DESIRE REPORT series

Compilation of site implementation plans and a list of available data

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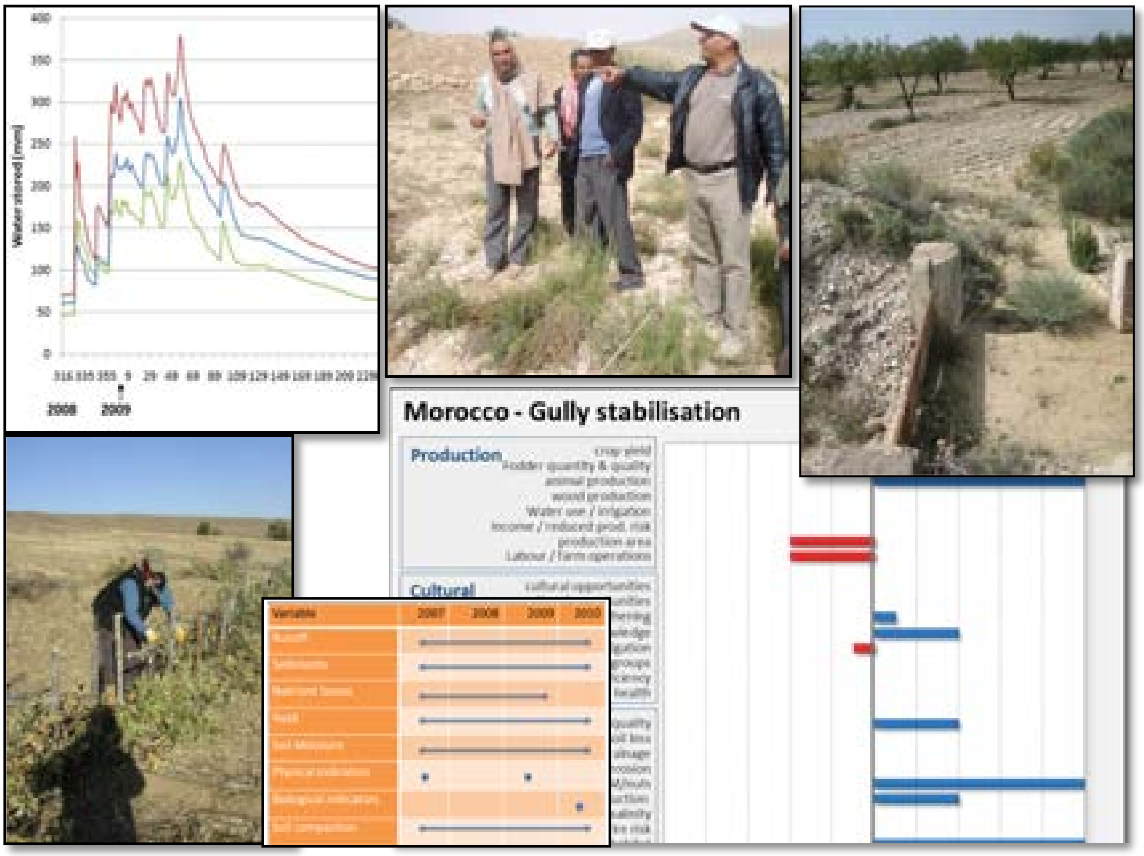
WB4 - Implementation of conservation technologies at stakeholder level

Results of field experiments



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Contents

1. IMPLEMENTATION OF CONSERVATION TECHNOLOGIES AT STAKEHOLDER LEVEL

This report is the deliverable 4.3.1 of Work Package 4.3 of the DEISRE project: the results of the field experiments of conservation technologies. This document contains the summary reports of each site and experiments. More extensive technical results are given in a separate report: the annex to deliverable 4.3.1.

1.1 MAIN OBJECTIVES

The objective of this part of the project (Workblock 4) is to test the effectiveness of the conservation and mitigation measures selected by the stakeholders in an interactive series of meetings following the WOCAT system (Workblock 3).

These technologies have two main goals: mitigate the biophysical problems form desertification processes, and at the same time improving the situation/livelihood for the stakeholders. While the first goal is needed to avoid further environmental degradation, the second is imparative to make a technology acceptable. One cannot do without the other. This immediately results in the following 'boundary conditions':

- The experiments must be directly visible and executed on a stakeholder level (field scale);
- The results, good or bad, must be made clear both as scientific analysis, and also translated for non-experts;
- Stakeholders will not gamble with their income, so the technologies chosen are 'proven' technologies and while new to the area, they are in most cases not innovative.

Based on their personal situations and the available experience and knowledge of themselves and the scientific tems, stakeholders selected between 1 and 3 conservation technologies to implement in their area. One or more farmers were willing to host a series of field trials. These trials were designed as much as possible as a comparative study: two or more adjacent fields or plots where usual farm practices are compared to a conservation technology. There are variations on the theme: for some desertification situations some situations do not warrant such a set up, such as forest fires, testing a biogass installation, or rangeland resting for instance.

The experiments were done accoding to Site Implementation Plans (SIP), which are described in deliverable 4.1.1 of this project. The SIPs were made to ensure a homogenation of the trials so that results are comparable as much as possible. This was followed by a period of 2 – 3 years of monitoring on each site. The *effectiveness* of the expeirments can be approached from two viewpoints:

1) the bio-physical scientific viewpoint: how are desertification processes altered by the experiment and what does that imply for desertification as an environmental problem. Conclusions of this are based on the experimental measurements, monitoring activities and (in part) on the experience of the scientific teams.
2) the stakeholder viewpoint: how are the technology *evaluated* by the stakeholders in terms of their personal and local context. Conclusions are based on an extensive questionnaire where changes brought about by these experiments are evaluated from an economical, socio-cultural

and also bio-physical viewpoint. Also pertinent remarks about the results are taken into consideration.

This procedure is described in more detail below. Because the understanding of the area is a major pre-requisite of the analysis, we chose from the beginning sites that were already under investigation by the coordination teams in ongoing research activities and previous projects. This strategy has paid of: the conclusions and context of the experiments are often of major importance and that insight would not have been achieved if new 'virgin' sites would have been chosen.

In order to integrate the results better in existing methodologies the experiments are closely related to the WOCAT system: World Overview of Conservation Approaches and Technologies (http://www.wocat.net). In this context, Workblock 4 focusses on the monitoring and evaluation of SLM *technologies*, defined as "agronomic, vegetative, structural and management measures that prevent, mitigate or rehabilitate land degradation and enhance productivity in the field". Technologies are embedded in wider strategies of implementation called *approaches,* defined as "ways and means of support that help to introduce, implement, adapt and apply soil and water conservation technologies on the ground". The emphasis in this report is on the technology level, although where possible important factors to be taken into consideration on an approach level are mentioned where possible.

1.2 BRIEF OVERVIEW OF DESERTIFICATION PROBLEMS

Table 1 gives an overview of the desertification problems and the locations that are investigated, summarized in one sentence. More detailed information about the sites can be found on the HIS (www.desire-his.eu). The majority of sites have a problem with soil rosion by water and drought. While erosion is more a long term problem, associate by the stakeholder to a slow loss of fertile soil leading to a decline in yield and yield quality, drought is a much more acute problem. It is experienced often and leading to harvest failure or decrease of grazing capavcity. Technical solutions such as irrigation systems do not always work or are applied wrongly (Nestos basin, Russian sites), causing water logging, salinization and even erosion my excessive surface irrigation leading to runoff.

Most sites with erosion concentrate on interfering with runoff (countour tillage), making flow barriers or terrace like structures (Turkey, Cape Verde, China), or protecting the surface with mulch (Spain, Crete, Morroco). Most sites with drought problems concentrate on water harvesting techniques, sometimes using or reviving traditional methods (Spain, Tunesia). Others try new solutions such as collection of snow melt (Russia), minimum tillage (Morocco, Chile), collection ditches (Chile, China). Agronomic measures such as intercropping and alternative crop types are tested in Spain, Chili, Cape Verde and to some extent in Mexico. In Mexico a change to Agave production was adopted late because of a lifting of trade restrictions between Mexico and the US (apart from civil unrest in the area), so a full reporting on these changes is not yet not possible.

Nr	Site	Desertification processes
1	Spain - Guadalentin Basin, Murcia	Drought, Soil erosion by water
2a,b	Portugal –Mação & Gois	Forest fires, vegetation degradation, soil erosion
3	Italy - Rendina Basin(*, Basilicata	Soil erosion by water, dam siltation
4a,b	Greece - Crete	Soil erosion by water, overgrazing
5	Greece - Nestos Basin, Maggana	Salinisation, irrigation problems
6	Turkey - Konya Karapinar Plain	Soil erosion by wind, drought, grazing problems
7	Turkey - Eskisehir Plain	Soil erosion by water
8a,b	Morocco - Mamora/Sehoul	Soil erosion by water, gullying, drought
9	Tunesia - Zeuss-Koutine	Drought, competition for scarce water resources, rangeland degradation
10	Russia - Djanybek	Water logging caused by over irrigation, salinization in depressions
11	Russia - Novij, Saratov	Water logging and leaching of chemicals, caused by over irrigation, erosion caused by flow irrigation
12	China - Loess Plateau	Soil erosion by water
13	Botswana - Boteti Area	Fuelwood depletion causing envir. degradation
14	Mexico - Cointzio catchment	Soil erosion by water, dam siltation.
15	Chili - Secano Interior	Fertility and mono culture leqading to envir. Degradation, soil erosion by water, gullying
16	Cape Verde - Santiago Island	Soil erosion, drought, flash floods, dam siltation.

Table 1. Brief descriptions of the bio-physical aspects of desertification on the sites. For more information see: www.desire-his.eu. Note that the numbering is not logical, but in line with the original project Description of Work, and maintained throughout the project. *) *site 3 (Italy) did not contribute directly to WB4 because the stakeholders did not cooperate and technology trials were not done, instead this site contributed to WB2 (designing new indicators) and WB5 (large scale analysis).*

2. WB4 STRATEGY AND IMPLEMENTATION

The Workblock 4 implementation follows a strategy that aims to create some unity in a wide range of bio-physical and socio-economic settings, This consists of 5 phases:

1) Selection of suitable SLM rechnologies in workblock 3, and collection of background data, information from previous experiments and general site information.

2) Design phase (W 4.1): each study site makes a detailed *Site Implementation Plan* (SIP) according to a general blueprint provided by the WB coordinator (partner 21). The SIP provides a summary of the situation on the monitoring locations, followed by a practical implementation of the SLM technologies, a detailed monitoring activity plan divided in several categories. The compiled SIPs are the subject of this report, deliverable 4.1.1.

3) Implementation phase (WP 4.2): each study site collects background data and implements the SLM technologies. During the implementation practical adaptations were sometimes made by the site coordination tem in discussion with the stakeholders, to better fit the circumstances. This happened without ajor deviations from the original plans. This happened in site 6 (Turkey, Eskeshir area) where sloping terraces with vegetation barriers were created, instead of fully constructed level terraces. Also in site 8, Morocco, olive plantations were not realized because the long term investment could not be met. Instead gully stabilisation with planting of natural vegetation was done.

A) General: Location of the monitoring plots B) Summary: Brief summary of the problems at this particular location and the SLM technologies chosen, based on the site descriptions and summary of the WB3 outcome C) Location description: coordinates; Google Earth picture if applicable; brief overview of environmental setting (soil types, relief, climate); photo's of the plot/field location D) Stakeholder info if applicable: name, level of technology applied on this location E) Land use: crops, rotation, tillage practices, grazing practice etc. F) Conservation measures and experimental setup: short description of SLM technologies, experimental setup, plot layout, situation map/sketch G) Monitoring activities: a. Climate/rainfall monitoring details b. One time measurements (usually environmental, topography etc) c. Repeated visual monitoring supported by digital photography (soil cover, structure, tillage activities, erosion traces etc) d. Repeated measurements (instrumental monitoring and logging) e. Stakeholder activities (tillage activities) H) Yield assessment or assessment of other returns (quantity, quality), general stakeholder appraisal.

Table 2. Information in the Site Implementation Plan, layout and sections (see deliverable 4.1.1)

4) Monitoring phase (WP 4.3): each site reports regularly based on the variables and situations described in the SIP. To help in deciding which monitoring techniques to apply, a document was compiled called "Guidelines for field assessment" (deliverable 4.2.1). The monitoring can be categorized into several types of monitoring: meteo data, one time measurements, regular observations and photos, regular measurements with equipment or sampling, stakeholder activities and yield analysis. An noverview of measurement and monitoring equipment is given in deliverable 4.1.1.

5) Analysis (WP 4.4/4.5): the analysis is done on various levels. The experimental setup provides for a "non-treated" field or plot against which the effect of the technologies is compared. *Bio-physical analysis* is done by direct data analysis and statistics. Socio-economic analysis is done by means of an extensive questionnaire fomr the WOCAT system (explained below).

3. Overview of SLM technologies in DESIRE

In this WP the field trials (experiments) are carried out for a period of 2-3 years. Table 4 gives an overview of the experiments, organized according to similarity and intended function. In total there are in 33 experiments, on 16 locations. Some of these are directly comparable because the same technology is done on more than one site, others are grouped based on a similarity of what they aim to achieve. This leads to 7 groups of which the experiments are compared (see table 3).

Many experiments serve a dual purpose, such as runoff control that increases infiltration and therefore increases water availability, gully planting with fodder type species, or crop rotation to promote fertility and soil cover. Often one of these purposes has a more agronomic context (promoting a higher yield) while the other combats a desertification process.

The only site not included in WB4 is Italy, as the farmers refused to cooperate. This site has focused from an early stage in the project on other results related to WB2 (new indicators related to sediment delivery and shallow landslides) and WB5 (large scale modeling).

#	Functional group	Description	Sites
1	Minimum Tillage	Minimum and no tillage experiments with and without additional agronomic operations such as herbicide control and deep ploughing	Spain, Chile, Morocco, Greece (Crete), Turkey (Karapinar)
2	Soil cover management	Mulch and stubble mulch, Green cover and green manure, crop rotation and intercropping to promote cover and have additional production	Greece (Crete), Spain, Turkey (Karapinar), Chile, Mexico
3	Runoff control	Contour ploughing and runoff barriers (wicker fences), gabions in gullies. Terracing also controls runoff but these are grouped under water harvesting,	Turkey (Eskesehir), Cape Verde, Spain
4	Water harvesting	Runoff water harvesting systems with and without terraces, bench terraces and check dams	Spain, Tunisia, China, Cape Verde
5	Irrigation management	Fresh water irrigation and drip irrigation for salinity control	Greece (Nestos), Russia (Dzhanybek, Novy)
6	Rangeland management	Fencing and set aside of rangeland, also gully control with fodder species, also biogas to conserve fuelwood.	Morocco, Tunisia, Botswana
7	Forest fire management	Techniques to combat forest fire	Portugal

Table 3. Experiments organized in functional groups, according to their intended effect on desertification processes.

