DESIRE REPORT series

Model outputs for each hotspot site to identify the likely environmental, environmental and social effects of proposed remediation strategies

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May 25th 2012

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Report number 100
Series: Scientific reports

Deliverable 5.3.1

This report was written in the context of the Desire project
www.desire-project.eu

UNIVERSITY OF LEEDS

DESERTIFICATION MITIGATION AND REMEDIATION OF LAND – A GLOBAL APPROACH FOR LOCAL SOLUTIONS

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Contents

Summary

This report presents the PESERA-DESMICE model results for the study sites where it has been applied. Modelling has been the key strategy adopted in the DESIRE project to scale up results from the field to the regional level. The PESERA model, extended with several process descriptions to account for a variety of degradation types and to enable taking into account the effects of land degradation remediation options, has been calibrated to local study site conditions with local input data and verification results from WB4 trials and secondary sources. It is used to model erosion, biomass, and (for Portuguese sites) a fire severity index under current conditions and under different technologies. The DESMICE model is informed by WB3 WOCAT database records, economic WB4 experimental results, additionally requested data on spatial variability of costs and benefits, and secondary data. It applies spatially-explicit cost-benefit analysis to calculate the financial viability of technologies. After setting up the PESERA-DESMICE modelling system, a series of scenarios were designed to assess land degradation and land (biomass) productivity under different circumstances. A scenario typology including baseline scenarios, technology scenarios, policy scenarios, adoption scenarios and global scenarios was used for this purpose. A total of 65 different scenario simulations were performed for 22 different technologies in 12 study sites.

The report first explains how the models were calibrated and how the scenarios were defined. It then presents a cross-site analysis of results and finally presents a series of detailed maps for individual scenarios run for the various study sites. From the model applications, it can be concluded that (simple) technological options exist that can minimize land degradation and increase food production. A major bottleneck for adoption is financial viability. Low (zero) cost agronomic measures and other options that deliver important benefits in the short term are the preferred technologies. Stakeholder evaluation and model output mostly concur on this. There are important design and opportunity cost considerations which influence the analysis. For larger (more expensive) technologies feasibility studies will need to be done on a case by case basis. Models can be used for first approximation.

The approach taken includes three key innovations: a) it allowed to incorporate inputs from multiple stakeholders in very different contexts into the modelling process, in order to enhance both the realism and relevance of outputs for policy and practice; b) site-selection modelling is being applied to land degradation mitigation to enable landscape-scale assessments of the most economically optimal way to attain environmental targets; and c) use of Cost-Benefit Analysis to investigate the spatial variability of the profitability of SWC measures, which may have important implications for the adoption of measures across landscapes and their consequent environmental effects.

There are however also some shortcomings in the modelling approach. Firstly it appeared to be difficult for study sites to estimate spatial variation in investment costs of technologies and this as identified as a data gap. Secondly, the temporal dimension of changes in productivity is crucial for land users. Biophysical models (e.g. PESERA) should be able to separate immediate and gradual aspects. Ongoing degradation in the without case is not yet implicitly considered. Analysis of robustness to climatic variability and prices is also essential. Finally, factors such as attitude towards conservation and risk are likely to be very important in decision-making and could further limit adoption of technologies.

1 Introduction

The DESIRE project takes an iterative, cyclical approach to combat desertification problems. The cycle, working bottom up and starting with the establishment of goals and context in local study sites, then explores and selects different mitigation options, which are subsequently trialed and assessed at larger scale to establish the potential for upscaling before finally being evaluated by stakeholders in order to formulate recommendations for extension and policy (Reed et al., 2011a). The current report deals with the potential for upscaling of desertication mitigation options across study sites. It follows on from previous deliverables which set out an approach (Fleskens et al., 2009; deliverable 5.1.1), and detailed model descriptions (Kirkby et al., 2010; deliverable 5.2.1).

To understand the role of modelling in the DESIRE project, we need to take one step back. When local stakeholders have selected promising soil and water conservation technologies for their area, and these technologies have been tested in field experiments, it may still be difficult to formulate recommendations for their use. There can be various reasons for this, for example:

1) The experimental conditions for which selected technologies were tested are limited and do not reflect the variable conditions within a region. Rains may have been plentiful so that water conservation did not boost yields, or a terracing experiment was set up on a slight slope so that it remains uncertain how terraces would perform on steeper slopes;

2) The time it takes for technologies to develop full effectiveness and benefits is longer than technologies can be tested during a five year research project. Build up of soil organic matter after changing tillage methods or crop rotations is a slow process, and long-term yield increases will not have been observed;

3) Policymakers and extension services would like to know whether a technology performs across a range of conditions before committing to stimulating adoption. Apart from differences in environmental conditions and the time it takes to develop full benefits, the investment costs and access to markets are important factors influencing the viability of a technology.

Thus, modelling offers an alternative and complementary approach to evaluate the likely biophysical effects of adopting different remediation strategies at a regional scale and their financial viability. The cyclical approach does not terminate here; instead, model outputs were together with field trials results presented to stakeholders in a series of workshops across study sites. The findings from stakeholder evaluation workshops are documented in Reed et al. (2011b; deliverable 5.4.1). Here the purpose is to present model outputs for the different study sites, as well as to provide a concise overall summary of the process that led to their creation and a cross-site analysis of main findings.

The report reflects this purpose and is divided into four sections: this introduction, a summary of the PESERA-DESMICE modelling strategy followed, a cross-site comparison section and a compilation of model results for individual study sites. The next section explains the modelling strategy.

2 The PESERA-DESMICE Model

2.1. Calibration of the PESERA model

In Deliverable 5.1.1, Fleskens et al. (2009) have described how the biophysical model proposed for the DESIRE project builds on and extends the PESERA model (Kirkby et al., 2008), originally developed for Pan-European Soil Erosion Risk Assessment within a dedicated EU (FP5) project. The original PESERA model was extended to capture the role of grazing, fire and wind erosion more effectively, and enhance pedotransfer functions on the basis of dialogue and data within each study area; this work is described by Kirkby et al. (2010) in Deliverable 5.2.1. For the current task to generate model output for each study area, PESERA is adapted to reflect indicators and land degradation drivers identified in WBs 1 & 2 as closely as possible. The modified model will look at the biophysical effects of different remediation options that have been trialled in study areas. The strategy to do this is by comparison of baseline to modified conditions:

I. The **PESERA baseline** is an assessment of a series of biophysical descriptors at an equilibrium state driven by mean climate, land use, soil and topography. These descriptors are an estimate of monthly estimates of biomass (productivity), runoff and erosion. The PESERA baseline assessment is achieved with best understanding and interpretation of current land management practice and technologies, and constitutes **the without case** in technology assessment.

II. The **adapted PESERA assessment** is a representation of the same biophysical descriptors, but now evaluated as the simulated effects of a specific desertification remediation option. Adapted assessments are achieved with best understanding of the functioning of technologies. It hence forms **the 'with' case** of technology application.

Both baseline assessments and adapted PESERA assessments are input for DESMICE (see Section 2.2).

Climatic regimes and appropriate technologies
The DESIRE study sites represent a very wide range of climatic conditions, and the climate exerts perhaps the strongest constraint on what are appropriate remedial technologies. Figure 1 illustrates this climatic range. Months represented as points above and to the left of the Rf=PE have insufficient water for unrestrained growth, so that water is a limiting resource. If rainfall is less than about 60% of the potential evapotranspiration during the growing season, then rain-fed agriculture is severely limited, and only some specialised crops, such as olives or agave, can survive without irrigation. However, the high temperatures provide good conditions for rapid growth, and often for several crops per year where irrigation water can be provided economically.

The various climatic regimes provide different constraints to sustainable land use, and these are summarised in Figure 2, drawn with the same axes and scales as Figure 1. Under appropriate conditions, the greatest constraints may be through wind or water erosion, water scarcity, wildfires or frost damage.

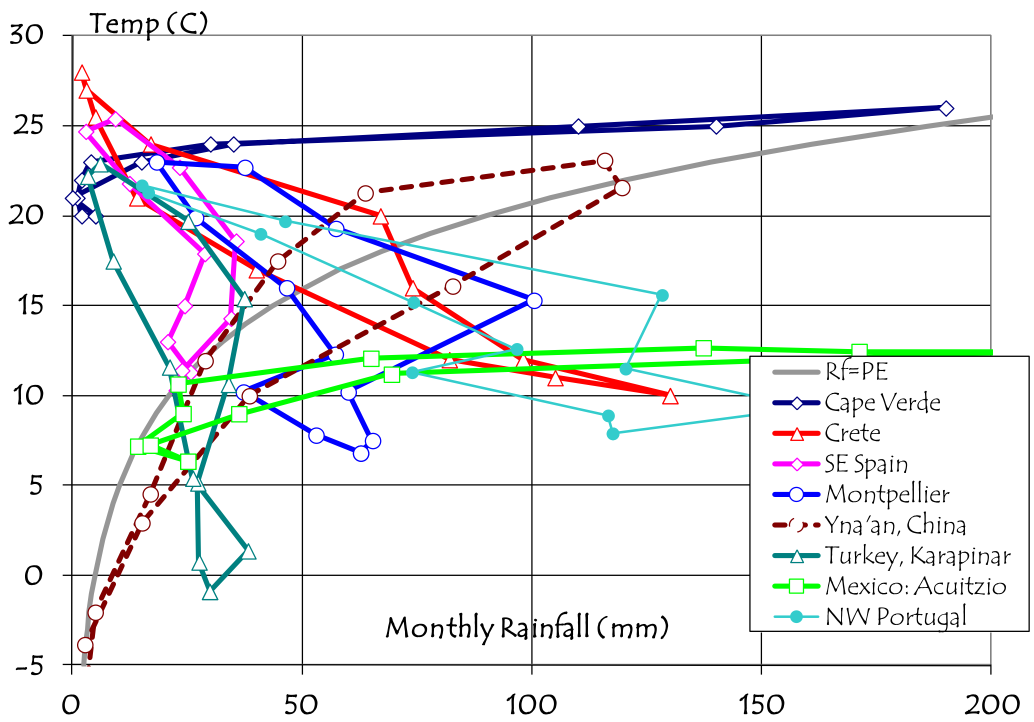


Figure 1: The climatic environment of study sites. Loops show mean monthly precipitations and temperatures for representative DESIRE study site areas.

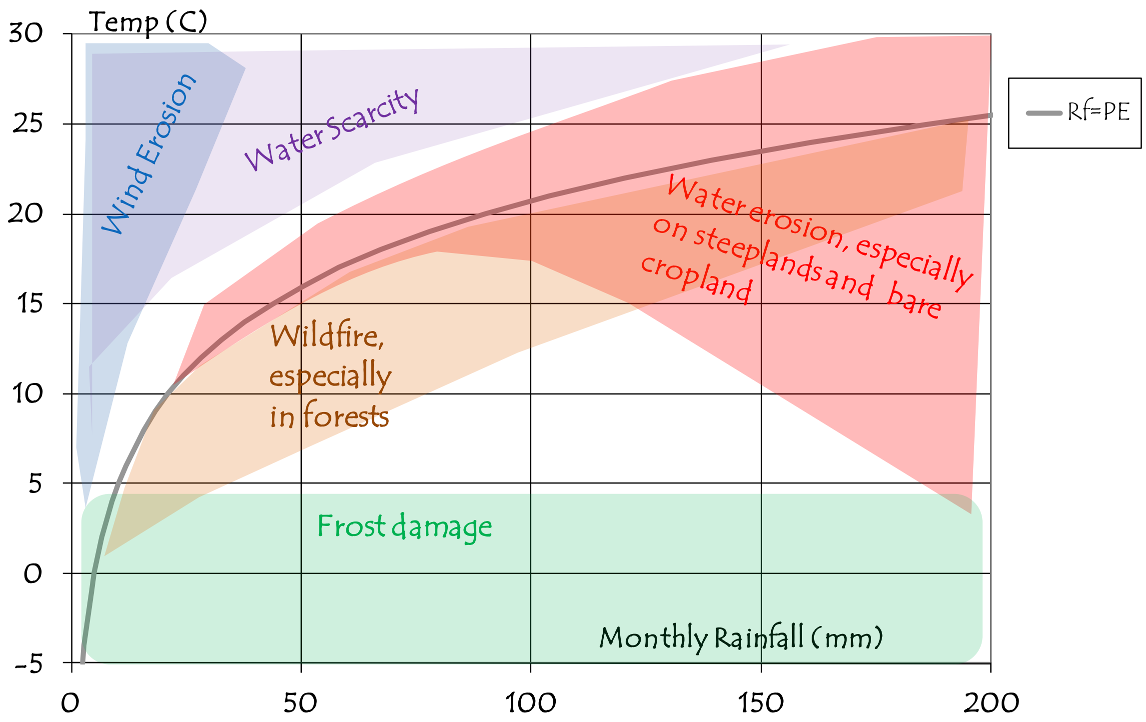


Figure 2: Factors that constrain sustainable land use.

PESERA adaptation for DESIRE technologies

Many of the DESIRE technologies consider rainfed cereal agriculture, where natural soil erosion rates are increased by an order of magnitude with long term on- and off-site impacts. Other technologies focus on biomass protection but more commonly on a combination of more than one technology (Table 1).

Table 1: Mitigation measures accommodated within the adapted PESERA modules

	DESIRE Study Site	Baseline (PESERA/ site)	Tillage (minTill /redTill /noTill)	noTill / subsoil	Mulch / stubble	cont' plough	grass terrace / woven fences	Water / Soil Harvesting	Biomass Protection / recovery (Green cover)
8	Sehoul	Y	Y						atriplex/ resting
6	Karapinar	Y	Y		Y				
7	Eskishir	Y				Y	Y		
1	Torrealvilla	Y	Y		Y				
17	Cauquenes	Y	Y	Y					
12	China	Y	Y				Y	check-dams	
14	Mexico	Y	Y		Y				(agave)
18	Cape Verde	Y					Y		pigeon peas
9	Tunisia	Y						jessour	resting
2	Gois	Y							prescriptive fires
2	Macao	Y							Preventative fires
13	Boteti								biogass

In rainfed cereal agricultural protection from erosion is generally most effective through measures that increase infiltration rates and so reduce the amount of overland flow runoff and soil loss. The most reliable measure is generally to increase ground cover. In areas at greatest risk, this may require the maintenance of a natural vegetation cover (without excessive grazing), but a number of conservation measures can reduce erosion within cropland. Inter-cropping ensures ground cover throughout the rainy season. Strip cropping reduces the distance over which runoff can build up before flowing back into a vegetated strip. Terracing reduces the overall gradient, and so the erosive power of runoff, but must be combined with measures to protect the over-steepened trace risers, by strengthening them with stone or perennial vegetation and/or by diverting runoff away from them. Over time, terraces generally accumulate deeper soils along their lower margins, often at the expense of the upper part of the terrace, and the deeper soils may help to retain more water for the growing crops. Table 2 shows typical change in PESERA parameters and variables used to simulate mitigation options and associated changes in cultivation management.

Table 2: Typical change in PESERA parameters and variables used to simulate mitigation options

	Vegetation Cover (kg/m^2)	Ground Cover (%)	Humus (kg/m^2)	crust	P1swap1 (mm)	Rough (mm)	Re- infiltration (mm)
minTillage	+	+	+	-			
Ploughed stubble			+				
stubble	+	+	+				
Contour ploughing						+	+
Woven fences / terraces					+		+

Prescriptive and preventative management is adopted in areas prone to wildfire (Esteves et al., 2012). Wildfire occurs wherever there is a substantial accumulation of dry above-ground biomass. This combination is usually associated with forest or shrub vegetation rather than with cropland. Fires are generally ignited either by lightning strikes, which are generally more frequent in the tropics, or through human intervention, either deliberate or accidental, related to the number of people using or visiting the forests and so substantial in Europe with its high densities of roads and population. Fires, once started, are most severe when the biomass loading is high, but they spread most quickly when the biomass is less and wind speeds are high, so that the fire moves through the canopy and burns the soil less severely. Under severely water-scarce conditions, biomass is dry, but too sparse to support large fires. Under humid conditions, there is a high biomass but it rarely dries out enough to support a fire. Intermediate conditions provide the conditions of greatest fire risk, with sufficient moisture to provide good growth and a dry season to reduce the moisture content of the canopy. Figure 3 shows how the greatest risk is associated with these intermediate areas.

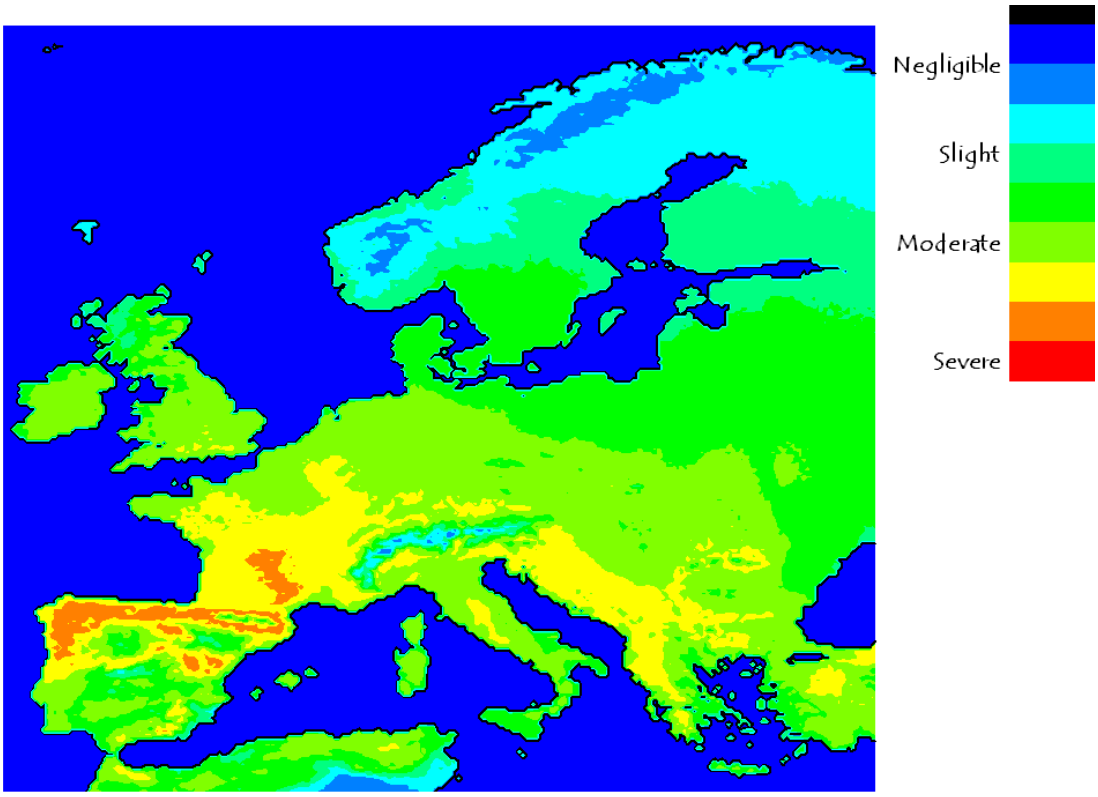
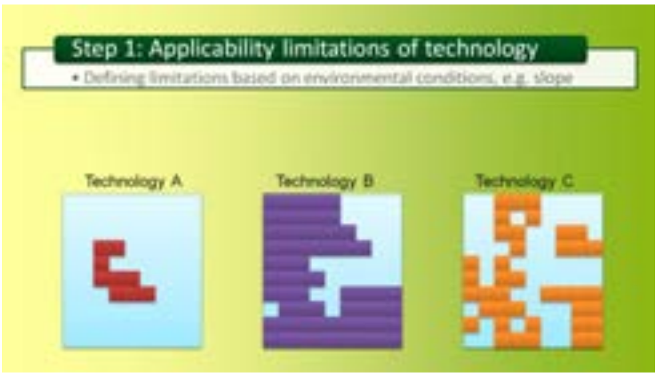


Figure 3: Climatic component of wildfire risk for Europe under natural vegetation.

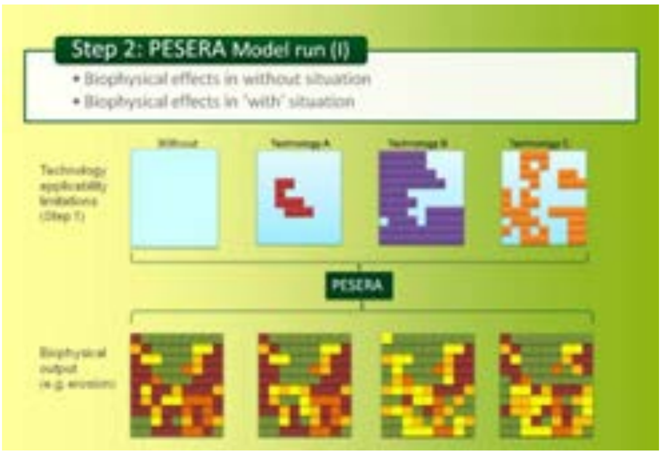
2.2. Scenario analysis with DESMICE model

The DESMICE model is developed as a series of ARCGIS Modelbuilder modules with subroutines programmed in Python. As explained in Deliverable 5.1.1 the socio-economic model (DESMICE) informs PESERA where remediation technologies can be implemented, and PESERA provides the biophysical output on which DESMICE will subsequently elaborate to calculate economic feasibility. Relative to the original model description, some simplifications were implemented. In some cases, this reflects the fact that data was limited. However, this also stems from a separation of model steps and scenario analysis, reducing the number of model steps from 12 to 6. The **6 model steps** are shown below:

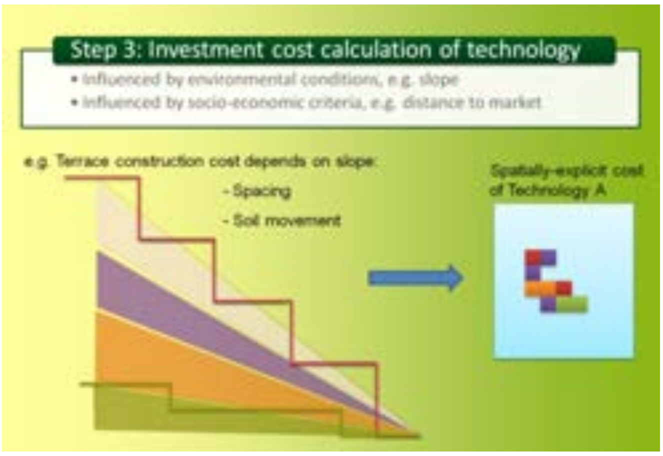
1. First it is necessary to define where each technology can, on biophysical grounds, in principle be applied. This is an important step in that it rules out the area where technologies cannot be applied e.g. terraces on steep slopes with shallow soils. Factors considered include: soil depth, slope, land use, climate and distance to streams.



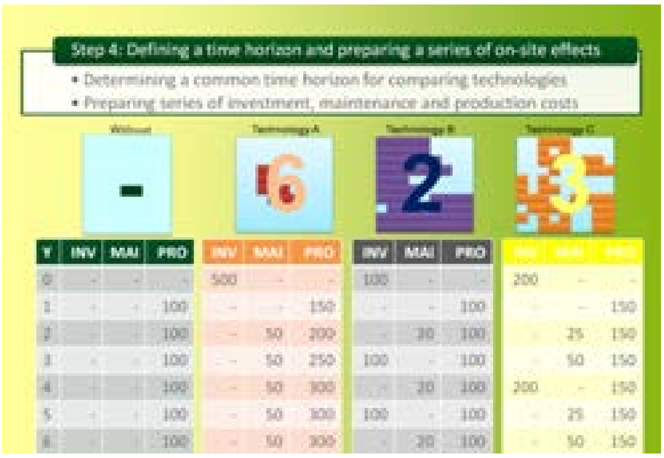
2. The PESERA model is run, taking into account each technology's potential applicability area, and compared to a case where no technology is applied. In practice, applicability limitations can also be clipped out later to reduce coordination effort.



3. WOCAT technology questionnaires currently show only one cost estimate; in reality this will depend on location. DESMICE can consider two different aspects: environmental conditions (e.g. terrace spacing and hence cost depends on slope) and distance to market. The latter functionality was not implemented in the analyses for this report.

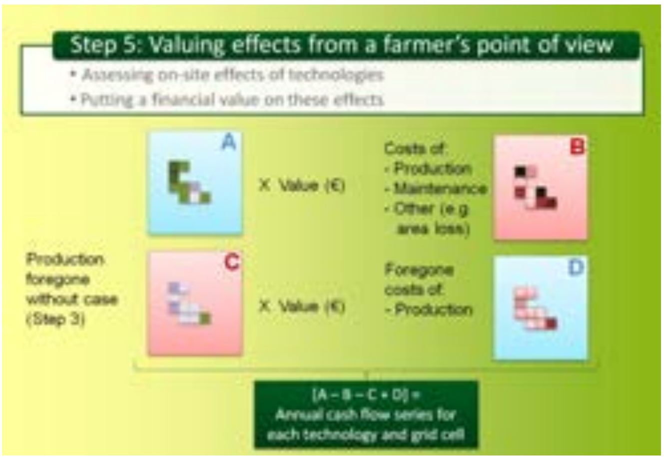


4. The technologies that are being assessed may have different economic lifetimes. Therefore, shorter-lived technologies are assessed over several cycles of re-investment (over the length of time that the longest lived technology is likely to last for). Years of (re-)investment are filled first; maintenance costs are subsequently added for years in between investment. Production costs need also to be considered because application of technologies may lead to a change of land use or use of input (e.g. more labour because of larger harvest).

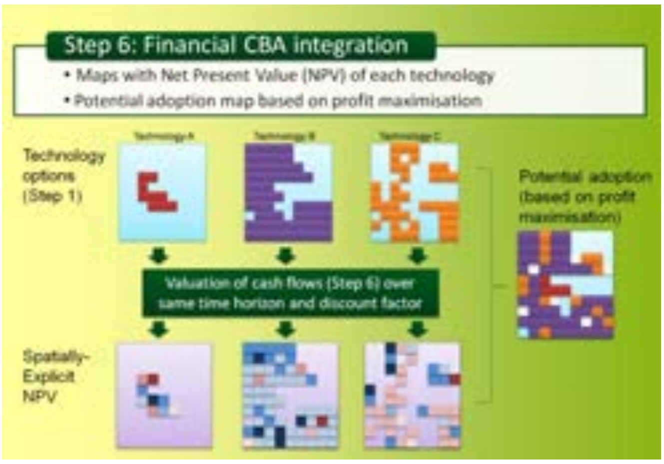


5. To value effects of a remediation strategy, the following will be assessed on a yearly basis for the lifetime of the technology (or multiple lifetimes):
   A. Evolution of production output (yield x value) over time
   B. Evolution of costs of implementing the technology and land use associated with it
   C. Evolution of production output (yield x value) as it would develop were the mitigation strategy not applied
   D. Evolution of the costs associated with the land use in this ‘without’ case

   For each year, the net result can then be calculated as [A-B-C+D] (note that benefits and costs may vary both in space and time).



6. The annual cash-flows of step 5 are subsequently used in a Financial Cost-Benefit Analysis (FCBA). An important issue in FCBA is discounting, i.e. introducing an interest rate that depreciates costs or benefits occurring in the future relative to those felt now. Summing discounted cash-flows gives the Net Present Value (NPV) for each technology. For each grid cell, one of the following three possible outcomes will apply:
    - The technology with highest NPV will be selected (when positive) (the adoption grid shows a possible configuration of technology A, B and C)
    - No technology will be selected if all NPVs are negative (i.e. white pixels in potential adoption grid)
    - No technology will be selected if no technology is applicable in the area (blue cells in adoption grid)



Model input data primarily comes from the WB3 WOCAT database. Additional data requests were made using two information sheets (for study sites and technologies respectively). Furthermore, data from field trials (WB4) were used in parameterizing the DESMICE model.

Different types of **scenarios** were developed to simulate the effects of proposed remediation strategies as well as of policies. These were:

1. **Baseline scenario**, the PESERA baseline run, see above.
2. **Technology scenario**, assessing the effects and financial viability of mitigation options for those areas where they are applicable.
3. **Policy scenario**, assessing the effectiveness of financial incentive (and alternative) mechanisms to stimulate adoption of technologies if they are not economically attractive. Local policies have in some cases been considered based on information from WB1 and study sites.
4. **Adoption scenario**, considering the simulated technologies (if more than one) in conjunction and assumes that the most profitable option has the highest potential for uptake by land users. In order to make the net present value of different options comparable, the same time horizon is applied to the analysis.
5. **Global scenario**; two types were defined, the food production and minimizing land degradation scenarios. The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation.

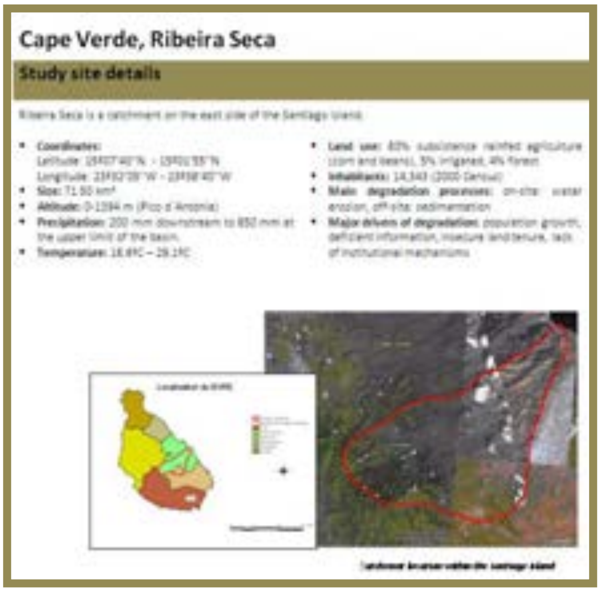
The **combined PESERA-DESMICE model** was run for all study sites with data and degradation processes for which the model can be applied to simulate both the bio-physical and socio-economic consequences of these scenarios. The field data collected in WB4 allowed performing a calibration check to get biophysical effects in the right order of magnitude. Model output was discussed in stakeholder workshops in 5.4 to allow further broad-based qualitative evaluation of integrated model results. This evaluation is discussed in Reed et al. (2011b).

3 Overview of PESERA-DESMICE Model Results

3.1. Guide to PESERA-DESMICE model output

This chapter will present an overall analysis of model outputs (in Section 3.2). Detailed model output for study sites is presented in Chapter 4. When referring to model output for a particular site, one will see that it follows a generic format. In this section, the format is explained as well as any assumptions made in the preparation of model outputs.

Study site details
The front page for each study site starts with a short facts section and overview map of the study site. The facts include a one-sentence description of the study site, the coordinates (latitude, longitude) of either the boundaries or center point of the study site and size of the area. Together with the overview map, these facts help the reader to locate the area. Note that none of the subsequent maps of model results offer location or coordinates – hence the importance of this front page section.



Further details include data on altitude, precipitation levels, temperature range, land use, population and perceived most important degradation processes and drivers. This information is mostly summarized from Van Lynden (Ed.) (2011; deliverable 1.2.1). Note that for model analyses, DEMs and spatial data sets of climate, soil and land use were used – the details provided here are just to give a snapshot view of study site characteristics. The number of inhabitants here reported is used in calculations such as per capita food production.

Overview of scenarios
The front page also lists the scenarios run for the particular study site. Their number varies, e.g. depending on the number of technologies tested or for which there was sufficient data, or the existence of policy options. Where scenarios relate to technologies included in the DESIRE WOCAT database the corresponding reference number is given (e.g. CPV01).

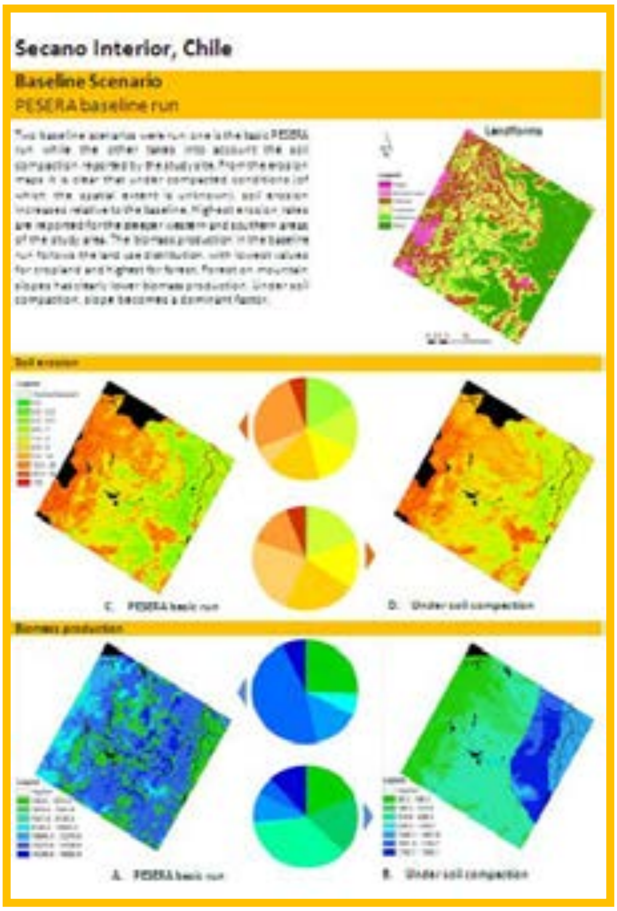
Baseline scenario

The PESERA baseline run shows model results for the study site under current conditions (see Section 2.1 for technical details). Usually, only one set of output maps is shown here. However, sometimes, such as in this Chilean case, there is a lack of clarity over current study site conditions – in this case the level of compaction. Hence two baseline output maps are shown, one for uncompacted and one for compacted conditions.

The first map (top right) shows a landforms map for the study area which is produced by a DESMICE submodule from the study site DEM. Not only is the landforms map frequently used to determine applicability limitations (as per WOCAT records), it is shown here as it gives a good overview of the topographic conditions of the study site.

Soil erosion maps are presented with fixed classification of soil loss, so that one can compare the severity of land degradation across study sites. To note that PESERA soil loss estimates are field-based, i.e. there is no routing of sediments through stream networks. In the Portuguese study sites, instead of soil erosion, maps of fire severity index (FSI) are depicted, as the local degradation problem is susceptibility to and occurrence of wildfires.

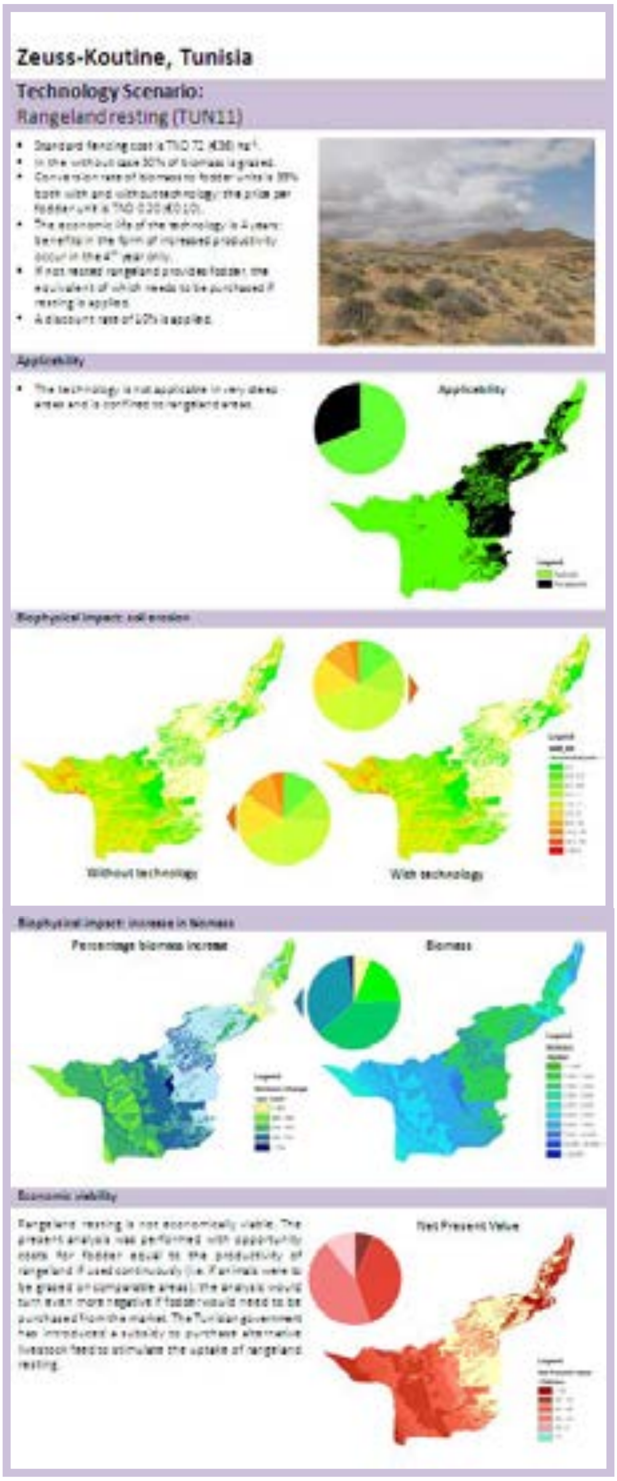
Biomass production maps do not have a fixed legend, as variations between study sites are too large for a single classification to be relevant. Within a study site, the map can show nuances in productivity caused by environmental gradients as well as the sometimes large variation between different land uses – e.g. arable land versus forests. The units of biomass production are kg/ha or ton/ha and include whole-plant biomass, not just yields. A harvest index is required to calculate the latter.



Box 1
Use of pie charts and use of background colour for no data

The model results are frequently presented in a dual format: as a distributed feature on a map and as a pie chart. Both formats are interrelated. The pie charts can be helpful to quickly assess the distribution of the characteristic depicted over a classification – which is sometimes difficult to see on the map. Pie charts are in principle drawn for the area for which data is shown on the map; i.e. the black background in the maps above represents areas with no data, which are consequently ignored in the pie charts. One exception are the green/black applicability limitation maps where green stands for 'the technology is applicable' and black for 'not applicable' (see an example on the next page about Technology scenarios). Background colours for no data sometimes vary per map for reasons of visibility – they can be recognized by bearing no association to the legend colour scheme.

Technology scenario
A technology scenario presents the model output for a specific remediation option. They form the core of the scenario simulations, as policy, adoption and global scenarios are based on them. The description starts with a number of facts or assumptions that were used in the simulations. These may pertain to the situation under the current conditions (without case), the situation after implementation of the technology, or both. Costs and prices are given in local currency and Euros to facilitate cross-comparison between sites. All numbers are either based on reports by study sites (WOCAT database), secondary sources or in some cases derived from other study sites with comparable conditions.



Applicability limitations show the share of the study area where the technology can, in biophysical terms, be implemented. Soil erosion maps compare annual soil erosion in the with and without situation. For the Portuguese study areas, where wildfires are the main degradation problem, erosion maps are replaced with fire severity index (FSI) maps. The impact of the technology on biomass is here considered especially as a degradation mitigation outcome and hence focuses on total biomass rather than yields (one can multiply values with a harvest index if given to arrive at yield levels; or refer to the global food production scenario). Shown are a map of the percentage of biomass increase relative to current conditions and total biomass after implementation of the technology.

Economic viability maps come in two flavours:

I. For agronomic measures that need to be repeated annually as part of the production cycle, the maps present the outcome of a partial budget analysis of the difference of costs and benefits in the with and without situation.
II. For technologies requiring investment (also if only in kind) and where benefits accrue only after a certain period, cost-benefit analysis (CBA) is applied and includes the use of a discount factor. The map in this case presents the Net Present Value (NPV) of the investment.

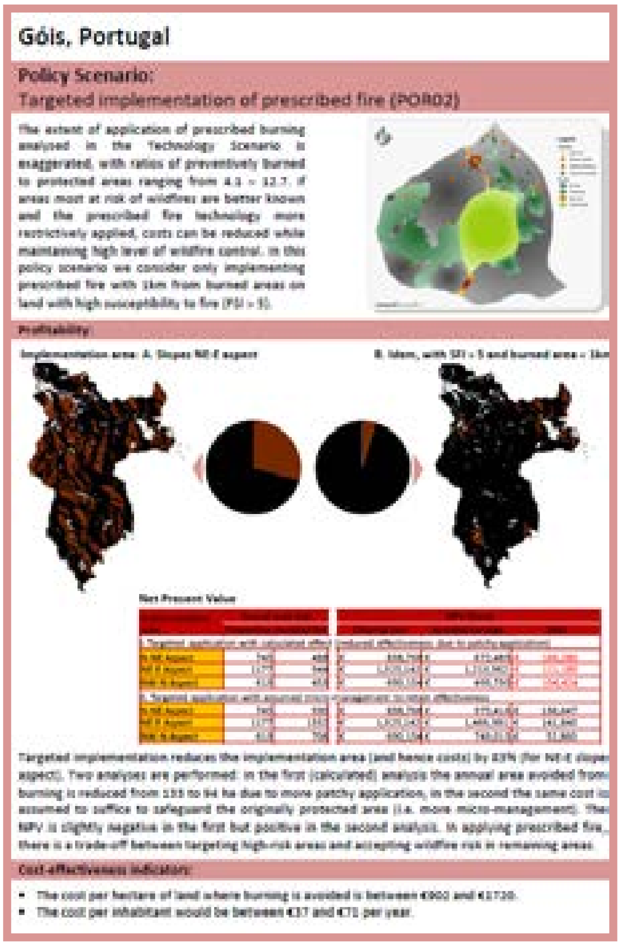
Box 2
Assumptions for economic viability calculations

Financial analysis of the technology under consideration is an essential element of each technology scenario, and is revisited in any policy scenario (if applicable). Exact cost and benefits are hard to define. Care has been taken to err on the conservative side so that the assessment does not paint a rosy picture of the technology. Here are some of the most important assumptions made and residual issues that need to be taken in mind when using the presented figures:

- A profitability or NPV of 0 is deemed to be the minimum required for financial viability of a technology. It is acknowledged that many factors come into play for a land user to decide to implement a technology, but if a technology does not at least maintain the current financial status quo the technology is not attractive.
- In the technology scenario, all costs are assumed to be incurred by the land user (or other decision-making entity). Any subsidies or other forms of incentives are excluded from the analysis. In the WOCAT terminology, the results thus reflect the financial attractiveness of a technology for spontaneous adoption.
- It appeared to be difficult for study sites to estimate spatial variation in investment costs of technologies. Environmental variations (e.g. with slope steepness) are taken into account for structural measures such as terraces, but distance to source areas and markets was not taken into account in the analyses.
- While the temporal dimension of changes in productivity is crucial for land users, PESERA assessments of technologies produce equilibrium outputs. The time lag to arrive at these equilibrium conditions is not explicit. In the case of some management measures, especially those implemented on severely degraded lands, it may take a very long time to arrive at equilibrium conditions. Linear trends are assumed in these cases, with equilibrium conditions assumed to be reached after 20 years.
- Similarly, current conditions are assumed to be at equilibrium. No ongoing productivity decline due to progressing degradation is considered in the without case.
- Where perennial crops are planted as part of a technology, progression of productivity is set according to local and species-specific trends.
- Some structural technologies harvest water or accumulate land from a larger area. In these cases, a conversion factor such as a catchment to cropped area ratio (CCR) has been assumed. Conditions in the catchment area are assumed to remain constant after implementing the technology.
- In the specific case of Portuguese study sites, where technologies are intended to mitigate risk of wildfire occurences, analyses have been performed based on actual fire outbreaks between 2000-2009 for which spatial data were available. In these cases, a single financial viability estimate is given as the application of the technologies is not assessed from an individual land user perspective but for a municipality as a whole.
- All financial analyses are of course sensitive to price fluctuations. Although no sensitivity analyses are performed, one of the most difficult assumptions is the price of labour (opportunity) costs. All analyses have duly priced all labour input at the going daily wage rate in the study areas. Land users are known to accept lower return to labour in several circumstances (slack season, conservation works around the home in spare time, etc.) so that fnancial viability maps can be regarded as conservative estimates.

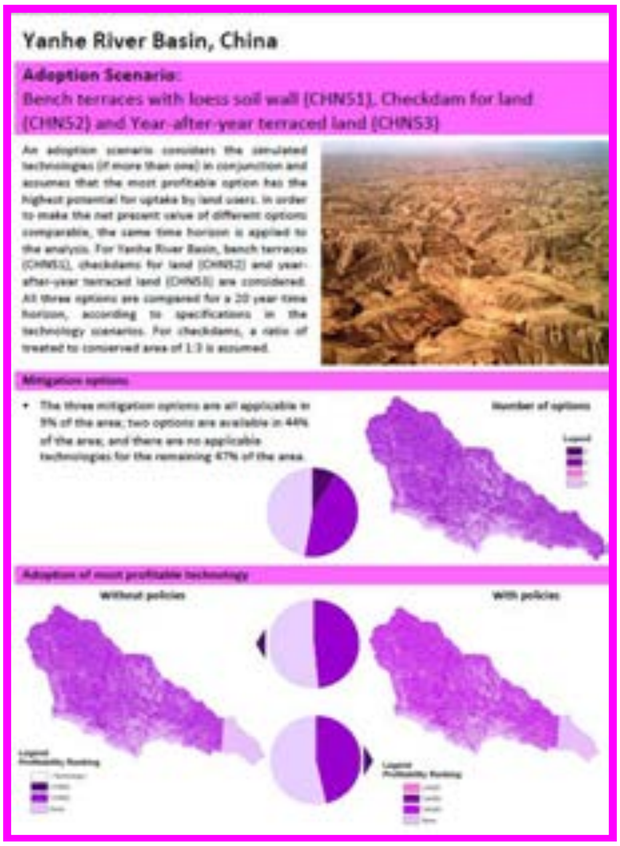
Policy scenario

Policy scenarios are presented for any incentive or strategy that could help to improve the viability and/or extend the adoption of a technology with the final goal of enhanced mitigation of land degradation. Most frequently, policy scenarios assess the cost-effectiveness of subsidies to reduce investment costs to implement a technology for land users (e.g. an incentive in the form of a 50% reduction is often presented). The policy scenario starts with a description of the issue and the type of incentive/strategy to be evaluated. Subsequently, the profitability of the technology with and without the policy is compared. In the Góis example used here, estimates for profitability are given for the entire area and are not spatially-explicit. Hence, the comparison is made in a table format and instead, the changes in the area subjected to prescribed fire are depicted in maps. Finally, cost-effectiveness indicators are presented to assess the cost of the policy measure (from a public, or governance perspective) in relation to the environmental benefit obtained. Cost-effectiveness can be expressed in monetary units per ton of soil loss prevented, or per hectare of land saved from burning.



Adoption scenario

Adoption scenarios are presented where multiple technologies with partially overlapping applicability areas are being assessed. The purpose of the adoption scenario is to provide a summary overall view of the spatial arrangement of the possible mitigation options, and the adoption patterns if it is assumed that in each cell, the most profitable technology (i.e. the one with the highest NPV) is selected. This assessment is made for all technology scenarios ('without policies') and all policy scenarios combined ('with policies'). For many study sites, only a single technology scenario was run, or different technologies had mutually exclusive applicability areas. In such cases, there would be no added value in presenting an adoption scenario, which is hence not elaborated.



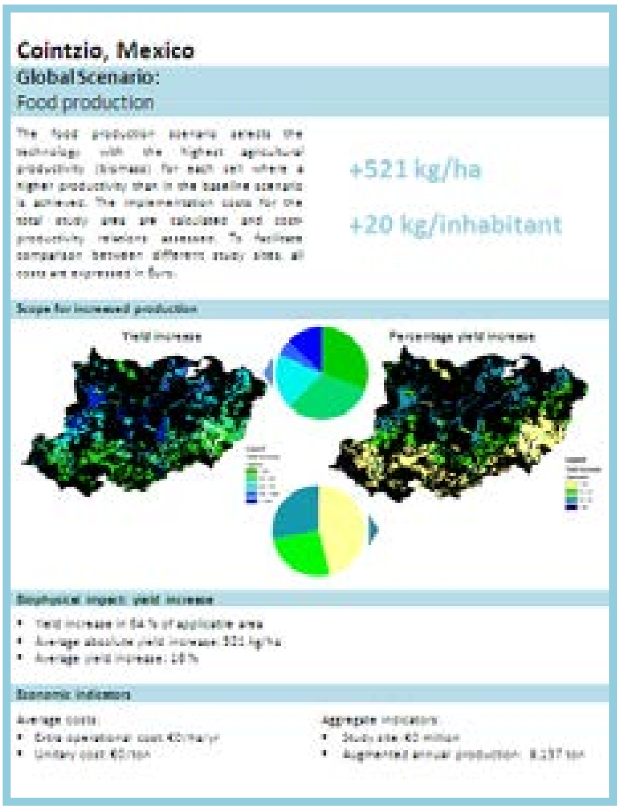
Global scenario

The final type of scenario takes a reverse approach to the policy scenario. Instead of asking the question what the effectiveness of a policy is, it considers the technical capabilities of the remediation option(s) in creating impact across the study area, and then provides an investment requirement. The objective of this analysis is not so much a local analysis, but to provide a global comparison of potential impact – hence the name 'global scenario'. Two types of global scenarios are presented:

I. Scope for increased food production, assessing how much more food could be produced in an area if desertification remediation strategies were adopted to the maximum extent (insofar as they enhance crop production); and
II. Scope for minimizing land degradation, assessing by how much soil erosion could be curbed if effective remediation strategies were fully implemented.

In both cases, the absolute and percentage improvements relative to current conditions are presented. Note that for food production, yield increases are reported rather than biomass increases. For erosion reduction, negative rather than positive numbers are effective and colour coding for soil erosion reduction classes have been inverted to illustrate this fact.

Biophysical impact and economic indicators are subsequently provided. These are also used to calculate the main indicators presented in the top-right corner: yield increase per hectare and per capita for food production scenarios, and erosion reduction per hectare and cost per ton of soil prevented from eroding for land degradation minimization scenarios.



Box 3
Food production increases

Increased cereal yields, even of different crops, are deemed to be directly comparable across study sites as they have similar calorific content. Yield increases of other crops, such as olives and apples, are also provided but not included in cross-site analysis due to their non-staple character. Still other production increases, such as rangeland productivity having an impact on livestock production, and agave production for alcohol distilling, have not been reported here.

Concluding remarks

The final page of each study site report recaptures the main points of the analyses, and provides a narrative for the specific study site context and processes. Where possible, reference is made to other DESIRE results, e.g.:

- The expert mapping of land degradation in WB1 is compared to the PESERA baseline run;
- Technology scenarios are assessed against experimental results (WB4);
- Stakeholder opinion about technologies and its evolution in time between WB3 and WB4/5 workshops is discussed in relation to model results;
- Local policies (WB1) and stakeholder opinion about how to promote sustainable land management (WB4/5 workshops) are revisited when discussing results of policy scenarios
- Adoption and global scenario results are presented with a view of supporting WB6 recommendations for extension and policy.
- Finally, an overall conclusion is given which refers to the general context of environmental change and the feasibility of the remediation options considered to build resilience, as well as any remaining research before such recommendations can be made.


Karapinar, Turkey

Concluding remarks

3.2. Cross-site analysis of model results

PESERA-DESMICE simulations were made for 11 study sites (Figure 4). For each of these, a series of model output maps is presented in Section 4. The DESMICE model was also applied in a non-spatially explicit manner to assess biogas as a desertification mitigation option in the Boteti area in Botswana (Perkins et al., in press) and is included in this cross-site analysis as well. The remaining study sites have not been included in this report for a variety of reasons. In the Rendina basin (Italy) shallow landslides are the main land degradation problem for which PESERA was extended (PESERA-L ; Borselli et al, 2011). The temporal and spatial dimensions at which shallow landslides occur are not readily translatable in land use management options for which to conduct a cost-benefit analysis, and therefore the DESMICE model could not be applied. However, the results of PESERA-L are described in DESIRE report 82 (Borselli et al, 2011). The Nestos site (Greece) and two Russian study sites (Novij and Djanybek) feature salinization and water logging problems for which PESERA is not applicable. In principle, it would be possible to couple the DESMICE model with alternative models that are more suitable for these problems than PESERA. The biophysical model results for the Russian sites as well as West Crete (Greece) are presented in separate addendum reports.

1. Botswana (Boteti)
2. Cape Verde (Ribeira Seca)
3. Chile (Seccano Interior)
4. China (Yanghe river basin)
5. Mexico (Cointzio)
6. Morocco (Sehoul)
7. Portugal (Góis)
8. Portugal (Mação)
9. Spain (Torrealvilla)
10. Tunisia (Zeuss-Koutine)
11. Turkey (Eskişehir)
12. Turkey (Karapinar)

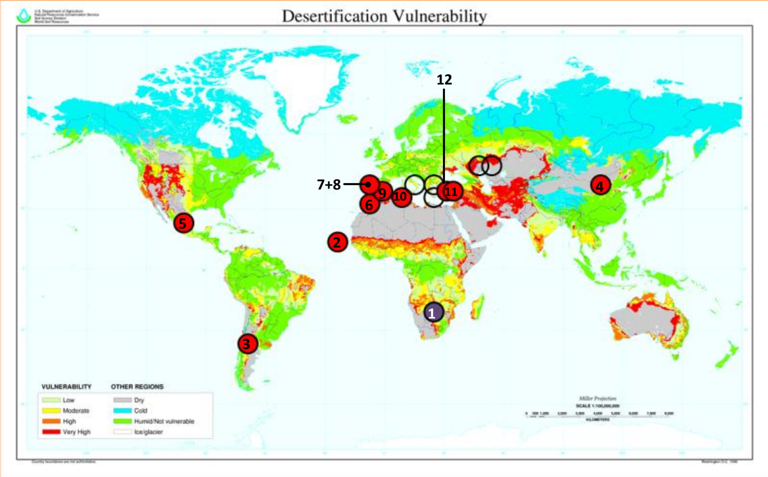


Figure 4: Locations of DESIRE study sites for which PESERA-DESMICE was run.

PESERA Baseline runs

Baseline assessments of soil erosion under current conditions were made for a range of study sites (Figure 5). Comparing these assessments, it becomes apparent that there are large differences between sites. One very remarkable result is the low degradation problem in Karapinar (Turkey). In this site, wind erosion rather than water erosion is the main degradation problem. Either lower soil loss rates are already alarming or wind erosion processes were not adequately modelled, e.g. because of a lack of good wind speed data. PESERA results put the Seccano Interior (Chile) in first place regarding the severity of soil erosion, while Yanhe river basin (China) and Eskisehir (Turkey) also rank high. Cointzio (Mexico), Sehoul (Morocco) show a more mixed picture, with both pockets of unaffected and severely affected land. According to these results, the Torrealvilla (Spain) and Zeuss-Koutine (Tunisia) areas are only moderately affected by soil erosion.

It is interesting to compare model assessment of soil erosion with land degradation mapping using expert knowledge (Figures 5 and 6). The latter was done in WB1 using the WOCAT mapping method (Van Lynden et al., 2011). When comparing Figure 5 with Figure 6 (taking care that do not feature in both charts), one can note:

- China – that the proportion of the area affected by serious land degradation is roughly similar; experts are more optimistic in classifying the remaining land as little affected than model results suggest;
- Mexico – little agreement between model results and expert opinion, with the latter assessing the situation much less degraded;
- Morocco – both model and experts sketch a mixed picture of land degradation, with a striking level of agreement;
- Spain – although both methods emphasize intermediate classes of land degradation, the model is on this account more optimistic than the experts;
- Tunisia – experts consider over 70% as severely degraded, whereas the model assesses 70% as very little degraded;
- Turkey (Eskisehir) – again a striking agreement between model and expert opinion, and a severely degraded site;
- Turkey (Karapinar) – little agreement, with experts noting severe land degradation and the model missing any degradation problem (as is briefly discussed above).

