>Extreme</td><td>*1%</td><td>1%</td><td>In all slope categories</td><td>Slowly decreasing</td><td rowspan="5">Insufficient runoff and erosion control measures (s2),

Heavy machinery (s3),

Tillage practice (intensive ploughing) (s4),

Choice of crops, crop rotations, and site-specificity (s5),

Shape, size, and arrangement of parcels (s5)

Settlements and roads (u1),

Topography (mainly slope) (n7),

Heavy / extreme rainfall (intensity and amounts) (n3)</td><td rowspan="5">Labour availability (l),

Economic efficiency (market access, market pressure, etc.) (r),

Requirements and incentives from the politics (e.g. agricultural policy) (g),

Entrepreneurial thoughts / business thinking (o1),

Other social aspects (o2)</td><td rowspan="5">Low negative impact:
Soil formation (E7),

Crop and income losses (P1),

Damage of private and public infrastructure (S7)

Negative impact: Water quality for consumption (P2)</td></tr>
<tr><td>Moderate/ strong</td><td>2%</td><td>0.2%</td><td>15-30%</td><td>Slowly decreasing</td></tr>
<tr><td>Moderate/ strong</td><td>3%</td><td>2.3%</td><td>3-15%</td><td>Slowly decreasing</td></tr>
<tr><td>Light</td><td>6%</td><td>0.6%</td><td>15-30%</td><td>Slowly decreasing</td></tr>
<tr><td>Light</td><td>9%</td><td>6.9%</td><td>3-15%</td><td>Slowly decreasing</td></tr>
<tr><td colspan="3">No degradation</td><td>>30%</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">No degradation</td><td>0-3%</td><td>0</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td></td><td colspan="7">* 1% of the entire cropland is extremely affected by surface erosion</td></tr>
</table>

Table 11 Study area Frienisberg (BE): Stakeholder workshop outputs (data in Annex 4), surface erosion on LUS cropland (Illustration: Fedrigo 2016, Data source: WOCAT QM)

In view of ecological intensification programs one would at least anticipate improvements of the degradation **rates**. Combining all slope categories and degradation intensities no obvious and stringent trend of surface erosion could be identified, although the concluding workshop discussions lead to the impression of an improvement in degradation rates in the course of the past decade (rated as slowly decreasing degradation, -1). However, for the future, in view of the land use intensification trend noticed in section 3.2.2, the expert groups' projections point towards an increasing degradation (rated as slowly increasing degradation, 1). Nevertheless, the participants ask these statements to be handled with extreme caution.

Throughout the study area and in all slope gradient categories, surface erosion depends mainly on inadequate management of soil, but also on "overbuilding" (extension of settlement area), water drainage from roads/settlement areas, as well as on natural causes. Following **direct causes** contribute to the processes: missing or insufficient runoff and erosion control measures (s2), heavy machinery (s3), tillage practice (intensive ploughing) (s4), choice of crops, crop rotations, and site-specificity as well as the shape, size, and arrangement of parcels (s5), settlements and roads (u1), topography (mainly slope) (n7), and eventually heavy rainfall (intensity and amounts) (n3).

Surface erosion is furthermore influenced by **socio-economic factors** acting as driving forces and triggering the direct causes, which can be detailed more specifically as labour availability (l), economic efficiency (market access, market pressure, etc.) (r), requirements and incentives from the politics (e.g. agricultural policy) (g), as well as entrepreneurial thoughts/business thinking (o1), and social aspects (o2). The latter two issues are closely linked: Similar to any entrepreneurial practice the question arises also in agriculture, "what are the neighbours doing?" Farmers can be influenced, both positively and negatively, by how other people perceive and by initiatives taken in the neighbourhoods. Accustomed by key factors, such as local and political conditions, recognized know-how, historical heritage, or a strong social capital, individual or traditional decisions and initiatives can influence and even transform a region. By way of illustration, Mr. Hanspeter Lauper (among other farmers) applies and promotes no-tillage agriculture since 1993. He is a major contributor stimulating Frienisberg's specific agricultural landscape while encouraging the development of less intensive cropping technologies.

Finally, the **impacts on ecosystem services (ESSs)** are reviewed across all degradation intensities and slope gradients. Inducing sediment deposition, and consequently potentially the spread of fertilizer and pesticide residues contained therein, surface erosion acts negatively on **ecological services** since the strongest impact (rated as negative impact, -2) is on the water quality for consumption (linking water degradation to sediment transport). Furthermore, with a somewhat negative impact (rated as low negative impact, -1), surface erosion affects the soil formation, triggering soil damage and loss, **productive services**, causing little crop and income losses, and sometimes it creates offsite effects damaging private and public infrastructure.

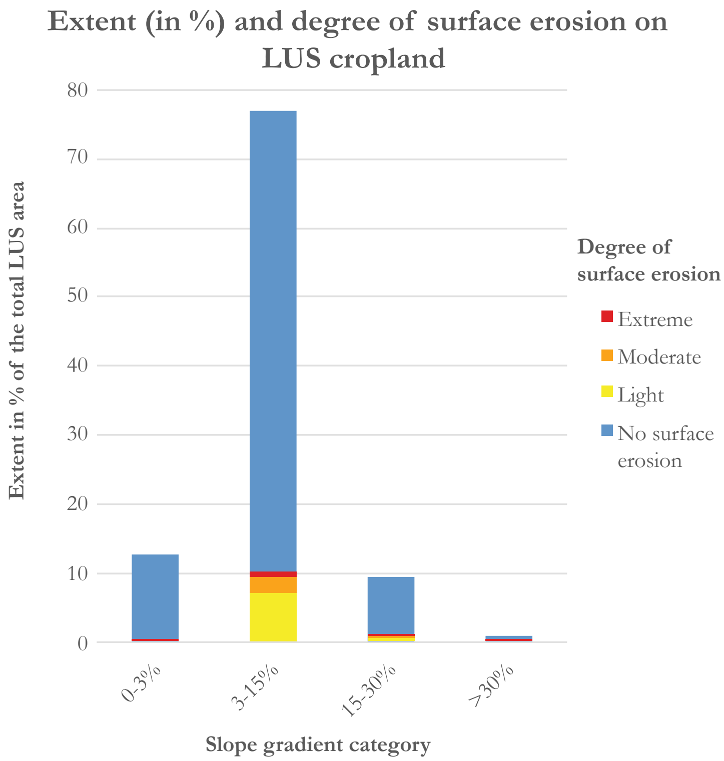

Fig. 16 Study area Frienisberg (BE): Extent (%) and degree of surface erosion on LUS cropland for each slope gradient category (Illustration: Fedrigo 2016, data source: WOCAT QM, data in Annex 4).

3.3.2.2 Pc: Compaction

Compaction is a structural process of physical soil deterioration extending over the entire LUS *cropland* (extent: 100% of the LUS area). According to the stakeholder workshop, it ties in closely with the soil texture, which is very homogenous in the region and in all slope categories. Given Frienisberg's humid climate a small but significant risk of compaction exists per se throughout the area. Generally, the inclination influences soil tillage and soil formation, and thus the susceptibility to degradation. On sloped lands soils are poorer and the structure is less stable, which makes these soils are more vulnerable or sensitive to degradation processes caused by tillage or other soil disturbance. Consequently, although drive-on is more frequent on *flat* areas (increasing the potential for compaction significantly) *sloped* areas are per se more sensitive to compaction (serious deterioration already appears with only few drive-on). So, even though theoretically the slope gradients are limiting factor to compaction, it is not expressed as such in Frienisberg, still its susceptibility is diminished by an adequate practice.

The **rate** of compaction on LUS *cropland* is characterised as "slowly increasing degradation" (rated as 1) throughout the region, although its' **degree** differs according to the section of land it belongs to (results detailed in Table 12): *In-plot* compaction is classified as "apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degradation, 2), whereas *on headland* it is qualified as "degradation beyond restoration" (rated as extreme land degradation, 4).

To all degrees, compaction affects principally **ecological** and **productive services**. The strongest impact (rated as high negative impact, -3) is on the regulation of excessive water (e.g. by reducing the water infiltration capacity), while it is negative (rated as negative impact, -2) on production and risk and on the soil structure.

According to the expert group, numerous **soil management factors** trigger compaction on LUS *cropland*, namely missing or insufficient runoff and erosion control measures (s2), heavy machinery (s3), tillage practice (ploughing, harrowing, etc.) (s4), and persistent vehicular traffic on headlands (s5a). Additionally, the cultivation of highly unsuitable/vulnerable soils (s1) and low lime contents (s5b) are understood as increasing the risk of compaction. These **direct causes** are strengthened by **indirect causes** designated as labour availability (l) and the shape, size, and arrangement of parcels (o), both implying more frequent drive-on and enforcing impacts relating to the machinery and equipment:

> "I would like to take the weeds by hand, but this would imply labour costs that are not affordable in the context of today's agriculture."[19]

Most on-land practices imply heavy machinery so that high-input mechanised farming exposes the lands to a high stress potential. The problem of compaction is accelerated when heavy machinery is used while the soils are still (too) wet. Farmers are very aware of this, yet when the market dictates the delivery date, farmers have little choice and flexibility on when to cultivate or harvest. Production sequences are tight and fallow times are shortened, while on-field crop variety wanes and cash crops flourish. Consequently, the degradation **rate** is increasing, which goes alongside with increasing machinery size, market pressure, and with the intensification of the production (increasing production for an increasing population).

[19] Stakeholder Workshop, discussions held on September 2, 2015, free translation from Swiss-German.

Since the costs of employing workers are quite important in Switzerland and the local farming products face vigorous competition on the regional and global markets, a substantial reduction of vehicular traffic appears hardly imaginable in first instance, and without changes in the structures. While markets request punctual delivery and readiness, nature and agriculture asks for flexibility, patience, and attention, recalling the proverb *everything comes to him or her who waits*.

The negative impacts of drive-on are repeatedly mentioned during the stakeholder workshop, since they are affecting *cropland* on all observable management practices (reference technology and conservation technologies). “It is a fact, farmers need to learn to cope with it”.[20] Thus, at the suggestion of the expert group, the intensities are documented in detail including each conservation technology separately. The results are presented in Fig. 17.

<table>
<tr><th>c) Degree</th><th>b) Extent %</th><th>Slope gradient</th><th>Land mana-gement</th><th>d) Rate</th><th>e) Direct causes</th><th>f) Indirect causes</th><th>g) Impact on ESS</th></tr>
<tr><td>Extreme</td><td>10%</td><td rowspan="2">Slope has no significant influence on compaction</td><td>On headland</td><td>Slowly increasing degradation</td><td rowspan="2">Cultivation of highly unsuitable / vulnerable soils (s1),

Missing or insufficient runoff and erosion control measures (s2),

Heavy machinery (s3),

Tillage practice (s4),

Persistent vehicular traffic on headlands (s5a)

Lime content (s5b)</td><td rowspan="2">Labour availability (l)

Shape, size, and arrangement of parcels (o)</td><td>Negative impact: Production and risk (P1),

Soil structure (E5)

High negative impact: Regulation of excessive water (E1)</td></tr>
<tr><td>Moderate</td><td>90%</td><td>In-plot</td><td>Slowly increasing degradation</td><td>Low negative impact: Production and risk (P1),

Soil structure (E5)

Negative impact: Regulation of excessive water (E1)</td></tr>
</table>

Table 12 Study area Frienisberg (BE): Stakeholder workshop outputs, compaction on LUS cropland (Illustration: Fedrigo 2016, Data source: WOCAT QM)

In first view the values in Fig. 17 are high, although it becomes observable that some land management practices succeed in reducing the degree of compaction: Five technologies (mulch ext., no-till int. and ext., as well as strip-till int. and ext.) manage to halve *in-plot* compaction so

[20] Ibid.

that on these lands the QM classification states that "there are some indications of degradation, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts" (rated as light degree, 1). These results are quite remarkable since alone *extensive mulching* represents approximately 21 % of the LUS *cropland* area, and combined these technologies cover roughly 32 % LUS area (494 ha). Although conservation practices are present in the region, questions emerge whether their potentials are fully exploited or if they may be extended to larger scales. However, the conservation technologies are further discussed in section 3.4.

Finally, *headlands* remain highly problematic in nearly all conservation technologies, yet with varying intensities ranging between moderate (2) and extreme (4). Even though some practices manage to reduce it slightly (*no-till ext.* and *strip till ext.*) this physical soil deterioration appears in almost all cases as evident (rated as strong, 3) so that, according to the category, "land properties are difficult to restore within reasonable time limits".

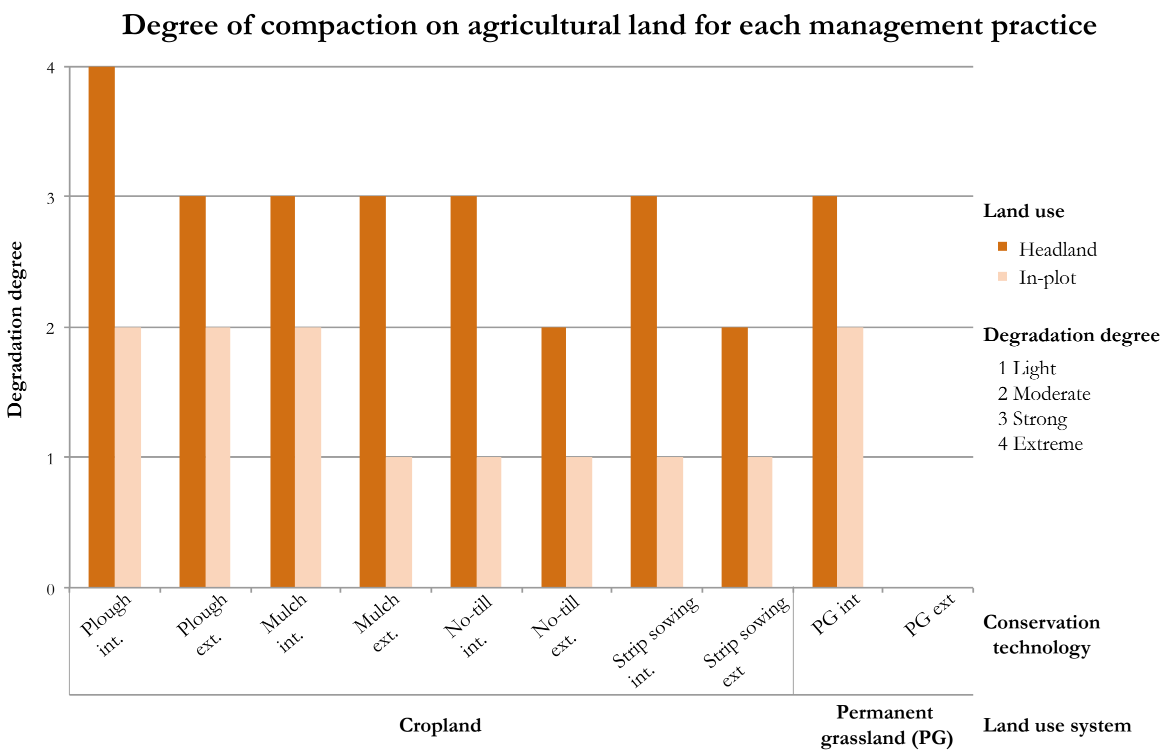

Fig. 17 Study area Frienisberg (BE): Stakeholder workshop outputs, observed degree of compaction on agricultural land for each land management practice. A distinction is made between the conservation technologies and the headlands. Definition of *headland*: 10% of the LUS area extending along the field boundaries. Definition of *in-plot*: the remaining plot surface that is not under headland (90% of the LUS area). Refer to section 3.3.1 for more details on the headland. (Illustration: Fedrigo 2016, Data source: WOCAT QM).

3.3.2.3 Water degradation: Change in quantity of surface water (Hs) and/or changes in groundwater (Hg)

Even though WOCAT differentiates between *change in quality of surface water* and *changes in groundwater*, the discussion held during the stakeholder workshop showed that in the case of Frienisberg both land degradation types could be documented together. Thus, *water degradation* is the generic term used in this study to describe circumstances that include both *change in quality of surface water* and *changes in groundwater*.

Changes in quality of surface water and changes in groundwater are not highly pressuring Frienisberg's waters, but, in spite of that, they still affect roughly 10% of the LUS *cropland* area. The **degree** of degradation is low on 7.5% of the LUS area and moderate-strong on 2.5%. Linked to the surface erosion processes, water degradation occurs principally on *moderately sloped* (rated as light degree of degradation on 9% and moderate-strong on 3% of the area within the SGC) and *steep* lands (rated as light degree of degradation on 6% and moderate-strong on 2% of the area within the SGC), whereas no apparent deterioration is observable on *flat* and *very steep* lands (extent and degree shown in Fig. 18). All documented workshop results are in Table 13.

The **direct** and **indirect causes** affecting surface and ground water degradation are the same as for surface erosion (see section 3.3.2.1), since water pollution related to agro-chemicals, such as phosphorous, herbicides, or pesticides, is closely linked to the transport of sediments causing the displacement of contaminants into water bodies (Ledermann et al., 2008; Prasuhn & Weisskopf, 2003). Add to the triggering factors generating soil erosion problems the inappropriate application, in terms of amount and timing, of fertilisers, herbicides, pesticides, and other agro-chemicals (c2), leading to the washing-out of these additives and causing water pollution.
Surface and ground water degradation has a negative impact on **ecosystem services (ESS).** Regardless of the degradation intensity and/or the slope steepness, the strongest negative impact affects biodiversity (rated as negative, -2), and then changes in water properties for human, animal and plant consumption (rated as slightly negative, -1) capable of resulting in possible health issues when not managed in appropriate form.

Additional **degradation types** have been noticed during the preliminary workshop discussions. As they only appear in margins and/or punctually, they have not been evaluated with the WOCAT QM. **Landslides** strike only in very few cases as a result of exceptional circumstances, and on a small-scale they might cause offsite degradation effects. Just as **sealing** and **silting**, which may appear separately or in combination with **waterlogging**. **Salinization** problems may occur as punctual contamination for instance in wintertime when the salt is washed out from the roads. Furthermore, due to local soil properties, **subsidence of organic soils** occurs somewhat in the region around Lobsigen (see Fig. 2 for details about locations). Losses of **bio-productive functions** due to other activities, mainly road constructions and urbanisation in general, have been highly problematic in the past, although fewer in more recent times. **Quality and species composition/diversity decline** increased continuously over the last decades, tendencies towards gentle stabilization might be observable today, which means that the decline might decrease. Additionally, the **loss of soil life** is another issue of major interest, as soils house the vastest biodiversity and this needs protection. Since FAO declared 2015 International year of soils it is expected that the general public and the decision makers are showing increasing interest in soils, their functions, and protection. For the moment in Switzerland, some national and regional support programs are devoted to this subject, e.g. Förderprogramm Boden (FOAG, 2009).

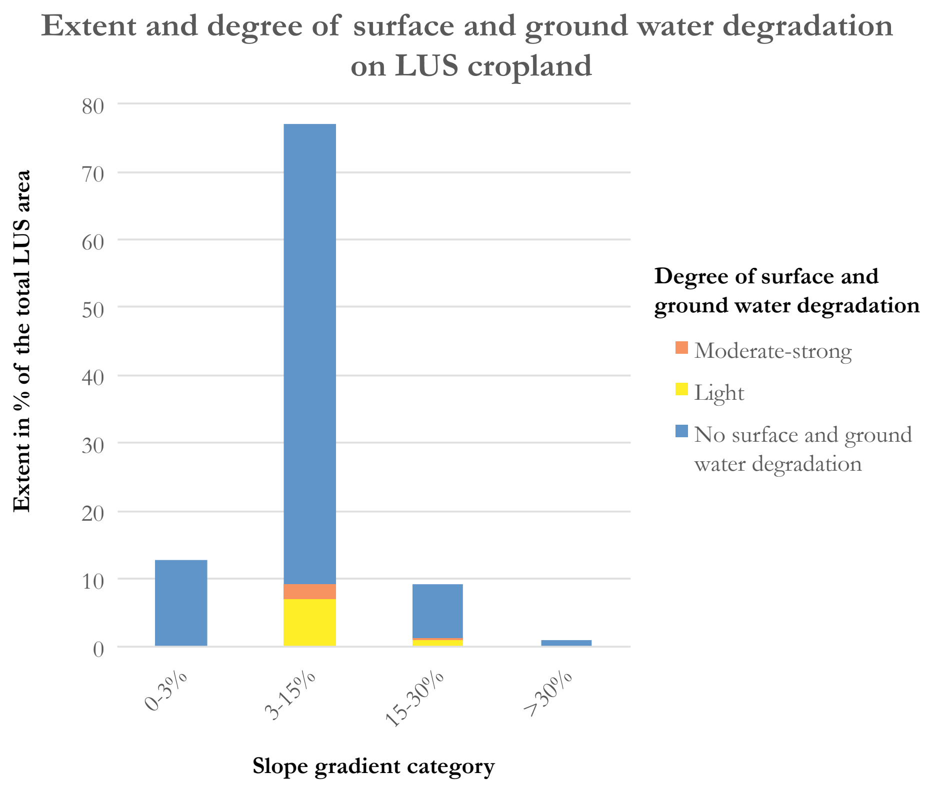

Fig. 18 Study area Frienisberg (BE): Extent (%) and degree of surface and ground water degradation on LUS cropland for each slope gradient category (Illustration: Fedrigo 2016, data source: WOCAT QM, in Annex 4).

Finally, for the future, the participating experts expect **weeds**, **invasive plants**, or **pests** and **diseases** to become more problematic. Climate changes and extremes might lead to the appearance of new undesirable organisms that are more adapted to the emerging climate conditions, however, others might disappear. Knowing that fungi for instance prefer damp and chilly environments they might propagate lesser in hotter and dryer climates. Additionally, the increasing demand for machinery contractors, using the machinery in a large area, elevates the risk for spreading pests and diseases. Parasites (i.e. weeds, pests, etc.) are dragged from one field on to the next while driving the same machinery for land preparation, seeding, and harvesting.

<table>
<tr><th rowspan="2">c) Degree</th><th colspan="2">b) Extent %</th><th rowspan="2">Slope gradient</th><th rowspan="2">d) Rate</th><th rowspan="2">e) Direct causes</th><th rowspan="2">f) Indirect causes</th><th rowspan="2">g) Impacts on ESS</th></tr>
<tr><th>% of slope category</th><th>% of LUS</th></tr>
<tr><td>Moderate / strong</td><td>3%</td><td>2.3%</td><td>3-15%</td><td>Slowly decreasing degradation</td><td rowspan="4">Insufficient soil conservation / runoff and erosion control measures (s2),

Heavy machinery (s3),

Tillage practice (intensive ploughing) (s4),

Settlements and roads (u1),

Heavy / extreme rainfall (n3)

Topography (mainly slope) (n7)

Inappropriate application of herbicides, pesticides, etc. (c2)</td><td rowspan="4">Labour availability (l),

Economic efficiency (market access, market pressure, etc.) (r),

Requirements and incentives from the politics (e.g. agricultural policy) (g),

Entrepreneurial thoughts/ business thinking (o1),

Other social aspects (o2)</td><td rowspan="4">Low negative impact: Water quality for consumption (P2)

Negative impact: Biodiversity (E8)</td></tr>
<tr><td>Moderate / strong</td><td>2%</td><td>0.2%</td><td>15-30%</td><td>Slowly decreasing degradation</td></tr>
<tr><td>Light</td><td>9%</td><td>6.9%</td><td>3-15%</td><td>Slowly decreasing degradation</td></tr>
<tr><td>Light</td><td>6%</td><td>0.6%</td><td>15-30%</td><td>Slowly decreasing degradation</td></tr>
<tr><td colspan="3">No land degradation</td><td>0-3%</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">No land degradation</td><td>> 30%</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
</table>

Table 13 Study area Frienisberg (BE): Stakeholder workshop outputs, surface and ground water degradation on LUS cropland (Illustration: Fedrigo 2016, Data source: WOCAT QM)

3.3.2.3.1 Problematic pollutants

Even though *water degradation* most likely occurs when combined with surface erosion, it is chosen to assess both degradation types individually so that particular situations, paths, and individual pollutants concerning water deterioration can be highlighted:

The distinction between surface water and ground water becomes decisive mainly when considering chemical substances (e.g. introduced by animal manure, fertiliser, pesticides) entering the water bodies, their origins and types. Even though in agriculture manure inputs could be reduced in the recent past, related pollutions remain a highly problematic issue. While **phosphorous** pollution represents a problem causing the contamination of **surface water**,

nitrate leaching is generally affecting **groundwater**. Broadly speaking, the processes are illustrated as follows:

Phosphorous pollution is rigorously restricted to **surface waters** and strictly bound to sediment transport. We can therefore state that the areas less affected by surface erosion have less phosphorous contamination. In agriculture, the phosphorous surplus is acknowledged as highly problematic and this applies also to the study area. Ecological standards made it possible to reduce this type of pollution considerably during the past decades. Since the establishment of IP in 1990/92 it is estimated that the surface water pollution resulting from phosphorous intrants originated by agriculture could be diminished by 10 to 30% (Herzog, Prasuhn, Spiess, & Richner, 2008), although it is still difficult to track back the origins of the substances (households, agriculture, etc.). **Surface water** contamination by **pesticides** is also quite problematic in high-input agriculture and in that respect this pollution process is also perceived as affecting Frienisberg together with surface erosion and surface runoff (discharge). Additionally, pesticide inputs can represent an intermittent source of stress and pollution, e.g. during syringe washing (after pesticide spraying). So far, there is no knowledge of pesticides causing long-term **ground water** contaminations in Frienisberg. By contrast, **groundwater** contamination cases relating to nitrate leaching, which are generally a widespread problematic in high-input agriculture, apply also to the study area, although, according to the stakeholder workshop, the impacts on Frienisberg's waters are perceived as "not so strong".

A reduction of both nitrate and phosphorous pollution is more likely expected in agriculture. Nevertheless, the tangible impacts of conservation tillage, as well as the use of cover crops are not quite understood yet. The uncertainties are principally related to the time lag between the implementation of the measures and the observable impacts on the land (Herzog et al., 2008).

3.3.3 Degradation on permanent grassland

In this study permanent grasslands have the particularity to be considered both as LUS and as conservation technique. Thus, they are discussed with slightly different perspectives in the sections *3.3 Land degradation per land use system* and *3.4 Land conservation per land use system*.

3.3.3.1 Pc: Compaction

In terms of compaction LUS *permanent grassland* has been subdivided in *intensive* and *extensive* management. This differentiation refers mainly to drive-on, fertilization, and mowing, as it is described in more details in section 3.3.1. As shown in the stakeholder workshop outcomes for *intensive permanent grassland* summarized in Table 14, the impacts on *headlands* have been detailed out in particular (see column *Land use* in Table 14) while no distinction needs to be made with respect to the slope gradient categories.

Intensive permanent grassland

Intensive permanent grassland includes both intensive pastures and meadows, although the may suggest more frequent mowing affecting the headland more intensely.

Compaction is the most wide-ranging (in terms of surface area disturbance) degradation type affecting permanent grassland, since it affects a large part of the LUS area. Although to different degrees, the **extent** of compaction implies 66% (~347 ha) of the total LUS *permanent grassland* area, corresponding to 100% of the surfaces under *intensive* management.

The **degree** of compaction is the strongest on headlands (8.2% of the LUS area), corresponding to approximately 10% (~35 ha) of the surface area under *intensive permanent grassland* (extent and degree summarized in Fig. 19): According to the QM classification there are "evident signs of degradation" on the lands belonging to this category and "changes in land properties are significant and very difficult to restore within reasonable time limits" (rated as strong degree, 3). The remaining 59% (~312 ha) of the LUS area, which correspond to the in-plot area (90% of the surfaces under *intensive permanent grassland*) fall into the QM classification affirming that compaction is "apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degradation, 2).

In reference to the regional land use intensification trends, the **rate** of land degradation is classified in both situations (on *headland* and *in-plot* areas) as "slowly increasing" (rated as slowly increasing degradation, 1). This development reflects the general intensification trend of the agricultural production. Although remarkable efforts addressing land conservation are been done, the trend cannot be attenuated. In practice, it is stated once again from the participants' perspective that, for the moment, the management undergoes an intensification that cannot completely satisfy the ecological objectives pursuit by the agricultural policy.

Various anthropogenic actions are identified as triggering compaction on *permanent grassland*: The participants emphasized on vehicular traffic and the use of heavy machinery (including timing of heavy machinery use) (s3), and more particularly on persistent movement and manoeuvring on headlands (s5a). Other complementary **direct causes,** principally allied to improper soil management, are to mention such as sowing and mowing highly unsuitable/vulnerable soils (s1) (e.g. (too) wet soils), missing or insufficient runoff and erosion control measures (s2), and low lime content (s5b).