		1	2			3		4			5		6			7
Site number		Minimum tillage	Mulch / residue /stubble	Green cover	Rotation/crop type	Contour ploughing	Woven fences/runoff control	Water harvesting	Terrace (bench)	Check dams	Fresh water irrigation	Drip irrigation	Gully control/Fodder	Rangeland management	Biogas	Fire break/prescribed burning
1	Spain	***X***	***X***	***X***		***X***		***X***								
2	Portugal															***XX***
4	Greece Crete	***X1***		***X1***										***X***		
5	Greece Nestos										***X***					
6	Turkey Karapinar	***X***	***X***													
7	Turkey-Eskisehir					***X***	***X***									
8	Morocco	***X1***	***X1***										***X***			
9	Tunisia							***XX***						***X***		
10	Russia Dzhanybek											***X***				
11	Russia-Novy											***X***				
12	China								***X***	***X***						
13	Botswana														***X***	
14	Mexico	***X***			***X***								***X***			
17	Chile	***X***			***X***	***X***	***X***									
18	Cape Verde						***X1***		***X1***							

Table 4. WB4 experiments grouped according to similkarity of purpose. (1) Minimum tillage; (2) Soil cover management; (3) Runoff control; (4) Water harvesting; (5) Irrigation management; (6) Rangeland management and fodder production; (7) Forest fire management.

4. ANALYSIS STRATEGY

4.1 BIO-PHYSICAL ANALYSIS

The monitoring strategy in WB4 allows a direct comparison with (normalized) timeseries of for instance soil moisture or sediment loss. Variables are generally soil physics related (moisture related) or chemistry related (fertility and salinity). Crop yields are measured for for arable farming and vegetation density and quality are measured for rangeland type environments. Also the sites that focus on a catchment level (such as the forest fire analysis in Portugal) will use catchment results to draw conclusions.

More extensive reports about the experiments are given in the annex of Deliverable 4.3.1. which is a separate report in the DESIRE project.

4.2 SOCIO-ECONOMIC ANALYSIS

Bio-physical effects only make sense within the context of a site. An increase of 30 mm of soil moisture per year may be significant in one setting where for instance the grazing capacity and fodder quality is increased, but not enough in another setting which depends on certain crops. This depends on many specific details, environmental, economic and socio-cultural.

The WOCAT system provides the users with a questionnaire to evaluate a technology (QT): http://www.wocat.net/en/methods/case-study-assessment-qtqa/questionnaires.html. QT addresses the following questions: what are the specifications of the Technology, where is it used (natural and human environment), and what impact does it have. The last section (QT chapter 3 - impact), is used in WB4 to evaluate the experiments. The WOCAT QT follows the logic that a technology is compared to an untreated reference situation. By means of a large series of questions the benefits and disadvantages with respect to the 0-situation are appraised. These effects are evaluated in 4 levels of change: 0-5%; 5-20%; 20-50% and >50% (decrease or increase). This is done in 4 classes for positive and 4 classes for negative effects: production & socio-economic, socio-cultural ecological and off-site effects. In total there are therefore 8 tables. Figure 2 shows a fraction of such a table.

These lists were used to create 59 questions that can be scored as positive or negative (for instance: ‘increase in crop yield’ and ‘decrease in crop yield’ becomes ‘crop yield’ that can be scored with +20 or for instance – 5. Then for the sake displaying the results into readable tables, some questions were grouped if they were related (see table 4).

The questionnaires were filled in by the site coordination themes, as many of the questions are very specific and require a specialist background, especially to quantify the level of change. However the teams had many discussions with the stakeholders during and after the experiments so we feel the evaluation is not biased towards one or the other experiment. IN several cases the results of the experiments were counterintuitive or disappointing, and this was noted objectively.

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Several answers possible	negligible (0-5%)	little (5-20%)	medium (20-50%)	high (>50%)	quantify (indicate unit) before conserv.	quantify (indicate unit) after conserva.	specify / comments
3.1.1.2 Socio-cultural benefits							
improved cultural opportunities (eg spiritual, aesthetic, others)	☐	☐	☐	☐	....	....	....
increased recreational opportunities	☐	☐	☐	☐	....	....	....
community institution strengthening	☐	☐	☐	☐	....	....	....
national institution strengthening	☐	☐	☐	☐	....	....	....
improved conservation / erosion knowledge	☐	☐	☐	☐	....	....	....
conflict mitigation	☐	☐	☐	☐	....	....	....

Figure 2. Extract of WOCAT technology questionnaire table

Production & Socio-economic	**Ecological**
crop yield	water availability /quality
fodder quantity & quality	*runoff and soil loss*
animal production	*groundwater recharge & drainage*
wood production	*wind erosion*
water use / irrigation	*plant cover/ biomass/ om/nuts*
income / reduced producrion risk	crusting and compaction reduction
production area	*reduced salinity*
labour / farm operations	*reduced fire risk*
	biodiversity and habitat
Socio-cultural	**off site**
cultural opportunities	*water availability*
recreational opportunities	*reduced flooding*
community strengthening	*stream discharge*
conservation knowledge	*reduced downstream siltation*
conflict mitigation	*reduced groundwater / river pollution*
situation disadvantaged groups	*buffering capacity*
food security/self sufficiency	*reduced wind transpored sediments*
health	*reduced damage neighbour fields*
	reduced damage infrastructure
	reduced grazing other areas

Table 4. Final set of factors used to summarize the answers to the questionnaires.

5. Conclusions for each technology

Because a large amount of data is collected on each site and we have both the bio-physical and evaluation results for each experiment, a 3-5 page summary is given per technology. These summary sheets are styled in a way that they can be read by non-experts, to improve their usefulness and go beyond the immediate scientific results. In other words, the real results are summarized as well as the evaluation form the EOCAT questionnaire, these are put in to context of the site's problems and conclusions are drawn with respect to the possibilities of implementation on larger scale and the degree of success. These summary statements are based booth on the scientific results but also on discussions with stakeholders held by the site coordinators.

Since the order in which the results are presented is always according to the initial list and order of the sites, this order is maintained here. In **deliverable 4.5.1** where the countries are compared this order is changed and areas with a similar desertification context are grouped and compared.

These summary sheets are organized as follows:

Country	Experiment	Conclusions
1a Spain Guadalentin	Water Harvesting	The traditional water harvesting technique does not necessarily improve soil moisture but the crops with shallow root system benefit the high water availability which will increase crop yield. Mulching does not increase soil moisture in very dry environment. It is not profitable and not liked by the farmers. Additional funds should be available to construct and maintain the traditional *boquera* system of water harvesting. Not all farmers have access to a functioning system so for a large scale application considerable investments would be needed.
1b Spain Guadalentin	Reduced tillage	Reduced tillage reduces soil loss (56%) and water loss (30%) as compared to conventional tillage. After the relatively short period (2 years) of monitoring with only 1 harvest, no effect was observed on cereal yield. This may be different after more years of monitoring. Nevertheless, even if yield is not affected by this treatment, a higher benefit was achieved because of lower operational costs under reduced tillage. Longer term monitoring is still required since most soil and water loss occurred during the low frequency high intensity events. The results show that there are various opportunities to increase economic benefits and at the same time provide increased ecological services by protecting and maintaining soil and water resources under rainfed agriculture in semi-arid conditions. For these reasons, these measures have a relatively high level of acceptance amongst stakeholders.
1c Spain Guadalentin	Green Manure	Reduced tillage reduced soil and water loss, but yield was not increased, at least not after 2 years of monitoring. Nevertheless, operation costs are lower, so if the yield is maintained at least at the same level there is an economic benefit compared to conventional treatment. These results also show that erosion under reduced tillage and green manure treatment was reduced on average by about 60% as compared to a conventional tillage regime.

		Green manure proved to be effective and feasible in reducing soil and water loss while increasing almond production. Since operation costs do not significantly increase, the profit is also higher than under conventional production.
2a Portugal Macao	Fire Corridors	Forest fire prevention using strip network is a useful technique but it can cause increased runoff and soil losses since the area along the strips will be bare and exposed to erosive rain. Villagers were very interesting in the technique and will attempt to maintain the strips themselves. Currently the main infrastructure is protected but not the side roads. Possibly the strip network will extend to those ass well. Where trees are cut at the strip there is a risk of erosion. Sediment loss from the strip area depends on tree species and terrain slope gradient. The erosion risk appears to be relatively low. Due to the testing activities, the erosion risk is now better integrated into the strip construction. Due to high implementation and maintenance costs, this technology requires the full support from public entities (as well as specific technology capacity).
2b Portugal Gois	Prescribed burning	Prescribed burning is increasingly used as a tool for landscape management, in order to increase diversity and reduce forest fire risk. To perform prescribed burning, one has to get approved in a special fire management course, the means to perform it are only possible with the involvement of local authorities, which became involved in the Vale Torto experimental fire. The stakeholders were responsible for getting all the permits and perform the prescribed burning. They followed up the recovery of the burn area. involved The Benefits are the improvement of pastures for grazing and the reduction of forest fire risk. Prescribed fire is probably the most cost effective technique for landscape management, it is an old practice that was forbidden during 60 years, and therefore has the adherence of local stakeholders. We expect a reduction on fire frequency and the diversification of local economy due to an increasing on grazing, bee keeping, cheese production, etc.
4a Greece Crete	Reduced tillage	The application of the appropriate land management practice can greatly affects land protection and reduction in runoff and erosion, consistently over the two years. The experiment shows that the no tillage – no herbicides land management results in minimizing sediment loss due to low surface runoff. Added ecological effects are higher soil water storage, lowering soil temperature, higher biodiversity. This is confirmed by a longer experience in the area and results from previous studies. Several stakeholders have accepted this type of land management practice due to low olive oil price. It may be if the olive price rises, a reversion to traditional tillage is seen because farmers want to minimize production risk. There are clear economic benefits as the reduced tillage reduces labour and fuel costs. An important bottleneck is the lack of knowledge transfer by

		the Greek Ministry of Agriculture on new sustainable land management practices and decreasing cost production.
4b Greece Crete	Rangeland resting	The experiment shows that the sustainable grazing results in minimizing surface runoff and sediment loss by more than half of that in the overgrazed areas. Sustainable grazing results in increasing plant cover and biodiversity, higher soil organic matter content and higher soil water storage. This shows that soil loss in this case is not only about sediment dynamics (the losses are actually small in absolute values), but these thin and fragile soils are an important part of natural ecosystem. The main bottleneck is the reduction of farm income due to reduced number of grazing animals. Currently the farmers receive EU subsidy based on the number of animals they have. The policy of farm subsidy has to be changed if the SLM technology has to be successfully implemented. Also funds should be made available to compensate for the reduction of animals. In this case conservation would mean providing an alternative means of income or some form of compensation, i.e. changing the subsidy from heads of lifestock to nature conservation.
5 Greece Nestos	Irrigation with fresh water	Irrigation with fresh water shows an immediate positive result in both soil degradation indicators as well as in crop yield, and fresh water technology is popular and ready to be accepted in principle. However the cost of installing the irrigation systems is too high for the farmers at the moment. Moreover, the fresh water wells are maybe not a solution in the long run. Heavy use of this water might well induce a further encroachment of saline sea water further inland. This leaves the water of the river Nestos system, but it is not clear if the river system can handle such an increased use of its freshwater and how this will affect the surrounding area.
6 Turkey karapinar	Minimum tillage and stubble mulching	Minimum tillage and stubble fallowing have clear advantages in terms of yield parameters of the Ekiz bread wheat in Karapınar hotspot. Minimum tillage particularly positively affects the sprouting intensity but not the branching number. The variations in yield parameters are probably explained in terms of removal of nutrient topsoil by wind erosion. It seems that minimum tillage and stubble fallowing decrease the shear stress of the wind and hence reduce the wind erosion. Contrary to vegetative parameters, the harvested product (both for grains and straw) is the maximum in stubble farming followed by ploughed stubble farming. Basic obstacles against the wider application of technologies are considered the lack of specialised machinery and required knowledge for minimum tillage and the decrease of net income due to fallowed parcel each year.
7 Turkey Eskeshir	Runoff barriers with woven fences	Contour ploughing and terracing seems to have a slight increase in top soil moisture due to reduced runoff but this depends on the seasonal rainfall. The technology helps in improving soil condition and crop growth as well as increased yield benefits. The yields over two years were much higher in the experiments than in the control plot, even while the rainfall was very different between the years.

		Regarding relatively smaller costs involved in contour ploughing, the technology is applicable in wider hill slope areas of semi-arid Central Anatolia. The levees with fences were considered less advantageous because of initial costs and loss of agricultural area, for little gain. Main bottleneck for the easy application of technologies seems sociological (lack of enough young farmers) and economic (prices etc.) rather than scientific.
8a Morocco Mamora Plateau	Gully Stabilisation	On a small scale the experiments are successful. The area is degraded in places but apparently a natural restoration seems possible when the areas are protected from grazing, at least temporarily. There are indications of a decrease in erosion while at the same time the fodder quality and quantity increases. Thus it can be beneficial for farmers. On the long run a further stabilization of the slopes is expected. This positive effect is off-set by a large initial investment in time, labour and money. This would make a large scale adaptation of this measure impossible, and fencing areas that are otherwise open for grazing may have also social and cultural implications. Also initially the area is set aside causing a decrease of grazing land of a few years. A viable approach could be to establish several of these experiments in strategic and visible locations both to combat erosion and to promote acceptance and increase understanding. A long term effect of a larger availability of fodder might be that a reduction in pressure on other ecosystems, such as the forested areas that are now overgrazed.
8b Morocco Mamora Plateau	Minimum tillage	The experiment does not give clear results yet. The increase in yield may be a result of the fencing, decreasing the grazing pressure. Also, minimum tillage as a conservation measure was not correct for this soil type: the stoniness hinders proper seed establishment. On a different soil type (also present in the area) the results might be better. As a positive effect a clear increase in water availability, especially deeper in the soil and later in the season, is observed. If no tillage can be done only with fencing this may be problematic. There are strong cultural objectives against fencing (apart from the costs). Traditionally there is free range grazing as a strategy for survival. The negative pressure on natural areas (forests) may actually increase when animals are excluded from some areas, while the better managed areas show a positive ecological effect(less runoff, better soils etc).
9a Tunesia Zeuss Koutin	Water harvesting traditional systems	The water harvesting technique increases farmer's income and it is very popular. The system is fragile and crop failure cannot be prevented without outside assistance in very dry years. A wider hydrological research is necessary to see how resilient the groundwater system is. The technology is well known by the local population but training is necessary for the younger generations to make them aware of the wider setting.