The Tunisian site is the most arid, followed by the Spanish and Turkish sites, which overall seem to have more severe land degradation in expert opinion than model assessment. It could be that low levels of vegetation typical for those more arid conditions influence the experts, or that PESERA is too sensitive to slope angle in comparison to plant cover.

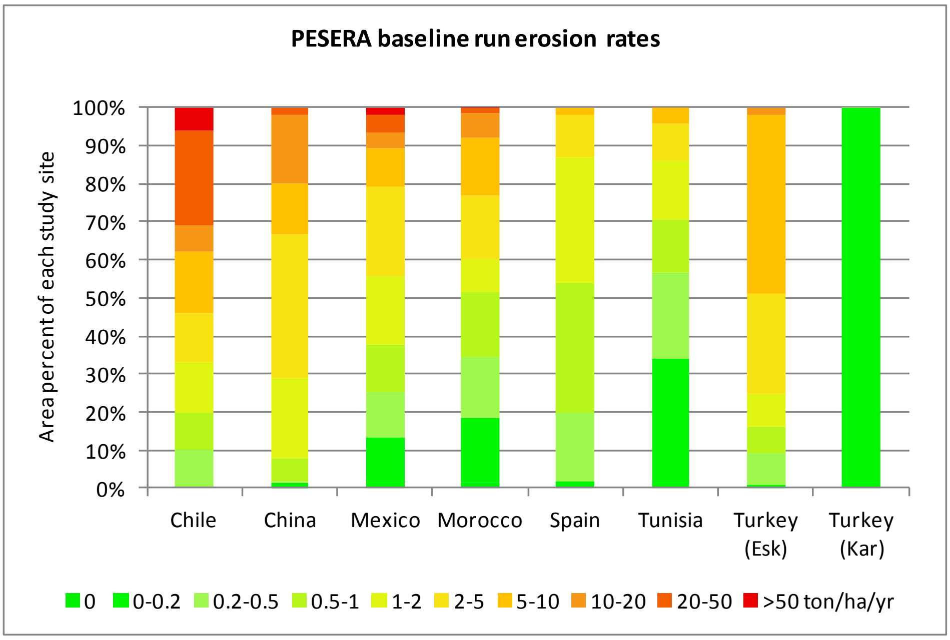


Figure 5: Overview of PESERA baseline run erosion rates for selected study sites.

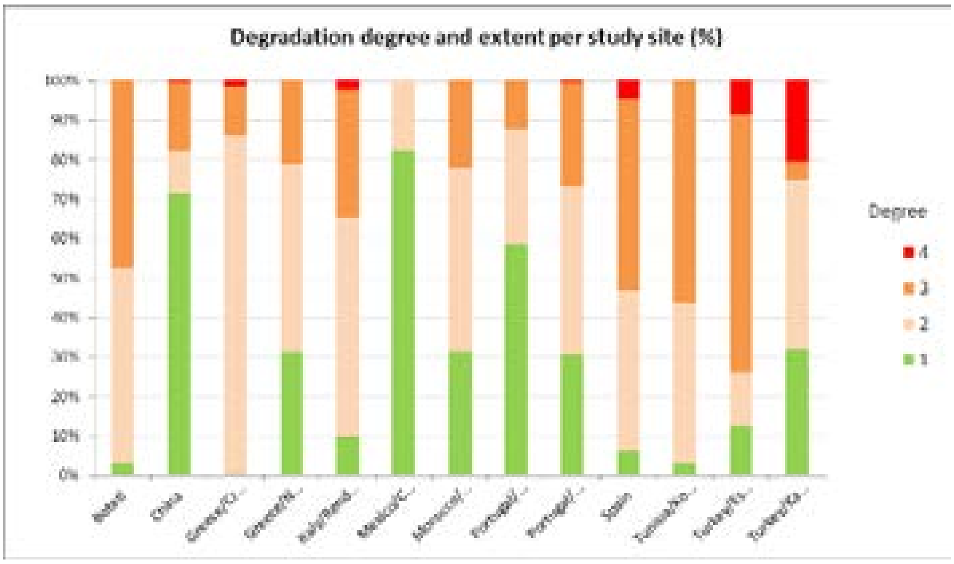


Figure 6: Degradation degree and extent in study sites according to WOCAT mapping. Source: Van Lynden et al., 2011

Technology scenarios

The effectiveness and financial viability of a total of 22 technologies were simulated in the combined study sites. As Table 3 shows, structural measures (n=8) were the most common, followed by agronomic measures (7), management measures (5) and vegetative measures (2). In order to include technologies, availability of experimental data (WB4 experiments) was in many cases a requirement to understand the functioning and effectiveness of the technology and to calibrate PESERA to local site conditions.

Table 3: Overview of technologies in each study site for which PESERA-DESMICE simulations were run and their classification according to main WOCAT categories: agronomic, management, structural & vegetative.

Study site	Technology name	Type
Boteti, Botswana	Biogas (BOT05)	Management
Ribeira Seca, Cape Verde	Terraces with pigeon pea (CPV01)	Structural
Seccano Interior, Chile	No tillage with subsoiling (CHL01)	Agronomic
Yanhe river basin, China	Bench terraces with loess soil wall (CHN51)	Structural
	Checkdam for land (CHN52)	Structural
	Year-after-year terraced land (CHN53)	Structural
Cointzio, Mexico	Minimum tillage in rainfed and irrigated maize	Agronomic
	Land reclamation by agave forestry with native species (MEX02)	Vegetative
Sehoul, Morocco	Gully control by plantation of atriplex (MOR15)	Vegetative
	Mulching (fencing) and conventional tillage (MOR16A)	Management
	Mulching (fencing) and direct seeding (MOR16B)	Management
Góis, Portugal	Prescribed fire (POR02)	Management
Mação, Portugal	Primary strip network system for fuel management (POR01)	Structural
Torrealvilla, Spain	Reduced contour tillage in semi-arid environments (SPA01)	Agronomic
Zeuss-Koutine, Tunisia	Jessour (TUN09)	Structural
	Rangeland resting (TUN11)	Management
	Tabia (TUN12)	Structural
Eskişehir, Turkey	Contour ploughing (ETH43)	Agronomic
	Woven fences with contour ploughing (TUR05)	Structural
Karapinar, Turkey	Minimum tillage	Agronomic
	Stubble fallowing	Agronomic
	Ploughed stubble fallowing	Agronomic

When classifying the simulated technologies according to the type of measure, a gradient of increasing cost of investment can be observed going from Agronomic < Management < Structural measures ≈ Vegetative (Figure 7A). Agronomic measures were very cheap and in one case actually presented a cost saving (range -€30 - €79 per ha); they can be incorporated in the annual crop production cycle and are confined to application on arable land. Management measures are more versatile and included a variety of technologies ranging from biogas to prescribed fire for fire prevention and controlling access to fields or rangelands. They typically command an investment analysis as benefits tend to accrue in the medium to long term. The same holds for structural measures. Variability in investment costs was high in this category due to the inclusion of some expensive structures (e.g. checkdams for land - China). Vegetative measures were surprisingly the most expensive category. Although only consisting of a non-representative sample size of two technologies, one could generalize and say that due to their implementation in restoration activities, large investments were required and in order to enable seedlings to survive additional management and structural measures are also used.

Next, we verified that for technologies modelled (under widely variable circumstances), most frequently about half of the hotspot can be treated due to applicability limitations. However, in some cases this is considerably less (checkdams for land – China: 9%; gully control by planting atriplex – Morocco: 10%) or more (terraces with pigeon peas – Cape Verde: 76%; rangeland resting – Tunisia: 69%). When aggregating per type of measures, management measures seem to have the widest range of applicability, followed by structural and agronomic measures (Figure 7B). It is suggested that vegetative measures typically demand more specific conditions and are consequently not as widely applicable.

Within applicable areas, many technologies are not profitable in about 70% of the area. Figure 7C shows aggregated financial feasibility of the technologies considered. This figure needs to be interpreted with caution as many factors come into play. For agronomic measures, effectiveness is an important factor. Yields may not respond or even be negatively affected, rendering the technology uneconomic despite low cost. For management measures, their versatile nature makes that although they are widely applicable, they are not universally financially sustainable. Together with structural measures, another factor with large influence is the time horizon after which the technology is evaluated. Some examples are included of measures that are not profitable after 10 years, but very profitable after 20 years. For structural measures, another factor that contributes to mixed financial performance is their sometimes very high investment cost. For the two vegetative measures, which are shown to be attractive in 100% of their applicability area, one should not forget that this is on a limited area – i.e. they may be highly specialized measures. More importantly however, the without case is unproductive in these cases, and the fact that plants need to grow to maturity means that the right time to evaluate the measure may be more easily determined.

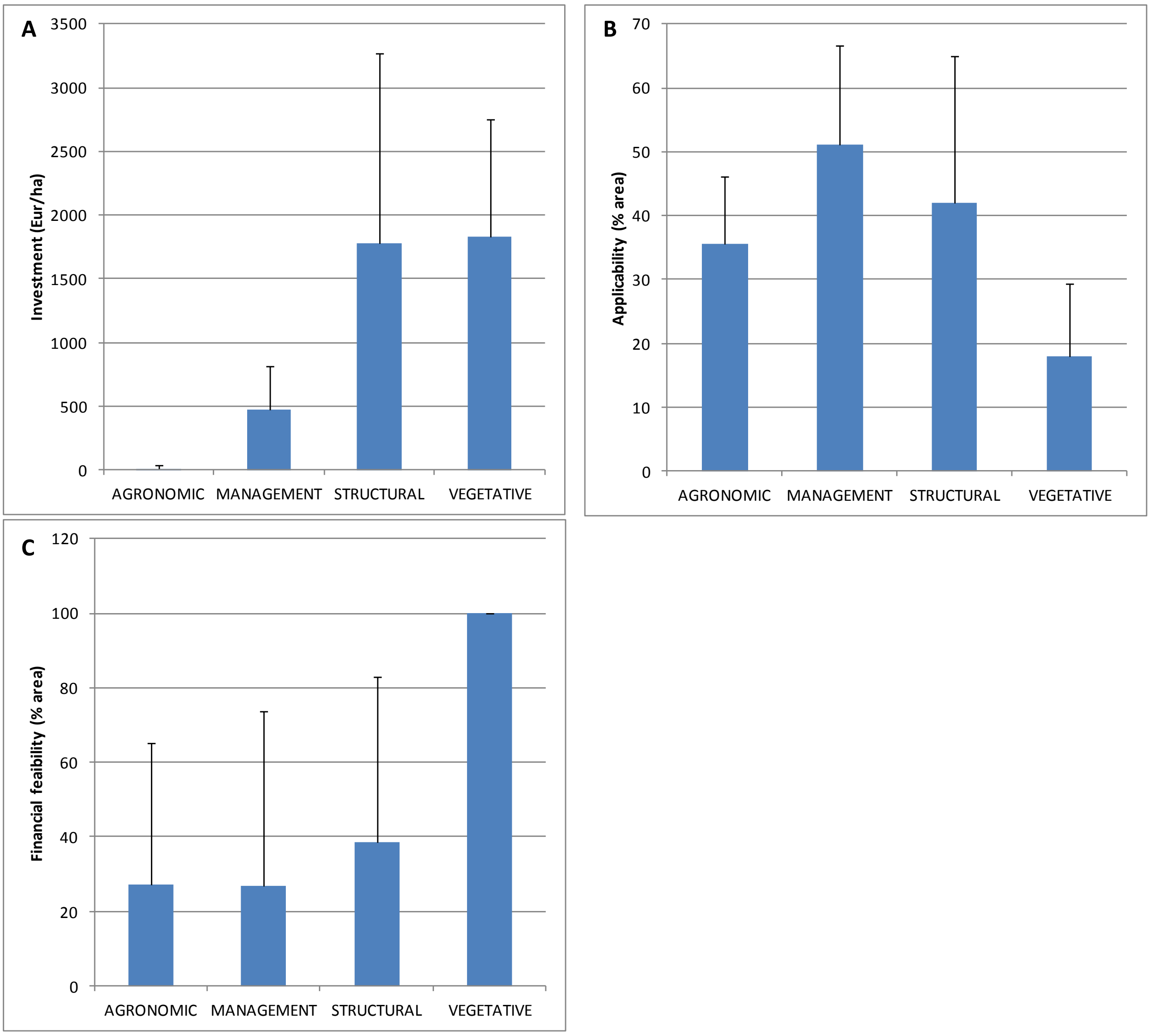


Figure 7: Investment costs (a), applicability limitations (b) and financial viability (c) of different types of measures.

Policy scenarios
A total of 11 policy scenarios were run for 8 different sites, of which this section provides a brief overview. The first question we can ask is whether policies contributed to the aim to facilitate upscaling of desertification remediation options. Figure 8A shows a large spread in feasibility of technologies under situations with and without policy interventions. The 1:1 line is the no-effect line and usually one expects only the area above the line to be populated; the larger the distance to this line the more effective a policy is. The chart shows that in a few instances, policies do not result in increased feasibility. On two occasions, there are slight improvements of an already quite high feasibility, e.g. from 81 to 93%. In the remaining cases, an unprofitable technology is raised to being feasible in between 33 and 94% of the applicable area.

Comparing the per area unit costs of technologies with their effectiveness in reducing soil erosion, from a sample of policy scenarios for which cost data was available (n=5), a general trend of increasing effectiveness with increasing cost can be observed (Figure 8B). A much better correlation was found between total cost of a policy and its effectiveness in reducing soil erosion (Figure 8C). The difference between the two charts is that in the first instance, the area aspect relates to the cost of (subsidies towards implementation of) technologies on a per hectare basis, whereas in the second case the total cost of a policy can be high because of a large applicability area.

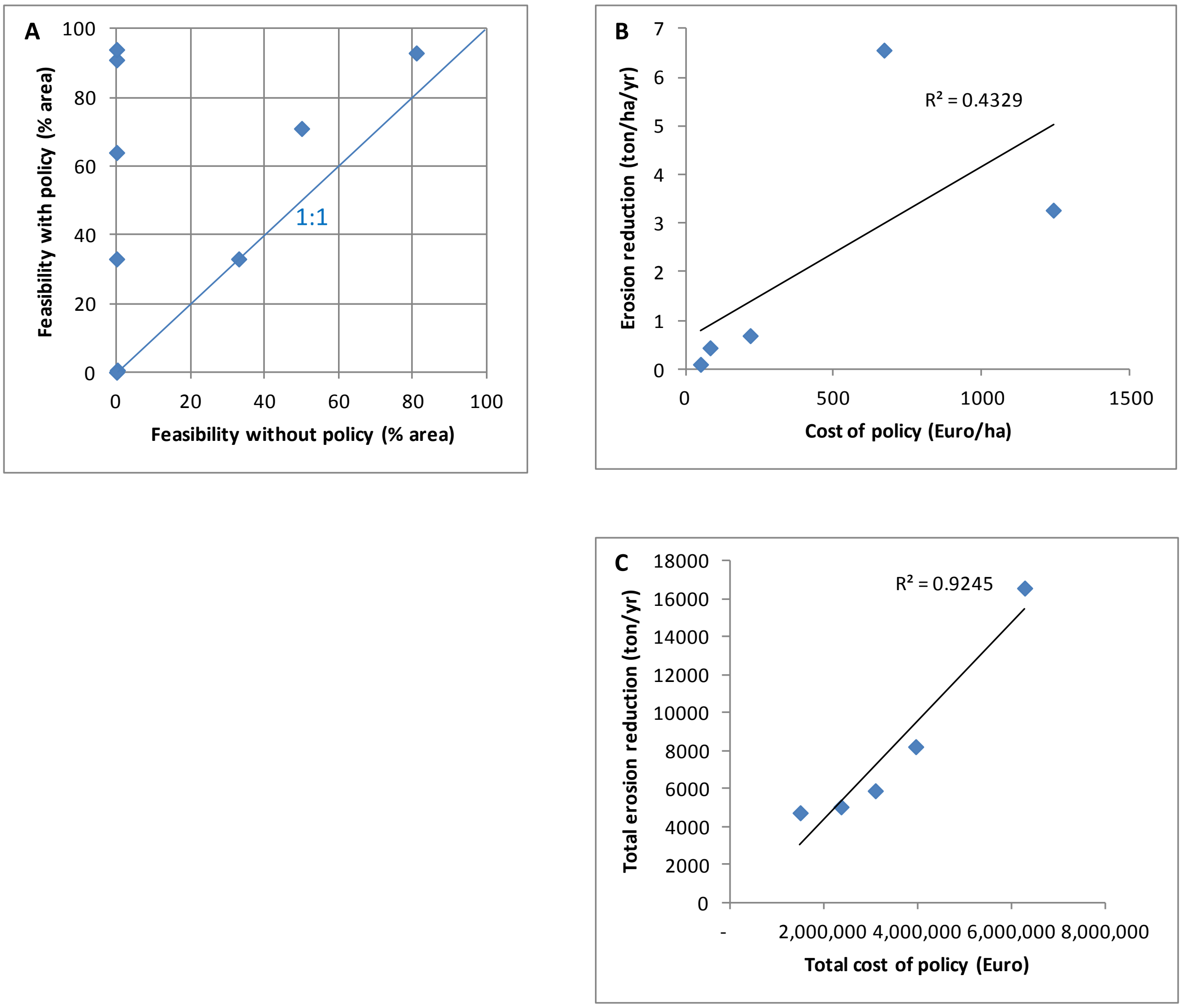


Figure 8: a) Effectiveness of policy scenarios on feasibility of technologies; b) per unit cost-efficiency of policy measures assessed; and c) total cost-efficiency of policy measures assessed.

Global scenarios

Figures 9 and 10 respectively show results of cross-site analyses of opportunities for increased food production and reduced soil erosion. Turning first to the food production scenario, average potential yield increase ranges from less than 50 kg/ha to more than 3000 kg/ha (Figure 9A). However, in three quarters of the study sites, productivity can increase by more than 500 kg/ha. In half of the cases where increased food production is possible, improvements can cover the lion share of the applicability area (Figure 9B). In all sites, yield increases can be obtained in more than 20% of the applicable area. The investment costs required to achieve this are substantial when looking at the first year (Figure 9C, n=12, average cost €567/ton when one case with 'cost' below zero is excluded), but are reduced when aggregating over the economic life of technologies (Figure 9D, n=9, average cost €145/ton).

Opportunities to reduce land degradation exist universally across applicability areas: at minimum, soil can be conserved by the technologies assessed on 70% of the applicable area. The rate by which soil loss can be reduced is either very high (80-100%) or moderate (0-40% reduction). In some cases, there are no additional costs involved to reduce soil loss, in others substantial investments (>€1000/ton) need to be made if analyses are done on a single year of erosion reduction. When spread out over the lifetime of technologies, erosion reduction becomes much more affordable, at rates often below €250/ton and in a considerable number of cases below €100/ton.

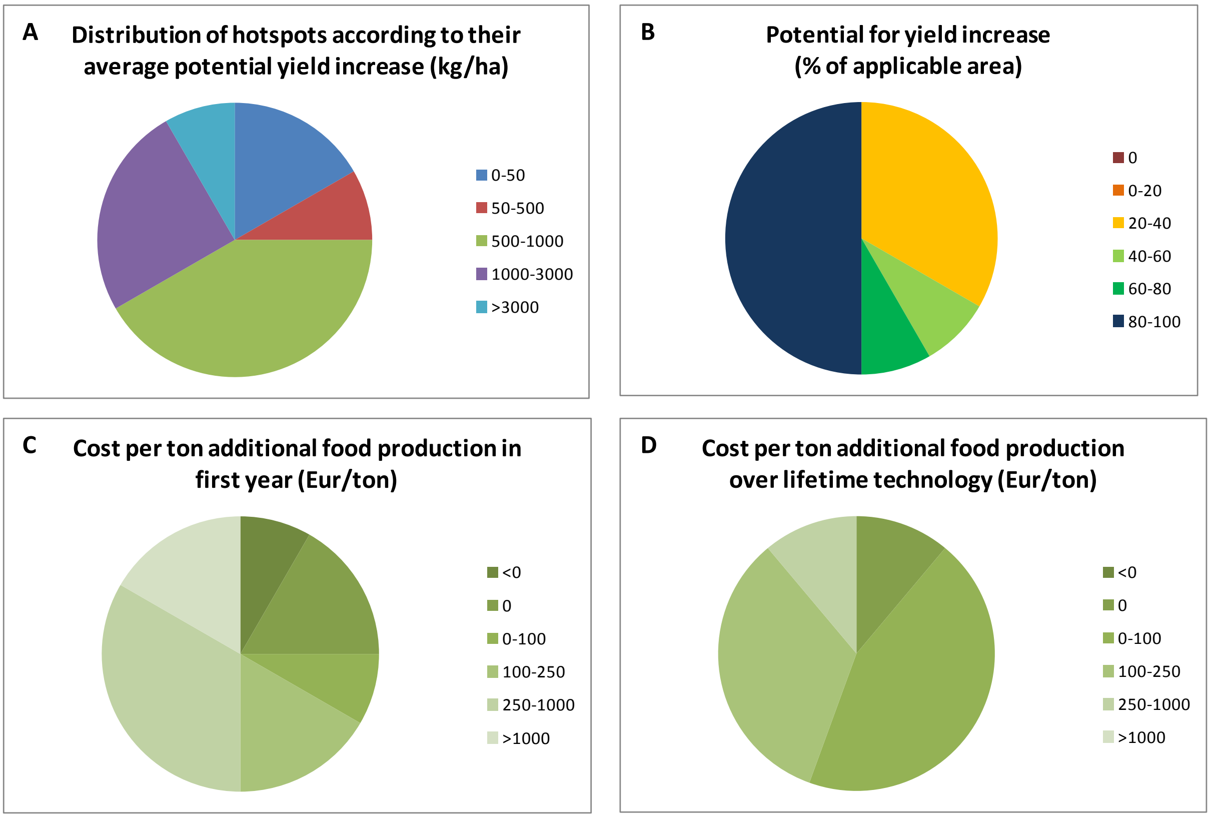


Figure 9A-D: Results for cross-site comparison of food production scenario.

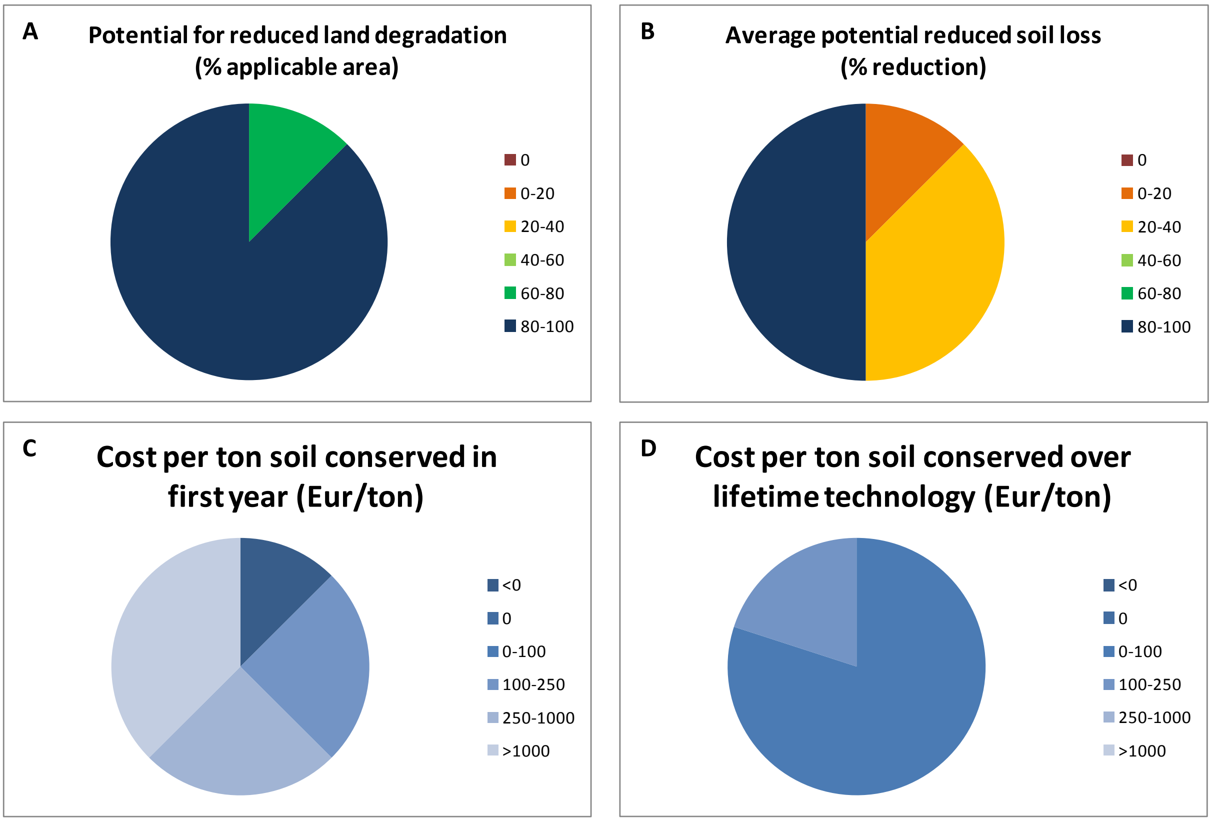


Figure 10A-D: Results for cross-site comparison of minimizing land degradation scenario.

3.3. Scale issues and uncertainty analysis

In applications of the PESERA-DESMICE modeling framework two complications were frequently encountered:

1. Spatial variability of investment costs is poorly known;
2. Timing of biophysical effects is not explicit;

The effects of these bottlenecks are explored in two case studies in the subsections below.

Effect of spatial variability of investment costs

Taking as an example the application of bench terraces with loess soil walls in the Yanhe River basin in the Loess Plateau of China, spatial variability of investment costs was defined as follows:

$$INV_S = US\$1{,}823 \ * S/30 \qquad (1)$$

where INV_S is the investment cost per hectare for slope gradient S (in percent) and US$1,823 is the investment cost reported for a standard slope of 30%.

Calculating the average investment cost per hectare across the area where the technology is applicable (3,732 km^2) with Equation 1 gives US$1,591 ± 717. To assess the effect of different levels of variation of investment costs with slope gradient, the mean was subtracted from the INV_S data layer and the resulting raster multiplied with factors 0.75, 0.5, 0.25 and 0 before adding the mean investment cost again. This approach resulted in a number of rasters with the same average investment cost but different standard deviation and ranges (Table 4), which were subsequently used to assess the financial viability of the technology following the steps of the PESERA-DESMICE framework.

Table 4: Levels of spatial cost variability and resulting range of investment costs for bench terraces in Yanhe river basin, China.

Investment cost (US$)	Relative level of spatial cost variability				
	0	0.25	0.50	0.75	1
Maximum	1,591	2,488	3,386	4,284	5,182
Minimum	1,591	1,196	801	406	12
Standard deviation	0	179	359	538	717

The case study of bench terraces in the Yanhe river basin in China shows an important influence of variable investment costs (Figure 11A). When no spatial variability is taken into account, terraces are financially attractive in 13% of the area where they can technically be implemented. This proportion rises to 50% if costs are taken proportionate to the reference slope (Equation 1). Figure 11A clearly demonstrates that the effect of spatial cost variability is not linear; not considering or underestimating the level of variability in costs may hence considerably underestimate potential profitability of bench terracing, whereas overestimating the level of variability of the required investment may rapidly lead to exaggerated viability estimates. Not only does the percentage of the area where the technology can be economically implemented change, but also the locations (results not shown). In absence of slope-related spatial variability, slope does not exert any influence and viability is in this case primarily responding to climatic variation. As the slope dimension is phased in, more and more less sloping land in areas with suboptimal climatic conditions replaces rugged areas with highly suitable climate.

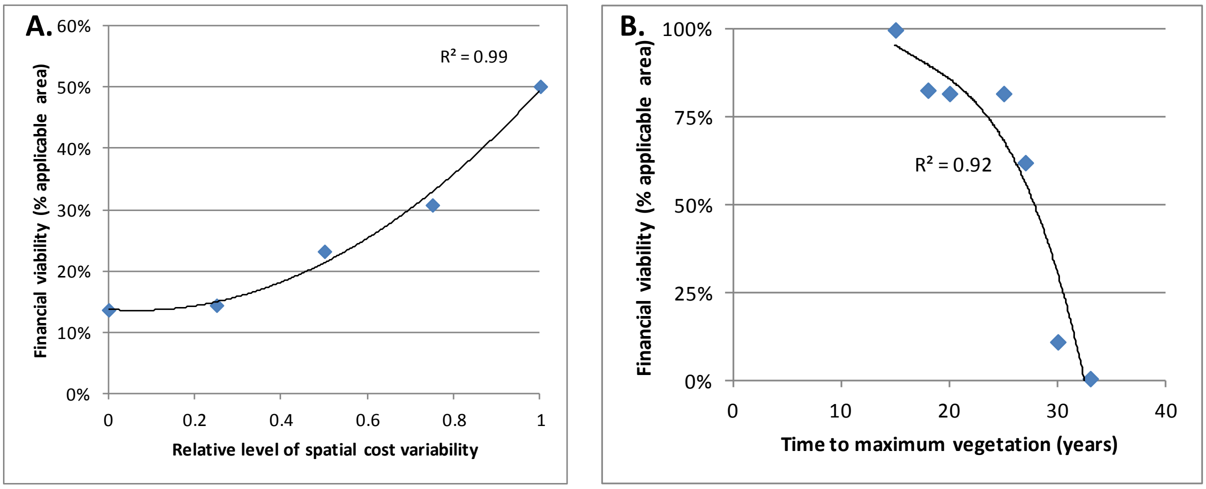


Figure 11: A. Financial viability of bench terraces in Yanhe river basin under different levels of spatial investment cost variability; B. Financial viability of gully control with atriplex in Sehoul as a function of time to reach maximum productivity.

Effect of timing of biophysical effects

The technologies assessed in the DESIRE project included agronomic (e.g. minimum tillage) as well as structural, vegetative and management SLM measures. All measures, but especially the second group, impact on slow soil ecological processes and will gradually improve soil structure and fertility, and hence system productivity. The PESERA model simulates the equilibrium conditions in the with and without technology case. One of the sites where PESERA predicted a particularly large improvement in productivity was in the Sehoul area close to Rabat, Morocco – for gully control by plantation of atriplex (*Atriplex halimus*). In the standard calculation, it was assumed that production would increase linearly until reaching its maximum value after 20 years - i.e. time to maturity TTM = 20. By employing Equation 2, net present value was calculated for time productivity series with different TTM values (15, 18, 25, 27, 30 and 33 years):

$$NPV_{TTM=j} = \left(\sum_{t=1}^{t=20} \frac{max(t/j, 1)}{(1.1)^t} \right) * NPV_{TTM=20} \qquad (2)$$

Where NPV_{TTM} refers to the net present value of the cashflow series over 20 years for the case with implementation of gully control only; *j* and *t* are measured in years and NPV in currency. After calculating NPV_{TTM} values, investment costs and total discounted production in the without case (which remain the same under different TTM values) need to be subtracted. Finally, for evaluation of the effect of TTM, the percentage of cells in the applicability area of the technology is calculated.

Gully control with atriplex in Sehoul, Morocco is not very sensitive to small changes around the assumed 20 years it takes to reach maximum productivity (Figure 11B). However, this is a rough assumption, so we should look further than the short range between 18 and 25 years where the viability of the technology is not affected. When approximating a TTM of 15 years, the viability of atriplex planting rapidly reaches 100% of the applicable area, up from 82% on the stable area from 18-25 year. Even more dramatic is the drop between a TTM of 25 and 30 years, when the technology ceases to be viable in more than 60% of the applicable area. The negative slope of the relation flattens of after 30 years, but gully control with atriplex by then remains profitable in only 13% of the area. From this example, it is clear that one would need to be confident of the interval 18-25 years it would take vegetation to reach maximum productivity, outside of which the system becomes very sensitive to the issue of timing.

Discussion of scale issues

In studies of adoption of SLM technologies, plot location is often found to be of importance (e.g. Staal et al, 2002; Noltze et al., 2012). The spatial variation in investment costs of SLM technologies and distance to markets are likely to play a key role, although explicit studies of variations in costs are scarce (e.g. Shively, 1999; Tenge et al., 2005). As Heidkamp (2008), be it in a more general context, puts it: “the environment has been largely ignored beyond its treatment as a more or less passive location condition or resource factor input”. Although the illustration of cost differentiation with slope for bench terraces in China provides an example of the susceptibility of outcomes to this factor, the finding that taking variability in investment cost into account leads to a larger viability is specific. In other cases, for example where data is gathered from a relatively cheap experiment in optimal conditions, considering spatial variability factors might lead to reduced levels of predicted viability. Much data on spatial variability of different types of SLM technologies probably exists in design manuals, project documents, and other grey literature. A review of those materials is recommended to define some generic relations that can be used to improve model assessments of SLM.

The timing of biophysical effects has potentially significant influence on viability of technologies. The point version of PESERA allows simulation in time series mode after equilibrium conditions have been established. The grid version of the model, which was used here, lacks this facility. Still, model validation, specifically of timing of effects, is difficult due to interactions and the paucity of long-term field trials which are intensively monitored. Although the illustrative case study had a long term restoration goal, the cumulative effects of annually repeated SLM technologies may also be significant (see e.g. Hobbs et al., 2008). The importance of the temporal dimension in evaluating technologies is clear from the inclusion of a discount factor in CBA. This can work two ways: in the case of technology application, it is important for land users to start reaping benefits as early as possible; but in the without case, ongoing degradation can further affect yield levels (Lal, 1995).

3.4. Concluding remarks

Quality and quantity of input data

- DESMICE primarily relies on economic data reported in the WB3 WOCAT database. It further makes use of additional information requested in information sheets from study sites. Variation of investment costs of technology has proved to be difficult to obtain, while, as shown above in Section 3.3, this can have important implications for the analysis. A review of international published and grey literature is therefore recommended as follow up work. Where price information was not available additional secondary data was collected. Input map material to a large extent coincides with PESERA input data. A digital elevation model is by default taken from the publicly available SRTM90 dataset. Price conversions of local currencies to Euro were done using oanda.com. Taking into consideration this need for secondary data, PESERA-DESMICE can be run but shortcomings should be kept in mind.

Findings

- (Simple) technological options exist that can minimize land degradation and increase food production. Many technologies are however only profitable in the long run (e.g 20 years) which means that high investment costs are a bottleneck for adoption.
- Low (zero) cost agronomic measures and other options that deliver important benefits in the short term are the preferred technologies. Stakeholder evaluation and model output mostly concur.
- There are important design and opportunity cost considerations which influence the analysis. For larger (more expensive) technologies feasibility studies will need to be done on a case by case basis. Model can be used for first approximation.

Novelties

- The PESERA-DESMICE modelling approach overcomes a number of challenges to incorporate inputs from multiple stakeholders in very different contexts into the modelling process, in order to enhance both the realism and relevance of outputs for policy and practice.
- Site-selection modelling is being applied to land degradation mitigation to enable landscape-scale assessments of the most economically optimal way to attain environmental targets.
- Use of Cost-Benefit Analysis to investigate the spatial variability of the profitability of SWC measures, which may have important implications for the adoption of measures across landscapes and their consequent environmental effects.

Shortcomings

- It appeared to be difficult for study sites to estimate spatial variation in investment costs of technologies (a review of data to produce estimates for different types of technologies to fill this gap is recommended that could serve to define default parameters in the DESMICE model).
- The temporal dimension of changes in productivity is crucial for land users. Biophysical models (e.g. PESERA) should be able to separate immediate and gradual aspects. Ongoing degradation in the without case is not yet implicitly considered. Analysis of robustness to climatic variability and prices is also essential.
- Factors such as attitude towards conservation and risk are likely to be very important in decision-making and could further limit adoption of technologies

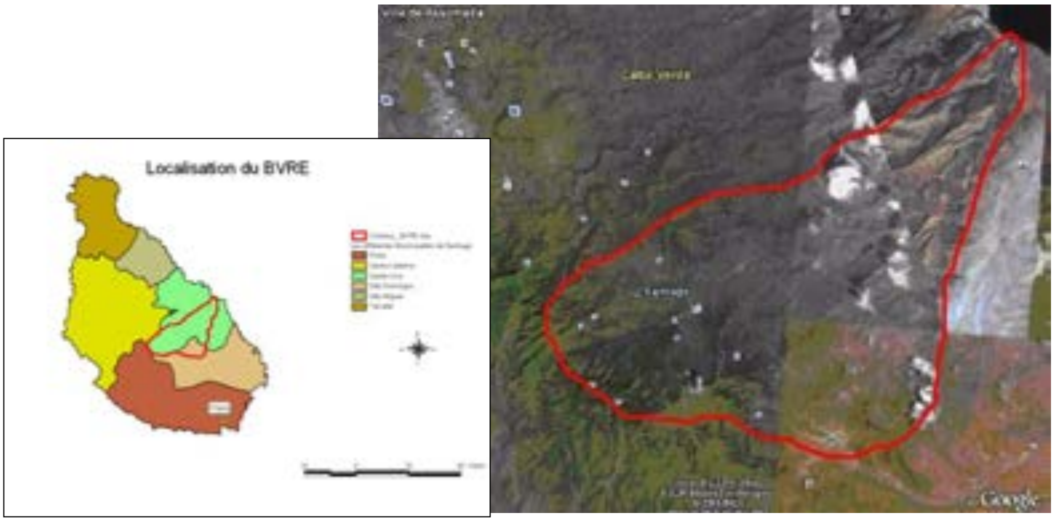
4 Study site model results

Ribeira Seca, Cape Verde

Study site details

Ribeira Seca is a catchment on the east side of the Santiago island.

- **Coordinates:**
  Latitude: 15º07'40''N - 15º01'55''N
  Longitude: 23º32'05''W - 23º38'40''W
- **Size:** 71.50 km²
- **Altitude:** 0-1394 m (Pico d´Antónia)
- **Precipitation:** 200 mm downstream to 650 mm at the upper limit of the basin.
- **Temperature:** 16.6ºC – 28.1ºC
- **Land use:** 83% subsistence rainfed agriculture (corn and beans), 5% irrigated; 4% forest
- **Inhabitants:** 14,343 (2000 Census)
- **Main degradation processes:** on-site: water erosion, off-site: sedimentation
- **Major drivers of degradation:** population growth, deficient information, insecure land tenure, lack of institutional mechanisms



Catchment location within the Santiago Island

Overview of scenarios

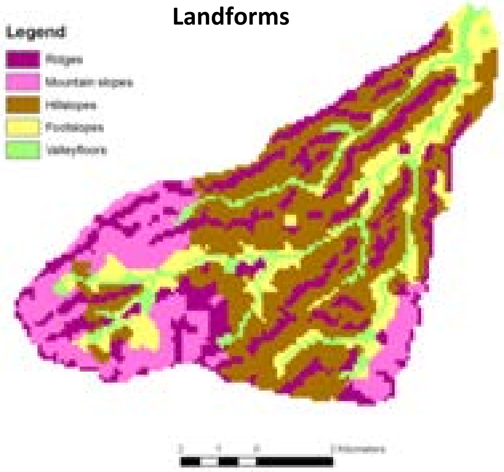
1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Terraces with Pigeon Pea (CPV01)
3. Policy Scenario: Subsidising terraces (CPV01)
4. Global Scenario: Food production

Ribeira Seca, Cape Verde

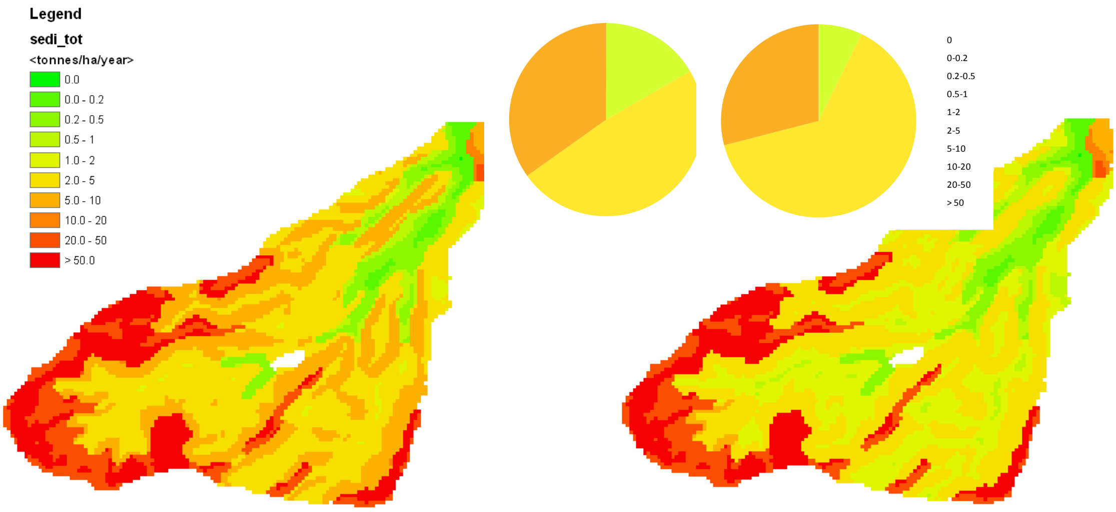
Baseline Scenario

PESERA baseline run

Two erosion baselines are produced, one assuming no existing SWC structures (A) and one with terracing (B). Very steep mountain slopes in the upper catchment coincide with highest erosion rates in both cases. Available climate data did not fully reflect the range of agro-ecological conditions, and as a consequence baseline biomass production mainly shows the difference between areas under irrigation and rainfed crops.



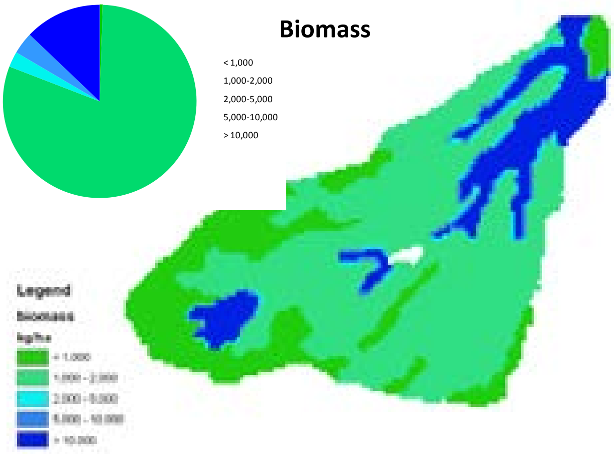
Soil erosion



A. Soil erosion (no terraces)

B. Soil erosion (terraces)

Biomass production



NB. The pie charts on this page pertain to the areas for which technology CPV01 is applicable (see this scenario for further details). Erosion rates under 2 tonnes/ha/year are not broken down.

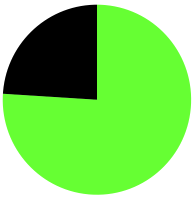
Ribeira Seca, Cape Verde

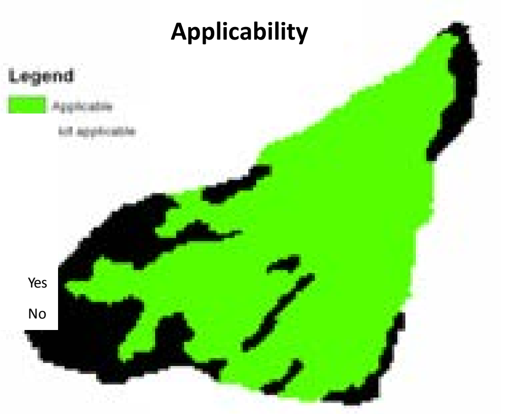
Technology Scenario:
Terraces with Pigeon pea (CPV01)

- Fixed investment costs of ECV 295,000 (€2675) are assumed.
- Transport costs of produce to market are considered; range ECV 17-2,500 per year.
- A discount rate of 13% has been applied
- A lifetime of 10 years has been set, with the first year no benefits.
- The baseline without terraces is taken as without case.

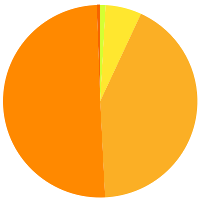
Applicability

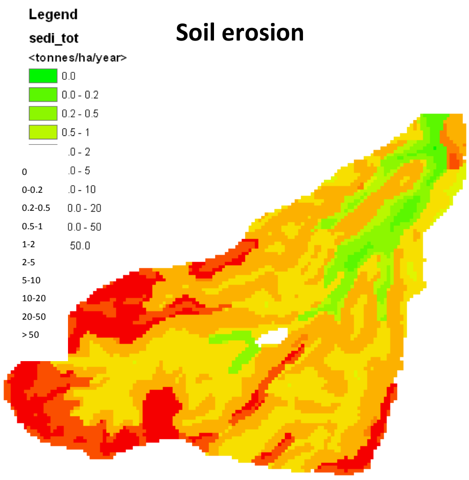
- The technology is not applicable in very steep and flat areas



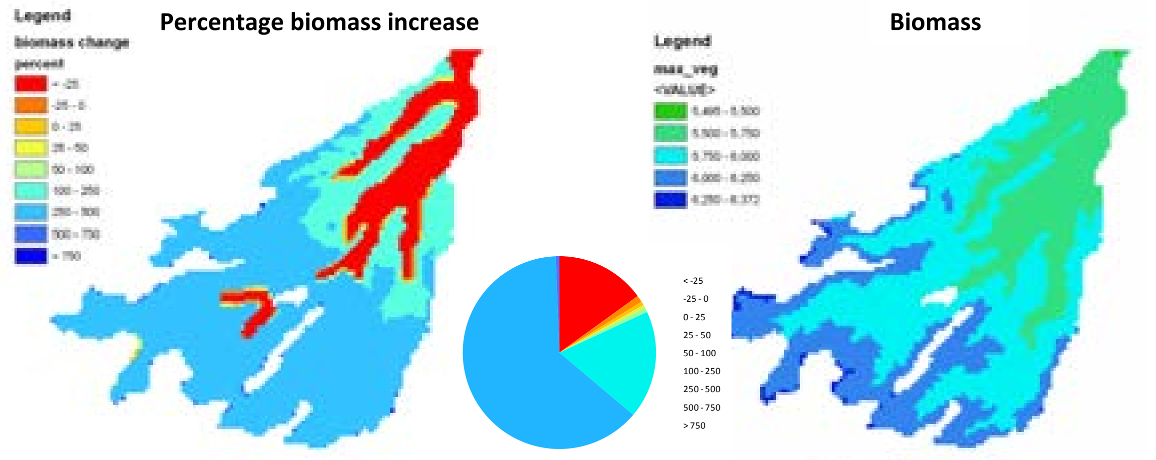


Biophysical impact: reduction of erosion





Biophysical impact: increase in biomass

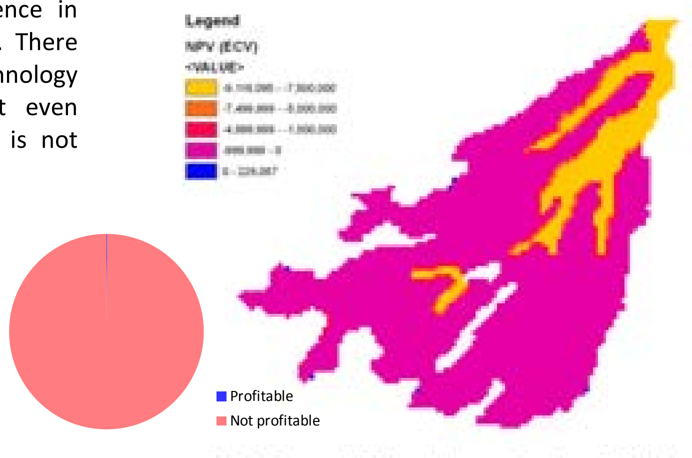


Economic viability

If economic viability is assessed assuming maize production in the without case, the difference in income is too low to justify the investment. There especially seems to be no scope for the technology where irrigated agriculture is applied, but even beyond those zones direct financial benefit is not apparent.

(This is the scenario with biomass pruning; in absence of pruning worse results)

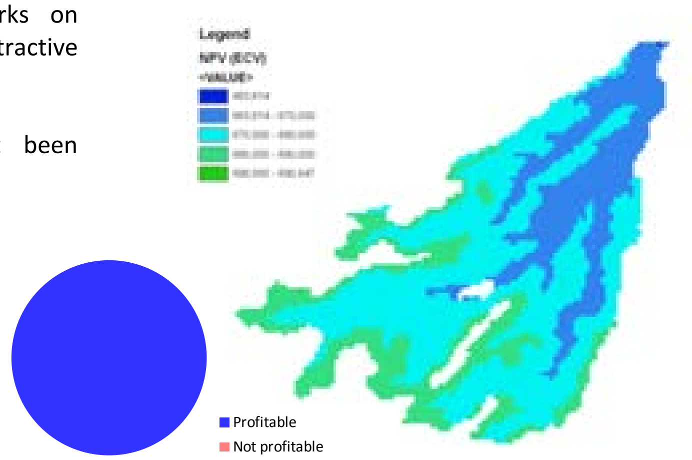
Net Present Value (without case: maize)



This analysis assumes no benefits will be obtained in the without case. If the technology works on unproductive land, It could be an attractive investment.

In both cases, off-site effects have not been considered.

Net Present Value (w/h case: unproductive)



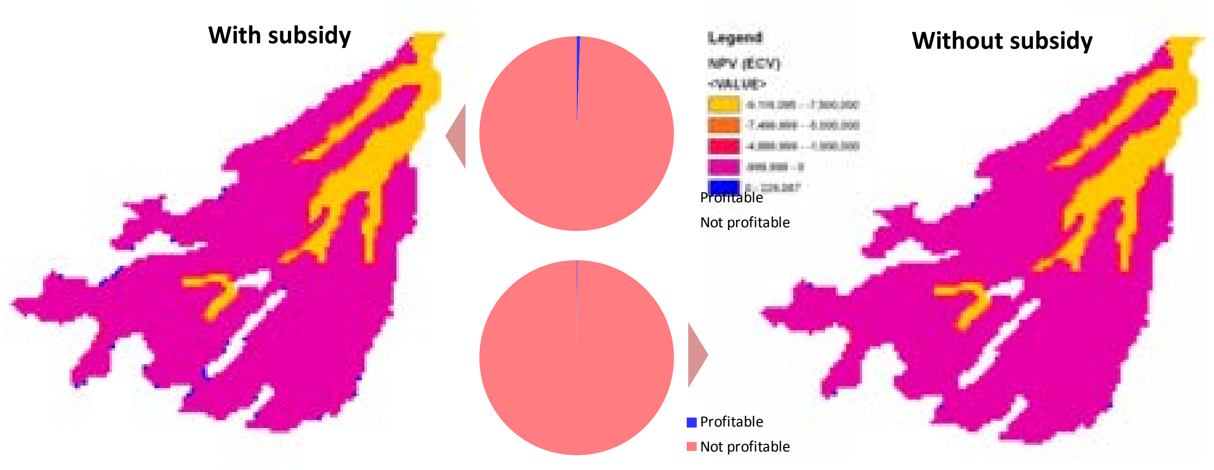
Ribeira Seca, Cape Verde

Policy Scenario:
Subsidising terraces (CPV01)

The technology 'Terraces with Pigeon Pea' requires heavy upfront investment. If implemented on unproductive (unused) land, the technology can be profitable. However, it is more likely that most land is already in use, in which case the technology has negative present value almost universally. A governmental Payment for Ecosystem Services (PES) scheme could go some way to incentivise farmers to adopt the technology. In this policy scenario we assess the effect of a subsidy of 50% of the investment cost.

50%

Profitability:



Cost-effectiveness indicators:

This PES scheme, although subsidising 50% of the investment cost, would have very marginal effect on profitability of terraces with pigeon pea. A total of 0.6% of the area where the technology is applicable would see NPV rise above 0. Accordingly the cost-effectiveness of the policy will be low. On unused land the technology would be profitable anyway and the subsidy would be 'perverse'.

Cost of the policy if perverse use on unused land is avoided: ECV 4.77 million (€38,800).

Ribeira Seca, Cape Verde

Global Scenario:
Food production

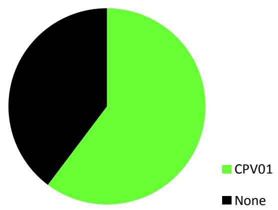
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+2568 kg/ha

+1218 kg/inhabitant

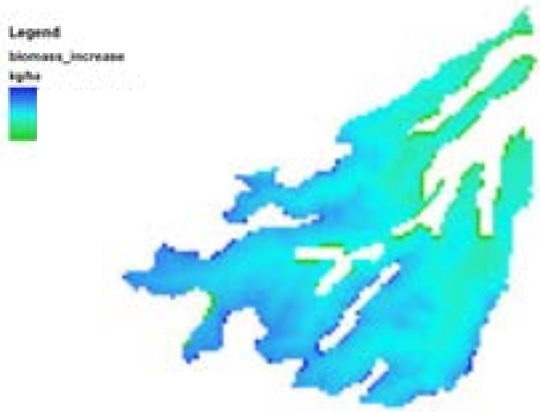
Scope for increased production

- Technology CPV01 can lead to increased productivity in 60% of the area



Biophysical impact: biomass increase

- Yield increase in 83% of applicable area
- Average yield increase: 115%



Economic indicators

Average costs:
- Investment cost: 2675 Eur/ha
- Unitary cost year 1: 628 Eur/ton(yr)
- Unitary cost lifetime: 63 Eur/ton

Aggregate indicators:
- Study site: 10.9 million Euro
- Augmented annual production: 17,470 ton
- Augmented total production: 0.175 million ton

Ribeira Seca, Cape Verde

Concluding remarks

- Baseline simulations show a clear relation between soil erosion and slope. The steep mountain areas have high erosion rates (in excess of 10 ton/ha/yr). However, as much of the study site is under terraces, actual erosion rates may be much lower than the baseline scenario run suggests.
- Terraces with pigeon pea (CPV01) were selected by scientists and local stakeholders as it appears to be the simplest, most accessible, least expensive, socio economically acceptable technique, with great impact on soil cover and land rehabilitation and reducing vulnerability to water erosion. The technology scenario shows that a considerable increase in biomass production is possible, but not in the valley floor where irrigated agriculture is practiced. Despite of this, the technology appears to be positive only when implemented on unproductive land. Where benefits are already derived from the land, the high investment cost and high discount rate applied (13%) come into play.
- Evaluating the results in a workshop, stakeholders reaffirmed their preference for the technology, based on high productivity in agronomic trials and multiple uses of pigeon pea.
- A policy scenario reducing costs by 50% made the technology profitable in only 0.6% of the applicable area if a without case of maize monocropping is assumed. This again stresses the high cost of the measure.
- The global scenario for food production shows that the technology can achieve very significant yield increases, both per area (2568 kg/ha) and per capita (1218 kg). Costs per ton of increased food production are €628 if only the first year is taken into account, and €63 when the total economic life of 10 years the investment is considered.
- Terraces with pigeon pea lead to higher yields and better soil cover, with positive impacts on soil conservation. For unproductive land it can be recommended with little risk. If terraces are present already and require maintenance only, a reduced cost would result which might help build resilience to climate change.

Secano Interior, Chile

Study site details

The 'Secano interior' (interior dryland) is a sub humid Mediterranean climate region of Chile extending from the V to the VIII Administrative Regions.