Indirect causes, such as the labour availability (l) as well as the shape, size, and arrangement of the parcels (o), accentuate the encountered difficulties committed to the machinery and equipment, since they imply more frequent drive-on. As mentioned for LUS *cropland*, there is a clear awareness within the key actor group that these problems are inherent in mechanized, high-input farming. The farmers learn to live with these issues, unless there are structural reforms in the production system.

Furthermore, compaction has negative impacts principally on **productive** and **ecological services**: Regardless of the compaction intensity and/or the slope steepness, the strongest negative impact hinders the regulation of excessive water deeply (rated as strong negative impact, -3), while increasing, among others, the potential for runoff, mass movements, or waterlogging. Finally, compaction lowers the quality and quantity of production and thus it increases the risks of production reduction, as much as it affects the soil structure by reducing the pore spaces for instance (rated in all cases as negative impact, -2). Surface and subsoil deterioration reduces infiltration as well as water and nutrient holding capacity.

Land use		**c) Degree**	**b) Extent %**	**d) Rate**	**Slope gradient**	**e) Direct causes**	**f) Indirect causes**	**g) Impact on ESS**
Intensive (Extent: 66% of the total LUS area)	On headland	Strong	6.6% of the LUS area (10% of the intensive permanent grassland)	Slowly increasing	No distinction between slope categories	Cultivation of unsuitable soils (s1) Missing / insufficient soil conservation (s2) Heavy machinery (s3) Vehicular traffic on headland (s5a) Lime content (s5b)	Labour availability (l) Shape, size, and arrangement of the parcels (o)	**Negative impact**: Production and risk (P1), Soil structure (E5) **High negative impact**: Regulation of excessive water (E1)
	In-plot	Moderate	59.4% of the LUS area (90% of the intensive permanent grassland)	Slowly increasing				
Extensive (Extent: 33% of the total LUS area)	No headland No compaction				-	-	-	-

Table 14 Study area Frienisberg (BE): Stakeholder workshop outputs, compaction on LUS permanent grassland (Illustration: Fedrigo 2016, Data source: WOCAT QM)

Extensive permanent grassland

No evident soil compaction disturbing permanent grassland with *extensive* land management could be identified in and around Frienisberg.

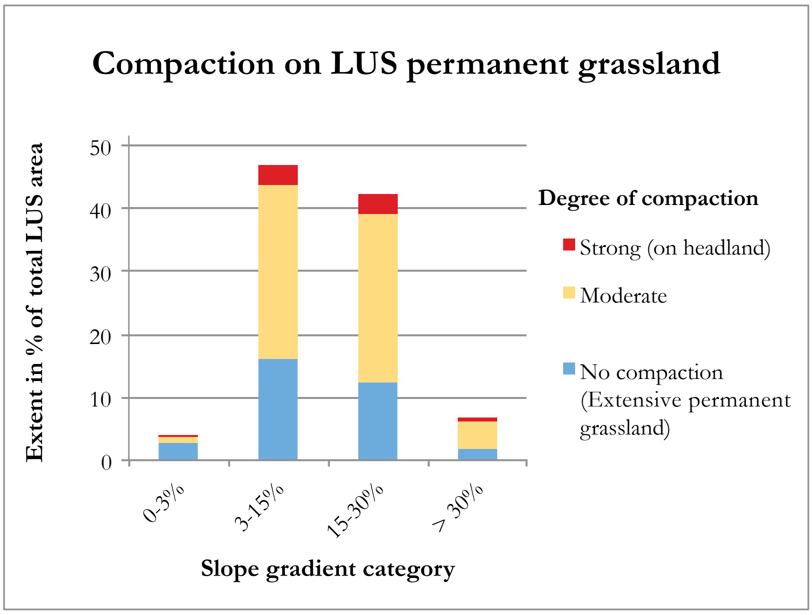

Fig. 19 Study area Frienisberg (BE): Extent (%) and degree of compaction on LUS permanent grassland (Illustration: Fedrigo 2016, Data source: WOCAT QM, data in Annex 4)

3.3.3.2 Wt: Loss of topsoil/surface erosion

No evident loss of topsoil/surface erosion has been identified on *permanent grassland*, regardless of slope gradient and management level (intensive/extensive). In this respect, while referring to permanent grassland as conservation technology on agricultural lands (or cropland), it is to be considered as highly effective in mitigating surface erosion in Frienisberg.

Furthermore, in other regions soil erosion can be observed also on permanent grasslands. As a general policy, no soil movement can be excluded. Degradation processes can only be mitigated with conscious management, attention, and knowledge adapted to the local context as well as to the site specificities. Parameters such as weather conditions, exposure, slope gradient, soil moisture and type, etc. should be considered whenever the land is being used.

Another interesting feature occurring occasionally, and only at small scales, on permanent grassland is qualified as "positive"[21] surface erosion by the expert group. Sometimes eroded portions of soils are washed from the *cropland* and sediment on *permanent grassland*. This is noteworthy to mention since positive impacts can be identified in the system, i.e. soil is added to the permanent grassland. In the strict sense land degradation is a negative process, but entitled as "Offsite degradation effects" in the QM it can have positive impacts on other LUSs or areas. It is known that important erosion events trigger the greatest off-site damage, although, partly for financial reasons, only little scientific knowledge can be based on validated long-term data (Prasuhn, 2011).

[21] Multi-stakeholder Workshop, discussions held on September 2, 2015

3.3.3.3 Hs: Change in quantity of surface water / and or Hg: Changes in groundwater

No changes in surface or ground water affecting areas of permanent grassland could be noticed in the study area. In this respect, while referring to permanent grassland as conservation technology on agricultural land (or cropland) it is to be considered as highly effective in mitigating changes in water quality.

Finally, the expert group identifies **acidification** as one additional land degradation type, which might be worth to mention. This process occurs occasionally on permanent grassland under *extensive* (or low intensive) land management. Nowadays excessive nutrient inputs enter these lands via the air, it is therefore extremely important that nutrient-poor meadows/pastures are regularly mown and that the chopped material is removed if their function shall be maintained. Nevertheless, the extent and intensity are considered far too marginal in the region to be investigated any further.

3.3.4 Degradation on forest

3.3.4.1 Combination: Aridification (Ha) – Increase of pests / diseases (Bp)

Frienisberg's forests are only little prone to degradation. Foresters work in all conscience to avoid land degradation, the results coming from the efforts are apparent when observing the land.

> "If managed properly the forest is not, or only little, prone to degradation. It has to be noted that if land degradation occurs it means that something might have been done wrong in the forest management"[22].

Despite this understanding, two **degradation types** are occurring: **aridification** and **increase of pests/diseases**. Based upon the assessment of these degradation processes, the forestland can be considered as an entity, without distinction of slope gradient categories.

It is emphasised from the outset that susceptibility to pests/diseases strongly depends on precipitation and climate conditions. Even though the whole forest area is occasionally assimilated to water stress, the issue becomes a matter of concern when combined with pest-susceptibility. With this reasoning, aridification and increase of pests/diseases are assessed as a combination: Trees affected by water stress produce less resin, which makes them more

[22] Interview with Mr. Rudolf Schweizer, district forester, interviewed September 14, 2015, free translation from Swiss-German.

vulnerable to pests/diseases. Consequently, trees with shallow roots systems are per se more vulnerable than others. In Frienisberg, the most relevant pests/diseases are bark beetles (*Borkenkäfer* in German) affecting spruces and fraxinus dieback (*Eschentriebsterben* in German) touching ash trees. Of course, according to the district forester, the harmful consequences caused by those parasites are not comparable to a forest dieback.

As mixed stocks cover nearly 80% of the woodland area (see land conservation on LUS *forest* in section 3.4.3), surface estimates may be quite difficult to quantify. Degraded lands are appraised to account for approximately 10% (96.6 ha) of Frienisberg's LUS *forest* area.

For the past decade, the **degree** of degradation is expressed according to the QM classification stating that "degradation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degree, 2), whereas the **rate** of land degradation is increasing (rated as slightly increasing degradation, 1). This increasing trend can be explained from real or perceived climate variations, since dry summers augmented notably over the recent past (the years 2003, 2006 and 2015 stood very dry), leading to apparent degradation intensities exceeding the mean values. Fortunately, the impacts of very dry years are partly mitigated by the succeeding wetter years. The district forester projects a steady increasing degradation trend also for the years to come since hot and dry summers are anticipated in terms of both frequency and intensity.

c) Degree	b) Extent %	Slope	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ESS
Moderate	10%	The slope has no influence on degradation	Slowly increasing degradation	Changes in temperature (n1), Changes of seasonal rainfall (n2), Droughts (n6)	Population growth (p), Consumption patterns/market demand (c) (Monetary) government supports (g)	**Low negative impact**: Aesthetic (S1)

Table 15 Study area Frienisberg (BE): Stakeholder workshop outputs, combination of aridification and increase of pests/diseases (land degradation type combination) on LUS forest (Illustration: Fedrigo 2016, Data source: WOCAT QM)

The leading **direct causes** for the occurring degradation of forests are agglomerated into one "factor climate"[23], or the changing climates: More frequent and intense dry summers, coupled

[23] Interview with Mr. Rudolf Schweizer, district forester, interviewed September 14, 2015, free translation from Swiss-German.

with milder winters, influence and trigger the development and dispersal of pests and diseases. According to the QM terminology this "factor climate" is expressed by a combination of natural causes such as changes in temperature (n1), changes of seasonal rainfall (n2), and droughts (n6). Be the variations in these dynamics anthropogenic or natural.
With their shallow root systems, birch and spruce trees are highly sensitive to drought and thus the first species affected by water stress. In turn, thanks to their deeper root systems, firs and ash trees are more drought resistant and stress tolerant, and consequently also more resilient to the related pests/diseases (e.g. the bark beetles). Generally, overall drought effects can be diminished by the water retention capacity of soils, varying according to the soil type. While mitigating evaporation losses Frienisberg's soils maintain moisture at more favourable levels, when compared to the soils of the southeaster surroundings. However, notwithstanding the soils' moisture holding capacity, Frienisberg's forests are subject to water stresses. In 2015, a premature autumn was expected for the regions, as part of a natural adaptation strategy some trees conclude their annual cycle earlier to alleviate the drought effects.

On the other hand the **indirect causes** sparking degradation are more likely population growth (p), the consumption patterns/market demand (c) and (monetary) government supports (g).
According to the district forester, pressured by a growing population and profitability (cost efficiency), as well as by financial cuts forestry in the Midlands is directed towards intensification. Government supports, such as contributions for rejuvenated forests (*Jungwaldförderbeitrag* in German), are gradually abolished, which enhances the need and desire for cost-effectiveness. Whether these external factors effectively trigger land degradation is uncertain, but in all probability they do not encourage mixed stocks. On the contrary, they might incite the landowners to grow more cash timber, and, in the worst case, eventually, monocultures.

Determining factors, encouraging industrial forestry and thus increasing anthropogenic degradation potentials, are more likely easy road traffic and access to the forests, as well as the market accessibility. An area-wide- and easy access to Frienisberg and its' surroundings (including the forest areas) is guaranteed by a well-developed road network, in which no noticeable restrictions are to mention. Even though, other factors, such as soil moisture, weather conditions and freezing, as well as property rights, must also be taken into account in determining the best management practice.

In Frienisberg, forest companies administer approximately 80% of the forest land and they give full commitment to good and sustainable forestry. Foresters are determined to perform forest and thinning cuts at the right time in order to avoid degradation, i.e. respecting all conditions and performing the interventions once all local and environmental settings are favourable. Although forestry work is frequently fixed on extremely tight schedules and the workloads can sometimes be very heavy to manage.

> "The intensity of the land use is closely tight to the euro, it increases with rising euro exchange rates".[24]

Since Frienisberg has no protection forest and, in comparison with agriculture, the wooden area is not supported by a system of direct payments, the land must be able to function with its profitability: meaning that forestry must either be beneficial or at least cost covering. Borne by a policy of economic liberalisation the local timber is merchandized on the world markets and therefore exposed to intense economic pressure, price fluctuation, as well as to the strength of the euro. As the timber market wants spruce wood, the industry and landowners effort to grow it. When local or domestic wood prises rise, already cut and prepared timber can be easily imported from bordering countries at lower prices. Although exposed to economic efficiency, the time constraints are considerably less by contrast with agriculture: If at a given point in time, selected species are unsuitable for markets they can quite easily be stored and sold once market conditions are more favourable. According to the district forester, "there is time to wait for market shifts"[25]. There are also a few existing tools for specific action to limit eventual damages caused by intensification, not the least since large-scale commercial forestry is subject to regulation while the district forester controls its procedure: Deforestation is illegal and in case clear cuts are carried out (characterized more properly as rejuvenation cuts) they need to be done taking account of the young forest growing underneath.

The impacts on **socio-cultural services** when damaging the aesthetic (rated as low negative impact, -1) of the landscape might also be worth to mention, since sick or dried-out trees are not that nice to look at. Nevertheless, remembering that the area affected by degradation remains a quite little phenomenon, and that the trees hit by the combined effects of aridity and disease/pest are caught up in a broad and mixed stock.

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[24] Interview with Mr. Rudolf Schweizer, district forester, interviewed September 14, 2015, free translation from Swiss-German.
[25] Interview with Mr. Rudolf Schweizer, district forester, interviewed September 14, 2015, free translation from Swiss-German.

Additionally, marginal and intermittent stresses caused by punctual nitrogen inputs when operating with drag hoses (*Schleppschlauch* in German) on farmlands seam to appear on forest land (offsite effects from LUS *cropland*). Nitrogenous pollutant emissions affect most likely ecosystems that are dependent on low-nitrogen conditions, such as forests or meadows with a large variety of species. Excessive nitrogen inputs can alter the composition of species and reduce the biodiversity, as well as lower the soil-pH (acidification) and thus facilitate the release of heavy metals. To the best of our knowledge this type of land degradation remains minor and the effects negligible in the study area.

Finally, although the **erosion** issue on forest land has clearly been rejected during the assessment with the district forester, results based on ten study years and nearly one hundred cases expose soil loss on forest land (Prasuhn, 2011). However, more detailed and area-wide on-field investigations and measurements are necessary. Because of time and resource limitations this concern will not be investigated any further as part of this study.

3.3.5 Concluding land degradation

These overviews (Fig. 20, Fig. 21) enable briefly the outcomes of the WOCAT land degradation assessment described in the previous sections. The averaged degrees and rates of land degradation (including, for each LUS, the land degradation types documented in the previous sections) can be summarised for each mapping unit as illustrated in Fig. 20.

LUS *cropland* is most affected by land degradation [involved degradation types: surface erosion, compaction, and surface and ground water degradation]: According to the QM classification "degradation is apparent and its control and full rehabilitation of the land is still possible with considerable efforts" (average rated as moderate degree, 2) all-over the area. In addition, land degradation is increasing (average rated as slowly increasing degradation, 1) particularly for lands fitting to the slope gradient categories 0-3% and >30%. This higher average may be explained by the fact that these lands are practically only affected by compaction (and very little soil erosion).

LUS *permanent grassland* is the second-most disturbed system in the study area, principally affected by the impacts of compaction on lands under *intensive* management. Marked differences merge among the slope categories (visible in Fig. 20): On parcels with slope gradients below 30% the degree of land degradation refers to the QM category: "the [land degradation] process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts" (average rated as light degree, 1), while compaction is minor on parcels with slope gradients above 30% (average rated as below light degree, 0.5). When referring to the trend of land degradation over the recent past, the rate value indicates eventually increasing degradation on *flat* parcels (average rated as slowly increasing degradation, 1), whereas negligible changes are documented on parcels fitting to the other slope gradient categories (average rated as no change in degradation, 0).

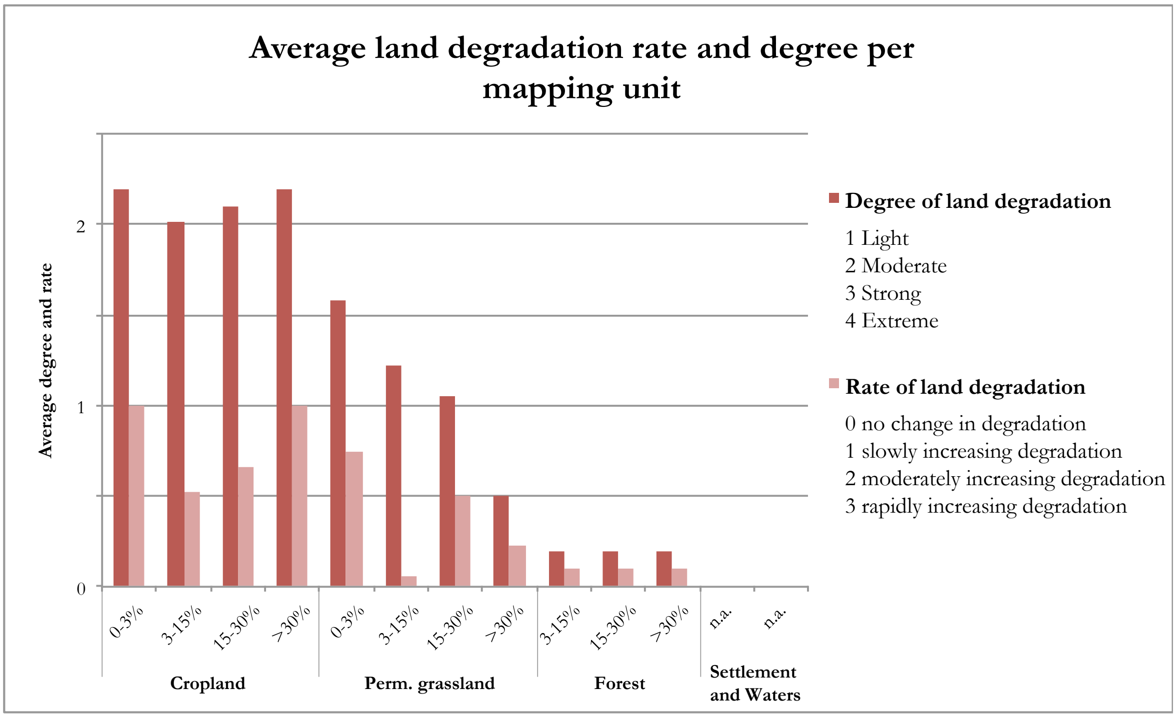

Fig. 20 Study area Frienisberg (BE): Averaged land degradation rate and degree (stakeholder workshop outcomes in Annex 3) per mapping unit combining for each LUS the impacts of the different land degradation types (involved degradation types on LUS cropland: surface erosion, compaction, and water degradation; on LUS permanent grassland: compaction; and on LUS forest: combination of aridification-increase of pests/diseases) (Illustration: Fedrigo 2016, Data source: WOCAT QM)

Finally, signs of land degradation are also perceivable all across the LUS *forest*, but according to the QM categories land degradation is classified as being "is still in an initial phase. It can be easily stopped and damage repaired with minor efforts" (average rated as below light degree, 0.2). Although the averaged degradation intensities are very little the rates are increasing, though very slowly (average rated as nearly "no change in degradation", 0.1), which indicates that the management cannot be considered as totally *appropriate* for the situation and that there are still remaining gaps.

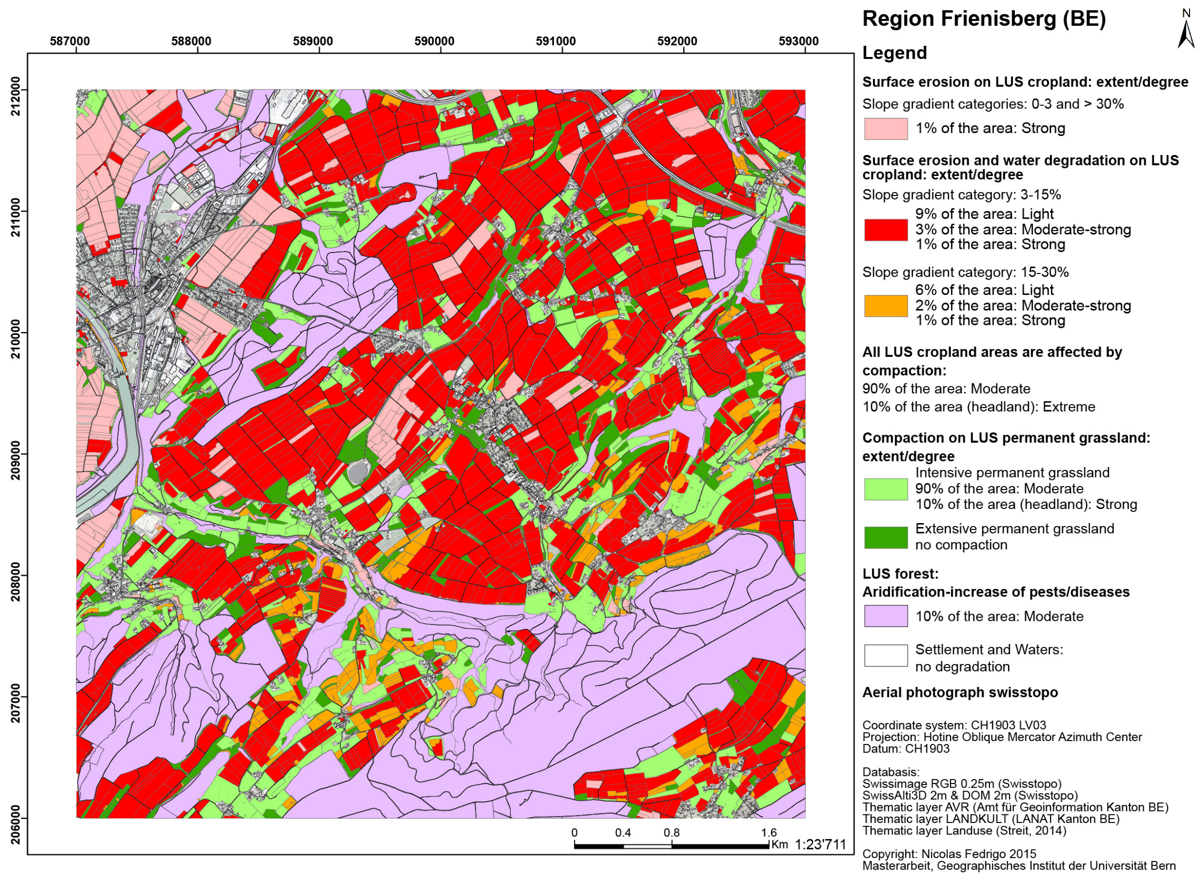

Fig. 21 Study area Frienisberg (BE): Overview of the degree and extent (%) of land degradation for each LUS. Stakeholder workshop outcomes. (Illustration: Fedrigo 2016, data source: WOCAT QM,)

3.4 Land conservation per land use system

The following section focuses on the land management technologies defined in section 2.3.3, their occurrence and application in the various LUSs. As proposed by the QM the management practices (conservation technologies) have been assessed with regard to their purpose, their effectiveness in addressing land degradation, and their impact on ESS (in accordance with the procedure presented in section 2.3.6). The practices that have a positive impact on the LUSs, while addressing degradation adequately, are identified in this procedure. The extent, effectiveness, and value-trend are discussed for each LUS. Entitling eventually well-conserved areas (bright spots) this process ultimately allows getting a precise image of the current situation.

3.4.1 Land conservation on cropland

3.4.1.1 Opening remarks

While considering site-specific conditions and using appropriate cultivation techniques, farmers are trying to achieve the best possible use of their land. The sustainable use of natural resources as soil, water, and air wants also to be accompanied by cost-efficiency in the production of high quality harvests (Chervet et al., 2006).

In general, the participating experts are sensitive to the potential harmfulness of intensive high-input agriculture. Although many agriculturalists do not exclusively refer to one particular cultivation system or tillage method, so that their patches are regularly characterised by the combination of technologies in various forms and arrangements. In accordance to the farmers' persuasion and commitment to their crop rotation, the practical choices (e.g. the cultivation technique) implemented on the field differ slightly, or considerably, from one year to another. The stakeholder workshop outcomes are clear: farmers may alternate the practice of conservation technologies or conventional ploughing throughout the crop-rotation period depending on the crop type, the site-specific conditions, or other external factors. Well-planned scenarios are repeatedly adapted by entrepreneurial choices (e.g. markets compelling the use of cash crops). An illustrating example of a seven-year crop rotation, meeting the criteria for *reduced tillage*, may be, spring wheat cultivated in accordance to the no-tillage method, followed by mulched winter barley and rape, succeeded by winter wheat (strip-till), and finally concluded by three years grass-cover leys (no-tillage).

The selected conservation technologies discussed hereafter are the most common practices observed in Frienisberg, combined they apply to approximately 70% (1144 ha) of the cropland area. Although, while the extent retained in Table 16 represent a ten-year LUS area average, with varying spatial distribution (cultivation plots), the effectiveness and the value of the conservation technologies only refer to one particular year of application. The long-term effectiveness of the technologies cannot be assessed since the plots are not cultivated rigorously with one management practice. An exception applies to *permanent grasslands*, which are commonly maintained over a six- or seven-year period, as well as to grass clover leys, which constitute ideally a bi-annual cover crop. Again, crop rotations are strongly exposed to pressuring markets, thus the desired periodicity cannot be maintained categorically.

3.4.1.2 Reference technology

Frienisberg's agricultural landscape is particular: it is composed of a significant number of small farms and, more exceptionally, a wide variety of cultivation systems. Although, ploughing is the most representative farming practice, *intensive ploughing*, suggesting high-input and mechanised agriculture, is the most intensive cultivation system and therefore designated as reference technology (please refer to section 2.3.3.1.1) when relating to the QM assessment. Even though, according to the expert group, *extensive mulching* represents the historical perception of "conventional" agriculture more truly (if this term would suggest "how it has been practiced over centuries"). The conditioning to only one management practice when assessing land degradation on LUS cropland is ordered by two major constraints: Firstly, the lack of area-wide data allowing the spatial localisation of all cultivation methods and, secondly, the inconsistency in the application of the cultivation systems. Both are a precondition for the QM land degradation assessment (issues expressed in more detail in section 4.2.1). The conservation technologies documented in the following sections are therefore to be considered as responses to the land degradation processes occurring on intensively ploughed surfaces.

In Frienisberg, *intensive ploughing* is performed on approximately 30% of the cropland area. The extent attains values comparable with those obtained in previous studies for ploughed areas with "root crops and maize" (Ledermann et al., 2010). Nevertheless, it stays confined to the lands belonging to the slope gradient categories below 15% (*flat* and *moderate* slopes) and is inexistent on lands with slope gradient above 15% (see Fig. 22). Preliminary discussions held with some of the participating experts lead to the selection of conservation technologies listed in Table 16 (and reviewed in section 2.3.3.1.2). As the reference technology only extends over 30% of the study area, each of the conservation technologies operates on potentially large surfaces. It seems therefore important to document all major practices, and even more since they could not be assessed as full share land use systems.

3.4.1.3 Conservation technologies

The extent (summarised in Fig. 22 and Fig. 23), effectiveness (summarised in Fig. 24) and impact on ESS (summarised in Fig. 31) of each technology are assessed individually in order to identify and qualify the usefulness and value of conservation for the LUS *cropland*.

Resulting from the stakeholder workshop the extent of the conservation technologies are illustrated with regard to two broader slope gradient categories distinguishing <u>flatter</u> (gradient categories: <15%) form <u>steeper</u> (gradient categories: >15%) areas. The other variables (addressed degradation, effectiveness and –trend, as well as the impacts on ESS) apply to the respective surfaces on the entire LUS *cropland* since in these cases no distinction between the slope gradients is held necessary.