9b **Tunesia** **Zeuss Koutin**	Rangeland resting	The rangeland resting technology helps increase plant cover and plant biodiversity, especially in dryer years, as compared to conventional grazing land. In wetter years the degradation is less visible, so resting is especially beneficial for resilience: recovery in dry years. To make the technology successful and sustainable it has to be accepted by the people. It could mean change of grazing culture (planning of resting areas which is agreed upon by the community and adapting to less grazing areas. This needs management of the communal lands and in the beg7inning possibly extra subsidy for fodder.
10 **Russia** **Dzhanybek**	Drip Irrigation	In highly dry areas of Volgograd and Saratov Regions it is possible to cultivate tomatoes and other vegetables with drip irrigation method. The use of drip irrigation allows changing the cropping patterns that encourages land cultivation. Drip irrigation is very adaptable to the soil conditions and local sources of fresh water. It can be successfully used as at the small holdings so at farms of different type of ownership. Drip irrigation is more conservative in water use and increases water availability for households. Using drip irrigation, more productive appeared to be tomato sorts that are grown in the Volgograd Region, their productivity was up to 50-60 t/ha. Vegetables of these sorts were also the best according to biochemical analysis. The sweetest (sugar contents – 3.74%) was the Dar Zavolgia. Initial Investments to install drip irrigation systems are the main bottleneck.
11 **Russia** **Novy**	Drip Irrigation	The traditional furrow irrigation of vegetables is a technology with high and inefficient water use: about 20-30% of water is absorbed by roots of growing plants and about 70-80% is lost, causing erosion. This obviously has an impact on the environment. Drip irrigation technology improves the moisture regime and water availability in soil root zone by a permanent slow input that can be adjusted to seasonal and diurnal variation of water consumption of plants during growing season. Yields under both techniques are very similar. However, Additional funds should be available to purchase drip irrigation systems. Not all farmers have access to a functioning system so for a large scale application considerable investments would be needed. A special regional drip irrigation supporting program is needed as well as an environmental protection program. Furrow irrigation systems could be taxed and excluding from the list of subsidy of energy needed for water transportation. This subsidy could instead be used for installation of drip irrigation systems.
12 **China** **Loess** **Plateau**	Check dam and terraces	Combatting erosion is possible in many ways and especially interesting tomitigate problems downstream. Measures that drastically improve the onsite circumstances, such as terracces and checkdams are interesting because they xcreate flat land with favourable conditions. This is shown by substantially

		incerased yields. In fact rainfed agriculture with staple food crops on slopes is hardly profitable because of the low yields. However constructing and maintaining check dams and terraces is expensive. Since Cropland is in short supply (0.1 ha per capita) it is impossible for most people to do this themselves. Therefore they are interested but also regard is as something unobtainable. Many farmers find an income in other types of work such as road and building construction.
13 Botswana Boteti	Biogas to conserve fuel wood	The biogas is running well, and the results are beginning to show i.e. how much gas is generated from what quantity of cow dung or food waste. This will be the first time in Botswana, where exact performance measurements are done. The impact of the biogas, is too early to show, but schools, villagers – have all expressed interest, citing the limited energy sources as a major challenge. Interest ranged from using the gas for: cooking, powering a generator to produce electricity, to larger scale like providing energy for cooking i.e. to replace 19 truckloads that are needed every 3 weeks for each secondary school in the area. However, the uptake of the biogas technology in the country is quite an expensive enterprise. Limited trained personnel and service providers, remain key challenges. For the poor households, the starting capital of around €600 is too steep. This is despite biogas being a feasible energy source in other countries. Additional cheaper designs are researched.
14a Mexico Cointzio catchment	Crop rotation and minimum tillage	Minimum tillage, good ground cover, fertilization and organic residue incorporation are the key solutions to reduce soil erosion. To control free cattle grazing, the economic situation of the farmers has to be taken into account. Farmer’s involvement is possible if program brings money to do concrete actions. During the project, as the farmers were paid, they were interested. But they don’t see a direct interest for themselves because our results are interesting at a watershed scale and not really at individual farm level. If the regional authorities want to stop sedimentation of the dam, an integrated policy is needed.
14b Mexico Cointzio catchment	Gully control	For the construction of check dams it needs good studies especially to identify the critical areas. Check dams should be constructed starting from the upper part of the watershed. 80% of the check dams have very few or no sediments at all. The remaining 20% check dams have 10 to 20% of their capacity filled by the sediments. The location of gully control and the influence downstream has to be spatially analyzed in a watershed context. Evaluation and effectiveness of control of gully erosion by small dams was discussed with some farmers. They are interested in soil conservation works but they consider that the dams are probably not so useful.
14c Mexico	Agave intercropping	This experiment started late and has not yet produced definite conclusions. However, evaluation and effectiveness of the

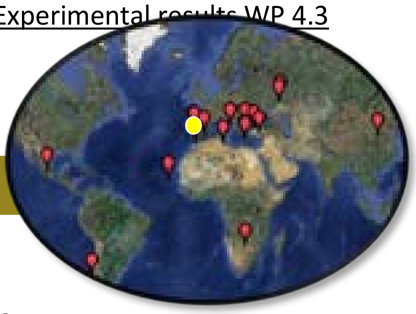
Cointzio catchment		Agave plantation have been discussed during workshops and directly on the field with some farmers. Farmers are interested to do some actions against soil erosion. For the Agave plantation and project, there is a lot of expectation. Agave plantation is a productive undertaking under agroforestry practices. It sustains biodiversity, generates work and remediates soils.
17a Chile Secano Interior	Crop rotation with Nitrogen binding species	Stakeholders think that their quality of life will be improved because of diversified income source. The farmers have more products to sell in addition to wheat. It also allows complementarity between crop production and livestock. The weakness of the technology is the difficulty in marketing the new products. There is also lack of appropriate machinery for harvesting the legumes. It helps carbon sequestration and thus minimises greenhouse effects. It also helps improve soil conditions by increased surface cover and soil organic matter. The main bottleneck of the technology is the difficulty in marketing the new products. There is also lack of appropriate machinery for harvesting the legumes.
17b Chile Secano Interior	Minimum tillage and sub-soiling	The no tillage with sub-soiling reduces soil loss by more than 70% of the soil loss as compared to conventional tillage. Also the runoff coefficient is reduced in the no tillage and sub-soiling practices. In addition, it increases soil cover and soil organic matter. The crop yield of no-tillage is slightly lower than conventional tillage although with subsoiling, the yield is actually higher. No Tillage saves on certain operations but there are additional farm costs for herbicides and including also additional use of farm machinery for removing the weeds and for sub-soiling will be required.
18 Cape Verde Ribera Seca	Runoff barriers with pigeon peas	This technology helps improve vegetation cover which helps in reducing surface runoff and soil erosion. Whether applied as terrace barrier or more mixed with the traditional Maize crop in an intercropping pattern crop yield is increased and supplemented with fodder supply from pruning of the pigeon peas. When applied in the entire catchment it should be noted that downstream water supply might be affected. This may have consequences for a dam was built downstream with a reservoir for irrigation which may have less inflow of water.

6. Experimental summary reports per country

In the following part the experiments are summarized in 4-5 page "summary sheets" combining the main results and the evaluation and remarks. These are also presented online (DESIRE-HIS). In some sites for every technology a summary sheet was made but when the experiments were part of a single comparative study, they were grouped in one summary to avoid redundancy.

The following profiles were prepared (numbers refer to site numbers in the DESIRE project):

Country	Experiment
1 Spain	Water Harvesting
	Reduced tillage
	Green Manure
2 Portugal	Fire Corridors
	Prescribed burning
4 Greece - Crete	Reduced tillage
	Rangeland resting
5 Greece - Nestos	Fresh water irrigation of saline soils
6 Turkey - karapinar	Minimum tillage and stubble mulching
7 Turkey - Eskeshir	Runoff fences and contour ploughing
8 Morocco	Gully stabilization
	Minimum tillage
9 Tunisia	Water harvesting
	Rangeland resting
10 Russia - Dzhanybek	Drip irrigation
11 Russia - Novy	Drip irrigation
12 China	Checkdam and terraces
13 Botswana	Biogass
14 Mexico	Crop rotation and minimum tillage
	Gully control
	Agave Agroforestry
17 Chile - Secano Interior	Crop rotation
	No Tillage
18 Cape verde	Runoff barriers

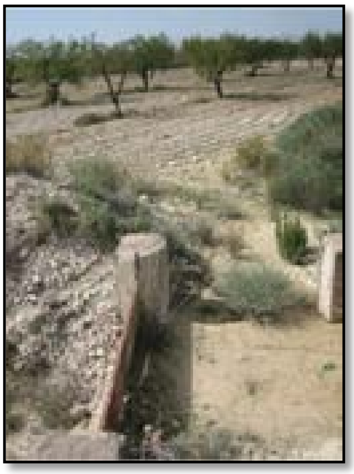


1a SPAIN – WATER HARVESTING

In the *Guadalentin* basin in south-eastern Spain, land degradation is considered severe due to a combination of several factors. The semi-arid climate has dry summers followed by intense autumn rainfall, while there is a steep topography and fragile soils. Desertification takes the form of soil erosion and drought. Moreover, considerable land use changes have taken place over the last centuries, which is an important driving force for further degradation in the area. A more efficient way of harvesting rain water might contribute to better yields while at the same time reducing surface runoff and erosion.

TWO EXPERIMENTS FOR HARVESTING WATER

Field trials were carried out to investigate the effects of a more efficient water use on terraced Almond orchards. The first is by collecting surface runoff through a traditional water harvesting technique (i.e. *boquera*). The second is by applying mulch below the Almond trees. The experimental fields are located in the upper part of the *Rambla de Torrealvilla* in the '*Los Alagüeces*' farm (Murcia).



Boquesra water inlet on terrace

A *boquera* is a system of partly or fully diverting water from an ephemeral stream (called *rambla*) to the nearby terraced fields through a series of man-made gateways and channels. To estimate the volume of water during flow events, a probe was installed that registers water height in the channel every 20 seconds.

In a second experiment a layer of 15 cm mulch was applied below the Almond tree canopies, in order to reduce evaporation. The straw mulch material was imported from further away. Furthermore a third control field was monitored without any water harvesting techniques.

Mulch patches below the Almond trees.

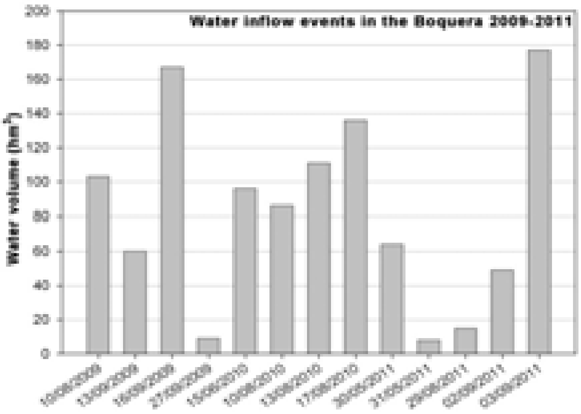
In all three plots soil water content was registered hourly at 35 cm depth, and about monthly for the first 20 cm with FDR equipment. The *boquera* and control fields were ploughed 3-5 times per year, whereas the field with straw mulch was ploughed only twice a year. The experiment was established in 2008 and data on soil moisture content, inflow amount of water and almond crop harvests were recorded as from 2009 until 2011.

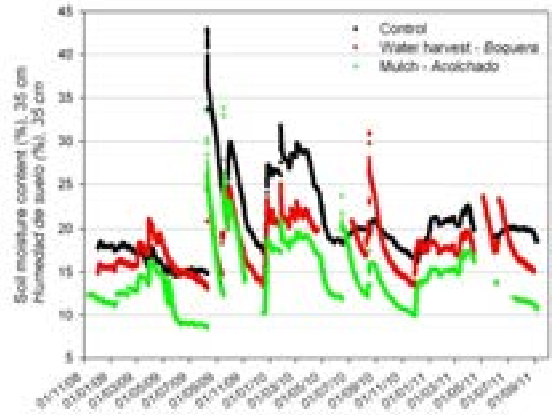
RESULTS

- During the monitoring period of 2 years, a total of 13 events of water entering through the *boquera* system were recorded (see figure below right). By these events an additional 550mm of water was supplied to a field of 10 ha. Therefore with a mean annual rainfall of about 300mm, the total available water for this field almost tripled.
- The field with *boquera* inflow has an average soil moisture content in the upper 20 cm that is on average 22.3% higher than in the field with no additional water inflow from water harvesting. However, at 35 cm depth soil moisture content is lower (Figure below left) which is probably due

to the development of surface crusts and the high rate of water inflow during events which impede infiltration of water.

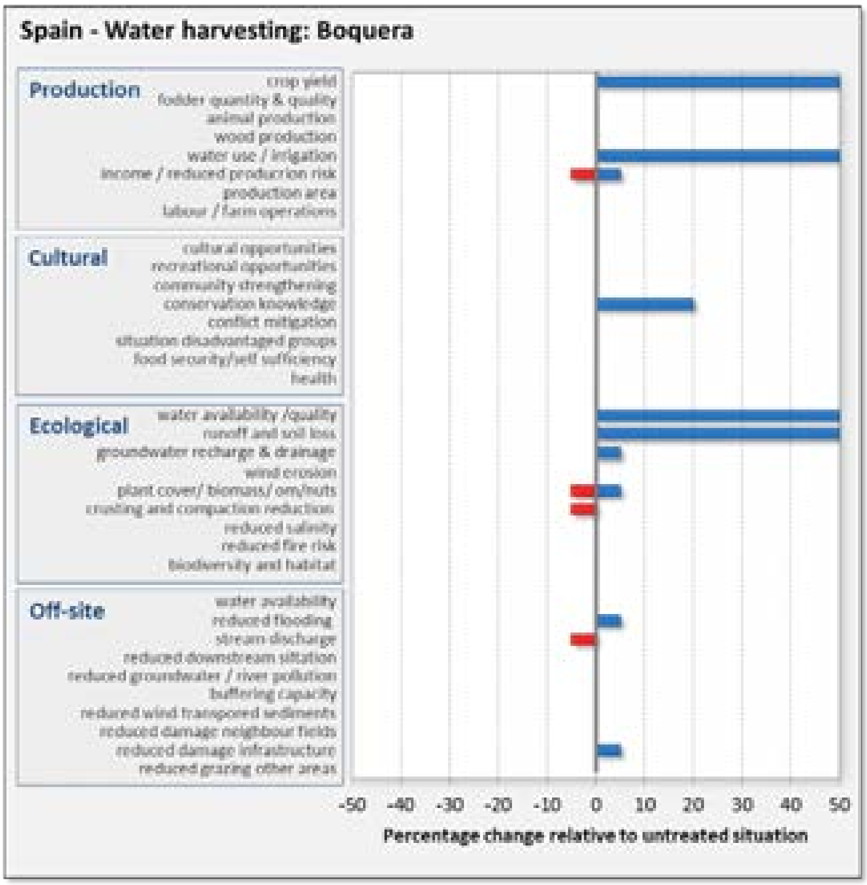
- In the mulch treatment and without *boquera*, soil moisture content was similar or sometimes even slightly lower than under control conditions in the upper 20 cm, whereas at greater depth soil moisture content under mulch was almost always lowest of the three treatments (Figure 3). A possible explanation may be that rainfall is intercepted directly by the mulch and evaporates. The mulch has a positive effect on crust reduction on locations where it is applied.
- The result also shows that the almond harvest in the *boquera* system is almost double of the harvest under conventional treatment or under mulching.