- **Coordinates:**
  Latitude: 35°57' S
  Longitude: 72°23' W
- **Size:** 9097km² (1699km^2 simulation zone)
- **Altitude:** 92 – 728 m (simulation zone)
- **Precipitation:** 250 – 1200 mm
- **Temperature:** 5° – 29°C
- **Land use:** cereals, forest plantations, grass and shrubland
- **Inhabitants:** ca. 300,000 farmers
- **Main degradation processes:** water erosion
- **Major drivers of degradation:** inappropriate land management, soil mining, destruction of natural woodland vegetation

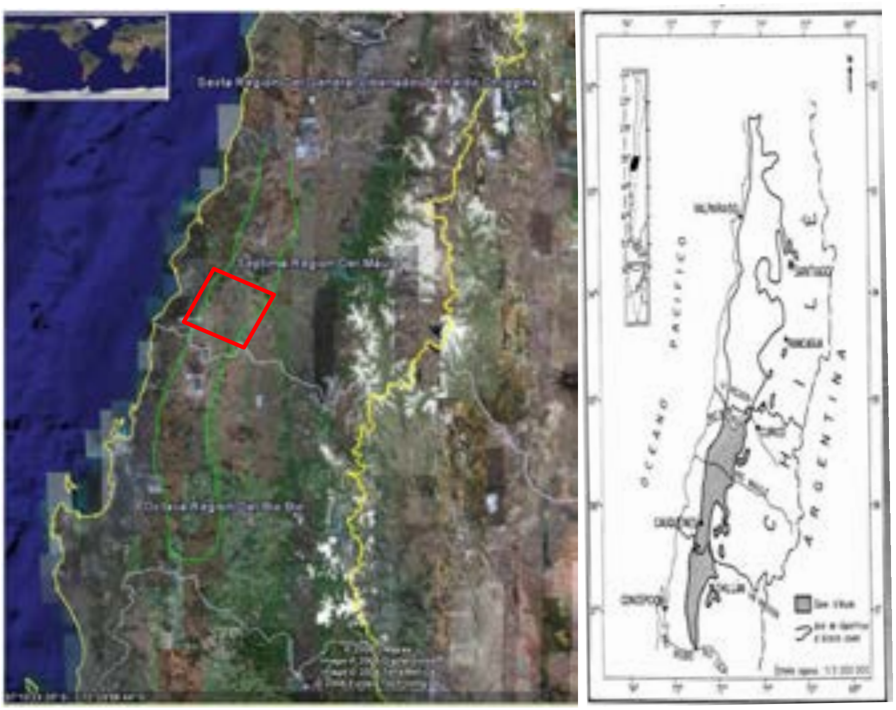


Figure 1: Study site location (green: interior dryland area, red: simulation zone).

Overview of scenarios

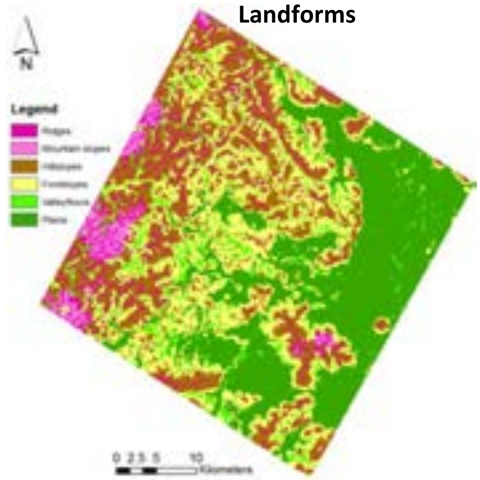
1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: No tillage with sub-soiling (CHL01)
3. Policy Scenario: Subsidising no tillage with sub-soiling (CHL01)
4. Global Scenario: Food production
5. Global Scenario: Minimizing land degradation

Secano Interior, Chile

Baseline Scenario

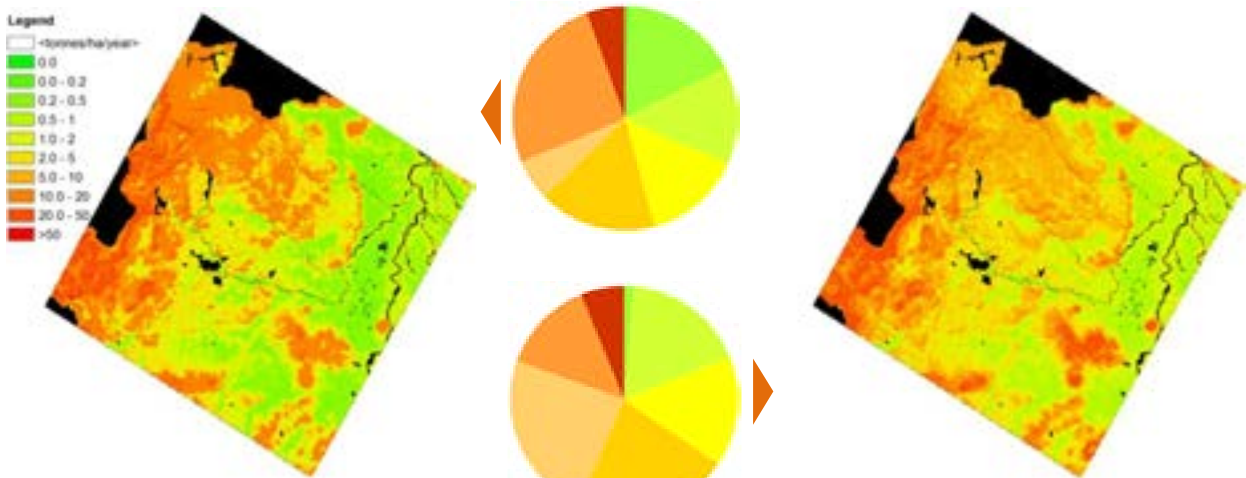
PESERA baseline run

Two baseline scenarios were run: one is the basic PESERA run while the other takes into account the soil compaction reported by the study site. From the erosion maps it is clear that under compacted conditions (of which the spatial extent is unknown), soil erosion increases relative to the baseline. Highest erosion rates are reported for the steeper western and southern areas of the study area. The biomass production in the baseline run follows the land use distribution, with lowest values for cropland and highest for forest. Forest on mountain slopes has clearly lower biomass production. Under soil compaction, slope becomes a dominant factor.



Landforms

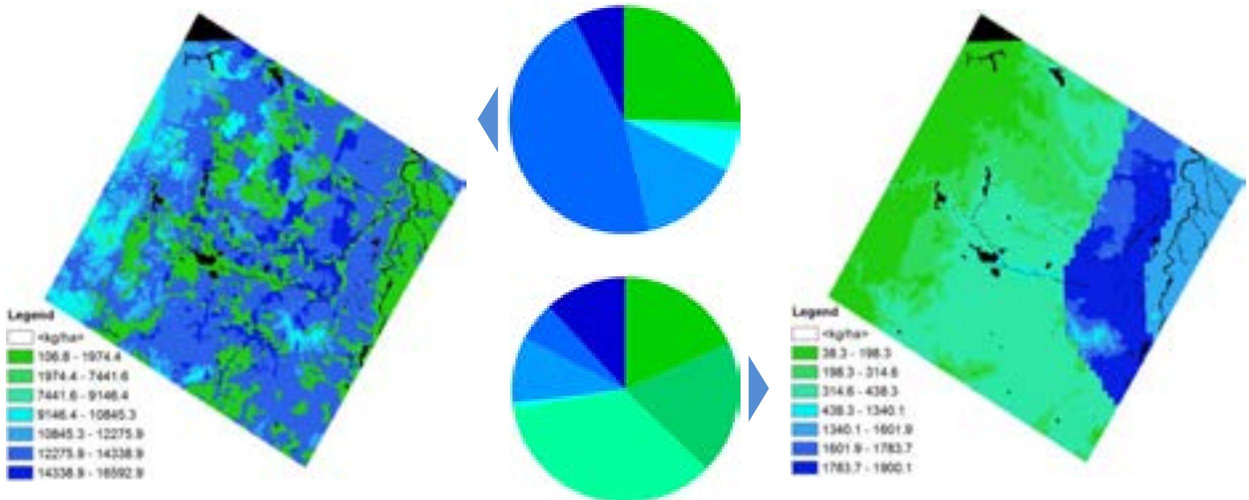
Soil erosion



C. PESERA basic run

D. Under soil compaction

Biomass production



A. PESERA basic run

B. Under soil compaction

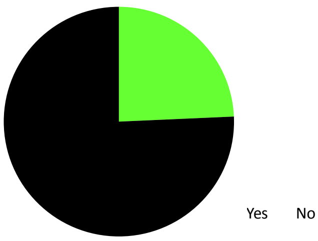
Secano Interior, Chile

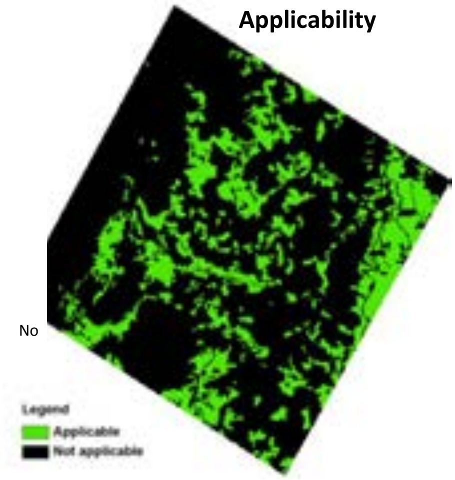
Technology Scenario:
No tillage with sub-soiling (CHL01)

- Total operation costs under different practices:
  - traditional tillage 483,478 CLP/ha (€455)
  - traditional mechanized 222,548 CLP/ha (€210)
  - no tillage with sub-soiling 306,979 CLP/ha (€289)
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The price of grains is 110 CLP/kg (€0.10)

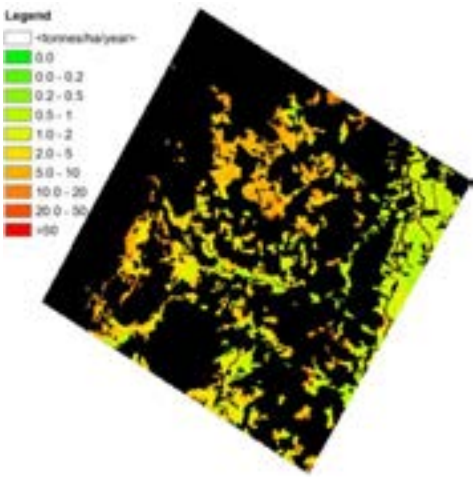
Applicability

- The technology is applicable on arable land with slopes below 20%, cultivated to cereal crops

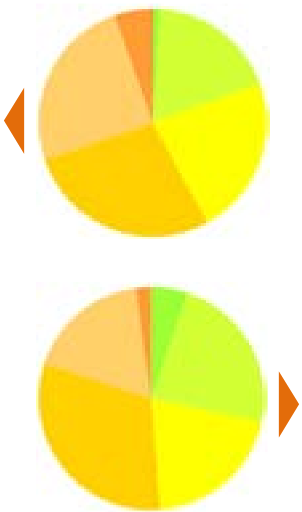


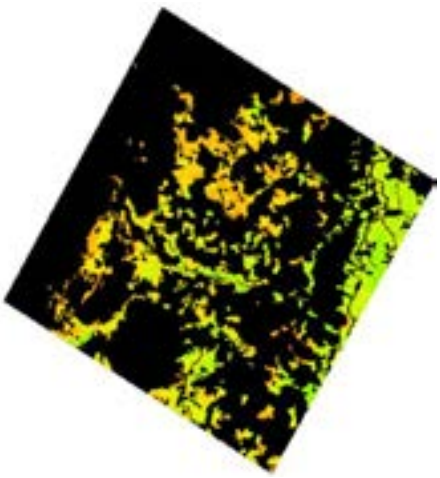


Biophysical impact: soil erosion



Without technology

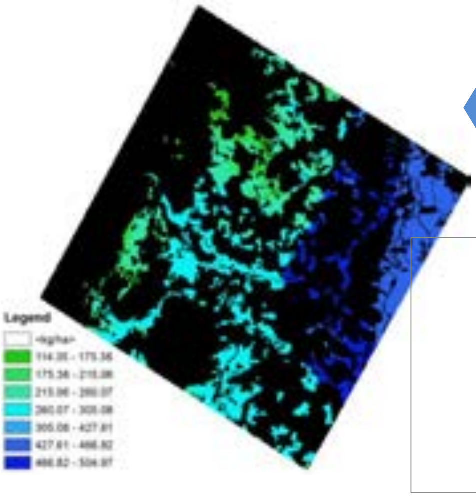


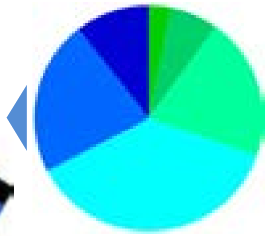


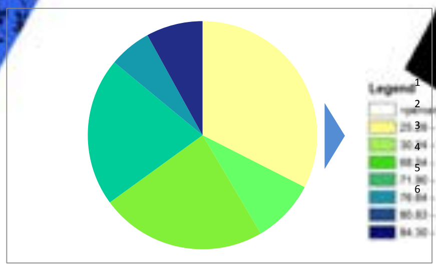
With technology

Biophysical impact: increase in biomass

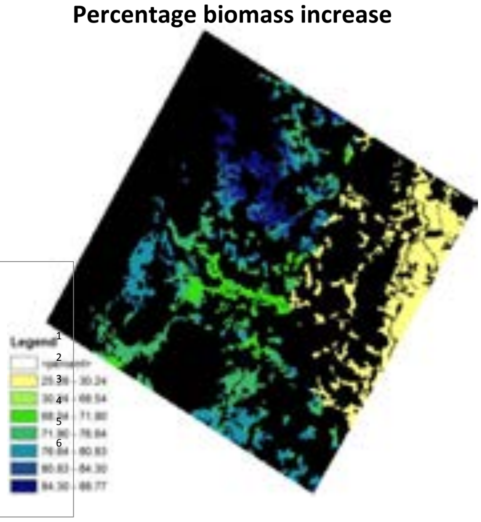
Biomass increase





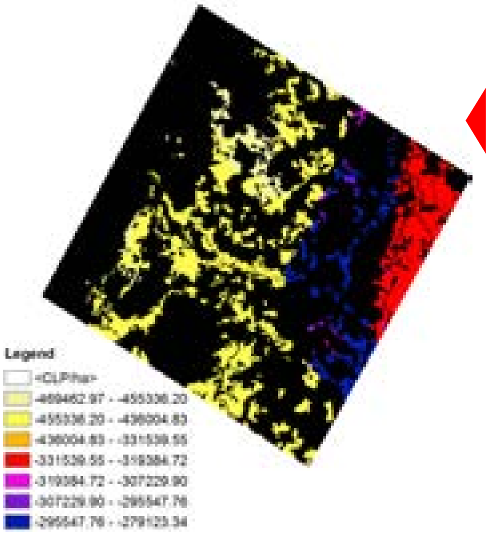


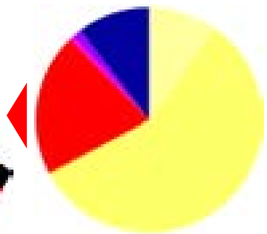
Percentage biomass increase

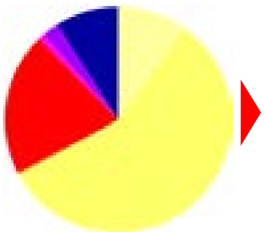


Economic viability

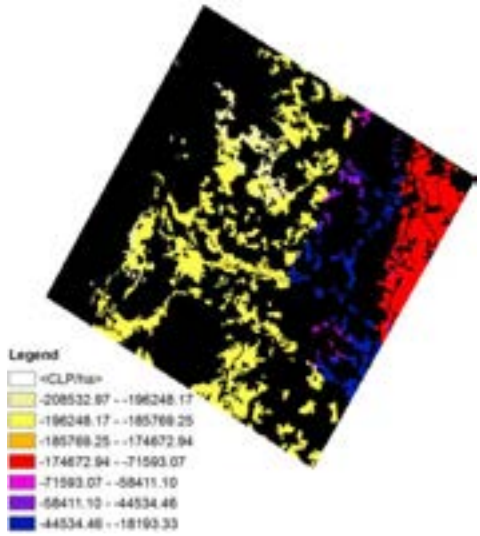
Net profit under traditional tillage system

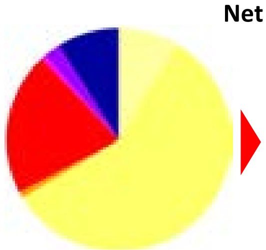






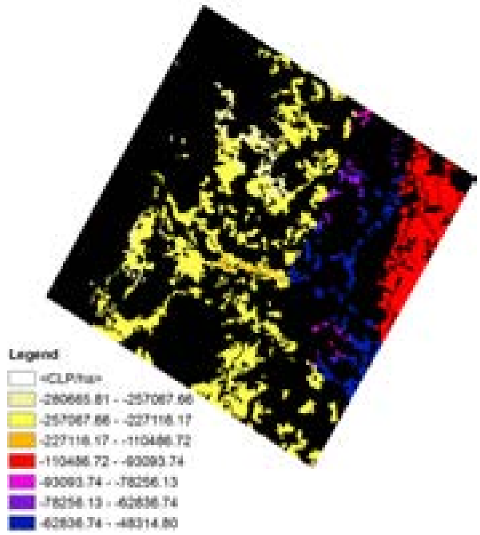
Net profit under mechanized tillage system





Although the technology leads to increased biomass production, the operational costs are too high in relation to the benefits. Experimental results come to the same conclusion regarding traditional and conventional mechanized tillage systems. However, in experiments no-till did show a positive return. The highest yield according to the PESERA model is 3956 kg/ha, and not 4500 as was obtained in experiments. The negative return for the two conventional systems can also have to do with labour opportunity costs being valued higher than farmers who practice these systems do apparently accept. As capital input in the no-till system is higher, it seems unlikely that the technology will spontaneously be widely adopted.

Net profit under no tillage with sub-soiling



Secano Interior, Chile

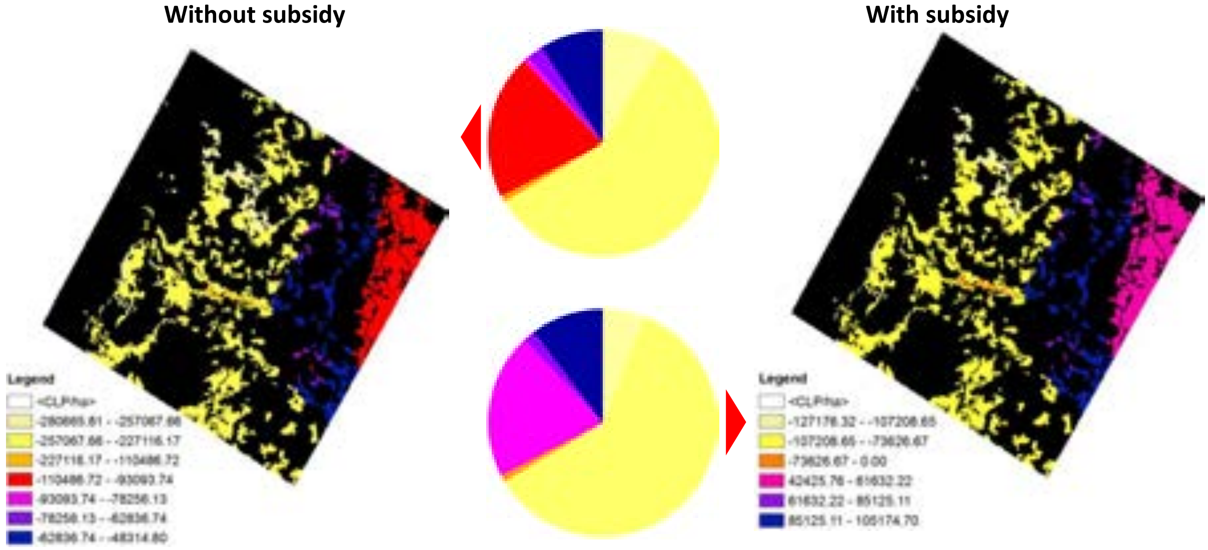
Policy Scenario:
Subsidising no tillage with sub-soiling (CHL01)

Due to low productivity in many parts of the study area and the relatively high cost of implementing no tillage with sub-soiling, without external financial incentive in all parts of the study area widespread adoption of the technology is very unlikely. In this scenario the effects of a subsidy equal to 50% of the operational costs on profitability of the technology and the potential for mitigating land degradation are explored.

50%

Profitability:

Without subsidy | **With subsidy**



Cost-effectiveness indicators:

- By introducing 50% subsidy towards the total operation cost of implementing no tillage with sub-soiling, the technology becomes economically attractive in 33% of the applicable area.
- This will result in an average reduction of erosion of 0.44 ton/ha/year.
- In total, an annual reduction of 5902 tonnes of eroded soil can be expected.
- The total amount of subsidy would be 3.3 billion CLP (€3.1 million) (excluding transaction costs).
- Hence a cost-effectiveness of 558,000 CLP/ton (€525) of soil conserved.

Secano Interior, Chile

Global Scenario:
Food production

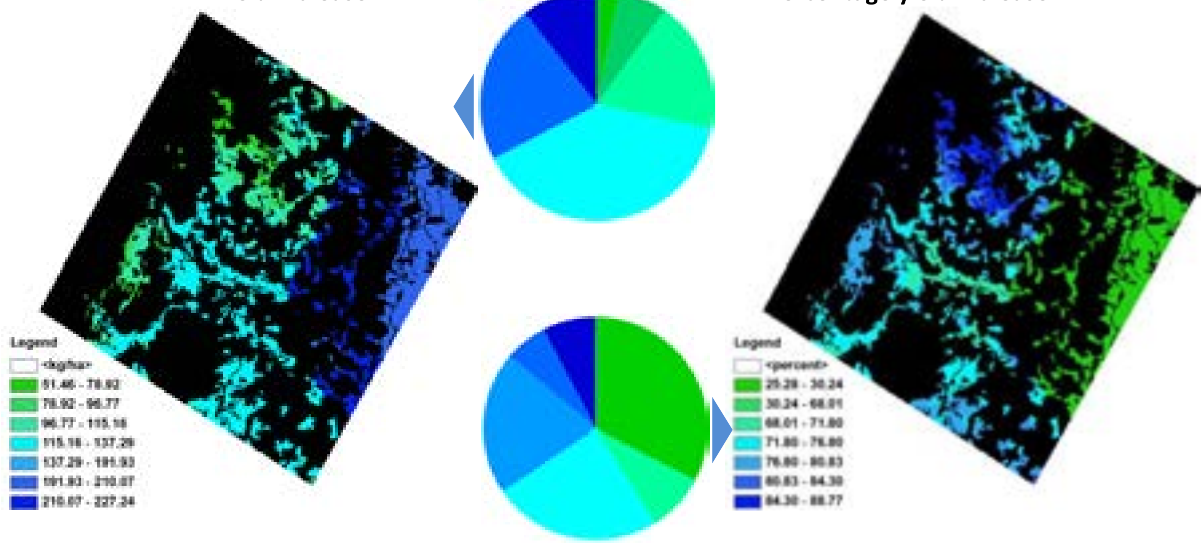
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+145 kg/ha

+20 kg/inhabitant*

Scope for increased production

Yield increase / **Percentage yield increase**



Biophysical impact: yield increase

- Yield increase in 100 % of applicable area
- Average absolute yield increase: 145 kg/ha
- Average yield increase: 61 %

Economic indicators

Average costs:
- Extra operational cost: €125/ha/yr
- Unitary cost: €862/ton

Aggregate indicators*:
- Study site: €5.2 million
- Augmented annual production: 5990 ton

* Note: aggregate indicators are calculated for the entire hotspot area assuming similar average yield increases as for the simulation zone. The total number of inhabitants is not reported; the per capita statistic is based on ca. 300,000 farmers.

Secano Interior, Chile

Global Scenario:
Minimizing land degradation

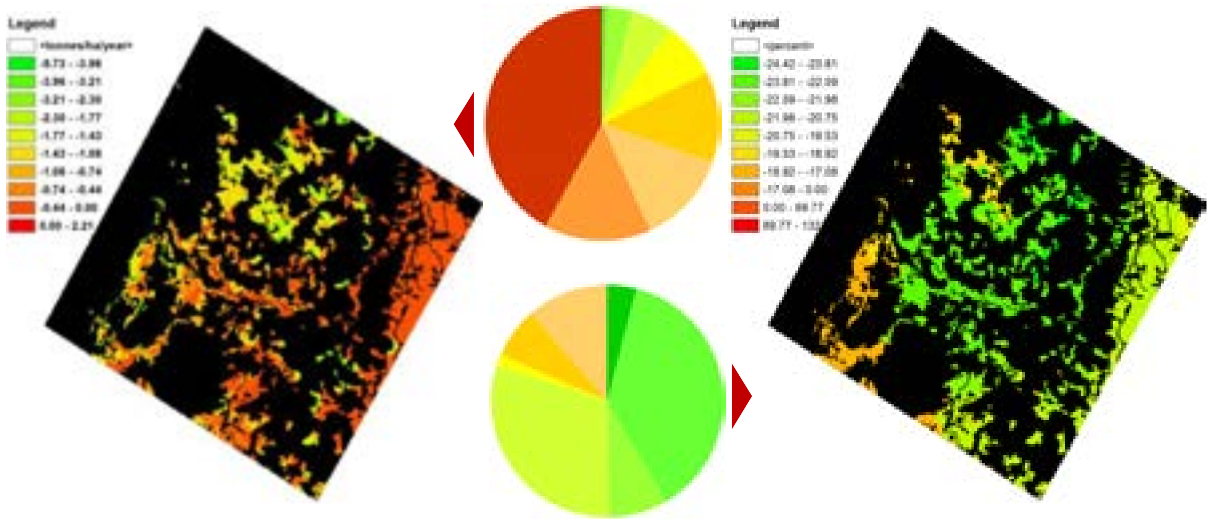
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-0.84 ton soil/ha

€148/ton soil

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 99.97 % of applicable area
- Average absolute erosion reduction: 0.84 tonnes/ha/yr
- Average percent erosion reduction: 22 %

Economic indicators

Average costs:
- Extra operational cost: €125/ha/yr
- Unitary cost: €148/ton soil

Aggregate indicators*:
- Study site: €5.2 million
- Aggregate annual erosion reduction: 33,600 ton

* Note: aggregate indicators are calculated for the entire hotspot area assuming similar erosion reduction as for the simulation zone.

Secano Interior, Chile

Concluding remarks

- Baseline simulations show a rather severe soil erosion problem in the Secano Interior, with PESERA model output suggesting that one third of the area has erosion rates over 10 ton/ha/yr.
- No tillage with subsoiling (CHL01) was selected by scientists and local stakeholders as the first-ranked of three technologies to counter soil loss by water erosion. The technology scenario shows that erosion rates can be reduced by the technology. No-till leads to considerable increase in biomass production, between 25 and 90%. Despite of this, application of the technology is not profitable. Although the conventional systems assessed also showed net losses, the no-till technology is the most capital intensive. Acceptance of lower return to labour may explain why these systems are nevertheless applied.
- Evaluating the results in a workshop, stakeholders did consider the technology to be highly profitable, perhaps as field experiments demonstrated higher yield than modelled by PESERA. They saw access to the machinery and loss of local employment as negative effects, and identified adequate and timely subsidies and pooling of machinery as main issues to enable widespread adoption. The technology maintained its preferred rank among mitigation strategies.
- A policy scenario reducing costs by 50% made the technology profitable in 33% of the applicable area. Such a subsidy would reduce soil erosion by on average 0.44 ton/ha/yr, at a cost of 558,000 CLP/ton (€525). The competitiveness of no-till relative to conventional systems would greatly improve, so that any underestimated profitabilities could play out to additional potential uptake.
- The global scenarios show that the technology can achieve yield increases and erosion reductions across virtually its entire applicability area. The extra operational cost of €125/ha/yr, i.e. the difference between the use of the no-till technology and conventional (mechanised) tillage, lead to an average yield increase of 145 kg/ha/yr and erosion reduction of 0.84 ton/ha/yr, at a cost of €862 and €148/ton food product and soil respectively.
- No-till leads to higher yields because of better soil water availability. As such, there are little risks involved in applying the technology, and it might be a sensible strategy with regards to adapting to climate change.

Yanhe River Basin, China

Study site details

The highly dissected Yanhe River catchment is a tributary to the Yellow River and originates from the Baiyu mountains on the Loess Plateau.

- **Coordinates:**
  Latitude: 36°23′—37°17′ N
  Longitude: 108°45′—110°28′ E
- **Size:** 7,678 km²
- **Altitude:** 495-1795 m
- **Precipitation:** 420-530 mm/year
- **Temperature:** 8.5°C – 11.4°C
- **Land use:** cropland, dam-land, paddy field, forest plantations, shrub, cash trees, orchards and grassland
- **Inhabitants:** 681,403 (1999)
- **Main degradation processes:** water erosion and sedimentation of reservoirs and riverbed
- **Major drivers of degradation:** global change; lack of resources for combating and monitoring land degradation

Location of the Yanhe River Basin

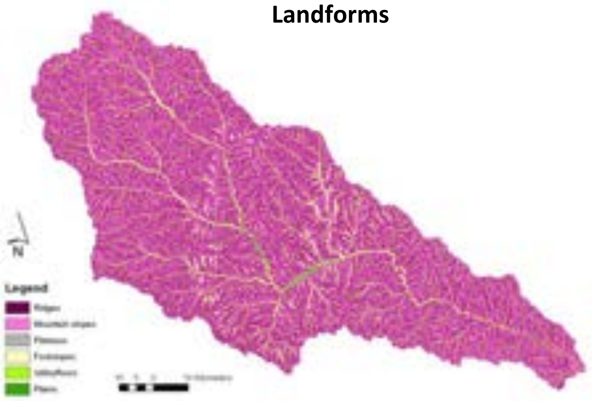
Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Bench terraces with loess soil wall (CHN51)
3. Technology Scenario: Checkdam for land (CHN52)
4. Technology Scenario: Year-after-year terraced land (CHN53)
5. Policy Scenario: Subsidizing terracing and checkdams (CHN51-53)
6. Adoption Scenario: Bench terraces with loess soil wall (CHN51), Checkdam for land (CHN52) and Year-after-year terraced land (CHN53)
7. Global Scenario: Food production
8. Global Scenario: Minimizing land degradation

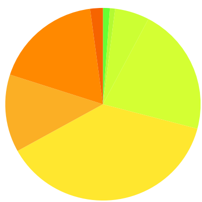
Yanhe River Basin, China

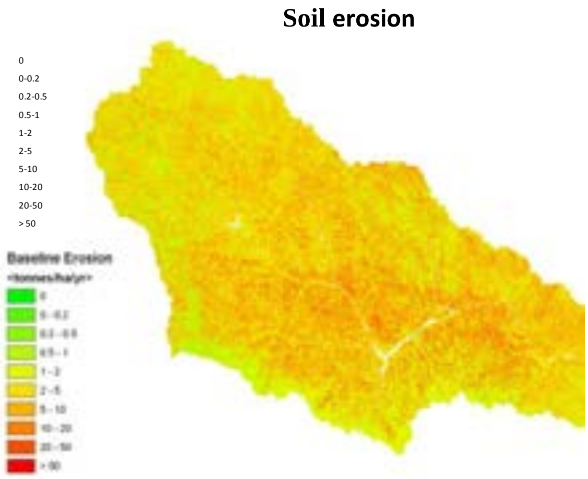
Baseline Scenario
PESERA baseline run

The erosion and biomass baseline maps represent a variety of land uses. Although erosion rates are clearly high in many parts of the study area, the pattern is patchy. Biomass production shows a pattern of climatic conditions but is also patchy reflecting differences in land use types.

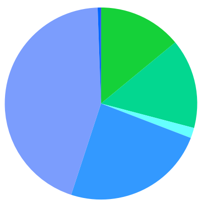


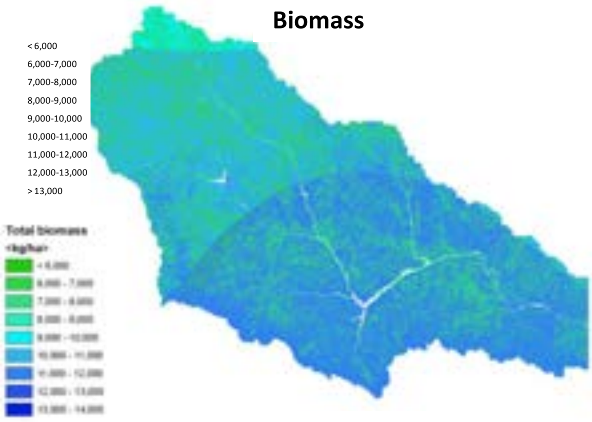
Soil erosion





Biomass production





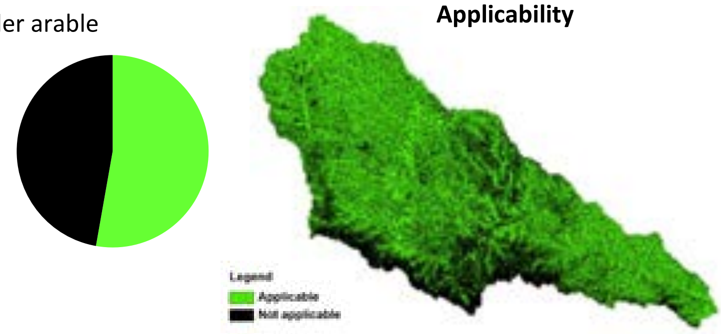
Yanhe River Basin, China

Technology Scenario:
Bench terraces with loess soil wall (CHN51)

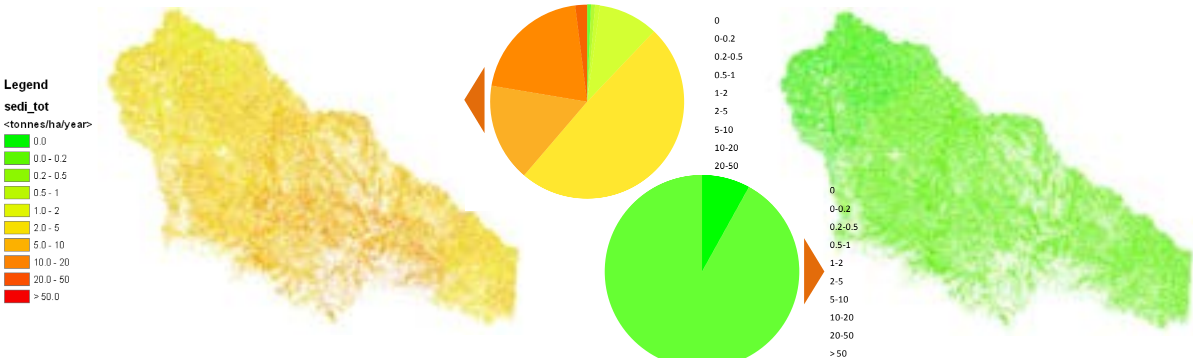
- It is assumed that apples are grown on terraces. A harvest to total tree biomass index of 0.19 is used based on secondary data
- Without case is unproductive as cereal cropping on slopes is indicated to make a loss
- Apple price of CNY 1.5/kg (€0.18) is used
- A 10% discount rate and an economic life of 20 years were assumed
- Apples produce 25% in year 4, 50% in Y5, 75% in Y6 and achieve full production in Y7.
- Further cost details under viability below.

Applicability

- The technology is applicable on land under arable or tree crops on slopes higher than 2%.



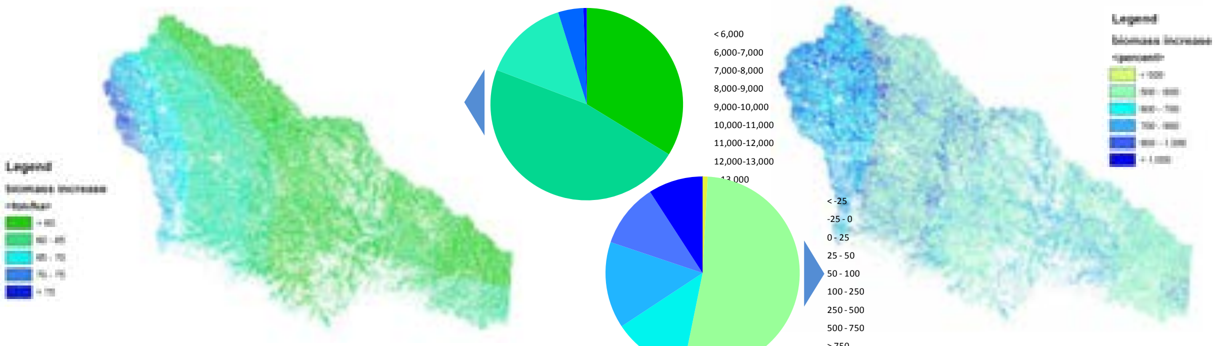
Biophysical impact: soil erosion



Without technology

With bench terraces

Biophysical impact: increase in biomass



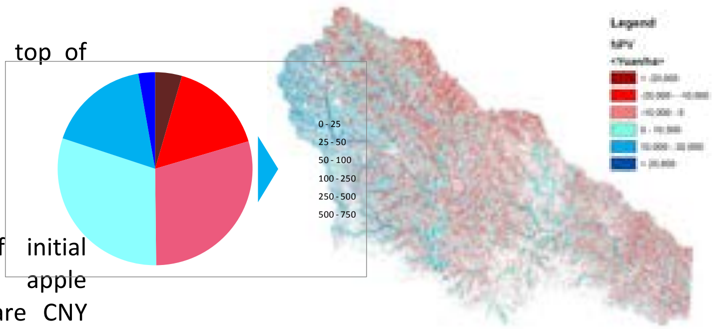
Biomass increase

Percentage biomass increase

Economic viability

Further assumptions for financial analysis:

The cost of terracing varies with slope. On top of investment cost in terracing (range CNY 80 – 35,392 (i.e. €10 – 4,358) for slopes from 2 to 79% respectively; mean CNY 10,864 ± 4901 (i.e. €1338 ± €603)) tree planting costs of CNY 2,052 (€253) are accounted for. Annual maintenance costs are set at 14.5% of initial investment costs. Production costs for apple production (chemical inputs and labour) are CNY 9,664 (€1,190).



Net present value after 20 years

With these assumptions, bench terracing is profitable in slightly less than half of the applicable area. The western part of the study area (more productive) and the less steep slopes are the most viable areas. Despite the profitability, the fact that the payback period of the investment is long (close to 20 years) might deter land users from applying the technology.

Yanhe River Basin, China

Technology Scenario:
Checkdam for land (CHN52)

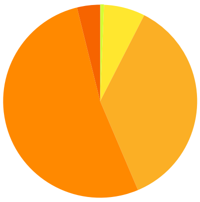
- It is assumed that maize is grown. A harvest index (HI), set at 0.4, was used and multiplied with the difference in maximum vegetation
- Maize price of CNY 1.57/kg (€0.19) is used
- A 10% discount rate and an economic life of 20 years were assumed
- Because construction of dams takes more than one year, the gross difference in output can be expected from year 2 onwards
- For further details see under viability below

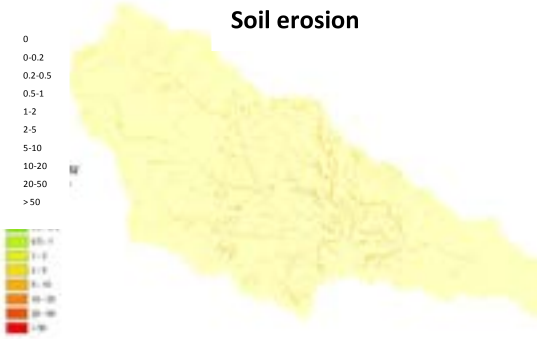
Applicability

- The technology is only applicable in valley bottoms with slopes lower than 20%, which restricts it to 9% of the area.

Biophysical impact: reduction of erosion

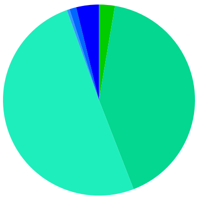
- Soil erosion after implementation of check-dams for land is still high; this is due to the assumption of a maize crop being grown. A reduction of between 3-5% relative to maize under baseline conditions is obtained. However, the technology to harvest the soil lost upstream to create new land; hence the net effect downstream will be significant (this could not be modelled).

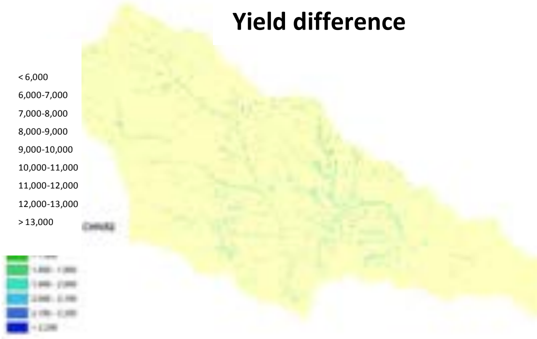




Biophysical impact: increase in yield

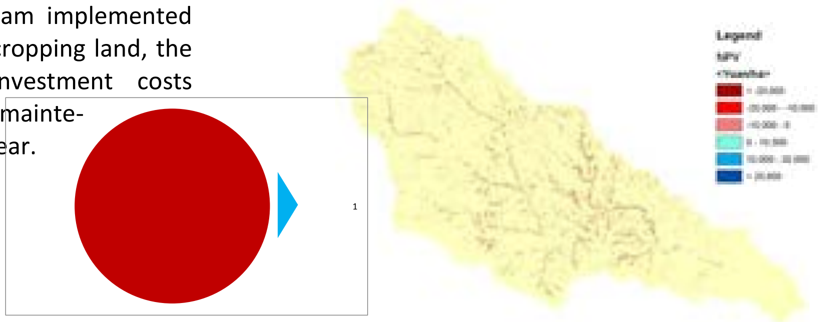
- The technology leads to substantial yield increases throughout the applicability area. Maize yields increase by 65-89% relative to maize grown under baseline conditions.





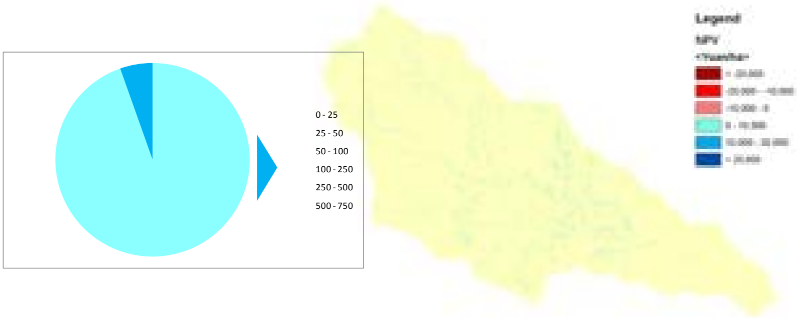
Economic viability

If it is assumed that each check-dam implemented results in a 1 hectare of improved cropping land, the technology is too expensive. Investment costs amount to CNY 40,495 (€4,993) and maintenance costs to CNY 900 (€111) per year.



Net present value if ratio investment: improved cropping land 1:1

If 1 ha of treated land leads to 3 ha land with improved yield, the analyses reverts to a 100% profitable outcome.



Net present value if ratio investment: improved cropping land 1:3

It is hence important to study each location where the technology would be implemented to assess expected costs and benefits in a feasibility study. Off-site impacts have not been valued but would, if sedimentation is the main concern, be very positive.

Yanhe River Basin, China

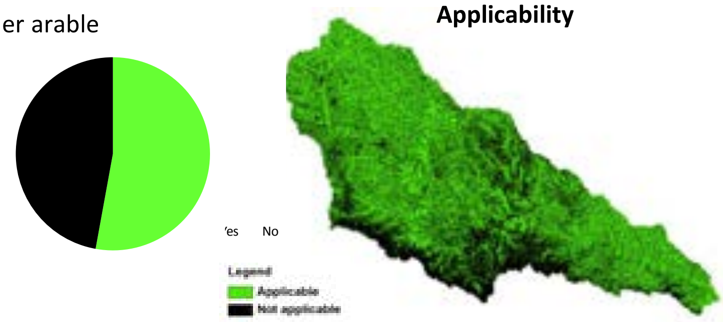
Technology Scenario:
Year-after-year terraced land (CHN53)

- It is assumed that apples are grown on terraces. A harvest to total tree biomass index of 0.19 is used based on secondary data
- Without case is unproductive as cereal cropping on slopes is indicated to make a loss
- Apple price of CNY 1.5/kg (€0.18) is used
- A 10% discount rate is assumed, with terraces gradually constructed over 5 years.
- Apples produce 25% in year 4, 50% in Y5, 75% in Y6 and achieve full production in Y7.
- Further cost details under viability below.

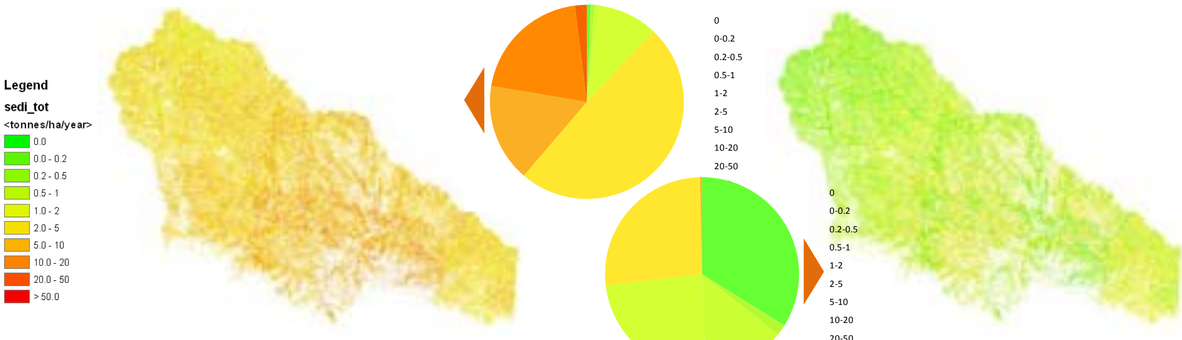
Applicability

- The technology is applicable on land under arable or tree crops on slopes higher than 2%.

Applicability



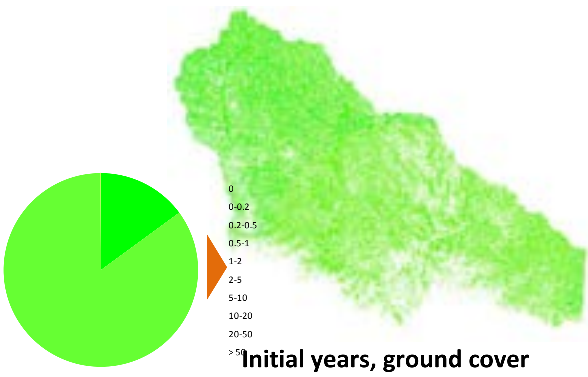
Biophysical impact: soil erosion



Without technology

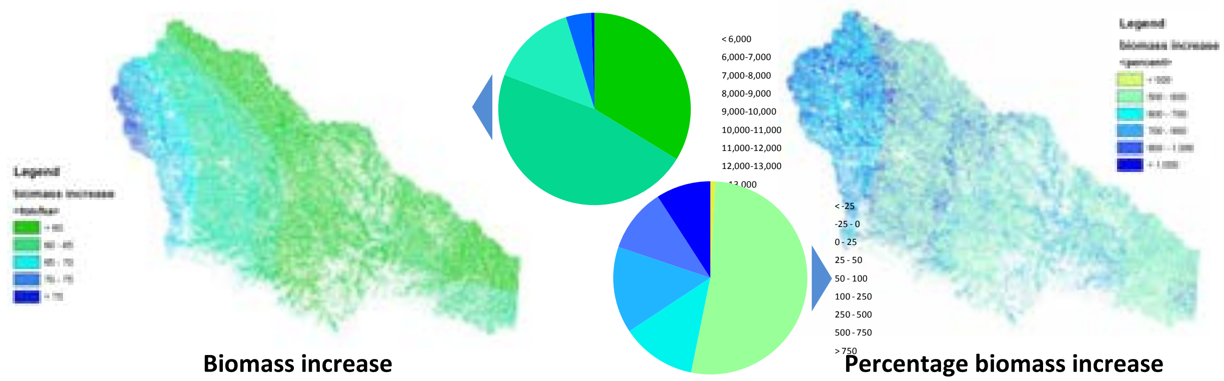
Initial years, bare soil

On year after year terraced land, it matters how ground cover is managed in apple orchards – especially in the initial years. If the ground is kept bare, soil loss is greatly reduced but on average still amounts to 1.26 ton/ha/year. If the ground is kept covered, e.g. through vegetated strips or mulch, the average soil loss drops to only 0.02 ton/ha/year. The latter is comparable in performance to bench terraces (CHN51).



Initial years, ground cover

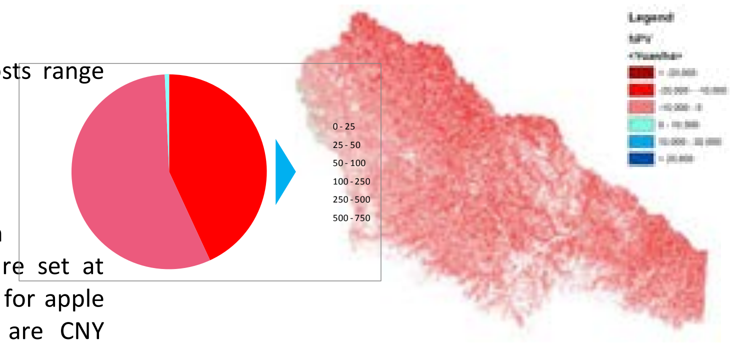
Biophysical impact: increase in biomass



Biomass increase **Percentage biomass increase**

Economic viability

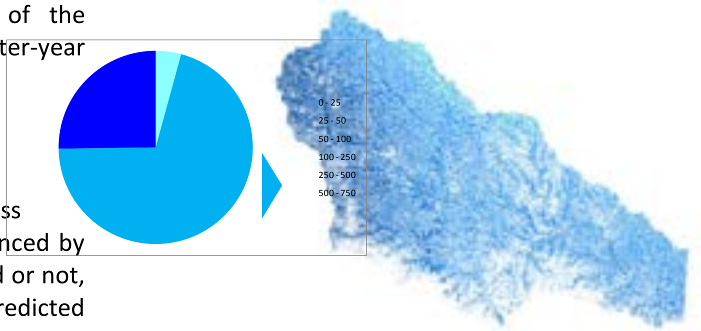
Further assumptions for financial analysis:



Net present value after 10 years

The cost of terracing varies with slope; costs range from CNY 30 –13,129 (i.e. €4 – 1,617) for slopes from 2 to 79% (mean CNY 4,019 ± 1,805 (i.e. €495 ± 222)), and are spread out equally over five years. In addition, tree planting costs of CNY 2,052 (€253) are taken into account. Annual maintenance costs are set at 6.7% of investment costs. Production costs for apple production (chemical inputs and labour) are CNY 9,664 (€1,190).

With these assumptions, in a tiny part of the applicable area (extreme west) year-after-year terracing is profitable after 10 years. This is in the extreme western part of the study area. When we extend the analysis to 20 years, the profitability map swaps completely, with the most profitable zones in the west and in the less steep valley floors. Yield levels are not influenced by the fact whether a ground cover is maintained or not, and are moreover in agreement with those predicted under bench terracing.



Net present value after 20 years

Yanhe River Basin, China

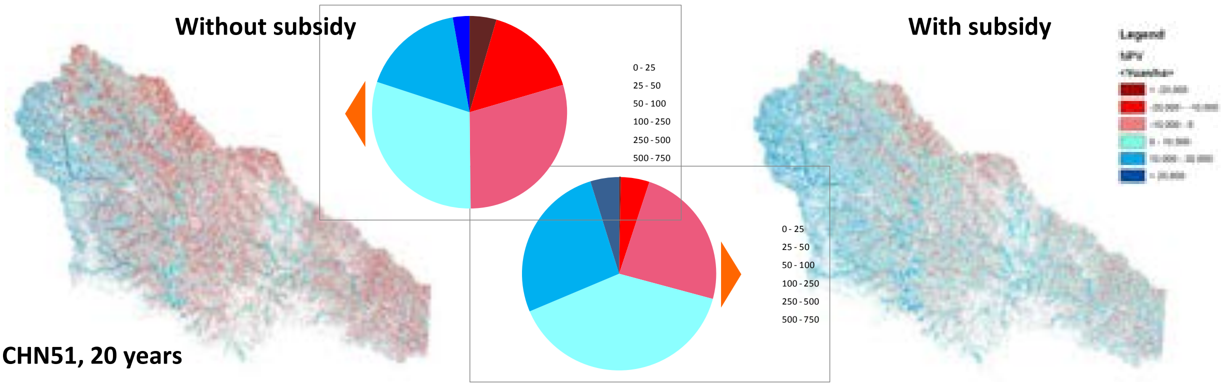
Policy Scenario:
Subsidising terracing and checkdams (CHN51-53)

At a time horizon of 10 years, none of the technologies is profitable and even after 20 years bench terraces are not financially attractive. Land users are unlikely to wait longer for benefits to accrue. Hence costs of the technology need to be reduced. This is possible through a subsidy, which could e.g. be part of a payment for ecosystem services scheme as there are significant downstream effects: reducing sedimentation and flood risk in the Yellow River basin. In this scenario a cost reduction equal to 50% of the investment costs is explored.