Land management	Total % LUS area	Total extent (ha)	*Slope gradient categories < 15%*		*Slope gradient categories > 15%*	
			Extent (%)	Extent (ha)	Extent (%)	Extent (ha)
LUS cropland reference technology						
Plough (int.)	27%	421.18	30%	421.18	0%	0
LUS cropland: conservation technologies						
Plough (ext.)	16.5%	259.09	15 %	210.59	30 %	48.50
Mulching (int.)	25%	391.41	25 %	350.99	25 %	40.42
Mulching (ext.)	21%	329.29	20 %	280.79	30 %	48.50
No-tillage (int.)	3%	46.97	3 %	42.12	3 %	4.85
No-tillage (ext.)	5.5%	86.37	5 %	70.20	10 %	16.17
Strip sowing (int.)	1.5%	23.49	1.5 %	21.06	1.5 %	2.43
Strip sowing (ext.)	0.5%	7.83	0.50 %	7.02	0.50 %	0.81
TOTAL	**100**	**1565.63**	**100%**	**1403.95**	**100%**	**161.68**
Grass clover ley	19%	296.69	17 %	270.79	2 %	25.95
LUS permanent grassland						
Permanent grassland (int.)	83%	430.62	69 %	165.51	94 %	265.11
Permanent grassland (ext.)	17%	90.22	31 %	73.94	6 %	16.28
TOTAL	**100**	**520.84**	**100%**	**239.45**	**100%**	**281.39**

Table 16 Study area Frienisberg (BE): Conservation technologies and their area coverage (in % and ha) on flatter (slope gradient categories: < 15%) and steeper (slope gradient categories: >15%) agricultural land (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern and WOCAT QM)

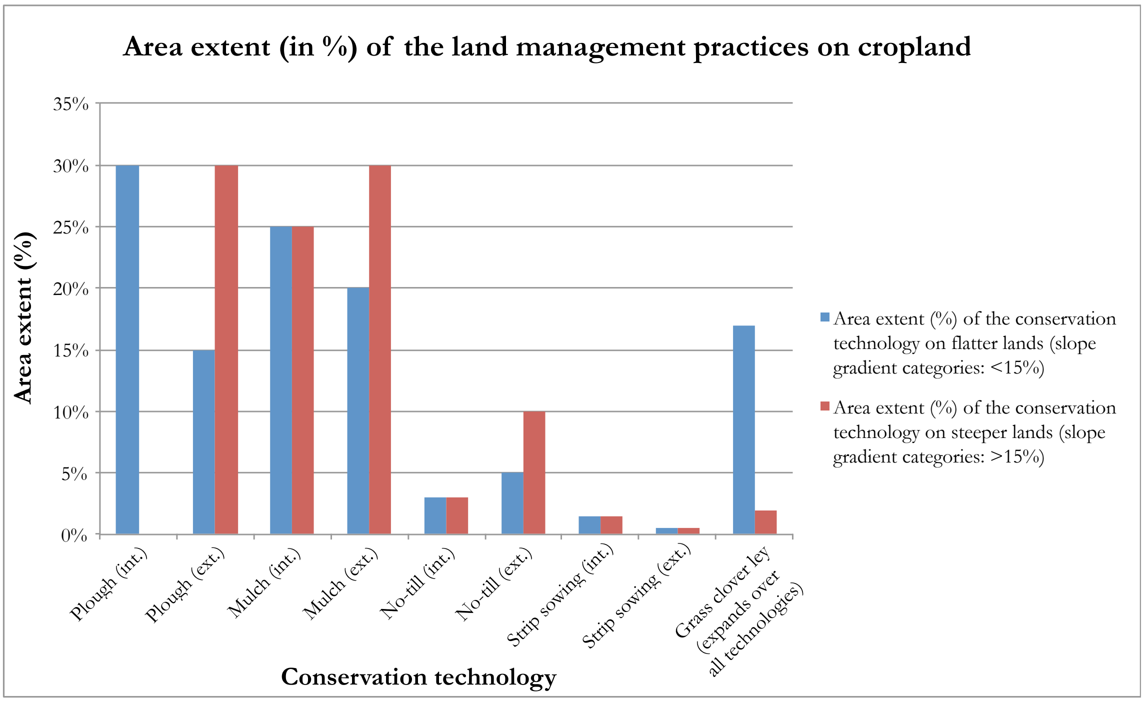

Fig. 22 Study area Frienisberg (BE): Area extent (in %) of the reference technology (plough int.) and all the conservation technologies on flatter (blue) and steeper (red) parcels on LUS cropland (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern, © Amt für Landwirtschaft und Natur des Kantons Bern and WOCAT QM)

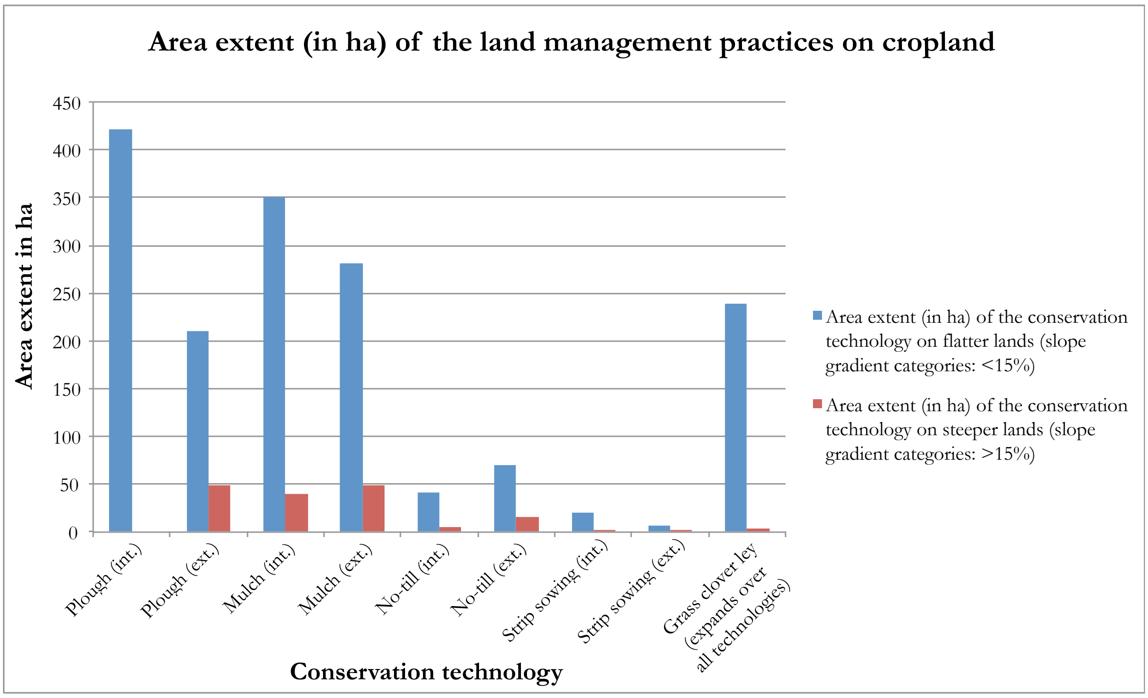

Fig. 23 Study area Frienisberg (BE): Area extent (in ha) of the reference technology (int. plough) and all the conservation technologies on flatter (blue) and steeper (red) parcels on LUS cropland (Illustration: Fedrigo 2016, Data source: © Amt für Geoinformation des Kantons Bern, © Amt für Landwirtschaft und Natur des Kantons Bern and WOCAT QM)

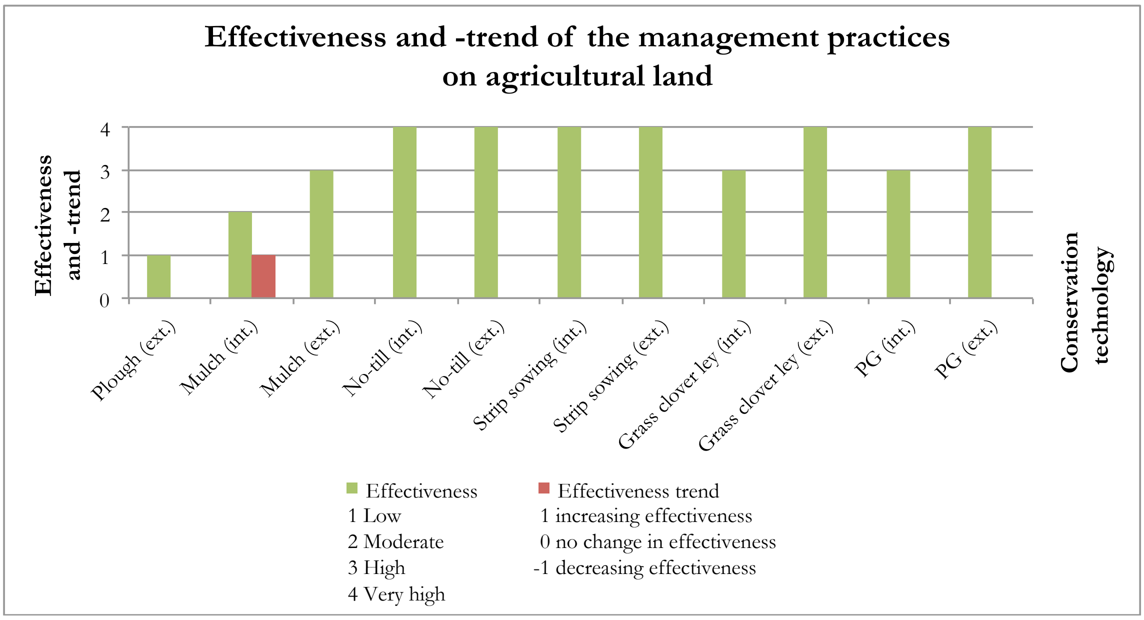

Fig. 24 Study area Frienisberg (BE): Effectiveness and -trend of the conservation technologies on LUS cropland documented during the stakeholder workshop (Illustration: Fedrigo 2015, Data source: WOCAT QM).

3.4.1.4 Extensive ploughing

Extensive ploughing appeared as such in the 19th century. This conservation technology applies to nearly 17% (259 ha) of the total LUS *cropland* area, out of which 80% are situated on parcels with slope gradients below 15% (see Table 16). According to the stakeholder workshop, extensive ploughing is practiced on 15% of the flatter (slope categories: <15%) and on 30% of the steeper lands (slope categories: >15%). The expert group suggests that on these steeper lands *extensive ploughing* is substituting intensive ploughing: roughly 30% of the parcels are ploughed yet no root crops are grown. Like all other conservation technologies the extensive management is expected to mitigate soil disturbance and to prevent surface erosion, compaction, and water degradation. However, the technology is not, or maybe only little effective according to the QM classification "the measures need local adaptation and improvement in order to reduce land degradation to acceptable limits. Much additional effort is needed to reach a "high" standard" (rated as low effectiveness, 1). This situation is not expected to evolve with the implementation period (rated as no change in effectiveness, 0). Since root crops have a long growing period, in which the competition with weedy plants is very high, the soil is recurrently tilled in order to rapidly suppress these undesired herbs. By avoiding such cultures *extensive ploughing* reduces slightly the land degradation processes. Even though the expert group recognizes the intention, but, despite the efforts, the rigorous and persistent mechanical ploughing affects **ecological services**, while unsettling the soil structure, the soil life, as well as the soil cover (rated as low negative impact, -1).

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
Plough (ext.)	Other (OT): no root crops	Change of intensity level (M2)	Prevention (P), Mitigation (M)	16.5%	Surface erosion, Compaction, Water degradation.	Low	No change in effectiveness	**Low negative impact:** Soil cover (E4) Soil structure (E5)	19th century

Table 17 Stakeholder workshop outcomes from the assessment of the conservation technology *plough extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

3.4.1.5 Mulching

Mulching practices are the most widespread conservation technologies covering approximately 46% of the LUS area (see Table 16). The stakeholder workshop outcomes resulting from the QM assessment for both *intensive* and *extensive mulch* are summarised in Table 18.

Practiced in Frienisberg since the late 1950s, *intensive mulching* covers roughly 25% of the LUS *cropland* area. It is the only documented practice revealing an increasing effectiveness trend (rated as increasing effectiveness trend, 1), which means that the beneficial impacts on the reduction of surface erosion, compaction, and surface and ground water degradation become more effective over time. According to the expert group, this favourable development is achieved with improved knowledge and operative use of the machinery. Land degradation can be reduced with *intensive mulch* but the processes of surface erosion (and related water degradation) and compaction cannot be totally avoided (rated as moderate effectiveness, 2). Involving reduced tillage (e.g. with grubbers or cutlers) and permanent soil cover over more than 30% of the surface area, the practice encourages soil structure building properties and the maintenance of a persistent vegetation cover (rated as low positive impact, 1). Covered soils are less exposed to rainfall impact and surface erosion since they support structural stability. However, intensive mulching includes root crop cultivation exposing therewith the soils to the intense disturbance during root crop harvesting, increasing the vulnerability to surface erosion and water degradation through sediments, chemicals, etc. Knowing that the vulnerability of lands to degradation also depends on external factors such as weather conditions during harvesting and right after.

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
Mulch (int.)	Mulching with root crops	Soil cover (A1), Change of intensity level (M2)	Prevention (P) Mitigation (M)	25%	Surface erosion Compaction Water degradation	Moderate	Increase in eff.	**Low positive impact**: Soil cover (E4) Soil structure (E5)	1950/ 60
Mulch (ext.)	Mulching without root crops	Soil cover (A1), Change of intensity level (M2)	Prevention (P) Mitigation (M)	21%	Surface erosion Compaction Water degradation	High	No change in eff.	**Low positive impact**: net income (S6) **Positive impact**: Regulation of excessive water (E1) Soil cover (E4) Soil structure (E5)	19th century

Table 18 Stakeholder workshop outcomes from the assessment of the conservation technologies *mulching intensive* and *extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

Extensive mulching excludes root crops in the rotation. It is the second most widespread conservation practice implemented on approximately 20% of the LUS area (329 ha). *Extensive mulching* induces also reduced soil disturbance in addition to the maintenance of permanent vegetal coverage (as *intensive mulching*) but, while abandoning root crops, farmers make an additional deliberate choice of lowering the management intensity to further reduce the soil disturbances. Even though there is no more tangible trend of improvement (rated as no change in effectiveness, 0), the measure controls "the land degradation problems appropriately" (rated as high effectiveness, 3). According to the QM classification the conservation practice is "able to stop further deterioration, but improvements are slow". For instance, surface erosion and water degradation through sediments, chemicals, etc., as well as compaction in-plot areas can be strongly reduced. *Extensive mulch* supports **ecological services**: the strongest positive effects are documented on soil cover and structure, as well as on the regulation of excessive water (rated as positive impact, 2), followed by an income increase (rated as low positive impact, 1). Parameter such as the water infiltration rate and the water retention capacity are increasing, in addition to the soil loss that "does not greatly exceed the natural rate of soil formation" according to the QM classification.

3.4.1.6 No-till

In Switzerland, the success and spreading of *no-tillage* technologies is a product of wide-ranging collaborations involving farmers, mechanical engineers, soil protection experts, as well as agricultural experts and contractors. The future development of no-tillage farming could strongly depend on how relationships are formed and sustained and how they are interpreted and applied in practice.

In Frienisberg, ploughless production is launched in the early 1990s based on the exchanges between farmers and other regional experts. It spreads particularly in its first decade of existence, though today, according to the expert group, it might be losing ground. The two together, *intensive* and *extensive no-till* technologies apply on approximately 8.5% (133 ha) of the total LUS *cropland* area. Within the LUS *cropland* area *extensive no-till* applies on 5% of the flatter (slope gradient categories: <15%) and on 10% of the steeper parcels (slope gradient categories: >15%), while *intensive no-till* extends over 3% of the total LUS area (in all slope gradient categories) (see Table 16). Mindset is often identified as probable prevailing concern to the expansion of no-tillage practices, and more particularly the acceptance, among farmers and the population, of systematically applying non-selective herbicides for weed control (D. Niggli, 2015b).

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
No-tillage (int.)	Conservation agriculture (CA), with root crops	Soil cover (A1), Change of intensity level (M2)	Prevention Mitigation	3%	Surface erosion Compaction Water degradation	Very high	No change	**Low positive**: Soil cover (E4) Soil structure (E5)	1993
No-tillage (ext.)	Conservation agriculture (CA), without root crops	Soil cover (A1), Change of intensity level (M2)	Prevention Mitigation	5.5%	Surface erosion Compaction Water degradation	Very high	No change	**Low positive**: Net income (S6) Production (P1) **Positive**: Soil cover (E4) Soil structure (E5)	1993

Table 19 Stakeholder workshop outcomes from the assessment of the conservation technologies *no-tillage intensive* and *extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

An undoubtable link between the intensity of the soil movement and the effectiveness of the conservation practices emerges from the overall QM results (results summarised in Annex Table 2). *No-tillage* technologies (both *int.* and *ext.*) provide a highly successful cultivation method (see Table 19) in mitigating and preventing water degradation, compaction, and soil erosion (rated as very high effectiveness, 3): According to the QM classification these conservation measures do "not only control the land degradation problems appropriately" they "even improve the situation compared to the situation before degradation occurred". While maintaining a permanent vegetation cover and reducing radically soil disturbances, hence allowing earthworms to substitute the plough in aerating, draining, and mixing the soils, these agronomic (vegetation cover) and management (production intensity) methods are favourable to the maintenance of **ecological services**: the strongest positive effects are documented on soil cover and long-lasting structural soil stability (rated as positive impact on *extensive no-till*, 2; and as low positive on *intensive no-till*, 1). In addition, *extensive no-till* permits slight net income and production growth while reducing risks (rated in all cases as low positive impact, 1). In no-till technologies the influence of including root crops in the rotation is visible in the impacts on ESS (shown in Fig. 31) as well as in the degree of compaction on headlands (shown in Fig. 17).

3.4.1.7 Strip sowing

Introduced in the early 1990s in Frienisberg, *strip sowing* is another practice reducing soil disturbances and maintaining high soil cover. However, since in the study area it is mainly used for maize cropping into grass-clover sods (Prasuhn, 2012), the weight of *strip sowing* technologies is only very little, with a total surface of only 2% (31 ha) of the total LUS cropland area. *Intensive strip sowing* is applied on 1.5% of the flatter (slope gradient categories: <15%) and on 2% of the steeper (slope gradient categories: >15%) cultivation plots, while *extensive strip sowing* extends over 0.5% of the total LUS surface. Both *intensive* and *extensive strip sowing* are highly effective technologies, according to the QM classification they do "not only control the land degradation problems appropriately, but even improve the situation compared to the situation before degradation occurred" (rated as very high effectiveness, 3). However, according to the expert group *strip sowing* is generally used as one out of many technologies involved in the multi-annual management scheme based on land degradation mitigation and prevention strategies. Its' inclusion generally depends on the land user's personal choices and long-term plans, or on site-specificities (e.g. crop rotations and types, slope gradient). While limiting tilling to 30 cm strips the technologies are expected to reduce the management intensity, which will have positive effects on **soil services**: positive effects are documented for soil cover and structure for both *intensive* and *extensive strip sowing* (rated as low positive impact, 1). Besides the encouraging effects on soil services *extensive strip sowing* contributes furthermore to a slight net income growth (rated as low positive impact, 1). All the QM results are presented in Table 20.

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
Strip sowing (int.)	Other: reduced tillage with root crops	Soil cover (A1), Change in intensity level (M2)	Prevention Mitigation	1.5%	Surface erosion Compaction Water degradation	Very high	No change	**Low positive**: Soil cover (E4) Soil structure (E5)	1990
Strip sowing (ext.)	Other: reduced tillage without root crops	Soil cover (A1), Change in intensity level (M2)	Prevention Mitigation	0.5%	Surface erosion Compaction Water degradation	Very high	No change	**Low positive**: Net income (S6) Soil cover (E4) Soil structure (E5)	1990

Table 20 Stakeholder workshop outcomes from the assessment of the conservation technologies *strip sowing intensive* and *extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

3.4.1.8 Grass clover ley

Last but not least, the expert group indorsed the important to document the impact of *grass clover ley* and to briefly discuss its conservative value. As described in section 2.3.2, regardless of the cultivation system in use, (bi)-annual cover leys are generally included in the crop rotations and are an integral part of most overall farmland management strategies. *Grass clover leys* are appropriate and successful management tools for weed and pest control, hummus enrichment, and erosion reduction. Furthermore, they offer a nutritional balance by providing nitrogen to the following crops, and are of vital interest for farms that only have few livestock. These vegetative and agronomic measures are effective in controlling, preventing, and mitigating land degradation: according to the QM classification *intensive grass clover leys* are "control land degradation problems appropriately" (rated as high effectiveness, 3), while *extensive grass clover ley* "even improve the situation compared to the situation before degradation occurred" (rated as very high effectiveness, 4). All documented *grass clover leys* have a positive effect on **soil services**: the strongest positive impact is documented on <u>soil structure</u> and <u>cover</u> since the soil disturbance is limited to 30 cm strips so that a high vegetation cover can be maintained (rated as high positive impact, 3). Additionally, by encouraging natural drainage and soil structure building processes, *extensive grass clover ley* has a positive impact on the <u>quality and quantity of water for consumption</u>, as well as on the <u>regulation of excessive water</u> (rated as positive impact, 2).

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
Grass clover ley (int.)	Grazing land manage-ment (GR)	Annual or bi-annual grasses (V2) Change in intensity level (M2)	Prevention Mitigation	19% of the total LUS area (includes also the area under conser-vation manage-ment)	Surface erosion Compaction Water degradation	High	No change	**High positive**: Soil cover (E4) Soil structure (E5)	19th century
Grass clover ley (ext.)	Grazing land manage-ment (GR)	Annual or bi-annual grasses (V2) Change in intensity level (M2)	Prevention Mitigation		Surface erosion Compaction Water degradation	Very high	No change	**Positive**: Regulation of excessive water (E1) Water for consumption (P2) **High positive**: Soil cover (E4) Soil structure (E5)	19th century

Table 21 Stakeholder workshop outcomes from the assessment of the conservation technologies *grass clover ley intensive* and *extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

3.4.2 Land conservation on permanent grassland

Land use	LUS	Slope	Gradient category	Area (%) total AL	Area (%) LUS per AL	Area (%) per LUS	Area (ha)	Area (ha) per LUS
Agricultural land (AL)	Cropland	*Flat*	0-3%	9.5	75%	12.7	198.82	1565.63
		Moderate	3-15%	57.8		77.0	1205.13	
		Steep	15-30%	7.0		9.3	146.07	
		Very steep	>30%	0.8		1.0	15.61	
	Permanent grassland	*Flat*	0-3%	0.7	25%	2.6	13.63	520.84
		Moderate	3-15%	10.8		43.4	225.82	
		Steep	15-30%	11.5		46.2	240.75	
		Very steep	>30%	1.9		7.8	40.64	
TOTAL:			**-**	**100**	**100**	**-**	**2086.47**	**2086.47**

Table 22 Spatial distribution of the agricultural land within the study area Frienisberg (BE): Area extent of LUS cropland and LUS permanent grassland divided into four slope gradient categories (Illustration: Fedrigo 2016, Data source: Data source: © Amt für Geoinformation des Kantons Bern and © Amt für Landwirtschaft und Natur des Kantons Bern).

For the conservation assessment, permanent grassland is also to be considered as a conservation technology on agricultural land, and thus addressing the land degradation types occurring on this land use type, namely surface erosion, compaction, as well as surface and ground water degradation.

a) Name	b) Group	c) Measure	d) Purpose	e) % of area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
PG (int.)	Grazing land management (GR)	Grasses (V2)	Prevention, Mitigation, Rehabilitation	67%	Surface erosion, Compaction, Water degradation	High	No change	**Positive impact**: Regulation of excessive water (E1), Water consumption (P2) **High positive impact**: Soil cover (E4), Soil structure (E5)	19th century
PG (ext.)	Grazing land management (GR)	Grasses (V2), Change of intensity level (M2)	Prevention, Mitigation, Rehabilitation	33%		Very high	No change		19th century

Table 23 Stakeholder workshop outcomes from the assessment of the conservation technologies *permanent grassland (PG) intensive* and *extensive* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

When observing the agricultural land as a whole, *permanent grassland* extends over roughly 25% (520 ha) of the total area in use. Out of these, approximately 24% (507 ha) are located on lands with *flat*, *steep*, and *very steep* slopes (referring to Table 22), whereas only 1 % of the lands are located on *flat* parcels. As mentioned in section 3.1 most permanent grassland surfaces extend along surface waters, at the edge of the woods, or close to the settlements in order to avoid pollution caused by cropland management (since the parcels would be used as such otherwise). Only sparse patches are located randomly in areas surrounded by cropland parcels (refers to Fig. 13).

Even though there is still potential for grasslands to be applied on patches with higher slope gradients (gradient categories: >15%), these areas are either already under permanent grassland, 12% (280 ha) of the total agricultural land area, or under forestland, concerning 18% (607 ha) of the total study area (see Table 6). *Steep* and *very steep* parcels are only marginally used as cropland since they represent 8% (161 ha) of the total agricultural land area, which limits the expansion capacity for permanent grassland on these areas per se. Although most permanent grassland parcels are located on lands with *moderate* (3-15%) and *steep* (15-30%) slope gradients (Fig. 25), the grasslands distributes quite evenly within the broader slope categories below and above 15% steepness (as shown in Fig. 25; data in Annex Table 5).

Though there might be differences in some of the specifics, most of the QM results documenting *grass clover ley* (presented in section 3.4.1.3) are also applicable to this land management practice. In addition to the qualities disclosed for *grass clover ley*, *permanent grassland* offers a long-lasting and structuring proposal addressing also degraded lands (rehabilitation processes). Since it was agreed during the workshop discussions that there is no substantial necessity to discriminate the land use types pastureland and meadow, the management intensities *intensive* and *extensive* permanent grassland are still differentiated (see Table 23) even though their conservation values are quite similar. Approximately 67% (347 ha) of the LUS permanent grassland area is under *intensive* management while the remaining 33% (173 ha) is used as *extensive grassland* (see data in Annex Table 5 for more details).

Permanent grassland is a vegetative measure controlling degradation while preventing and mitigating further land deterioration, as well as the eventual offsite damages. According to the QM classification, *intensive permanent grasslands* "control the land degradation problems appropriately" (rated as high effectiveness, 2) while *extensive permanent grasslands* "even improve the situation compared to the situation before degradation occurred" (rated as very high effectiveness, 4). On agricultural land, the conservation value of both latter technologies is undisputable when calling upon the outcomes of the land degradation assessment documented in section 3.3.3 since the only issue raised is compaction affecting lands under *intensive permanent grassland.*

According to the expert group *intensive* and *extensive permanent grassland* has a positive impact on **ecosystem services**: the strongest positive impact is documented on <u>soil structure</u> and <u>cover</u> (rated as high positive, 3). By encouraging natural drainage and soil structure building processes, *permanent grassland* has additionally a positive impact on the quality and quantity of water for consumption, as well as on the regulation of excessive water (rated as positive impact, 2).

The complementary assessment of *permanent grassland*, fist as LUS (QM step 3) and then as SLM practice (QM step 4), provides a more comprehensive picture of the state of the grasslands. While the degradation assessment provides factual information on the impacts (revealing the compaction issues under intensive grasslands illustrated in section 3.3.3.1), the conservation assessment allows the evaluation of solutions brought to light (all outcomes are shown in Table 23). Combined these assessments enable to state that, even though *intensive permanent grassland* is subject to compaction, permanent grassland has broadly regenerating effect on the agricultural lands, while favouring high herbal soil cover, water regulation, and soil structure development, characterised active living organisms, maintaining nutrient cycle and organic matter decomposition, and pore water availability.

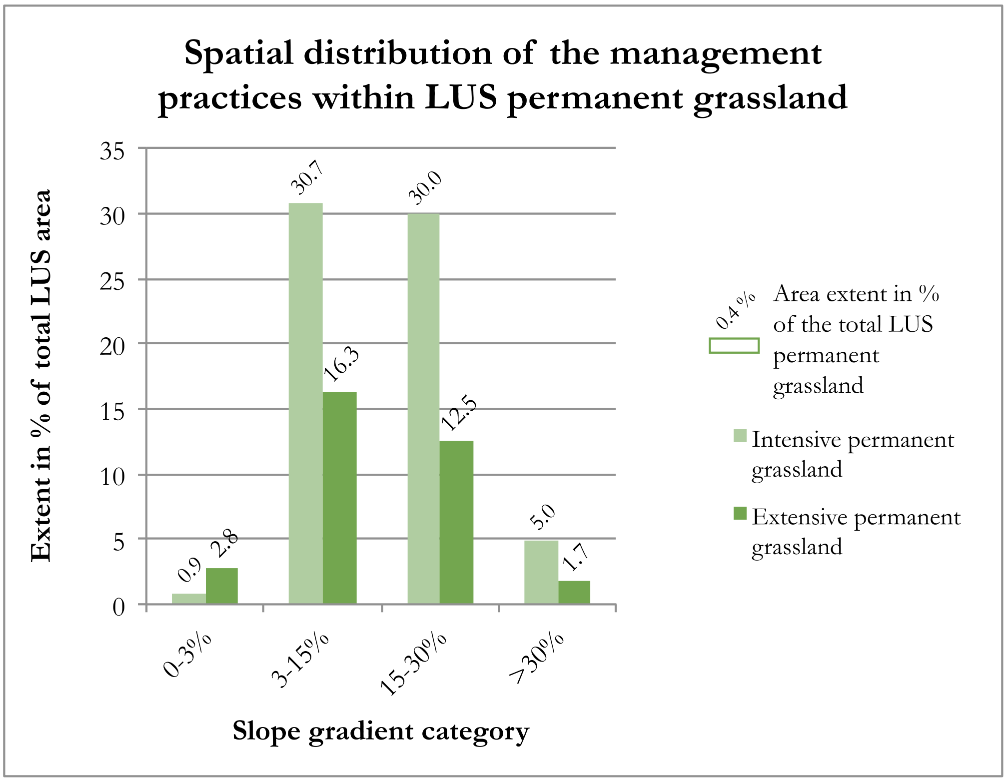

Fig. 25 Study area Frienisberg (BE): Area extent of the land management technologies *extensive* and *intensive permanent grassland* on LUS permanent grassland (Illustration: Fedrigo 2016, Data source: © Amt für Landwirtschaft und Natur des Kantons Bern, data in Annex Table 6).

