Mapping the impact of SLM – the WOCAT –DESIRE experience

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ABSTRACT

Since 1992, the World Overview of Conservation Approaches and Technologies (WOCAT) initiative has developed a standardized method for documentation of Sustainable Land Management (SLM) practices. The resulting on-line database currently counts over 450 technologies and over 350 approaches (implementation strategies) from around 50 countries. WOCAT also developed a tool to map land degradation and conservation. This method complements the information provided by the individual case studies on technologies and approaches. It evaluates what land degradation is occurring where and what is done about.

The challenge is now to *implement* SLM practices that address environmental, economic and social concerns, i.e. decreasing degradation and improving ecosystems, while enhancing agricultural productivity and the livelihoods of land users. Research to show and quantify these impacts of SLM practices and on implementation strategies is undertaken in projects like DESIRE, in which the WOCAT methods and tools were used and further developed, from which results are presented herewith. These showed that land degradation mainly occurred as water erosion on cultivated and mixed land use. Degradation was increasing in most sites, primarily caused by inappropriate soil management. Indirectly, population pressure, insecure land tenure, and poverty appeared to be major causes of degradation. Land degradation negatively affected ecosystem services for almost all degraded areas. High negative impacts were observed regarding regulation of ecosystem services indicating that these require particular attention when developing and implementing remediation strategies. SLM measures appeared most effective on cultivated land, but positive impacts were also recorded for relatively large areas of forest and grazing land. Combinations of SLM measures appeared to perform better than single measures. Overall, there appears to be scope for improving SLM contributions to ecosystem services in cultivated land.

INTRODUCTION

While huge amounts of money have been invested in soil and water conservation (SWC) projects and programmes over the past few decades, very little is known about the spatial extent and effectiveness of these efforts. This document describes the methods and results developed and used by the World Overview of Conservation Approaches and Technologies (WOCAT) and DESIRE 'Desertification mitigation and remediation of land' projects to map the spatial extent of land degradation and conservation (Sustainable Land Management – SLM).

BODY OF PAPER

Background

The World Overview of Conservation Approaches and Technologies (WOCAT) initiative started in 1992, in reaction to the Global Assessment of Soil Degradation (GLASOD) by ISRIC (Oldeman et al. 1991). The original idea of WOCAT was to develop a world map similar the GLASOD one, however showing the positive side, i.e. describing what achievements had been made to combat soil degradation.

During the past 20 years WOCAT developed, tested and implemented a standardized and harmonized documentation and evaluation method for soil and water conservation (later expanded to the broader term SLM. Below SLM and SWC are used interchangeably). At the heart of this system are three questionnaires, for documenting "Technologies" (what is actually implemented in the field), "Approaches" (what is needed in terms of "enabling environment" for a successful implementation of a technology) and for Mapping the extent and impact of both degradation and SLM (WOCAT, 2012, Schwilch et al., 2011).

The resulting database currently counts more than 450 technologies and over 350 approaches documented in around 50 countries. The original mapping idea only recently received a new boost through collaboration with the LADA and DESIRE projects. The interactive, scale-independent mapping tool was jointly revised and used to map area coverage, degree, impact, effectiveness, and other parameters of land degradation and conservation for predefined spatial units based on land use systems. In the LADA project mapping took place at national level in 6 pilot countries, in DESIRE 17 smaller study sites were the subject of a mapping exercise which is described herewith.

The WOCAT questionnaire for mapping complements the information provided by the individual case studies on Technologies and Approaches. It evaluates what type of land degradation is actually happening where and what is done about it in terms of conservation. Linking this information to a Geographical Information System (GIS) facilitates the production of maps as well as area calculations on various aspects of land degradation and conservation. The on-line map database and map viewer provide a powerful tool to obtain an overview of land degradation and conservation in a catchment, a country or a region.