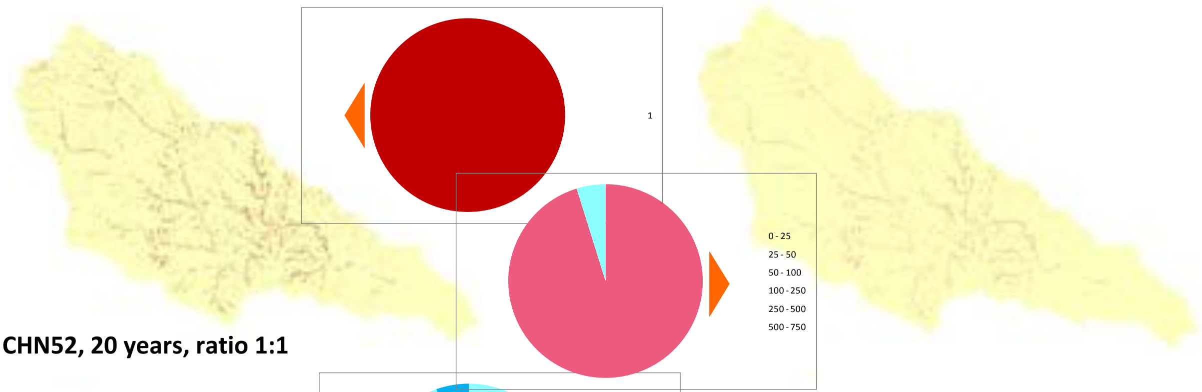
50%

Profitability:

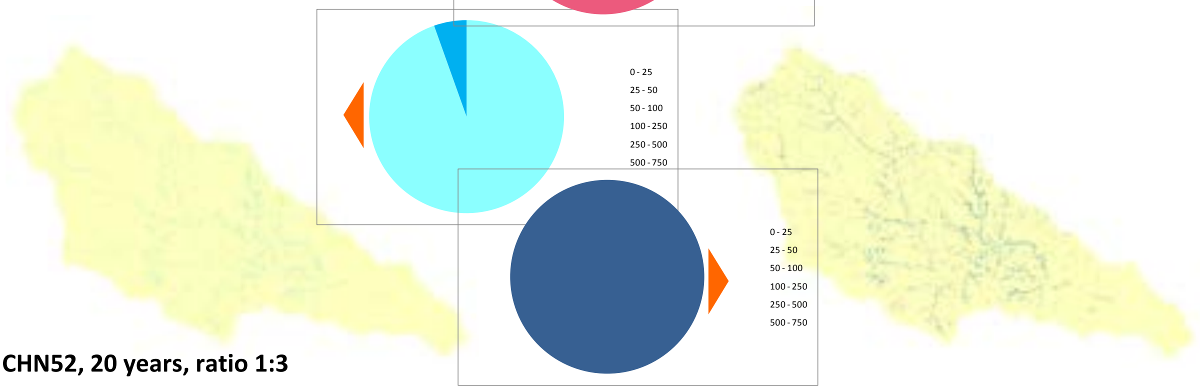
Without subsidy **With subsidy**



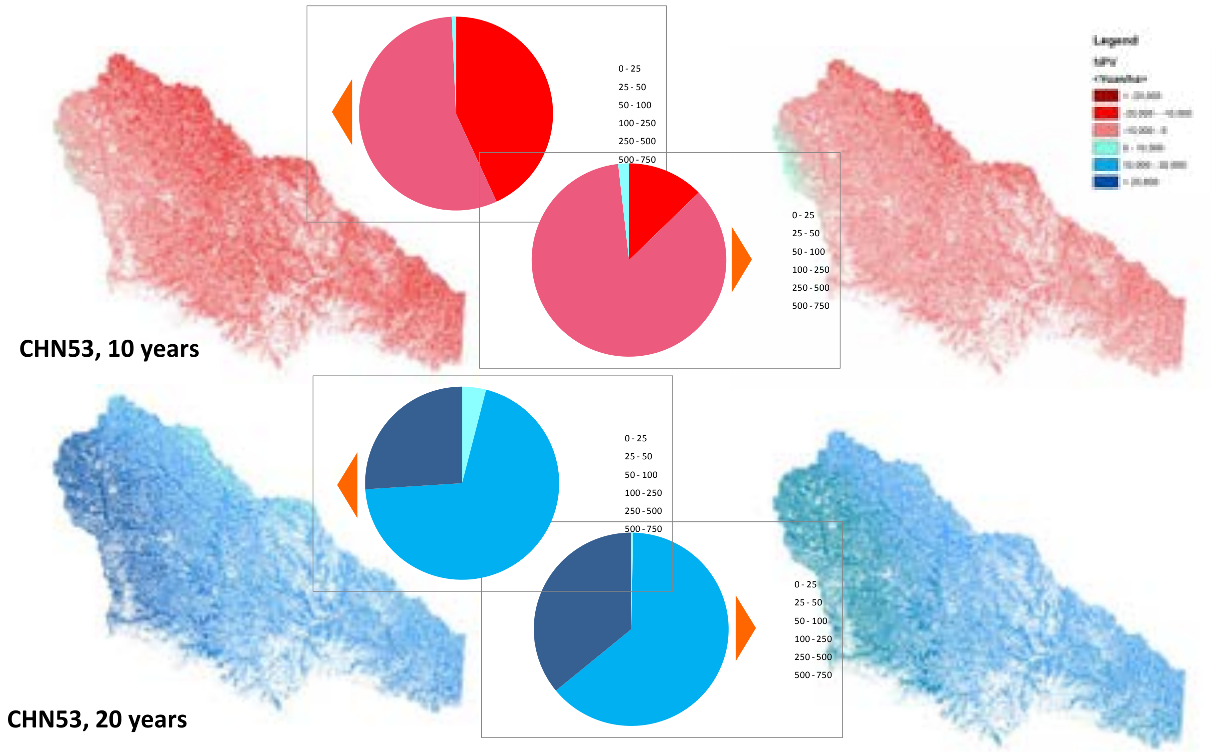
CHN51, 20 years



CHN52, 20 years, ratio 1:1



CHN52, 20 years, ratio 1:3



Cost-effectiveness indicators:

- A reduction in investment costs of 50% is especially important for bench terraces, which then become profitable in 71% of the applicable area (up from 50%), based on the net present value after 20 years.
- This will result in an average reduction of erosion of 6.56 ton/ha/year.
- In total, an annual reduction of 505,428 tonnes of eroded soil can be expected.
- If the cost reduction would be in the form of a subsidy, the total cost would be CNY 1,925 million (€237 million), including those areas where bench terraces would already be feasible but not considering subsidies for year-after-year terraced land and checkdams for land.
- Hence a cost-effectiveness of CNY 3,808/ton (€470) of soil conserved.

Yanhe River Basin, China

Adoption Scenario:

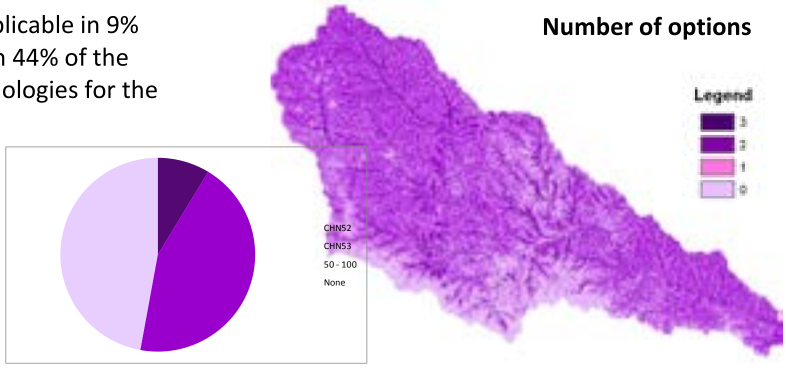
Bench terraces with loess soil wall (CHN51), Checkdam for land (CHN52) and Year-after-year terraced land (CHN53)

An adoption scenario considers the simulated technologies (if more than one) in conjunction and assumes that the most profitable option has the highest potential for uptake by land users. In order to make the net present value of different options comparable, the same time horizon is applied to the analysis. For Yanhe River Basin, bench terraces (CHN51), checkdams for land (CHN52) and year-after-year terraced land (CHN53) are considered. All three options are compared for a 20 year time horizon, according to specifications in the technology scenarios. For checkdams, a ratio of treated to conserved area of 1:3 is assumed.

Mitigation options

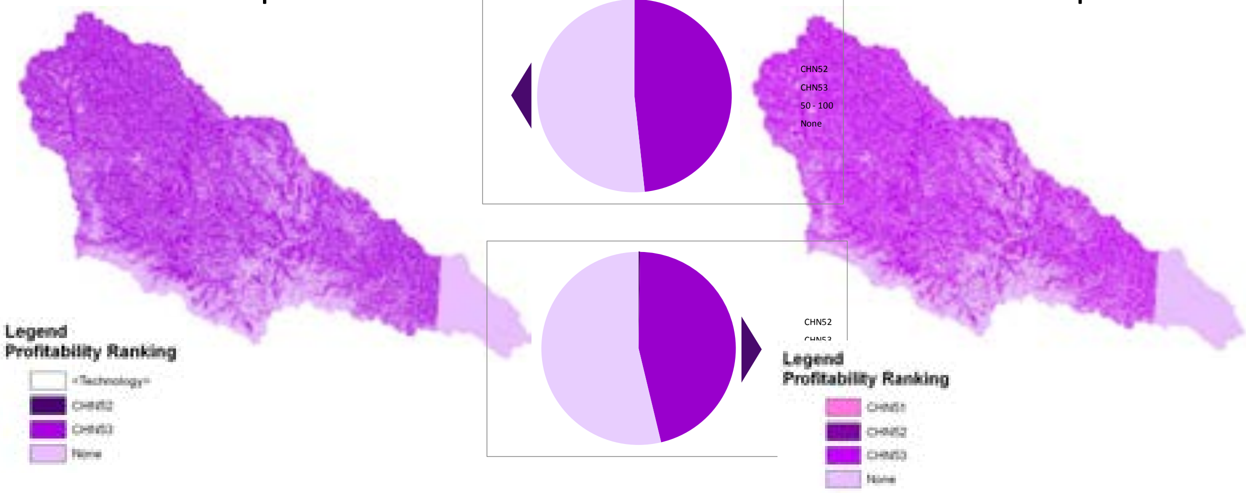
- The three mitigation options are all applicable in 9% of the area; two options are available in 44% of the area; and there are no applicable technologies for the remaining 47% of the area.

Number of options



Adoption of most profitable technology

Without policies **With policies**



Yanhe River Basin, China

Global Scenario:
Food production

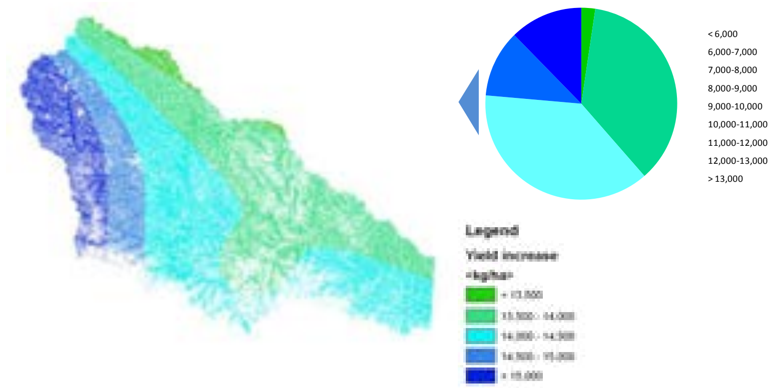
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+14,272 kg/ha*

+7,821 kg/inhabitant

Scope for increased production

Yield increase



Biophysical impact: yield increase

- Yield increase in 100 % of applicable area
- Average absolute yield increase: 14,272 kg/ha
- Average yield increase: na

Economic indicators

Average costs:
- Investment cost: €1,109/ha
- Unitary cost year 7: €78/ton**
- Unitary cost lifetime: €5/ton

Aggregate indicators:
- Study site: €414 million
- Augmented annual production: 5,329,250 ton
- Augmented total production: 82,603,375 ton

*Note: this yield increase is for fresh weight apples
**Note: year 7 is the first year when full production is reached

Yanhe River Basin, China

Global Scenario:
Minimizing land degradation

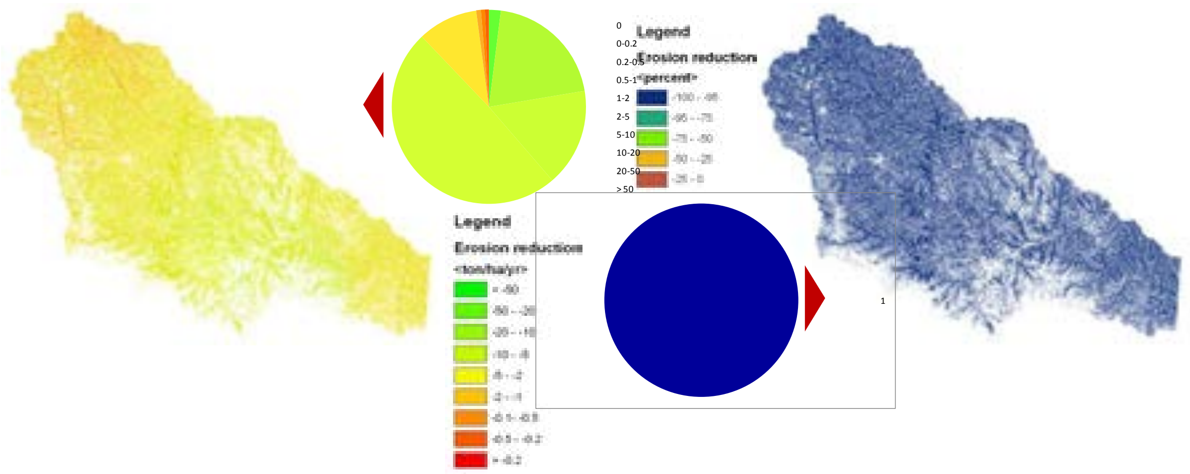
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-6.32 ton soil/ha

€212/ton soil

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 100 % of applicable area
- Average absolute erosion reduction: 6.32 tonnes/ha/yr
- Average percent erosion reduction: 99.9 %

Economic indicators

Average costs:
- Investment cost: €1338/ha
- Unitary cost year 1: €212/ton soil
- Unitary cost lifetime: €11/ton soil

Aggregate indicators:
- Study site: €500 million
- Aggregate annual erosion reduction: 2.36 million ton
- Total erosion reduction: 47.2 million ton

Yanhe River Basin, China

Concluding remarks

- Baseline simulations show a mixed picture of soil erosion in the Yanhe River Basin area: roughly equal parts of the area experience soil erosion rates below 1 ton/ha/yr, between 2 and 5 ton/ha/yr and over 5 ton/ha/yr.
- Six options were prioritised by scientists and local stakeholders to control soil erosion: level bench terraces; reforestation; checkdams; level groove on the slope; fish-scale pits; and mulching. Three technologies were tested: level bench terraces (CHN51), checkdams (CHN52) and reforestation. Reforestation was not modelled but replaced by year-after-year terraced land (CHN53). The technology scenarios show that both terracing technologies can drastically reduce erosion rates; this was confirmed in field rainfall simulation experiments. Checkdams are less effective in reducing runoff within the field but capture sediments in-stream to build up terrace land. The downstream effects will thus still be significant. Maize on checkdam land yielded 70-90% higher yields than in baseline situation according to PESERA simulations. The difference observed in field experiments was higher (7-fold). Biomass on terraces increased spectacularly but with and without situations cannot really be compared as arable land is converted to apple orchards. Being structural soil conservation measures, investment costs are high. Least costly is year-after-year terraced land, which moreover has the advantage of gradual investment requirements. But as apple trees need to grow to maturity before they start producing, there is a time lag which means the pay-back period for terracing occurs only after a minimum of 10 years, but typically in the range of 20 years. For checkdams the amount of land that can be gained is an important variable requiring local, site-specific planning. If a ratio of 1:3 is assumed, the technology is profitable over a period of 20 years.
- In the workshop to evaluate monitoring and modelling results, stakeholders reaffirmed their priority interest in checkdams. Low maintenance costs and high productivity were important factors in justifying their choice. Terraces were not very popular due to low productivity (of maize) and long gap before trees become productive (apples).
- A policy scenario reducing investment costs by 50% for all technologies did not make a large difference in potential uptake (based on profitability) of checkdams and year-after-year terraced land. However, level bench terraces become of interest in an additional 21% of the applicable area. Such a subsidy would reduce soil erosion in the incremental area by on average 5.6 ton/ha/yr, and at a cost of CNY 3,808/ton (€470). Such subsidies do however not make a notable difference in bridging the production gap: after 10 years in most of the cases the technology is not yet profitable. Subsidies might be justified when considering downstream benefits of reduced flooding/sedimentation. These effects were not included in the analysis.
- The adoption scenario summarises the above: the technologies tested are together applicable in 53% of the study area. Without policies, year-after-year terraced land is the most profitable technology, with checkdams surpassing profits in isolated locations in a reduced number of cases. With subsidies, the relative profitability of bench terraces and checkdams improves but substitutes land where year-after-year terraced land would be most beneficial. There is thus no change in the total area of land that would be attractive for technology implementation.
- The global scenarios show that the technology can achieve very significant yield increases and erosion reductions in the vast majority of the applicability area. The investment costs to achieve this are moderately low, at €78/ton food produced and €212/ton soil conserved. Per area unit, investment costs are nevertheless substantial. Food production is however fresh weight apples, which cannot be directly compared to indicator values based on grain production.
- The technologies considered are very effective to conserve soil and water. In the case of checkdams for land, productivity increases are instant and might justify the high investment costs. However, local feasibility studies need to be conducted on a case-by-case basis. For terracing, the cost is high in relation to the benefits, which, in the case of apple production, leave an important unproductive gap period. As it takes longer than 10 years to see a return on investment, the technology might be of less interest. Under climate change, the performance of all technologies considered will improve. However, the downstream impacts should be included in the assessment of large scale introduction of terracing and checkdams.

Cointzio, Mexico

Study site details

The Cointzio basin is situated in the altiplano of the Transmexican Volcanic Belt and consists of a small plain surrounded by mountains, the outflow of which is controlled by a dam.

- **Coordinates:**
  Latitude: 19°23' – 19°38' N
  Longitude: 101°10' – 101°34' W
- **Size:** 640 km^2
- **Altitude:** 1999 – 3007 m
- **Precipitation:** 750 – 1100 mm (annual mean)
- **Temperature:** 12° – 20°C (annual mean)
- **Land use:** scrublands, forests, rainfed and irrigated agriculture, and grasslands
- **Inhabitants:** 42,150 (2000)
- **Main degradation processes:** water erosion
- **Major drivers of degradation:** lack of awareness, low profitability, inappropriate land management (overgrazing)

Figure 1: Study site location.

Overview of scenarios

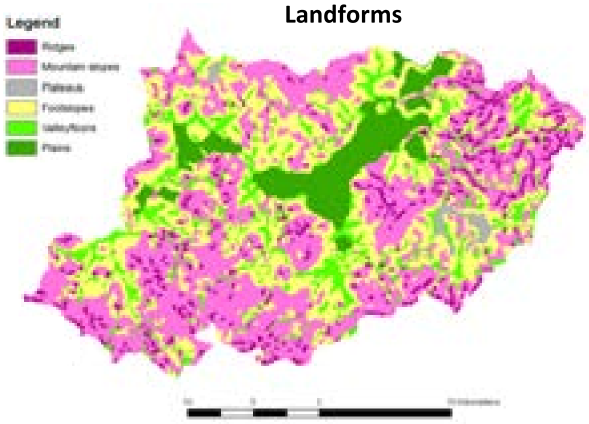
1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Land reclamation with native Agave and trees through participative action for economical benefits (MEX02)
3. Technology Scenario: Minimum tillage in rainfed and irrigated maize
4. Global Scenario: Food production
5. Global Scenario: Minimizing land degradation

Cointzio, Mexico

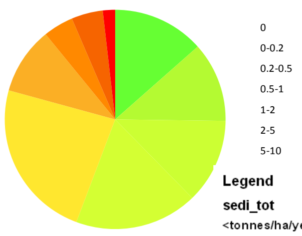
Baseline Scenario

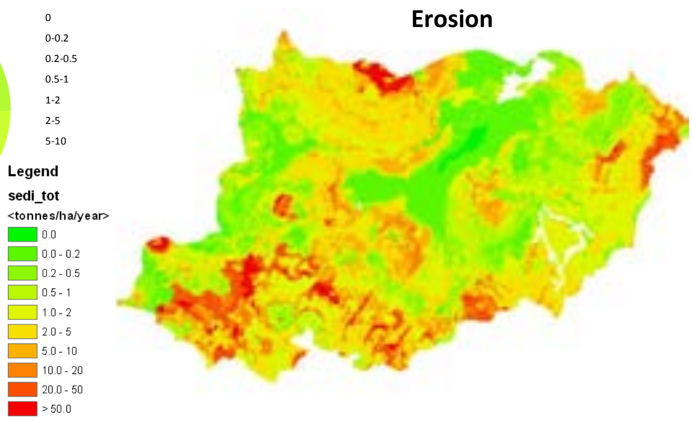
PESERA baseline run

The baseline erosion map clearly follows landforms: mountain slopes demonstrate high soil loss rates whereas plains experience little soil erosion. Some areas are simulated to experience very high soil erosion rates of over 200 tons/ha/year. Biomass production follows the land use pattern, with forests vegetation types representing highest values. Arable land is partially irrigated and have higher productivity than rainfed land. Overall, biomass production is high due to the subhumid climatic conditions and deep soils.

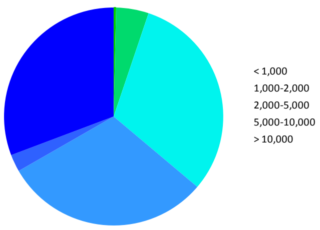


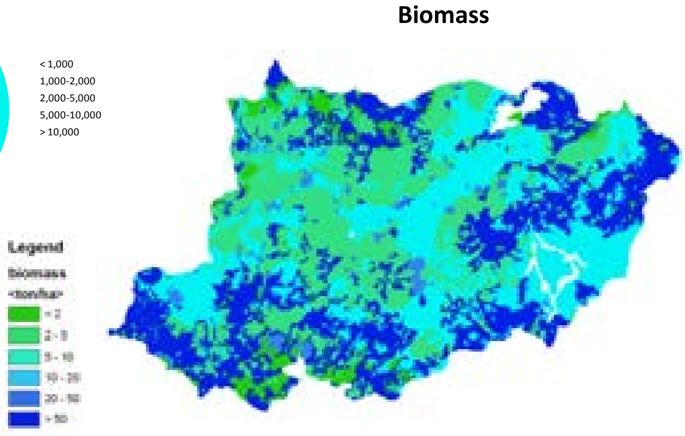
Soil erosion





Biomass production





Cointzio, Mexico

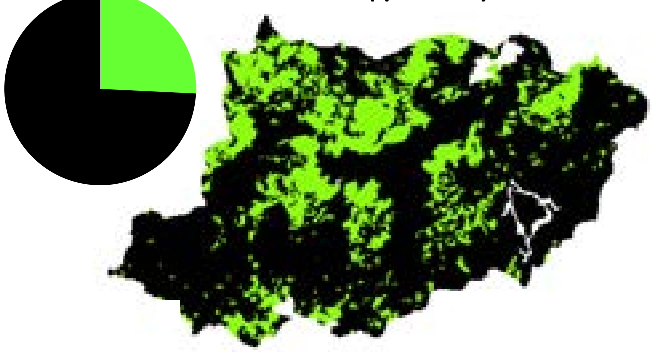
Technology Scenario:
Land reclamation with native Agave and trees through participative action for economical benefits (MEX02)

- Total investment costs (seed collection, nursery, transplanting): MXN 20,000 (€1174)
- Without case: unproductive land
- Agave can be harvested after 10 years. It is assumed that on average 1500 litres of Mescal will be produced and sold at MXN 200/litre (€12); the average productivity of 1500 litres is related to average biomass increase in the applicable area and assumed to vary accordingly
- A discount rate of 10% is applied
- Reduction of erosion is assessed as a result of increased biomass


Applicability

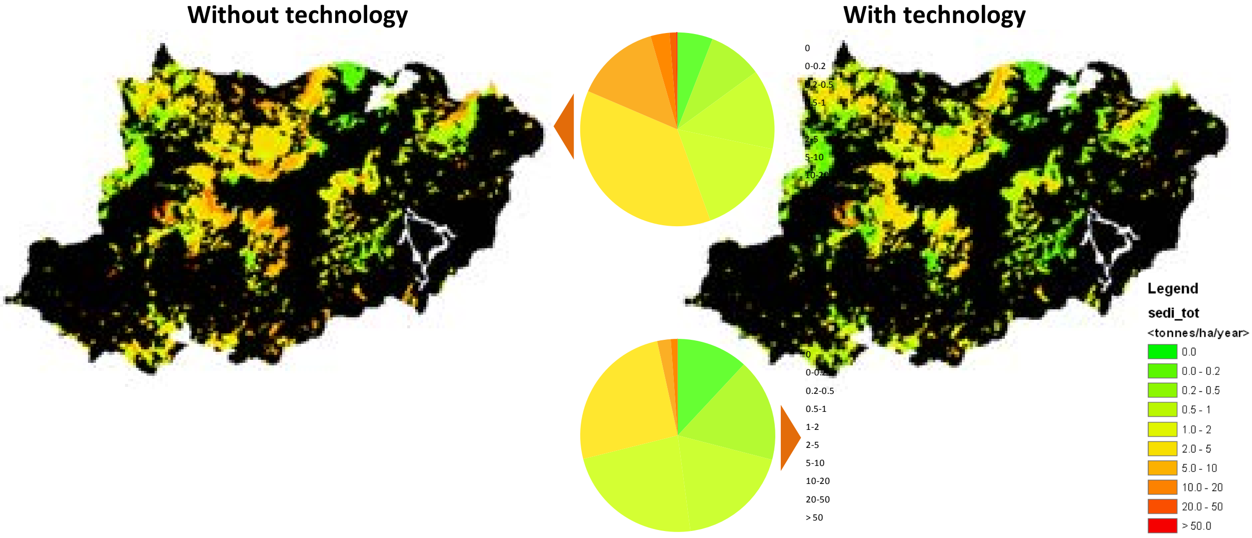
- The technology is applicable on degraded land, natural grasslands, and open matorral.

Applicability



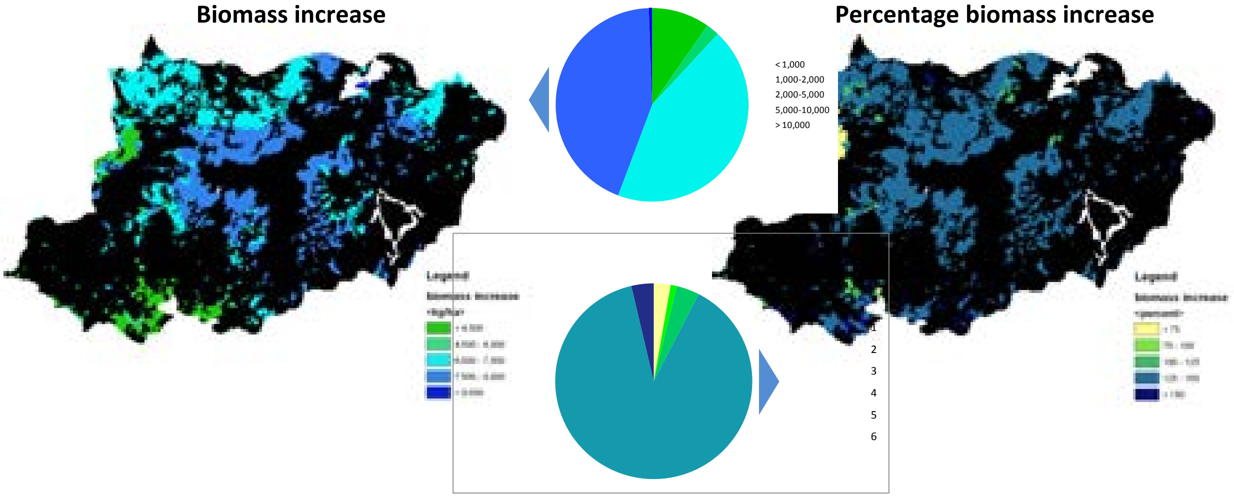
Biophysical impact: soil erosion

Without technology **With technology**



Biophysical impact: increase in biomass

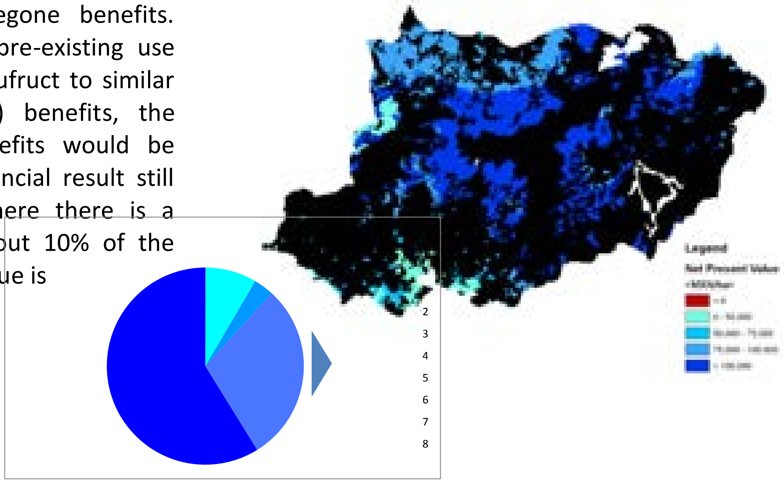
Biomass increase **Percentage biomass increase**



Economic viability

As it is assumed the technology is implemented on unproductive land, there are no foregone benefits. Another approach to this is that any pre-existing use value of the land can continue to be usufruct to similar extent. Due to the distant (in time) benefits, the technology is less viable than if benefits would be obtained instantly, but overall the financial result still looks pretty good, with a tiny bit where there is a negative return on investment and about 10% of the applicable area where the net present value is relatively low.

Net present value after 10 years



Cointzio, Mexico

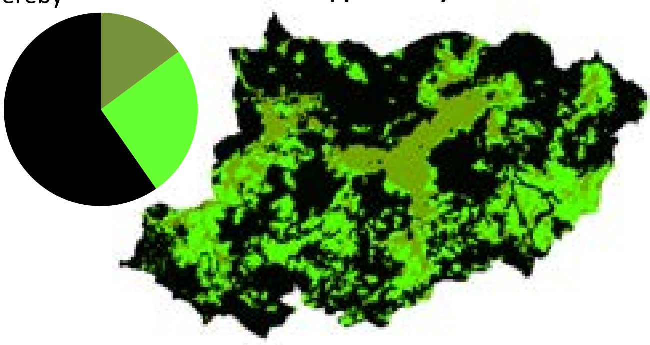
Technology Scenario:
Minimum tillage in rainfed and irrigated maize

- Assumed production costs of maize, both under conventional and minimum tillage:
  - Hills and piedmonts: MXN 1,000/ha (€59)
  - Plains: MXN 1,700/ha (€100)
- A harvest index of 0.4 is applied
- Maize prices are applied as follows:
  - Hills and piedmonts: MXN 5/kg (€0.30)
  - Plains: MXN 6/kg (€0.35)

Applicability

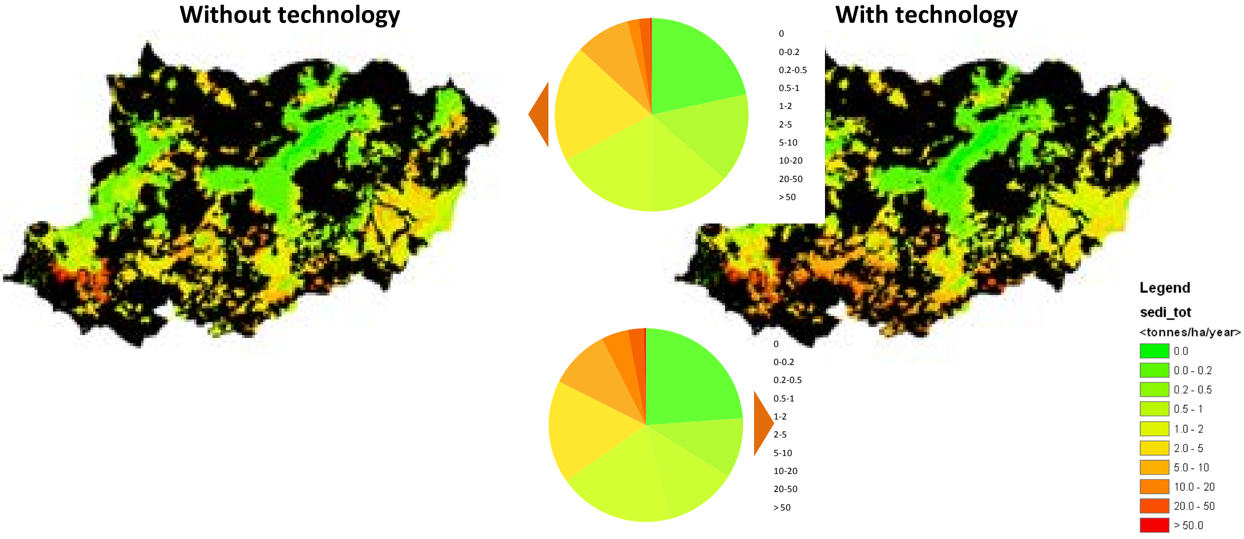
- The technology is applicable on arable land, whereby it is assumed that maize in plains (olive) is irrigated and maize on hillslopes and piedmonts (light green) rainfed.

Applicability



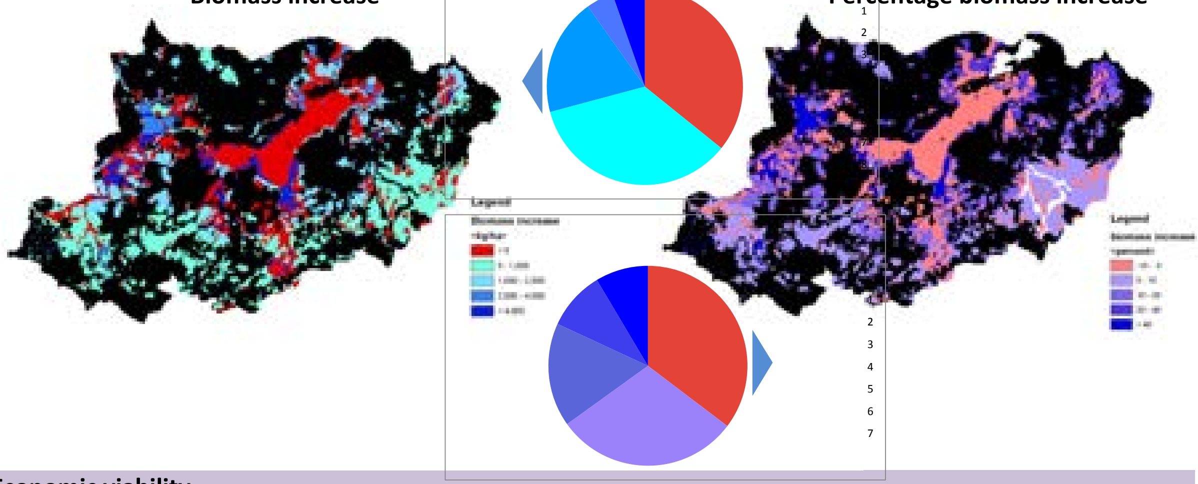
Biophysical impact: soil erosion

Without technology **With technology**



Biophysical impact: increase in biomass

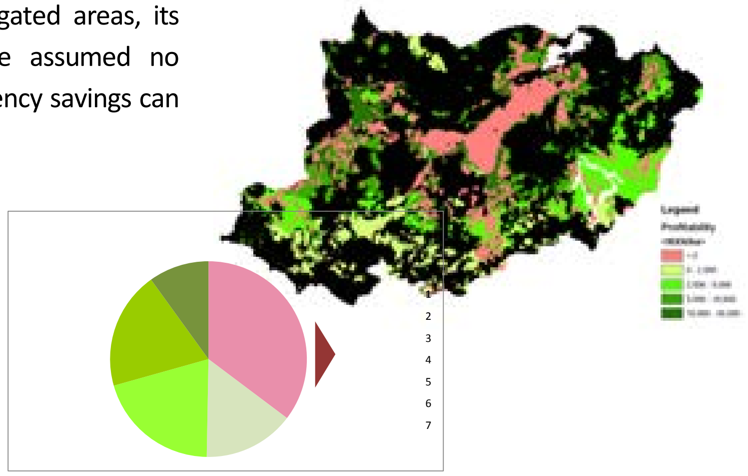
Biomass increase **Percentage biomass increase**



Economic viability

The technology leads to improvements in about two thirds of the applicability area. In irrigated areas, its usefulness is less obvious. We have assumed no difference in operational costs; if efficiency savings can be made the viability might improve.

Net present value after 10 years



Cointzio, Mexico

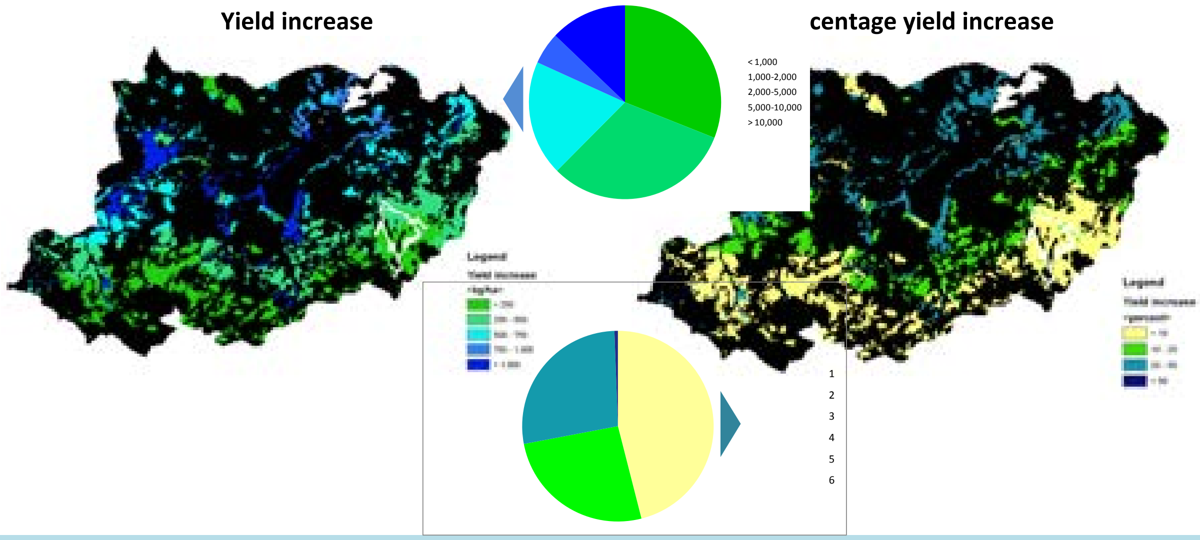
Global Scenario:
Food production

The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+521 kg/ha

+217 kg/inhabitant

Scope for increased production



Biophysical impact: yield increase

- Yield increase in 64 % of applicable area
- Average absolute yield increase: 521 kg/ha
- Average yield increase: 16 %

Economic indicators

Average costs:
- Extra operational cost: €0/ha/yr
- Unitary cost: €0/ton

Aggregate indicators:
- Study site: €0 million
- Augmented annual production: 9,137 ton

Cointzio, Mexico

Global Scenario:
Minimizing land degradation

The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

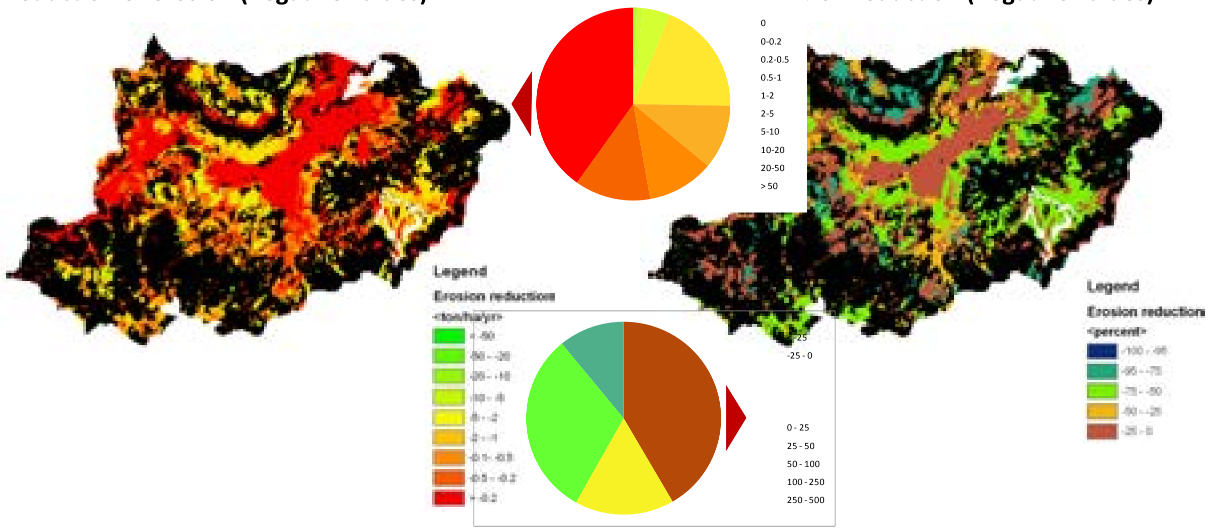
-1.54 ton soil/ha

€323/ton soil

Scope for reduced erosion

Reduction of erosion (negative values)

Percentage of erosion reduction (negative values)



Biophysical impact: erosion reduction

- Reduction of erosion in 70 % of applicable area
- Average absolute erosion reduction: 1.54 tonnes/ha/yr
- Average percent erosion reduction: 39 %

Economic indicators

Average costs:
- Investment cost: €498/ha
- Unitary cost year 1: €323/ton soil
- Unitary cost lifetime: €32/ton soil

Aggregate indicators:
- Study site: €15.47 million
- Aggregate annual erosion reduction: 47,900 ton
- Total erosion reduction: 478,700 ton

Cointzio, Mexico

Concluding remarks

- The PESERA baseline simulation shows a quite severe soil erosion problem in Cointzio, with 20% of the area featuring erosion rates over 10 ton/ha/yr.
- Whereas initially scientists and local stakeholders selected agronomic measures and wood saver ovens as priority strategies, later agave plantations were trialled to counter soil loss by water erosion. The technology scenarios show that erosion rates can be reduced – more so by agave plantations than by minimum tillage in maize. Agave plantation can raise biomass production by as much as 75 – 150%. In contrast, minimum tillage leads to lower biomass increases: up to 50% in rainfed maize, but also leads to reductions of up to 10% in irrigated areas. As a consequence, minimum tillage is not profitable in about a third of the applicability area. Agave plantations take long to produce benefits, but are nevertheless simulated to have positive net present value everywhere where it can be implemented.
- Evaluating the results in a workshop, stakeholders clearly prioritized agave plantations along with wood saver stoves, and downgraded agronomic measures (minimum tillage) to the second tier. Participatory establishment of a pilot agave plantation was instrumental in this result. Agronomic measures were not rated very highly due to low labour input in farming (which only constitutes for 10-20% of rural livelihoods).
- The global food production scenario shows that minimum tillage can boost maize yields by 16% on average in 64% of the applicability area. We suggest this can be achieved at virtually no extra cost. The potential for reducing soil erosion is higher on slopes than in plains. At an average investment cost of almost €500/ha, erosion can be reduced by 1.54 ton/ha/yr. Over 10 years (the lifetime of agave plantations) this investment plays out at 32€/ton soil prevented from eroding.
- Minimum tillage leads to higher yields under rainfed, but not under irrigated conditions. It is therefore recommended to only apply this technology on the first maize production system. Agave plantations are established on unproductive land and there are little risks involved in applying this technology, which can generate an additional source of income in the long run and contribute to more resilient livelihoods.

Sehoul, Morocco

Study site details

The Sehoul Plateau is located between the highway from Rabat to Fes in the north, and the Grou River in the south. It is a part of the old Atlantic Meseta.

- **Coordinates:**
  Latitude: 33°54’ N
  Longitude: 6°38’ W
- **Size:** 397 km²
- **Altitude:** 45 – 359 m
- **Precipitation:** 450 mm
- **Temperature:** na
- **Land use:** arable land, forest, shrubland
- **Inhabitants:** 19,706 (2004)
- **Main degradation processes:** water erosion
- **Major drivers of degradation:** inadequate land management, land use change, groundwater overexploitation

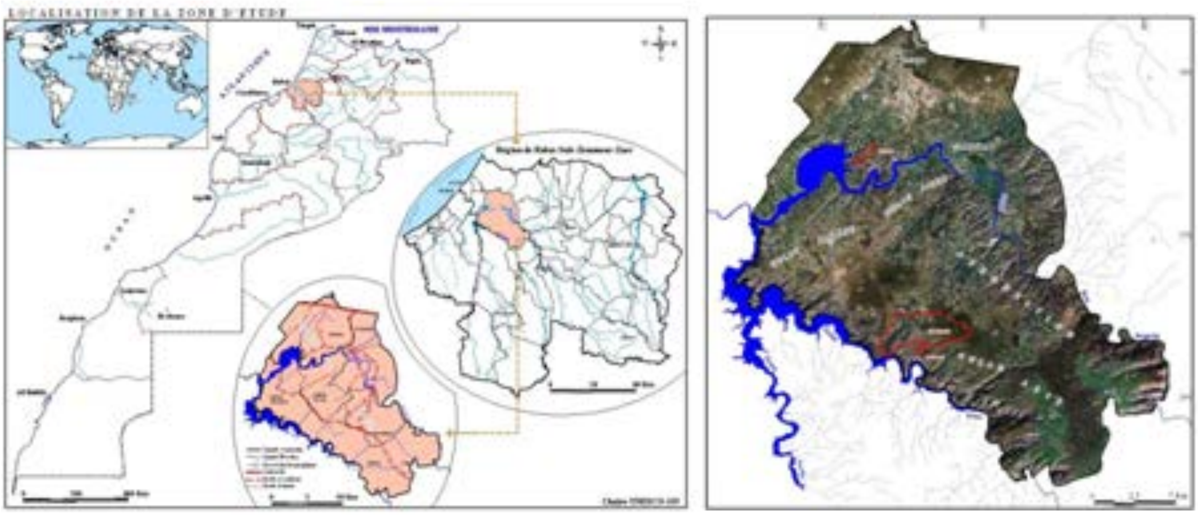


Figure 1: Study site location

Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Protection of pastures affected by gullies and rills, by fencing and the plantation of fodder shrubs (atriplex) (MOR15)
3. Technology Scenario: Mulching (fencing) and cultivation techniques (conventional tillage - MOR 16A or direct seeding - MOR16B)
4. Policy Scenario: Subsidising the protection of pastures affected by gullies (MOR15)
5. Policy Scenario: Prohibiting livestock stubble grazing (MOR16A/B)
6. Adoption Scenario: Fencing and atriplex (MOR15), Mulching (MOR16A) and Mulching with direct seeding (MOR16B)
7. Global Scenario: Food production
8. Global Scenario: Minimizing land degradation

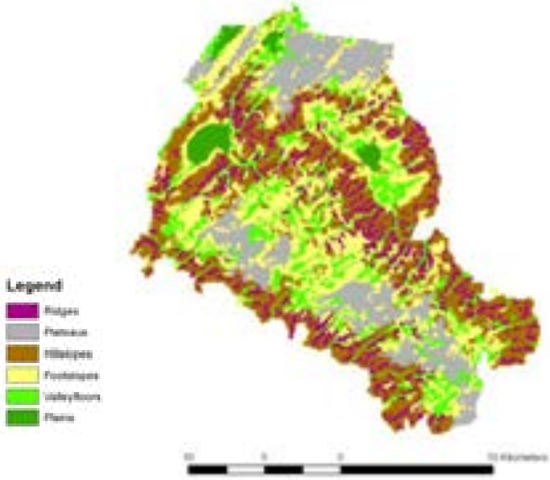
Sehoul, Morocco

Baseline Scenario

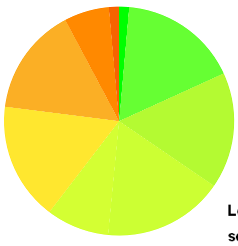
PESERA baseline run

The baseline scenario shows that soil erosion risk is highest on the steep hillslopes along the rivers that dissect or limit the area in a predominantly northwest-southeast direction. The plateaus, for the larger part forested, stand out as low erosion areas. Biomass production correlates with land use, with highest values for forest areas and lowest values for arable land. For forests, the biomass is relatively low due to high amount of grazing. For arable land, the areas with steep slopes and shallow soils are much less productive than alluvial areas.

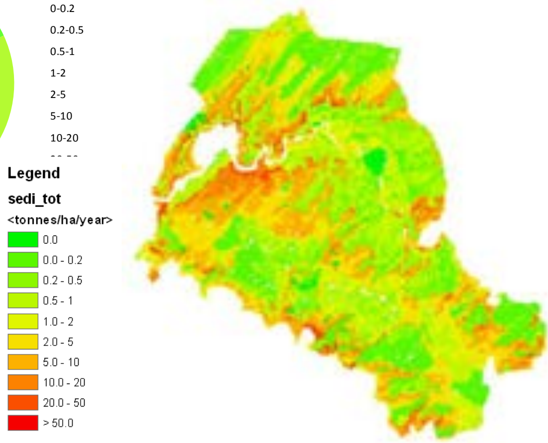
Landforms



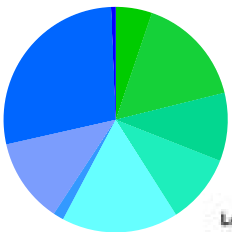
Soil erosion



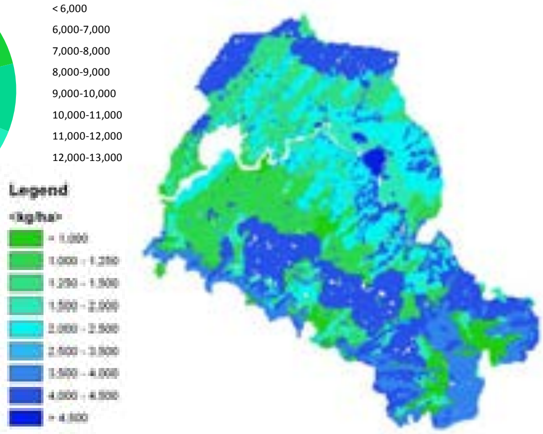
Soil erosion



Biomass production



Biomass production



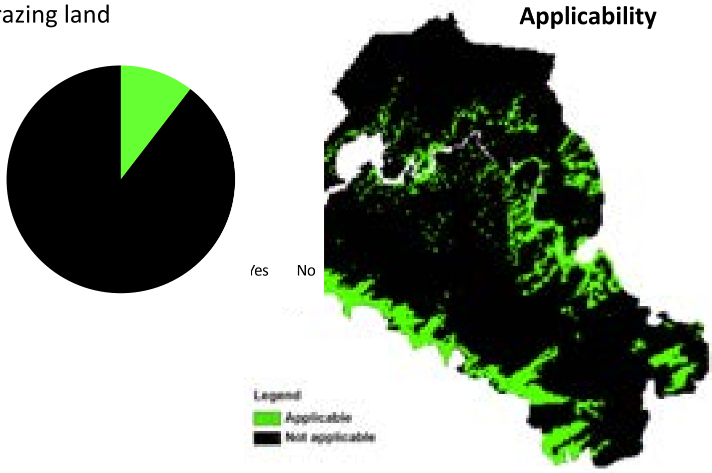
Sehoul, Morocco

Technology Scenario:
Protection of pastures affected by gullies and rills, by fencing and the plantation of fodder shrubs (atriplex) (MOR15)

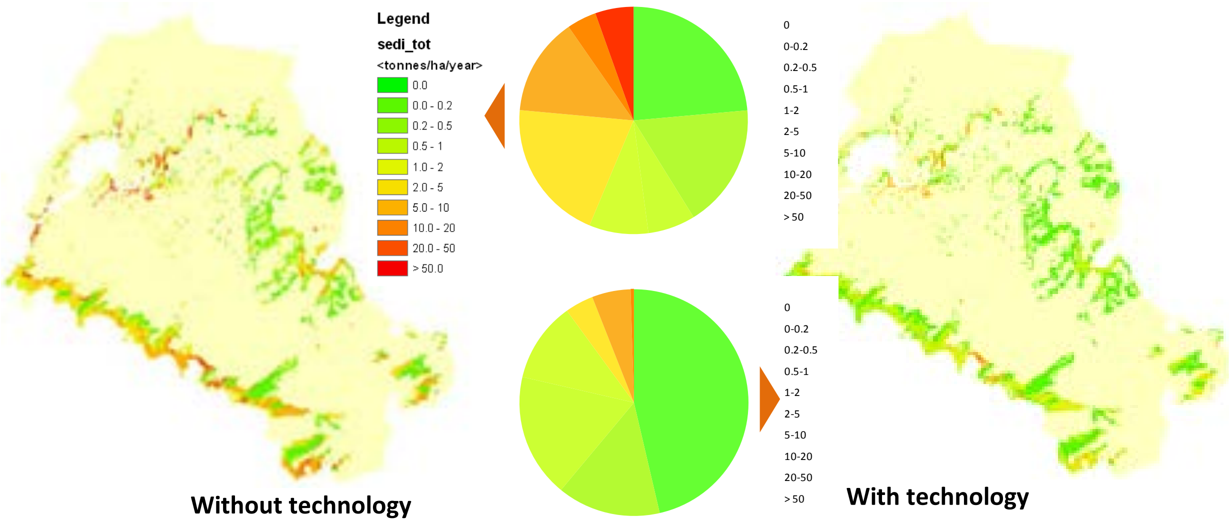
- The investment costs for atriplex plantation amount to 28,020 MAD/ha (€2480)
- Full biomass increase is assumed to be achieved after 20 years; a linear growth trend is assumed.
- Grazing is assumed in without case. Apart from differences in fodder production, fodder quality is assessed by a conversion factor of 35% (without case) and 56% (technology) of fodder units to biomass.
- Price of fodder is 2.16 MAD/fodder unit (€0.19)
- Cost of fodder collection and feeding is assumed to be equal to herding animals
- A discount rate of 10% is applied

Applicability

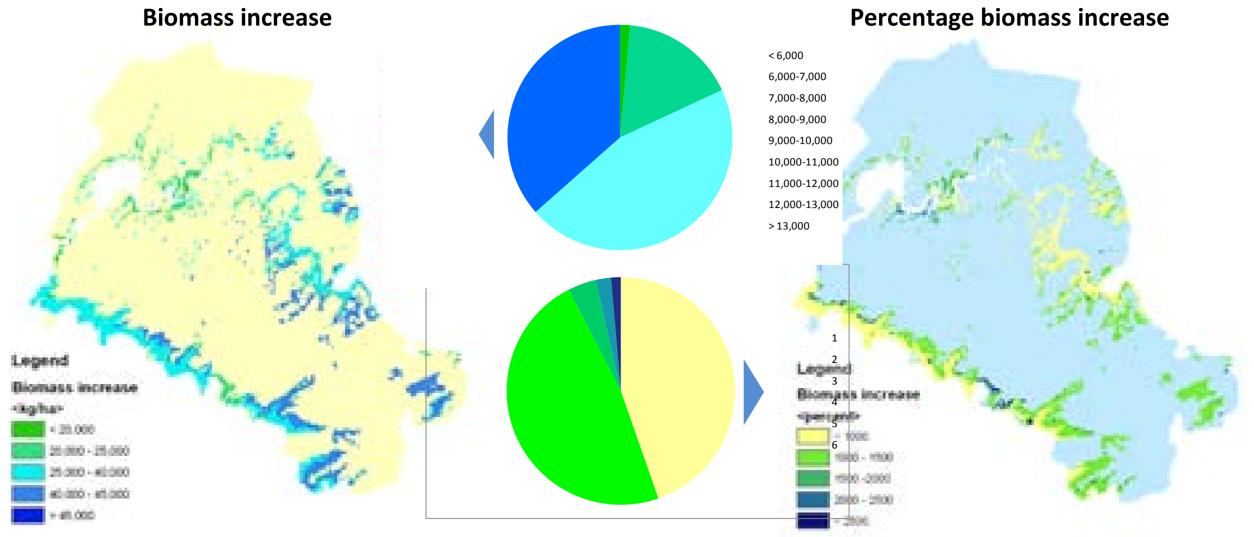
- The technology is applicable on extensive grazing land and bare land. It can also be applied on steep cropland prone to gullying. All cropland above 20% slope is assumed to fall in this category.