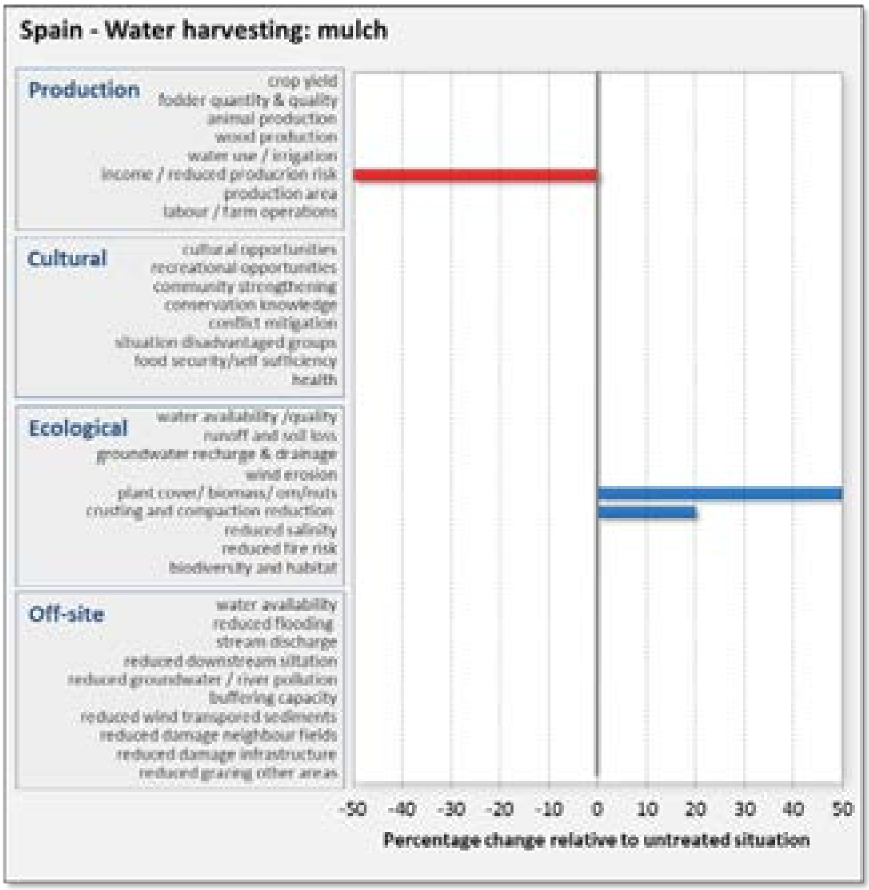




HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.





STAKEHOLDER'S OPINIONS

- A lot of farmers show interest in SLM technologies to protect the land, the interest in conservation is improved.
- Despite the implementation and maintenance costs, the *boquera* increases the benefits enormously (52%) so the farmers will continue using this.
- Mulching is not profitable compared to conventional cultivation practices since it does not increase the yield. Moreover the farmers consider the land not tidy when mulching is applied. As a third disadvantage the mulch would have to be purchased or collected from surrounding natural vegetation, which would then mean increased labour. In both cases this has negative economic consequences.

CONCLUSIONS

The traditional water harvesting technique does not necessarily improve soil moisture but the crops with shallow root system benefit the high water availability which will increase crop yield.

Mulching does not increase soil moisture in very dry environment. It is not profitable and not liked by the farmers.

Additional funds should be available to construct and maintain the traditional *boquera* system of water harvesting. Not all farmers have access to a functioning system so for a large scale application considerable investments would be needed.

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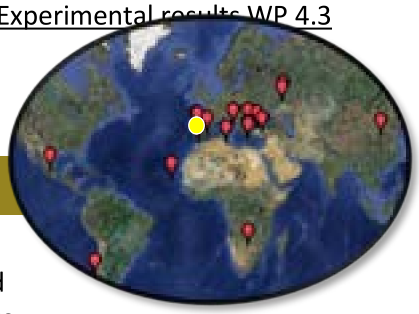


1b SPAIN – REDUCED TILLAGE OF CEREALS

In the *Guadalentin* basin in south-eastern Spain, land degradation is considered severe due to a combination of several factors. The semi-arid climate has dry summers followed by intense autumn rainfall, while there is a steep topography and fragile soils. Desertification takes the form of soil erosion and drought. Moreover, considerable land use changes have taken place over the last centuries, which is an important driving force for further degradation in the area. Reduced tillage may improve the soil structure, improve infiltration and reduce runoff and erosion.

AN EXPERIMENTS USING MINIMUM TILLAGE TO REDUCE RUNOFF

The experiment was carried out in a cereal field where minimum tillage was compared with conventional tillage. Under conventional farming practice winter wheat is sown in October-November after the autumn rains. The crop matures in May and harvesting is done in June. Crop residues are left on the field as mulch or for a post-harvest grazing by cattle until September, the fields are then ploughed with a mouldboard plough for seeding in November or left fallow for one year. Under this conventional system, the land was ploughed 5 times in two years, one of which with a mouldboard plough. Under minimum tillage, the land was ploughed only three times in two years with a disc or chisel plough and never with a mouldboard plough. The purpose is to gradually create a more stable soil structure which would reduce runoff and erosion while at the same time increasing available water.

To monitor the effect of the treatments on ecological criteria, three adjacent runoff-erosion plots (Gerlach type, see picture) were installed for the treatment and the reference field, giving a total of 6 runoff plots. To determine the exact contributing areas of the open runoff plots, a terrestrial laser scanner (TLS) was used to construct a high resolution digital elevation model. After every event, runoff and soil loss were measured by collecting the water and sediments from storage tanks.

Storage tanks (left) and runoff collectors on adjacent open plots (upstream to the right)

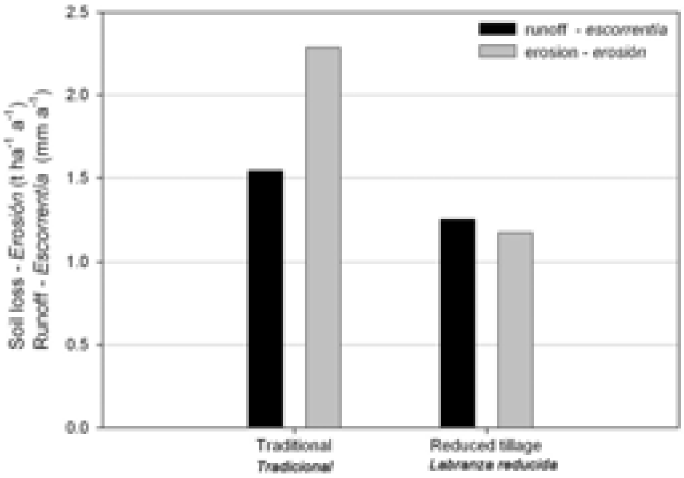
To evaluate the economic impact of reduced tillage measures, all farm operation costs of each treatment (ploughing, implementation, seeding, etc.) were registered in a logbook, and the harvest was determined individually per treatment. Unfortunately, since each harvest is followed by a fallow year, only 1 cereal harvest was obtained during the monitoring period.

RESULTS

The results indicated that under reduced tillage there is decrease of soil loss (56%) and water loss (30%) as compared to conventional tillage (see figure below). These data are based on 2 years of monitoring in which 18 events were registered.

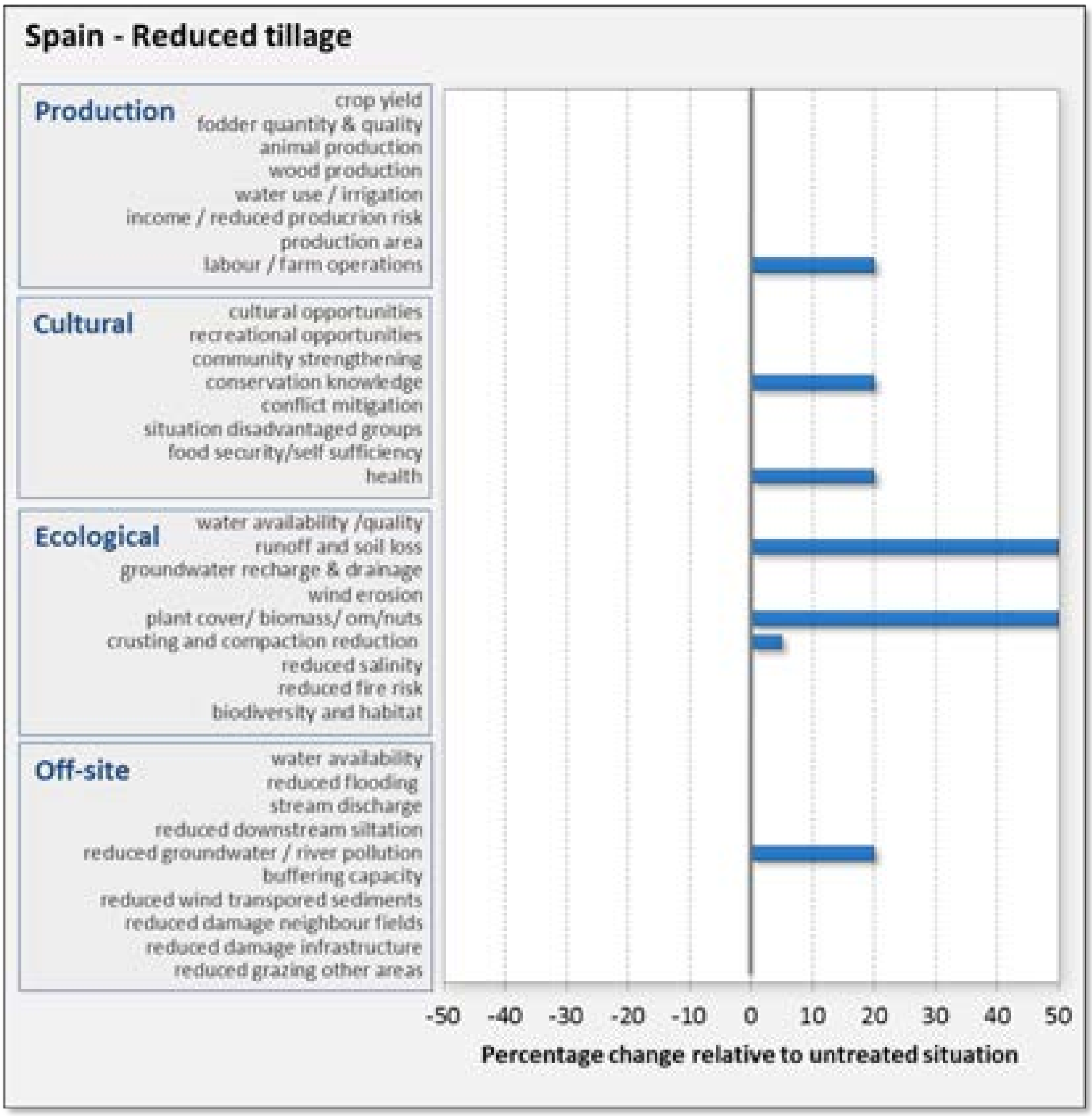
It is expected that the reduction in soil and water loss may be higher on the longer term when soil organic matter content in the soil under reduced tillage increases and the soil structure further improves.

The result also shows that the reduced tillage with mulching results in a 12% higher profit due to a reduction in operation costs for ploughing. It is expected that on the longer term, harvest under reduced tillage will increase due to an increasing organic matter content (and fertility) of the soil.



HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

Stakeholders were involved from the beginning of the experiment. A demonstration day was organized where stakeholders representing farmers, regional policy makers, NGO's and scientists discussed and exchanged ideas. The farmers are aware of the land degradation problem and they can make their own experiment or trials in their field for minimising the land degradation problem.

On the other hand there was no clear advantage from a perspective of yield, although there is some reduced cost with fewer operations. The evaluation shows that the advantage is purely ecological for the moment. More time is needed to show if the clear advantages are permanent.

CONCLUSIONS

Reduced tillage reduces soil loss (56%) and water loss (30%) as compared to conventional tillage. After the relatively short period (2 years) of monitoring with only 1 harvest, no effect was observed on cereal yield. This may be different after more years of monitoring. Nevertheless, even if yield is not affected by this treatment, a higher benefit was achieved because of lower operational costs under reduced tillage. Longer term monitoring is still required since most soil and water loss occurred during the low frequency high intensity events.

The results show that there are various opportunities to increase economic benefits and at the same time provide increased ecological services by protecting and maintaining soil and water resources under rainfed agriculture in semi-arid conditions. For these reasons, these measures have a relatively high level of acceptance amongst stakeholders.

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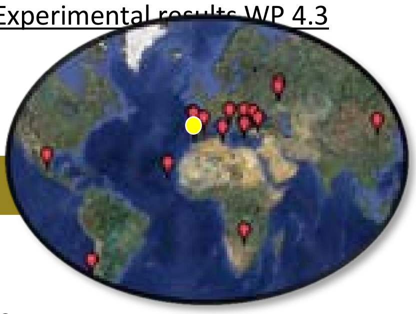


1c SPAIN – GREEN MANURE

In the *Guadalentin* basin in south-eastern Spain, land degradation is considered severe due to a combination of several factors. The semi-arid climate has dry summers followed by intense autumn rainfall, while there is a steep topography and fragile soils. Desertification takes the form of soil erosion and drought. Moreover, considerable land use changes have taken place over the last centuries, which is an important driving force for further degradation in the area. Reduced tillage may improve the soil structure, improve infiltration and reduce runoff and erosion. Green manure will provide a better soil cover and additional nutrients when the vegetation matter is ploughed into the soil.

AN EXPERIMENT COMBINING GREEN MANURE AND MINIMUM TILLAGE

An experiment was carried out in an almond field without terraces where reduced tillage and green manure technologies were applied. The location of the experiment was in the Torrealvilla catchment, Murcia, Spain. For green manure a mixture of barley and vetch (*Vicia sativa)* was sown in autumn and ploughed into the soil in spring. Ploughing was done only twice in a year in both the green manure field and the reduced tillage field, whereas the field under conventional tillage was ploughed between 3-5 times per year, a practice commonly followed in the study area.

To monitor the effect of the treatments on ecological criteria, three replica open runoff erosion plots (Gerlach type) were installed in each treatment, giving a total of 9 runoff plots (Figure below). To determine the exact contributing areas to the open runoff plots, a terrestrial laser scanner (TLS) was used to construct a high resolution digital elevation model. Furthermore, soil moisture of the upper 20 cm was measured about every month at 30 random points in each field with FDR equipment.