Method

The mapping method is described in WOCAT-LADA- DESIRE mapping questionnaire (Liniger et al. 2008). Land use is one of the main drivers of degradation / conservation and therefore forms the basis for delineating the mapping units for which subsequently the information on land degradation and conservation is filled in.

The mapping attributes on which information had to be collected consist of the following blocks: Land use, Degradation and Conservation/SLM). The information on degradation and conservation is more or less "mirrored", as shown in table 1 below.

Table 1

Degradation / Mapping unit	**SLM / Mapping unit**
Type	Name / Group / Measure
Extent (area)	Extent (area)
Degree	Effectiveness
Impact on ecosystem services	Impact on ecosystem services
Direct causes	
Indirect causes	Degradation addressed
Recommendation	

The collected data are largely qualitative, based on expert opinion and consultation of land users from the various study sites. This permitted a fairly rapid and general assessment of the spatial extent, status and trend of degradation and extent, effectiveness and impact of SLM as well as their drivers.

The information collected allows a range of different map outputs to be prepared, of which a few examples are given below. For instance, the extent of degradation in general or for specific types can be displayed, as well as their impact on ecosystem services. Similarly, conservation types and their effectiveness, as well as their impact on ecosystem services can be shown. Both conservation and degradation can simultaneously have positive effects on some ecosystems and negative effects on others. But normally the balance would be negative for degradation and positive for conservation.

Even though the mapping method is scale-independent, the accuracy and level of information of course vary with the size of the area mapped and hence with the scale applied.

Results

Some results from the mapping exercise in the 17 DESIRE study sites in 13 countries are presented and discussed using study site maps as well as bar graphs, which summarize results for all study sites.

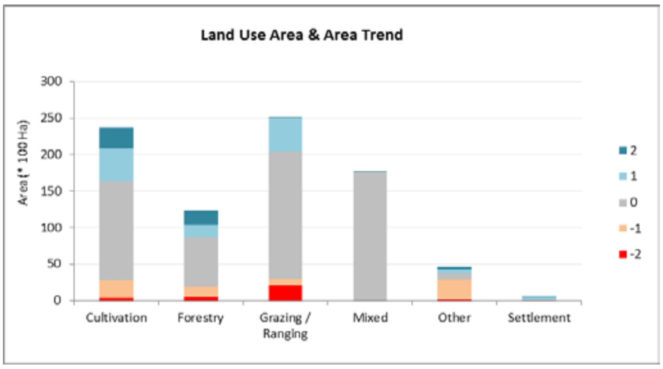

Figure 2. Trend in area of major land use types for all study sites, from rapidly decreasing in size (-2) to rapidly increasing in size (+2).

Land use

Within the DESIRE study sites (total area for all sites 838.493 ha), the areas of cultivated land, grazing land and mixed land are approximately the same size, covering 175.000 -200.000 ha each. Forestry covers about 100.000 ha, mainly in the two Portuguese sites and Mexico. Grazing and mixed land are predominant in Botswana (which covers by far the largest area in absolute terms), Russia, the two Turkish sites and Tunisia. Cultivated land and grazing/ranging are the dominant major land use types in relative terms (Figure 1).

The increase or decrease in areas with the major land use types was assessed over the past 10 years. As can be seen in Figure 2, the area covered by the major land use types in the majority of the study sites has remained stable. At the same time, due to increased numbers of livestock in the study sites in Botswana, Crete and Tunisia over the last ten years, the land use intensity of grazing and ranging has increased in about 50.000 ha of the DESIRE study sites.