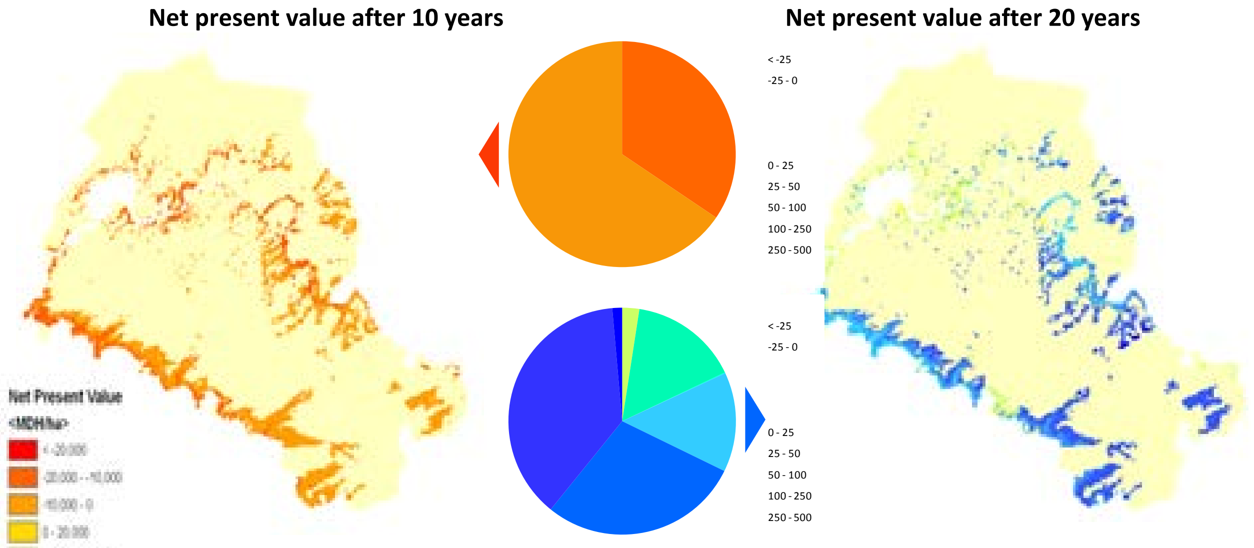
Biophysical impact: soil erosion

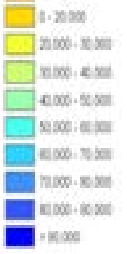


Biophysical impact: increase in biomass



Economic viability





Although the technology is projected to lead to a very strong increase in biomass, this is likely a slow process, particularly on degraded lands for which the technology is intended. An investment for a time horizon of 10 years leads - under the assumptions made - to negative net present value. In the longer term, i.e. 20 years, the technology is highly profitable. Some effects are not taken into account, e.g.:

- Adoption of the technology reduces need for stubble and forest grazing, and productivity of cropland and forest may go up as a consequence.
- Off-site effects, such as avoiding the development of gullies in adjacent farmland and reduced sedimentation in the river network.
- Costs of implementing the technology may have an element of spatial variability (distance to markets for inputs, water source for irrigation and opportunity cost of labour for livestock grazing)
- The scale of application (e.g. fencing costs per unit area can be much reduced by closing contiguous larger areas – for instance by 50% for 4 ha and by 75% for 16 ha).

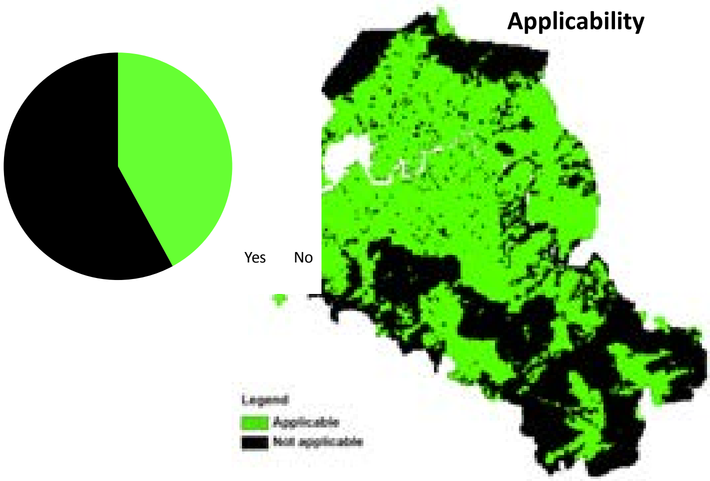
Sehoul, Morocco

Technology Scenario:
Mulching (fencing) and cultivation techniques (conventional tillage - MOR 16A or direct seeding - MOR16B)

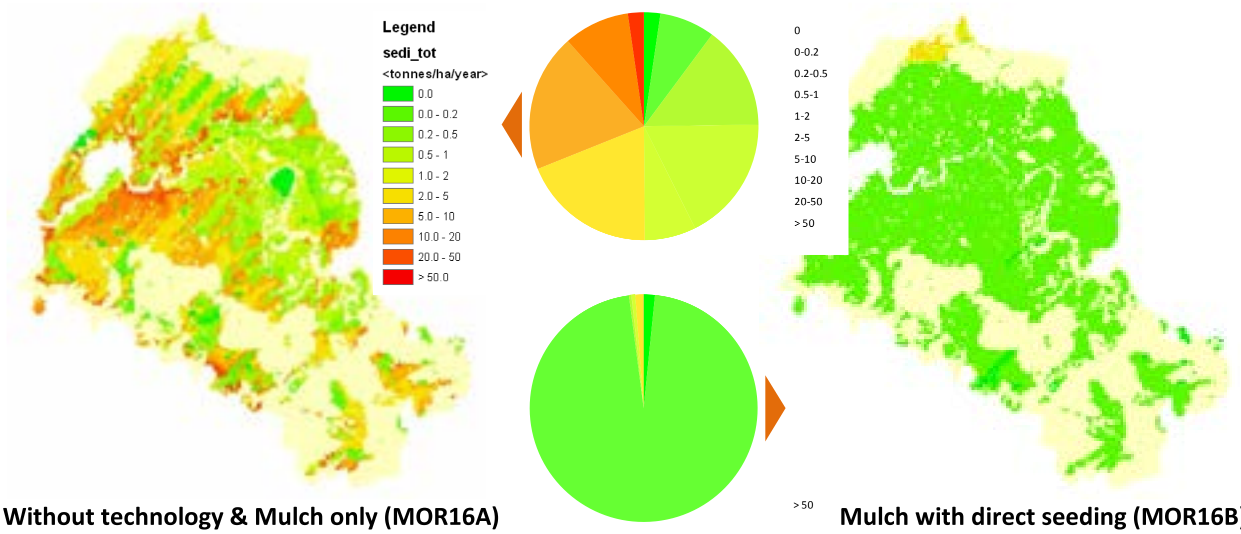
- Two variants considered MOR16A and B.
- The investment costs for fencing amount to 6,520 MAD/ha (€577) in both cases.
- Due to initial fencing cost, an investment analysis with an economic life of 10 years is made.
- In the without case, conventional tillage is assumed followed by fallow grazing.
- Technical assumptions: harvest index of 31%; 0.4 fodder units (FU) per kg fallow stubble.
- Unit prices (kg or FU): barley 4 MAD (€0.35); straw 0.5 MAD (€0.02); fodder 2.2 MAD (€0.19)
- Added cost direct seeding is 1500 MAD (€133)
- A discount rate of 10% is applied

Applicability

- The technology is applicable on arable land.



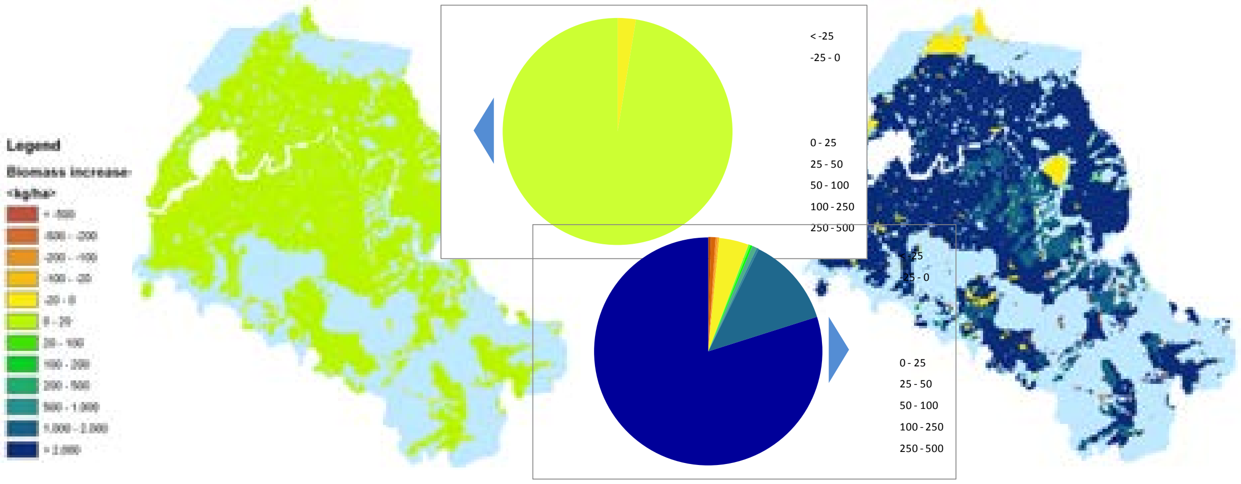
Biophysical impact: soil erosion



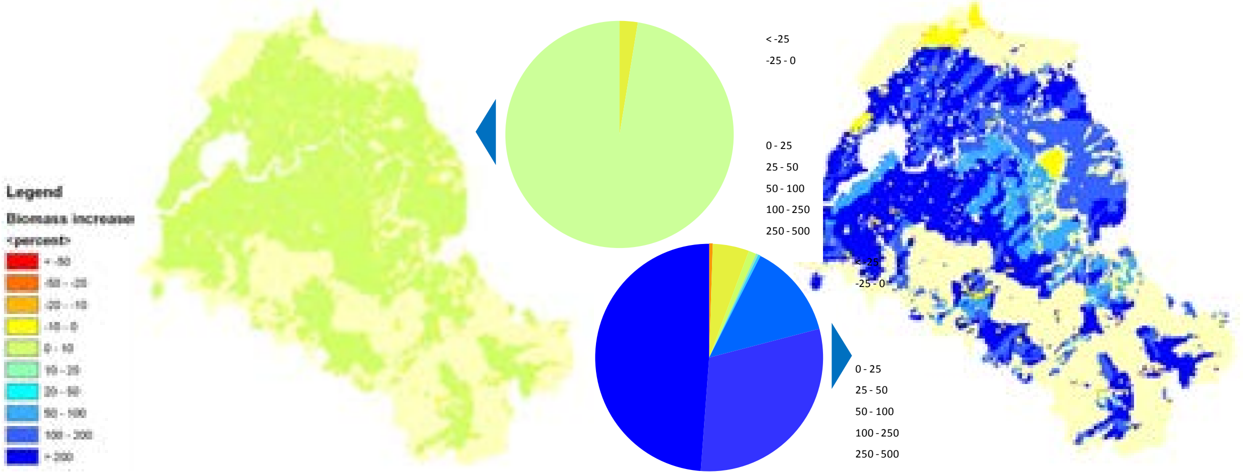
Without technology & Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**

Biophysical impact: increase in biomass

Biomass increase: Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**

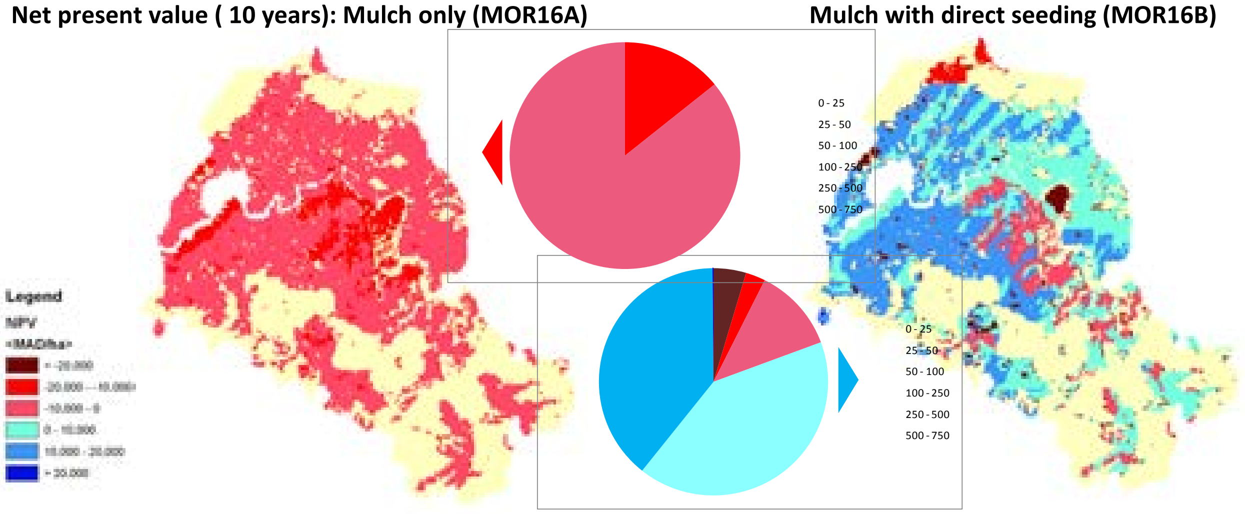


Percentage biomass increase: Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**



Economic viability

Net present value (10 years): Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**



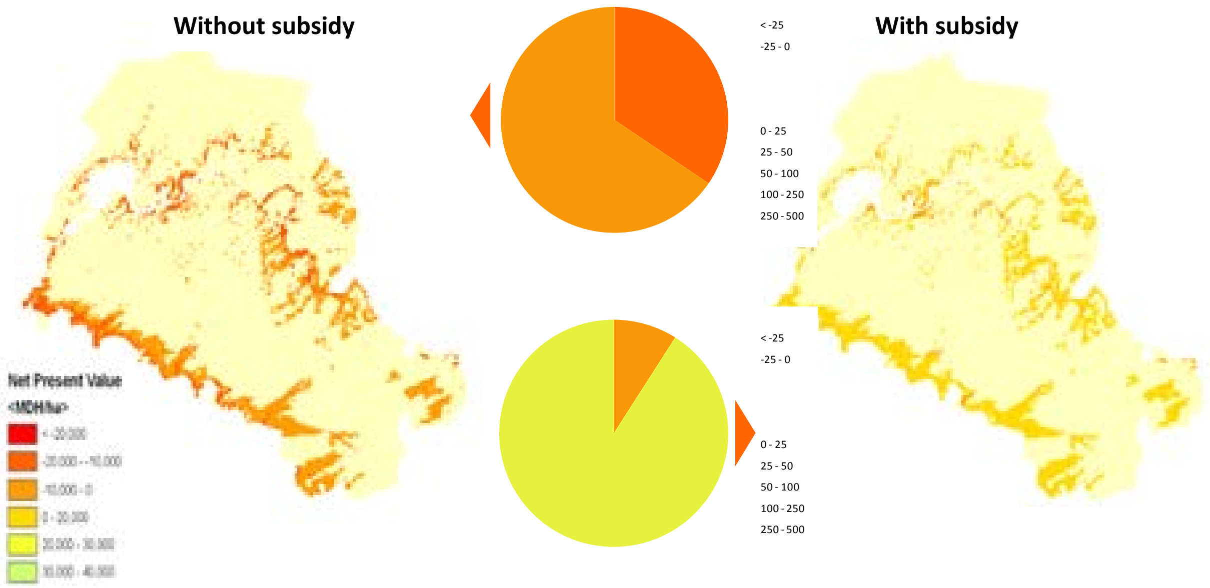
The important upfront fencing costs are not justified in the case of mulch only as the technology leads to only very modest (<10%) biomass increase. Moreover, no erosion reduction results (fallow period dry). In the case of direct seeding, erosion rates and biomass respond impressively. Economic viability is more mixed due to high operational costs of direct seeding but profitable in 81% of the applicable area.

Sehoul, Morocco

Policy Scenario:
Subsidising the protection of pastures affected by gullies (MOR15)

At a time horizon of 10 years, fencing and planting atriplex is not profitable. Land users are unlikely to wait longer for benefits to accrue. Hence costs of the technology need to be reduced. This is possible through a subsidy and/or coordinating the scale of implementation which will reduce per area unit cost. A subsidy could be part of a payment for ecosystem services scheme as stabilization of areas affected by gullies and rills has important off-site effects, e.g. reduction of sedimentation of the reservoirs in the study area, and relieving pressure on state forests. In this scenario a cost reduction equal to 50% of the investment costs is explored.

Profitability:



Cost-effectiveness indicators:

- A reduction in investment costs of 50% makes the technology profitable in 91% of the applicable area, based on the net present value after 10 years.
- This will result in an average reduction of erosion of 3.27 ton/ha/year.
- In total, an annual reduction of 16,582 tonnes of eroded soil can be expected.
- If the cost reduction would be in the form of a subsidy, the total cost would be 71.4 million MAD (€6.28 million).
- Hence a cost-effectiveness of 4,306 MAD/ton (€379) of soil conserved.

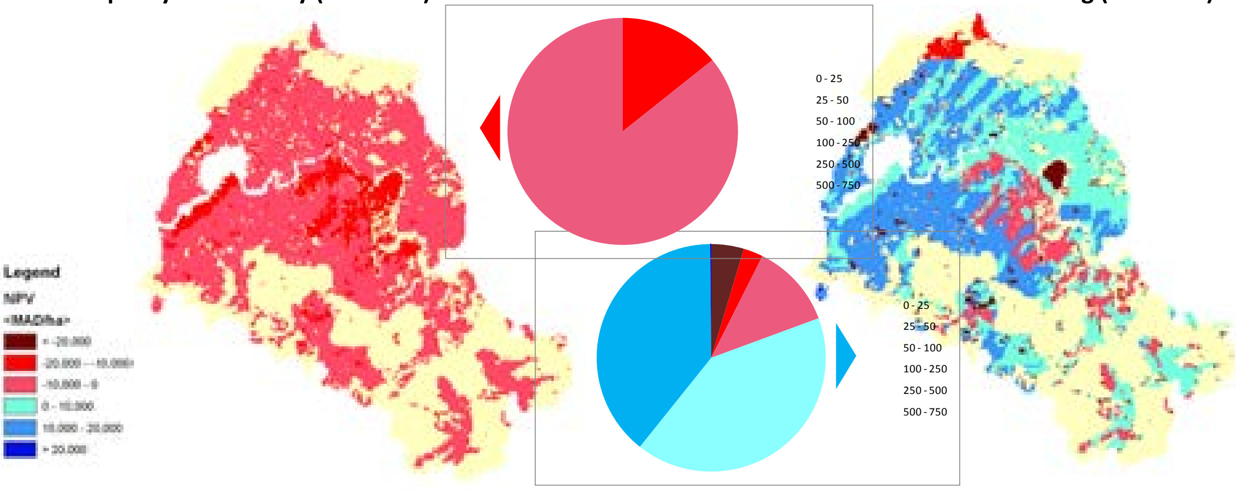
Sehoul, Morocco

Policy Scenario:
Prohibiting livestock stubble grazing (MOR16A/B)

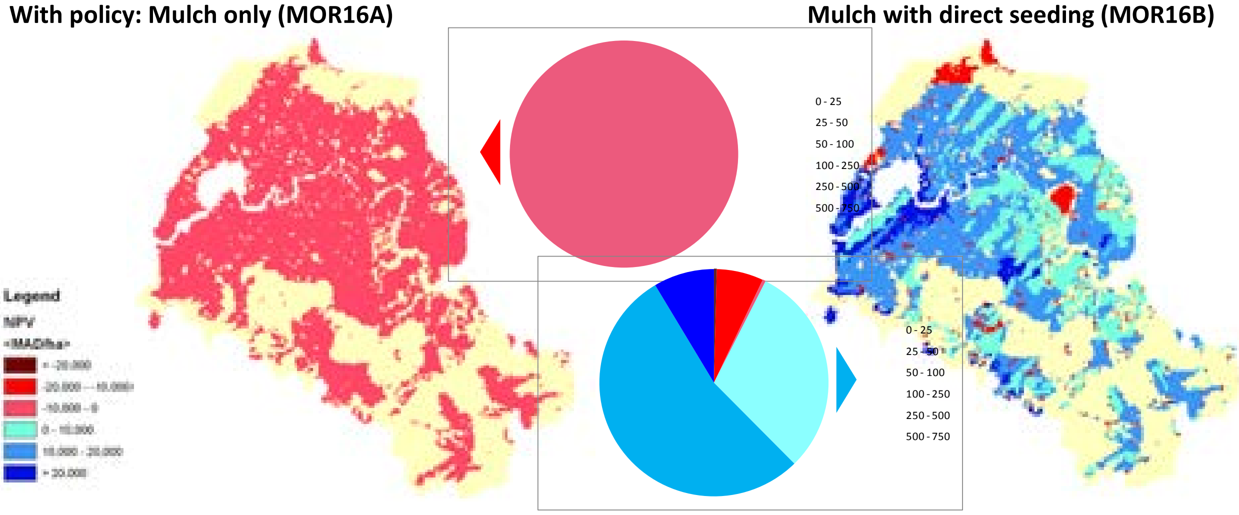
The need for fencing makes the application of mulching (with conventional tillage or direct seeding) difficult. Fencing implies a need for upfront investment – the resources for which may not be readily available. Moreover, land users might consider it a risky investment as they are unsure if costs can be recouped and when this will happen. This scenario explores the changes in economic viability of the mulching technologies if fencing would not be required. This could be the case if animals can be kept of the land, e.g. through policy enforcement.

Profitability:

Without policy: Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**



With policy: Mulch only (MOR16A) **Mulch with direct seeding (MOR16B)**



Cost-effectiveness indicators:

- Without a need for fencing, the technology (MOR16B only) becomes profitable in 93% of the applicable area, based on the net present value after 10 years. This is an additional 12%.
- This will result in an average reduction of erosion of 0.59 ton/ha/year, much lower than the average reduction obtained in the area where the technology is already profitable without policy (4.91 ton/ha/year).
- In total, an annual reduction of 1,553 tonnes of eroded soil can be expected.
- The cost of such a policy would from a governance perspective entail controlling implementation. From a land user perspective differences in livestock keeping systems would need to be assessed. For arable land productivity, it is clear that productivity will increase significantly.

Sehoul, Morocco

Adoption Scenario:

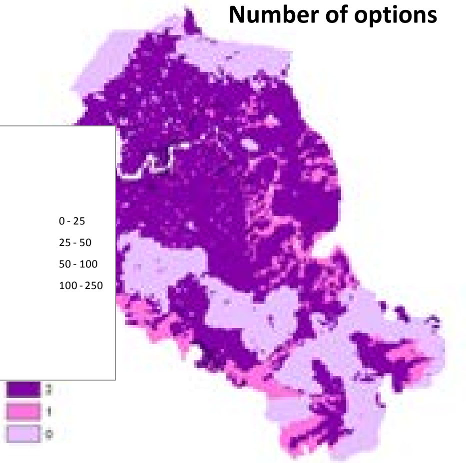
Fencing and atriplex (MOR15), Mulching (MOR 16A) and Mulching with direct seeding (MOR16B)

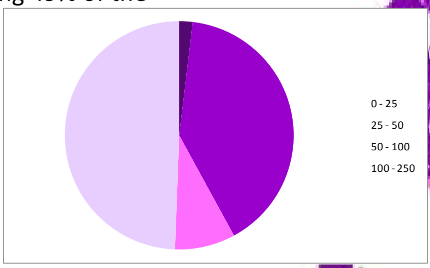
An adoption scenario considers the simulated technologies (if more than one) in conjunction and assumes that the most profitable option has the highest potential for uptake by land users. In order to make the net present value of different options comparable, the same time horizon is applied to the analysis. For Sehoul, fencing and atriplex plantation (MOR15), applicable on degraded land, and the two mulching variants (conventional tillage and direct seeding – MOR16A/B) for arable land are considered. All three options are compared for a 10 year time horizon.

Mitigation options

- The three mitigation options are all applicable in 2% of the area; two options are available in 40% of the area; only 1 option is suitable on 9% and there are no applicable technologies for the remaining 49% of the area.

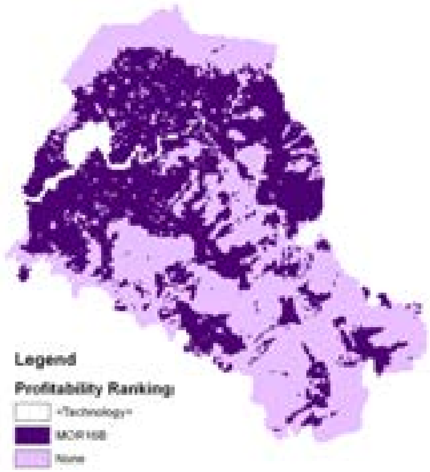
Number of options

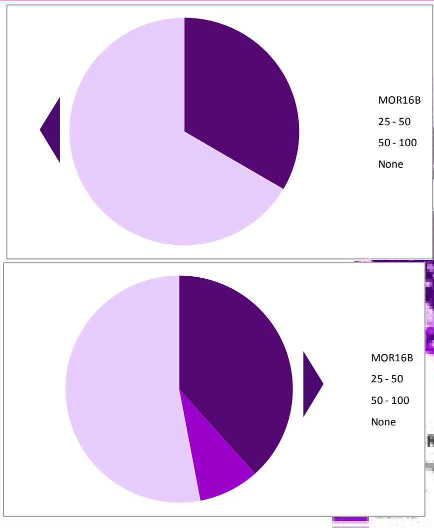




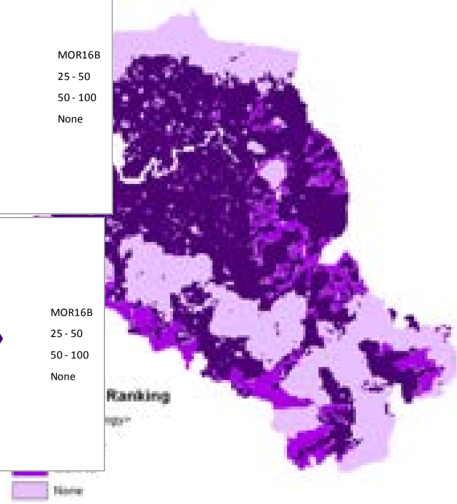
Adoption of most profitable technology

Without policies





With policies



Sehoul, Morocco

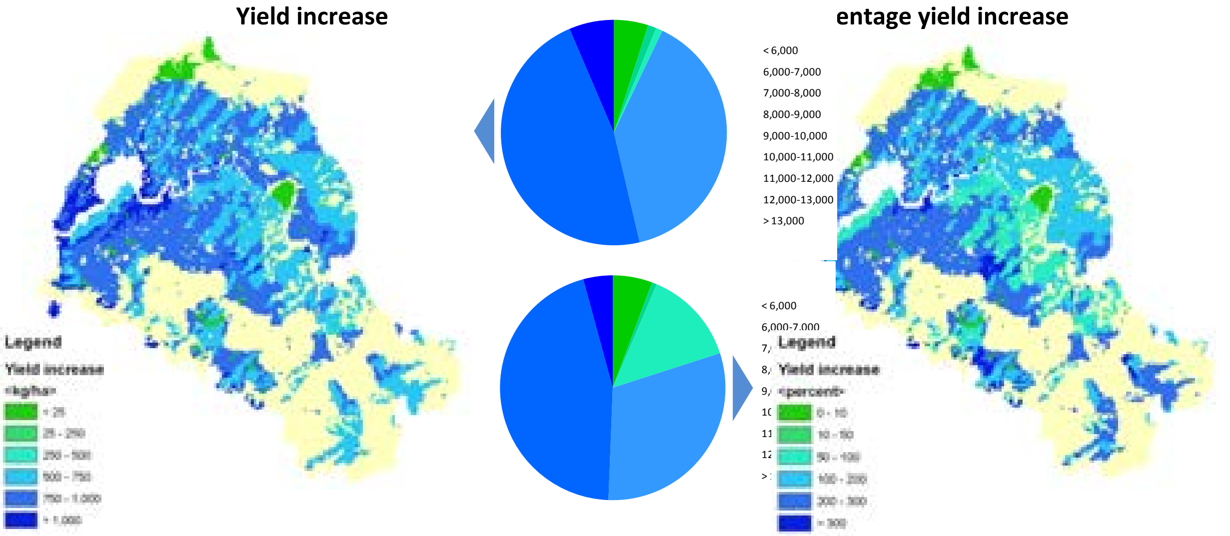
Global Scenario:
Food production

The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+758 kg/ha

+841 kg/inhabitant

Scope for increased production



Biophysical impact: yield increase

- Yield increase in 99 % of applicable area
- Average absolute yield increase: 758 kg/ha
- Average yield increase: 181 %

Economic indicators

Average costs:

- Investment cost: €577/ha
- Unitary cost year 1: €928/ton
- Unitary cost lifetime: €243/ton

Aggregate indicators:

- Study site: €15.4 million
- Augmented annual production: 16,568 ton
- Augmented total production: 165,683 ton

Sehoul, Morocco

Global Scenario:
Minimizing land degradation

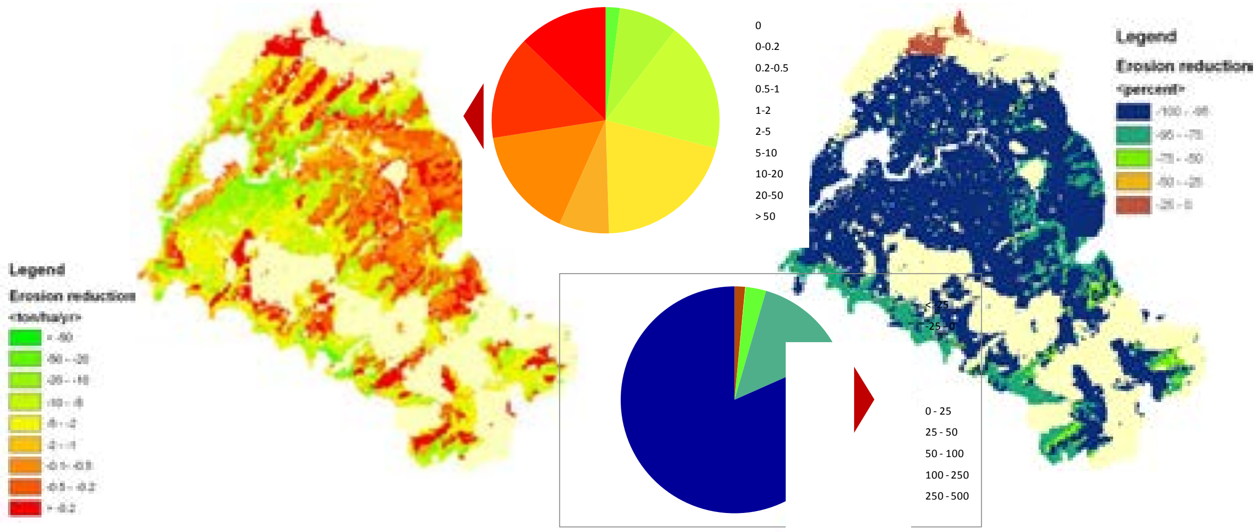
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-3.93 ton soil/ha

€50/ton soil

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 94 % of applicable area
- Average absolute erosion reduction: 3.93 tonnes/ha/yr
- Average percent erosion reduction: 95 %

Economic indicators

Average costs:

- Investment cost: €1008/ha
- Unitary cost year 1: €257/ton soil
- Unitary cost lifetime: €50/ton soil

Aggregate indicators:

- Study site: €25.2 million
- Aggregate annual erosion reduction: 99,486 ton
- Total erosion reduction: 0.995 million ton

Sehoul, Morocco

Concluding remarks

- Baseline simulations show a mixed picture of soil erosion in the Sehoul area: about half of the area has soil erosion rates below 1 ton/ha/yr, but over 20% has rates of more than 10 ton/ha/yr.
- Improved crop rotations for cereals and improved rangelands with control of gullies were prioritised by scientists and local stakeholders to control soil erosion, soil fertility depletion and vegetation decline. Two concrete technologies were tested: protection of pastures affected by gullies and rills (MOR15) and mulching (fencing) of arable land (MOR16A/B). The technology scenarios show that both technologies can drastically reduce erosion rates. However, for mulching this only applies in combination with direct seeding (MOR16B) – mulching with conventional tillage (MOR16A) is ineffective in PESERA simulations. Atriplex planting on degraded land is according to model output capable of leading to 10-fold increase in biomass production. The time scale over which this occurs would need to be assessed, but experimental results were encouraging. A doubling of biomass production is obtainable in cereals under mulching and direct seeding, but only marginal improvements (<10%) are simulated for mulching and conventional tillage. Experimental results showed issues with direct seeding, and the divergence between both variants was not clear cut. Due to high initial cost of fencing, the tested technologies are only in the long term (> 10 years) profitable. Mulching with direct seeding performs best and is simulated to be profitable in 81% of the applicable area over a 10-year planning horizon.
- In the workshop to evaluate monitoring and modelling results, stakeholders downgraded the mulching technology based on inconclusive experimental results. This might also be due to the perception that cereal farming is not profitable, and needs to be diversified with leguminous crops and tree species. On the other hand, management measures that can be adopted without the need for profound changes in cultural practices were suggested to have better adoption prospects. Incentives and 'bold political decisions' were deemed necessary to exclude grazing and reverse degradation trends.
- A policy scenario reducing fencing costs by 50% made atriplex planting profitable in 91% of the applicable area. Such a subsidy would reduce soil erosion by on average 3.4 ton/ha/yr, at a cost of 4,306 MAD/ton (€273). Given that the zones where the technology would be implemented are riparian areas surrounding waterways and reservoirs, there could be important off-side benefits. For mulching, a policy scenario considered the effect of regulations to keep animals off the land – which would remove the need for fencing. An additional 12% of the applicable area would see mulching and direct seeding become profitable, but with limited further decrease of soil erosion problems. Throughout the applicable area, productivity (and profitability) would increase. The combination of mulch and conventional tillage is too ineffective to become profitable. Importantly, the implications of such changes for livestock keeping must be clearly understood. As expressed in the workshop, the land users' priorities lie with their livestock and there is reluctance to change grazing systems.
- The adoption scenario summarises the above: the technologies tested are together applicable in about halve of the study area (woodlands being excluded). Without policies, only mulch with direct seeding offers scope for adoption, in about a third of the area. Considering the policy scenarios separately for each technology, roughly 15% of the area could be additionally made attractive to technology implementation.
- The global scenarios show that the technology can achieve very significant yield increases and erosion reductions in the vast majority of the applicability area. The investment costs to achieve this are relatively low, at €243/ton grain and €50/ton soil conserved. Per area unit, investment costs are nevertheless substantial. The modelling results need further experimentation to support claims of the effectiveness of direct seeding in particular.
- Planting atriplex and mulching and direct seeding are in principle robust land degradation mitigation strategies. However, fencing of determined areas might lead to overgrazing elsewhere; a holistic natural resource management approach is necessary to balance human and ecosystem needs. Planted on degraded land, atriplex can reclaim areas that have become unproductive. The mulching systems need further testing to identify risks and establish best practice.

Góis, Portugal

Study site details

Gois is a municipality situated on the northern slopes of the Lousã Mountains in Central Portugal.

- **Coordinates of central point:**
  Latitude: 40°06'26.28" N
  Longitude: 8°06'57.19" W
- **Size:** 263 km²
- **Altitude:** 145 – 1200 m
- **Precipitation:** ca. 1200 mm
- **Temperature:** na
- **Land use:** pine and eucalyptus forests, arable land, unproductive land and settlements
- **Inhabitants:** 4,499 (2006)
- **Main degradation processes:** forest fires, land abandonment through depopulation
- **Major drivers of degradation:** depopulation and ageing population, land abandonment, monocultural forestry, inadequate laws and lack of enforcement, financial constraints

Figure 1: Study site location

Overview of scenarios

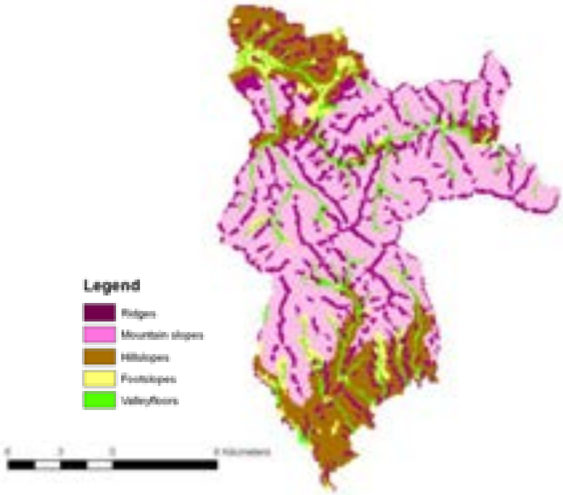
1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Prescribed fire (POR02)
3. Policy Scenario: Targeted implementation of prescribed fire (POR02)
4. Global Scenario: Food production

Góis, Portugal

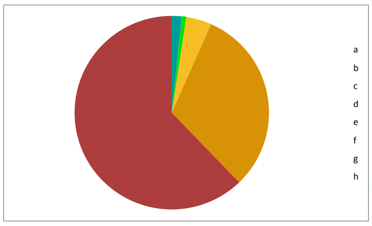
Baseline Scenario
PESERA baseline run

Two baseline indicators were calculated, the fire severity index as a measure of fire susceptibility and biomass production as a measure of fuel load. The main influencing variable controlling both indicators is land use. Output shown is limited to forest areas as these are the areas where fire ignitions occur. The fire severity index is very high in 90% of the study area. Three-quarters of the forest area contains more than 20 tons of biomass per ha, followed by ca. 20% having between 15-20 ton per ha.

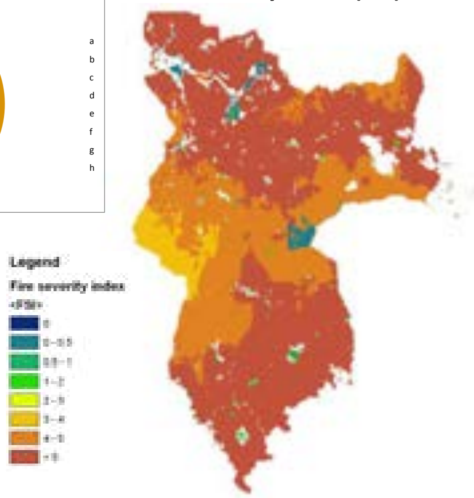
Landforms



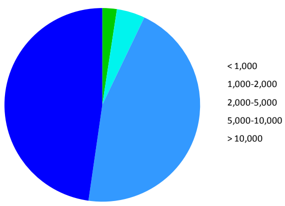
Fire susceptibility



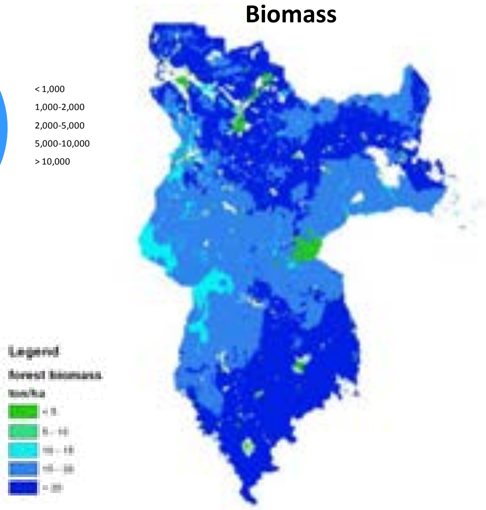
Fire Severity Index (FSI)



Biomass production



Biomass



Góis, Portugal

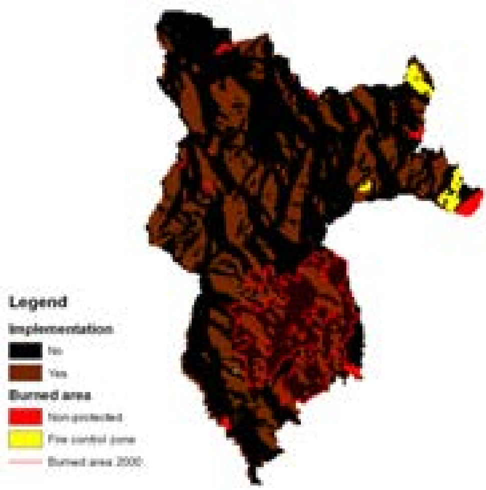
Technology Scenario:
Prescribed fire (POR02)

- Areas burned in a controlled way are assumed to act as a 100% effective fire break. Repeated burning every 2 years is assumed.
- The cost of prescribed fire is assumed to be fixed at €270/ha; planning and fire brigade stand-by are the main cost factors.
- A discount rate of 10% has been applied
- Analysis is carried out for an implementation period of 10 years, with the benefits derived from analysis of avoidable damage from observed fire-affected areas over the period 2001-2009.

Applicability

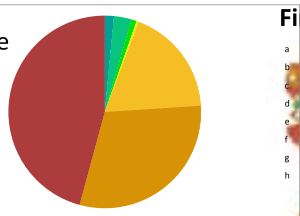
- Prescribed fire needs to be carefully planned in relation to wind speed, humidity and temperature. Slope aspect is another important aspect to take into account. Shown here is the area with NE-E facing slopes, which was assessed to have the highest potential impact on forest fire reduction.

Applicability

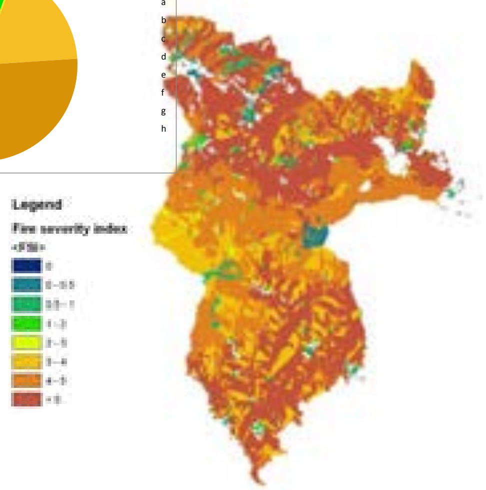


Biophysical impact: fire susceptibility

- Fire severity index is reduced when prescribed fire is implemented. The FSI values shown here are representative for the situation 2 years after controlled burning of NE-E facing slopes (FSI values in other slope aspects are not affected).



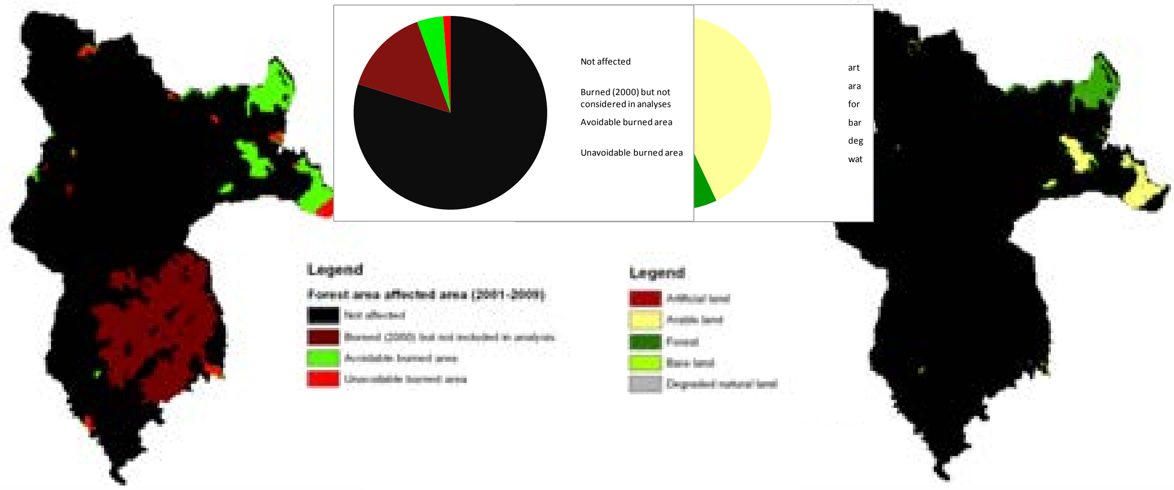
Fire Severity Index (FSI)



Biophysical impact: forest fire prevention

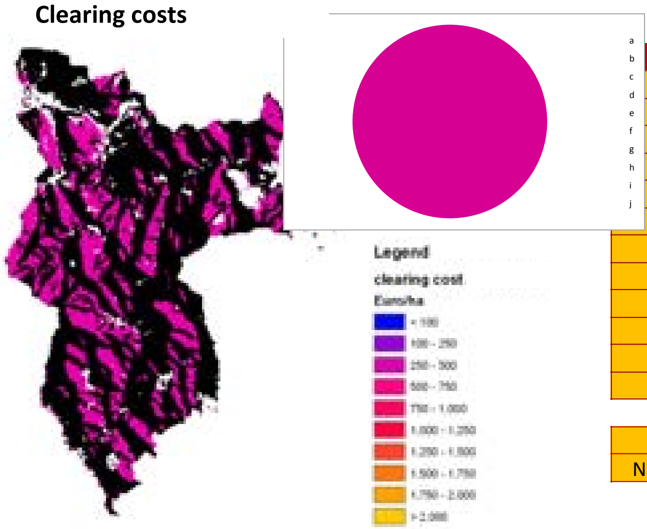
Fire-affected area

Avoided burning



Economic viability

Clearing costs

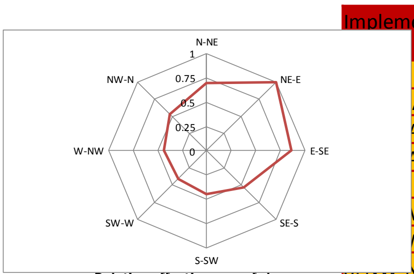


Net Present Value

Year	Clearing cost	Avoided damage
0	€ 1,886,220	
1		€ 238,744
2	€ 1,886,220	€ 238,744
3		€ 238,744
4	€ 1,886,220	€ 238,744
5		€ 238,744
6	€ 1,886,220	€ 238,744
7		€ 238,744
8	€ 1,886,220	€ 238,744
9		€ 238,744
10		€ 238,744
Total	€ 9,431,100	€ 2,387,444

Discount factor	10%
Net present value	€ -6,398,302

Scenario analysis of implementation zone



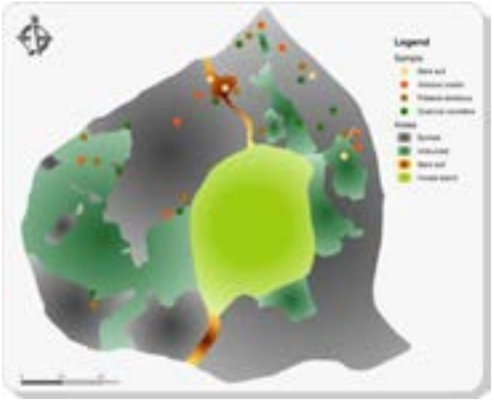
Relative effectiveness of slope aspect for fire containment

Implementation	Size of area (ha)		NPV (Euro)		
	Preventive	Avoided fire	Clearing cost	Avoided damage	Nett
Aspect	5412	930	€ 6,093,174	€ 975,416	-€ 5,117,758
Aspect	6986	1332	€ 7,865,284	€ 1,466,981	-€ 6,398,302
Aspect	6425	1139	€ 7,233,674	€ 1,269,604	-€ 5,964,070
Aspect	5360	702	€ 6,034,629	€ 698,569	-€ 5,336,060
Aspect	6223	589	€ 7,006,250	€ 735,163	-€ 6,271,086
V Aspect	6851	541	€ 7,713,292	€ 634,324	-€ 7,078,968
V Aspect	5763	579	€ 6,488,352	€ 483,031	-€ 6,005,321
N Aspect	4626	706	€ 5,208,245	€ 743,015	-€ 4,465,231
9. Ridges	4560	1121	€ 5,133,938	€ 1,090,797	-€ 4,043,141

An economic analysis of prescribed fire is difficult due to lack of clarity over the optimal scale of implementation. Clearing costs if indiscriminately applied across areas of similar slope aspect (or ridges) appear to be too high to justify investment based on damage by forest fires in the period 2001-2009. However, the damage in this time frame has been limited, and extending the analysis with the year 2000, when 15% of the municipality was burned would give a different picture. That said, more informed application of prescribed fire could decimate the clearing (burning) costs without compromising effectiveness. Slopes with N-NE aspects appear to be the most effective in terms of containing wildfires but might not be the most cost-effective.

Góis, Portugal

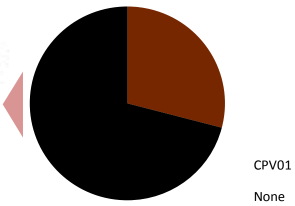
Policy Scenario:
Targeted implementation of prescribed fire (POR02)



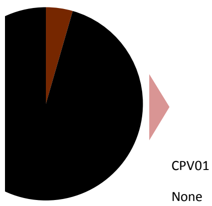
The extent of application of prescribed burning analysed in the Technology Scenario is exaggerated, with ratios of preventively burned to protected areas ranging from 4.1 – 12.7. If areas most at risk of wildfires are better known and the prescribed fire technology more restrictively applied, costs can be reduced while maintaining high level of wildfire control. In this policy scenario we consider only implementing prescribed fire with 1km from burned areas on land with high susceptibility to fire (FSI > 5).

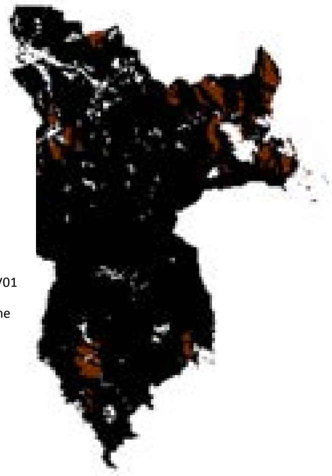
Profitability:

Implementation area: A. Slopes NE-E aspect



B. Idem, with SFI > 5 and burned area < 1km





Net Present Value

Implementation area	Size of area (ha)		NPV (Euro)		
	Preventive	Avoided fire	Clearing cost	Avoided damage	Nett
I. Targeted application with calculated effect (reduced effectiveness due to patchy application)					
N-NE Aspect	745	488	€ 838,768	€ 672,489	-€ 166,280
NE-E Aspect	1177	944	€ 1,325,142	€ 1,213,962	-€ 111,180
NW-N Aspect	613	453	€ 690,154	€ 495,730	-€ 194,424
II. Targeted application with assumed micro-management to retain effectiveness					
N-NE Aspect	745	930	€ 838,768	€ 975,416	€ 136,647
NE-E Aspect	1177	1332	€ 1,325,142	€ 1,466,981	€ 141,840
NW-N Aspect	613	706	€ 690,154	€ 743,015	€ 52,860

Targeted implementation reduces the implementation area (and hence costs) by 83% (for NE-E slope aspect). Two analyses are performed: in the first (calculated) analysis the annual area avoided from burning is reduced from 133 to 94 ha due to more patchy application; in the second the same cost is assumed to suffice to safeguard the originally protected area (i.e. more micro-management). The NPV is slightly negative in the first but positive in the second analysis. In applying prescribed fire, there is a trade-off between targeting high-risk areas and accepting wildfire risk in remaining areas.

Cost-effectiveness indicators:

- The cost per hectare of land where burning is avoided is between €902 and €1720.
- The cost per inhabitant would be between €37 and €71 per year.

Góis, Portugal

Global Scenario:
Food production

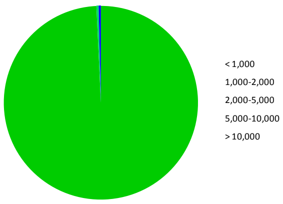
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

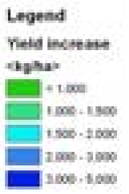
+958 kg/ha

+130 kg/inhabitant

Scope for increased (i.e. not lost) production

Yield increase





Biophysical impact: yield increase

- Yield increase in 39% of applicable area (all arable land)
- Average absolute yield increase: 958 kg/ha
- Average yield increase: na (avoided burning)

Economic indicators

Average costs (arable land as share of total):
- Investment cost: €1,571/ha*
- Unitary cost year 1: €1,640/ton(yr)*
- Unitary cost lifetime: €820/ton*

Aggregate indicators:
- Study site: €0.96 million*
- Augmented annual production: 583 ton
- Augmented total production: 5,833 ton

* Note that costs can be reduced with more targeted application of the technology (see Policy scenario), to: Investment cost: €216/ha; unitary cost year 1: €226/ton(yr); unitary cost lifetime: €113/ton; Aggregate investment study site: €0.13 million.

Góis, Portugal

Concluding remarks

- The baseline simulation shows very high fire susceptibility in about 70% of the forest and unmanaged area. Biomass production is more than 15 ton/ha in 90% of the forest area.
- Prescribed fire was prioritised by scientists and local stakeholders to control wildfires. Field experiments were conducted to assess the effects of controlled fire in comparison to wildfires. The analyses included post-fire hydrology, measuring erosion and nutrient losses. It was concluded that prescribed fires result in less degradation effects than wildfires, confirming it can be used as a landscape planning tool. Modelling concentrated on an analysis of the potential of using prescribed fire as a fire break at landscape scale, using data on burned areas and ignitions over the period 2001-2009. Slope aspect was considered as a basic management factor, as fire is more easily controlled on relatively homogeneous slopes. Applying controlled fire on slopes with NE-E aspect was found to result in the highest reduction of wildfire. The average annual area burned by wildfires could be reduced from 1703 to 317 ha (a 78% reduction). From an economic point of view a crucial factor is how much area should be burned in a controlled fashion to achieve this effect. Indiscriminate application is too expensive but there is likely to be much room for improvement, which was explored as a policy scenario. It should also be pointed out that the rate of burning was relatively low over the period assessed (e.g. wildfires in the year 2000 burned 3842 ha, or 15% of the municipality).
- In the workshop to evaluate monitoring and modelling results, stakeholders confirmed their preference for prescribed fires (and the fuel strips network), evaluating it slightly higher than in the second workshop – perhaps because of increased knowledge derived from pilot implementation of the technology. In order to promote the technology, recommended actions in four domains (regulation, awareness, forest intervention areas, and funding) were agreed by the participants.
- A policy scenario explored whether the benefit-cost ratio could be improved by more contextual knowledge leading to a more targeted application of the technology. Two additional management factors were taken into account: the fire severity index (FSI) in the baseline situation and the distance from burned areas over the past decade. Both factors could potentially weaken the firebreak effect of prescribed fires: the FSI because introducing a threshold FSI creates a more scattered pattern of areas with low susceptibility, and proximity to known fire hotspots because there is no guarantee that ignitions would not occur in an area where no recent wildfires occurred. The patchiness due to FSI threshold was modelled to reduce protection against wildfires. Due to less effective firebreak function, the greatly reduced investment costs were still too high to warrant application of prescribed fire. However, if we assume field knowledge is sufficient to avoid reduction of effectiveness, the technology turned positive. Application across NW-N slopes was most cost-effective in this analysis.
- The global scenario for food production shows that although the technology is not primarily intended to protect cropland (which is a limited land use in the area), its impact in avoiding the burning of crops is noticeable. For simplicity the analysis assumes that all fires would affect crops in the field (i.e. occur before harvesting). The investment costs to protect crop production, when attributed equally to all areas where burning would have been avoided, range from €1,640 to potentially €113/ton grain.
- The analyses show that the required scale of application of prescribed fire is a crucial factor in assessing its economic viability. Targeted application is essential in order not to apply the technology too widely, perhaps introducing degradation impacts that are not serving to offset more devastating wildfires. Results obtained were based on several assumptions and based on an analysis of areas burned in the period 2001-2009. While the long-term average area burned could deviate from the observed burned areas in this period, it is under future climate change likely that wildfires will increase rather than decrease, in which case the viability of implementing prescribed fire could be improved. For example, would the 2000 burned areas have entered the analysis and the effectiveness of prescribed fire would have been the same as observed over the period 2001-2009, even the large scale application of wildfires across all ridges would have been economically attractive.

Mação, Portugal

Study site details

Mação lies in a transition zone between the Atlantic and the Mediterranean climate types, and is located on the northern bank of the lower Tejo River, central Portugal.