3.4.3 Land conservation on forest land

While investigating for ecological solutions, renewable and CO_2-neutral resources become attractive to the economy dependent on raw material. Considered an environmentally friendly resource, the demand for timber grows for both the industry and construction, wherewith the prices rise. Hence, subject to liberalisation and intensification, forests might be more strongly exposed to overexploitation and parasites. In such a perspective, *mixed forests* (mixed stocks) are expected to guarantee a durable and stable forest stock even when one tree species is endangered (e.g. infested by parasites, overexploited).

As exposed previously, Frienisberg's forests are affected by strengthened and increased droughts, raising the susceptibility to pests and diseases. Thus, the QM assessment focuses on the conservation value of the technology *mixed forest* and on its' effectiveness in addressing the combined impact aridification and increase in pests/diseases. The management assessment made by the district forester building on the QM is presented in Table 24.

a) Name	b) Group	c) Measure	d) Purpose	e) % of LUS area	f) Addressed degradation	g) Eff.	h) Eff. trend	i) Impact on ESS	j) Period
Mixed forest	Afforestation and forest protection	Tree and shrub cover (V1), change of intensity level (M2), Control of species composition (M5)	Prevention Mitigation Rehabilitation	80%	Aridification - Increase in pests / diseases	High	Increase in eff.	**High positive**: Soil structure (E5) Biodiversity (E8), GHG emission (E9) Micro-climate (E10) Aesthetic (S1) **Low negative**: Net income (S6)	19th century

Table 24 Interview outcomes from the assessment of the conservation technology *mixed forest* within the study area Frienisberg (BE). The data presented in this table applies to all slope categories (Data source: WOCAT QM).

In view of land degradation forests are in a "healthy" state. This situation can be mainly attributed to the prevalent use of *mixed forest* enclosing nearly 80% (770 ha) of the LUS *forest* area. The large extent of this conservation practice is quite remarkable knowing that 50% of the woodland is privately owned and apportioned among more than 500 owners, which makes uniform management more difficult.

A mixture of conifers and broadleaf trees generally qualifies mixed stocks. Although, the amount of each species must be fulfilled so that it can assume its ecological value. However, the ecological value of *mixed forest* is not the only reason for its success. Mixed tree stands reach different soil depths and create a larger and better-branched root system so that the soil moisture reserves can be maintained. Additionally, increased tree spacing mitigated the parasite transfer between members of the same species. For these reasons, *mixed forest* is considered as effective conservation technology, in Frienisberg, and, according to the QM classification, it allows to "control the land degradation problems appropriately" (rated as high effectiveness, 3). By comparison with monocultures, *mixed forest* mitigates the establishment and spread of some pests and/or diseases considerably: The damages caused by the bark beetle for instance can be reduced by up to 65%. Unfortunately, some parasites (e.g. the ascomycete fungus *Hymenoscyphus fraxineus* causing strong dieback of spruce trees all through Europe) cannot be simply stopped by mixed forests since the fine spores can be transported and passed on over long distances (Schöbel, 2015).

Mixed forest is not only considered a popular and widespread conservation practice, confining the spread of certain parasites and reducing water stress severity, the technology is also classified with a "growing positive impact on the reduction of degradation" (rated as increase in effectiveness, 1).

Furthermore, *mixed forest* has an undisputable positive impact on **ecological services**: the strongest positive impact (rated as high positive impact, 3) is documented on the soil structure, maintained and enhanced by large and well-branched root systems, on the enrichment of biodiversity, on the reduction of greenhouse gas emissions (carbon sink and/or CO_2-neutral resource), as well as on the development of favourable environments (e.g. through rejuvenation cuts, shady spots) contributing in creating and maintaining (micro-) climatic conditions (temperature, moisture, etc.). With the meaning of preserving a permanent forest, *mixed forest* has also a positive impact on **socio-cultural services** such as aesthetic, recreation, cultural landscape, tourism, etc. (rated as high positive impact, 3). Various stages of vegetation are maintained constantly, making the forest always look pleasant, enjoyable, and "healthy". Thus, in a well-managed *mixed forest* the eyes of the spectator perceive no signs of timber extraction or land degradation. Mixed stocks are the most attractive view of a forest, for hikers or for people wanting to relax. Yet, the maintenance efforts (higher operating costs) are more important in mixed forests, which might provoke slight net income reductions (rated as low negative impact, -1).

Seeking the highest economic efficiency some landlords might conceive other management strategies. In pure terms of forestry operation mixed stands are more burdensome for the forester and thus more labour intensive than pure stands (monocultures). Thus, even though *mixed forest* is an old practice (already used in the 19th century) its' **period** of implementation strongly depends on the owners' disposition and conviction. Pressured by the world market, the Swiss timber market is in a progressive trend of liberalization. According to the district forester, Frienisberg's forests (like others in the Central Lowland) are subject to intensification, which could lead to a withdrawal of the conservation measure. As of now, the preference for mixed stocks prevails unconditionally in state-owned forests (extending over 50% of the LUS *forest* area) that are managed in order to hold coniferous populations at a certain percentage. While using a systemic approach *mixed forest* management is expected to diminish the vulnerability and hazards, with respect to diseases, pests, climate changes and adverse weather outcomes, as well as price insecurity, and to increase ecosystem benefits. Regular rejuvenation cuts (clear-cuts of the uppermost canopy) are very important since old and dense forests are not only highly susceptible to natural hazards such as storms, they are also in conflict with the multi-functionality (e.g. ecological, socio-cultural, economic) and ecological value given to forests.

3.4.4 Concluding land conservation

The averaged effectiveness and –trend in addressing the occurring land degradation processes are resumed in Fig. 26 and illustrated through Fig. 27. An overview of land conservation is given through Fig. 28.

It is pleasing to note how the overall result of the applied land conservation measures, in reducing the addressed land degradation (with reference to the degradation types documented in section 3.3 for each LUS), is classified according to the QM as "acceptable for the given situation" on nearly all mapping units (rated in average at least as moderate effectiveness, 2).

The most concerning overall situation affects LUS *cropland* and especially lands belonging to the *flat* and *moderate* slope gradient categories where the conservation technologies do not entirely reduce the degree of land degradation [surface erosion, compaction, and surface and ground water degradation] for it to be classified as "acceptable for the given situation" (rated in average as between low and moderate effectiveness, 1-2). Hence, according to the QM classification the measures applied on flatter lands (slope gradient categories: <15%) still "need local adaptation and improvement in order to reduce land degradation to acceptable limits". This overall state is not surprising since the most widespread conservation technologies (resumed in Table 16) *ext. plough* and *int. mulch* are those with the lowest effectiveness (rated respectively as low and moderate effectiveness, 1 and 2; see Fig. 24). On the other hand, on steeper lands (slope gradient categories: >15%) the overall effectiveness of the conservation practices is classified as "acceptable for the given situation" (rated in average as moderate effectiveness, 2): The absence of *int. plough* and the therewith the larger proportion of some of the conservation technologies classified as being more effective (notably *ext. mulch*) could be enough to explain the higher means. Thus, the sole fact of abandoning *int. plough* in Frienisberg (BE) may already result in a sensible reduction of the degree land degradation on cropland.

On LUS *forest* the overall conservation measures are also classified as "acceptable for the given situation" (rated in average as moderate effectiveness, 2) for all slope gradient categories, though the measure [*mixed forest*] requires additional inputs to "control land degradation problems appropriately".

Finally, since compaction is the only occurring land degradation type on LUS *permanent grassland*, it is hardly surprising that the highest means are identified it that system: According to the QM classification, "the measures [*int.* and *ext. permanent grassland*] control the land degradation problems appropriately" (rated in average as high effectiveness, 3) for all slope gradient categories and on very steep parcels (slope gradient category: >30%) they may "even improve the situation compared to the situation before degradation occurred" (rated in average as very high effectiveness, 4).

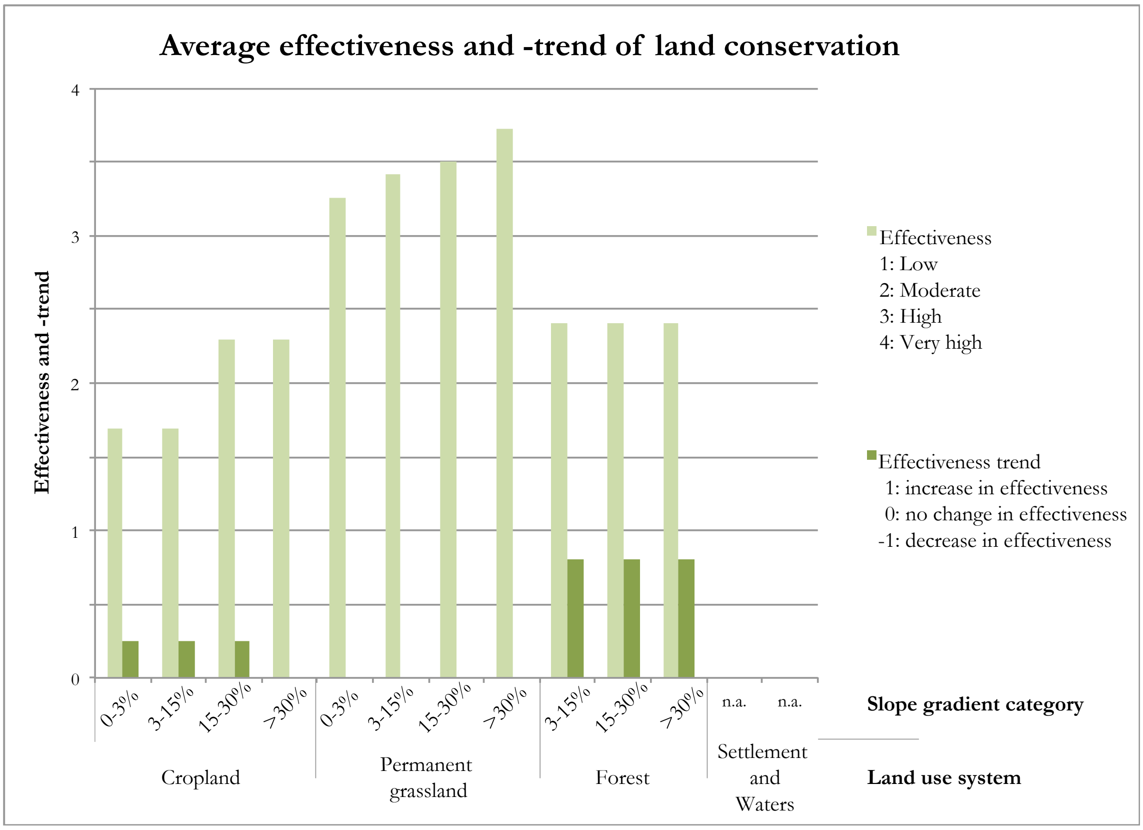

Fig. 26 Study area Frienisberg (BE): Average effectiveness and -trend of the land conservation combining for each mapping unit the effectiveness of all conservation technologies identified during the stakeholder workshop (Illustration: Fedrigo 2016, Data source: WOCAT QM).

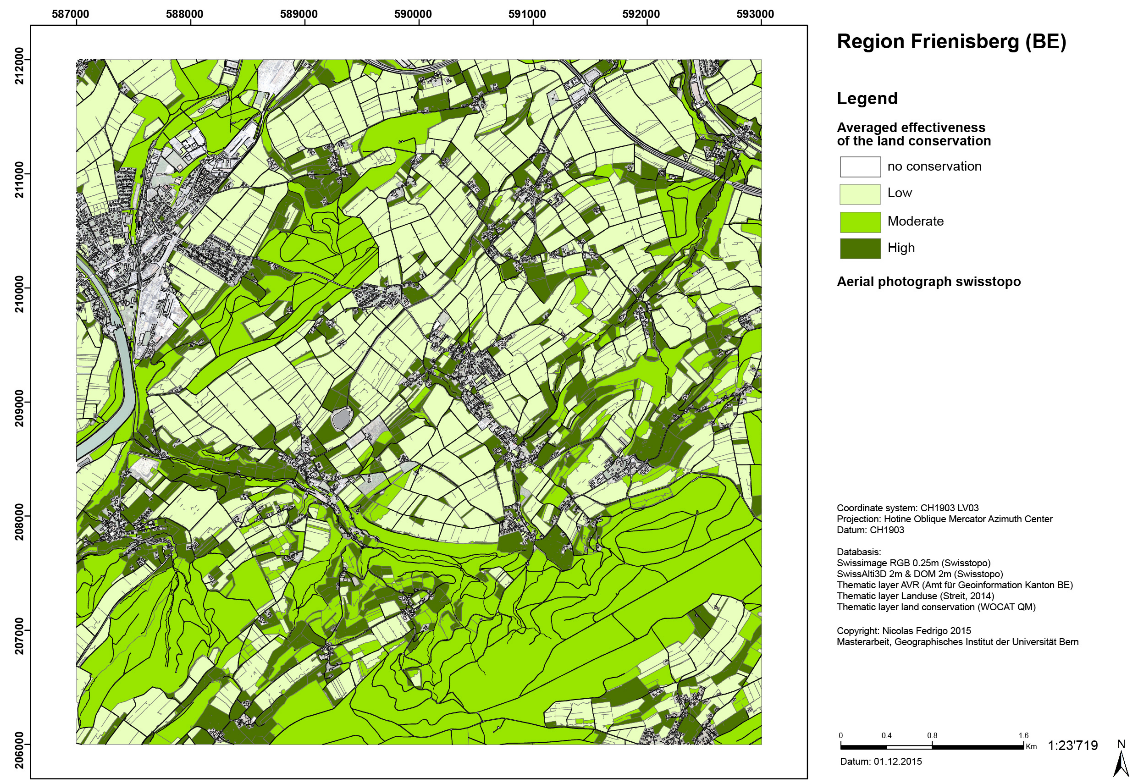

Fig. 27 Study area Frienisberg (BE): Averaged effectiveness of land conservation combining for each LUS the effectiveness of all conservation technologies identified during the stakeholder workshop (Illustration: Fedrigo 2016, data source: WOCAT QM).

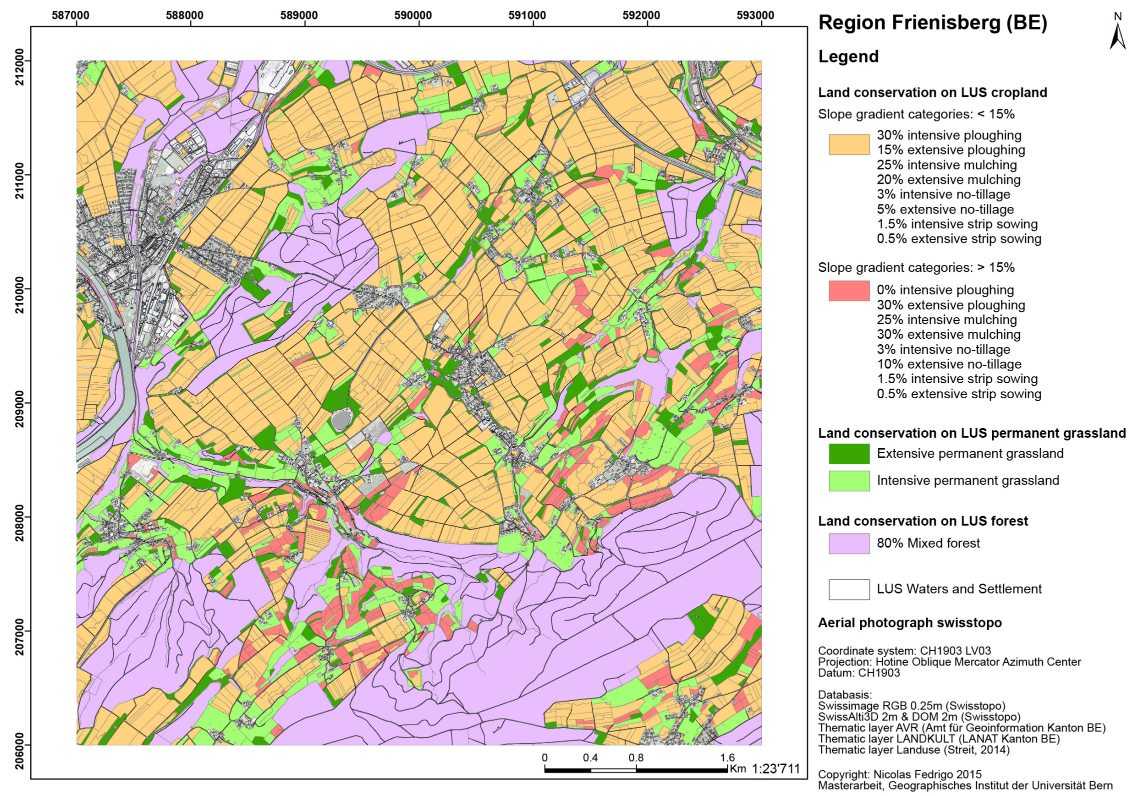

Fig. 28 Study area Frienisberg (BE): Overview of the land conservation practices for each LUS. Stakeholder workshop outcomes (Illustration: Fedrigo 2016, data source: WOCAT QM).

3.5 Impacts of land management on ecosystem services (ESS)

The impacts of land degradation and land conservation on ecosystem services have already been discussed, when appropriate, in the previous sections 3.3 and 3.4. Thus, this section presents an overview of the documented impacts on ecosystem services and highlights for each LUS some of the outstanding impacts of land degradation and conservation.

3.5.1 Impacts of land degradation on ecosystem services

The succeeding paragraphs focus briefly on the most significant or problematic impact of land degradation on productive, ecological, and socio-economic ESS.

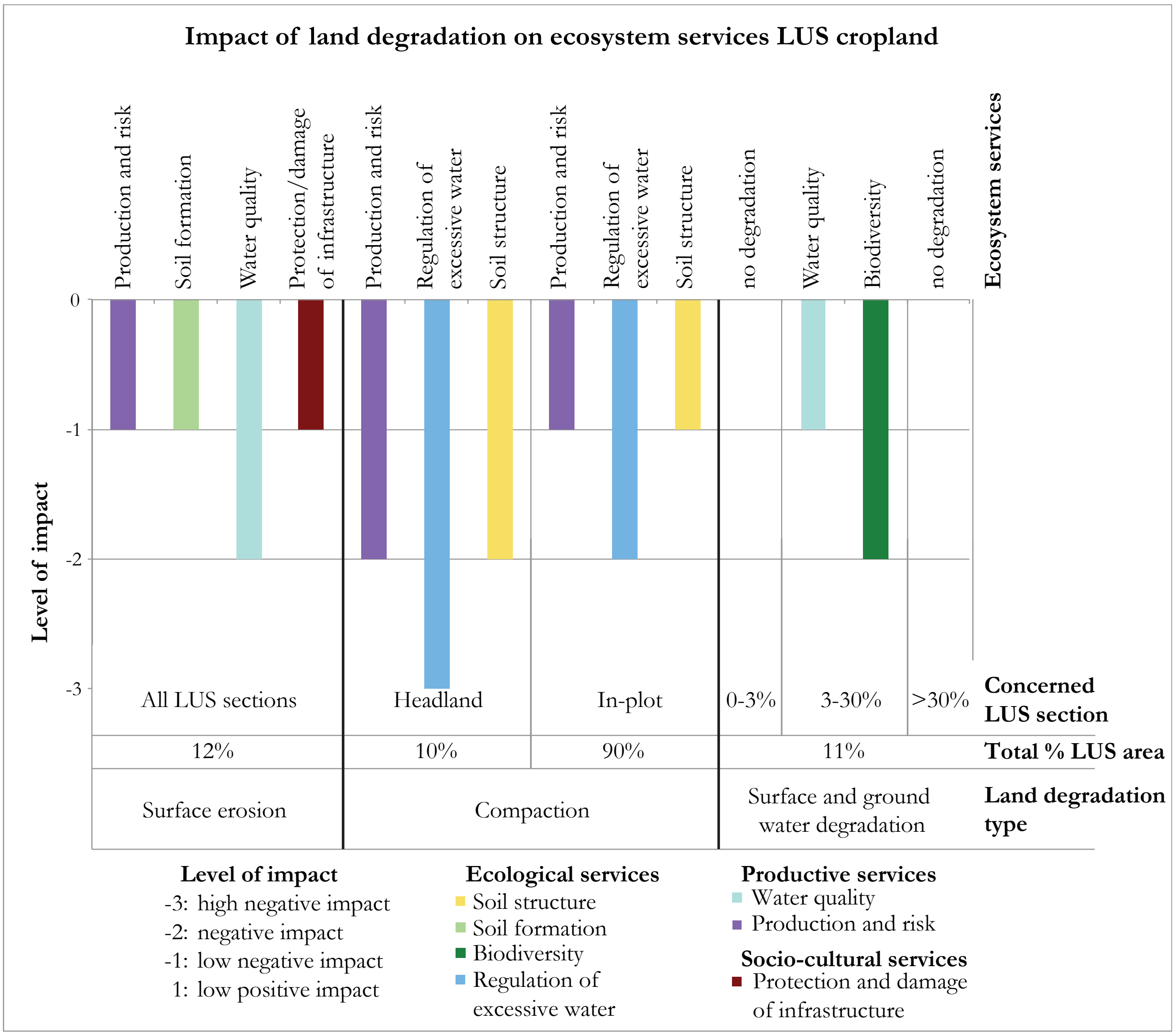

Fig. 29 Study area Frienisberg (BE): Impacts on ecosystem services of the land degradation types (surface erosion, compaction, and surface and ground water degradation) affecting LUS cropland. The reference technology used during the assessment is *intensive ploughing*. The variable "concerned LUS section" specifies where on the LUS land degradation occurs. The variable "total % LUS area" specifies the extent (in %) of the land degradation type affecting the concerned LUS section (Illustration: Fedrigo 2016, Data source: WOCAT QM).

To facilitate reading and examination of Fig. 29 and Fig. 30 it has been chosen to illustrate the strictly most important distinctions resulting from the stakeholder workshop. As a consequence, no difference is made between slope gradients, management intensity, or headland/in-plot in the figures if it is not necessary.

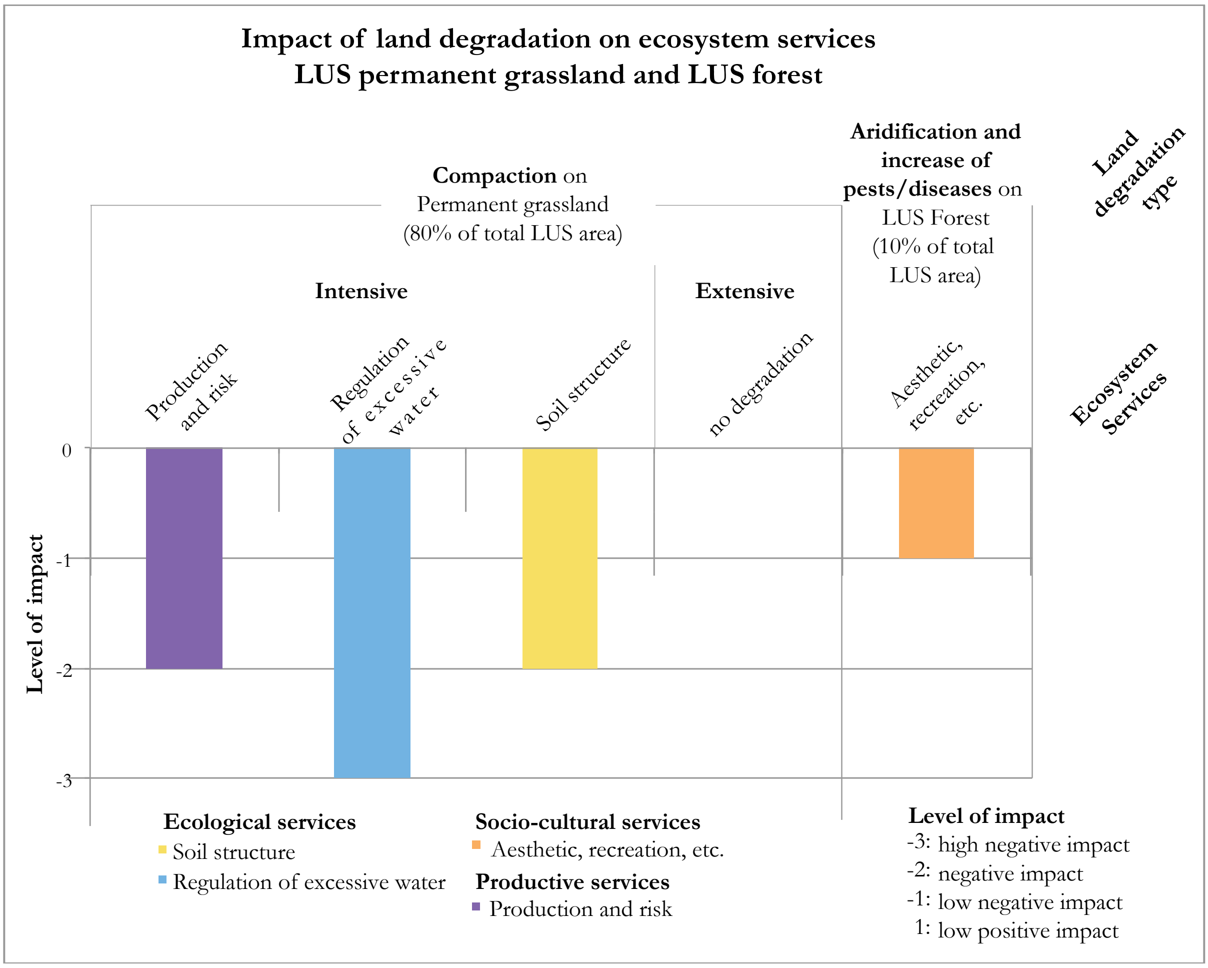

Fig. 30 Study area Frienisberg (BE): Impacts on ecosystem services of the land degradation types affecting LUS permanent grassland and LUS forest. The concerned land degradation and the affected LUS surface (in % of the total LUS area) are specified by the variable "land degradation type" (Illustration: Fedrigo 2016, Data source: WOCAT QM).

As a result of the stakeholder workshop we can observe through Fig. 29 and Fig. 30 that all degradation processes affect ESSs. If we give some attention to the figures, it turns out that there is no mention to the "degree of land degradation", within the assessed land degradation types. This allows us to understand that this variable has no influence on the "level of impact" of land degradation on ESSs. Furthermore, it turns also out that the processes of land degradation only produce negative impacts on ESSs, extending from low (-1) to high negative (-3) impact according to the QM classification.

On both LUS *cropland* and LUS *permanent grassland* ecological services are the most affected by land degradation, particularly the soil structure and the regulation of excessive water. This could be comprehended as a question of priority, considering that the land management concentrates primarily on the maintenance of productive services. As a matter of fact, all types of land degradation affecting these two LUSs have an impact on water, whether by reducing the infiltration capacity through compaction, or by affecting the water quality for consumption through sediment deposition in water bodies. The impact on water quality is further strengthened when the sediment load, reaching the water bodies, is polluted by chemical inputs from agriculture.

Furthermore, caused by processes relating to surface and ground water degradation, biodiversity is particularly affected on LUS *cropland* in terms of quality and quantity. Even though biodiversity declines appear to be an inherent part of industrial agriculture, voluntary ecological non-product dependent direct payments try to counteract these situations (Popp, 2013).

Besides the damaging impacts on public and private infrastructure no socio-cultural service is mentioned at all on LUSs *cropland* and *permanent grassland*. Reasons for this situation may be: that land degradation has effectively only marginal impact on socio-cultural services; that there is a lack of knowledge or interest on these services in the expert group; or that, due to the difficulty to measure and assess the impacts on these services, they are simply being neglected.

The ESSs on LUS *forest* are the least affected, since the only aesthetic and recreational functions of forests are affected. It is of no doubt that forests do have productive, ecological, and socio-cultural values. Dead, sick, or dried-out trees may disturb people when they are hiking or lounging in the forests. However, the mixed forest stock (covering approximately 80% of the LUS area) allows hiding the affected trees in a set of healthy vegetation. As a consequence, Frienisberg's forests may eventually be slightly disadvantaged as a leisure destination if land degradation increases in the future.

3.5.2 Impacts of land conservation on ecosystem services

Fig. 31 and Fig. 32 illustrate the impacts of the land conservation on ESS. Since all the impacts have already been mentioned in preceding sections while discussing the results, the succeeding paragraphs focus only briefly on the most outstanding concerns.