Degradation types, extent, degree, rate, causes and impact

Spatial planning of SLM activities requires a spatial overview of the types, extent and causes of actual land degradation phenomena. The WOCAT-LADA-DESIRE mapping method distinguishes six major **types** of land degradation, each with several subtypes:

B: *Biological degradation*
C: *Chemical soil deterioration*
E: *Soil erosion by wind*
H: *Water degradation*
P: *Physical soil deterioration*
W: *Soil erosion by water*

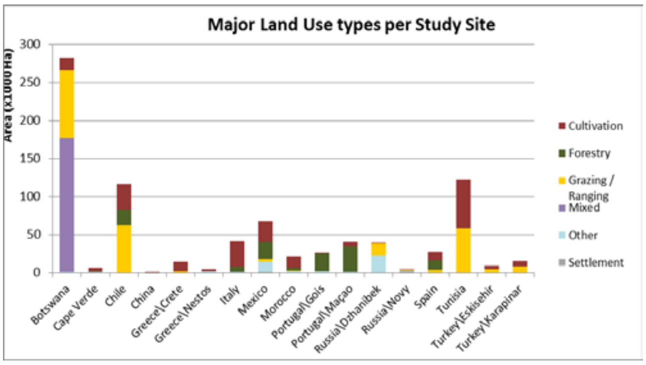

Figure 1. Distribution of major land use types per site

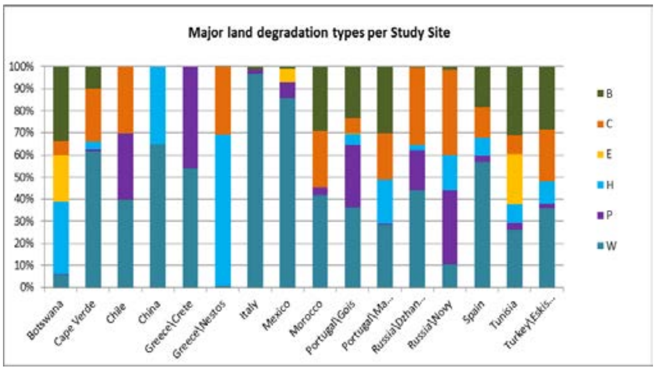

Figure 2. Major land degradation types per study site.

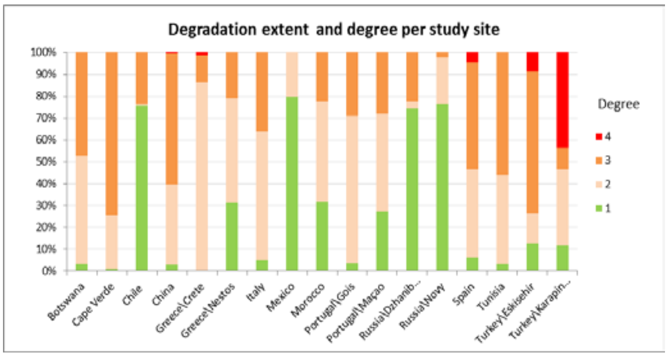

Figure 4. Relative extent of degradation and degree per study site.

Figure 3 shows the relative distribution of major degradation types within the DESIRE study sites. Water erosion (W), in particular sheet erosion by water, is the most commonly reported type of degradation, occurring in almost all sites. In about 70% of the degraded area various types of degradation occur simultaneously, and may have a combined effect (e.g. erosion and soil nutrient decline).Water erosion is the most important on cultivated land, followed by forest and grazing land. Grazing land shows the broadest range of degradation types and together with mixed land has the highest occurrence of wind erosion, probably because grazing (and mixed land use types that include grazing) often occurs in the drier lands that are less suitable for cultivation.

The **degree** of degradation refers to the intensity of the land degradation process. For example, in the case of soil erosion it is the amount of soil washed or blown away. The larger part of degraded land in the DESIRE study sites was recorded as being degraded at moderate to strong degrees (Figure 4). Extreme degree of land degradation was only recorded for the study sites in Spain and Turkey. For the Turkish site the degradation refers to wind erosion and soil fertility decline in the Karapinar site, and to several degradation types in the Eskisehir site (soil fertility decline, water erosion, biological degradation, water degradation).

While the degree of land degradation indicates the state of degradation at the moment of observation, the degradation **rate** indicates the trend of degradation over a recent period of time.