- **Coordinates of central point:**
  Latitude: 39°33’19.17’’N
  Longitude: 7°59’59.88’’W
- **Size:** 400 km²
- **Altitude:** 28 – 640m
- **Precipitation:** <600 – 1000 mm (South to North transect)
- **Temperature:** na
- **Land use:** pine and eucalyptus forests, arable land, unproductive land and settlements
- **Inhabitants:** 7,419 (2006)
- **Main degradation processes:** drought, compounded by catastrophic forest fires
- **Major drivers of degradation:** depopulation and ageing population, land abandonment, monocultural forestry, inadequate laws and lack of enforcement, financial constraints

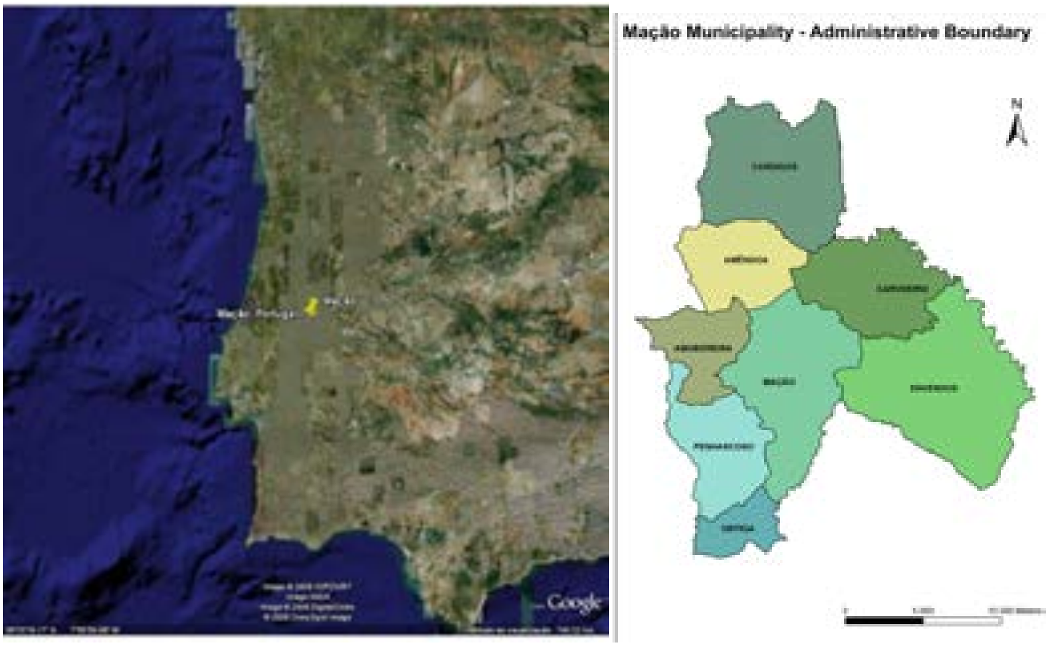


Figure 1: Study site location

Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Primary Strip Network System for Fuel Management (POR01)
3. Policy Scenario: No consideration of catastrophic events (POR01)
4. Global Scenario: Food production

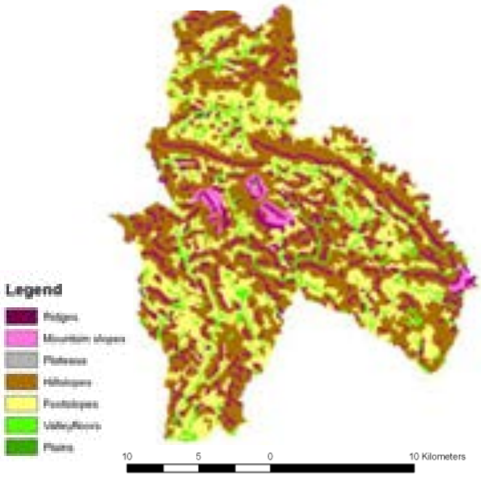
Mação, Portugal

Baseline Scenario

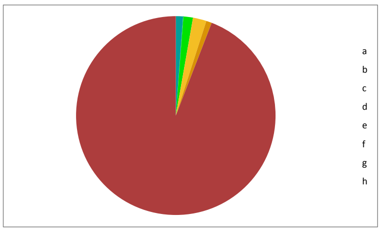
PESERA baseline run

Two baseline indicators were calculated, the fire severity index as a measure of fire susceptibility and biomass production as a measure of fuel load. The main influencing variable controlling both indicators is land use. Output shown is limited to forest areas as these are the areas where fire ignitions occur. The fire severity index is very high in 90% of the study area. Three-quarters of the forest area contains more than 20 tons of biomass per ha, followed by ca. 20% having between 15-20 ton per ha.

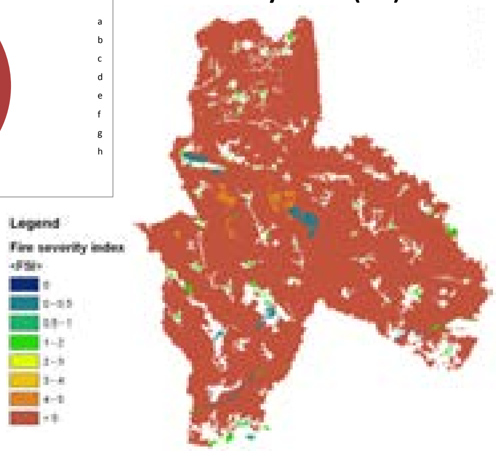
Landforms



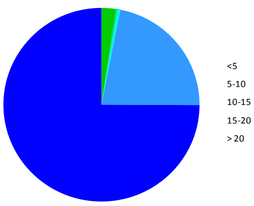
Fire susceptibility



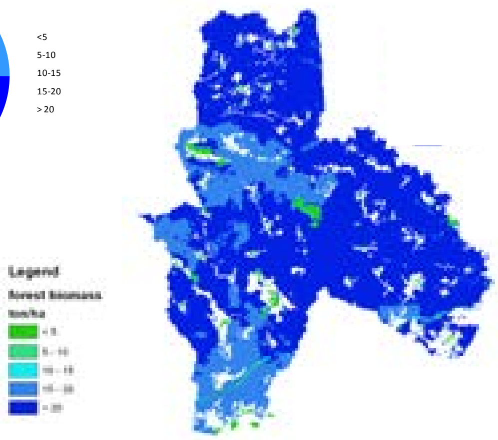
Fire Severity Index (FSI)



Biomass production



Biomass



Maçåo, Portugal

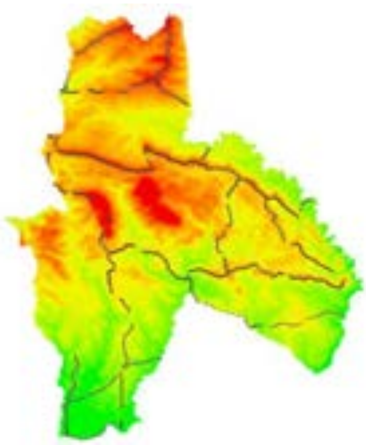
Technology Scenario:
Primary Strip Network System for Fuel Management (POR01)

- Strips are assumed to be 100% effective as fire break and are maintained by reducing fuel load every 2 years.
- Initial investment costs are €1,741,358; thereafter maintenance costs of €1,158,454 are assumed to be made biannually; both based on clearing costs of €73/ton biomass.
- A discount rate of 10% has been applied
- A lifetime of 10 years has been set, with the benefits derived from analysis of avoidable damage from observed fire-affected areas over the period 2001-2009.

Applicability

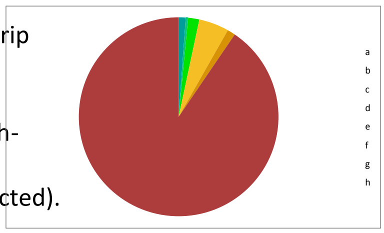
- The Primary Strip Network System for Fuel Management (PSNSFM) follows many ridges in the landscape. In total 1287 ha of strips are included in this municipal plan.

Applicability

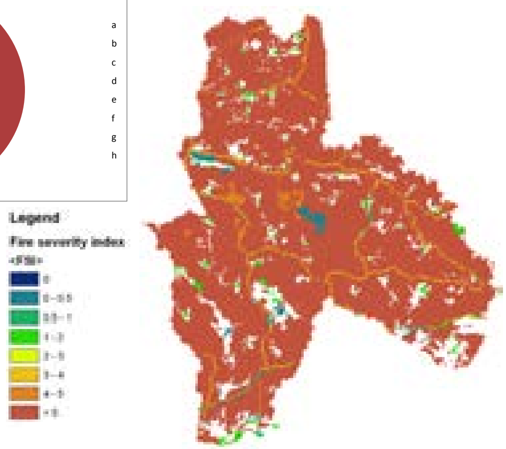


Biophysical impact: fire susceptibility

- Fire severity index is reduced in the strip network, acting as fire break. The FSI values shown here are representative for the situation 2 years after establishment of the strip network (FSI values outside the strip network are not affected).

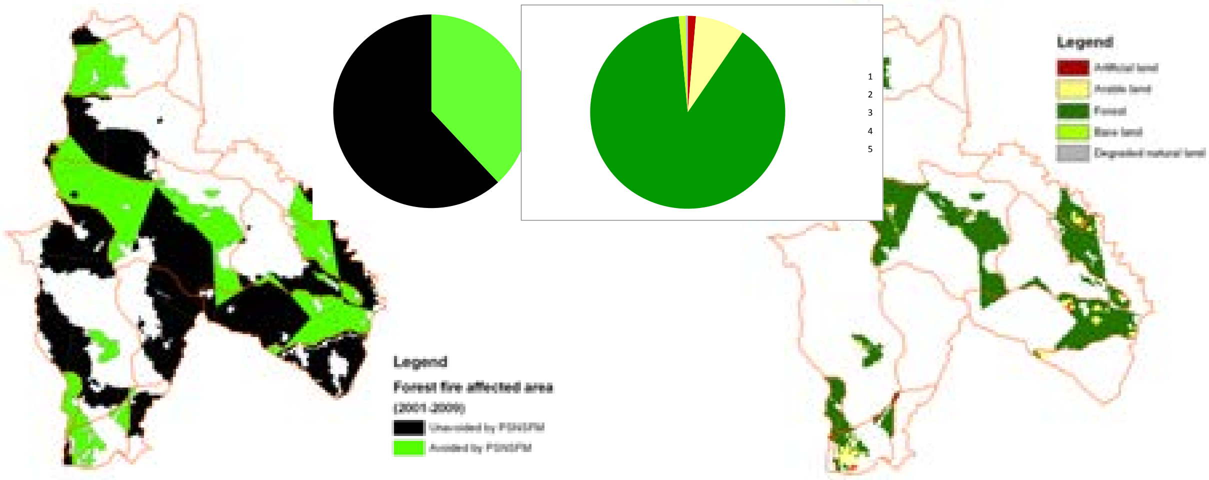


Fire Severity Index (FSI)



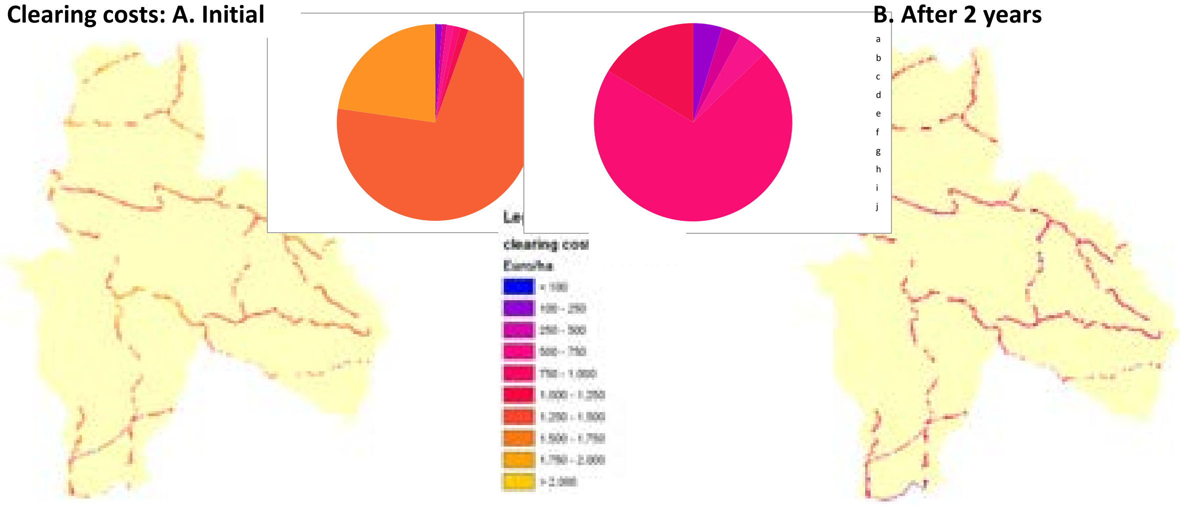
Biophysical impact: forest fire prevention

Fire-affected area | **Avoided burning**



Economic viability

Clearing costs: A. Initial | **B. After 2 years**



The economic analysis is based on the costs of clearing strips every 2 years, because only with this frequency can they be considered 100% effective as fire break.

If we assume damage if burnt as follows:

- Artificial land: €100,000 ha^{-1}
- Arable land: €1,000 ha^{-1}
- Forest: €2,000 ha^{-1} (PNDFCI, 2005)
- Bare land: €200 ha^{-1}
- Degraded land: €100 ha^{-1}

Based on analysis of the fire break effect, 958 ha could be protected annually. The average damage avoided is €3,221 ha^{-1} burnt.

Net Present Value

Year	Clearing cost	Avoided damage
0	€ 1,741,358	
1		€ 3,085,400
2	€ 1,148,454	€ 3,085,400
3		€ 3,085,400
4	€ 1,148,454	€ 3,085,400
5		€ 3,085,400
6	€ 1,148,454	€ 3,085,400
7		€ 3,085,400
8	€ 1,148,454	€ 3,085,400
9		€ 3,085,400
10		€ 3,085,400
Total	€ 6,335,628	€ 30,854,000

Discount factor	10%
Net present value	€ 14,299,510

Although this analysis does not consider fire extinguishing and replanting costs, the PSNSFM appears to be very viable. Results are heavily influenced by the 2003 forest fires which were responsible for more than three-quarters of the total damage between 2001 and 2009.

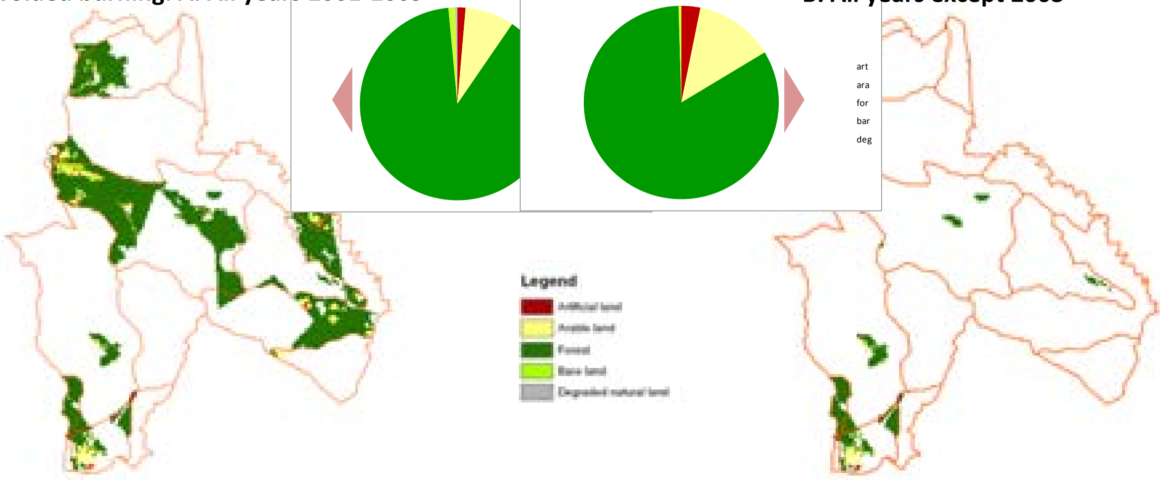
Mação, Portugal

Policy Scenario:
No consideration of catastrophic events (POR01)

The 2003 forest fires in the region were of such unprecedented magnitude that it is questionable whether the PSNSFM could have made a difference. In planning terms, one can take the view that such catastrophic events cannot be avoided and accounted for. Hence, in this policy scenario we consider the potential benefits of the PSNSFM by looking at the last decade without 2003.

Profitability:

Avoided burning: A. All years 2001-2009 **B. All years except 2003**



The annual area avoided from burning is reduced from 958 to 147 ha. However, the composition of the burned area shows a higher percentage of artificial (and arable) land, due to which the average damage avoided increases from €3221 to €4962 per ha. The new NPV calculation, using the same assumptions as in the Technology (POR01) scenario, is shown right. If major fires such as in 2003 cannot be avoided, the technology appears to be just not profitable. When considering extinguishing costs and replanting costs however, the analysis would probably easily be positive. Also a longer planning horizon could achieve this.

Net Present Value

Year	Clearing cost	Avoided damage
0	€ 1,741,358	
1		€ 731,578
2	€ 1,148,454	€ 731,578
3		€ 731,578
4	€ 1,148,454	€ 731,578
5		€ 731,578
6	€ 1,148,454	€ 731,578
7		€ 731,578
8	€ 1,148,454	€ 731,578
9		€ 731,578
10		€ 731,578
Total	€ 6,335,628	€ 7,315,780

Discount factor	10%
Net present value	€ -163,708

Cost-effectiveness indicators:

- The cost per hectare of land where burning is avoided is €4310.
- The cost per inhabitant would be €85 per year.

Mação, Portugal

Global Scenario:
Food production

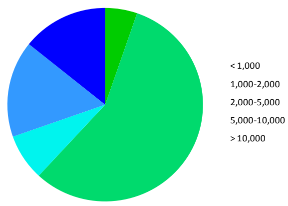
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

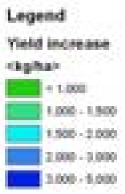
+1709 kg/ha

+18 kg/inhabitant

Scope for increased (i.e. not lost) production

Yield increase





Biophysical impact: yield increase

- Yield increase in 33% of applicable area (all arable land)
- Average absolute yield increase: 1709 kg/ha
- Average yield increase: na (avoided burning)

Economic indicators

Average costs (arable land as share of total):
- Investment cost: 182 Eur/ha
- Unitary cost year 1: 106 Eur/ton(yr)
- Unitary cost lifetime: 39 Eur/ton

Aggregate indicators:
- Study site: 1.7 million Euro
- Augmented annual production: 133 ton
- Augmented total production: 1333 ton

Mação, Portugal

Concluding remarks

- The baseline simulation shows a very high fire susceptibility in over 90% of the area. Biomass production is more than 15 ton/ha in 95% of the area (corresponding to *Pinus pinaster* and *Eucalyptus globulus* forests).
- The primary strip network system for fuel management (PSNSFM) was prioritised by scientists and local stakeholders to control wildfires. Whereas this preventive forestry measure represents an important instrument against forest fires, the removal of vegetation tends to expose bare soil to the erosive effects of rainfall. In field experiments, rainfall simulations were used to assess erosive processes, such as runoff and sediment loss. Modelling of the PSNSFM showed that on average 958 ha of land (under various land uses, but mostly forest) can be protected from burning annually. Over a decade, this is 9578 ha. This is realised by implementing a strip network of 1287 ha. Experimental findings can help optimize management of the strips to minimize soil erosion, but it is clear that the vast area saved from burning also avoids the increased soil erosion problems following wildfires. Economic evaluation of the technology with the model was very positive.
- In the workshop to evaluate monitoring and modelling results, stakeholders confirmed their preference for the PSNSFM (and prescribed fires), evaluating it slightly higher than in the second workshop – perhaps because of increased knowledge derived from pilot implementation of the technology. In order to promote the technology, recommended actions in four domains (regulation, awareness, forest intervention areas, and funding) were agreed by the participants.
- A policy scenario excluding the 2003 forest fire damage from the cost-benefit analysis resulted in slightly negative net present value. However, fire extinguishing and replanting costs were not considered and could tip the balance. Also, establishing and maintaining the PSNSFM for a period longer than 10 years could make it economically viable even if the structure could not prevent catastrophic wildfires from occuring.
- The global scenario for food production shows that although the technology is not primarily intented to product cropland (which is a limited land use in the area), its impact in avoiding the burning of crops is noticeable. For simplicity the analysis assumes that all fires would affect crops in the field (i.e. occur before harvesting). The investment costs to protect crop production are, when attributed equally to all areas where burning would have been avoided, low at €39/ton grain.
- The analyses show that investing in a strip network is viable. As the model analyses were performed for a single strip network system, it is not necessarily the best lay-out or may not have the most economic strip density. Results obtained were based on several assumptions and based on an analysis of areas burned in the period 2001-2009. While the long-term average area burned could deviate from the observed burned areas in this period, it is under future climate change likely that wildfires will increase rather than decrease, in which case the impacts of implementing strip networks can be even more important. Results from experimental research should be taken into account to reduce erosion risk in strips, and could also help devise management strategies for burned areas (which to some extent will always be unavoidable).

Rambla de Torrealvilla, Spain

Study site details

The ‘Rambla de Torrealvilla’ is a catchment within the Guadalentin basin in south-eastern Spain near the city of Lorca.

- **Coordinates:**
  Latitude: 37°47'8"N
  Longitude: 1°41'55"W
- **Size:** 266 km^2
- **Altitude:** 378 – 1499 mm
- **Precipitation:** 300 – 500 mm
- **Temperature:** 12°C - 17°C
- **Land use:** rainfed agriculture (cereals, almonds, olive), irrigated agriculture (horticulture, fruit trees, grapes), livestock.
- **Inhabitants:** na
- **Main degradation processes:** water erosion, soil salinization
- **Major drivers of degradation:** agriculture, water availability, human population, tourism, transport, climate, and land use subsidies.

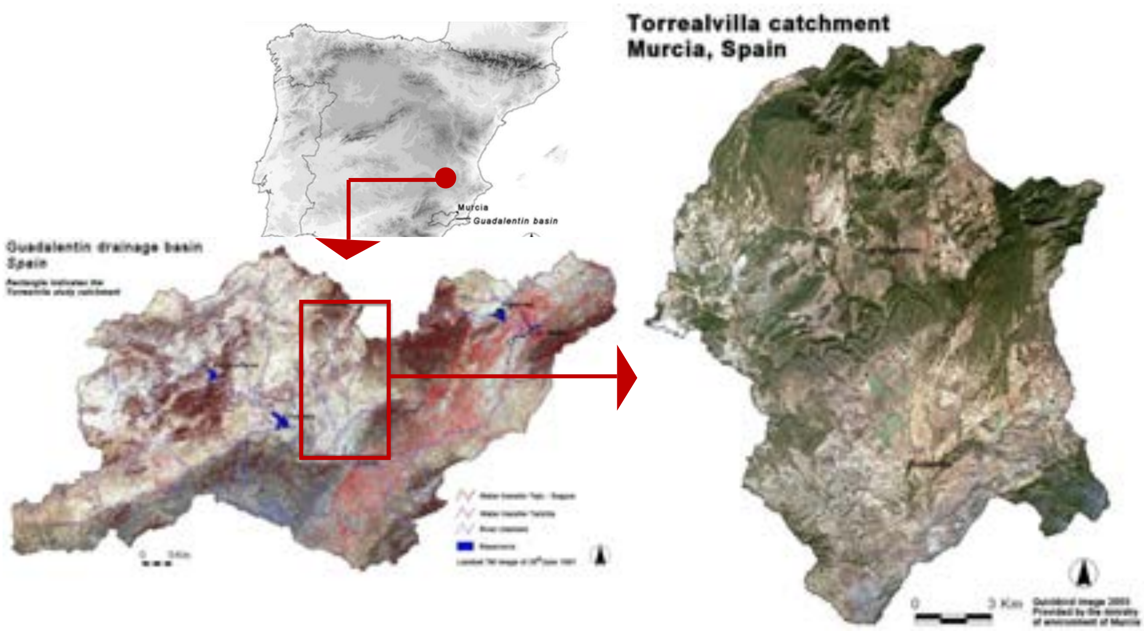


Figure 1: Study site location

Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Reduced contour tillage in semi-arid environments (SPA01)
3. Policy Scenario: Subsidising reduced tillage (SPA01)
4. Global Scenario: Food production
5. Global Scenario: Minimizing land degradation

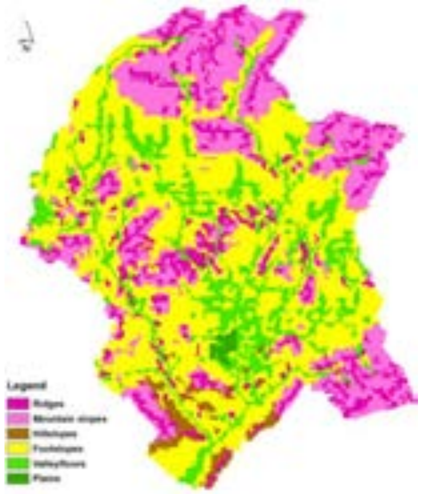
Rambla de Torrealvilla, Spain

Baseline Scenario

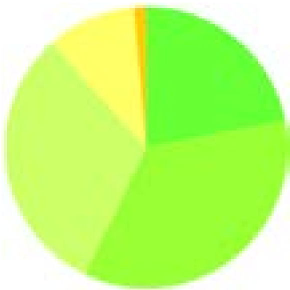
PESERA baseline run

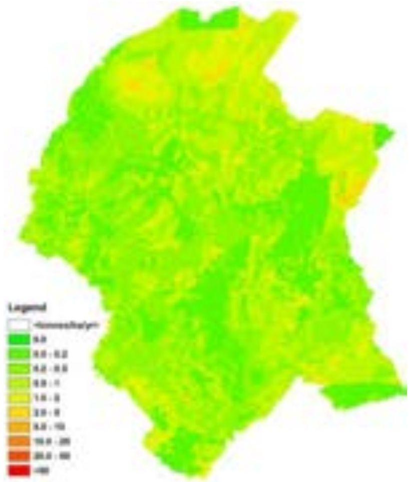
The baseline scenario shows mostly low and moderate soil erosion risk. Mountain slopes in the North-East have the highest risk. Valleyfloors display low risk. Biomass production follows the rainfall gradient towards the East, and is also influenced by land use. For example, the dry central area of the catchment with its dry land farming area shows very low biomass production (0 – 2000 kg/ha). Nevertheless, in more than half of the catchment area biomass production surpasses 10,000 kg/ha.

Landforms

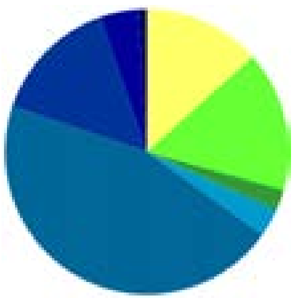


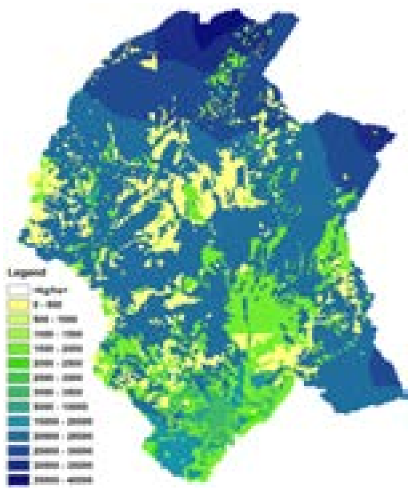
Soil erosion





Biomass production





Rambla de Torrealvilla, Spain

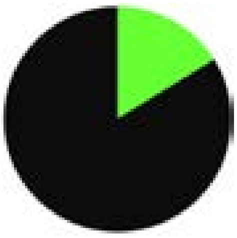
Technology Scenario:
Reduced contour tillage in semi-arid environments (SPA01)

The technology could be applied to cereal plots and tree crops. Here the focus is on application on cereals.

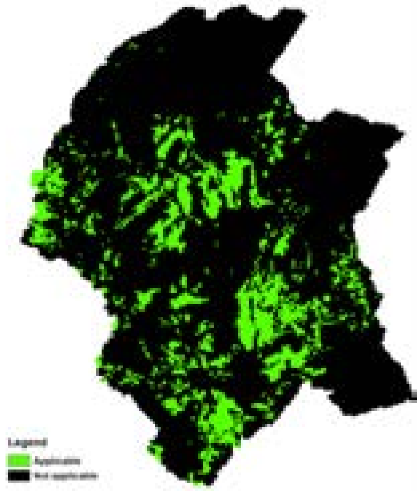
- Total operation costs under different practices:
  - traditional tillage €75/ha
  - reduced tillage €45/ha
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The price of grains is €0.21/kg

Applicability

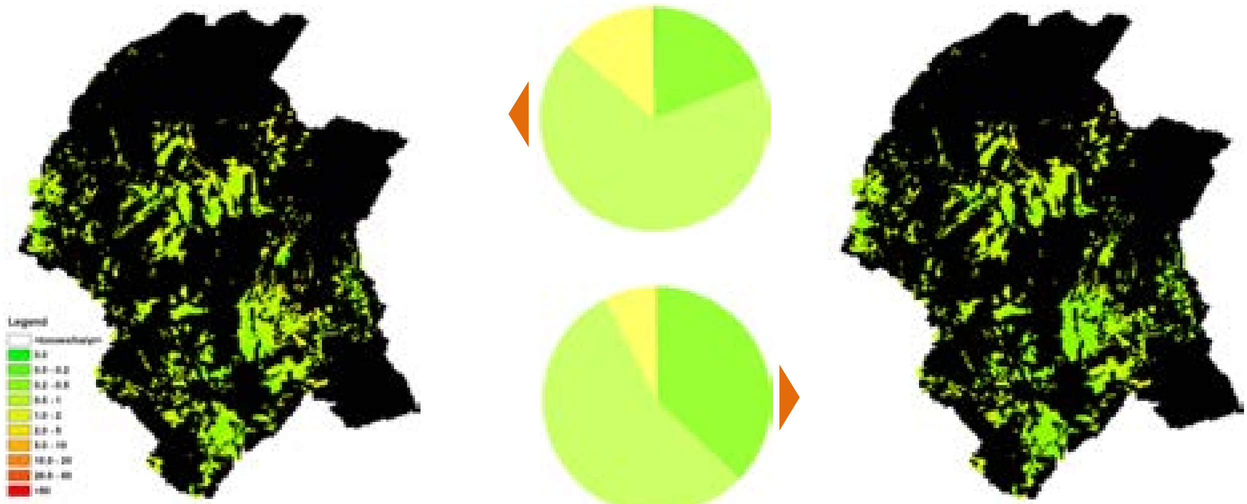
- The technology is applicable in grain fields, with further restrictions based on slope and soil depth.



Applicability



Biophysical impact: soil erosion

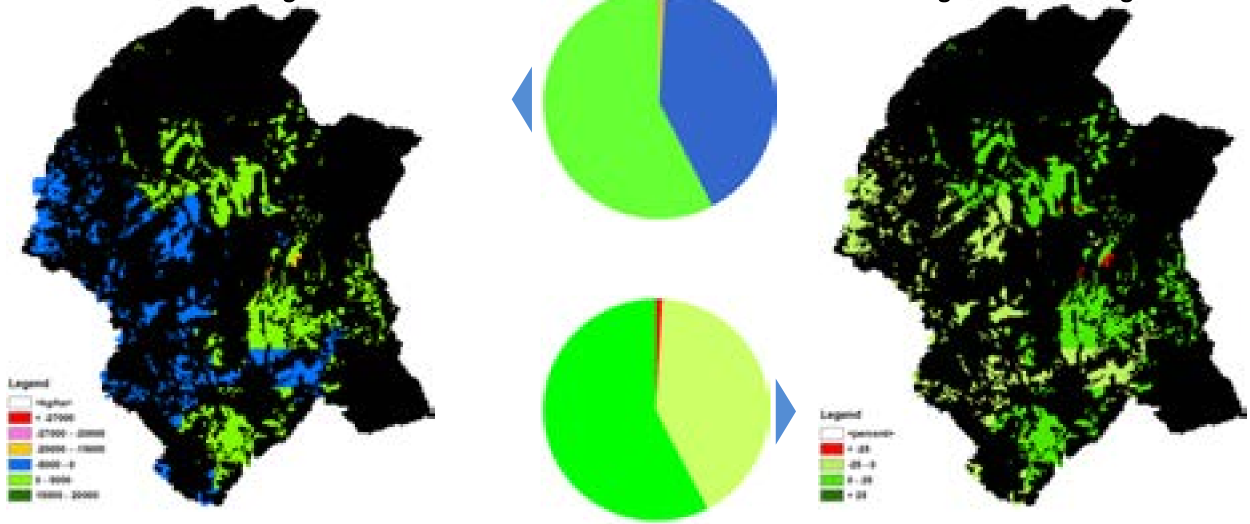


Under traditional tillage

Under reduced tillage

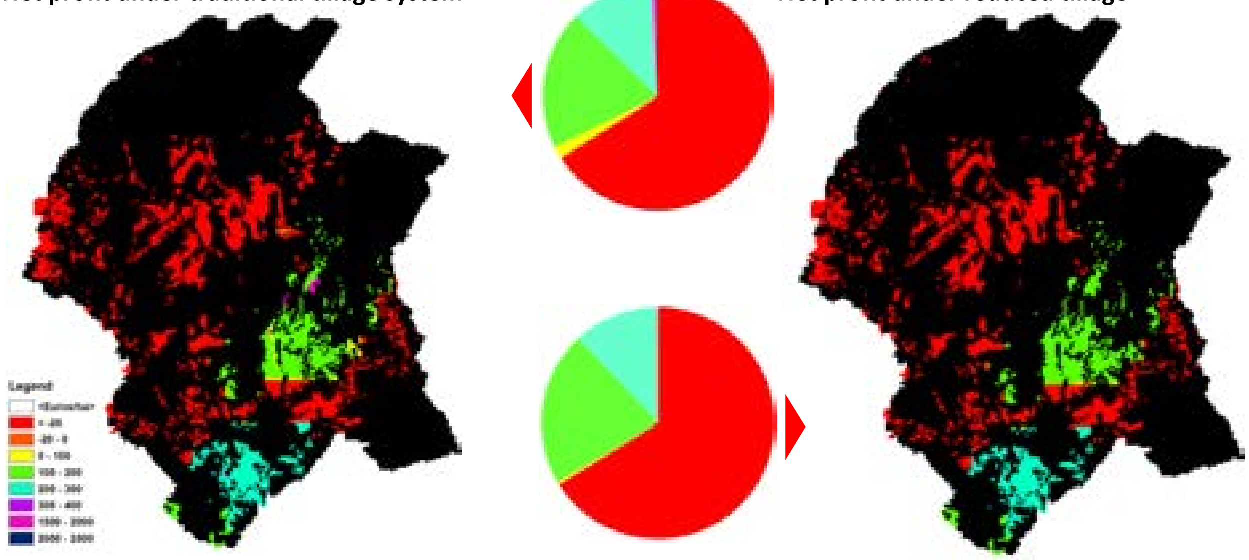
Biophysical impact: change in biomass

Biomass change | **Percentage biomass change**



Economic viability

Net profit under traditional tillage system | **Net profit under reduced tillage**



Erosion rates are typically low in the valleyfloors and footslopes where the technology is applied, even if under conventional tillage. Minimum tillage somewhat reduces the highest category soil loss, but especially leads to reduction of soil erosion in the below 1 ton/ha class. Biomass change is positive in about 60% of cases and negative in 40%. In percentages the changes almost entirely fluctuate between -25% and +25% of yields under conventional systems. Although reduced tillage is cheaper than conventional tillage, it is not enough to enable more widespread adoption. Profitability slightly improves where the technology already leads to a positive profitability - i.e. roughly in a third of the area.

Rambla de Torrealvilla, Spain

Policy Scenario:

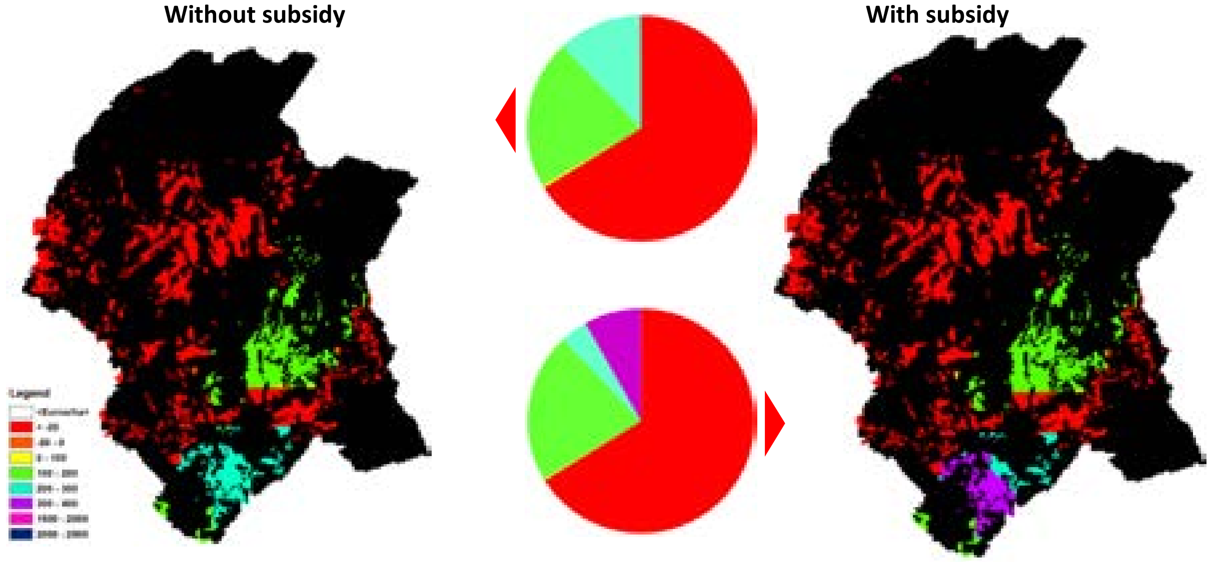
Subsidising reduced tillage (SPA01)

Due to low productivity in many parts of the study area, without external financial incentive in all parts of the study area widespread adoption of the technology is very unlikely. In this scenario the effects of a subsidy equal to 50% of the operational costs on profitability of the technology and the potential for mitigating land degradation are explored.

50%

Profitability:

Without subsidy **With subsidy**



Cost-effectiveness indicators:

- The introduction of 50% subsidy does not have significant impact as the proportion of the study area with negative economic gain largely remains the same before and after the subsidy.
- No cost-effectiveness indicators can be calculated; in fact, a subsidy scheme of this nature would only raise the profitability for those already in a position to implement minimum tillage.
- The issue here is that no-tillage leads to a reduction in biomass (and yields) in part of the area. Field experiments have not confirmed such effect, and stakeholders do not perceive this as a risk either. The validity of these conclusions should be confirmed by field research.

Rambla de Torrealvilla, Spain

Global Scenario:
Food production

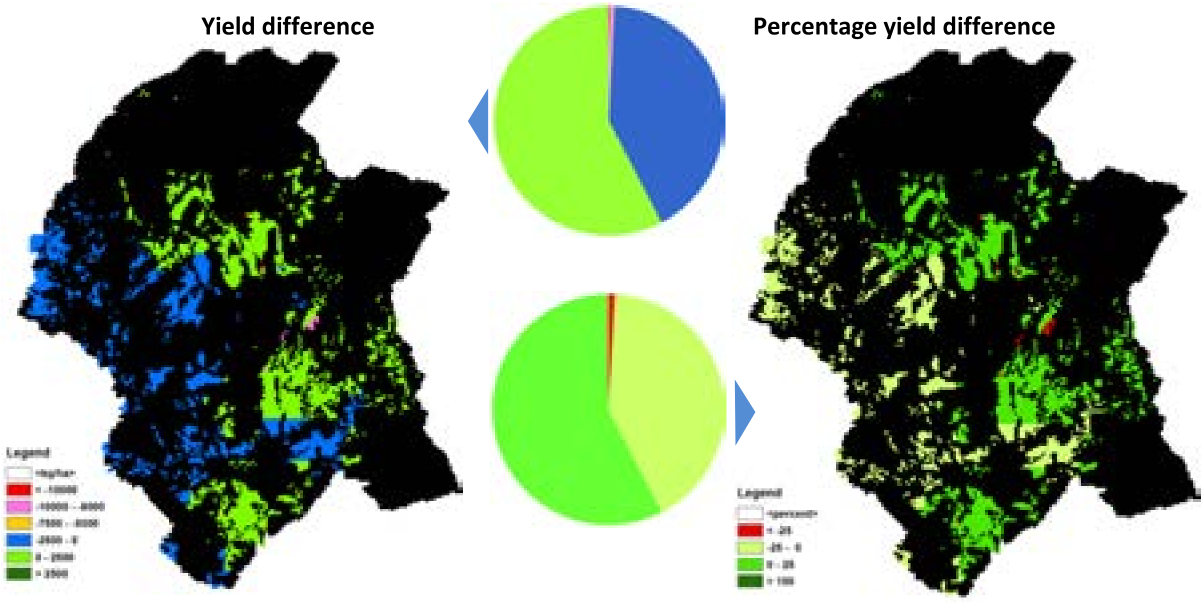
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+3.8 kg/ha

+? kg/inhabitant

Scope for increased production

Yield difference **Percentage yield difference**



Biophysical impact: yield difference

- The implementation of reduced tillage would see yield increase in 58 % of applicable area;
- Average absolute yield change: 3.8 kg/ha
- Average yield change: 0.4 %

Economic indicators

Average costs:
- Extra operational cost: - €30/ha/yr (saving!)
- Unitary cost: - €7,895/ton (saving!)

Aggregate indicators:
- Study site: - €75,000 (saving!)
- Augmented annual production: 9.5 ton

Rambla de Torrealvilla, Spain

Global Scenario:
Minimizing land degradation

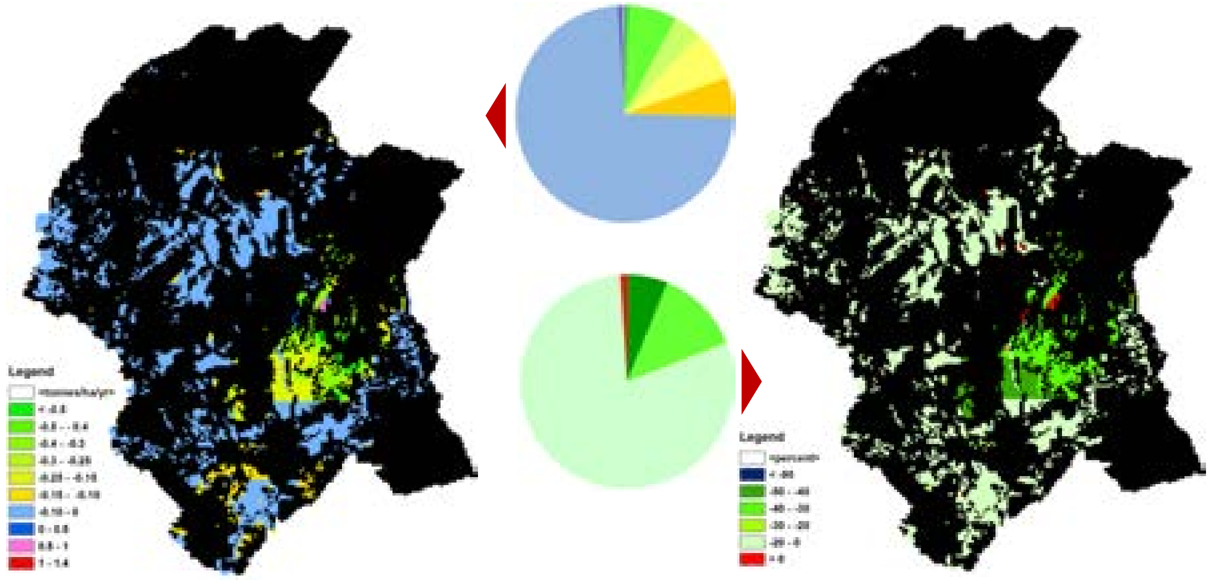
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-0.1 ton soil/ha

-€300/ton soil*

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 99 % of applicable area
- Average absolute erosion reduction: 0.1 tonnes/ha/yr
- Average percent erosion reduction: 10 %

Economic indicators

Average costs:

- Extra operational cost: - €30/ha/yr* (saving)!
- Unitary cost: - €300/ton soil* (saving)!

Aggregate indicators:

- Study site: - €129,000* (saving)
- Aggregate annual erosion reduction: 443 ton

* Note: As there is on average across the applicable area a net decline of grain yields of -102 kg/ha, the actual 'benefit' is smaller (unitary cost: - €86/ton soil; study site aggregate: - €36,900).

Rambla de Torrrealvilla, Spain

Concluding remarks

- Baseline simulations show comparatively low erosion rates in the Torrealvilla catchment. More than 80% of the area displays soil erosion rates below 1 ton/ha/yr. High risk areas are limited in extent. Expert mapping showed a more generic concern of soil erosion by water.
- Reduced tillage in cereals (and almonds) was the second-ranked technology selected for field testing by scientists and local stakeholders. The technology scenario shows that minimum tillage involves a reduction of operational costs. Such a saving, even in absence of a positive effect on crop yield, could make the technology profitable. The technology scenario shows a mixed picture: there are slight increases in crop yield in about 60% of the applicable area, and yield reductions in the remaining 40%. The technology is profitable in only one third of the applicable area, which seems to indicate that cereal farming is a marginal economic activity. In field experiments, the savings on operations were confirmed and no significant change in yield was observed between minimal tillage and control.
- In the workshop to evaluate monitoring and modelling results, stakeholders reiterated their views that minimum tillage in cereals is economical and that it does not lead to yield reduction risks. The technology was ranked second again. The negative effect of minimum tillage on yield simulated by PESERA contradicts this view to some degree. Margins on cereal farming are low, so that can be one factor that easily influences outcomes of model simulation. It is also possible that labour costs are not valued according to market price. Incentives for adoption of sustainable land management strategies was among the recommendations to improve adoption.
- A policy scenario reducing costs by 50% did not lead to any additional uptake of the technology. With no evidence of environmental benefits, it would be inappropriate to stimulate adoption through a subsidy. Likely, the subsidies would be applied for in areas where the technology is economically feasible without support.
- The global scenarios show that minimum tillage is beneficial through cost-saving relative to conventional tillage. It actually pays to reduce tillage operations, with environmental benefits (soil and water conservation) as side effect. Although the technology is not beneficial in the entire applicability area, the aggregate study site result is still positive. The technology will however not lead to important productivity increases: this is limited to 3.8 kg/ha on average.
- The cost-saving nature of the technology has led to it being appreciated as an easy to implement measure by local land users. Margins are small though, and dryland cereal farmers in the area may generally struggle to generate a profit. However, *relative* to conventional tillage there is little risk involved in adopting minimum tillage.

Zeuss-Koutine, Tunisia

Study site details

The study site is a transect from the Great Oriental Erg and the Dahar plateau in the west, crossing the Matmata mountains, Jeffara plain and sebkhat before ending into the Gulf of Gabès.

- **Coordinates of central point:**
  Latitude: 33°16' N
  Longitude: 10°08' E
- **Size:** 897 km²
- **Altitude:** -3 – 666m
- **Precipitation:** below 100 mm in the Oriental Erg to 240 mm in the Matmata mountains.
- **Temperature extremes:** -3ºC – 48ºC
- **Land use:** rangeland, tree crops, annual crops (cropping linked to water harvesting)
- **Inhabitants:** 151,000 (1994)
- **Main degradation processes:** water & wind erosion, rangeland degradation and drought.
- **Major drivers of degradation:** population growth, deficient information, insecure land tenure, lack of institutional mechanisms

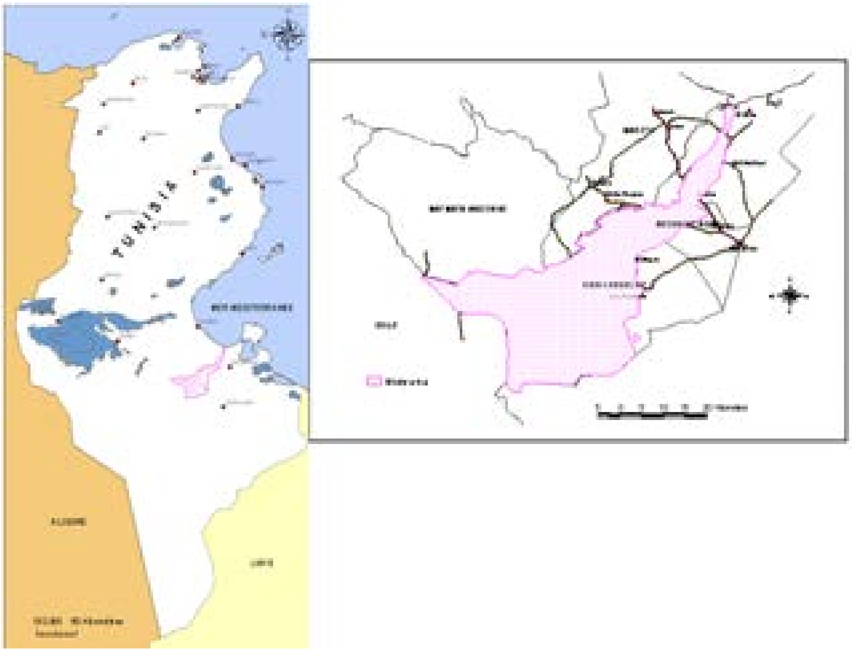


Figure 1 Study site location

Overview of scenarios

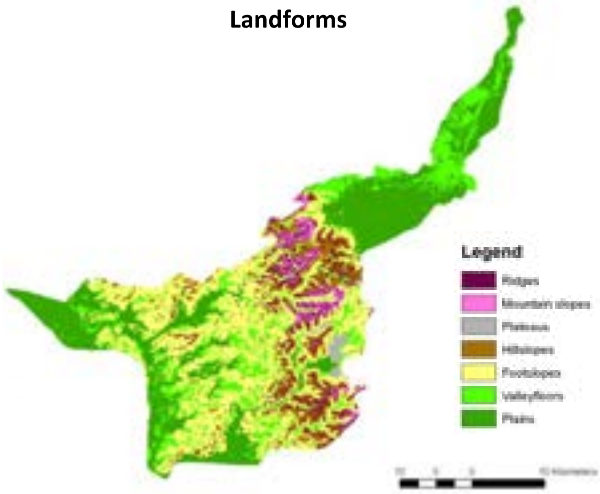
1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Jessour (TUN09)
3. Technology Scenario: Rangeland resting (TUN11)
4. Technology Scenario: Tabia (TUN12)
5. Policy Scenario: Subsidising alternative feed purchases (TUN11)
6. Policy Scenario: Subsidising the construction of jessour and tabias (TUN09 & 12)
7. Global Scenario: Food production
8. Global Scenario: Minimizing land degradation

Zeuss-Koutine, Tunisia

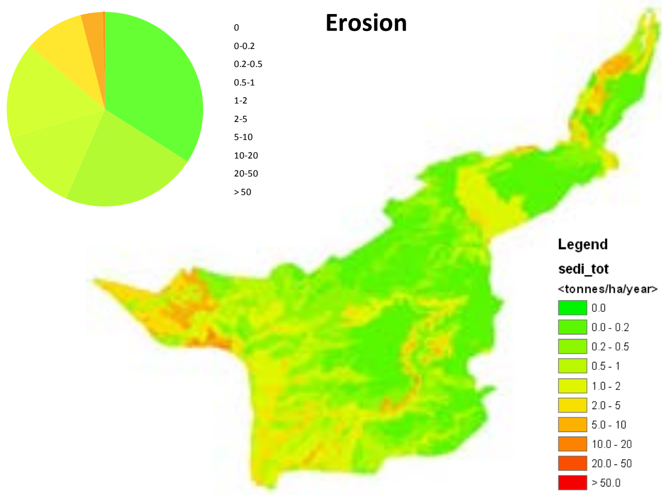
Baseline Scenario

PESERA baseline run

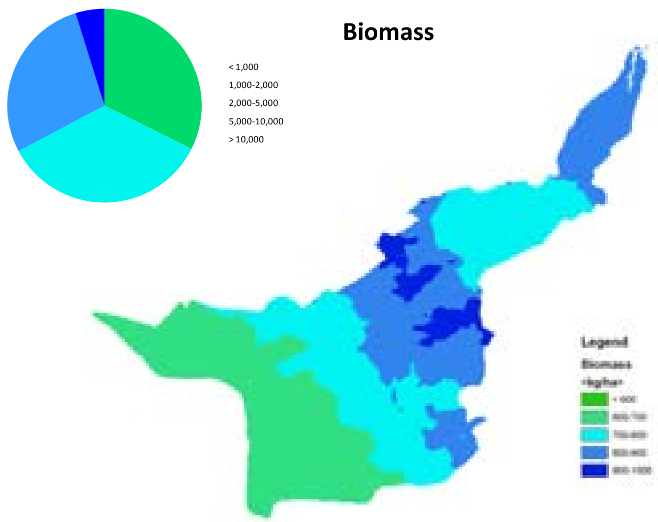
The erosion baseline map is affected by land use, soil cover and availability of erodible sediment. Hence, the Matmata mountain range does not feature prominently, whereas some footslope, valleyfloor and plain areas represent higher maximum erosion values. For the estimation of biomass production it was assumed that grazing is an intrinsic part of the system and an average of 30% of annual production is grazed annually.



Soil erosion



Biomass production



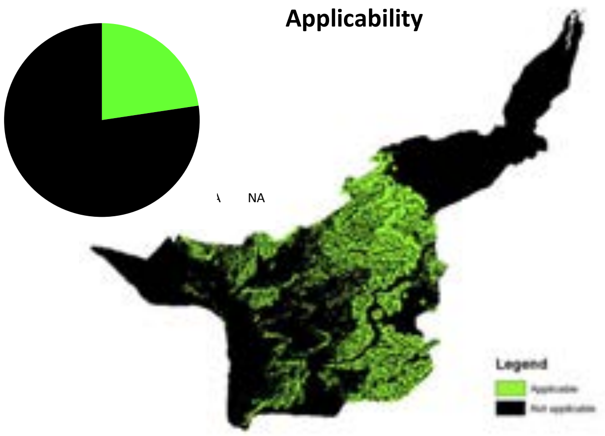
Zeuss-Koutine, Tunisia

Technology Scenario:
Jessour (TUN09)

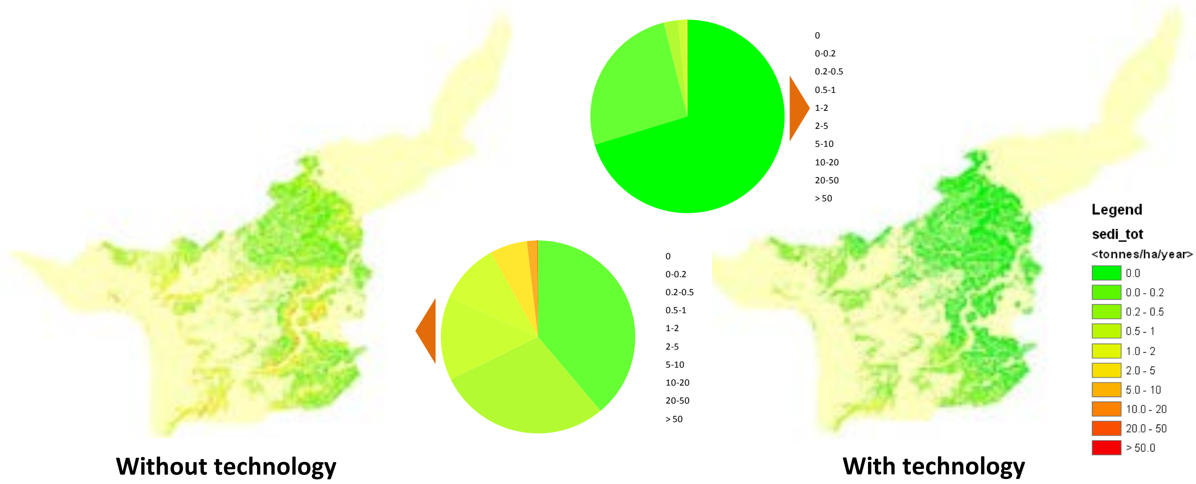
- Investment cost is fixed at TND 3,900 (€1945).
- An economic life of 20 years has been set.
- Maintenance costs amount to TND 1170 (€584), including agricultural management.
- A discount rate of 10% has been applied.
- A CCR of 1:6 has been assumed. Extensive grazing (without case) is not affected.
- Terrace is cropped to olive. Trees become productive after 6 y (25%); mature after 12 y.
- Olive harvest index (HI) is set at 0.1 and olive price at TND 0.55 (€0.27) per kg.
- Wheat intercropped until year 12. Max. yield is 930 kg/ha; price is TND 0.43 (€0.21) per kg.