Fist of all, it is remarkable to see how the conservation technologies contribute positively to the changes in ESS. Only one technology (*ext. plough*) on LUS *cropland* affects soil cover and structure negatively (rated as low negative impact, -1). These undesired impacts are easily understandable since, even though no root crops are cultivated, the technology implies recurrent ploughing causing undesirable soil disturbances. These negative impacts support the QM classification for *ext. plough* affirming that the "measures need local adaptation and improvement in order to reduce land degradation to acceptable limits" (rated as low effectiveness, 1).

Two management practices are of particular interest in this context (*ext. mulch* and *ext. no-till*), while all other practices contribute equally only to minor positive changes in ESS (see Fig. 31): Both *ext. mulch* and *ext. no-till* guarantee positive changes in soil cover and structure (rated as positive impact, 2), as they maintain nearly permanent soil cover (expanding over up to 70% of the surface) and they abandon ploughing completely (or allow only strongly reduced and attentive soil disturbance). These cultivation systems are applied while recognizing the values of soils, their life, structure, and functions, helping to regulate and avoid the damaging impacts of excessive water. Well-established soil structures increase the water infiltration capacity and the soil nutrient flow. Lastly, for both technologies the financial statements, detailing the expenditures and the revenues, reveal slight increasing net income rates (rated as low positive impact, 1).

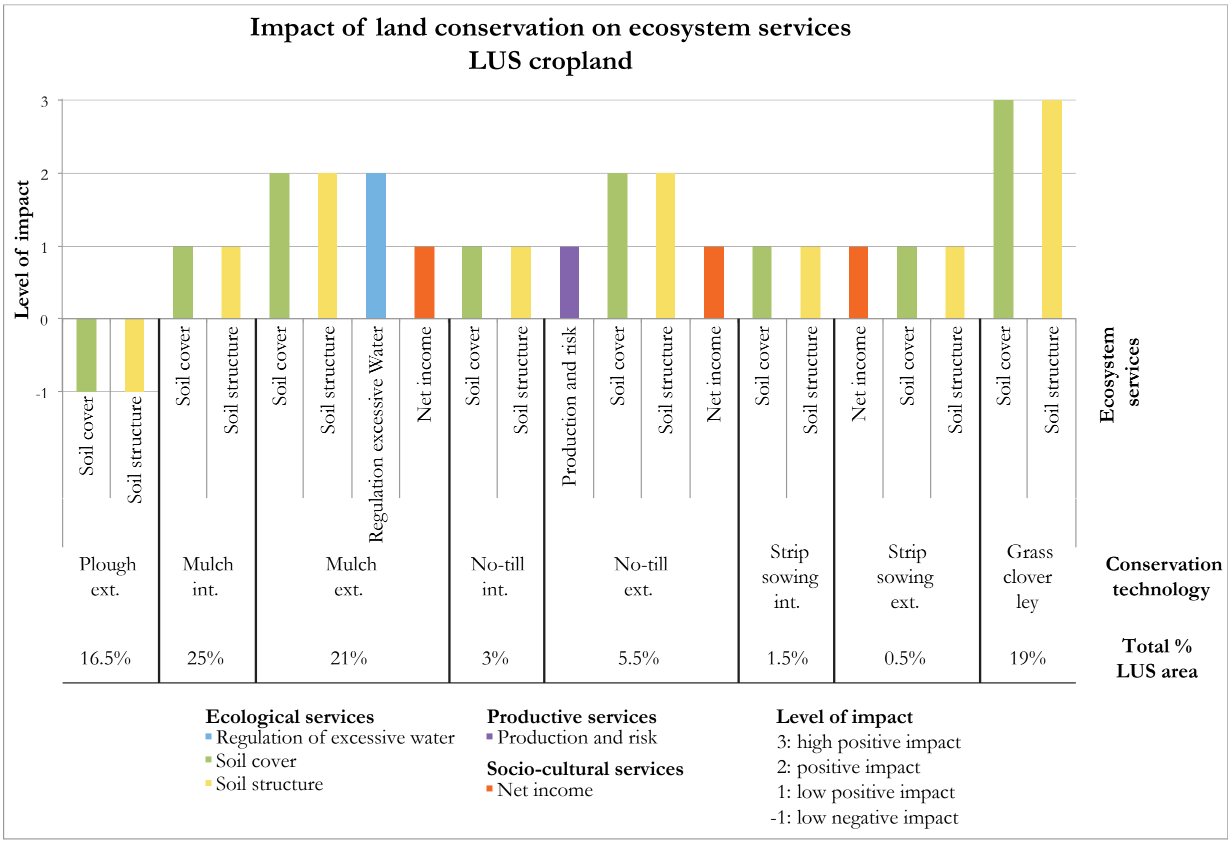

Fig. 31 Study area Frienisberg (BE): Impacts of the applied land conservation technologies on ecosystem services on LUS cropland. The variable "total % LUS area" specifies the extent (in %) of the land conservation technology on the concerned LUS. Note that the reference technology *intensive ploughing* applies on 27% of the total LUS area and that the % of *grass clover ley* is to be understood as extending over the reference technology as well as all conservation technologies (Illustration: Fedrigo 2016, Data source: WOCAT QM).

Additionally on LUS *cropland*, it is noteworthy to mention how all other conservation technologies contribute positively to changes in ecological services, indeed to varying degrees depending on the technology (rated as positive impact varying between low and high, 1 and 3). These positive impacts are particularly encouraging since the conservation practices stimulate some ecological services (soil structure and cover, as well as the regulation of excessive water) and productive services (water quality and production and risk) that are the most affected by land degradation (c.f. Fig. 29 and Fig. 31): All conservation technologies have a positive impact on the soil services that have been deeply affected by *int. ploughing*.

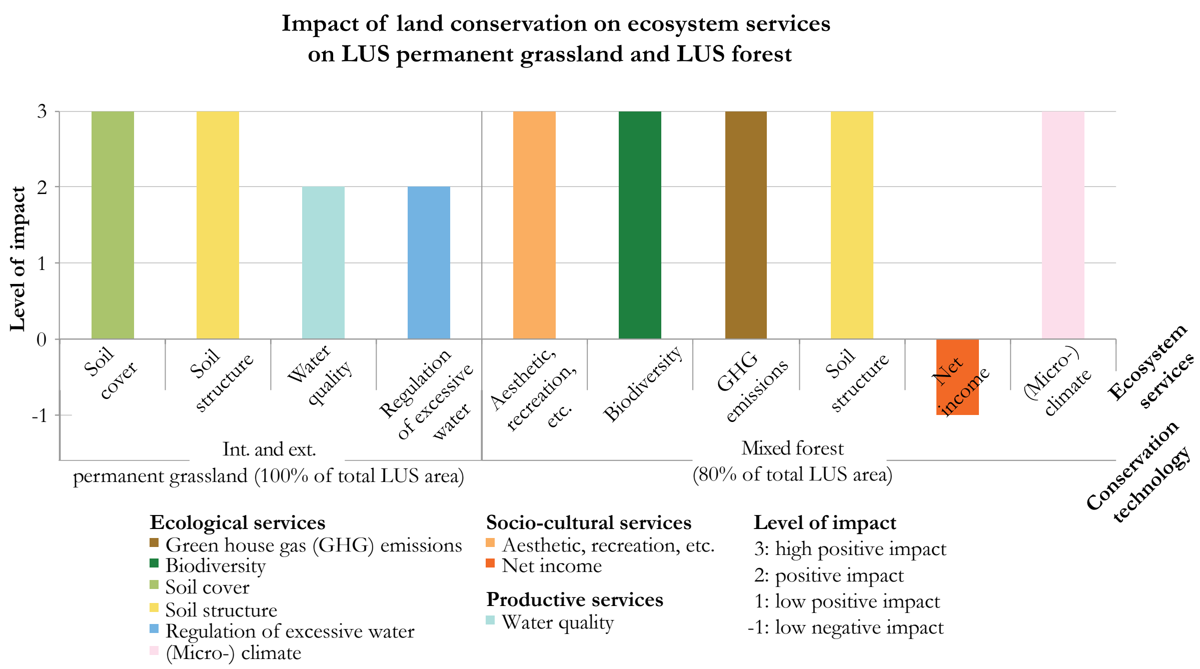

Fig. 32 Study area Frienisberg (BE): Impacts of the implemented land conservation technologies on ecosystem services on LUS permanent grassland and LUS forest. The variable "conservation technology" specifies the land conservation technology and its' extent (in %) on the concerned LUS (Illustration: Fedrigo 2016, Data source: WOCAT QM).

On LUS *permanent grassland*, both *int.* and *ext. grassland* managements have a high positive impact on the soil structure and cover (rated as high positive impact, 3), since they maintain quasi-permanent vegetation cover and do not (or only occasionally) mechanically disturb the soil. Moreover *permanent grassland (int.* and *ext.)* contributes positively to the changes in water quality and to the regulation of excessive volumes (rated as positive impact, 2). It is interesting to note how the negative impacts on soil structure and regulation of excessive water, caused by compaction (QM step 3) on *intensive permanent grassland* (rated respectively as negative and high negative impact, 2 and 3; see Fig. 30), turn into positive impacts when assessing *permanent grassland* as a conservation technology (QM step 4) (rated as positive [for excessive water] and high positive [for the soil structure] impact, 2 and 3). Again, this nuance highlights the significance of the point of view bound to the QM assessment either as conservation technology or as individual LUS: We should note that despite the positive impacts resulting from the conservation technology assessment (QM step 4), it cannot be assumed that no degradation occurs on these lands even though the effectiveness of the conservation technologies is high.

On LUS *forest*, mixed stocks do have highly positive impacts on ESSs. Despite the fact that landowners expect a slight lower net income compared to cash-timber monocultures (rated as low negative impact, 1), the conservation value of *mixed forest* has become undisputable for biodiversity (creating additional habitats), (micro)-climates (disposing micro-conditions), greenhouse gas emissions (admitting carbon sinks), soil structure (through well-developed root systems), and aesthetics (rated as high positive impact, 3). Finally, forests do not only provide timber or recreational spaces, they do also have an important function in providing pure drinking water: They are a water reservoir, a natural filter for water purification, as well as an area for protected water infiltration, since the use of chemicals is prohibited in forests. However, these factors have not been mentioned during the QM assessment and are therefore not shown in the various tables and figures showing the outcomes for the Frienisberg region. Due to time limitations we could not conduct further interviews to examine this issue more deeply.

3.6 Expert recommendations

3.6.1 Cropland

In order to recreate and maintain ideal land properties the experts would recommend the area-wide implementation of the management technologies, which have "delivered the best result"[26] to the questionnaire: *permanent grassland*, *extensive mulch*, *extensive strip sowing*, and *extensive no-till*. However, it is also mentioned that the decision for conservation should be taken freely and they should not be seen as an apology to overlook production. Farmers feel that they have the responsibility to do their utmost to ensure the largest yield, while recognising the need to protect the natural resources. It turns out that sometimes they know what would theoretically be the recommended management practice, but they are pushed by markets, profitability, and by their will to produce, which leads them to act against these recommendations:

The expert recommendations differ in some respects slightly according to the slope category: The production should be intensified on flat areas (slope gradient category (SGC): 0-3%) while

[26] Stakeholder Workshop, discussion held on September 2, 2015, free translation from Swiss-German

encouraging as widely as possible adequate cultivation practices (mulching and reduced tillage technologies) and crop rotations, as well as the conscious use of machinery (e.g. verify tire pressure and load) including the right drive-on period (e.g. verify the adequate soil moisture). On moderately sloped areas (SGC: 3-15%), it is encouraged that the cultures are intensified or extensified depending on the local conditions (e.g. exposure, soil type, soil moisture), while emphasising on locally adapted measures making the best use of the different spatial production potential, encouraging the preservation of natural livelihoods, and reducing the risk exposure. On plots with steep slopes (SGC: 15-30%) the experts recommend also locally adapted measures emphasising on the use of extensive cultivation technologies. Finally, on very steep areas (SGC: >30%) the management intensity must absolutely be reduced whether by converting the patches into permanent grassland or by using *ext. no-till*. It is assumed that some of these precautions are already partially implemented, since there is nearly no cropland on *very steep* plots. Adopting new cultivation systems requires a complete restructuring of the farming strategy, wherewith these recommendations cannot be simply applied without reflecting upon the farming structure, not least because of the cost of the physical capital (Hösl & Strauss, 2016, available online 16 September 2015).

3.6.2 Permanent grassland

In terms of conservation technologies, *permanent grasslands* can be subdivided in different management practices (*intensive* and *extensive*) drafting different degradation controls. The participating actor group considers this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the *extensive* practice avoiding drive-on is particularly recommended.

Since permanent includes cover or nurse (e.g. oats) crops and no agricultural crops in the strict sense it cannot be understood as area-wide strategy, although its' inclusion in the regional agricultural scheme is undisputable. Additionally, the extensification potential of the existing permanent grassland parcels is quite substantial, since only one third of the permanent grassland is under extensive use (details in Annex Table 5). Furthermore, it is highly recommended to apply *extensive permanent grassland* on vulnerable and steep lands, although in Frienisberg the expansion potential is only little. Generally the farmers recognize the vulnerable parcels, unfortunately it is of no small concern that sometimes the economic choice prevails the right action (inter alia they cultivate parcels known at high risk).

3.6.3 Forest

According to the district forester, while adopting a rather pessimistic perspective, it can be argued that *mixed forest* is eventually compromised. Cutting contributions for young tree might lead forest owners to reconsider their forest management strategy. Fact is: trees are of very little economic value as long as the tree-stem diameters do not reach 25 cm and once they exceed 1m width. According to the district forester, the profit can be maximised with large-size 50 cm wide spruce tree monocultures. Noticeably, this solution is of no ecological or socio-cultural value.
Mixed forest reduces the risk of stock loss (e.g. due to pests) but also do reduce economic efficiency. It is therewith noted that mixed stocks can only be maintained in market driven structures as long as the owners are willing to cover the operating costs associated to the conservation practices. Basically, the forest management is controlled by the owners' attitude and conviction and only two restrictions apply to enter the timber market: First, the wood needs to be marked by the district forester and second, the use of chemicals is totally forbidden in the forest.

Schweizer identifies some paths that might help maintaining public confidence in growing mixed forests, inter alia, restoring contributions for young tree care (*Jungwaldpflege Förderbeiträge* in German). These government funds are intended to facilitate natural forestland rejuvenation, create a balanced age structure in the tree composition, promote species composition and biodiversity with respect to location specificity, and protect soils and vegetation (Volkswirtschaftsdirektion des Kantons Bern, 2012). In comparison with the amounts disbursed for agricultural direct payments, only little contributions would be necessary to make an important impact. Political choices and strategies control whether such finances are to be allocated to woodland, or whether they are concentrated on other priorities. The district farmer feels that the general public plays a specific role in this issue: Public opinion must show interest in topics related to forest management and call for a political claim. Otherwise, when facing the landowners, it may become difficult for the foresters to keep interest alive and defend ecological management.
Exposed to market pressure and subject to intensification and profitability, not only the ecological (e.g. provision of pure drinking water, carbon storage, biodiversity enhancement) but also socio-cultural (e.g. recreational and relaxation area) functions of forestlands are at risk, also in state-owned forests (they are also expected to be lucrative, or at least cost covering).
The question is therefore:

> "Do we see an inconvenience saying that only the forest owners must support the socio-cultural and ecological achievements without any government support?"[27]

Once the forest has to be profitable, immediately there are fewer margins for conservation. Only conviction brands decisions. It appears recurrently that Frienisberg's architects or constructors deliberately opt for German timber, which it is cheaper and can be imported already cut and processed, endangering the viability of the region's wood market. Thus, according to the district forester, a clear political statement needs to be engaged upholding the ecological, socio-cultural, and economic value of local timber production.

[27] Discussion held with Mr. Rudolf Schweizer, district forester, interviewed September 14, 2015, free translation from Swiss-German

Part Four

Synthesis and Outlooks

4 Reflexions and recommendations

4.1 Synthesis

The following section includes the most significant outcomes of the WOCAT QM assessment presented in part three. In coherence with the goal and the objectives set out in section 1.5 it summarises the LUSs with substantial degradation, in terms of extent, degree, and rate, the impacts on ESS, as well as the LUS with the most effective conservation practices. This exercise allows the identification of problem areas as well as the proposal of suitable conservation measures adapted to the local conditions. Without questioning any statement, it might be worthwhile noting that the stakeholder involved might be slightly biased by their function. The multi-actor perspective can reduce these inevitable biases involved in working with peoples perceptions.

4.1.1 Cropland

Many degradation studies, principally focusing on soil erosion, have been performed throughout the years in Frienisberg. The creation of first contacts and finally the institution of a trust-network strengthens the choice of the study site, underpinned by a wide-ranging cooperation of distinctive groups of actors and the existence of diversified farming operations (cultivation systems) established in the region over the decades. Ideally, in order to fully and individually understand their impacts on the land, each cultivation system would have been assessed as independent LUS. Unfortunately, due to lacking data availability and insufficient coherency in the practice, the systems are understood and evaluated as conservation/SML technologies.

However, reliable information about land degradation, *what* arises, *where* it occurs, as well as to what *extent* and *intensity*, in order to address the damaged areas properly or to prevent further degradation was assembled and created. While processing the data produced and collected through the questionnaire it could be reconfirmed that, in Frienisberg, the agricultural land and more particularly LUS *cropland* is prone to degradation. Despite the known risks when practicing high-input and heavily mechanised agriculture, *ploughing* (*intensive* and *extensive*) remains the most common practice in Frienisberg. More than a dozen land degradation processes could be identified in the region's LUS *cropland* (see Table 10). It is reassuring to know that only three degradation types were retained as significant and thus documented. Though expressed in different extents and intensities they are the most important constraints on agricultural land: surface erosion, compaction, and surface and ground water degradation.

Even though surface erosion and surface and ground water degradation are not assessed as a combination these degradation types are closely related, since water degradation is often associated to pollution through the transport of sediments. The questionnaire outcomes clearly confirm this causal link is clearly (documented in section 3.3.2): These degradation types, either one or in combination, affect roughly 12% of the cropland area, fortunately with decreasing intensity trend. Plots with *moderate* (3-15%) and *steep* (15-30%) slope gradients are more affected by surface erosion and surface and ground water degradation, while almost no such processes occur on *flat* (0-3%) and *steep* (>30%) parcels (shown in Fig. 16 and Fig. 18). This confirms the recognition of the relief (principally the slope) as being one major influencing factor for soil erosion on farmland (Chisholm, 2008). For both degradation types, the issues raised are the failure to adopt appropriate land management (alert to site-specificity, the use of heavy machinery, the tillage practice, the shape, size, and arrangement of parcels, etc.) as well as socio-economic constraints, such as the appeal for economic efficiency (market pressure), the labour costs, as well as the requirements and incentives from the government (e.g. ecological intensification). It is worth noting that the rate of degradation could be reduced with regard to surface erosion and water degradation, despite the increasing LUS intensity and the decreasing area trend. It is acknowledged how on-field conservation actions, such as the "slope subdivision through a field seam", can be effective in reducing surface erosion and soil loss on the plots as well as their offsite effects on settlement areas (D. Niggli, 2015c).

Recognizing the threats of *conventional, high-input intensive ploughing* the farmers and local actors develop land management strategies to reduce surface erosion, compaction, and surface and ground water degradation. Summarized, the conservation technologies extend over roughly 73% of the cropland area (see Annex Fig. 2 for the detailed results for each mapping unit), although *extensive ploughing* has almost no conservation value (see Table 17 for the QM outcomes). Excluding *extensive ploughing*, the conservation technologies attain approximately 56% of the surface area, which is a remarkable result. Decisively, positive effects can be retained from the conservation technologies, mitigating and preventing soil erosion and surface and ground water degradation, and with a little restraint in respect of compaction, since all technologies, with the exception of *int. mulch*, "control the land degradation problems appropriately" (all rated as high and very high effectiveness, 3 and 4).

The expert group gives special attention to the compaction issues in the study area, which is an ongoing process occurring in all cultivation systems and conservation technologies, though at different degrees (see Fig. 17). Despite the measures taken by the farmers to mitigate land degradation, compaction remains a major issue for high-input, mechanized agriculture, especially since it affects all areas in use (100% of the *cropland* area) with an increasing trend (rated as slowly increasing land degradation, 1) (Table 12). Five conservation technologies (*ext. mulch*, *int.* and *ext. no-till*, and *int.* and *ext. strip sowing*) documented in this study manage to reduce the degree of compaction *in-plot* significantly: according to the QM classification "there are some indications of degradation, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts" (rated as light degradation degree, 1). Unfortunately, only two out of these (*no-till ext.* and *strip-till ext.*) mange to reduce the degree of compaction *on headlands*, since according to the QM classification "degradation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degree of degradation, 2).

Using conservation technologies farmers take numerous actions to reduce the risks and minimize the variability: by reducing the soil movement while implementing conservation practices (e.g. *ext. no-till* and reduced tillage systems with mulch cover/*ext. mulching*); by considering the topography while organising the shape, size, and orientation of the plots (recurrently mentioned as a cause of land degradation); by encouraging farmland management with crop rotations reducing erosion risk, increasing water infiltration capacity, and improving soil structure stability (e.g. *grass clover ley*: "the longer the better for soil protection"[28]); by avoiding root crops (termed *extensive* land management in this study) especially on sloped lands; by converting problem zones into plots under permanent grassland, reducing runoff, increasing water infiltration, and maintaining good soil structure; by growing shelterbelts gathering up dispersed flow and mitigating soil erosion; and by running conscious drive-on (knowledge-building strategies) to reduce soil compaction (i.e. diminish amount and unnecessary drive-on, reduce machinery weight, distribute weight ideally, increase the contact surface between soil and tyres). There are some parallels here with the results in Prasuhn (2011), who accredit the absence of erosion to a valuable soil structure and enough soil cover, obtained thanks to favourable site properties (relief, soil), crop rotations, conservation tillage, and the presence of temporary grass-clover leys.

In an effort of identifying **bright spots** two technologies (extending over 26.5% of the total LUS area) are to mention: *ext. no-till* and *ext. mulch*. The support programme soil (*Förderprogramm Boden* in German) of the canton of Bern involves the promotion of these practices, among other soil conserving technologies. According to the QM classification *ext. much* allows to "control the land degradation problems appropriately" (rated as high effectiveness, 3) and *ext. no-till* "even [to]

[28] Stakeholder Workshop, discussion held on September 2, 2015, free translation from Swiss-German

improve the situation compared to the situation before degradation occurred" (rated as very high effectiveness, 4). While all conservation technologies have a positive impact on the **soil services** soil cover and soil structure (rated as low positive impact, 1), additionally *ext. no-till* has a positive impact on the net income, as well as on the production and risk (rated as low positive impact, 1), whereas *ext. mulch* has also a positive impact on the net income and on the regulation of excessive water (rated as low positive impact, 1) (more details in Fig. 31). Even if conservation agriculture fails in preventing land degradation entirely (Grob, 2010), many authors consider *no-tillage* as a possible path towards a more sustainable agriculture, creating for instance significantly lower erosion charges (Chervet et al., 2005; Montgomery, 2007), with erosion values that may be close to soil production rates (Montgomery, 2007). These results my be expanded by those published in Prasuhn & Weisskopf (2003) for the Bernese lowlands showing that barely any soil loss is identified on areas with applied *no-till* and *mulch*. Additionally, willing to reduce soil pollution and surface water deterioration on plots under *no-till* management, farmers make efforts to reduce the use of herbicides through targeted application and improved safety e.g. while singing washing (D. Niggli, 2015b).

However, despite these efforts made, the expert group acknowledges some socio-economic factors as reasons compelling an area-wide conversion towards more preventing practices, for instance: market pressure and impatience, labour costs and availability, both the lack of knowledge and training on how to use the machinery, as well as upholding traditions. Thus, it needs to be emphasised on the farmers calling on civil society to take responsibility for appropriate land management:

> "We [everyone] need to be involved and responsible for what is happening in the fields."[29]

These explicit words are spoken during the stakeholder workshop. They call for collective responsibility, a fundamental concern that is also expressed by the WOCAT initiators. Not only the farmers, the scientists, or the decision makers, but also the people individually (e.g. consumers, etc.) and the society as an entity (i.e. public awareness) need to feel responsible for mitigating land degradation and participating in structuring a sustainable and appropriate agricultural production. As it has been repeatedly mentioned how Frienisberg's farms are subject to intensification and highly exposed to market pressure and fluctuations (e.g. contract conditions request harvesting at some point in time with no regard for environmental conditions).

[29] Stakeholder Workshop, discussion held on September 2, 2015, free translation from Swiss-German

Additionally, the functional conditioning, expressed in high-input agriculture (e.g. dependence on fossil resources for both synthetic inputs and severe mechanisation) and high labour costs, fosters the pressure on the land.

> "I would love to remove weeds by hand, but the high labour costs make it unattainable in practice."[30]

The arrangements of today's societies and agribusinesses make concrete conservation actions, reflecting long-term feasibility and calling for structural change, nearly impossible, unless the farmers can at least count on committed community members and partners. Exactly while taking this societal responsibility and structuring a more viable production system, alternative social, societal, and business models emerge, notably as presented by the network *soliTerre* in Bern (Spoerri, 2010). Willing to hear the requests formulated by the participants during the stakeholder workshops and to truly mitigate the problems that Frienisberg's farmers are facing, I believe in the need to strengthen research on the potentials of such community-based, social, and ecological agro-systems, combined with the benefits of organic production, in creating a sustainable agriculture in Frienisberg and the Switzerland (further discussed in the concluding section 4.2.2).

4.1.2 Permanent grassland

Permanent grassland is accepted as a totally practicable system when referring to land degradation and conservation. With the exception of problems of compaction in systems under *intensive* management (principally caused by frequent drive-on) no evidence suggesting surface erosion as well as surface and ground water degradation is perceivable on permanent grassland. Even though 100% of the permanent grassland under *intensive* management is affected by compaction, the impacts are less adverse *in-plot* than *on headland*: while the QM classification of the land *in-plot* indicates that "degradation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degree, 2), on *headlands* it specifies: "evident signs of degradation. Changes in land properties are significant and very difficult to restore within reasonable time limits" (rated as high degree, 3).
Despite its conservation value it is not imaginable converting all LUS *cropland* neither in *extensive* (rated as very high effectiveness, 4) nor in *intensive permanent grassland* (rated as high effectiveness, 3). However, the QM outcomes may suggest that it would be desirable converting steeper and risk areas (belonging to the slope gradient categories: >15% steepness) into *permanent grassland*

[30] Stakeholder Workshop, discussion held on September 2, 2015, free translation from Swiss-German

while keeping flatter zones with valuable and nutrient rich soils for *cropland* (*ext. mulching*, *ext. no-till*, or *ext. strip-till*).

4.1.3 Forest

Relatively little wooden areas are affected by the land degradation: the combination of aridification and increasing pests/diseases extends over 10% of the LUS *forest* and the degradation is classified as "apparent, but its control and full rehabilitation of the land is still possible with considerable efforts" (rated as moderate degree, 2). Unfortunately, the land degradation has been increasing over the observation period 2005-2015 (rated as slow increasing rate of land degradation, 1). According to the district forester, the principal direct causes of land degradation appear to be natural or related to the changing climate (mentioned variables: droughts, changes in temperature, and changes in seasonal rainfall), while the indirect causes more closely tight to population pressure, consumption patterns, and government policies (abolishment of contributions for young trees).

However, the questionnaire outcomes, which allow us to believe that Frienisberg's forests are in a general "healthy" state in view of land degradation, are to be attributed to the effectiveness of the conservation technology *mixed forest* (rated as high effectiveness, 3) extending over approximately 80% of the LUS area. Cultivating mixed forest stocks, including various levels of vegetation, foresters manage to create less vulnerable, more resilient, as well as more drought- and pest-resistant forests notably through their larger and better-branched root systems. Using this technology the diffusion of the bark beetle could be reduced by up to 65%. Although further action is necessary to fight, inter alia, other life threatening pests and diseases, the conservation measure has "a growing positive impact on the reduction of degradation" (rated as increase in effectiveness, 1).

Despite the above, and in view of the increasing impact of a changing climate (expecting more frequent and dryer summers coupled with milder winters) together with increasing market pressure, the expert is a little concerned about the future: The combination of highly complex property regimes (hundreds of private owners only in Frienisberg), the call for forests to be profitable or self-founded, highly pressuring and fluctuating global markets, the absence of public founding, and the marginal interest given by the landowners (who generally own forests as sideline business) make woodland management difficult and forests vulnerable.

Since forests are not only of economic but also of ecological, social, and recreational value, the expert calls for the sense of collective enlightenment. He believes that if the public is aware of the challenges faced by the foresters it might consider accessing and mobilizing funds for protective forest management. Only little capitals are needed to ensure long lasting and effective management, assuring the ecological, economic, cultural, and social values of forests.