Land degradation appeared to increase moderately to rapidly in most of the DESIRE study sites (Figure 5). Some of these sites already exhibit moderate to strong land degradation. For other sites slowly decreasing degradation was reported (China and

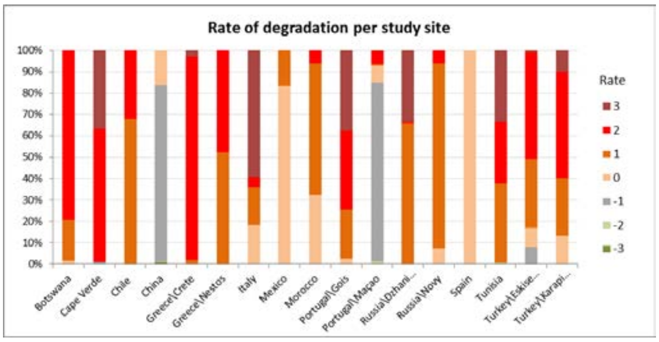

Figure 5. Rate (increase/decrease)of degradation per study site. 3: rapid increase, 2: moderate increase, 1: slow increase, 0: no change in degradation, 1: slow decrease , 2: moderate decrease, -3: rapid decrease.

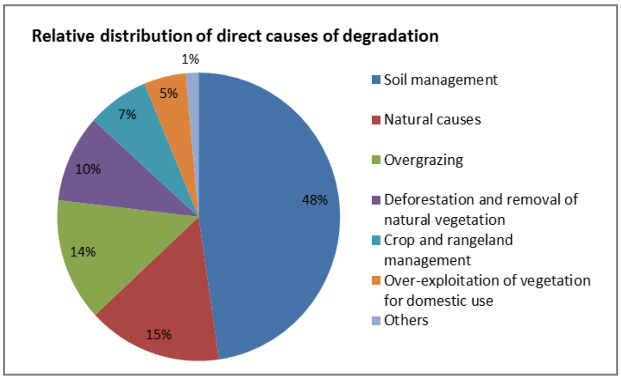

Figure 3. Relative distribution of direct causes of land degradation in the DESIRE study sites

Portugal/Maçao) as a result of SLM efforts already in place. This is confirmed by the mean effectiveness of conservation measures reported for these sites (see below).

Various **direct causes** may lead to land degradation. These often are human-induced but degradation also occurs due to natural causes, for example mass movements, droughts or flash floods, although these sometimes may also be influenced by human activities.

Figure 6 shows that inappropriate soil management, missing or insufficient soil conservation measures, or the use of heavy machinery, is by far the most common cause of land degradation. It is responsible for about half of the degraded area in the DESIRE study sites. Crop or rangeland management refers to the improper management of annual, perennial (e.g. grass), shrub and tree crops, like the reduction of plant cover and residues for burning.

In over 70% of the degraded area in the DESIRE study sites more than one causative factor is responsible for land degradation. In 20% of the degraded area five or more direct causes of land degradation apply. This illustrates the complexity of land degradation, and highlights the need for SLM technologies to address multiple forms of land degradation.

Indirect causes of land degradation include socio-economic factors. Population pressure and land tenure were reported as the two most important indirect drivers of land degradation in the DESIRE study sites (Figure 7). In most study sites a combination of indirect causes of land degradation was reported, implying that SLM strategies should be adapted to various socio-economic