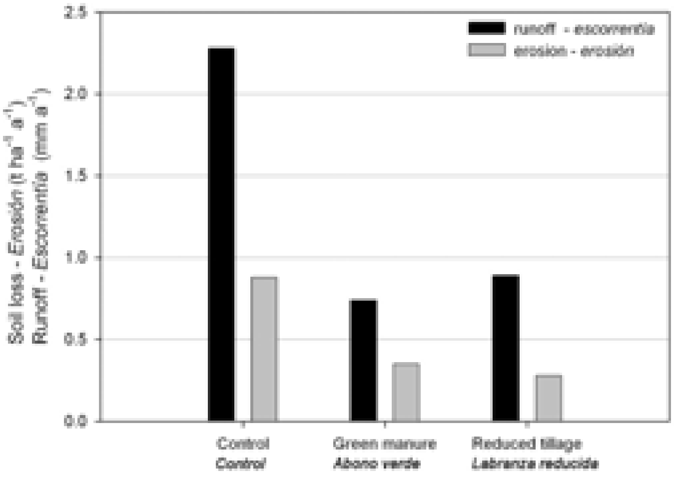
After every event, runoff and soil loss were measured by collecting the water and sediments from the Gerlach runoff plots and storage tanks. The experiment started in autumn 2008. Data on soil moisture, runoff and erosion was collected until 2011. In addition amount of applied green manure seed and almond crop harvest data was also collected.

RESULTS

The results show that green manure reduces surface runoff whereas the soil loss amount is the lowest in reduced tillage (see figure below). These results also show that erosion under reduced tillage and green manure treatment was reduced on average by about 60% as compared to a conventional tillage regime.

Monitoring of soil moisture did not show consistent differences between the different treatments. Differences were very small, while in general soil moisture tended to be even higher under reduced tillage and green manure treatment than under control conditions, possibly due to the effect of dew formation on plants below the almond trees.

Reduced tillage reduces production costs as compared to conventional cultivation practices but it does not increase the yield.



HOW WELL DOES IT WORK?

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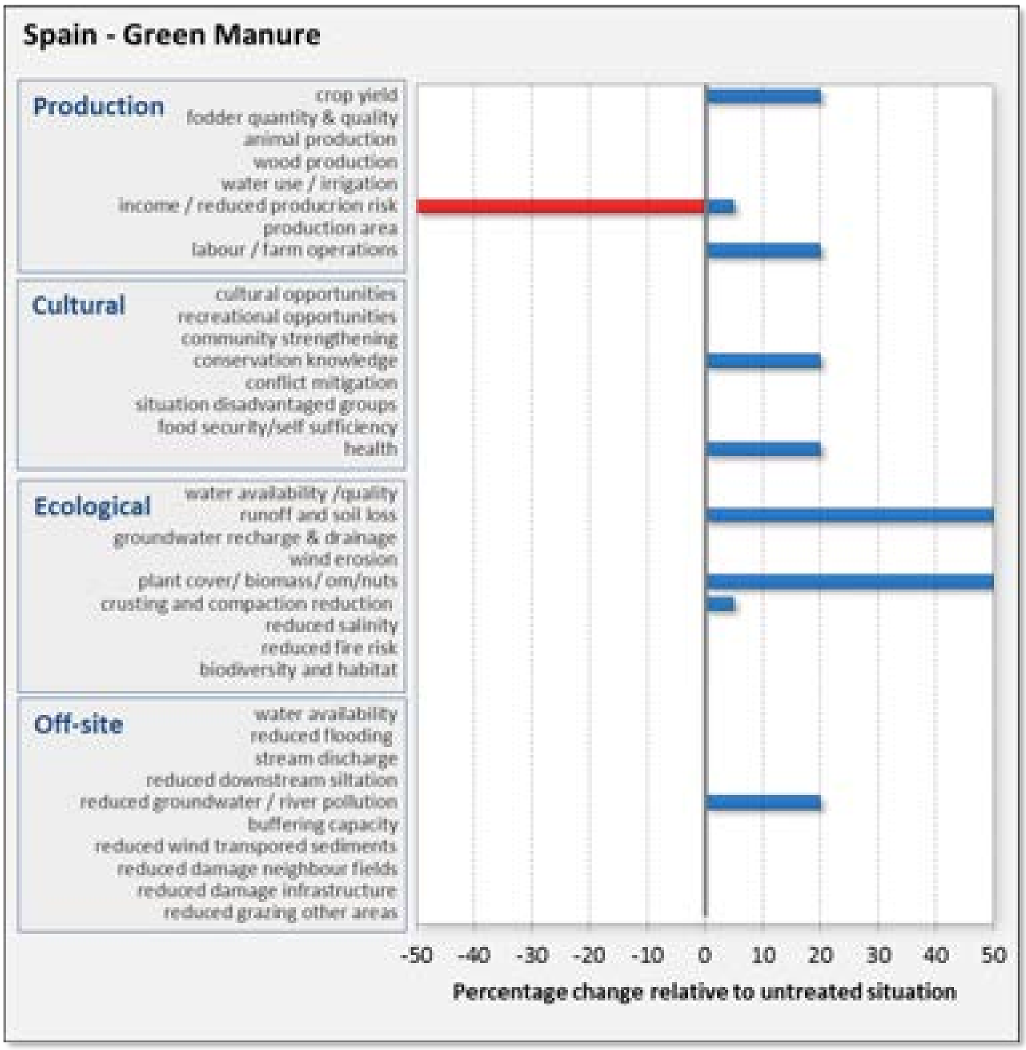

STAKEHOLDER'S OPINIONS

Low operation cost due to reduced tillage and with high quality ecological product is interesting for the farmers but there should be better marketing of eco-almonds and olives.

Green manure is effective and feasible although it doesn't give a direct economic benefit so the acceptance is not yet very high. More information should be given about this.

CONCLUSIONS

Reduced tillage reduced soil and water loss, but yield was not increased, at least not after 2 years of monitoring. Nevertheless, operation costs are lower, so if the yield is maintained at least at the same level there is an economic benefit compared to conventional treatment. These results also show that erosion under reduced tillage and green manure treatment was reduced on average by about 60% as compared to a conventional tillage regime.

Green manuring proved to be effective and feasible in reducing soil and water loss while increasing almond production. Since operation costs do not significantly increase, the profit is also higher than under conventional production.

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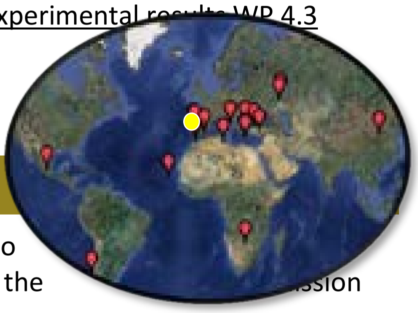
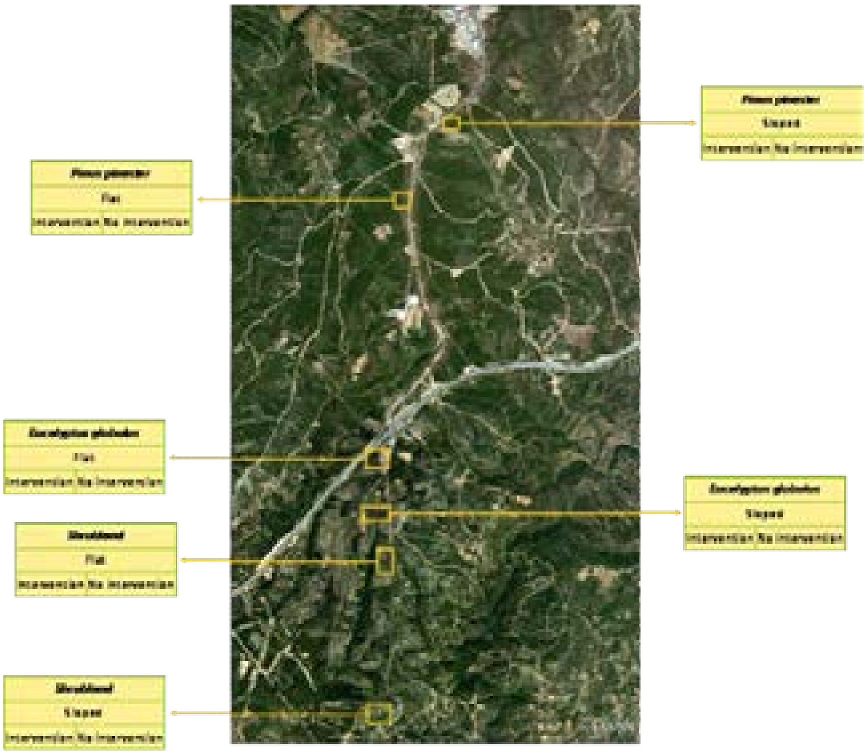


2a PORTUGAL– MACAO: FIRE STRIP NETWORK

Like many Mediterranean countries Portugal suffers from forest fire due to its dry and hot climate. The problem is not only degradation of forest and the ssion of carbon dioxide to the atmosphere but it also increases soil losses and pollution of water and air. The Mação Region in Portugal suffered massive fires in 2003 and 2005 affecting more than 70% of the municipality area. To protect the forest from wild fire strip network is constructed. This can have negative impact by increasing surface runoff and soil losses due to the removal of vegetation along the strips. An experiment was carried out to study runoff and sediment loss from different tree species.

THE EXPERIMENT: FIRE CORRIDORS FOR PROTECTION



Forest is the dominant land use in the Mação Region in Portugal, which consist dominantly of *Pinus pinaster,* with some *Eucalyptus globulus* trees. Preventive forestry is composed of a set of measures applied to forest stands, shrubs and other spontaneous species to protect against fires. These measures deal with forest stands composition, structure and location, aiming to reduce fire risk and to increase vegetation resilience to fire but the removal of vegetation tends to expose bare soil to the erosive effects of rainfall.

Rainfall simulators were used to assess erosion processes. Considering the intensity of the extreme rainfall of the area the rain simulators were adjusted to intensity of 45 mm/h. Run off and suspended sediments were measured from a plot of size a 0.26 m^2 located in the center of the target areas. All the measurements have 3 replications. They were carried out in all the plant species (table below). In addition soil samples were collected for analysis of texture, soil moisture and organic matter content.

Pinus pinaster				*Eucalyptus globulus*				*Shrubland*			
Mitigation strip		No intervention		Mitigation strip		No intervention		Mitigation strip		No intervention	
Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat
3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas	3 replicas

RESULTS

▸ Rainfall simulations in flat Shrubland and sloped Eucalyptus sites resulted on the highest cumulative sediment losses; Shrubland did not have vegetation cover and Eucalyptus is located on a stony ground (>90%).

▸ Flat Eucalyptus and Pine sites led to insignificant soil losses.

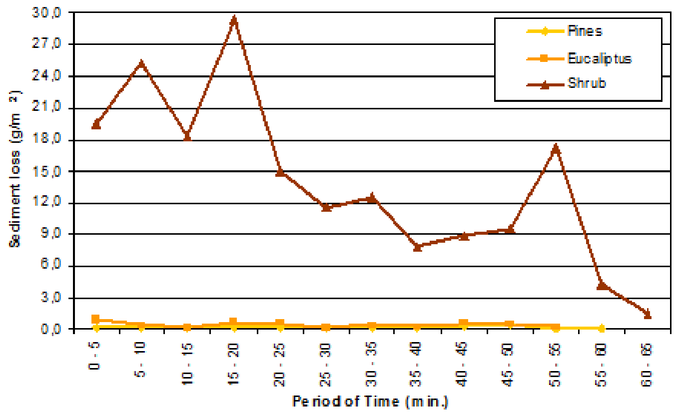
▸ The influence of slope only had a significant impact in Eucalyptus sites.

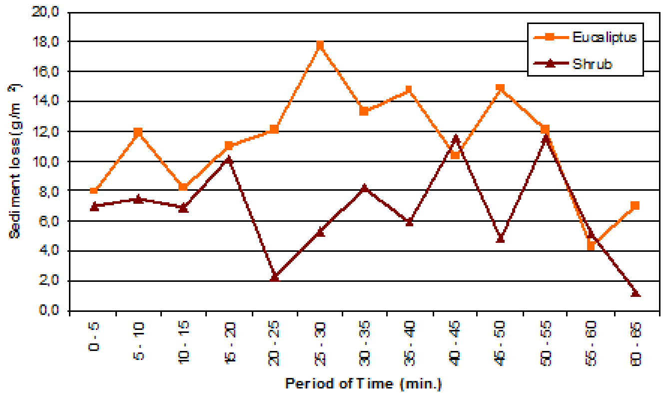
▸ Sediment loss on flat Shrubland was higher than on sloped Shrubland.

▸ There was small variation of sediment loss on flat Pine and Eucalyptus sites throughout rainfall simulations.

▸ Sediment loss on flat Shrubland site was higher in the first 20 min but decreased significantly until the end of the simulations; the presence of high peaks may be explained by micro relief water accumulation.