4.2 Limits and perspectives

4.2.1 Methodological thoughts and restrictions

This study represents the first attempt to examine Switzerland's midlands using the effective WOCAT QM. Some thoughts illustrating the strengths of the method and the limitations raised during the assessment are discussed in the following paragraphs.

First of all, stakeholders' implication is essential, their knowledge and determination contributing to a more sustainable and viable agriculture is crucial. Frienisberg's farmers and local stakeholders feel concerned by the land, and fortunately they also feel involved in partaking to seek transdisciplinary, participatory processes. As intended by the QM, these experts with a broad and diverse understanding of the region are solicited for the research process.

It has to be noted, that the establishment of truly participative, actor-oriented, and non-hierarchical research processes, requires real commitment and profound social embeddedness. Thus, it goes without saying that one master thesis does not dispose of enough capital to provide this safe framework on its own, and that the intention to create a participatory and transdisciplinary process within the unique scope of one master thesis is certainly too ambitious. The cross-sectional bonds and collaborations between science and society cannot emerge from a one-year master thesis. Fortunately, we are privileged to work with a region where sincere collaboration and networks of trust gradually set in place over more than two decades. Longstanding and close relationships exist between society and science in Frienisberg creating favourable preconditions for transdisciplinary research. This study builds on, and is par of, an existing partnership between local practitioners and professional researchers in Frienisberg. Hence, participation is of concern all along the research process, even though the developments transpiring prior and after, shaping the framework for participation research, exceed the capacities of this thesis.

In the first instance, the QM emphases on the situational analysis, while establishing an overview of the place as perceived by local actors. Given that all data emerged in an inclusive context, the maps may be considered as an illustration of the collective knowledge among key actors willing to engage in dialogue, intentioned without creating a hierarchy of experience or understanding. Even thought the experiences gained during the stakeholder workshop could be further reinforced involving more contributing actors, it has been agreed, since many regional actors are already involved in the RECARE project, or in other studies conducted by the University of Bern in and around Frienisberg, not to extend any further the persons solicited for the this study, in order to prevent the establishment of a general feeling of over-participation. This reasoning arose due to the understanding that many local community members recognise how research is desirable, however they cannot make themselves incessantly available[31]. Thus, the fear of stimulating a sensation of over-participation, or worse over-research (which would mean that the local actors would have been regarded as the research topic rather than research partners), sustained the necessity to limit community attendance to the minimum necessary in order to meet the set research objectives. Both, the number of workshop participants and the number of workshops have therefore been kept to a strict minimum. In light of these issues, the participation of key actors in this one-day workshop is taking on an essential dimension, since both, the local practitioners and the SLM/SWC specialists are unconditional to the research process and to its successful accomplishment. Supported by the existing, solid partnership, a complementary, experienced, and specialized research team, with great knowledge on both the region and the occurring processes, is shaped on the commitment for adapted and viable development of the area. In fact, the functioning of the one-day workshop and the exchange of knowledge and experience has been highly appreciated by the expert group, which collected and produced in their view satisfactory data.

Secondly, the choice of the relatively small perimeter, legitimated by the shape of Switzerland's agricultural landscape and the extensive presence of alternative cultivation methods to the reference technology *intensive, high-input ploughing* in Frienisberg (BE), is reasoned by the meaning to give a detailed and precise picture of the current situation in terms of land management and degradation/conservation. In the first instance, ambitioning to subdivide the agricultural land by cultivation system (i.e. ploughing, no-tillage, mulching, strip seeding), I was looking for data to localise these systems area-wide. Unfortunately, this information is not readily available from any database, nor can it be easily generated. Desiring to pursue this option I printed a high-resolution aerial photograph showing all cultivation plots. With a large-format printing of this photograph, I met several of the local farmers hoping to identify the management practices to the accuracy of the cultivation plots. It goes without saying that this is a long-range effort, given that the study area includes more than 6'000 cultivation plots. Rapidly two difficulties emerge: First, fearing the implications of misleading or false information most farmers do not wish to comment on the

[31] Feelings expressed in preliminary telephone conversations. Feelings of over-participation or over-research where expressed by a certain number of respondents. It goes without saying that the discussions were not recorded and are therefore not documented in this master thesis.

plots they do not own or farm themselves. They fear that false information on the land management may lead to legal implications if it turns out that it does not fit with the information given for direct payments/government subsidies. To rectify this situation they advise me to consult all concerned local farmers; involving a far too heavy workload, this is not an option. In response to the farmers fear it is a conscious choice not to create any map illustrating or localising the land conservation technologies. Secondly, the farmers have been repeating that mostly the cultivation systems are not strictly bound to defined farming plots. The field sizes, shapes, and arrangements may change from one year to the next, as well as the applied cultivation systems, making meticulous and reliable spatial localisation impossible. So, due to the lack of available data, which could not be compensated by the production of new data, the discrete land management practices (cultivation systems on LUS *cropland*) could not be localized spatially, which would have been a prerequisite for the them to be documented as particular LUSs. Thus, in response to these constraints, proper land use systems are reduced to *conservation technologies*.

The WOCAT QM comprehends conservation technologies as measures addressing degradation, with the purposes of prevention, mitigation, and rehabilitation confined to one or more LUS. Instead of being considered as independently moving and evolving systems, defined as "conservation technologies" the cultivation systems are responses to reduce the extents, degrees, and rates of land degradation, ideally by addressing causes. Even though the information obtained through the QM is useful, the method will not allow differentiating practical knowledge relating to the land degradation on conservation areas. During the stakeholder workshop, the expert group sees the information on land degradation on areas conservation practices as important wherewith more precise information on compaction across all conservation technologies used on cropland has been documented on their initiative. For the future, it could be interesting, while revisiting the QM, reflecting on how to systematise the documentation of this knowledge during the QM assessment. This recommendation should be construed as a response to the concerns expressed by the workshop participants, desiring also information on land degradation on areas under conservation, and by the local community members, feeling over-participation. However, emphasis on a more detailed analysis of the conservation technologies is given by the questionnaires on technologies (QT) and approaches (QA). In Frienisberg, Deborah Niggli has focused on these questionnaires as part of her bachelor thesis but, for reasons of scheduling, her results are entirely included in this thesis.

4.2.2 Concluding thoughts

This work concludes with some thoughts for further reflexions on appropriate, long-term visions of agriculture.

4.2.2.1 Organic farming and combination of cultures

With rising awareness about the importance of factors, such as the soil fertility maintenance or the ecological concerns when using industrially synthetised fertilisers, alternatives reinforce. Attentive to the practitioners and experts opinion the industrial farming practices have been considered indiscriminately, even though, when compared with conventional, high-input agriculture, some benefits of organic farming could be discussed. Although incomplete, the following paragraphs are used to report a brief introduction to organic farming.

Organic farming sustains a multi-functional perception of agriculture, by creating, cultivating products and attending ethical issues (e.g. principles of animal welfare) (Harper & Makatouni, 2002; U. Niggli, 2015a). Driven by the will to manage the plentiful pool of organic material, providing plant nutrients, as well as increasing soil stability and the adaptive capacity through established humus fractions, organic farmers extend their management. Some may include livestock in the crop production, wherewith on-farm manure can be provided, while integrating grass-cover lays in the crop rotation permits roughage fodder production for ruminants, nitrogen fixation for succeeding crops, and improvement of soil physical properties. Others may practice intercropping or mixed cropping that, while including cereals, legumes, maize, and other crops, assures persistent soil protection and momentary nutrient fixation, particularly throughout the winter period (U. Niggli, 2015b). Thus, in order to avoid spreading chemicals, organic agriculture, and much more agroecological farming, includes systemic recycling of organic material and residues in their production cycle (Bourguignon & Bourguignon, 2008). By avoiding chemicals and synthetic inputs, and encouraging systemic recycling organic farming reduces also the dependence on fossil fuels, which brings us back to the reflections on sustainable land management (see section 2.1.1).

In Switzerland ecological compensation areas (e.g. hedgerows, extensive grassland, or field margins with flowers) and specific agro-environmental measures are much more cost-effective when realized on organic agro-ecosystems compared to conventional, high-input farms (U. Niggli, 2015a). This statement is supported by the numerous advantages that could be revealed on organic farms, notably higher species diversity and broader richness of both flora and fauna caused principally by the absence of herbicides, pesticides, and fast-release fertilisers, as well as by varied crop rotation and sufficient semi-natural (conservation) areas alleviating also pest populations. Higher soil fertility and more stable physical properties are found on land under organic management, encouraged by great bacteria, fungi, earthworms and insect populations building stable soil aggregates. Thus, according to Niggli (2015a, 2015b) organic farming might lead per se to soil conservation and structuring soil fertility, by reducing the disturbance of many

of the regulating soil functions, as well as off-site effects such as nitrogen leaching, which are less expected to occur, as no synthetic fertilizers are applied. Moreover, since many soil fertility-building techniques, notably fertilisation by animal manure, diversifying crop rotations introducing leguminous plants as well as grass and cover leys for ruminants, or composted harvest residues, used in organic agriculture are effective methods to increase carbon sequestration. Due to higher aggregate stability, the reduction of soil erodibility is also expected in organic systems (Siegrist et al., 1998) and without noticeable yield loss despite increasing weeds when, in addition, the system is under reduced tillage (Armengot et al., 2015). The combination of no-till, or at least reduced tillage, and organic agriculture is considered of high potential in further increasing carbon sequestration: By renouncing to return the field, and instead preparing the seedbed in a soil loosening process with a chisel plough (*Grubber* in German), the experiment held in Switzerland allowed an increasing sequestration rate of nearly 900 kg C/ha (Gadermaier, Berner, Fliessbach, Friedel, & Mäder, 2012).
In spite of these advantages, challenges mitigating the diffusion of organic farming the difficulty remain in the management of undesired weeds, or in the barriers preventing people from looking into these issues more deeply. Therefore it appears quite appropriate to suggest the promotion of structures encouraging more social commitment and labour availability and to reinvigorate that universities, national institutes, and government funds devote intense research attention and programs to phytosociology, agro-ecology, permaculture, organic farming, and community-supported agriculture. Joining knowledge, application, and action, the on-field combinations of annuals and perennials grouped with community-supported structures (discussed in the following section 4.2.2.2) may represent a viable vision for the future.

4.2.2.2 Community-supported agriculture

All across the world smallholder farmers are forced to leave their lands, expelled by the ruthlessness of the global market secured by the dictatorship of worldwide finance capital (Ziegler, 2014). Spanning over only few decades, free trade has driven family farms and smallholder farmers to the point of hopelessness, in both countries of the *South* and the *North* (Henderson, 2010).

> "The definite choice of micro-economics is the only power to make every citizen an economic actor." (Rabhi, 2009, p. 28, free translation)

Although, in Frienisberg the situation can truly not be regarded as dramatic as elsewhere, the constraining market pressure and the highly pressuring mechanised production have been mentioned repeatedly throughout the stakeholder workshop discussion on land degradation. Reacting to market constraints, farmers act out of full consciousness: repeatedly, and in clear violation with their moral tenets and beliefs, they take fully informed decisions in the knowledge that some will seriously affect the health of their lands.

> "We [everyone] need to be involved and responsible for what is happening in the fields."[32]

Or

> "I would love to remove weeds by hand, but the high labour costs make it unattainable in practice."[33]

To echo these words expressed during the stakeholder workshop – maintaining firmly that not only the farmers are accountable for the good management practices but also the society collectively and every resident individually – we must contribute consciously to and support structural changes in agriculture. Changes that shall contribute in creating just, ecological, and socially conscious agro-ecosystems, or social-ecological systems, in which humans involve and use groups of plants, animals, as well as their biophysical milieu and their interactions (van Apeldoorn et al., 2011). It has been demonstrated that, next to the physical, biological, and chemical aspects of the landscape, degradation processes are also closely linked to socio-cultural and economic issues. In order to breach these forces leading to land degradation and related issues, alternative models have emerged, including in particular community-supported agriculture, that can be considered as an association of people around a farm willing to resist the overriding food industry through their comportment and feeding patterns, while inspiring larger independence and tangible choices in the food selection (DeLind & Ferguson, 1999).

> "Direct marketing methods, especially those operating on the community supported agriculture model, help foster a consumer recognition of the link between production and consumption." (Heller & Keoleian, 2003, p. 1035)

By creating joint farmer-consumer networks, community-supported agriculture strives the quality of the food resource and the empowerment and subsistence of smallholders (Cone & Myhre, 2000; Cooley & Lass, 1998). The monetary value established for the commercialised product must assure both production charges and on-site salaries, and consequently comfort decent livelihood insurance for agriculturalists and farm workers (Horváth, 2013). Overproduction must

[32] Stakeholder Workshop, discussion held on September 2, 2015, free translation from Swiss-German
[33] Ibid.

be prevented and in case of poor harvest, the risks are shared between producers and consumers. Essentially, community-supported agriculture reviews the negotiation of life quality and criticizes established paradigms such as infinite growth and production, unconstrained consumption, and relentless economic rationality. These structures are expected to induce community-building paths that may precisely enable potentials for getting around some difficulties inducing land degradation mentioned during the stakeholder workshop (e.g. referring to market pressure and market exposure, heavy machinery) since they do not only increase interaction between people sensitive to the agricultural cause, they do also generate potentially new markets for farm products (through direct marketing methods) and labour forces (network-community participation), and eventually build new social capital (Sharp, Imerman, & Peters, 2002).

> "…the power to socially construct new identities, to create democratic spaces for autonomous social action, and to reinterpret norms and reshape institutions" (Cohen, 1985, p. 690 quoted in DeLind & Ferguson, 1999).

While interrogating how we relate to others (in local and global perspectives), to the food, to the agribusiness, to the environment we live in, or just to the will conveyed by the agricultural policy community-based networks are exposed as a viable solution, eventually aspiring profound questionings of the value system. Productive agricultural systems must internalise the interactions between agriculture and ecosystem services in order to become truly sustainable and to overcome their dependence on non-renewable resources. Thus, the results of the QM assessment, supported by discussions held during workshops and during informal exchanges in prior preparation, lead to the following outlook: Community solicitation is desired, collective awareness-building is wanted, structural and societal change involving community participation is required and necessary to succeed, in both agriculture and forestry. While emphasizing on transdisciplinary and participation, I believe in the necessity to encourage research in order to give scientific ground to such bottom-up initiatives.

To make reference to the words of Fukuoka:

> "[…] a farmer would also have plenty of time for leisure and social activities within the village community. I think this is the most direct path toward making this country [Japan] a happy, pleasant land." (Fukuoka, Berry, & Lamothe, 2005, p. 135)

Denn die einen sind im Dunkeln,

Und die andern sind im Licht.

Und man siehet die im Lichte,

Die im Dunkeln sieht man nicht.[34]

Bertold Brecht

[34] Brecht, Bertold (1928, premiered in Berlin). *Die Dreigroschenoper* (*The Threepenny Opera* in Englisch). In English (1954 Mark Blitzstein translation): "There are some who are in darkness, and the others are in light. And you see the ones in brightness, those in darkness drop from sight." Quoted in: Armstrong, Louis, "*A theme from the Threepenny Opera (Mack the Knife)"*, Single, Columbia Records, 1956.

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Annex 1 Tables and figures

Properties	Mapping element [productivity]			
	Very good (red)	*Good (blue)*	*Moderate (yellow)*	*Unsuitable (grey)*
Agricultural suitability (c.f. Fig. 3)	Very suitable for cultivation of grain or cereals and fodder, suitable for root and field crop	Suitable for "natural" fodder leys, moderately suitable "artificial" fodder leys	Suitable for "natural" fodder leys, moderately suitable "artificial" fodder leys	Very suitable for young cattle pasture, suitable for "natural" fodder leys, and moderately suitable for cattle pasture
Slope	< 25%	< 25%	< 25%	Ø > 25%
Occurring soil types	Mostly Braunerde (B), Saure Braunerde (SB), Parabraunerde (PB), and Kalkbraunerde (KB) (WRB: *Cambisols* or *Brunic Arenosols)*, partly Braunerde-Gley (BGl), Buntgley (BG), Fahlgley (FG), Regosol (RS), Fluvisol (FS) and Halbmoor (HM)			
Soil depths	B moderately to very deep, BGl mod. to deep, BG mod. deep, FG mod. deep, HM mod. deep, KB relat. shallow to mod. deep, PB deep to very deep, SB mod. deep to very deep.	B mod. deep to deep, KB mod. deep to very deep, PB deep, SB deep to very deep	B shallow to very deep, BGl mod. to deep, BG relat. shallow to deep, and HM relat. shallow to mod. deep	B relat. shallow to deep, BGl unlevied, BG mod. deep, FG unlevied, FS unlevied, KB relat. shallow to very deep, RS unlevied, SB mod. to very deep
Soil permeability	Normal	Excessive to normal	Very slow	Slow
Nutrient storage capacity	Good	Low	Good	Low
Root penetration depth	Deep	Deep	Superficial	Superficial

Annex Table 1 Soil properties of the area of interest. Data source: © swisstopo and © Bau, Verkehrs- und Energiedirektion des Kantons Bern (Geoportal).

a) Name	**b) Group**	**c) Measure**	**d) Purpose**	**f) Addr. degr.**	**g) Eff.**	**h) Eff. trend**	**i) Impact on ESS**	**j) Period**	**l) Comm.**
Plough (ext.)	OT	M2	P, M	Wt Pc Hq, Hp	0-1	0	-1: E5, E4	Prev. 1900	OT: no root crops
Mulching (int.)	CA, OT	A1, M2	P, M	Wt Pc Hq, Hp	2	1	1: E5, E4	1955 / 60	OT: CA but root crops
Mulching (ext.)	CA	A1, M2	P, M	Wt Pc Hq, Hp	3	0	1: S6 2: E1, E5, E4	Prev. 1900	
No-tillage (int.)	CA, OT	A1, M2	P, M	Wt Pc Hq, Hp	4	0	1: E5, E4	1993	Root crops
No-tillage (ext.)	CA	A1, M2	P, M	Wt Pc Hq, Hp	4	0	1: P1, S6 2: E5, E4	1993	
Strip sowing (int.)	(PR) (CA)	M2	P, M	Wt Pc Hq, Hp	4	0	1: E5, E4	1990	Root crops
Strip sowing	(PR) (CA)	M2	P, M	Wt Pc	4	0	1: S6, E5, E4	1990	

(ext.)				Hq, Hp					
Grass clover ley (int)	(GR)	V2	P, M, R	Wt Pc	3	0	3: E5, E4	Prev. 1900	
Grass clover ley (ext.)	GR, SA	V2	P, M, R	Wt Pc	4	0	2: E1, P2 3: E4, E5	Prev. 1900	P2: Water quality
Perm. grassland (int.)	GR, SA	V2	P, M, R	Wt Pc	3	0	2: E1, P2 3: E4, E5	Prev. 1900	
Perm. grassland (ext.)	GR, SA, CO	V2	P, M, R	Wt Pc	4	0	2: E1, P2 3: E4, E5	Prev. 1900	P2: Water quality

Annex Table 2 Stakeholder workshop outcomes from the assessment of the conservation technologies within the study area Frienisberg (BE). The data presented in this table applies to all slope categories. Abbreviations according to the QM (Liniger et al., 2008) (Data source: WOCAT QM)

Land management practice	**Compaction on headland**	**Compaction in-plot area**
Ploughing intensive	Extreme (4)	Moderate (2)
Ploughing extensive	Strong (3)	Moderate (2)
Mulching intensive	Strong (3)	Moderate (2)
Mulching extensive	Strong (3)	Light (1)
No-tillage intensive	Strong (3)	Light (1)
No-tillage extensive	Moderate (2)	Light (1)
Strip sowing intensive	Strong (3)	Light (1)
Strip sowing extensive	Moderate (2)	Light (1)
Permanent grassland intensive	Strong (3)	Moderate (2)
Permanent grassland extensive	n.a.	None

Annex Table 3 Stakeholder workshop outcomes: Compaction on cropland, including the lands under conservation technologies, in the study area Frienisberg (BE) (Data source: WOCAT QM)

		Aarberg	**Bargen (BE)**	**Gross-affoltern**	**Kappelen**	**Lyss**	**Radel-fingen**	**Schü-pfen**	**Seedorf (BE)**	**Mei-kirch**
Settlement area	**1979/85**	170	54	119	94	374	89	181	136	89
	1992/97	174	56	158	111	450	95	201	154	94
	01.09.04	186	55	164	119	479	99	213	161	96
Area trend in %	**From 92/97 to 2004**	**6.9**	**-1.8**	**3.8**	**7.2**	**6.4**	**4.2**	**6.0**	**4.5**	**2.1**
Agricultural area	**1979/85**	376	558	993	830	620	857	1144	1271	664
	1992/97	361	553	935	808	537	853	1119	1250	660
	01.09.04	351	556	941	804	513	851	1105	1248	657
Area trend in %	**From 92/97 to 2004**	**-2.8**	**0.5**	**0.6**	**-0.5**	**-4.5**	**-0.2**	**-1.3**	**-0.2**	**-0.5**
Forest area	**1979/85**	210	136	376	154	472	450	638	663	267
	1992/97	218	138	380	152	474	450	641	663	267
	01.09.04	221	137	381	150	474	450	641	662	267
Area trend in %	**From 92/97 to 2004**	**1.4**	**-0.7**	**0.3**	**-1.3**	**0.0**	**0.0**	**0.0**	**-0.2**	**0.0**

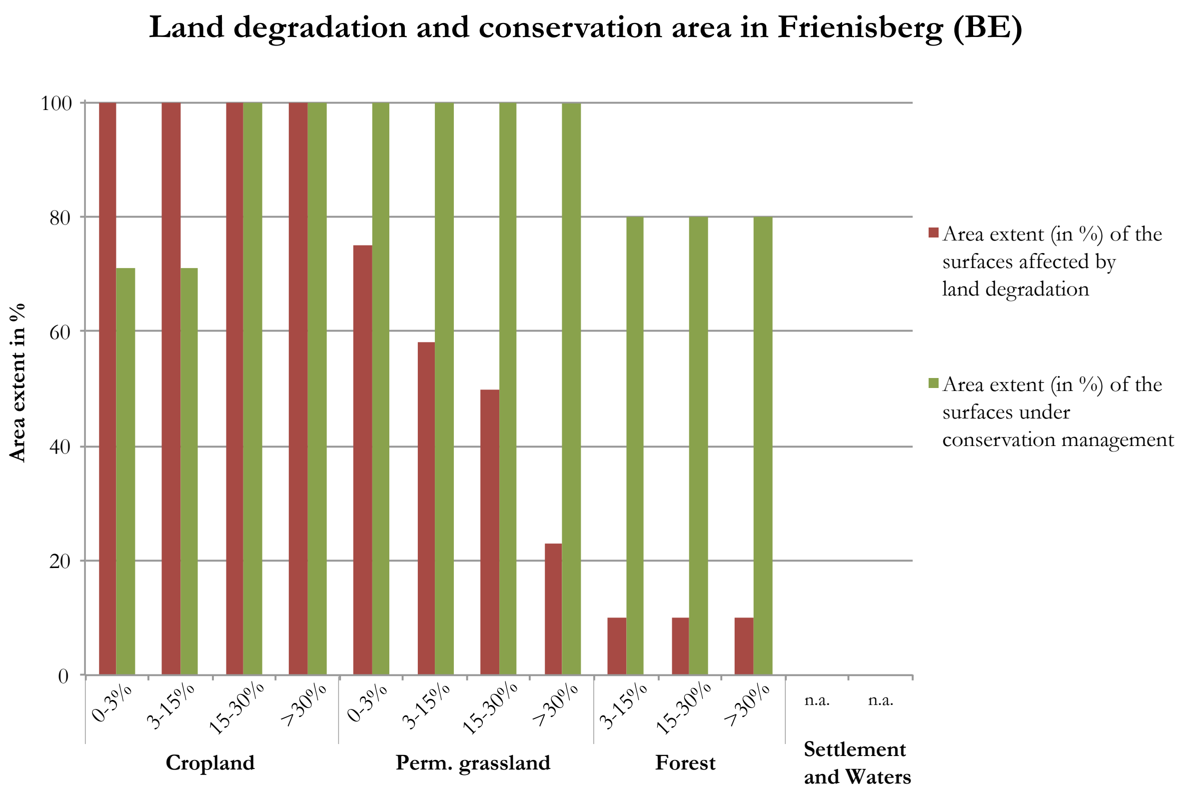
Annex Table 4 Area coverage per municipality (*Gemeinde*) and statement period (area values given in ha) (BFS, 2015).

Slope category	Area extent (%)		Area extent (ha)			Area extent (%)		Area extent (ha)		
	Int. PG	Ext. PG	Int. PG	Ext. PG	**Total (row)**	Ext. meadow	Ext. pasture	Ext. meadow	Ext. pasture	**Total (row)**
Steepness > 15%	64.6	35.4	181.92	99.47	**281.39**	75.6	24.4	75.16	24.31	**99.47**
Steepness < 15%	69.1	30.9	165.52	73.94	**239.46**	96.0	4.0	70.99	2.94	**73.93**
Extent Total LUS area	**66.7**	**33.3**	**347.43**	**173.41**	**520.84**	**84.3**	**15.7**	**146.16**	**27.25**	**173.41**

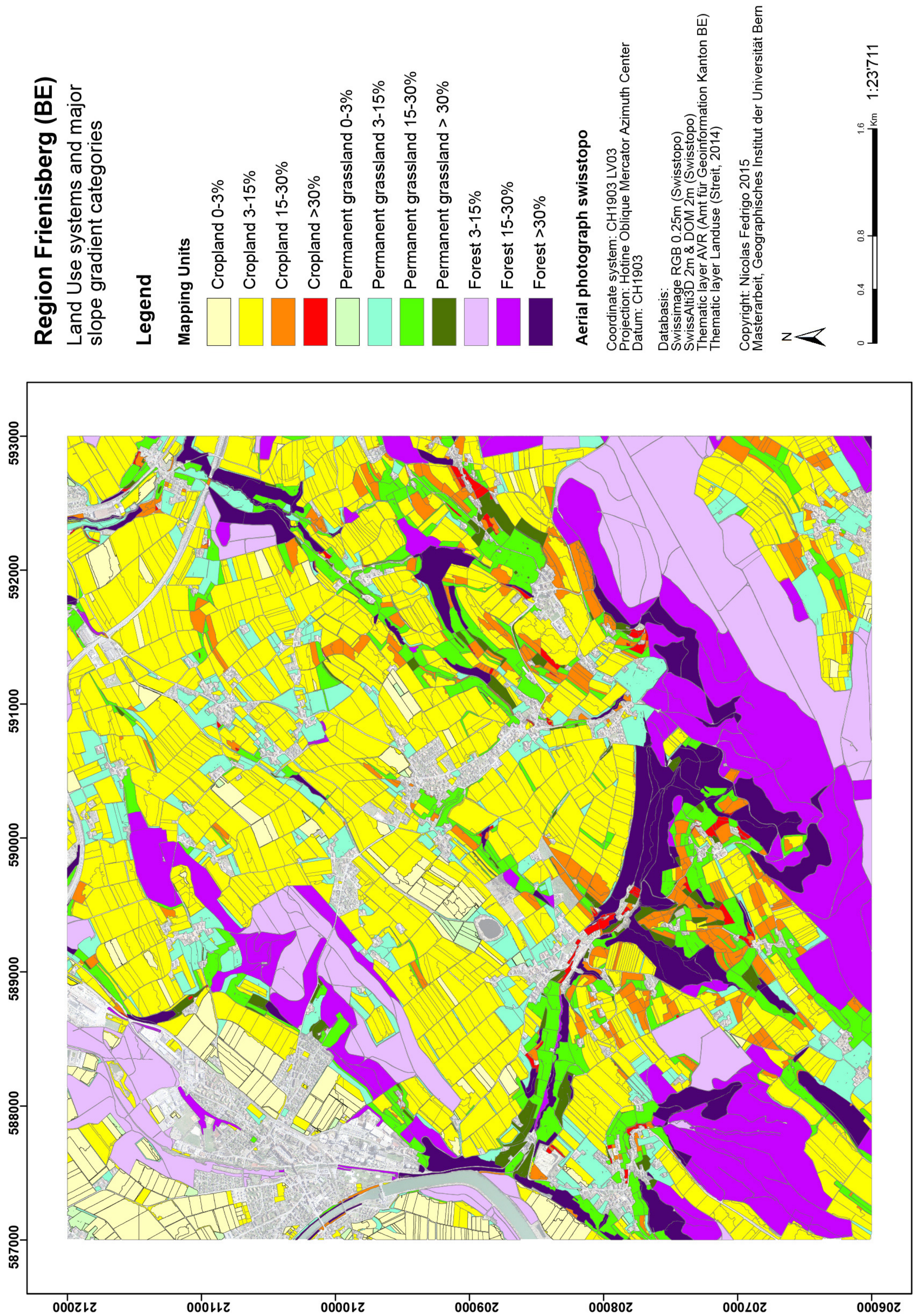
Annex Table 5 Study area Frienisberg (BE): Area coverage LUS intensive and extensive permanent grassland (PG) on flatter (slope gradient categories: <15%) and steeper lands (slope gradient categories: >15%) (Fedrigo 2016, Data source: © Amt für Landwirtschaft und Natur des Kantons Bern).