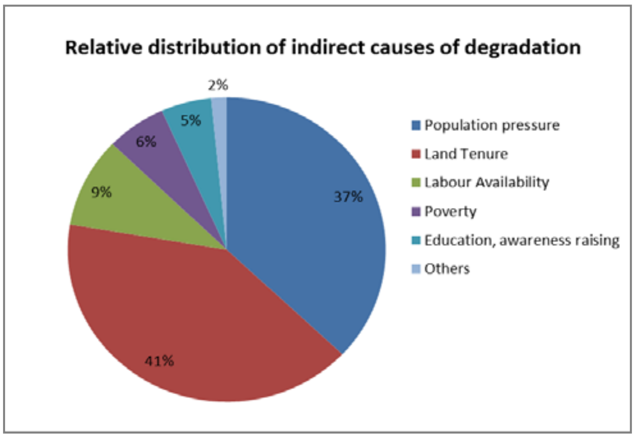

Figure 4. Relative distribution of indirect causes of land degradation in the DESIRE study sites

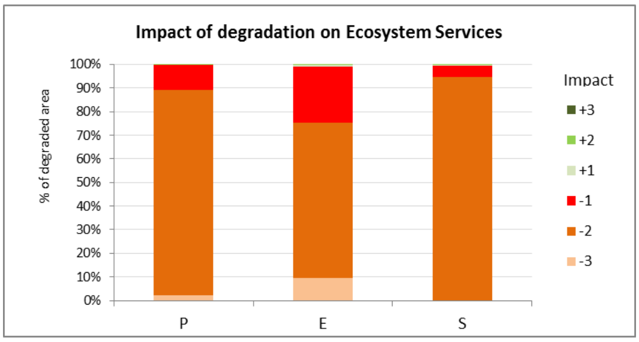

Figure 6. Impact of land degradation on ecosystem services (ES) in all DESIRE study sites. P: production services, E: ecological services, S: socio-cultural services. Negative/Positive contributions to changes in ES: (-)3: >50%, (-)2: 10-50%;(-)1: 0-10%

conditions in the farms or communities for which they are designed.

The **impact of land degradation on ecosystem services** (MEA, 2005; TEEB, 2010). is compared to situations without land degradation at present (e.g. areas that are already well conserved).

The mapping method regroups the ecosystem services as defined in the TEEB (2010) into the following categories:

P Productive services (provisioning services)
E Ecological services (regulating and habitat services)
S Socio-cultural services (cultural services)

The same degree of land degradation can have different impacts on ecosystem services in different places. For example, the removal of a 5 cm layer of soil may have a greater impact on the crop or fodder production on a poor shallow soil than on a deep,

Conservation technologies are clustered into groups which have names familiar to most SLM specialists and rural development specialists. The technology groups cover the main types of existing soil and water conservation systems.

CA: Conservation agriculture / mulching
NM: Manuring / composting / nutrient management
RO: Rotational system / shifting cultivation / fallow /slash and burn
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 / salinity regulation / water use efficiency
WQ: Water quality improvements
SD: Sand dune stabilization
CB: Coastal bank protection
PR: Protection against natural hazards
SC: Storm water control, road runoff
WM: Waste management
CO: Conservation of natural biodiversity
OT: Other

Box 1. Conservation groups in the WOCAT mapping method.