Applicability

- The technology is not applicable in very steep an flat areas

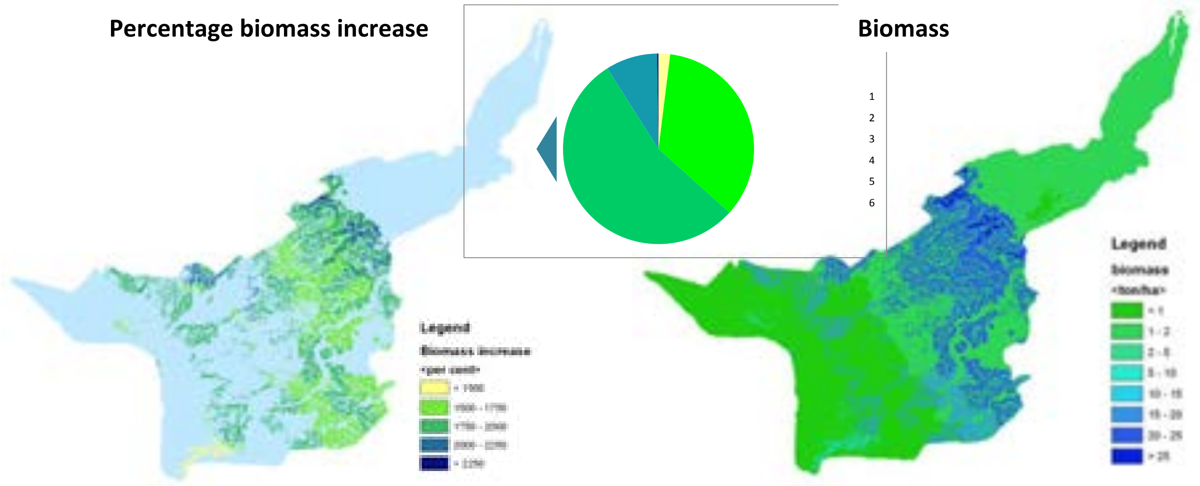


Biophysical impact: soil erosion



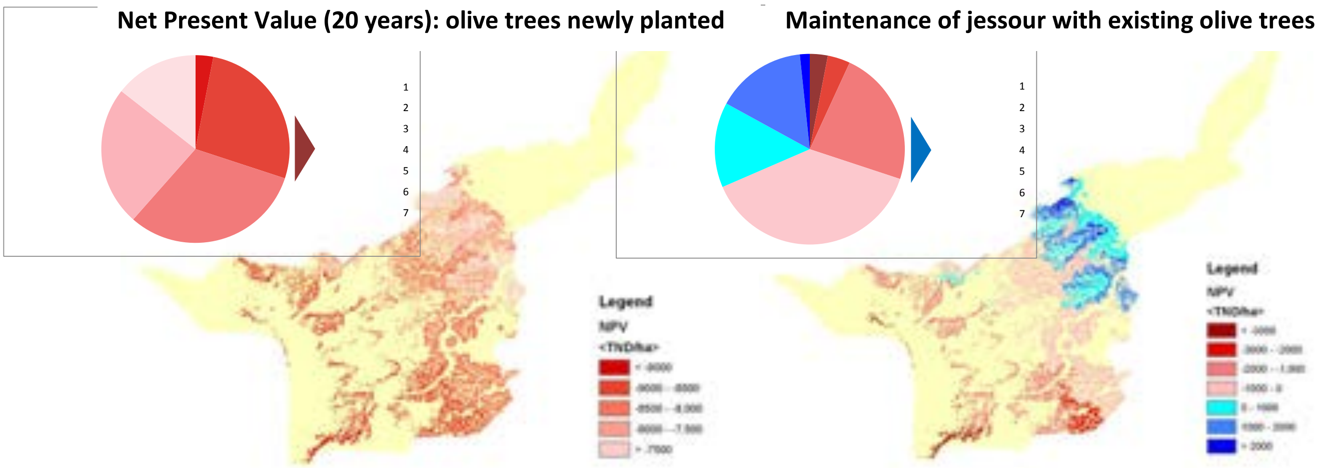
Biophysical impact: increase in biomass

Percentage biomass increase **Biomass**



Economic viability

Net Present Value (20 years): olive trees newly planted **Maintenance of jessour with existing olive trees**



In the case of construction of new jessour, planting of new olive trees means that it takes 6 years before the first olives can be harvested, and 12 years before the trees reach full productivity. Even if in this build up period wheat is grown, the investment and maintenance costs are too high, resulting in negative Net Present Value. However, the maintenance of existing jessour where olive trees have reached maturity is profitable in part of the applicability area: there is a positive NPV in 31% of the applicability area. These analyses are based on average conditions, and years with insufficient runoff-producing rainfall events may see much lower olive harvests. Equilibrium biomass per hectare of terrace area may seem high; the olive harvest index has been set quite low to arrive at a yield of 100 kg per full-grown tree. Note that NPV is given per hectare of terraced land, so for total land productivity including the impluvium values should be divided by 6 (the CCR ratio).

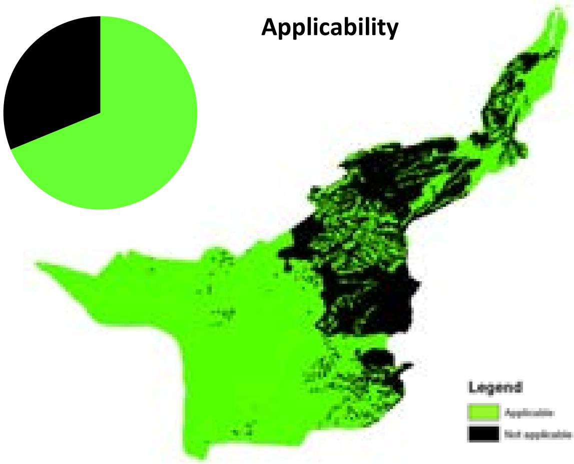
Zeuss-Koutine, Tunisia

Technology Scenario:
Rangeland resting (TUN11)

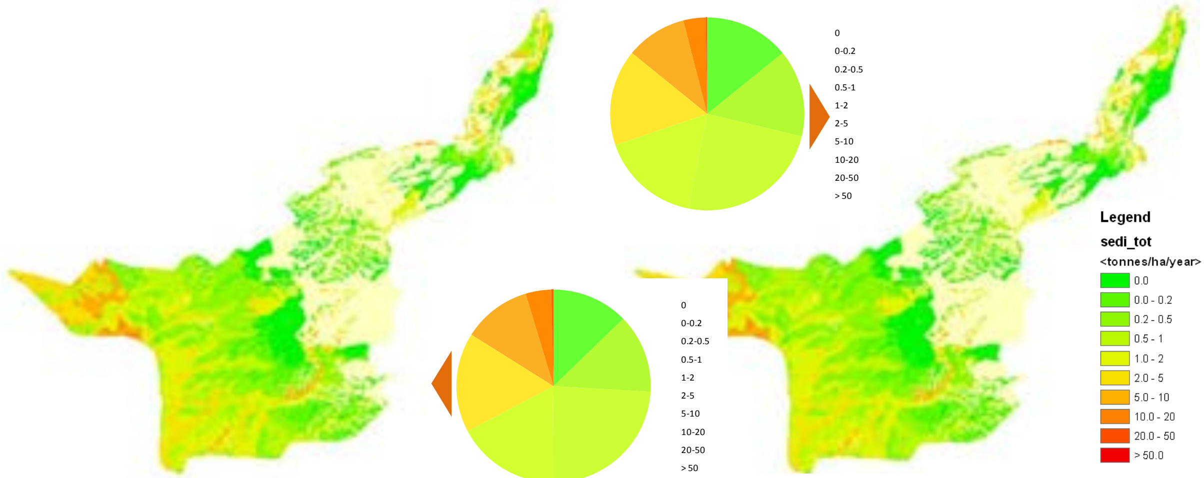
- Standard fencing cost is TND 72 (€36) ha^{-1}.
- In the without case 30% of biomass is grazed.
- Conversion rate of biomass to fodder units is 35% both with and without technology; the price per fodder unit is TND 0.20 (€0.10).
- The economic life of the technology is 4 years; benefits in the form of increased productivity occur in the 4th year only.
- If not rested rangeland provides fodder, the equivalent of which needs to be purchased if resting is applied.
- A discount rate of 10% is applied.

Applicability

- The technology is not applicable in very steep areas and is confined to rangeland areas.

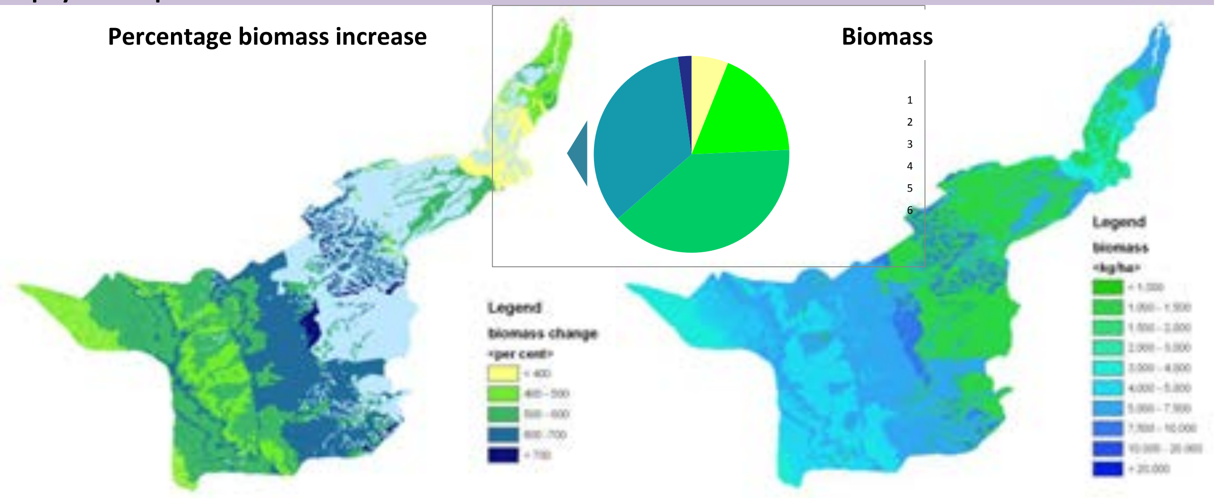


Biophysical impact: soil erosion



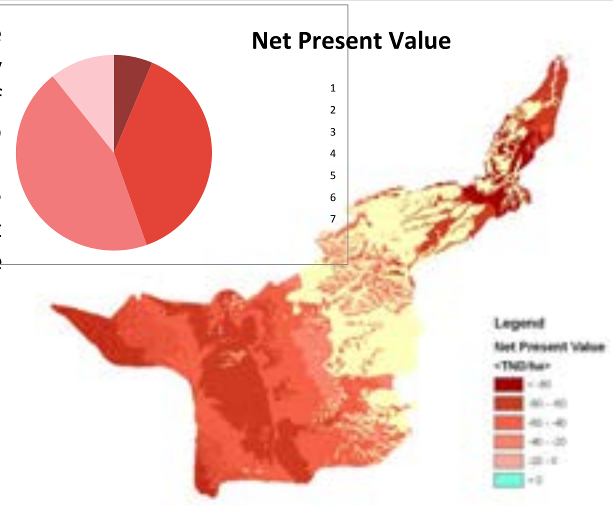
Without technology   With technology

Biophysical impact: increase in biomass



Economic viability

Rangeland resting is not economically viable. The present analysis was performed with opportunity costs for fodder equal to the productivity of rangeland if used continuously (i.e. if animals were to be grazed on comparable areas); the analysis would turn even more negative if fodder would need to be purchased from the market. The Tunisian government has introduced a subsidy to purchase alternative livestock feed to stimulate the uptake of rangeland resting.



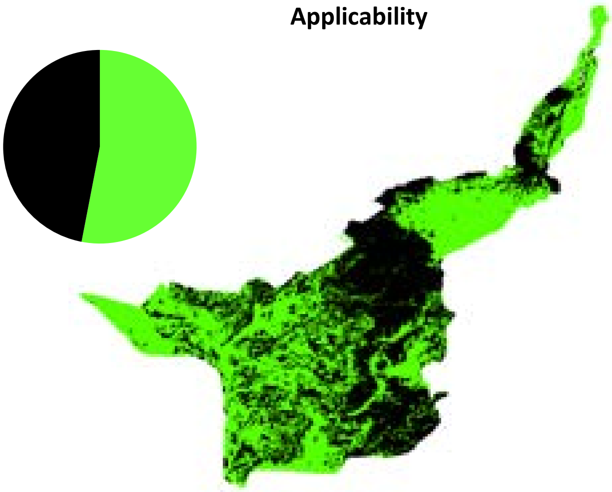
Zeuss-Koutine, Tunisia

Technology Scenario:
Tabia (TUN12)

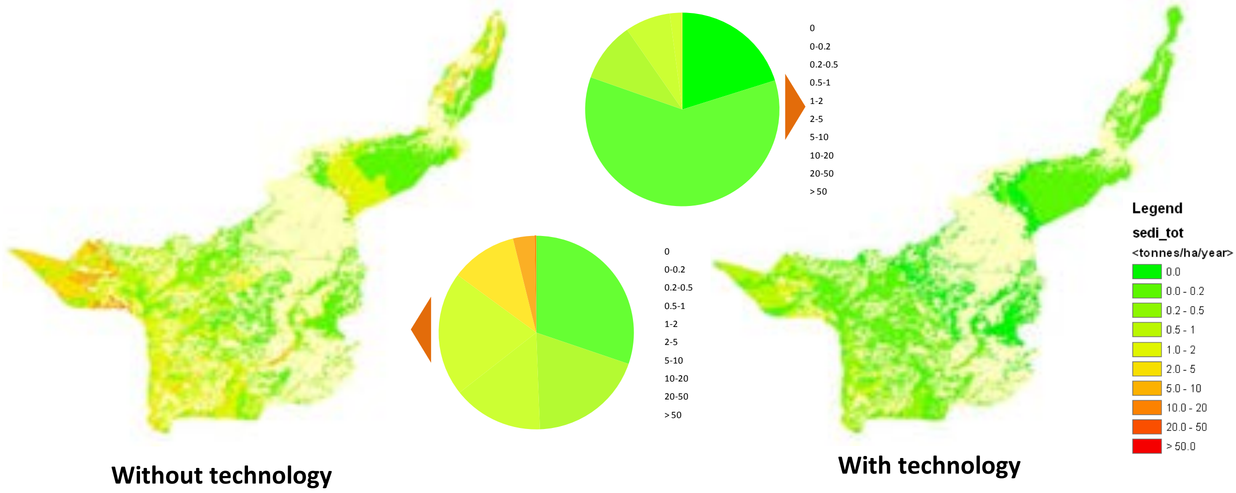
- Investment cost is fixed at TND 871 (€435).
- An economic life of 20 years has been set.
- Maintenance costs amount to TND 260 (€130), including agricultural management.
- A discount rate of 10% has been applied.
- A CCR of 1:6 has been assumed. Extensive grazing (without case) is not affected.
- Terrace is cropped to olive. Trees become productive after 6 y (25%); mature after 12 y.
- Olive harvest index (HI) is set at 0.1 and olive price at TND 0.55 (€0.27) per kg.
- Wheat intercropped until year 12. Max. yield is 930 kg/ha; price is TND 0.43 (€0.21) per kg.

Applicability

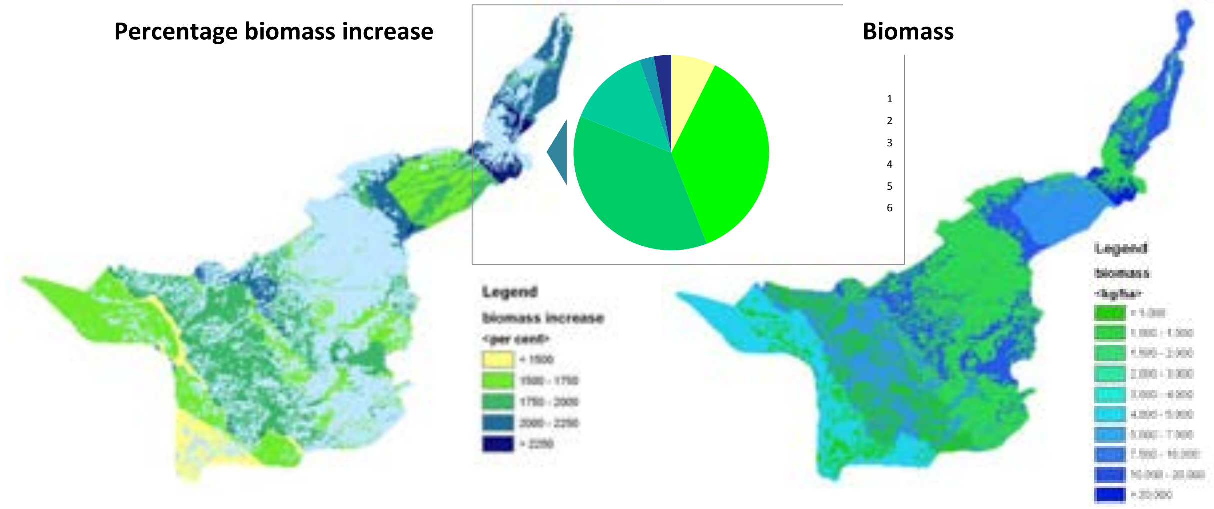
- The technology is applicable in gentle sloping areas with deep soils



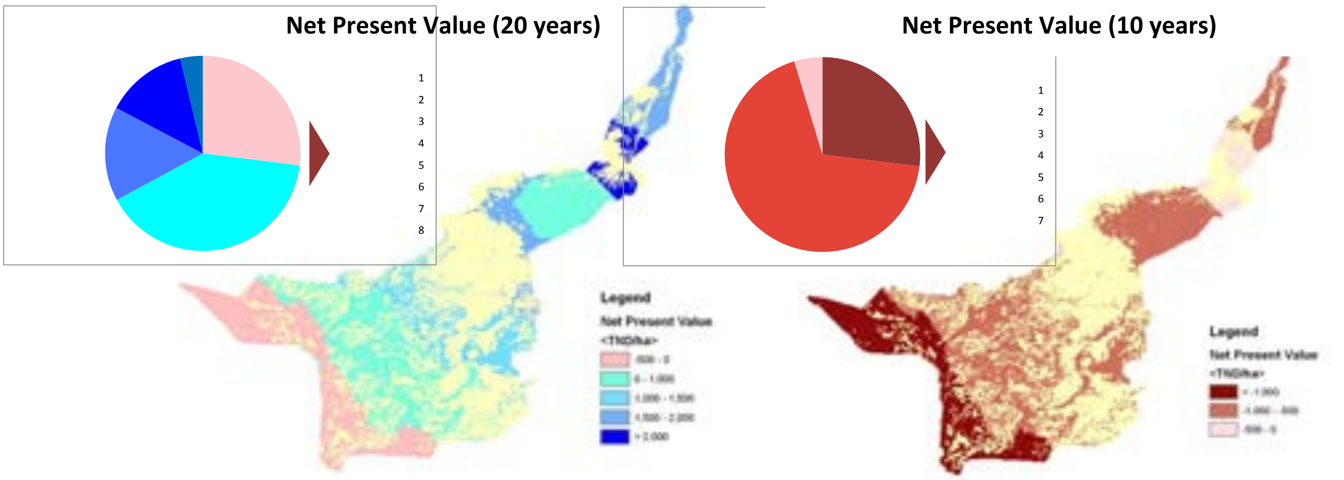
Biophysical impact: soil erosion



Biophysical impact: increase in biomass



Economic viability



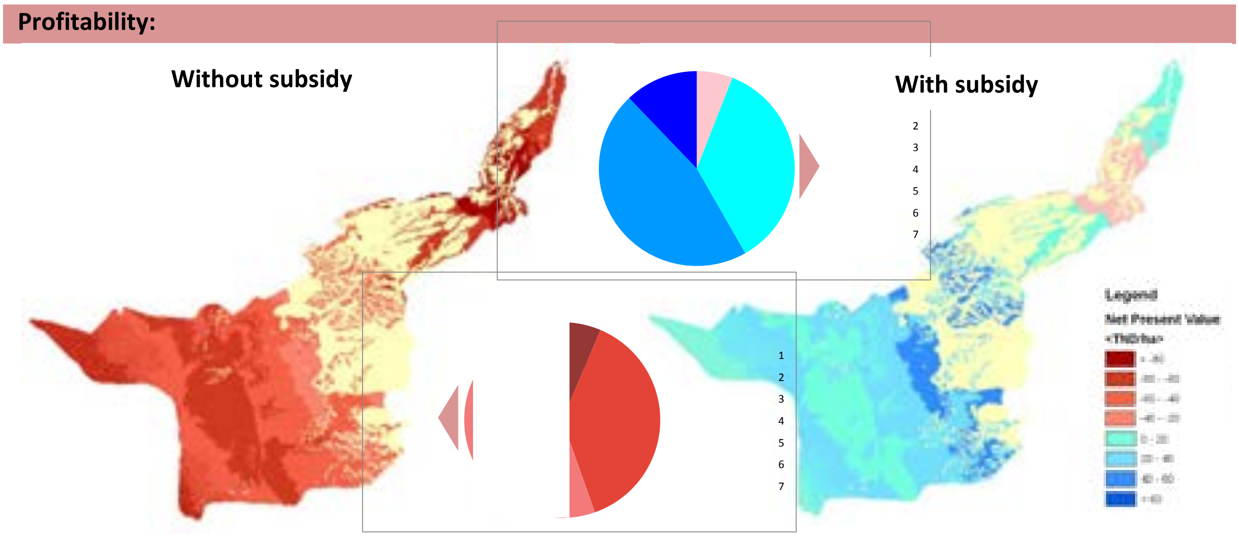
Although tabias are profitable in most of the applicability area, planting of new olive trees means that it takes 6 years before the first olives can be harvested, and 12 years before the trees reach full productivity. Therefore, land users have to wait a long time before the investment pays off, as demonstrated by the 10-year investment analysis, where all analyses point to a negative return. These analyses are based on average conditions, and years with insufficient runoff-producing rainfall events may see much lower olive harvests. Equilibrium biomass per hectare of terrace area may seem high; the olive harvest index has been set quite low to arrive at a yield of 100 kg per full-grown tree. Note that NPV is given per hectare of terraced land, so for total land productivity including the impluvium values should be divided by 6 (the CCR ratio).

Zeus-Koutine, Tunisia

Policy Scenario:
Subsidising alternative feed purchases (TUN11)

Rangeland resting is difficult for farmers as it requires access to alternative feed, which is expensive if sourced from the market. The government has devised a subsidy to compensate land users for alternative feed requirements. The subsidy amounts to TND 30 (€15) per ha in the first year, and TND 70 (€35) spread over the next three years. The policy applies to designated areas and requires land users to rest rangeland for a minimum of four years.

Profitability:



Cost-Effectiveness indicators:

- Bridging of the period in which the rested rangeland is closed for grazing with subsidies for alternative feed purchases makes the technology profitable in 94% of the applicable area.
- This will result in an average reduction of erosion of 0.1 ton/ha/year.
- In total, an annual reduction of 8,225 tonnes of eroded soil can be expected.
- The subsidy for the area where the technology would become profitable amounts to TND 7.9 million (€3.96 million).
- Hence a cost-effectiveness of TND 964 per ton (€482) of soil conserved.

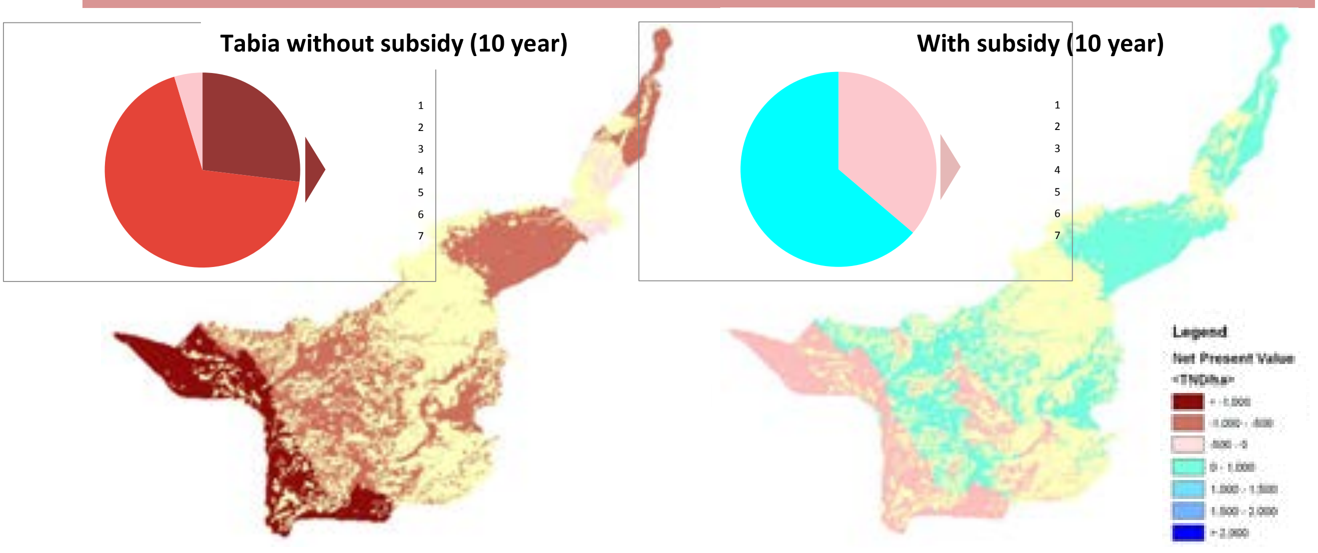
Zeus-Koutine, Tunisia

Policy Scenario:
Subsidising the construction of jessour and tabias (TUN09 & 12)

At a time horizon of 10 years, jessour and tabias are not profitable. Land users are unlikely to wait longer for benefits to accrue. Hence costs of the technology need to be reduced. This is possible through a subsidy and/or coordinating the scale of implementation which will reduce per area unit cost. A subsidy could be part of a payment for ecosystem services scheme as stabilization of areas affected by gullies and rills has important off-site effects, e.g. reduction of sedimentation of the reservoirs in the study area, and relieving pressure on state forests. In this scenario a cost reduction equal to 50% of the investment costs is explored.

50%

Profitability:



Cost-effectiveness indicators:

- A reduction in investment costs of 50% makes tabias (TUN12) profitable in 64% of the applicable area, based on the net present value after 10 years; jessour (TUN09) however are too costly in construction and maintenance, and an investment subsidy does not make any difference.
- On the area where NPV becomes profitable, an average reduction of erosion of 0.69 ton/ha/year is obtained.
- In total, an annual reduction of 4742 tonnes of eroded soil can be expected*.
- The subsidy for the area where tabias would become profitable amounts to TND 3.0 million (€1.5 million)*.
- Hence a cost-effectiveness of TND 632 per ton (€316) of soil conserved.

*Note: these figures reflect the fact that the technology can in fact only be implemented on 1/6th of the applicable area due to the need to take into account a catchment to cropped area ratio.

Zeuss-Koutine, Tunisia

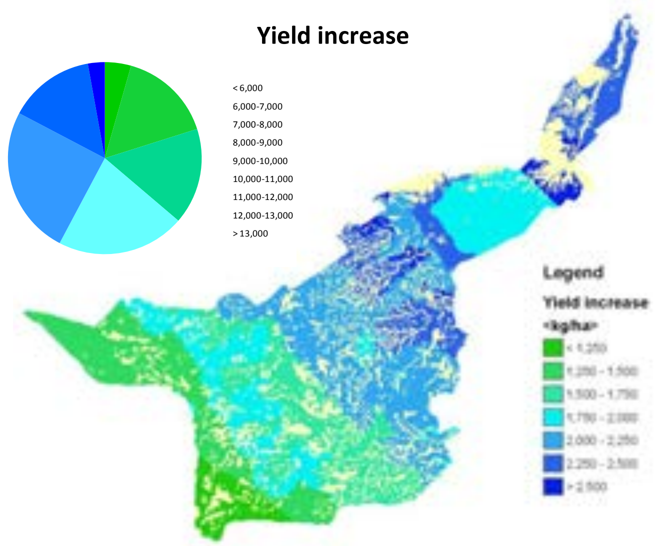
Global Scenario:
Food production

The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+1863 kg/ha*

+187 kg/inhabitant**

Scope for increased production



Biophysical impact: biomass increase

- Yield increase in 100 % of applicable area
- Average absolute yield increase: 1,863 kg/ha
- Average yield increase: na

Economic indicators

Average costs:
- Investment cost: €888/ha
- Unitary cost year 12: €477/ton***
- Unitary cost lifetime: €40/ton

Aggregate indicators**:
- Study site: €13.5 million
- Augmented annual production: 28,260 ton
- Augmented total production: 339,111 ton

*Note: this yield increase is for fresh weight olives
**Note: the per hectare increase is only feasible on 1/6th of the applicable area due to the catchment to cropped area ratio (CCR) of jessour and tabias. These values reflect this reduction.
***Note: year 12 is the first year when full production is reached

Zeuss-Koutine, Tunisia

Global Scenario:
Minimizing land degradation

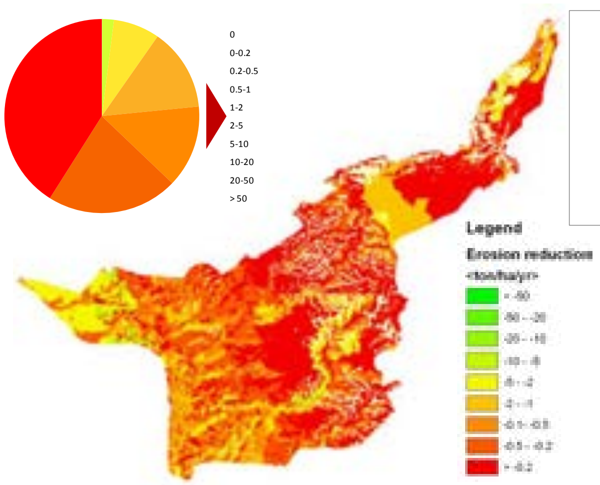
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-0.77 ton soil/ha

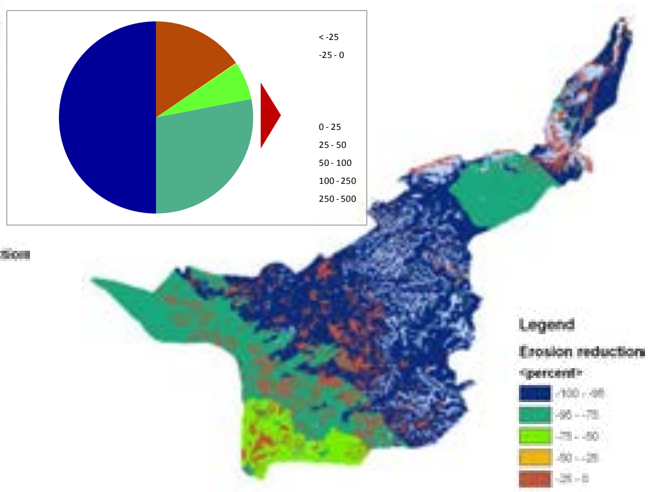
€1087/ton soil

Scope for reduced erosion

Reduction of erosion (negative values)



Percentage of erosion reduction (negative values)



Biophysical impact: erosion reduction

- Reduction of erosion in 100 % of applicable area
- Average absolute erosion reduction: 0.77 tonnes/ha/yr
- Average percent erosion reduction: 80 %

Economic indicators

Average costs:
- Investment cost: €837/ha
- Unitary cost year 1: €1087/ton soil
- Unitary cost lifetime: €57/ton soil

Aggregate indicators*:
- Study site: €8.63 million
- Aggregate annual erosion reduction: 18,200 ton
- Total erosion reduction: 365,000 ton

*Note: for jessour and tabias only 1/6th of the applicable area is counted to account for the catchment to cropped area ratio (CCR) involved in these technologies.

Zeus-Koutine, Tunisia

Concluding remarks

- Baseline simulations show that the Zeus-Koutine area has mostly low soil erosion rates, with rates over 2 ton/ha/yr confined to about 20% of the territory.
- Jessour, tabia, supplemental irrigation, rangeland resting and groundwater recharge structures were prioritised by scientists and local stakeholders to mitigite soil erosion, water scarcity and vegetation degradation. Available data allowed to simulate the effects of jessour (TUN09), rangeland resting (TUN11) and tabias (TUN12). The technology scenarios show that jessour, and to lesser extent tabias are effective in reducing erosion rates. The effect of rangeland resting is not very pronounced, possibly because the aridity of the area means vegetative soil cover remains limited even if not grazed. Jessour and tabia can by concentrating runoff at a ratio of catchment to cropped area of 6 : 1 greatly enhance biomass production. The time scale over which this occurs is not specifically addressed in research, but as olive trees are planted it takes several years for trees to accumulate the important increase in biomass. Experimental results were hampered by droughts and short monitoring period. Due to high initial cost the tested technologies are only in the long term (> 10 years, or even >20) profitable. Tabias perform best and are simulated to be profitable in over 75% of the applicable area over a 20-year planning horizon. Jessour are too expensive to newly develop cost-effectively, but maintaining existing ones is economically feasible in about a third of the area.
- In the workshop to evaluate monitoring and modelling results, stakeholders downgraded all tested technologies, either because they were initially assessed too positively or because of inconclusive experimental results. A greater coping ability with the harsh environment and adverse climatic conditions was considered essential by participants, who now choose for groundwater recharge structures, supplemental irrigation and medicinal herbs and aromatic plants as preferred technologies. Recommendations for upscaling included the streamlining of various research and development activities, integration of local and scientific knowledge and the need to look at land management integrally with diversification of livelihood opportunities.
- A policy scenario of the existing government policy to subsidize supplementary feed for animals showed high effectiveness in augmenting the profitability of rangeland resting in 94% of the applicable area. Such a subsidy would however reduce soil erosion only by on average 0.1 ton/ha/yr, at a cost of TND 964 per ton (€482) of soil conserved. For jessour and tabias, a policy scenario reducing the investment cost by 50% was run. While for jessour, the investment and maintenance cost were so high that the policy is not effective, such a policy enables tabias to become profitable after 10 years in 64% of the applicable area.
- The global scenarios show that the technologies can achieve very significant yield increases and erosion reductions in the entire applicability area. The investment costs to achieve this are low at €40/ton olives and €57/ton soil conserved. Per area unit, investment costs are nevertheless substantial at over €800/ha.
- Jessour and tabias are in first instance water harvesting technologies to allow making productive use of land in an area otherwise too arid for any form of agriculture except extensive grazing. Rangeland resting may restore vegetation but requires a bridging period of four years during which feed must be purchased from markets. All these measures remain critically linked to rainfall, as the performance during field experimentation clearly indicated.

Eskişehir, Turkey

Study site details

The Eskişehir study site is located in the western part of the central Anatolian Plateau, at its northern margin, and partially at the floor of a through-going depression, called the Eskişehir Basin.

- **Coordinates:**
  Latitude: 39°53'8"N
  Longitude: 30°16'12"E
- **Size:** 90 km^2
- **Altitude:** 819 – 1362 m
- **Precipitation:** 380 mm
- **Temperature:** generally below 0°C during winter and may exceed 40°C in summer days
- **Land use:** arable land (cereals, sugar beet, sunflower), pastures, forest
- **Inhabitants:** 3,040
- **Main degradation processes:** Water and wind erosion, droughts, urbanisation
- **Major drivers of degradation:** Inappropriate land management, urban expansion

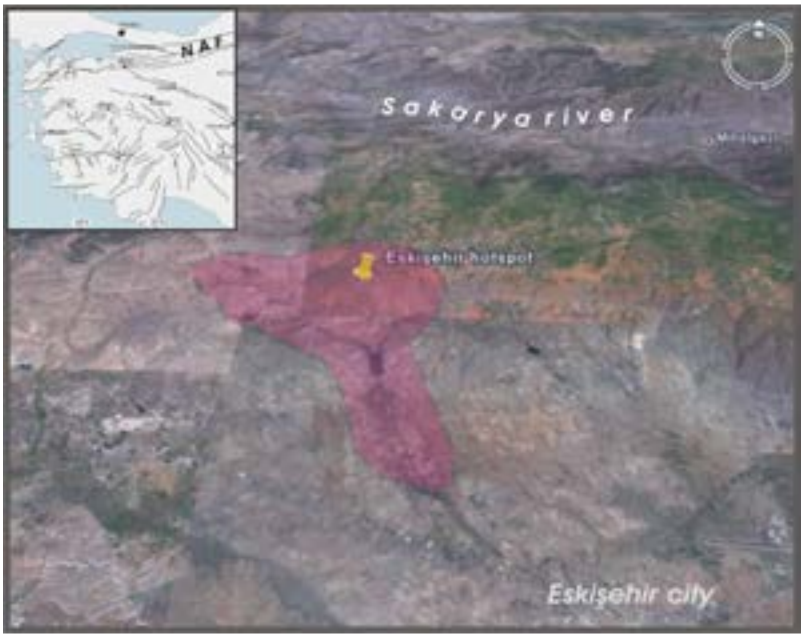


Figure 1: Study site location

Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Contour ploughing (ETH43)
3. Technology Scenario: Woven fences with contour ploughing (TUR05)
4. Policy Scenario: Subsidising woven fences (TUR05)
5. Global Scenario: Food production
6. Global Scenario: Minimizing land degradation

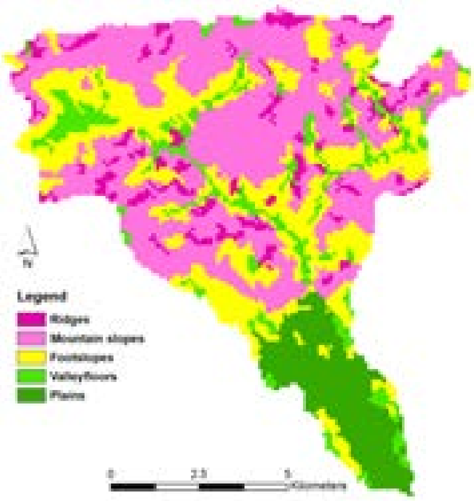
Eskişehir, Turkey

Baseline Scenario

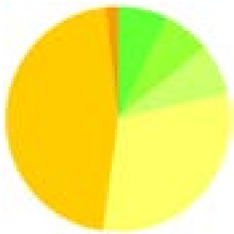
PESERA baseline run

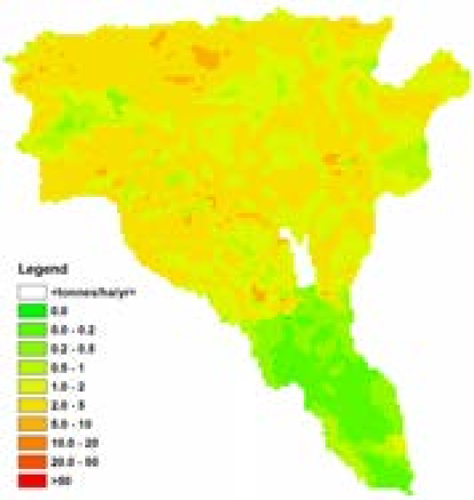
The baseline run clearly shows distinct erosion rates for two areas: the mountain slopes and the plains. Several valleyfloors also have low erosion rates. Roughly 80% of the area has simulated erosion rates of over 1 ton/ha/yr, but only a very small area experiences erosion rates of over 10 ton/ha/yr. Biomass production output shows a clear cut difference between dryland farming (mostly 500-1000 kg/ha) and irrigated farming (typically larger than 3500 kg/ha). Pastures occupy the intermediate ranges.

Landforms

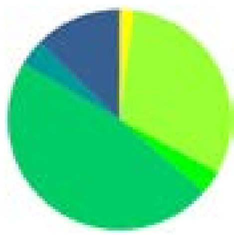


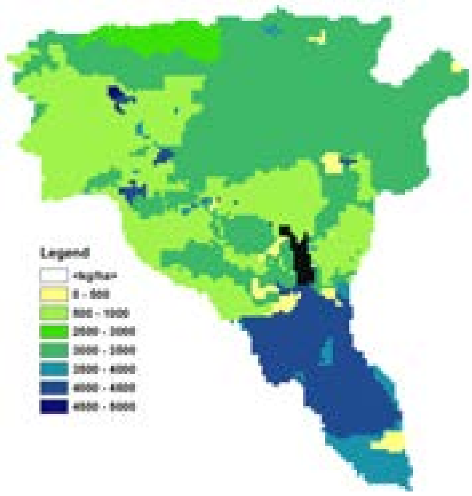
Soil erosion





Biomass production





Eskişehir, Turkey

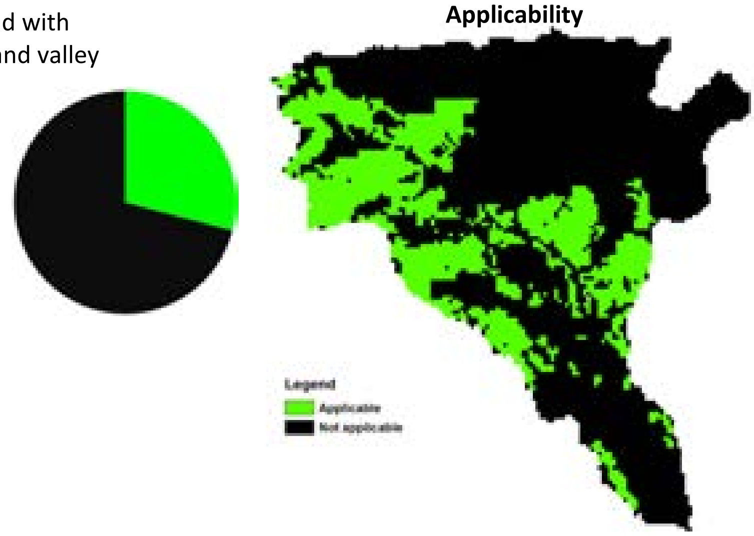
Technology Scenario:
Contour ploughing (ETH43)

- Total operation costs under different practices:
  - traditional ploughing 286 TRY/ha (€216)
  - contour ploughing 286 TRY/ha (€216)
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- NPV was calculated on 20 year period basis at 10% discount rate
- The price of grains is 0.384 TRY/kg (€0.16)

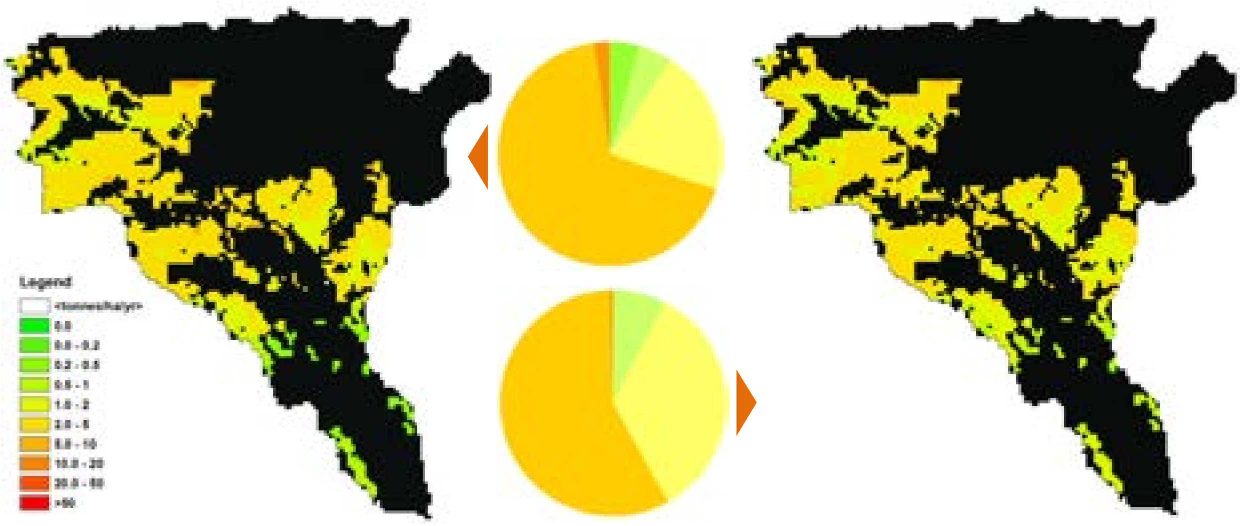
Applicability

- The technology is applicable on arable land with slopes between 2 and 35% (not in plains and valley floors).

Applicability



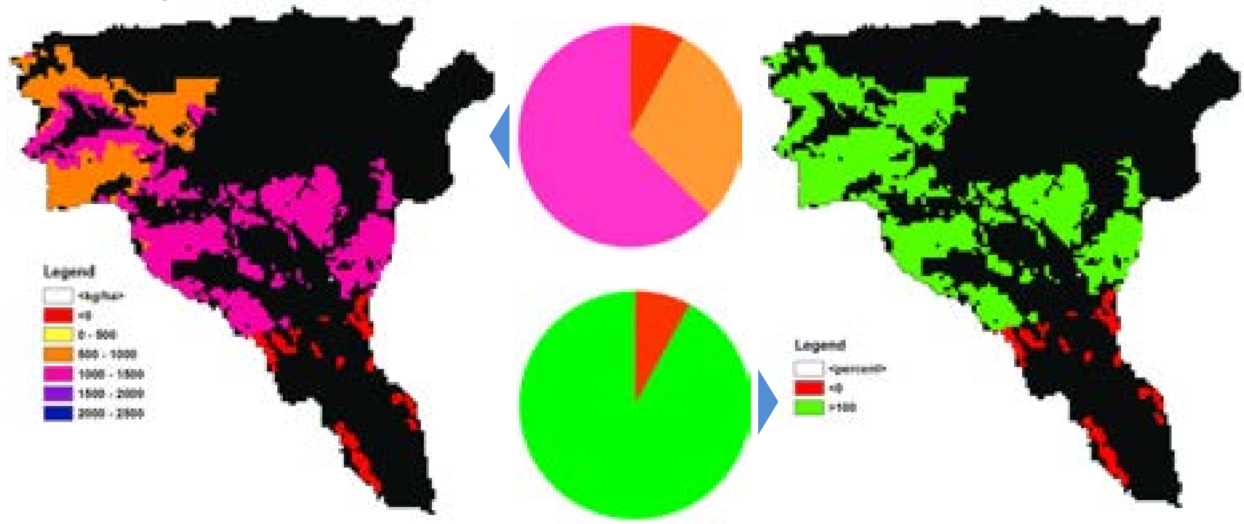
Biophysical impact: soil erosion



Under traditional ploughing **Under contour ploughing**

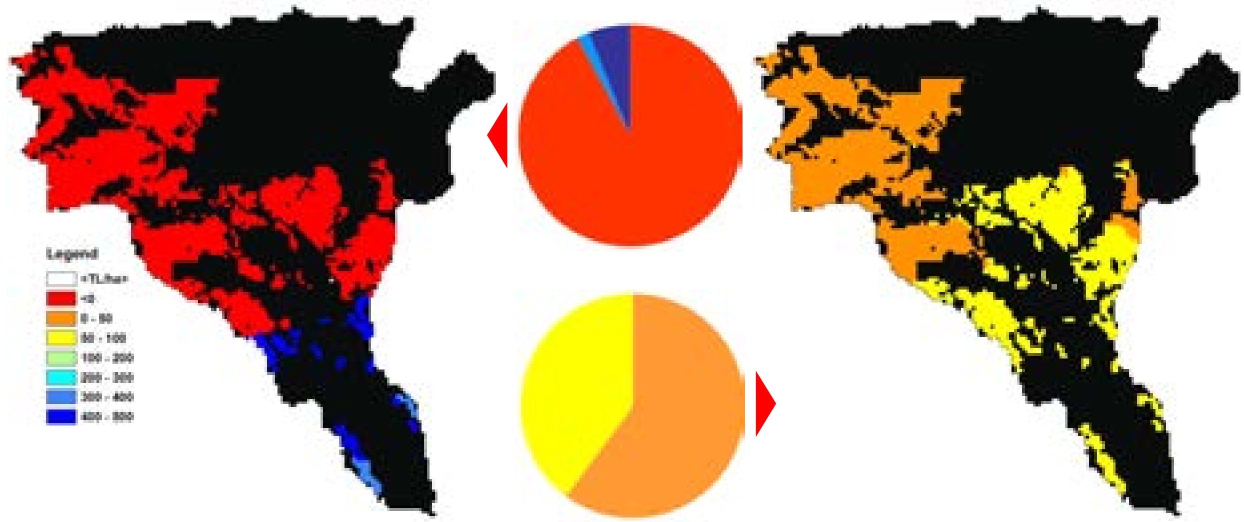
Biophysical impact: change in biomass

Biomass change **Percentage biomass change**

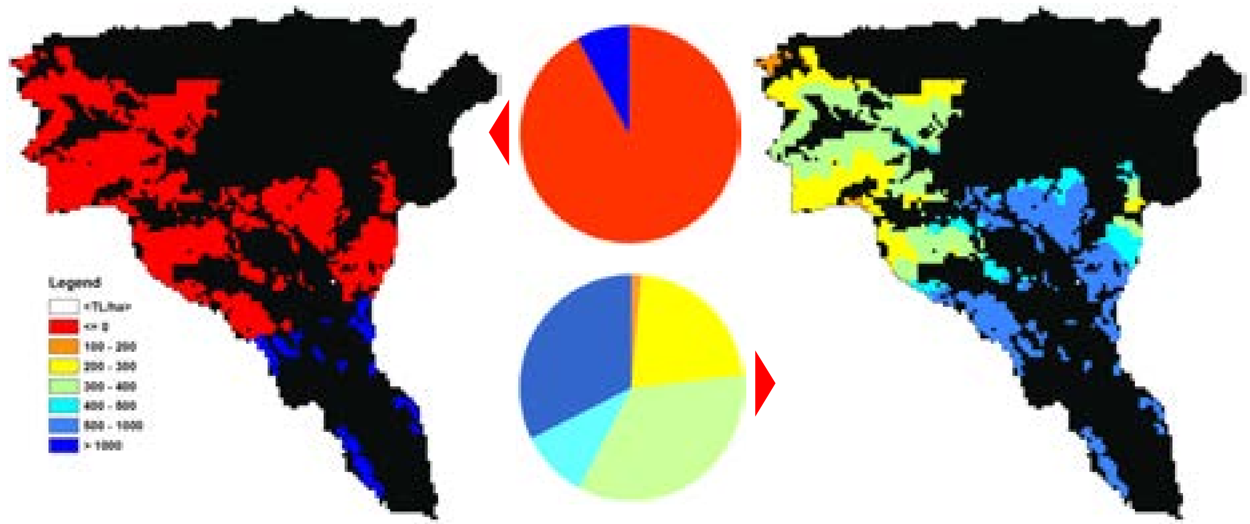


Economic viability

Net profit under traditional ploughing **Net profit under contour ploughing**



NPV under traditional ploughing **NPV under contour ploughing**



- Contour ploughing is profitable as it does not require extra costs but increases production.

Eskişehir, Turkey

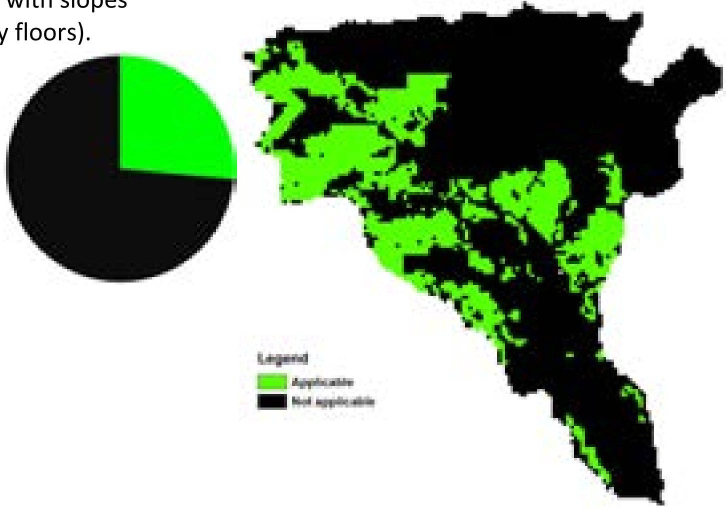
Technology Scenario:
Woven fence and contour ploughing (TUR05)

- Total operation costs under different practices:
  - traditional ploughing 286 TRY/ha (€216)
  - woven fence and contour ploughing 286 TRY/ha (€216with an initial investment cost of 2500 TRY/ha (€1014 – first year only), annual maintenance cost of 5% of investment cost
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The life of the technology is 20 years.
- The price of grains is 0.384 TRY/kg (€0.16)
- 10% discount rate was used for calculating NPV

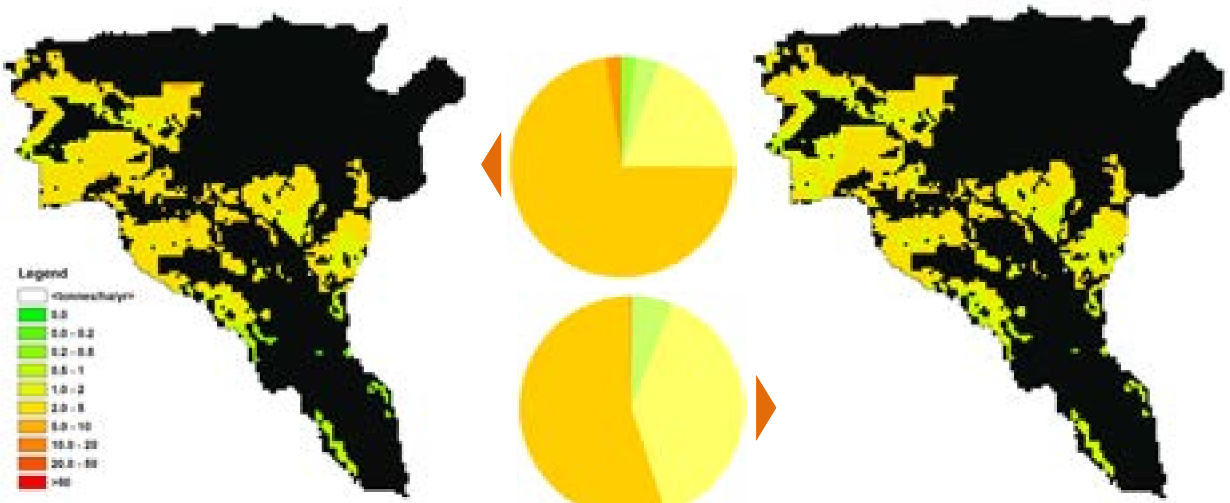
Applicability

- The technology is applicable on arable land with slopes between 3 and 35% (not in plains and valley floors).