	Intensive permanent grassland		**Extensive permanent grassland**	
Slope gradient category	Area % of total LUS	Area extent in ha	Area % of total LUS	Area extent in ha
0-3%	0.9	4.7	2.8	14.8
3-15%	30.7	160.1	16.3	84.7
15-30%	30.0	156.0	12.5	65.0
>30%	5.0	25.9	1.7	8.9
TOTAL:	**66.6%**	**346.7 ha**	**33.3%**	**173.4 ha**

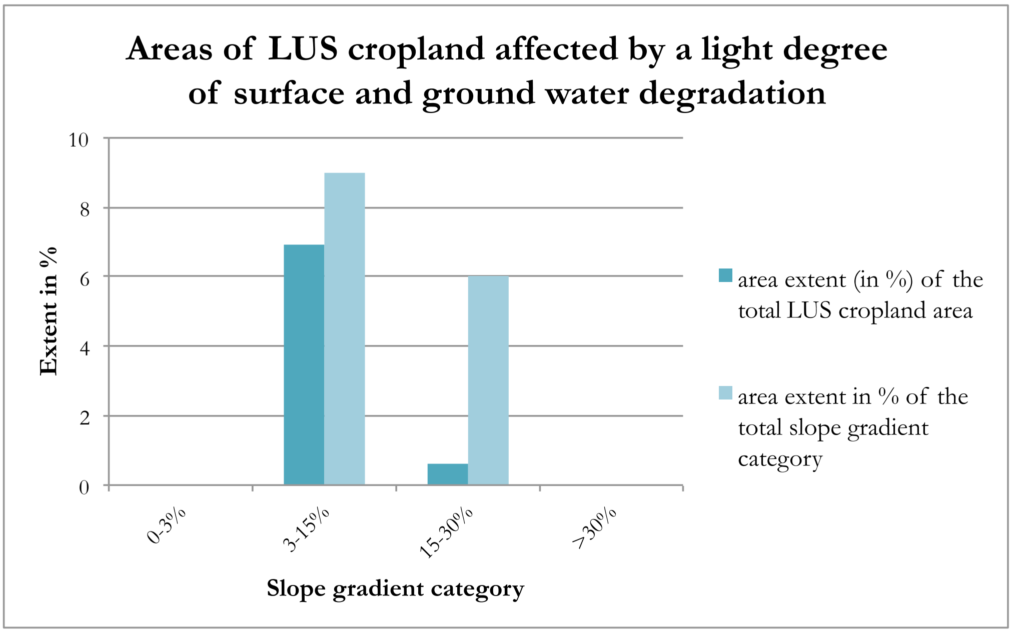
Annex Table 6 Study area Frienisberg (BE): Area extent (in % and ha) of the conservation technologies intensive and extensive permanent grassland according to each slope gradient category (Fedrigo 2016, Data source: © Amt für Landwirtschaft und Natur des Kantons Bern)



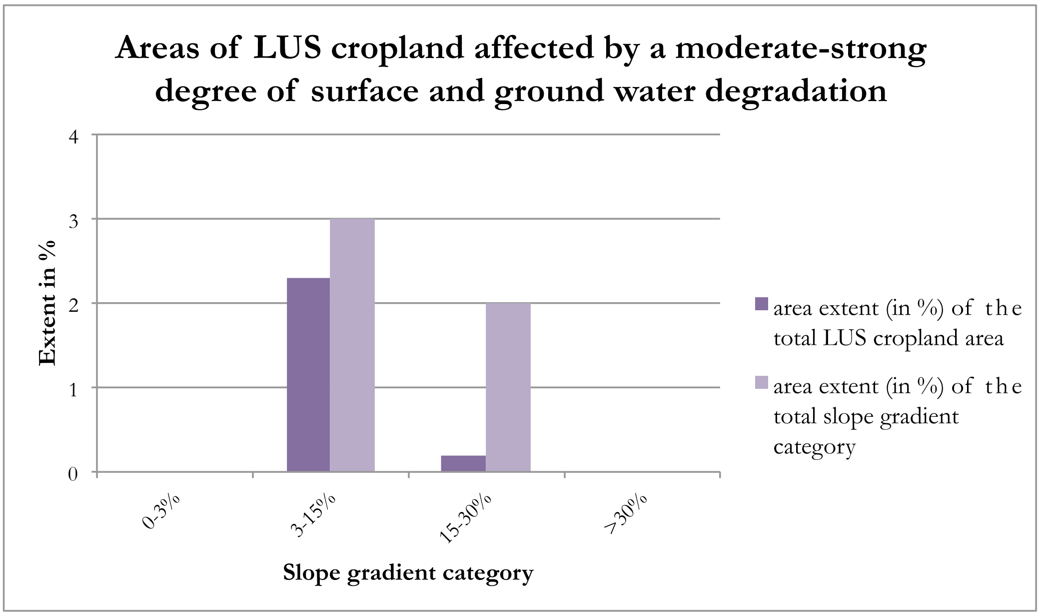
Annex Fig. 1 Study area Frienisberg (BE): Area extent (in %) of land degradation and conservation for each mapping unit (Illustration: Fedrigo 2016, Data source: WOCAT QM).



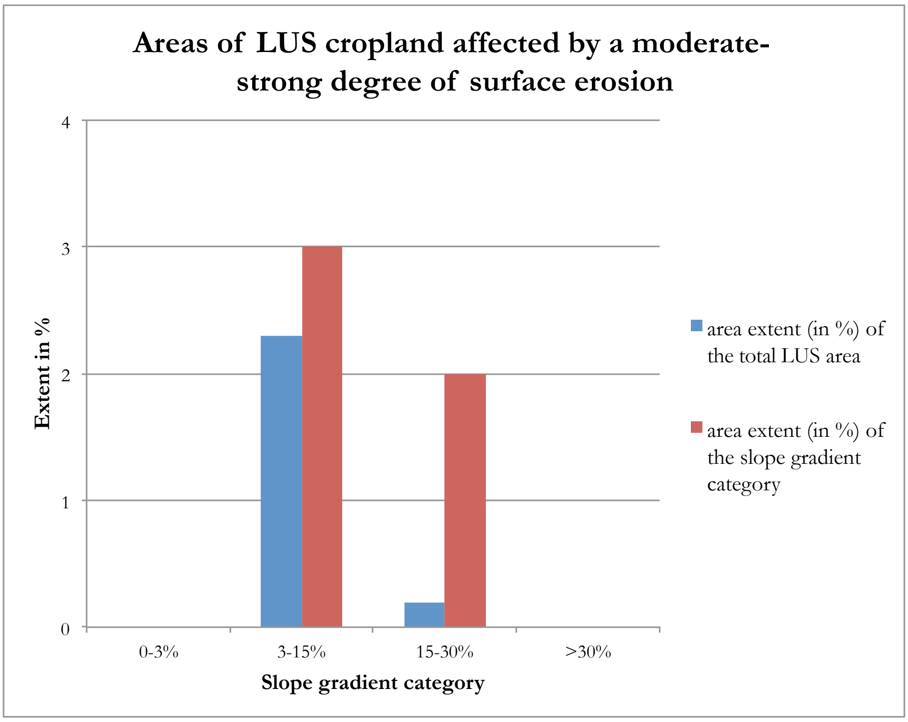
Annex Fig. 2 Study area Frienisberg (BE): Base map including all major land use systems and slope gradient categories. LUS waters and LUS settlement are not shown on the map since they have not been entirely documented (Fedrigo 2016).



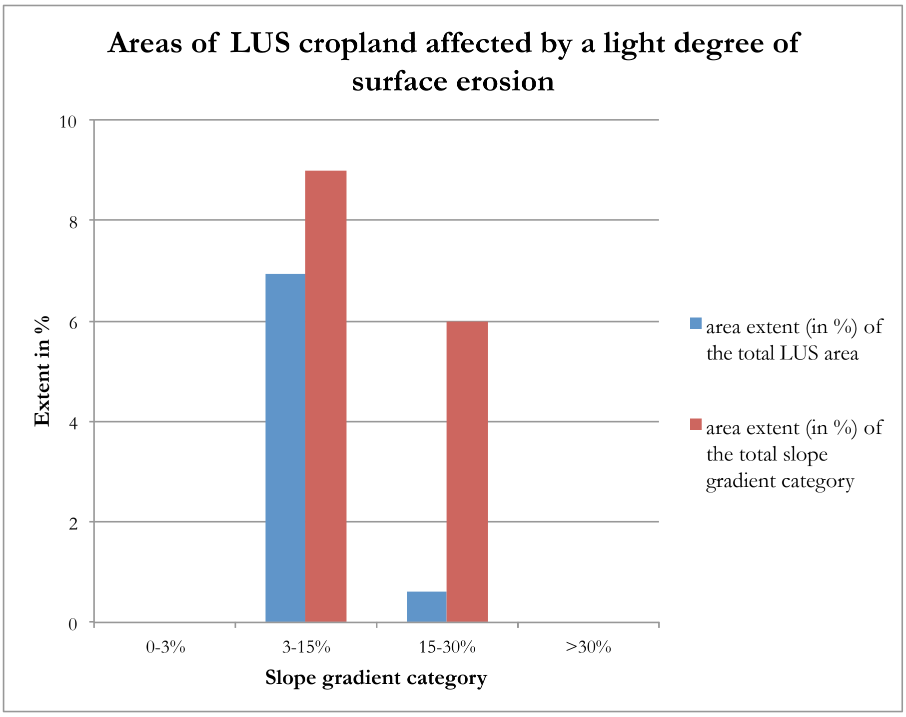
Annex Fig. 3 Study area Frienisberg (BE): Stakeholder workshop outputs (data in Annex 4), LUS cropland areas affected by a light degree of surface and ground water degradation (Illustration: Fedrigo 2016, Data source: WOCAT QM).



Annex Fig. 4 Study area Frienisberg (BE): Stakeholder workshop outputs (data in Annex 4), LUS cropland areas affected by a moderate-strong degree of surface and ground water degradation (Illustration: Fedrigo 2016, Data source: WOCAT QM).



Annex Fig. 5 Study area Frienisberg (BE): Stakeholder workshop outputs (data in Annex 4), LUS cropland areas affected by a moderate-strong degree of surface erosion (Illustration: Fedrigo 2016, Data source: WOCAT QM).



Annex Fig. 6 Study area Frienisberg (BE): Stakeholder workshop outputs (data in Annex 4), LUS cropland areas affected by a light degree of surface erosion (Illustration: Fedrigo 2016, Data source: WOCAT QM).

Annex 2 Workshop materials

Workshop Merkblatt

1. **Schritt : Involvierte Fachpersonen**

2. **Schritt : Landnutzungssystem (LUS)**

i) LUS Flächentrend		**ii) LUS Intensitätstrend**	
-2	Fläche nimmt rasch ab (d.h. > 10% der LUS-Fläche/10 Jahren)	**-2**	Starke Abnahme der Landnutzungsintensität, z.B. von mechanischem zu manuellem Pflug
-1	Fläche nimmt langsam ab (d.h. < 10% der LUS-Fläche/10 Jahren)	**-1**	Leichte Abnahme der Landnutzungsintensität, z.B. leichte Abnahme externer Einträge (z.B. Pestizide)
0	Fläche bleibt stabil	**0**	Keine nennenswerte Veränderungen der Einträge, des Managementlevels, usw.
1	Fläche nimmt langsam zu (d.h. < 10% der LUS-Fläche/10 Jahren)	**1**	Mässige Zunahme: z.B von keinen/wenigen externen Einträge zu gewissen Pestiziden; von Hand- zu Tier-Pflug
2	Fläche nimmt rasch zu (d.h. > 10% der LUS-Fläche/10 Jahren)	**2**	Starke Zunahme: z.B. von manuellem zu mechanisiertem Pflug

Tabelle 1: Flächen- und Intensitätstrend (Daten Quelle: Liniger, van Lynden, et al., 2008, p. E4)

3. **Schritt: Landdegradierung**

a) Typen	**O: Keine Degradierung** **W: Bodenerosion durch Wasser:** **Wt**: Oberflächenerosion **Wg**: Grabenerosion (Gully Erosion) **Wm**: Massenbewegung/Erdrutsch/Hangrutsch **Wr**: Flussufererosion **Wo**: Offsite Degradierungseffekte (z.B. Sedimentablagerungen) **C: Chemische Bodendegradierung:** **Cn: Reduktion der** Fruchtbarkeit und organischer Substanz **Ca:** Versauerung (Abnahme Boden-pH) **Cp:** Bodenverunreinigungen (toxische Stoffe) **Cs:** Versalzung/Alkalinisierung **P: Physikalische Bodendegradierung** **Pc:** Bodenverdichtung **Pk:** Versiegelung und Krustenbildung **Pw:** Staunässe **Ps:** Absenkung organischer Böden **Pu:** Verlust bio-produktiver Funktionen durch andere Aktivitäten (z.B. Strassenbau, Minen)		**H: Wasserdegradierung** **Ha:** Aridifizierung (Zunahme Trockenheit) **Hs:** Änderungen Oberflächengewässer(z.B.Quantität, Abflussveränderungen) **Hg:** Änderungen des Grundwasserspiegels (Quantität) **Hp:** Qualitätsabnahme des Oberflächenwassers **Hq:** Qualitätsabnahme des Grundwassers **Hw:** Reduktion der Pufferkapazität von Feuchtgebieten **B: Biologische Degradierung** **Bc:** Abnahme der Vegetationsbedeckung **Bh:** Verlust an Lebensräumen **Bq:** Abnahme der Biomasse (quantitativ) **Bs:** Qualität und Artenzusammensetzung / Abnahme der Artenvielfallt **Bl:** Rückgang der Bodenlebewesen **Bp:** Zunahme der Schädlinge/Krankheiten
b) Betroffene Fläche % (extent)	Soll für jeden Degradierungstyp angegeben werden (% der LUS-Fläche)		
c) Grad / Ausmass (degree)	**1**: Leicht **2**: Moderat		**3**: Stark **4**: Extrem
d) Geschwindig-keit der Degradierung	Zunehmende Degradierung: **3**: schnell **2**: mässig **1**: langsam	**0**: keine Veränderung der Degradierung	Abnehmende Degradierung: **- 3**: schnell **- 2**: mässig **- 1**: langsam

e) Direkte Ursachen	**S: Bodenmanagement** **s1**: Bewirtschaftung ungeeigneter/empfindlicher Böden **s2**: fehlender/unzureichender Bodenschutz **s3**: Gebrauch schwerer Maschinen	**I: Industrie und Bergbau** **i1**: Industrie **i2**: Bergbau **i3**: Abfallablagerung

	s4: Bodenbearbeitungsmethode (Pflug, Eggen, etc.) **s5**: weitere (ausführen unter h – Anmerkungen) **C: Acker- und Weidewirtschaft** **c1**: Rückgang der Pflanzenbedeckung und Pflanzenüberreste **c2**: ungeeigneter Einsatz von Gülle, Dünger, Agrochemikalien, etc. **c3**: übermässige Nährstoffentnahme ohne entsprechenden Ersatz **c4**: Verkürzung der Brachzeit **c5**: Unangemessene Bewässerung **c6**: Inadäquater Wasserverbrauch im Regenfeldbau **c7**: Verbuschung und Verdichtung des Waldes **c8**: Auftreten und Verbreitung invasiver Pflanzen und Unkraut **c9**: weitere (ausführen unter h – Anmerkungen) **F: Entwaldung/Entfernung natürlicher Vegetation** **f1**: groß angelegte kommerzielle Forstwirtschaft **f2**: Ausbau von Siedlungsgebieten und Industrie **f3**: Umnutzung zu landwirtschaftlicher Zone **f4**: Waldbrände **f5**: Straßen- und Schienenbau **f6**: weitere (ausführen unter h – Anmerkungen) **E: Übernutzung der Vegetation für Hausgebrauch** **e1**: übermässiges Sammeln von Brenn-/Bauholz **e2**: Entfernung für Futter **e3**: weitere (ausführen unter h – Anmerkungen) **G: Überweidung (overgrazing)** **g1**: Übermässige Anzahl Vieh **g2**: Trampeln entlang Tierpfaden **g3**: Überweidung/Trampeln in der Nähe von Futter- oder Wasserstellen **g4**: zu lange Weideperioden, führend zu Übernutzung schmackhafter Arten **g5**: Veränderung des Viehbestands (z.B. gross → klein) **g6**: weitere (ausführen unter h – Anmerkungen)	**i4**: weitere (ausführen unter h – Anmerkungen) **U: Urbanisierung und Infrastrukturausbau** **u1**: Siedlungen und Strassen **u2**: Erholungs-/Freizeitstandorte **u3**: weitere (ausführen unter h – Anmerkungen) **P: Abfluss(discharges), resultierende Kontaminierung von Oberflächen-und Grundwasser** **p1**: Entsorgung von Sanitärabwasser **p2**: Abwasserableitung **p3**: Übermassiger Abfluss (runoff) **p4**: Mangel an Infrastruktur zur Abfallentsorgung **p5**: weitere (ausführen unter h – Anmerkungen) **Q: Freisetzung von Luftschadstoffen (urban)** **q1**: Verschmutzung der Veg./Pflanzen und Boden **q2**: Verschm. der Oberflächen- und Grundwasserressourcen **q3**: weitere (ausführen unter h – Anmerkungen) **W: Störung des Wasserkreislaufs** **w1**: niedrigere Infiltrationsraten / erhöhter Oberflächenabfluss **w2**: weitere (ausführen unter h – Anmerkungen) **O: Übermässige Wasserentnahme für… :** **o1**: Bewässerung **o2**: industrielle Nutzung **o3**: Hausgebrauch **o4**: Bergbau **o5**: Abnahme der Wassernutzungseffizienz **o6**: weitere (ausführen unter h – Anmerkungen) **N: Natürliche Ursachen** **n1**: Temperaturänderung **n2**: Variation/Veränderung des saisonalen Niederschlags **n3**: Extremniederschläge (Intensität und Menge) **n5**: Überschwemmungen **n6**: Dürren **n7**: Topographie **n8**: weitere (ausführen unter h – Anmerkungen)
f) Indirekte Ursachen	**p**: Bevölkerungsdruck/Bevölkerungswachstum **c**: Konsumgewohnheiten und individuelle Nachfrage **t**: Landbesitz **h**: Armut **l**: Verfügbarkeit der Arbeitskräfte	**r**: landwirtschaftliche Einträge (Inputs) und Infrastruktur **e**: Bildung, Zugang zu Wissen, ... **w**: Krieg und Konflikte **g**: Regierungsgewalt (Governance), Institutionen, Politik, Gesetze, ... **h**: weitere (ausführen unter h – Anmerkungen)
g) Einfluss auf Ökosystem-dienstleistungen (Einflusstypen)	**P : Produktive Dienstleistungen** **P1** : Produktion (Qualität und Quantität von Vieh und Pflanzen) und Risiko **P2** : Wasserkonsum, Qualität und Quantität (für Mensch, Pflanze und Tier) **P3** : Landverfügbarkeit **P4** : weitere (ausführen unter h – Anmerkungen) **E : Ökologische Dienstleistungen** **E1** : Regulierung von überschüssigem Wasser **E2** : Regulierung von knappem Wasser **E3** : Zustand der organischen Substanz **E4** : Bodenbedeckung **E5** : Bodenstruktur **E6** : Nährstoffzyklus (N, P, K) und Kohlenstoffzyklus **E7** : Bodenbildung **E8** : Biodiversität	**E9** : Treibhausgasemissionen **E10** : (Mikro-)Klima **E11** : weitere (ausführen unter h – Anmerkungen) **S : Soziokulturelle Dienstleistungen** **S1** : Spirituell, Ästhetik, Kulturlandschaft, Erholung, Tourismus, etc. **S2** : Bildung und Wissen **S3** : Konflikttransformation **S4** : Nahrungssicherheit und Sicherung der Lebens-/Existenzgrundlage **S5** : Gesundheit **S6** : Nettoeinkommen **S7** : Schutz/Beschädigung der Infrastruktur **S8** : Vermarktungsmöglichkeiten (Marktzugang) **S9** : weitere (ausführen unter h – Anmerkungen)
Einflussstufe	**Positiver Einfluss:** **3**: Stark positiv **2**: Positiv **1**: Leicht positiv	**Negativer Einfluss:** **- 3**: Stark negativ **- 2**: Negativ **- 1**: Leicht negativ

Tabelle 2: Übersicht zur Bewertung der Landdegradierung (Daten Quelle: Liniger, van Lynden, et al., 2008, pp. E6–E15)

4. Schritt: Landkonservierung

a) Name der Technologie	**Vorschlag**: Pflug extensiv, Mulch intensiv, Mulch extensiv, Direktsaat intensiv, Direktsaat extensiv, Streifenfrässaat intensiv, Streifenfrässaat extensiv, Kunstwiese, Dauergrünfläche	
e) Flächenanteil % der Konservierungs-massnahme	Flächenanteil **(extent)** als % der Mapping Unit angeben	
f) Degradierung, welche bekämpft werden soll	Degradierungsformen angeben, welche durch die Konservierungsmassnahmen bekämpft werden sollen (in Bezug auf die Degradierungstypen in Schritt 3)	
g) Effizienz/ Wirksamkeitsgrad der Konservierungs-massnahme	**1**: schwach **2**: mässig **3**: hoch **4**: Sehr hoch	
h) Effizienztrend/ Wirksamkeitstrend	**1:** Zunehmende Wirksamkeit **0:** keine Veränderung der Wirksamkeit **-1:** Abnehmende Wirksamkeit	
i) Einfluss auf Ökosystem-dienstleistungen (Einflusstypen)	**P : Produktive Dienstleistungen** **P1** : Produktion (Qualität und Quantität von Vieh und Pflanzen) und Risiko **P2** : Wasserkonsum, Qualität und Quantität (für Mensch, Pflanze und Tier) **P3** : Landverfügbarkeit **P4** : weitere (ausführen unter h – Anmerkungen) **E : Ökologische Dienstleistungen** **E1** : Regulierung von überschüssigem Wasser **E2** : Regulierung von knappem Wasser **E3** : Zustand der organischen Substanz **E4** : Bodenbedeckung **E5** : Bodenstruktur **E6** : Nährstoffzyklus (N, P, K) und Kohlenstoffzyklus **E7** : Bodenbildung **E8** : Biodiversität	**E9** : Treibhausgasemissionen **E10** : (Mikro-)Klima **E11** : weitere (ausführen unter h – Anmerkungen) **S : Soziokulturelle Dienstleistungen** **S1** : Spirituell, Ästhetik, Kulturlandschaft, Erholung, Tourismus, etc. **S2** : Bildung und Wissen **S3** : Konflikttransformation **S4** : Nahrungssicherheit und Sicherung der Lebens-/Existenzgrundlage **S5** : Gesundheit **S6** : Nettoeinkommen **S7** : Schutz/Beschädigung der Infrastruktur **S8** : Vermarktungsmöglichkeiten (Marktzugang) **S9** : weitere (ausführen unter h – Anmerkungen)
Einflussstufe	**Positiver Einfluss:** **3**: Stark positiv **2**: Positiv **1**: Leicht positiv	**Negativer Einfluss:** **- 3**: Stark negativ **- 2**: Negativ **- 1**: Leicht negativ
j) Zeitraum der Konservierungs-massnahme	Zeitraum angeben, in dem die Konservierungsmassnahme(n) eingesetzt/angewandt wurde(n). Bsp. 1970-90	

Tabelle 3: Übersicht zur Bewertung der Konservierungsmassnahmen (Daten Quelle: Liniger, van Lynden, et al., 2008, pp. E16–E23)

5. Schritt: Expertenempfehlung

Für jede Mapping-Einheit soll eine fundierte Empfehlung (Maximal 2) gegeben werden, wie die Degradation in Zukunft bekämpft werden kann/soll. Als Erstes muss der bestmögliche Eingriff (entweder Anpassung, Prävention, Minderung oder Rehabilitation) definiert werden. Liefern Sie in der Spalte "Bemerkungen und zusätzliche Informationen" mehr Details über das "Was" und "Wie" dieses spezifischen Eingriffs.

Landnutzungssysteme (LUS)

Kartierungseinheit	**LUS**	**Kartierungskriterium**	**Neigungsgruppe (%)**
1	Ackerland	Konventioneller Pflug	0-3%
2	Ackerland	Konventioneller Pflug	3-15%
3	Ackerland	Konventioneller Pflug	15-30%
4	Ackerland	Konventioneller Pflug	> 30%
5	DGF	Dauergrünfläche	0-3%
6	DGF	Dauergrünfläche	3-15%
7	DGF	Dauergrünfläche	15-30%
8	DGF	Dauergrünfläche	> 30%
9	Wald	Wald	3-15%
10	Wald	Wald	15-30%
11	Wald	Wald	> 30%
12	Siedlung	Siedlung	
13	Gewässer	Oberflächengewässer	

Tabelle 4: Landnutzungssysteme und Kartierungseinheiten (mapping units)

Annex 3 WOCAT Database outputs

Step 2: Land use system trends

Country code	**SWI**
Base map edition	**frienisberg_2015**

Mapping Unit ID	LUS	Sub Div 1	Sub Div 2	Sub Div 3	a) LUS area trend	b) LUS intensity trend
1	Cropland	0-3%	1		-1	1
2	Cropland	3-15%	2		-1	1
3	Cropland	15-30%	3		-1	1
4	Cropland	>30%	4		-1	1
5	Permanent grassland	0-3%	1		0	0
6	Permanent grassland	3-15%	2		0	0
7	Permanent grassland	15-30%	3		0	0
8	Permanent grassland	>30%	4		0	0
9	Forest	3-15%	2		0	0
10	Forest	15-30%	3		0	0
11	Forest	>30%	4		0	0
12	Waters	n.a.	0		0	0
13	Settlement	n.a.	0		1	0

Step 2: Land use system trends

c) Remarks
The intensity trends need to be interpreted with precaution. All farmers practicing in the region should be questionned in order to truly render the actual status.
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Step 3: Land Degradation

Country code	SWI						Base map edition	frienisberg_2015	
Mapping Unit ID	a) Type			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services
	i	ii	iii						
1	Pc			10	4	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
1	Pc			90	2	1	s1; s2; s3; s4; s5	l; o	P1-1; E1-2; E5-1
2	Pc			66	2	1	s1; s2; s3; s4; s5	l; o	P1-1; E5-1; E1-2
2	Hp	Pc		3	2	-1	s2; s3; s4; u1; n7	l; o	P2-1; E8-2
2	Wt	Pc		9	1	-1	s2; s3; s4; s5; u1; n7	l; r; g; o	P1-1; E7-1; S7-1; P2-2
2	Hp	Pc		9	1	-1	s2; s3; s4; u1; n7	l; o	P2-1; E8-2
2	Wt	Pc		3	2	-1	s2; s3; s4; s5; u1; n7	l; r; g; o	P1-1; E7-1; S7-1; P2-2
2	Pc			10	4	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
3	Wt			1	4	-1	s2; s3; s4; s5; u1; n7	l; r; g; o	P1-1; E7-1; S7-1; P2-2
3	Pc			73	2	1	s1; s2; s3; s4; s5	l; o	P1-1; E5-1; E1-2
3	Pc			10	4	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
3	Hp	Pc		2	2	-1	s2; s3; s4; u1; n7	l; o	P2-1; E8-2
3	Hp	Pc		6	1	-1	s2; s3; s4; u1; n7	l; o	P2-1; E8-2
3	Wt	Pc		2	2	-1	s2; s3; s4; s5; u1; n7	l; r; g; o	P1-1; E7-1; S7-1; P2-2
3	Wt	Pc		6	1	-1	s2; s3; s4; s5; u1; n7	l; r; g; o	P1-1; E7-1; S7-1; P2-2
4	Pc			10	4	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
4	Pc			90	2	1	s1; s2; s3; s4; s5	l; o	P1-1; E5-1; E1-2
5	Pc			8	3	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
5	Pc			67	2	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
6	Pc			52	2	0	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
6	Pc			6	3	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
7	Pc			5	3	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
7	Pc			45	2	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
8	Pc			2	4	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
8	Pc			21	2	1	s1; s2; s3; s4; s5	l; o	P1-2; E5-2; E1-3
9	Ha	Bp		10	2	1	n1; n2; n6	p; g; c	S1-1
10	Ha	Bp		10	2	1	n1; n2; n6	p; g; c	S1-1
11	Ha	Bp		10	2	1	n1; n2; n6	p; g; c	S1-1
12	O			100	1	0			0
13	O			100	1	0			0

Step 3: Land Degradation

h) Remarks
This degree of land degradation applies to headlands
Lower lime content increases compaction susceptibility
The degradation type is to be considered as Pc (intra-plot) referring to 90% of the LUS area. Since the LUS area cannot exceed 100% the remaining 24% are assessed in the two degradation types Wt: surface erosion and Hq: water degradation.
Depending on the pollutant the degradation type Hp is to be understood as type Hq. For more details ii Pc please refer to the section Pc: Compaction (intra-plot)
For more details to the degradation type compaction please refer to the section Pc: Compaction (intra-plot).
Depending on the pollutant the degradation type Hp is to be understood as type Hq. For more details ii Pc please refer to the section Pc: Compaction (intra-plot)
For more details to the degradation type compaction please refer to the section Pc: Compaction (intra-plot)
Refers to headlands
Pc intra-plot refers to 90% of the LUS area. For technical reasons it is reduced to 73%. The remaining 16% are regarded as combinations in other degradation types.
For more details to the degradation type compaction please refer to the section Pc: Compaction (intra-plot).
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For more details to the degradation type compaction please refer to the section Pc: Compaction (intra-plot).
The degradation occurs on grassland under intesive management. This degree refers to the impacts on headlands.
This degree refers to intra-plot degradation and implies roughly 90% of the parcel area. The degradation occurs on parcels under intesive management.
The degradation occurs on grassland under intesive management. This degradation degree refers to the impacts intra-plot.
Degradation occurs on grassland under intesive management. This degradation degree refers to the impacts on headlands.
The degradation occurs on grassland under intesive management. This degradation degree refers to the impacts on headlands.
The degradation occurs on grassland under intesive management. This degradation degree refers to the impacts intra-plot.
The degradation occurs on grassland under intesive management. This degradation degree refers to the impacts on headlands.
The degradation occurs on grassland under intesive management. This degradation degree refers to the impacts intra-plot.