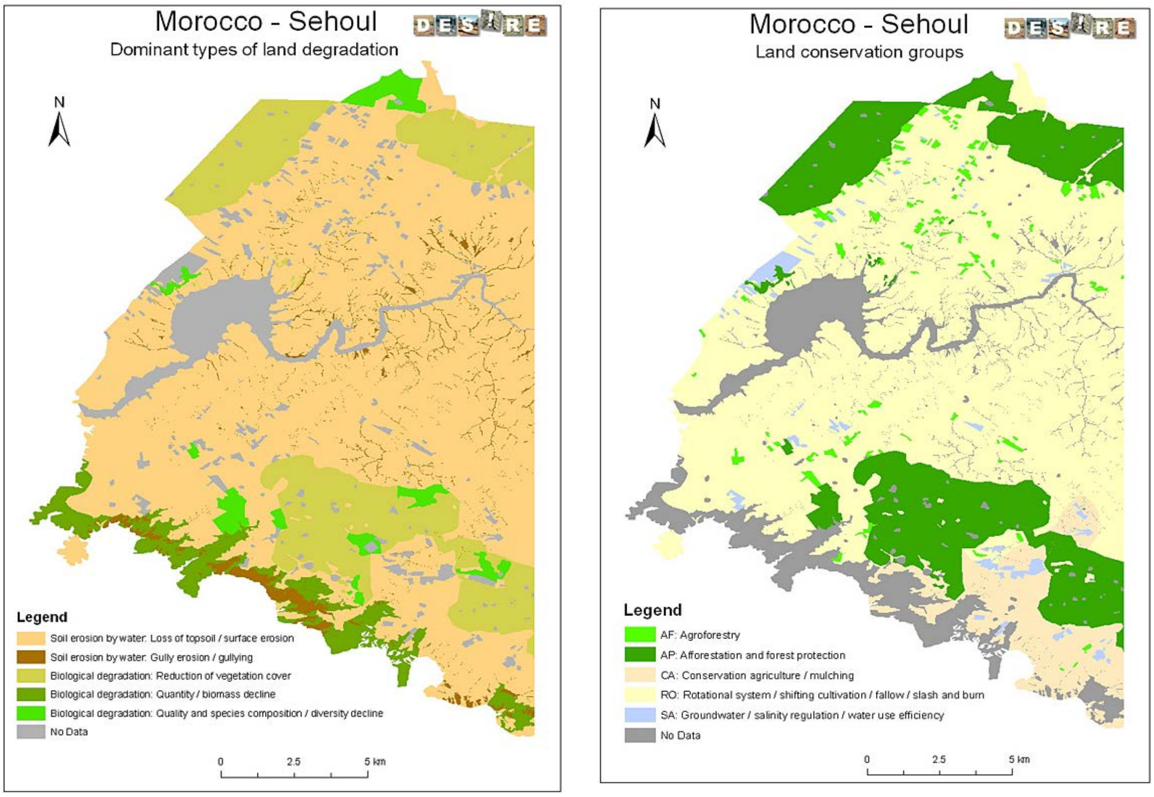

Figure 7. Types of dominant land degradation and conservation groups in the Moroccan study site. Source: Laouina et al., 2011.

fertile soil. Likewise, the reduction of water availability in a semi-arid environment has much higher impacts on humans and livestock than a similar reduction in a humid environment.

Land degradation may also have positive impacts on ecosystem services, for example where soil erosion leads to the accumulation of fertile sediment downstream. But generally the negative impacts of land degradation (mostly moderate, -2) are predominant (Figure 8). For half of the mapping units, corresponding to 35% of the degraded areas, impacts on more than one type of ecosystem services is reported per type of land degradation type. The highest level of negative impact was observed for regulating ecosystem services, indicating that these require specific attention in the process of developing and implementing remediation strategies against land degradation.

Conservation groups, measures, extent, effectiveness and impact

The mapping of conservation practices includes the identification of the SLM technologies in the field, including their combinations. Technologies are grouped into broader ‘conservation groups’ (Box 1). The extent of the technologies is assessed, along with their (trend of) effectiveness, and the impact on ecosystem services. The number of conservation groups recorded differs between the study sites and per land use (Figure 10). In the Moroccan study site for example, rotational systems and mulching and some conservation agriculture were applied in response to soil erosion by water (loss of topsoil/surface erosion) on cropland (Figure 9).

The **effectiveness** of conservation technologies is defined in four categories (1-4) indicating how much they reduce the degree of degradation, or how well they prevent degradation. For most conservation groups in the DESIRE study sites the effectiveness is moderate to high (Figure 11). Water harvesting and groundwater salinity regulation appear to be highly effective technologies for the areas concerned.

The conservation efforts reported do not necessarily correspond directly with the degradation occurrences in the same mapping unit: areas with no degradation may have this status *because* of effective conservation, or conversely strong degradation occurs because of lacking conservation.