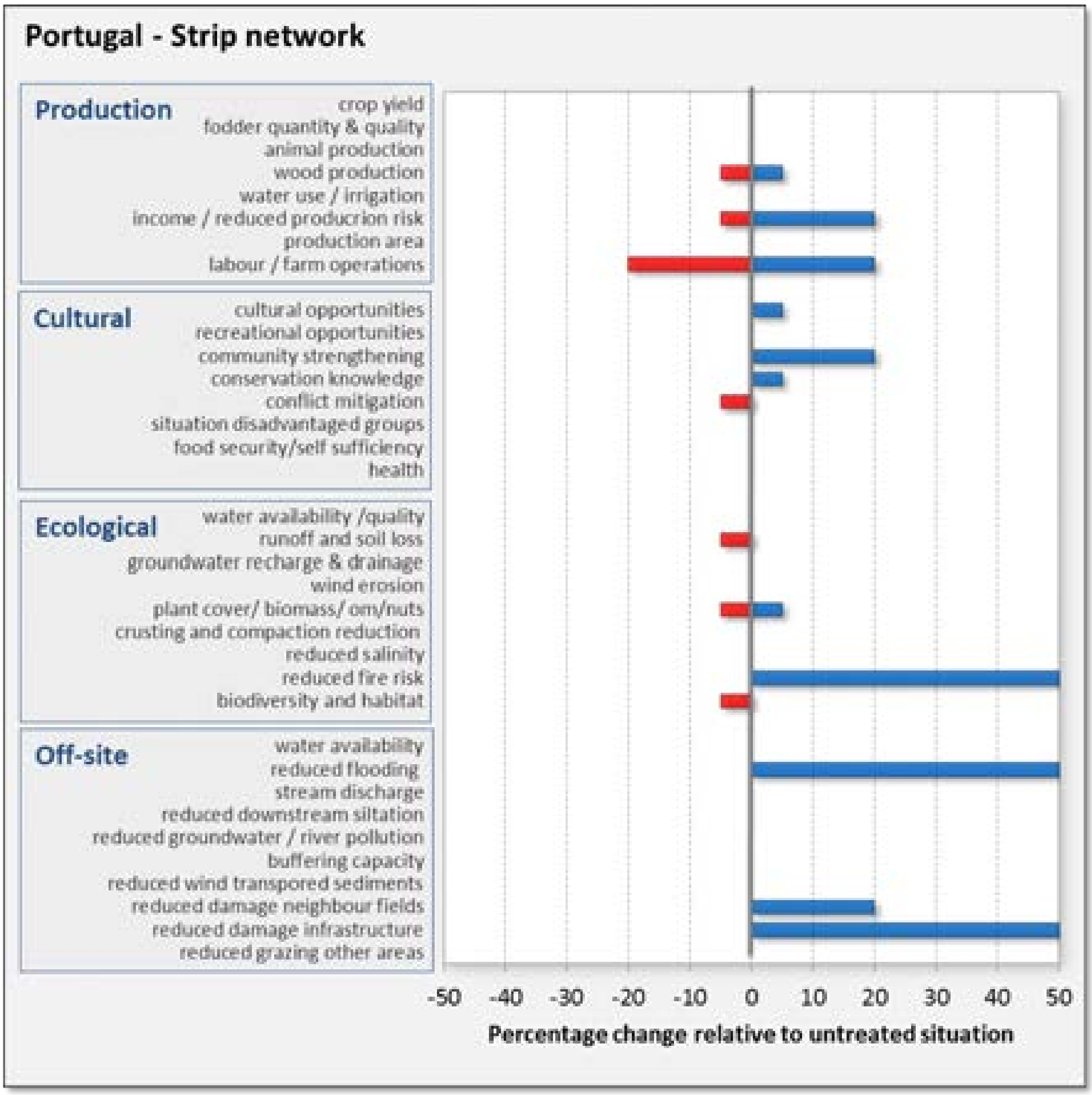
▸ No runoff on sloped Pine sites was registered (Figure 5); there was higher variation of sediment loss during rainfall simulations both on sloped Shrubland and on Eucalyptus sites.





HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

Field work in close collaboration between researchers and local technicians from GTF (Forestry Technical Office of the Municipality of Mação) and Aflomação (Forestry Association of Mação) – selection and assessment of field-test areas.

Increase knowledge among researchers and local stakeholders about the effects of the mitigation strips technology on soil erosion and/or conservation.

Promotion of future opportunities for dissemination and further developments under the suitability of this technology.

Due to high implementation and maintenance costs, this technology requires the full support from public entities (as well as specific technology capacity).

CONCLUSIONS

Forest fire prevention using strip network is a useful technique but it can cause increased runoff and soil losses since the area along the strips will be bare and exposed to erosive rain.

Sediment loss from the strip area depends on tree species and terrain slope gradient.

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➜ This project has been funded by the European Commission DG Research-Environment Programme
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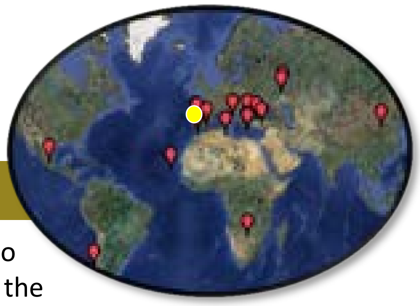
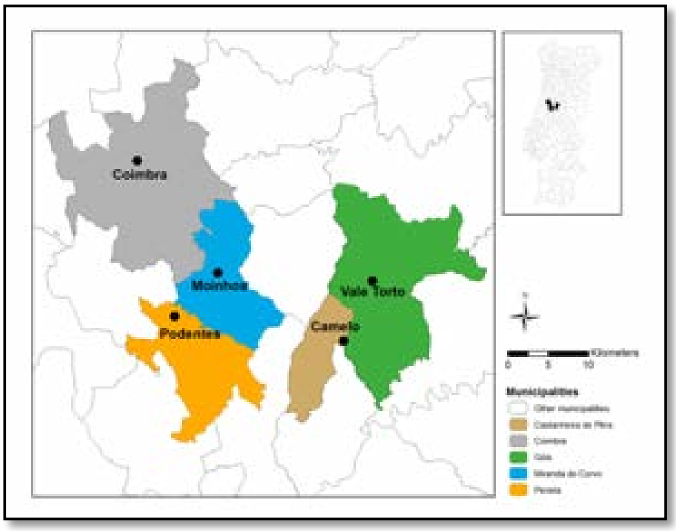


2b PORTUGAL– GOIS: PRESCRIBED FIRE

Like many Mediterranean countries Portugal suffers from forest fire due to its dry and hot climate. The problem is not only degradation of forest and the emission of carbon dioxide to the atmosphere but it also increases soil losses and pollution of water and air. The Vale Torto area near Góis in Portugal was burned by several fires in the 1970s and the early 1980s. Similarly the Camelo catchment near Góis also suffers from forest fire with the recent fire taking place in July 2008. In order to reduce soil losses caused by wild fire and to minimise the amount of flammable materials an experiment was applied which uses a technology called prescribed fire.

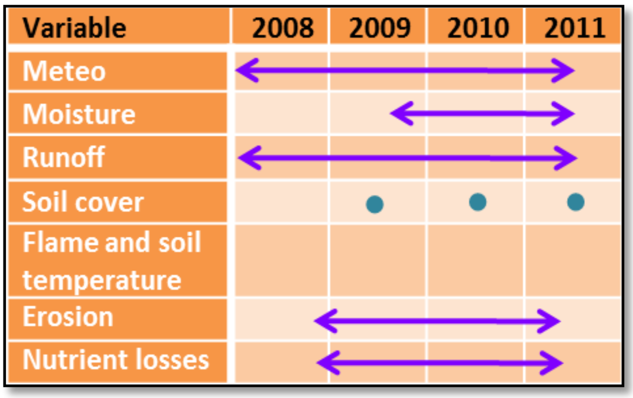
THE EXPERIMENT: CONTROLLED BURNING IN SPRING



To compare the effect of prescribed burning with that of wild fire four sites were selected: Two sites in Camelo catchment and Vale Torto area close to in Góis, both haviong similar conditions with respect to geology (schist and quartzite), relief, vegetation, soil and climate. The two other sites were located in Podentes and Moinhos study sites. The Podentes site is in a limestone area.

For studying the effect of wild fire and prescribed fire following data were used: Wild fire in Camelo study site (3.3 ha) in early summer 2008 comprising scrub vegetation representing a fuel load of 65 t/ha (Photo below left); Vale Torto, submitted to an experimental fire (9 ha) with a lower fuel load (23 t/ha) in February 2009 (Photo below right); Podentes subjected to a prescribed fire in April 2009. In Podentes, the forestry service burned a smaller area (2 ha) comprising scrub vegetation on calcareous bedrock with fuel load of 70 t/ha. In Moinhos an area of 95 ha was burnt in September 2009 where eucalyptus were planted. To study the effect of forest fire, field study was carried out to collect data on soil moisture, infiltration,

suspended sediments and nutrient contents. In addition to collecting data on soil, Vegetation recovery monitoring was also carried out using vertical-photography of plots of size 0.25m.



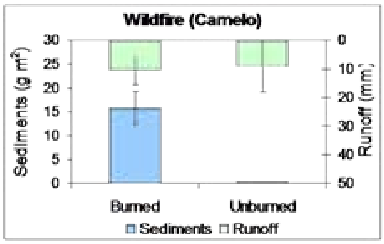
In addition, a lysimeter was also used to assess fire impact on soils started during 2010. During the experimental lysimeter fire flame temperature was assessed using an infrared heat sensor, that shows temperatures values of over 700ºC.

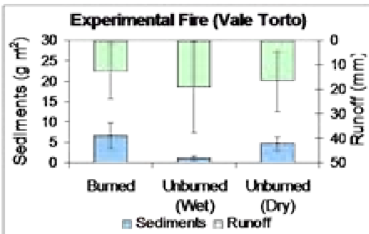
RESULTS

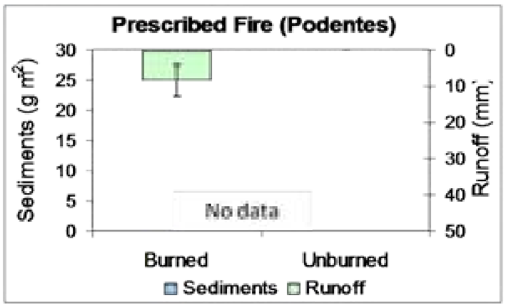
	Infiltration rate (mm/h)			Infiltration capacity (mm/h)		
	Burnt	Unburnt	ratio	Burnt	Unburnt	ratio
Bare soil		7.50			13.85	
Q. coccifera S	10.45	13.80	0.76	30.26	30.56	0.99
P. lentiscus S	15.05	22.39	0.67	29.64	31.13	0.95
A. unedo S	7.99	12.09	0.66	11.89	32.45	0.37
Average	**11.16**	**16.09**	**0.69**	**23.93**	**31.38**	**0.76**
Q. coccifera N	25.47	41.03	0.62	26.87	46.13	0.58
P. lentiscus N	28.94	29.42	0.98	30.25	31.76	0.95
A. unedo N	16.23	24.57	0.66	16.62	30.10	0.55
Average	**23.55**	**31.67**	**0.74**	**24.58**	**36.00**	**0.68**
Whole area	**15.81**	**21.14**	**0.75**	**21.94**	**29.14**	**0.76**

The result shows an increase in soil water repellence after burning which is not shown by the unburned area. Burning intensified soil hydrophobicity (compared with the unburned site) probably due to enhanced drying and high temperatures during the fire. Studies carried out in the effects of ash in Podentes study site revealed that water repellence depends on plant species and to some extent also on slope aspect. The ash from *A. Unedo* shows major water repellence behaviour as compared to ash from other shrub species (Quercus coccifera, Pistacia lentiscus).

Fire also influences soil infiltration. The study shows reduction of soil infiltration by about 25 per cent. Highest decline of infiltration capacity was observed in the burnt shrub species, *A. unedo*, which has also high soil water repellence value. This could be related to different surface litter and root systems of plant species. The results also show higher infiltration capacities on limestone area as compared to the area with schist bedrock. On schist sites, the fire had no discernible impact on runoff, and the average runoff coefficients for the burned sites were 24% Camelo, 29% Vale Torto and 8% Podentes.





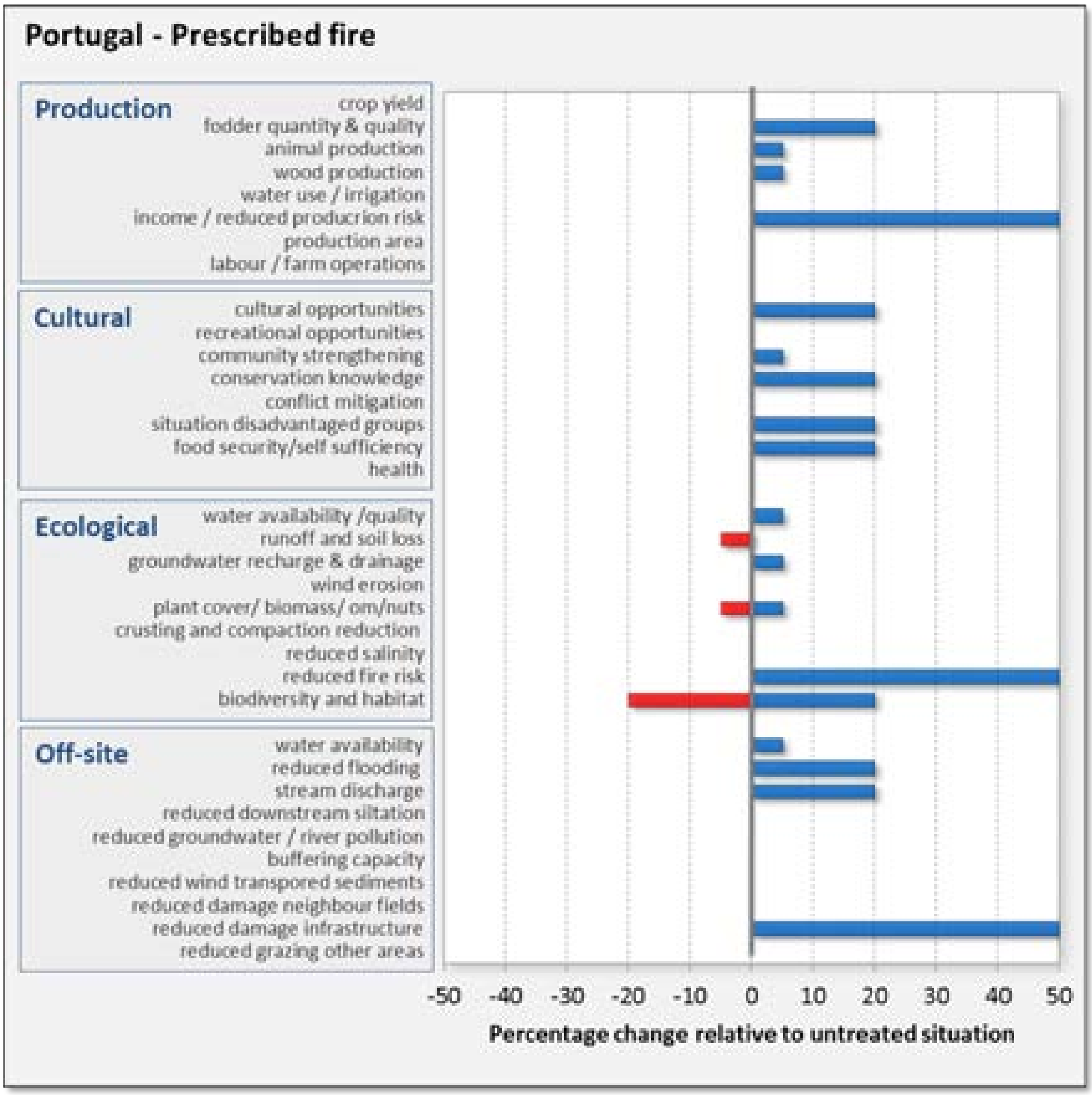


In case of soil losses, the schist study site shows a significant increase of soil loss for both cases: wild fire versus un-burned area (3.8 g m^{-2} vs 0.1 g m^{-2}), and prescribed fire versus un-burned area (1.6 g m^{-2} vs 1.2 g m^{-2}). In case of Vale Torto the increase in soil erosion after the fire was so significant. Soil loss results in Vale Torto site show a distinct increase (upto 8 -15 times) as compared to pre fire periods. In Camelo site, soil losses per unit contributing area are on average 1-2 orders of magnitude higher (2.2 t/ha for the first year after the wildfire, and 3.6 t/ha for the whole 19-month monitoring interval up to March 2010) compared with prescribed fire.