Step 4: Land Conservation

Country code	SWI
Base map edition	frienisberg_2015

Mapping Unit ID	a) Name	b) Group	c) Mesasure			d) Purpose	e) % of area	f) Degradation addressed			g) Effectiveness
			Measure 1	Measure 2	Measure 3			Deg 1	Deg 2	Deg 3	
1	Extensive Strip sowing	OT	A1	M2		M	1	Wt	Pc	Hp	4
1	Extensive mulching	OT	A1	M2		M	20	Wt	Pc	Hp	3
1	Extensive ploughing	OT	M2			M	15	Pc	Wt	Hp	1
1	Intensive no-tillage	CA	A1	M2		M	3	Wt	Pc	Hp	4
1	Intensive mulching	CA	A1	M2		M	25	Wt	Pc	Hp	2
1	Extensive no-tillage	OT	A1	M2		M	5	Wt	Pc	Hp	4
1	Intensive Strip sowing	CA	A1	M2		M	2	Wt	Pc	Hp	4
2	Intensive strip sowing	CA	M2			M	2	Wt	Pc	Hp	4
2	Extensive ploughing	OT	M2			M	15	Wt	Pc	Hp	1
2	Intensive mulching	CA	A1	M2		M	25	Wt	Pc	Hp	2
2	Extensive mulching	OT	A1	M2		P	20	Wt	Pc	Hp	3
2	Intensive no-tillage	CA	A1	M2		M	3	Wt	Pc	Hp	4
2	Extensive no-tillage	OT	A1	M2		M	5	Wt	Pc	Hp	4
2	Extensive strip sowing	OT	M2			M	1	Wt	Pc	Hp	4
3	Intensive mulching	CA	A1	M2		P	25	Wt	Pc	Hp	2
3	Extensive strip sowing	OT	M2			M	1	Wt	Pc	Hp	4
3	Intensive strip sowing	CA	M2			M	1	Wt	Pc	Hp	4
3	Extensive no-tillage	OT	A1	M2		M	10	Wt	Pc	Hp	4
3	Intensive no-tillage	CA	A1	M2		P	3	Wt	Pc	Hp	4
3	Extensive mulching	OT	A1	M2		P	30	Wt	Pc	Hp	3
3	Extensive ploughing	OT	M2			P	30	Wt	Pc	Hp	1

Step 4: Land Conservation

4	Extensive strip sowing	OT	M2			M	1	Wt	Pc	Hp	4
4	Extensive ploughing	OT	M2			M	30	Wt	Pc	Hp	1
4	Extensive mulching	OT	A1	M2		M	30	Wt	Pc	Hp	3
4	Intensive mulching	CA	A1	M2		M	25	Wt	Pc	Hp	2
4	Intensive no-tillage	CA	A1	M2		M	3	Wt	Pc	Hp	4
4	Extensive no-tillage	OT	A1	M2		M	10	Wt	Pc	Hp	4
4	Intensive strip sowing	CA	M2			M	1	Wt	Pc	Hp	4
5	Extensive pemanent grass	GR	V2	M2		M	25	Wt	Pc	Hp	4
5	Intensive permanent gras	GR	V2			M	75	Wt	Pc	Hp	3
6	Intensive permanent gras	GR	V2			M	58	Wt	Pc	Hp	3
6	Extensive permanent gras	GR	V2	M2		M	42	Wt	Pc	Hp	4
7	Intensive permanent gras	GR	V2			M	50	Wt	Pc	Hp	3
7	Extensive permanent gras	GR	V2	M2		M	50	Wt	Pc	Hp	4
8	Intensive permanent gras	GR	V2			M	23	Wt	Pc	Hp	3
8	Extensive permanent gras	GR	V2	M2		M	76	Wt	Pc	Hp	4
9	Mixed forests	AP	A1	M2	M5	M	80	Ha	Bp		3
10	Mixed forests	AP	V1	M2	M5	M	80	Ha	Bp		3
11	Mixed forests	AP	V1	M2	M5	M	80	Ha	Bp		3
12			O				100				1
13			O				100				1

h) Effect. Trend	i) Impact on ESS	j) Period	k) Ref	l) Remarks
0	S6+1, E4+1, E5+1	1990		Degradation addressed 3 refers to Hq and Hp depending on the pollutant.
0	S6+1, E1+2, E4+2, E5+2	1900		Degradation addressed 3 refers to Hq and Hp depending on the pollutant. The start period hardly qualifiable since this is probably the oldest cultivation technique.
0	E4-1, E5-1	1900		Degradation addressed 3 refers to the Hp and Hq depending on the type of pollutant
0	E4+1, E5+1	1993		Degradation addressed 3 refers to Hq and Hp depending on the pollutant.
1	E4+1, E5+1	1950		Degradation addressed 3 refers to the Hp and Hq depending on the type of pollutant
0	P1+1, S6+1, E4+2, E5+2	1993		Degradation addressed 3 refers to Hq and Hp depending on the pollutant.
0	E4+1, E5+1	1990		Degradation addressed 3 refers to Hq and Hp depending on the pollutant.
0	E4+1, E5+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	E4-1, E5-1	1900		This technology has been introduced in the 19th century. Depending on the pollutant the degradation type Hp is to be understood as type Hq.
1	E4+1, E5+1	1950		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	S6+1, E1+2, E4+2, E5+2	1900		This is the most ancient cultivation system applied in the region. Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	E4+1, E5+1	1993		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	P1+1, S6+1, E4+2, E5+2	1993		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	S6+1, E4+1, E5+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
1	E4+1, E5+1	1950		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	S6+1, E4+1, E5+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq. The extent is 0.5%, do to technical issues in the database it referred to as 1%
0	E5+1, E4+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq. The extent is 1.5%, do to technical issues in the database it is referred to as 1%
0	P1+1, S6+1, E4+2, E5+2	1993		Degradation addressed 3 refers to the Hp and Hq depending on the type of pollutant
0	E4+1, E5+1	1993		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	S6+1, E1+2, E4+2, E5+2	1900		This is probably one of the most ancient technologies used in the region. Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	E4-1, E5-1	1900		This technology emerged in the 19th century. Degradation addressed 3 refers to the Hp and Hq depending on the type of pollutant

Step 4: Land Conservation

0	S6+1, E4+1, E5+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq. Due to technical issues in the database the extent is indicated as 1% rather than 0.5%.
0	E4-1, E5-1	1900		This technology emerged in the 19th century.
0	S6+1, E1+2, E4+2, E5+2	1900		This is one of the most ancient technologies.
0	E4+1, E5+1	1950		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	E4+1, E5+1	1993		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	P1+1, S6+1, E4+2, E5+2	1993		Depending on the pollutant the degradation type Hp is to be understood as type Hq.
0	E4+1, E5+1	1990		Depending on the pollutant the degradation type Hp is to be understood as type Hq. Due to technical issues in the database the extent is indicated as 1% rather than 1.5%.
0	E1+2, P2+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	P2+2, E1+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	P2+2, E1+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	P2+2, E1+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	E1+2, P2+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	E1+2, P2+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	P2+2, E1+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
0	P2+2, E1+2, E4+3, E5+3	1900		This is an ancient technology maybe ever since there is agricultural production.
1	E5+3, E8+3, E9+3, E10+3, S1+3, S6-1	1900		Mixed forests are an ancient management technique.
1	E5+3, E8+3, E9+3, E10+3, S1+3, S6-1	1900		Mixed forests are an ancient management technique.
1	E5+3, E8+3, E9+3, E10+3, S1+3, S6-1	1900		Mixed forests are an ancient management technique.
0	0			
0	0			

Step 5: Expert recommendation

Country code	SWI
Base map edition	frienisberg_2015

Mapping Unit ID	Expert recommendation	Remarks and additional information
1	M	The cultures should be strengthened on flat areas (0-3%) encouraging as widely as possible adequate cultivation practices (mulching and reduced tillage) as well as the conscious use of machinery and the selected drive-on period.
1	P	The cultures should be strengthened on flat areas (0-3%) encouraging as widely as possible adequate cultivation practices (mulching and reduced tillage) as well as the conscious use of machinery and the selected drive-on period.
2	P	On moderately sloped areas (3-15%) it is emphasised that depending on the site-specific properties the management intensity of cultures could be strengthened or reduced (mulching, reduced tillage, but also permanent grassland).
2	M	On moderately sloped areas (3-15%) it is emphasised that depending on the site-specific properties the management intensity of cultures could be strengthened or reduced (mulching, reduced tillage, but also permanent grassland).
3	P	The management intensity must absolutely be reduced on sloped areas (> 15%) whether by the implementation of extensive technologies (no-tillage, mulching) or by a LUS conversion into permanent grassland.
3	M	The management intensity must absolutely be reduced on sloped areas (> 15%) whether by the implementation of extensive technologies (no-tillage, mulching) or by a LUS conversion into permanent grassland.
4	P	The management intensity must absolutely be reduced on sloped areas (> 15%) whether by the implementation of extensive technologies (no-tillage, mulching) or by a LUS conversion into permanent grassland.
4	M	The management intensity must absolutely be reduced on sloped areas (> 15%) whether by the implementation of extensive technologies (no-tillage, mulching) or by a LUS conversion into permanent grassland.
5	P	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
5	M	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.

Step 5: Expert recommendation

5	R	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
6	P	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
6	M	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
6	R	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
7	P	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
7	M	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
7	R	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
8	P	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.

Step 5: Expert recommendation

8	M	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
8	R	On permanent grassland the degradation processes can be maintained at low levels (with both prevention and mitigation effects), whereas already degraded lands (e.g. due to cropland use) can be rehabilitated. The participating experts consider this land use effective, very valuable, and highly recommendable in the management strategy. Obviously, the extensive practice avoiding drive-on is particularly recommended.
9	M	In Schweizer's opinion the general public plays a specific role in this issue. Public opinion must show interest in topics related to forest management and call for a political claim. Otherwise, when facing the landowners, it may become difficult for the foresters to keep interest alive and defend ecological management.
10	M	In Schweizer's opinion the general public plays a specific role in this issue. Public opinion must show interest in topics related to forest management and call for a political claim. Otherwise, when facing the landowners, it may become difficult for the foresters to keep interest alive and defend ecological management.
11	M	In Schweizer's opinion the general public plays a specific role in this issue. Public opinion must show interest in topics related to forest management and call for a political claim. Otherwise, when facing the landowners, it may become difficult for the foresters to keep interest alive and defend ecological management.
13	P	To avoid additional arable land surface losses the expansion of settlement areas should be thoughtfully elaborated in terms of regional development.

Annex 4 Stakeholder workshop outputs (WOCAT QM)

Mapping unit	LUS	Slope	i) LUS area trend	ii) LUS intensity trend	a) Degradation types: Important	a) Degradation types: Marginal	Type a i	Type a ii	Type a iii	Type b i	Type b ii	Type b iii	Type c i	Type c ii	Type c iii	
1	Cropland	0-3%	-1	1	Wt, Pc Hp und Hq	Wm, Wo, Ca, Cp, Cs, Pk, Pw, Ps, Pu, Bs	Wt			Pc			Hp	Hq		
2	Cropland	3-15%	-1	1			Wt			Pc			Hp	Hq		
3	Cropland	15-30%	-1	1			Wt			Pc			Hp	Hq		
4	Cropland	>30%	-1	1			Wt			Pc			Hp	Hq		
1	Cropland	0-3%	-1	1	Wt, Pc Hp und Hq	Wm, Wo, Ca, Cp, Cs, Pk, Pw, Ps, Pu, Bs	Wt			Pc			Hp	Hq		
2	Cropland	3-15%	-1	1			Wt			Pc			Hp	Hq		
3	Cropland	15-30%	-1	1			Wt			Pc			Hp	Hq		
4	Cropland	>30%	-1	1			Wt			Pc			Hp	Hq		

PG: Permanent grassland

Mapping unit	LUS	Slope	i) LUS area trend	ii) LUS intensity trend	a) Degradation types: Important	a) Degradation types: Marginal	Type a i	Type a ii	Type a iii	Type b i	Type b ii	Type b iii	Type c i	Type c ii	Type c iii	
5	PG	0-3%	0	0						Pc						
6	PG	3-15%	0	0						Pc						
7	PG	15-30%	0	0						Pc						
8	PG	>30%	0	0						Pc						
5	PG	0-3%	0	0						Pc						
6	PG	3-15%	0	0						Pc						
7	PG	15-30%	0	0						Pc						
8	PG	>30%	0	0						Pc						

	Surface erosion						
	b) Extent (%)	**c) Degree**	**d) Rate**	**e) Direct causes**	**f) Indirect causes**	**g) Impacts on ESS/ Degree of impact**	**h) Remarks**
Moderate/ Strong	0	0	0	-	-	P1/-1, E7/-1, P2/-2, S7/-1,	s5a: Kulturwahl, Wahl der Fruchtfolge, Standortgerete Kulturen; s5b: Form, Grösse und Anordnung der Parzellen; o: o1: unternehmerisches Denken (ein Bauer•in kann auch Einfluss haben auf andere; bsp. Lauper mit der DS); o2: Soziales (was macht der Nachbar, was wird in der Region bereits gemacht, Betriebsübernahme (Eltern-Kinder)
	3%	2/3	-1		l, r, g, o		
	2%	2/3	-1	s2, s3 ,s4, s5, u1, n3, n7	l, r, g, o		
	0	0	0	-	-		
Light	0	0	0	-	-	P1/-1, E7/-1, P2/-2, S7/-1,	
	9%	1	-1		l, r, g, o		
	6%	1	-1	s2, s3 ,s4, s5, u1, n3, n7	l, r, g, o		
	0	0	0	-	-		
Extreme (> 10t/ha/yr.)	1%	4	-1	s2, s3 ,s4, s5, u1, n3, n7	l, r, g, o	P1/-1, E7/-1, P2/-2, S7/-1,	
intensiv	No signs of surface erosion on LUS permanent grassland in the area of interest.						
extensiv							

	Compaction						
	b) Extent (%)	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impacts on ESS/ Degree of impact	h) Remarks
Headland	10%	4	1	s1, s2, s3, s4, s5a, s5b	l, o	P1/-2, E5/-2, E1/-3	s5a: Fahrverkehr (im Vorgewende), s5b: Kalkgehalt; o: Parzellenform/-Groesse und /-Anordnung
	10%	4	1		l, o		
	10%	4	1		l, o		
	10%	4	1		l, o		
In-plot	90%	2	1	s1, s2, s3, s4, s5b	l, o	P1/-1, E5/-1, E1/-2	s5b: Kalkgehalt (je tiefer der Kalkgehalt desto höher ist das Verdichtungsrisiko/die Versdichtung; o: Parzellenform/-Groesse und /-Anordnung
	90%	2	1		l, o		
	90%	2	1		l, o		
	90%	2	1		l, o		
Intensiv **Headland**	10%	3	1	s1, s2, s3, s5a, s5b	l, o	P1/-2, E5/-2, E1/-3	s5a: Fahrverkehr (im Vorgewende), s5b: Kalkgehalt; o: Parzellenform/-Groesse und /-Anordnung
	10%	3	1		l, o		
	10%	3	1		l, o		
	10%	3	1		l, o		
Intensiv **Intra-plot**	90%	2	1	s1, s2, s3, s5a, s5b	l, o	P1/-2, E5/-2, E1/-3	s5a: Fahrverkehr (im Vorgewende), s5b: Kalkgehalt; o: Parzellenform/-Groesse und /-Anordnung
	90%	2	1		l, o		
	90%	2	1		l, o		
	90%	2	1		l, o		
Extensiv	No signs of compaction on permanent grassland with extensive management						

	Surface and ground water degradation						
	b) Extent (%)	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impacts on ESS/ Degree of impact	h) Remarks
Moderate/ Strong	0	0	0	-	-	-	o1: unternehmerisches Denken (Einfluss auf Nachbaren; bsp. Lauper DS); o2: Soziales (was macht der Nachbar, was wird in der Region bereits gemacht, Betriebsübernahme; Wasserqualität: Phosphorverunreinigungen ein Problem für Oberflächengewässer (nicht Grundwasser); Nitratauswaschung ins Grundwasser ist grundsätzlich ein Problme des Ackerbaus, auch in dieser Region jedoch nicht so stark ausgeprägt. Für Oberflächengewässer sind Pestizideinträge aus Landwirtschaft mit Bodenerosion und Oberflächenabfluss generell ein Problem;
	3%	2/3	1	s2,s3,s4, u1, n3, n7, c2,	l, r, g, o	P2/-1, E8/-2	
	2%	2/3	1		l, r, g, o		
	0	0	0	-	-	-	
Light	0	0	0	-	-	-	
	9%	1	1	s2,s3,s4, u1, n3, n7, c2,	l, r, g, o	P2/-1, E8/-2	
	6%	1	1		l, r, g, o		
	0	0	0	-	-	-	
intensiv	No signs of water degradation on LUS permanent grassland						
extensiv							

Map unit	LUS	Slope	i) LUS area trend	ii) LUS intensity trend	a) Degradation types			Aridification - Increase of pests/diseases						
					i	ii	iii	b) Extent (%)	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impacts on ESS/ Degree of impact	h) Remarks
9	Forest	3-15%	0	0	Ha	Bp		10%	2	1	n1, n2, n6	p, c, g	S1/-1	-
10	Forest	15-30%	0	0	Ha	Bp		10%	2	1	n1, n2, n6	p, c, g	S1/-1	-
11	Forest	>30%	0	0	Ha	Bp		10%	2	1	n1, n2, n6	p, c, g	S1/-1	-

Kart. Einheit	LUS	Neig. (in %)	a) Name der Kons. Massnahme	e) Fläche %	f) Adressierte Degradation 1	2	3	g) Wirksam-keit der SLM Techno-logie	h) Effizienz-trend	i) Einfluss auf ESS (Ökosystemdienst-leistungen)	j) Zeitraum
Reference technology:			**Pflug int.**	**30%**							
1 and 2	Offene Acker-fläche		Pflug ext	15%	Wt	Pc	Hq, Hp	schwach	0	E5/-1, E4/-1	19. Jhd.
			Mulch int	25%	Wt	Pc	Hq, Hp	mässig	1	E5/1, E4/1,	1955/60
			Mulch ext	20%	Wt	Pc	Hq, Hp	hoch	0	S6/1, E1/2, E5/2, E4/2	19. Jhd.
			DS int	3%	Wt	Pc	Hq, Hp	sehr hoch	0	E5/1, E4/1	1993
			DS ext	5%	Wt	Pc	Hq, Hp	sehr hoch	0	P1/1, S6/1, E5/2, E4/2	1993
			SFS int	1.5%	Wt	Pc	Hq, Hp	sehr hoch	0	E5/1, E4/1	1990
			SFS ext	0.50%	Wt	Pc	Hq, Hp	sehr hoch	0	S6/1, E5/1, E4/1	1990
			KuWi int	17% der Gesamtfläche	Wt	Pc	Hq, Hp	sehr hoch	0	E5/3, E4/3	19. Jhd.
			KuWi ext		Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, P2/2, E5/3, E4/3	19. Jhd.
			DGF int	See LUS PG	Wt	Pc	Hq, Hp	hoch	0	E1/2, E5/3, E4/3, P2/3	19. Jhd.
		0-15%	DGF ext	See LUS PG	Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, E5/3, E4/3, P2/2	19. Jhd.
Reference technology:			**Pflug int.**	**0%**							
3 and 4	Offene Acker-fläche		Pflug ext	30%	Wt	Pc	Hq, Hp	schwach	0	E5/-1, E4/-1	19. Jhd.
			Mulch int	25%	Wt	Pc	Hq, Hp	mässig	1	E5/1, E4/1,	1955/60
			Mulch ext	30%	Wt	Pc	Hq, Hp	hoch	0	S6/1, E1/2, E5/2, E4/2	19. Jhd.
			DS int	3%	Wt	Pc	Hq, Hp	sehr hoch	0	E5/1, E4/1	1993
			DS ext	10%	Wt	Pc	Hq, Hp	sehr hoch	0	P1/1, S6/1, E5/2, E4/2	1993
			SFS int	2%	Wt	Pc	Hq, Hp	sehr hoch	0	E5/1, E4/1	1990
			SFS ext	0.50%	Wt	Pc	Hq, Hp	sehr hoch	0	S6/1, E5/1, E4/1	1990
			KuWi int	2% der Gesamtfläche	Wt	Pc	Hq, Hp	sehr hoch	0	E5/3, E4/3	19. Jhd.
			KuWi ext		Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, P2/2, E5/3, E4/3	19. Jhd.
			DGF int	Siehe LUS DGF	Wt	Pc	Hq, Hp	hoch	0	E1/2, E5/3, E4/3, P2/3	19. Jhd.
		> 15%	DGF ext	Siehe LUS DGF	Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, E5/3, E4/3, P2/3	19. Jhd.

Kart. Einheit	LUS	Neig. (in %)	a) Name der Kons. Massnahme	e) Fläche %	f) Adressierte Degradation			g) Wirksam-keit der SLM Techno-logie	h) Effizienz-trend	i) Einfluss auf ESS (Ökosystemdienst-leistungen)	j) Zeitraum
					1	2	3				
5 and 6	DGF	0-15%	PG int	70%	Wt	Pc	Hq, Hp	hoch	0	E1/2, E5/3, E4/3, P2/2	19. Jhd.
		0-15%	PG ext	30%	Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, E5/3, E4/3, P2/2	19. Jhd.
7 and 8	DGF	> 15%	PG int	94%	Wt	Pc	Hq, Hp	hoch	0	E1/2, E5/3, E4/3, P2/2	19. Jhd.
		> 15%	PG ext	6%	Wt	Pc	Hq, Hp	sehr hoch	0	E1/2, E5/3, E4/3, P2/2	19. Jhd.
9	Wald	3-15%	Mischwald	80%	Ha, Bp	-	-	3	1	E5/3, E8/3, E9/3, E10/3, S1/3, S6/-1	19. Jhd.
10	Wald	15-30%	Mischwald	80%	Ha, Bp	-	-	3	1		19. Jhd.
11	Wald	>30%	Mischwald	80%	Ha, Bp	-	-	3	1		19. Jhd.
12	Gewässer	n.a.	-	-	-	-	-	-	-		
13	Siedlung	n.a.	-	-	-	-	-	-	-		

Deutsch	**English**
Offene Ackerfläche	Cropland
DFG	Permanent grassland
Wald	Forest
Gewässer	Waters
Siedlung	Settlement
KuWi	Grass clover ley
DS	No-till
SFS	Strip sowing
Pflug	Ploughing

Map unit	LUS	Neig. (%)	Expertenempfehlung	Anmerkungen und zusätzliche Informationen
			Eignung der angewandten Methoden? Effizienz gegen Degrad. Welche weiteren Methoden sind zu empfehlen?	
1	oA	0-3%	Intensivierung der Kulturen, Standortangepasste Bewirtschaftung	Allgemein kann jedoch gesagt werden: es muss wachsen, Bauer soll soviel tun wie nötig damit es wächst (--> wir kommen immer wieder darauf zurück: die Bauern haben den Fokus immer und immer wieder auf die Produktino); Bauern sagen -->In jeder Neigungsklasse solle in der SLM-Technologie nachgeschaut werden welche Konservierungsmassnahme am besten bewertet wurde: diese Technologie sei somit zu empfehlen und sollte theoretisch Flächendecken angewendet werden (sie sagen jedoch auch, dass obwohl sie wissen was theoretisch am besten wäre können sie es wegen der Wirtschaftlichkeit und dem Wille zu produziern nicht wirklich anwenden.)
2	oA	3-15%	Intens. Und extens. Der Kulturen, Standortangepasste Bewirtschaftung	
3	oA	15-30%	Extensivierung der Kulturen, Standortangepasste Bewirtschaftung	
4	oA	>30%	DGF, Standortangepasste Bewirtschaftung	
5	DGF	0-3%		DGF sind eine allgemein anerkannte Technologie. Sie soll weiter so angewendet werden. Um Kompaktierung zu vermeiden sollten möglichst extensive DGF umgesetzt werden.
6	DGF	3-15%		
7	DGF	15-30%		
8	DGF	>30%		

9	Wald	0-3%	Die angewandten Methoden Mischwald und Dauerwald sind konkrete und effiziente Methoden für die Konservierung des Landes. Sie eignen sich in der Region sehr gut, auch im Anbetracht der pedologischen Gegebenheiten.	Die Methode Mischwald ist effizient gegen Degradierung. Beispielsweise kann die Verbreitung des Borkenkäfers zu 65% gestoppt werden (sagt Schweizer). Gegen Eschentriebsterben ist die Methode des Mischwaldes jedoch nicht wirksam. Die Effizienz ist somit effektiv, jedoch nicht absolut gegen die Gesammtheit der Schädlinge.	Mischwald und Dauerwald sind zwei konservierende Waldbewirtschaftungsmethoden die zu empfehlen sind.	
10	Wald	3-15%			Die Bevölkerung soll sensibilisert werden auf die Notwendigkeit die Waldwirtschaft auch finanziell (durch Steuergelder) zu unterstützen. Heutzutage wir ausschliesslich auf die Wirtschaftlichkeit der Waldwirtschaft gesetzt, dies sei eine grosse Gefahr für die nachhaltige Nutzung des Waldes. Es stosse eher gegen Intensifizierung und Monokulturen (obwohl sich alle bewusst sind, dass Monokulturen absolut nicht zu empfehlen sind).	
11	Wald	15-30%			Der Wald spielt eine grosse Rolle für die Erholung/Freizeit/Tourismus/Ästhetik, es sei erstaundlich und gar "egoistisch" behaupten zu wollen, dass die Waldbesitzer diese Rolle erfüllen müssen ohne staatliche Unterstützung. Schweizer meint, dass die Bevölkerung sicher bereit wäre diese finanziell zu Unterstützen wenn ihnen die Möglichkeit gegeben worden wäre sich diesbezüglich auszudrücken (z.B. in einer Volksabstimmung).	
12	Siedlung	n.a.	n.a.			
13	Gewässer	n.a.	n.a.			

German	**Englisch**
Offene Ackerfläche (oA)	Cropland
Dauergrünfläche (DGF)	Permanent grassland
Wald	Forest
Siedlung	Settlement
Gewässer	Waters

Erklärung

Gemäss Art. 28 Abs. 2 RSL 05

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Bachelor ☐ Master ☐ Dissertation ☐

Titel der Arbeit:	Assessing land use and land management and the impacts on land degradation and conservation in Frienisberg (BE)
Leiter/-in der Arbeit:	Prof. Dr. Hans Hurni Co-Leitung: Hanspeter Liniger

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Ich erkläre hiermit, dass ich diese Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen benutzt habe. Alle Stellen, die wörtlich oder sinngemäss aus Quellen entnommen wurden, habe ich als solche gekennzeichnet. Mir ist bekannt, dass andernfalls der Senat gemäss Artikel 36 Absatz 1 Buchstabe o des Gesetzes vom 5. September 1996 über die Universität zum Entzug des auf Grund dieser Arbeit verliehenen Titels berechtigt ist.

18.01.2016

Ort/Datum

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Unterschrift