Like the degree of degradation, the effectiveness of conservation is weighted by the area under conservation technologies within one mapping unit. An example is given for the

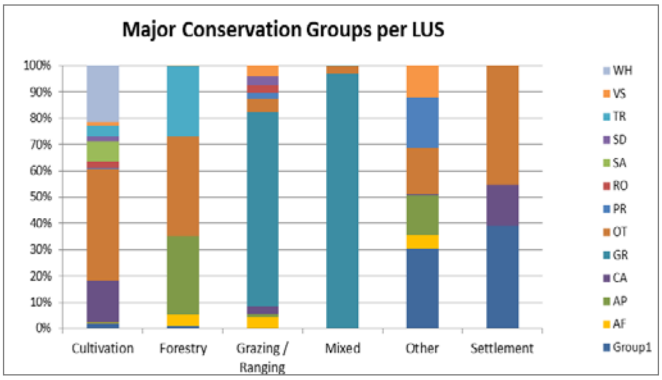

Figure 10. Relative distribution of major Conservation Groups per land use type. Group 1 is an aggregation of all minor groups.

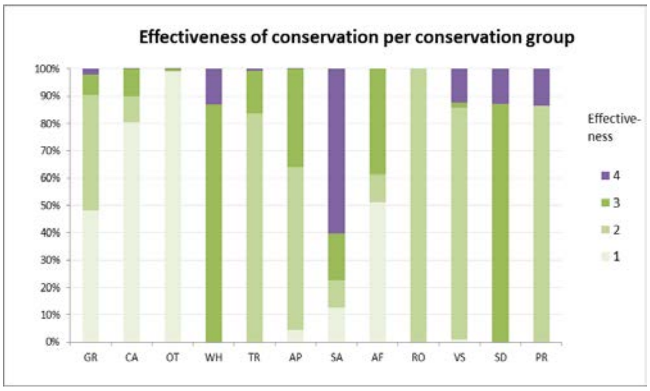

Figure 9. Extent and effectiveness of major Conservation Groups in the DESIRE study sites

Eskesehir study site in Turkey in Figure 12, showing a moderate to high effectiveness of conservation technologies for grazing management in its downstream part.

Highly effective conservation technologies over the entire area of application were reported for Tunisia, but far less effective technologies for Italy and Mexico. The techniques applied in Tunisia are ancient and have a long record of development and experimentation. The sites in Italy and Mexico experience severe soil erosion by water, which is aggravated by land levelling (Italy), and inadequately managed by the conservation measures applied (agroforestry in Mexico and no tillage, fallow and cover crops in Italy).

The WOCAT mapping framework distinguishes four categories of conservation **measures**:

1. Agronomic (.g. mulching)
2. Vegetative (e.g. contour grass strips)
3. Structural (e.g. check dams)
4. Management (e.g. resting of land).

A conservation measure is a component of an SLM Technology, which may consist of a combination of several conservation measures.

Figure 13 shows that in the DESIRE study sites, agronomic measures are the most widespread. However, combinations of two or more measures were reported for about 40% of the mapping units or approximately 20% of the area under conservation. The

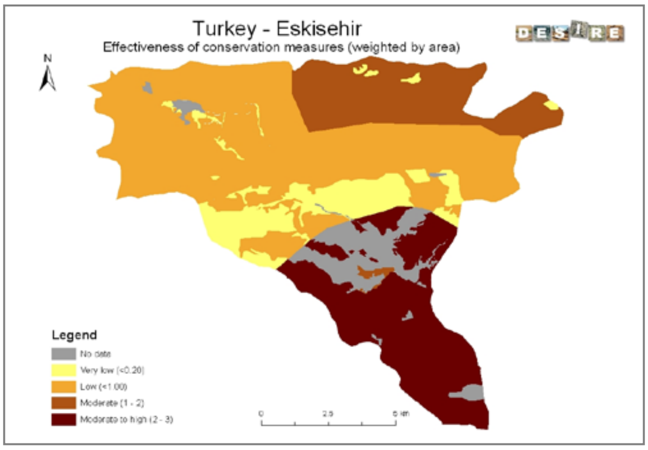

Figure 8. Effectiveness of Conservation in the Eskeshir study site (Turkey). Source: Ocakoglu et al. (2011).