The lysimeter data shows that the top soil (0-2cm depth) temperature during fire varied spatially, average temperature was around 250ºC, but in some places it reached 450ºC. At the sub-surface layer (2-5cm), soil temperature during the fire was around 60ºC which indicates that organic matter will be burnt only in the top 2 cm of soil.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

Prescribed burning is increasingly used as a tool for landscape management, in order to increase diversity and reduce forest fire risk.

To perform prescribed burning, one has to get approved in a special fire management course, the means to perform it are only possible with the involvement of local authorities, which became involved in the Vale Torto experimental fire.

The stakeholders were responsible for getting all the permits and perform the prescribed burning. They followed up the recover of the burn area. involved

The Benefits are the improvement of pastures for grazing and the reduction of forest fire risk.

Prescribed fire is probably the most cost effective technique for landscape management, it is an old practice that was forbidden during 60 years, and therefore has the adherence of local stakeholders.

We expect a reduction on fire frequency and the diversification of local economy due to an increasing on grazing, bee keeping, cheese production, etc.

CONCLUSIONS

- Prescribed burning, during the wet period seems to have less impacts on the soil and vegetation than the summer wildfires, therefore it is suitable as a land management technique.
- It has a reduce cost/effect rate, specially when compared with other techniques.
- Can be used to promote higher landscape diversity and therefore promote biodiversity.
- The landscape diversity can induce a higher diversity of economic activities, therefore increasing the appeal of mountain areas, by improving the local communities livelihoods.

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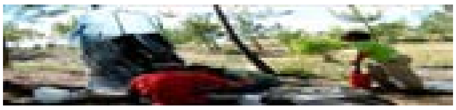


4a GREECE – CRETE: MINIMUM TILLAGE

The eastern and central part of the Greek island Crete is suffering from land degradation problems, while the rest of the island is highly sensitive to desertification. Soil erosion due to surface runoff and tillage operations, collapse of terraces, overgrazing, salinization of lowlands, and overexploitation of ground water are the major processes of land degradation in the area. A lot of forested areas were converted into cultivated land In the last century. Overgrazing and fires further destroyed the natural vegetation cover and prevented its regeneration.

Olive groves are an important form of land use in the area, but have various degrees of due to the different land management practices. Farmers perceive a herb cover as a competition for water for the Olive trees and keep the field clean and bare below the trees. A minimum tillage experiment with and without herbicides was carried out to see if it is possible to maintain a soil cover, restore the natural soil structure, promote infiltration and reduce runoff and helps in minimizing soil losses.

THE EXPERIMENTS: COMBINING MINIMUM TILLAGE WITH LEVELS OF HERBICIDE APPLICATION

The experimental field is located on moderately steep slope (slope gradient 17%) which is prone to erosion. The soil is moderately deep (55-65 cm). The experimental setup included three management practices prevailing in the area with two replicates: (a) no tillage – no herbicide application, (b) no tillage – herbicide application, and (c) tillage operation – no herbicides with soil cultivated perpendicular to the contour lines at depth 20 cm using a disk harrow. The plots are of the size 3x5m^2.

Tipping buckets were installed at the bottom of the plots to collect surface runoff. Also there are facilities for collecting soil sediments. Meteorological variables are measured at the same field using an automatic station (see photo). The experimental station is remotely controlled from the laboratory of Soils in the Agricultural University of Athens.

One time measurements were carried out such as: texture and stoniness, organic matter, aggregate stability, etc. Repeated measurements were conducted such as soil moisture with permanent installed TDRs, soil temperature, while sediment loss was measured every rainfall event, and surface water runoff every 5 minutes.

Variable	2008	2009	2010
Meteo data			
Soil moisture			
Water runoff			
Soil sediment loss			
Organic matter	*		*
Plant cover		* * * * * * *	* * * * * * * *
Aggregate stability	*		*

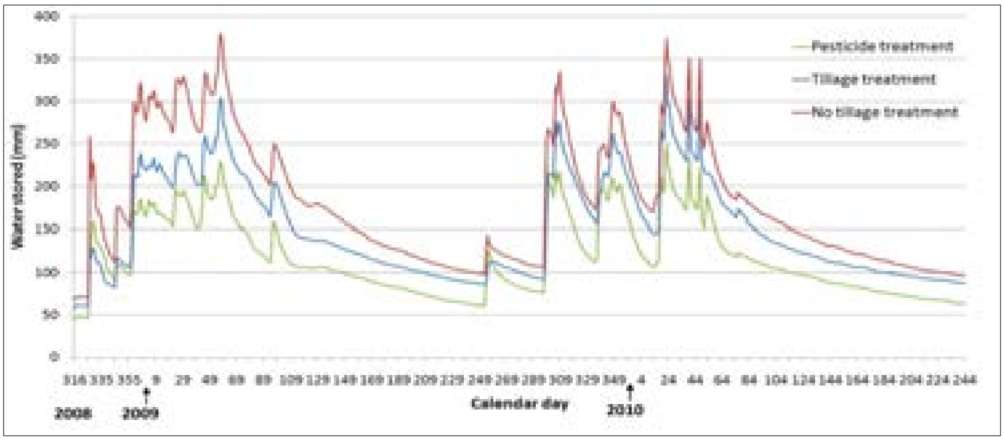
RESULTS

The experiments in the olive grove show significant differences in surface runoff and sediment loss as a result of applying different land management practices. The highest amounts of surface runoff have been measured in the experimental plot subjected to tillage operation with 44.7 mm and 7.9 mm of runoff recorded in the first and second year of study, respectively. Under no tillage and no tillage-herbicides application the surface runoff reduced by approximately 1/4 times. The lowest runoff was recorded under the no tillage land management practices since soil was fully covered with vegetation (weeds, top left photo).

Soil losses show similar trends. The soil loss was highest in the tillage land management practices, especially in the first year of measurements. This is due to high rainfall amount in that year. Sediment loss in this management practice ranged from 44.2 to 255.9 kg ha^{-1} yr^{-1} during the two year period of measurements (see figure below).

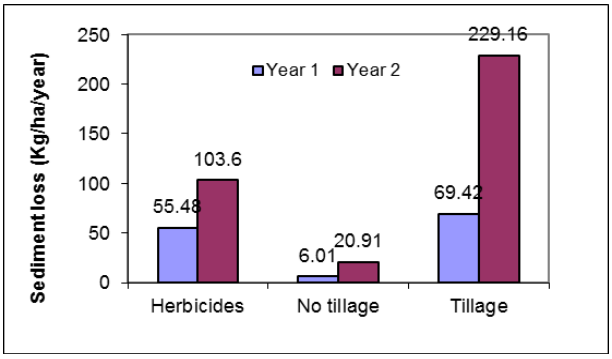
The no-tillage land management practices also reduce production costs by minimizing cost involved in man power.

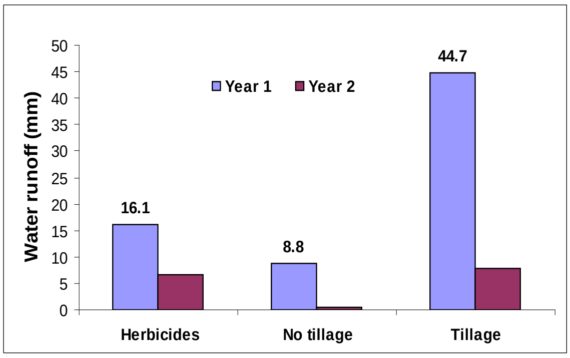
The three treatments: minimum tillage, no herbicide (top), minimum tillage with herbicide (middle), conventional (bottom)



Left: recorded runoff is consistently hiogher in the tillage plot

Below: totals in runoff and sediment losses for the two years. Year 2(2010) was a wetter year.





HOW WELL DOES IT WORK?

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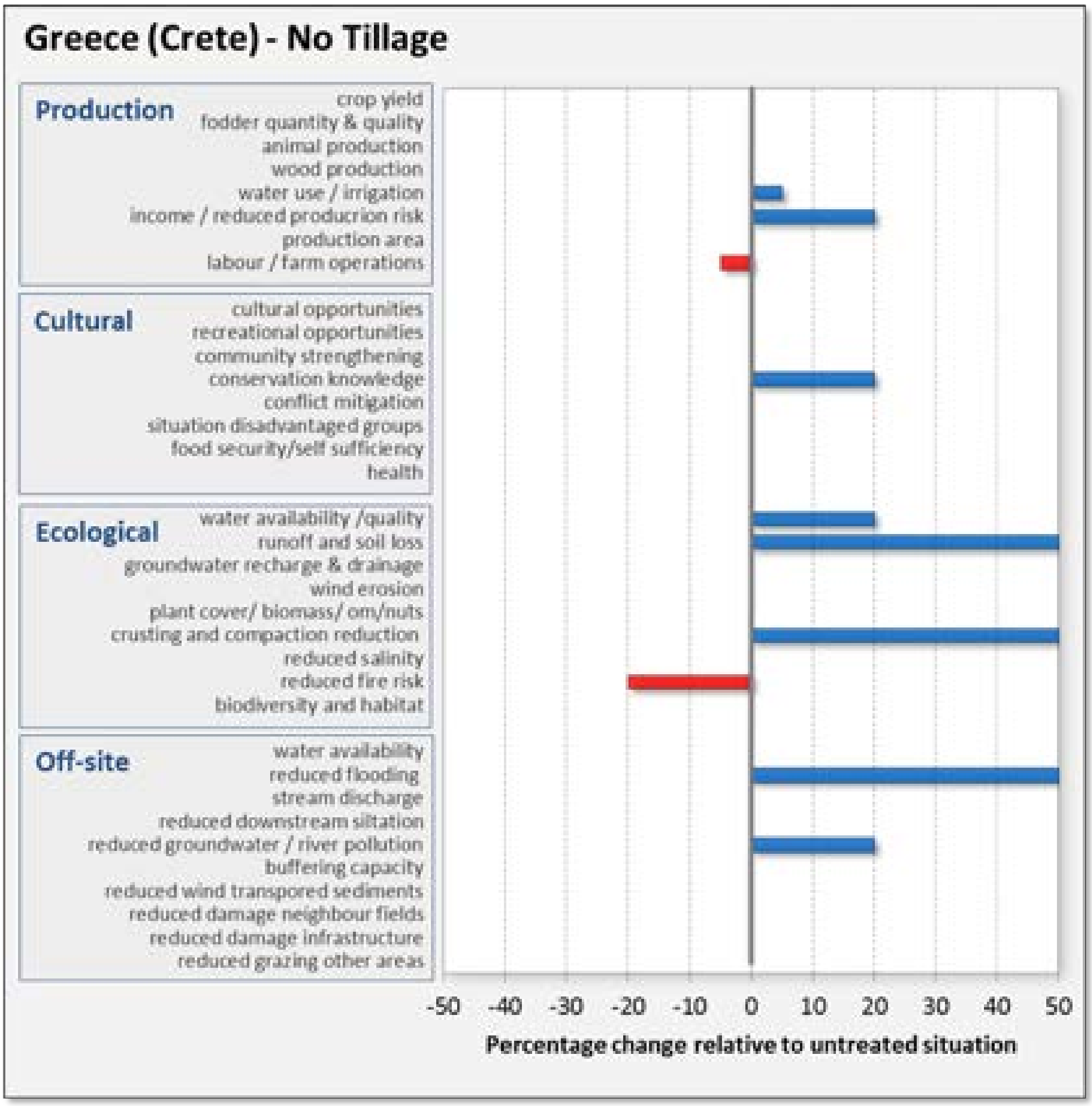

STAKEHOLDER'S OPINIONS

Many of local farmers have visit the monitoring site and observed the work carried out. They have many times discussed the issue of desertification and the measures for protecting the land from further degradation in local meetings. They have considered the applied land management practices and included in the agricultural program of "Integrated Land Management of Olive Groves" for receiving higher subsidies.

The benefits are related to: (a) lower cost production of olive oil, (b) higher income due to the application of integrated land management of olive groves for protection of the environment. The application of no-tillage or minimum tillage land management practices did not require additional cost for implementation.

On the other hand thereis still a discussion whther the herb layer gives water competition for the olive trees, which has not yet been resolved. Moreover in a very dry year the dried out herb layer could give an extra wildfire risk.

CONCLUSIONS

The application of the appropriate land management practice can greatly affects land protection and reduction in runoff and erosion, consistently over the two years. The experiment shows that the no tillage – no herbicides land management results in minimizing sediment loss due to low surface runoff. Added ecological effects are higher soil water storage, lowering soil temperature, higher biodiversity. This is confirmed by a longer experience in the area and results from previous studies.

Several stakeholders have accepted this type of land management practice due to low olive oil price. It may be if the olive price rises, a reversion to traditional tillage is seen because farmers want to minimize production risk. There are clear economic benefits as the reduced tillage reduces labour and fuel costs.

An important bottleneck is the lack of knowledge transfer by the Greek Ministry of Agriculture on new sustainable land management practices and decreasing cost production.

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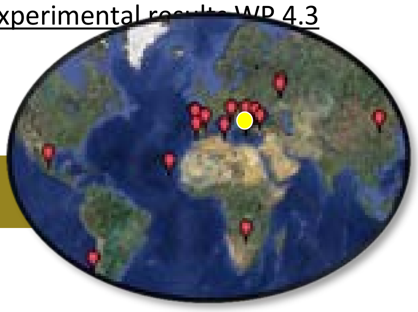


4b GREECE – CRETE: RANGELAND FENCING

The eastern and central part of the Greek island Crete is suffering from land degradation problems, while the rest of the island is highly sensitive to desertification. Soil erosion due to surface runoff and tillage operations, collapse of terraces, overgrazing, salinization of lowlands, and overexploitation of ground water are the major processes of land degradation in the area. A lot of forested areas were converted into cultivated land In the last century. Overgrazing and fires further destroyed the natural vegetation cover and prevented its regeneration.

Overgrazing on the shallow stony soil decreases cover and destroys soil structure, and therefore promotes runoff and erosion. This further destroys what little soil there is left and jepordizes the entire ecosystem that depnds on it. Erosion is therefore see as the main problem and a driver behind evironmental degradation.

THE EXPERIMENT: RANGELAND FANCING TO REDUCE OVERGRAZING EFFECTS

The experiment was carried out near Agia Barbara village on a steeply sloping overgrazed land (23% slope) with shallow soil (35-45 cm deep). Four runoff plots of size 10 m^2 were established (two treatments with two replicas with (a) sustainable grazing (SG), and (b) overgrazing (NSG). At the bottom of each plot a drainage ditch and a tube connecting to a dipping bucket and a sediment trap are installed to collect surface runoff and suspended sediment from the corresponding LMPs with their replicates. Meteorological variables are measured at the same field using an automatic station (see photo below). The experimental station is remotely controlled from the laboratory of Soils in the Agricultural University of Athens.

Soil aggregate stability, particle size distribution, and soil organic matter content were measured twice during the execution of the experiment (12/11/2008, and 30/9/2010). Plant cover was recorded periodically throughout the period during which field observations were carried out.