Applicability



Biophysical impact: soil erosion

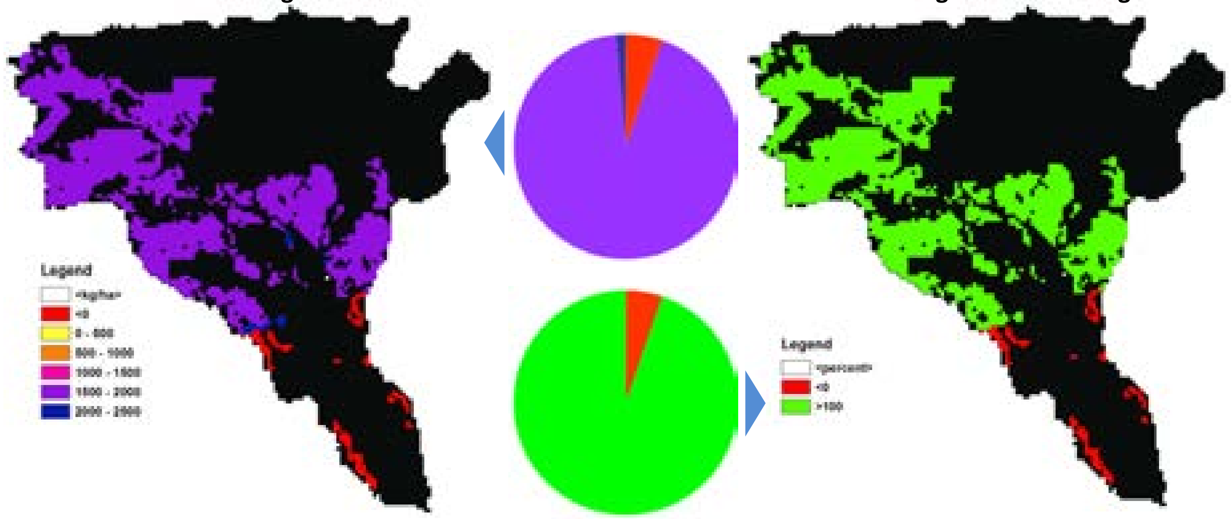


Under traditional ploughing

Under woven fence and contour ploughing

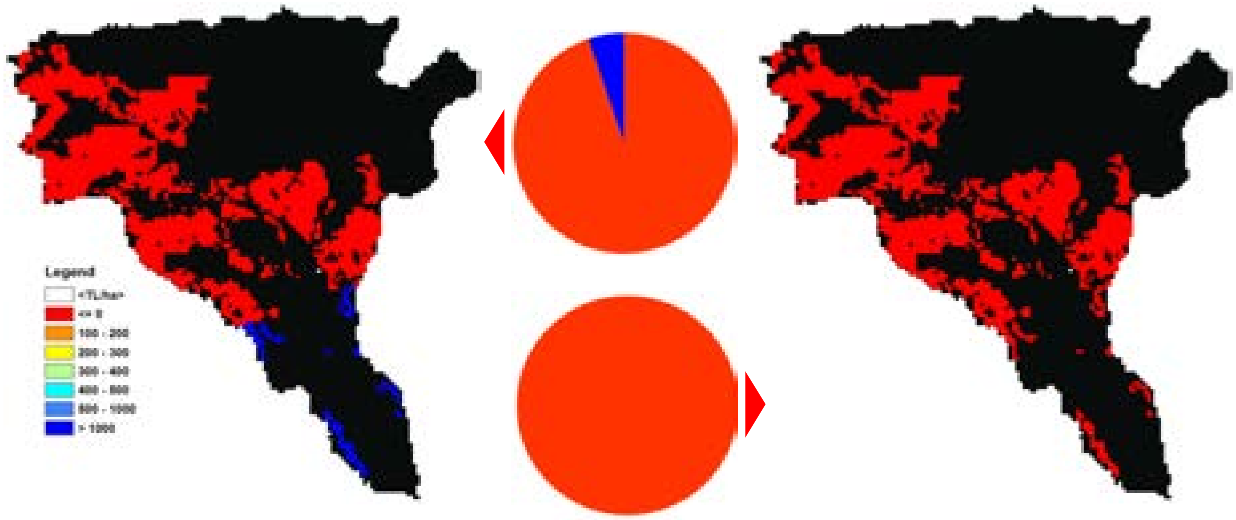
Biophysical impact: change in biomass

Biomass change **Percentage biomass change**



Economic viability

NPV under traditional ploughing **NPV under woven fence and contour ploughing**



The technology has, according to the model simulations, the potential to double yields across much of the applicability area. Nevertheless, the net present value of woven fences and contour ploughing is negative due to the substantial initial investment costs. Under these circumstances, the technology is unlikely to be adopted unless policy incentives reduce the initial costs. Also, the technology has been assumed to require annual maintenance costs equal to 5% of the investment costs. Productivity increases are such that these can be easily covered. A third observation which can be made is that traditional ploughing also shows negative returns in most of the area considered. This could indicate that farmers accept lower return to labour than the opportunity cost used in the simulations.

Eskişehir, Turkey

Policy Scenario:
Subsidising woven fence (TUR05)

Due to a high investment cost for building the woven fence, without external financial incentive in all parts of the study area widespread adoption of the technology is very unlikely. In this scenario the effects of a subsidy equal to 50% of the investment costs on profitability of the technology and the potential for mitigating land degradation are explored.

50%

Profitability:

Without subsidy **With subsidy**

Cost-effectiveness indicators:

- The introduction of 50% subsidy does not have significant impact as the proportion of the study area w negative economic gain remains the same with and without the subsidy.
- The technology was ranked first in the stakeholder evaluation based on its performance in the experiment, which is also supported by model output. However, the investment costs were in the experimental case not borne by the land user, and as such it could have been assumed by the participants that these would be subsidised. This scenario shows that such subsidies would be required to stimulate adoption, as even a 50% reduction in investment cost does not justify the investment. An additional question would be if such high rates of subsidies would still be cost-effective in reducing environmental degradation.

Eskişehir, Turkey

Global Scenario:
Food production

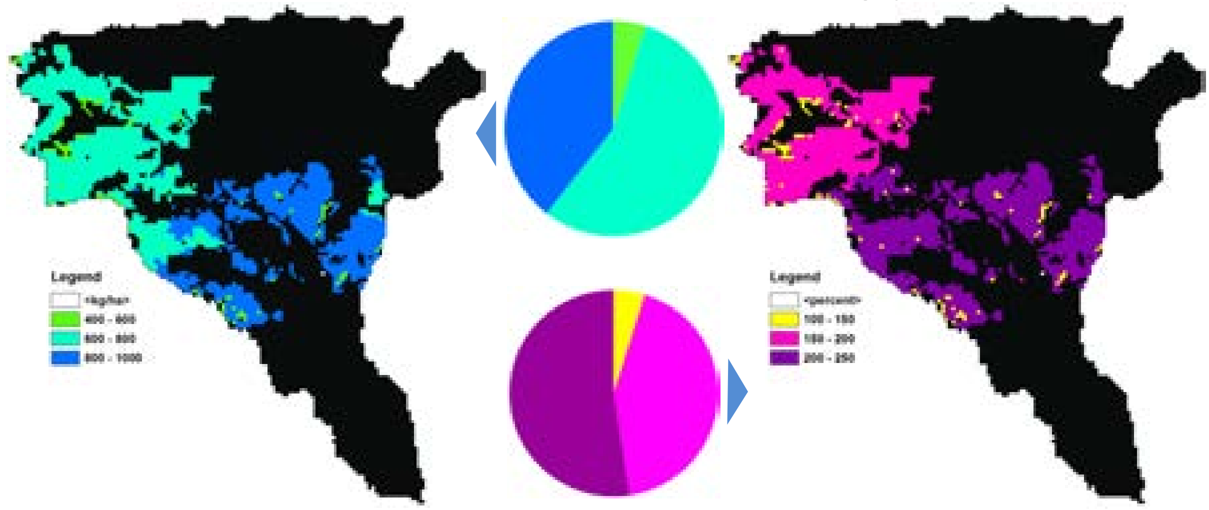
The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

+ 788 kg/ha

+ 607 kg/inhabitant

Scope for increased production

Yield difference | **Percentage yield difference**



Biophysical impact: yield difference

- The implementation of the most productive technology in each location would see yield increase in 91% of applicable area
- Average absolute yield increase: 788 kg/ha
- Average yield increase: 200 %

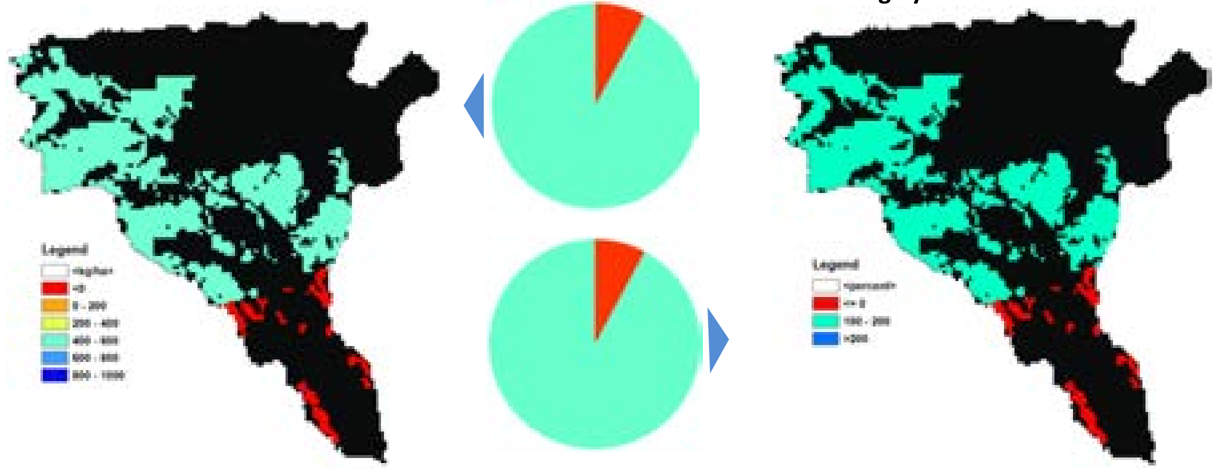
Economic indicators

Average costs:
- Extra operational cost: €0/ha/yr
- Investment cost: €926/ha/yr
- Unitary cost year 1: €1293/ton
- Unitary cost lifetime: €129/ton

Aggregate indicators:
- Study site: €0
- Study site: €2.4 million
- Augmented annual production: 1845 tonnes
- Augmented total production: 36,900 tonnes

Scope for increased production under ETH43

Yield difference | **Percentage yield difference**



Biophysical impact: yield difference

- The implementation of reduced tillage would see yield increase in 92% of applicable area
- Average absolute yield increase: 472 kg/ha
- Average yield increase: 120%

Economic indicators

Average costs:

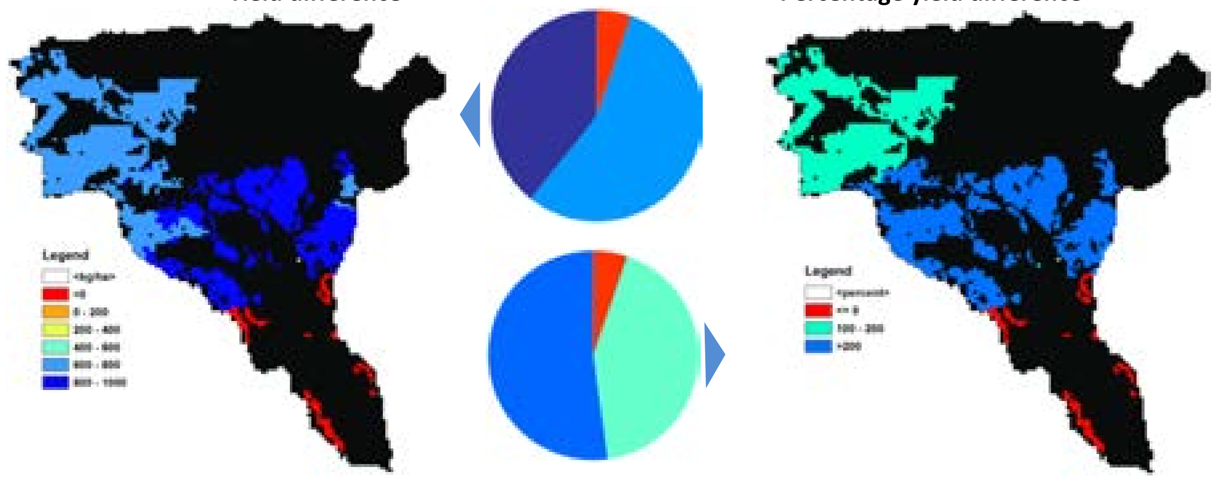
- Extra operational cost: €0/ha/yr
- Unitary cost: €0/ton

Aggregate indicators:

- Study site: €0
- Augmented annual production: 1105 tonnes

Scope for increased production under KEN05

Yield difference | **Percentage yield difference**



Biophysical impact: yield difference

- The implementation of reduced tillage would see yield increase in 95% of applicable area
- Average absolute yield increase: 805 kg/ha
- Average yield increase: 204%

Economic indicators

Average costs:

- Investment cost: €1014/ha/yr
- Unitary cost: €1260/ton

Aggregate indicators:

- Study site: €2.3 million
- Augmented annual production: 1793 tonnes

Eskişehir, Turkey

Global Scenario:

Minimizing land degradation

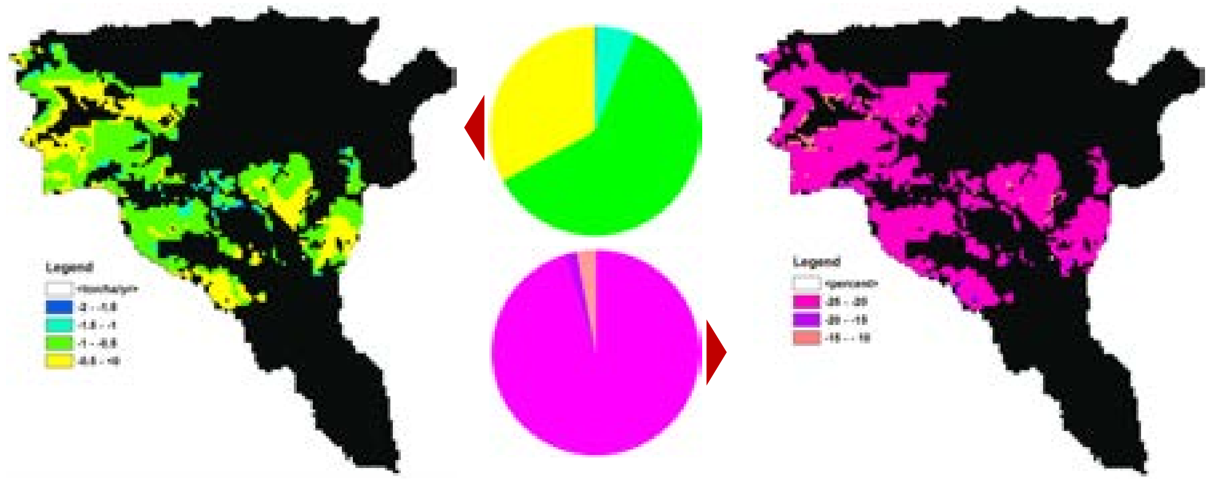
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

-0.6 ton soil/ha

€1648/ton soil

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 91% of applicable area
- Average absolute erosion reduction: 0.6 ton/ha/yr
- Average percent erosion reduction: 22%

Economic indicators

Average costs:

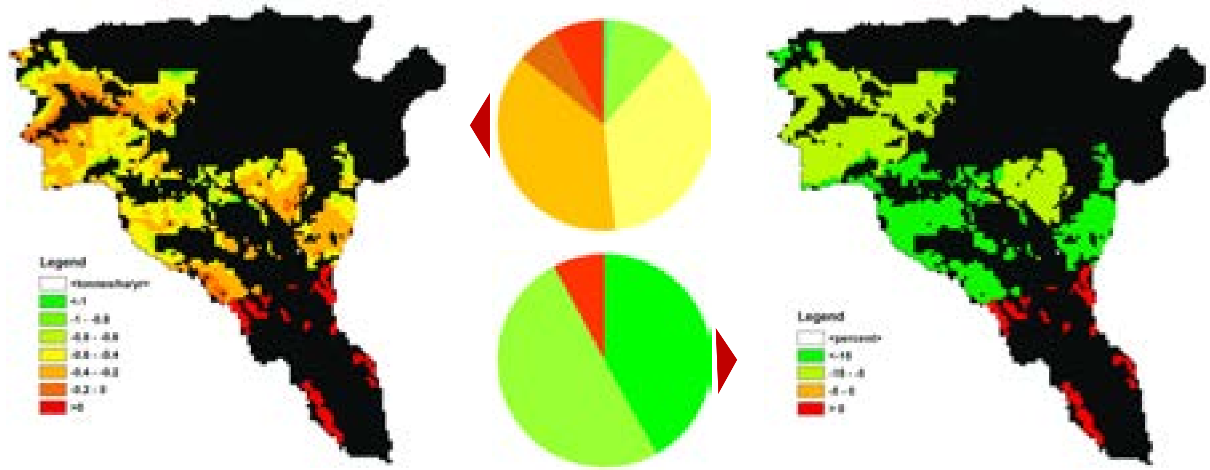
- Extra operational cost: €0/ha/yr
- Investment cost: €926/ha/yr
- Unitary cost year 1: €1648/ton
- Unitary cost lifetime: €165/ton

Aggregate indicators:

- Study site: €0 million
- Study site: €2.4 million
- Aggregate annual erosion reduction: 1447 ton soil
- Total erosion reduction: 28,940 ton soil

Scope for reduced erosion under ETH43

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 92% of applicable area
- Average absolute erosion reduction: 0.4 tonnes/ha/yr
- Average percent erosion reduction: 15%

Economic indicators

Average costs:

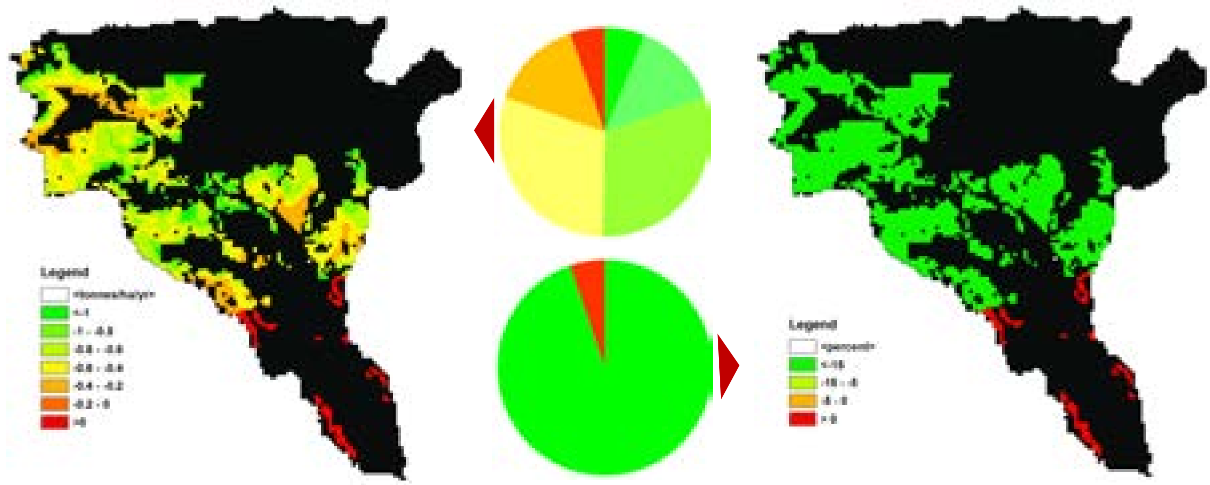
- Extra operational cost: €0/ha/yr
- Unitary cost: €0/ton soil

Aggregate indicators:

- Study site: €0 million
- Aggregate annual erosion reduction: 981 ton

Scope for reduced erosion under KEN05

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 95% of applicable area
- Average absolute erosion reduction: 0.6 tonnes/ha/yr
- Average percent erosion reduction: 22 %

Economic indicators

Average costs:

- Investment cost: €1014/ha/yr
- Unitary cost: €1677/ton soil

Aggregate indicators:

- Study site: €2.4 million
- Aggregate annual erosion reduction: 1422 ton

Eskişehir, Turkey

Concluding remarks

- Baseline simulations show that the study site experiences considerable erosion, especially in the sloping areas; roughly 80% of the area has erosion rates of over 1 ton/ha/yr, although only a very small area experiences erosion rates of over 10 ton/ha/yr.
- The technologies simulated are the technologies for which field experiments were conducted. These technologies were further specifications of remediation options selected by scientists and local stakeholders to address water erosion problems. The technology scenario shows that contour ploughing (ETH43) goes some way in reducing the area with erosion rates greater than 2 ton/ha/yr from about 70 to 60% of the applicable area. More impressive is its effect on biomass production, generating a more than 100% increase in about 90% of the applicable area. The technology requires no additional costs, and is thus profitable everywhere where it increases productivity. This only excludes some productive low-lying areas. Similarly, woven fences with contour ploughing (TUR05) have a more notable effect on production than on reduction of erosion. On both criteria, TUR05 outperforms ETH43. Despite of this, application of the woven fences is not economically viable under the assumptions made.
- Evaluating the results in a workshop, stakeholders preferred woven fences over contour ploughing. They did so based on the experimental results, which showed superior performance of the woven fences. There was also concern that contour ploughing would not be effective under high intensity rainfall. The modelling results support the idea that contour ploughing is not very effective in areas with high erosion rates. They acknowledged the investment costs of woven fences, but do not seem to have internalised these to their decision-making perspective – perhaps assuming that this would be subsidised as was the case for the experiment. The statement that incentives would stimulate adoption could imply however that land users are aware of the fact that profitability is an issue.
- A policy scenario subsidising investment costs of woven fences by 50% sorted no effect on its profitability. It could be that labour opportunity costs were too high (i.e. farmers may accept return to labour lower than the going wage rate). Given the vicinity of Eskişehir city this is probably not a very significant factor. High levels of subsidy would be difficult to justify on cost-effectiveness criteria.
- The global scenarios show that the technologies can achieve yield increases and erosion reductions across virtually their entire applicability areas. Yield increases are impressive, at 200% overall and for woven fences in most of the area (i.e. a tripling of yields), and still 120% on average for contour ploughing. Overall, erosion can be reduced by up to 25%, however contour ploughing only delivers reductions of over 15% in about 40% of its applicability area. The average yield increase is 788 kg/ha/yr and the average erosion reduction 0.6 ton/ha/yr, at a cost of €1293 and €1648/ton food product and soil respectively.
- Based on the analyses and perspectives, contour ploughing can easily be adopted but could entail some level of risk in high erosion risk areas and under high intensity events. The effects of woven fences with contour ploughing are clearly demonstrated, but their implementation is not recommended based on economic analysis. A case for subsidies should establish the level of off-site benefits to be obtained.

Karapinar, Turkey

Study site details

The rectangular Karapinar study site is located in the Great Konya Basin of south central Anatolia, 120 km east of Konya city. It includes a military zone (40 km^2) and an erosion control area (15 km^2).

- **Coordinates:**
  Latitude: 37°37'8"N
  Longitude: 33°21'20"E
- **Size:** 156 km^2
- **Altitude:** 998 – 1178 m
- **Precipitation:** 285 mm
- **Average temperature:** 11.5°C
- **Land use:** arable land (cereals, maize, sugar beet, potato, fodder crops), pastures
- **Inhabitants:** na
- **Main degradation processes:** wind erosion, salinization, overgrazing
- **Major drivers of degradation:** inappropriate land management and irrigation techniques

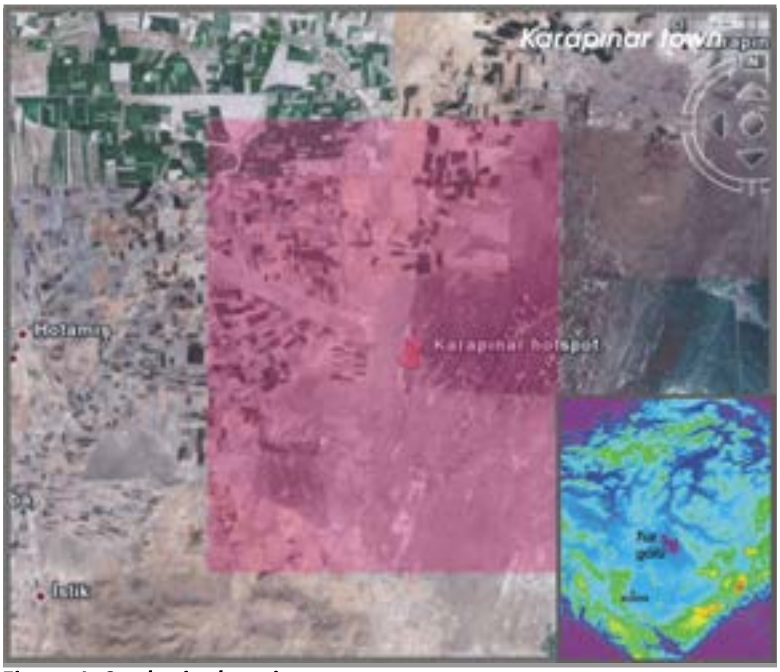


Figure 1: Study site location

Overview of scenarios

1. Baseline Scenario: PESERA baseline run
2. Technology Scenario: Minimum tillage
3. Technology Scenario: Stubble fallowing
4. Technology Scenario: Ploughed stubble fallowing
5. Global Scenario: Food production
6. Global Scenario: Minimizing land degradation

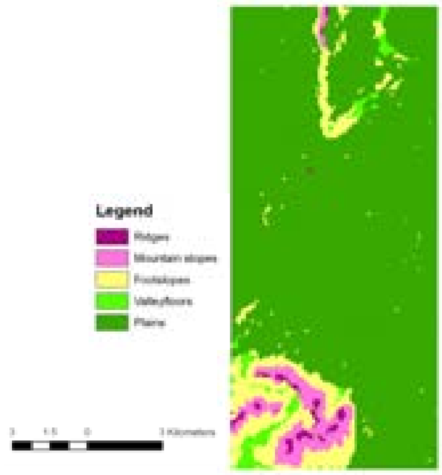
Karapinar, Turkey

Baseline Scenario

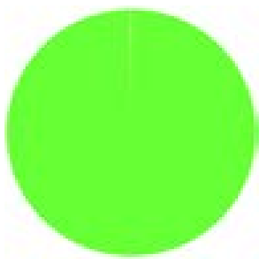
PESERA baseline run

The baseline run shows very low erosion rates across the entire study site area (below 0.5 ton/ha). The biomass production varies with land use, where arable land has low values. The 200 m altitude range within the study site does show as landforms in the southwest and north of the area, but this has no noticeable further influence on erosion and biomass production.

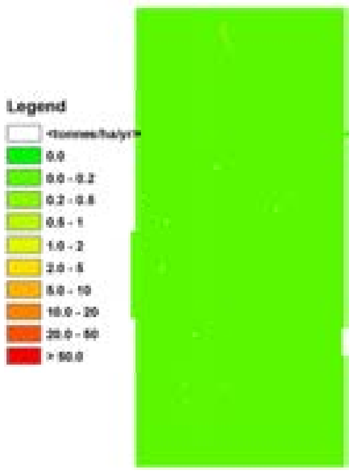
Landforms



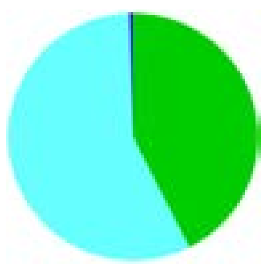
Soil erosion



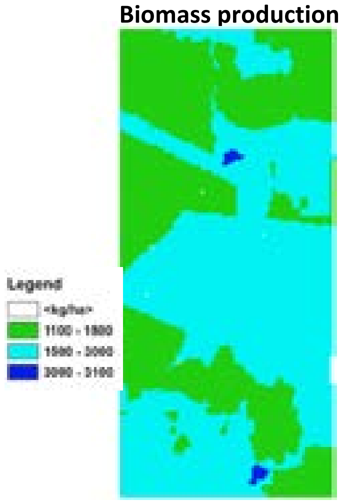
Soil erosion



Biomass production



Biomass production



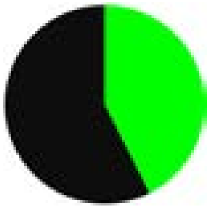
Karapinar, Turkey

Technology Scenario:
Minimum tillage

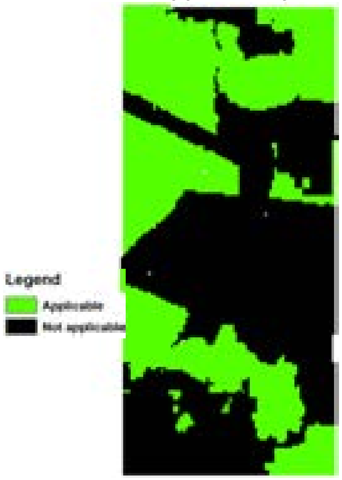
- Total operation costs under different practices:
  - traditional ploughing 736 TRY/ha (€298)
  - Minimum tillage 736 TRY/ha (€298)
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The price of grains is 0.5 TRY/kg (€0.20)

Applicability

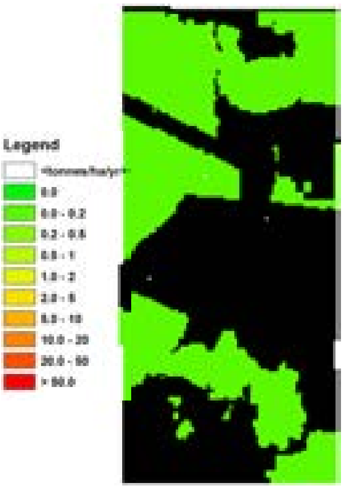
- The technology is applicable on arable land



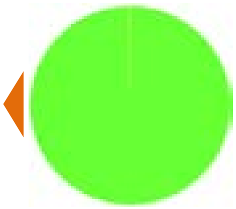
Applicability

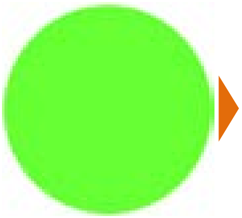


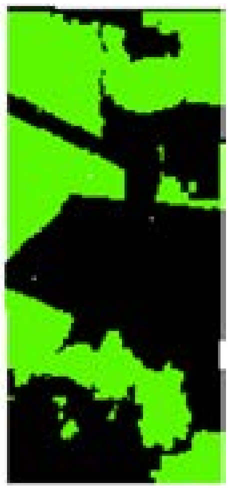
Biophysical impact: soil erosion



Under traditional ploughing



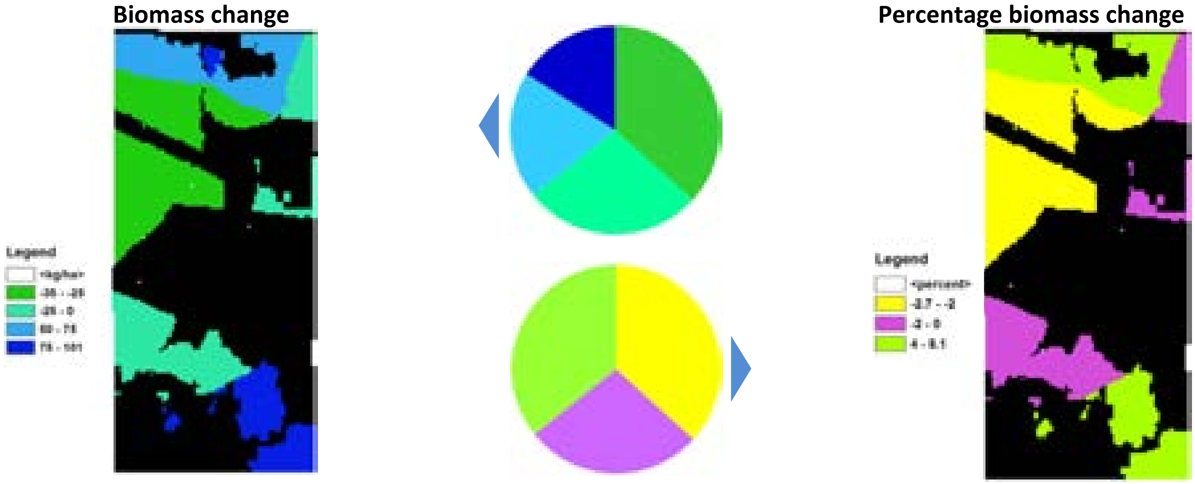




Under minimum tillage

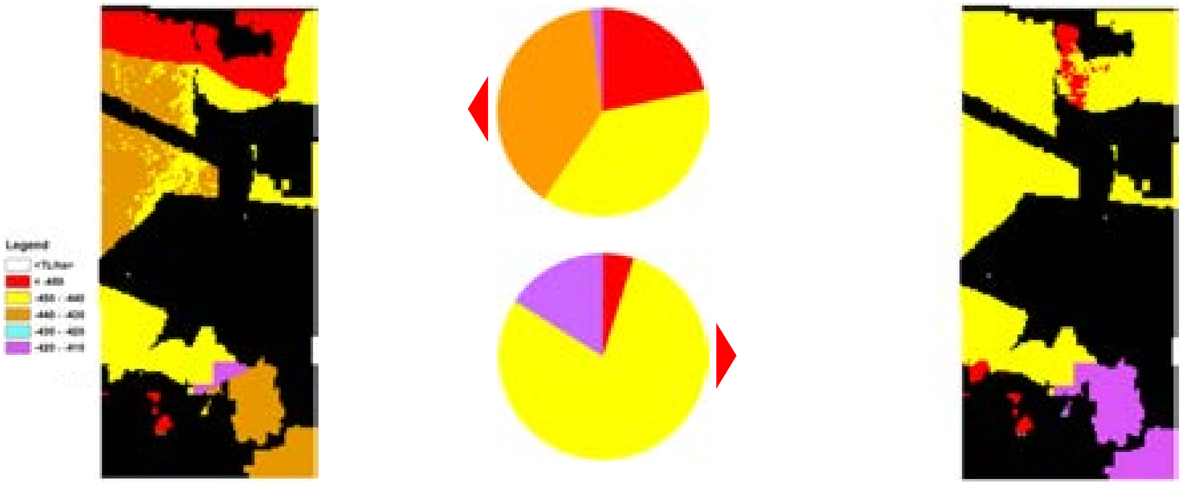
Biophysical impact: change in biomass

Biomass change | **Percentage biomass change**



Economic viability

Net profit under traditional ploughing | **Net profit under minimum tillage**



Minimum tillage has mixed effects on biomass production: in about a third of the applicable area it leads to yield increases of 4-8%, in the remaining area it leads to yield reductions of 0-3%. These differences are mostly due to differences in soil type. As the cost of minimum tillage does not differ from traditional ploughing, the effect on net profit is either slightly positive or slightly negative, but under the assumptions made cereal farming is not profitable in either case.

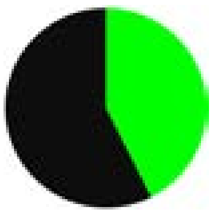
Karapinar, Turkey

Technology Scenario:
Stubble fallowing

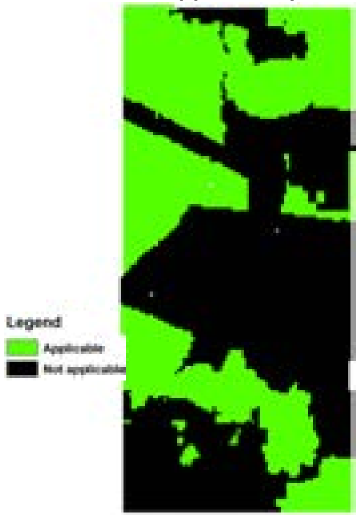
- Total operation costs under different practices:
  - traditional ploughing 736 TL/ha (€298)
  - stubble fallowing 736 TL/ha (€298)
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The price of grains is 0.5 TL/kg (€0.20)

Applicability

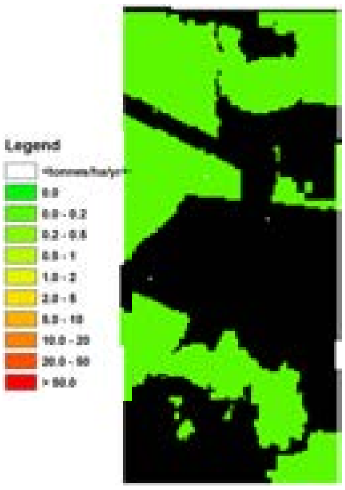
- The technology is applicable on arable land.



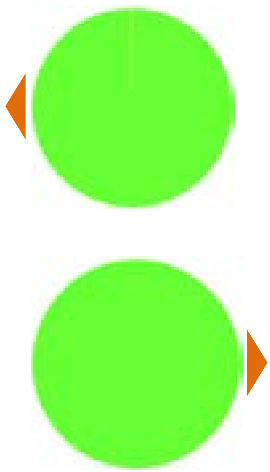
Applicability

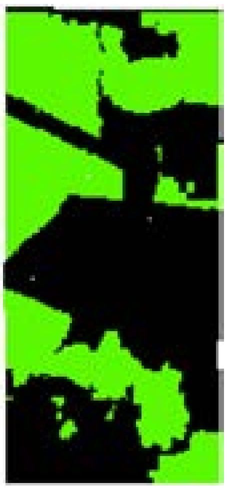


Biophysical impact: soil erosion



Under traditional ploughing

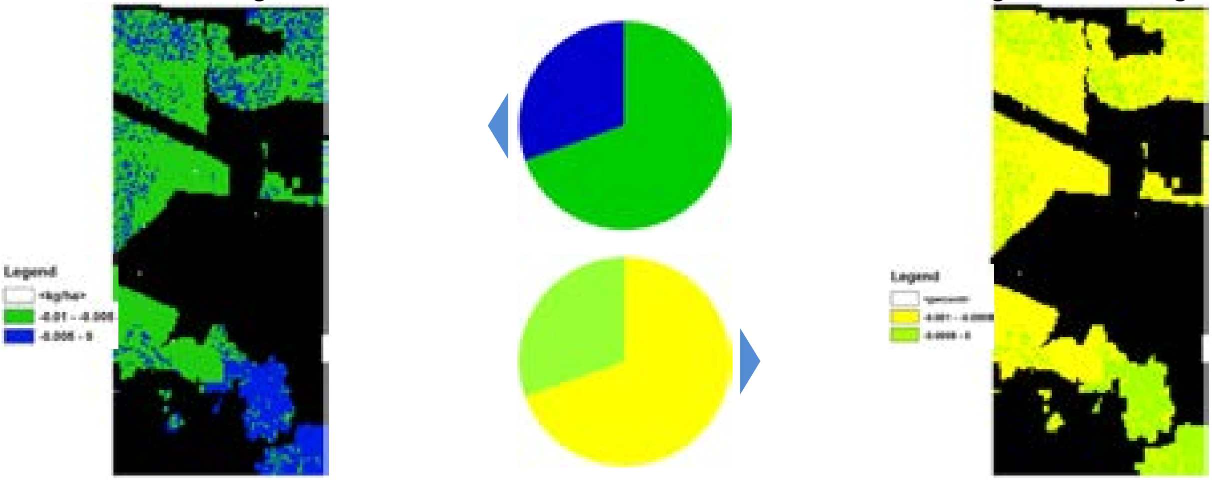




Under stubble fallowing

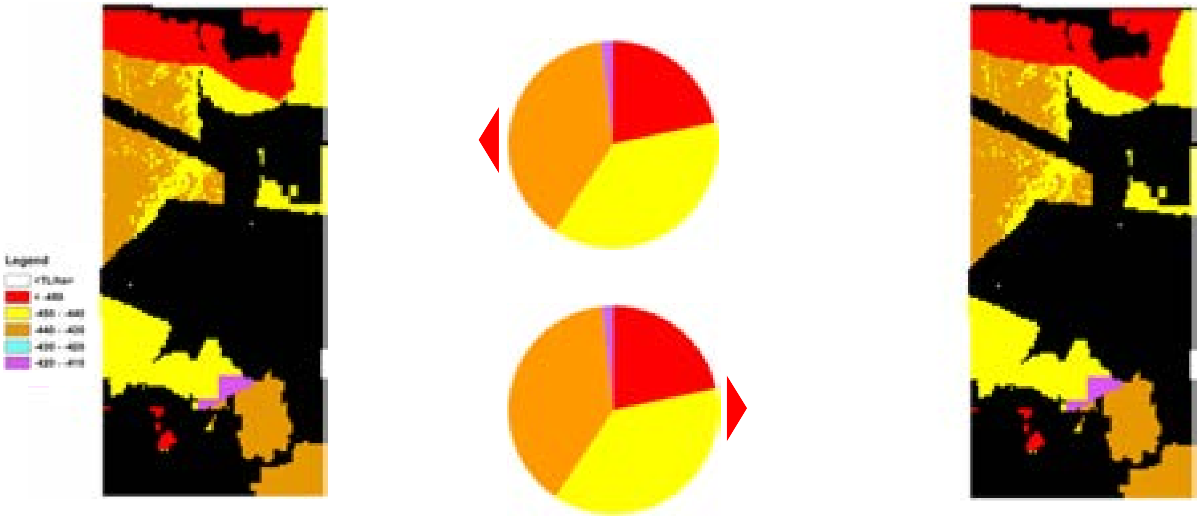
Biophysical impact: change in biomass

Biomass change | **Percentage biomass change**



Economic viabilit

Net profit under traditional ploughing | **Net profit under stubble fallowing**



Stubble fallowing has an insignificant effect on biomass production. As operational costs are not different from traditional ploughing, the economic viability of cereal farming is not altered (i.e. net profits remain negative).

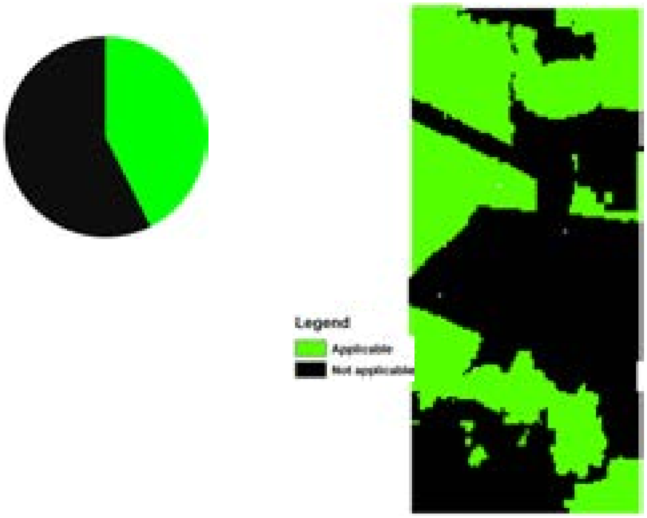
Karapinar, Turkey

Technology Scenario:
Ploughed stubble fallowing

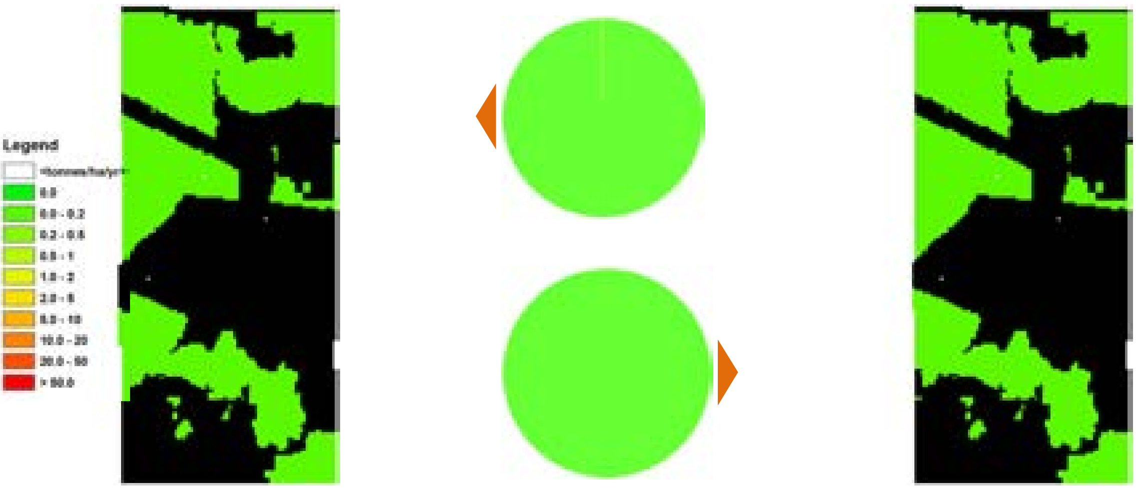
- Total operation costs under different practices:
  - traditional ploughing 736 TL/ha (€298)
  - ploughed stubble fallowing 736 TL/ha (€298)
- The above operation costs include renting of equipment to implement each practice
- A harvest index for grains of 45% of total biomass was assumed
- The price of grains is 0.5 TL/kg (€0.20)

Applicability

- The technology is applicable on arable land.



Biophysical impact: soil erosion



Under traditional ploughing

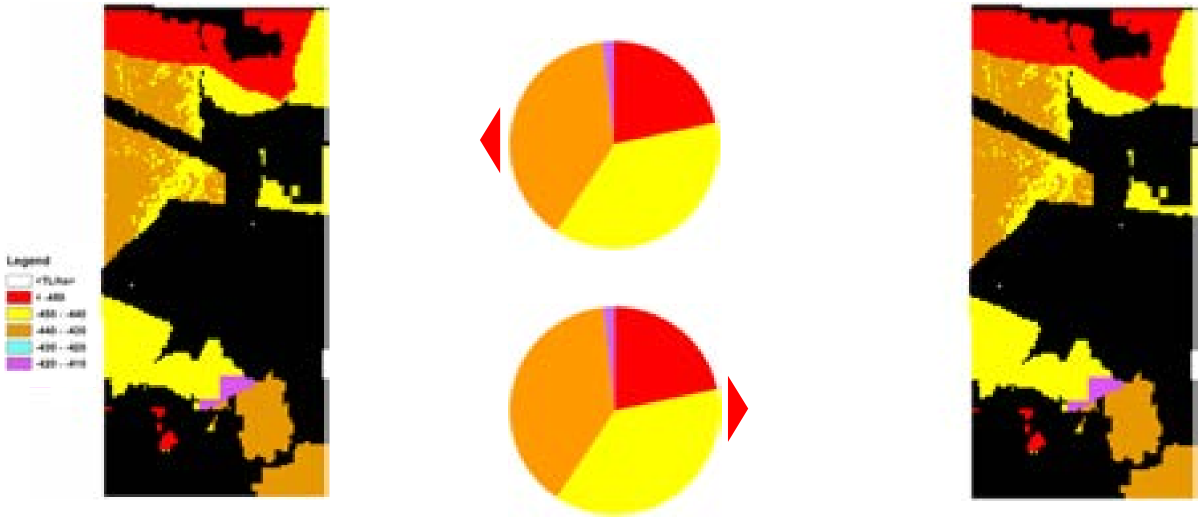
Under ploughed stubble fallowing

Biophysical impact: change in biomass

There is no difference in biomass production between under baseline scenario and under ploughed stubble fallowing.

Economic viability

Net profit under traditional ploughing **Net profit under ploughed stubble fallowing**



Ploughed stubble fallowing has no effect on biomass production. As operational costs are not different from traditional ploughing, the economic viability of cereal farming is not altered (i.e. net profits remain negative).

Karapinar, Turkey

Global Scenario:
Food production

The food production scenario selects the technology with the highest agricultural productivity (biomass) for each cell where a higher productivity than in the baseline scenario is achieved. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

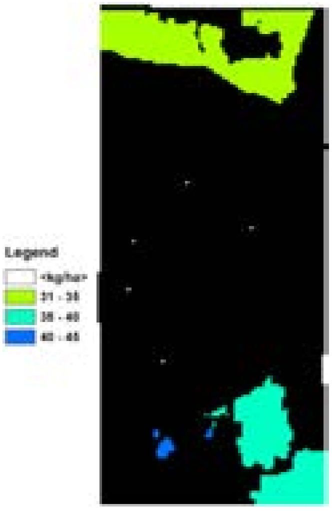
+ 34kg/ha

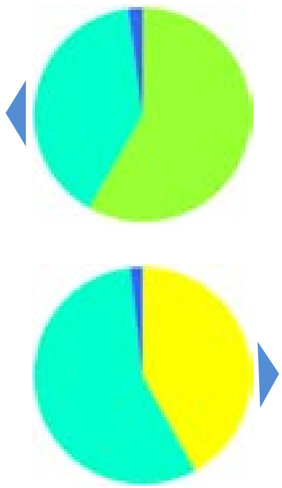
+? kg/inhabitant

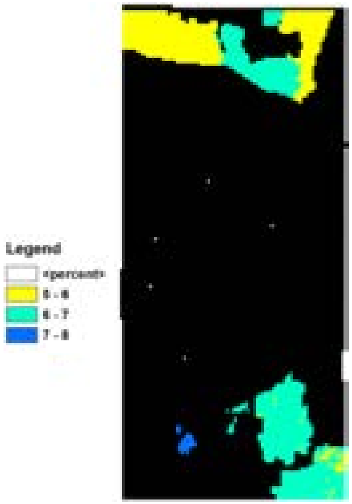
Scope for increased production

Yield increase

Percentage yield increase







Biophysical impact: yield difference

- The implementation of the technologies would see yield increase in 36% of applicable area
- Average absolute yield increase: 34 kg/ha
- Average yield increase: 6%

Economic indicators

Average costs:

- Extra operational cost: €0/ha/yr
- Unitary cost: €0/ton

Aggregate indicators:

- Study site: €0
- Augmented annual production: 81 ton

Karapinar, Turkey

Global Scenario:
Minimizing land degradation

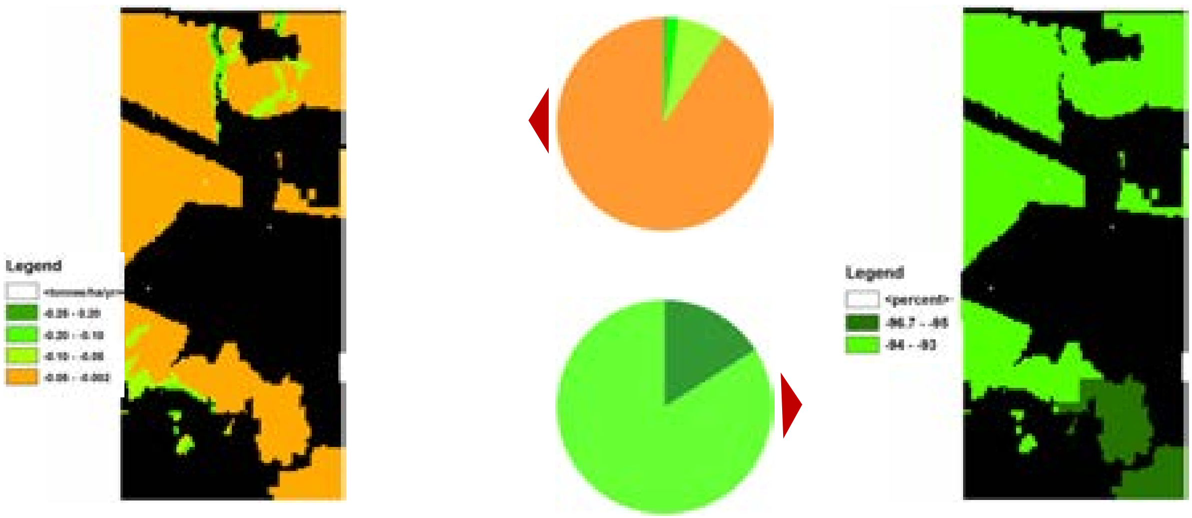
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed. To facilitate comparison between different study sites, all costs are expressed in Euro.

- 0.03 ton soil/ha

€0/ton soil

Scope for reduced erosion

Reduction of erosion (negative values) **Percentage of erosion reduction (negative values)**



Biophysical impact: erosion reduction

- Reduction of erosion in 100% of applicable area
- Average absolute erosion reduction: 0.03 tonnes/ha/yr
- Average percent erosion reduction: 94%

Economic indicators

Average costs:

- Extra operational cost: €0/ha/yr
- Unitary cost: €0/ton soil

Aggregate indicators:

- Study site: €0
- Aggregate annual erosion reduction: 190 ton

Karapinar, Turkey

Concluding remarks

- Baseline simulations show that the study site experiences low erosion rates, but this might be misleading as the erosion level scale may be more appropriate for water than for wind erosion, which constitutes the dominant degradation process in Karapinar. According to degradation mapping by experts, arable land experiences light to moderate degrees of land degradation by loss of topsoil through wind erosion.
- The technologies simulated are the technologies for which field experiments were conducted. The field experiments concentrated on biophysical indicators in a strip cropping set up which is thought to mitigate wind erosion. Minimum tillage rather than no-till was implemented, together with stubble farming and ploughed stubble farming. Hence, experiments concentrated on variants of no-till technology which was prioritised by local stakeholders to address wind erosion problems. The technology scenarios show reductions in soil erosion and limited effect on biomass production, although soil erosion reductions were small in absolute terms relative to the scale of erosion levels used in presenting maps. Effects on biomass were positive (4-8%) for minimum tillage in part of the applicability area (one soil type). Although the technologies requires no additional costs, their limited effects on biomass production mean that economic viability of arable farming is, under the assumptions made, nowhere improved.
- Evaluating the results in a workshop, stakeholders ranked the three tested technologies in the order stubble fallowing, ploughed stubble fallowing, and minimum tillage. The down-ranking of minimum tillage was a consequence of disappointing yield levels – an observation not confirmed by modelling results. The most significant concern about all technologies was that it requires fallowing, which local stakeholders regarded as having an important opportunity cost. Notwithstanding, the model analyses deemed returns to traditional ploughing very negative. The assumptions made (e.g. about labour costs, or agricultural management operations and inputs applied) were derived from experimental plots and resulting costs may have been too high in relation to the average farm(er) conditions. Despite of this, participants stressed the need for government subsidies to promote the technologies, which does support that land users are aware of the fact that profitability is an issue.
- The global scenarios show that the technologies can achieve significant relative erosion reductions (94%) across the entire applicability area, despite the fact that erosion levels are already quite low. Yield effects are more limited, with a 6% increase possible on 36% of the applicability area. The average yield increase is 34 kg/ha/yr and the average erosion reduction 0.03 ton/ha/yr, at no additional cost.
- From an ecological point of view, all technologies are effective to reduce soil erosion. Effects on biomass and yield levels are relatively small and experimental and modelling results do not fully support each other. The main obstacle for adoption of the technologies is their economic viability, especially if conventional ploughing can be implemented without fallowing and the technologies require fallowing. There is little risk in applying the technologies and stakeholders realise that when water becomes scarcer and more expensive in the future, fallowing can become an increasingly viable strategy. Further confirmation of the (economic) effects is necessary before any of the technologies can be recommended. Given that subsidies are said to be required, it would be important to consider the off-site costs and benefits due to wind erosion in the area.

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