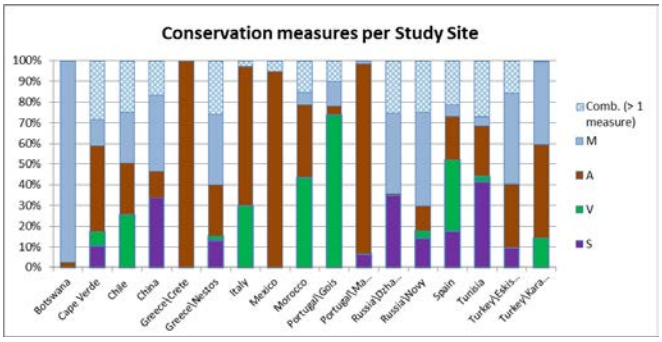

Figure 11. Relative distribution of conservation measures per study site, expressed in % coverage of the treated area.

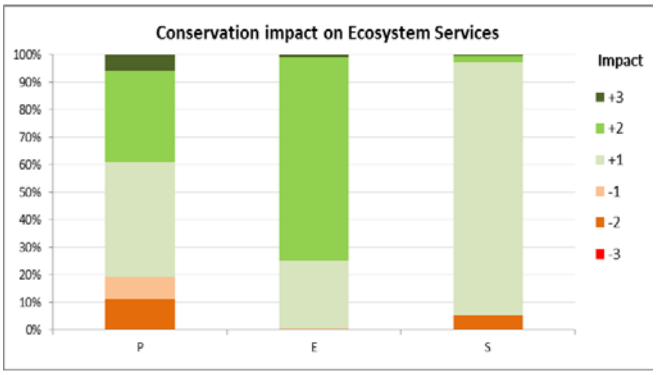

Figure 12. Impact of conservation on ecosystem services (ES) in all study sites. P: production services, E: ecological services, S: socio-cultural services. Negative/Positive contributions to changes in ES: (-)3: >50%, (-)2: 10-50%;(-)1: 0-10%

sites having a predominance of conservation measures of a single type appeared to have a relatively low effectiveness of conservation. This confirms that combinations of conservation measures are more effective than single measures, as is often reported in the literature (e.g. WOCAT, 2007; FAO, 2011; Liniger et al., 2011).

Ecological (regulating) services and socio-cultural services appear to be positively impacted by conservation measures over the larger part of the area under conservation. But the opposite is true for production services (P), which could be caused by a reduced intensity of land management, weeds or a loss of land due to area occupied by conservation measures. Negative impacts on production services were most frequently reported for agronomic and management measures, mostly in combination with the conservation groups Conservation Agriculture (CA) and Others (OT).

CONCLUSIONS

The WOCAT-DESIRE-LADA method for mapping degradation and conservation allows a relatively rapid inventory of the extent of degradation and conservation, based on expert opinion. The method was successfully used in the DESIRE project. Results showed that land degradation mainly occurred as water erosion on cultivated and mixed land use. Degradation was increasing in most sites, primarily caused by inappropriate soil management. Indirectly, population pressure, insecure land tenure, and poverty appeared to be major causes of degradation. Combinations of SLM measures appeared to perform better than single measures. Land degradation negatively affected ecosystem services for almost all degraded areas. High negative impacts were observed regarding regulation of ecosystem services indicating that these require particular attention when developing and implementing remediation strategies. SLM measures appeared most effective on cultivated land, but positive impacts were also recorded for relatively large areas of forest and grazing land. Overall, there appears to be scope for improving SLM contributions to ecosystem services in cultivated land.

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