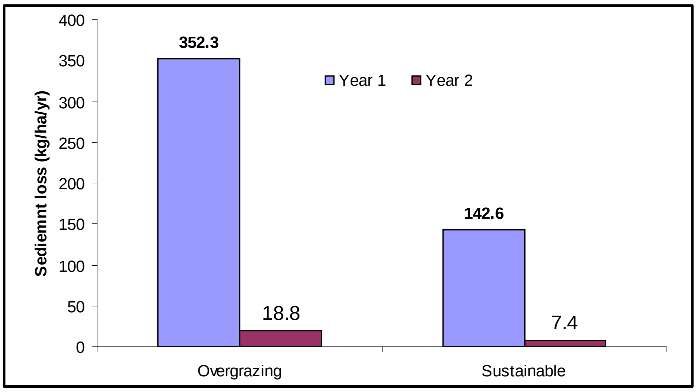
Variable	2008	2009	2010
Meteo			
Moisture			
Runoff			
Sediments			
Organic matter	*		*
Aggregate stability	*		*

RESULTS

Top: overgrazed area, bottom, fenced area

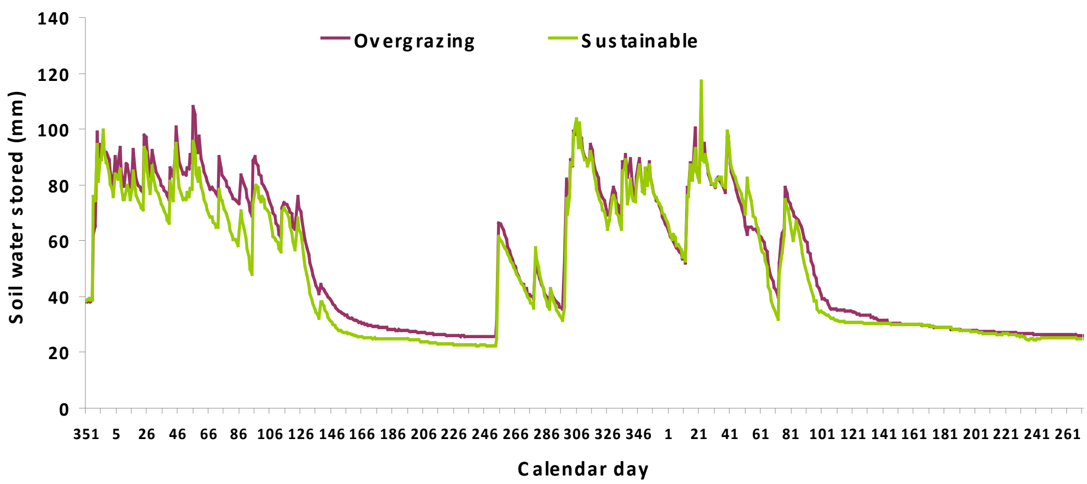
In year 1 and 2 of the experiment annual rain was 520 mm and 625 mm respectively. During that period 10 big rainfall events occurred for which surface runoff volumes were measured. In the sustainable grazing plots the annual as well as the perennial vegetation and the plant residues covers about 85% of the soil surface, protecting the soil from splash detachment, formation of surface crusting, and minimizing surface runoff. The sustainable grazing management practice reduces surface runoff by more than half in both the study years. In year 1, surface runoff from overgrazed plot was 43.7 mm and that of sustainable plot was 28 mm. In year 2, the difference was even more (19 mm verses 7 mm).

Sediment loss was similarly affected by grazing intensity. As shown by figure above sediment losses in the overgrazed plots in year 1 is 352 kg ha-1 yr-1 whereas it is 143 kg ha-1 yr-1 in the sustainable grazing plot. Similar result is shown in year 2. The result shows that soil losses can be minimized by about 2.5 times by employing sustainable grazing.



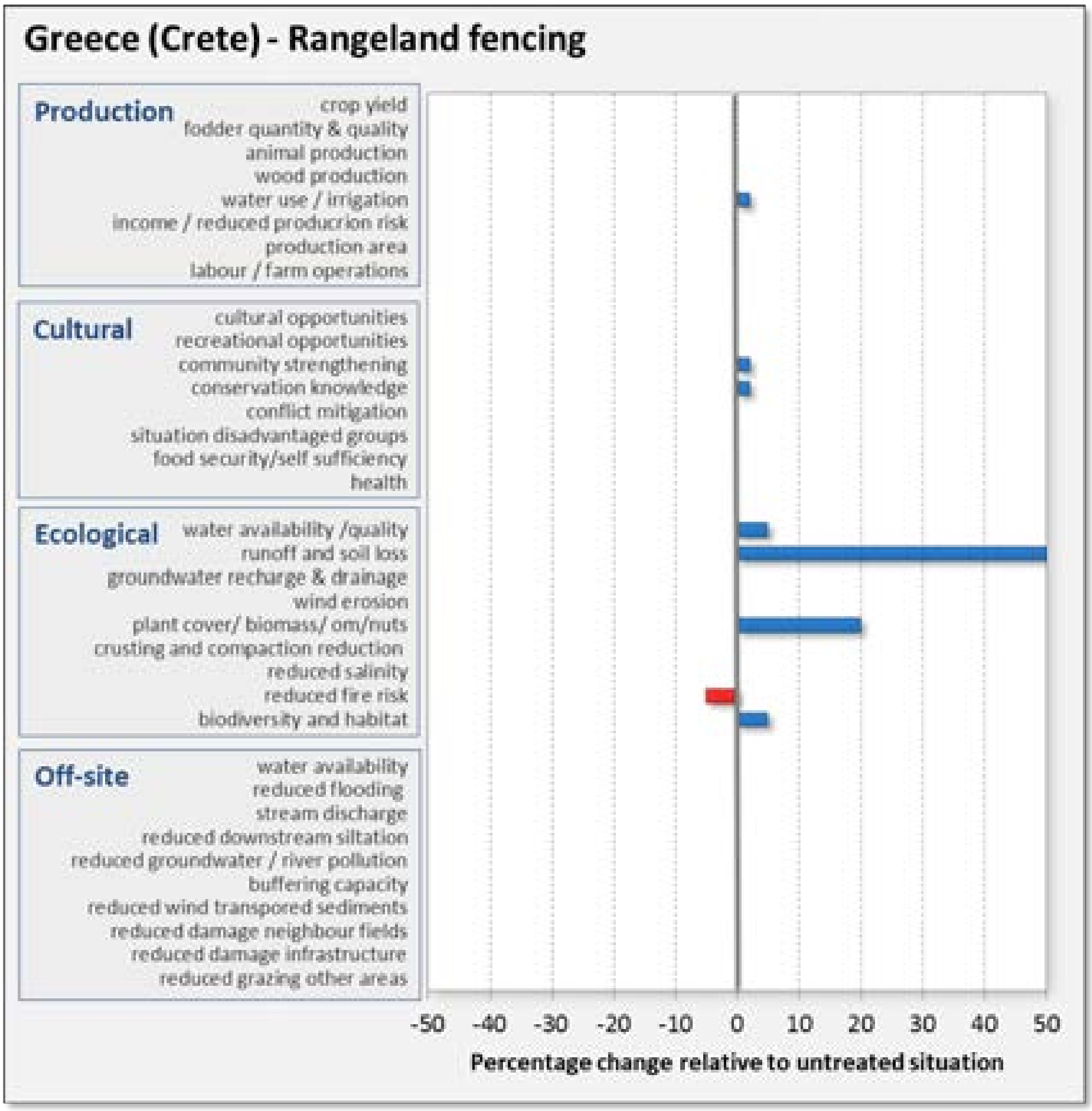
Left: effect of grazing management practices on soil losses

Bottom: soil moisture monitoring in the two plots. A slightincrease in soil moisture is measured in the first year while in the second yearthe moisture contents are almost equal.



How well does it work?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



Stakeholder's opinions

While this is ecologically a good measure, fencing would be very costly for very little return for land owners. Rangeland resting where agreements are made to leave an area as set aside without fencing might be possible. However, the landowners receive EU subsidy based on the number of animals so this effectively negates any means to protect the fragile soil. Since fencing or set aside would mean a decrease in animal density, this is a further lossm of income.

Conclusions

The experiment shows that the sustainable grazing results in minimizing surface runoff and sediment loss by more than half of that in the overgrazed areas. Sustainable grazing results in increasing plant cover and biodiversity, higher soil organic matter content and higher soil water storage. This shows that soil loss in this case is not only about sediment dynamics (the losses are actually small in absolute values), but these thin and fragile soils are an important part of natural ecosystem.

The main bottleneck is the reduction of farm income due to reduced number of grazing animals. Currently the farmers receive EU subsidy based on the number of animals they have. The policy of farm subsidy has to be changed if the SLM technology has to be successfully implemented. Also funds should be made available to compensate for the reduction of animals. In this case conservation would mean providing an alternative means of income or some form of compensation, i.e. changing the subsidy from heads of lifestock to nature conservation.

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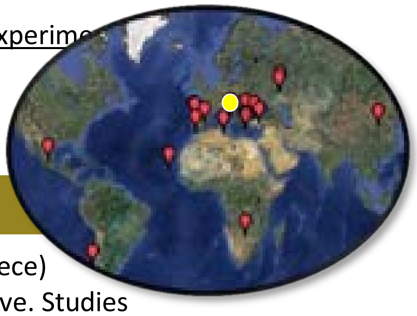


5 GREECE – NESTOS: SALINITY

The coastal region of the East Nestos River Delta (Maggana, northern Greece) has limited freshwater supplies although irrigation is exceptionally intensive. Studies show that there is intrusion of seawater into the coastal aquifer. The shallow brackish groundwater is in use for irrigation since the last 40-50 years, which has caused severe salinization of the soil.

Apart from the chemical problems for crop growth, salinization affects the permeability of soil and causes infiltration problems, because sodium in the groundwater replaces calcium and magnesium adsorbed on the soil clays and causes dispersion of soil particles: a breakdown of aggregates and natural soils structure. Also deeper in the soil this has caused compacted layers to form.

Salinization is very difficult to reverse, and the only possible solution in the area lies in flushing the soil with fresh water from the river systems or fresh groundwater further inland. This experiment tests the soil degradation can be reversed on a field scale and if this results in better crop performance.

THE EXPERIMENT: FRESH WATER FLUSHING AFTER BRACKISH GROUNDWATER IRRIGATION

A corn field which has been irrigating with freshwater from a local stream for the last 10 years was selected for the study. A second field which is traditionally irrigated with saline groundwater was also selected. In both fields, the data on soil physical and chemical properties and crop production was collected. The freshwater field serves as reference for the evaluation below. The saline field was irrigated with relatively fresh groundwater from a well further inland (the river was too far). In addition, different amelioration strategies (deep ploughing to break deeper compacted layers, addition of gypsum) were tested.

Variable	2008	2009	2010
Meteo Data	√	√	√
Moisture			√
Groundwater Level	√	√	√
Groundwater EC	√	√	√
Soil EC		√	√
Soil pH		√	√
Soil Chemistry		√	√
Yield		√	√

The nearby well with improved water quality was selected and an electric powered pump and two sprinklers were installed for irrigation. Moisture, temperature and Electrical Conductivity sensors were installed.

Meteo data and data on groundwater were collected from 2008 to 2010 and soil samples were taken starting from August 2009 at various depths: 0-5, 5-10, 10-15, 15-20 cm, 40-50 and 60-70 cm. Laboratory analysis of the samples was conducted for EC, pH, moisture content and other soil chemical analysis.

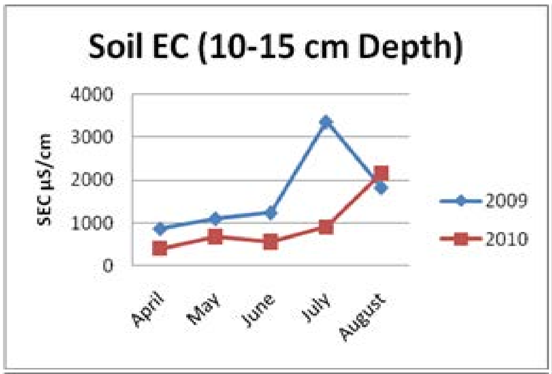
The top soil of these soils is sandy while between 50 cm and 1 meter bands of heavier material can be found (sandy loam and sandy clay loam). While sandy soil is less prone to soil structure loss, the sub soil is more sensitive.

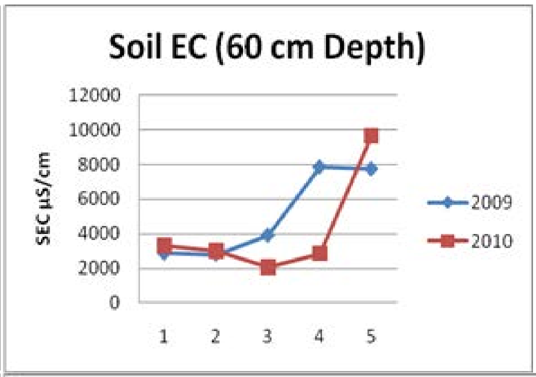
RESULTS

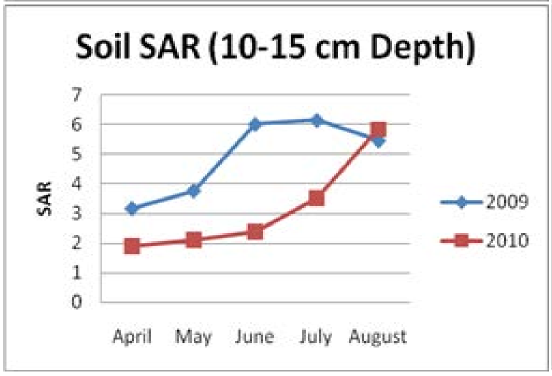
Parameter	2009	2010
EC (µS/cm)	2350	1912
pH	7.67	7.2
SAR	2.41	2.85
Ca^{2+} (mg/L)	424	246
Na^{+} (mg/L)	175	194
Mg^{2+} (mg/L)	84	63
K^{+} (mg/L)	10	15
Cl^{-} (mg/L)	470	295

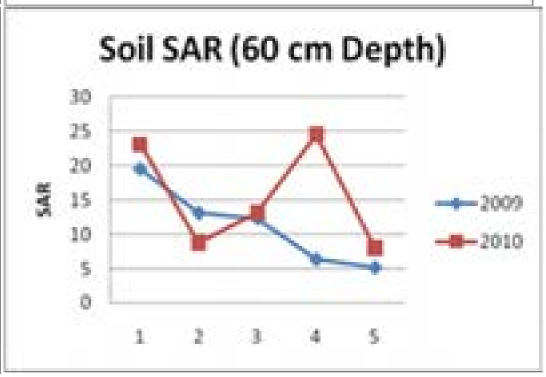
The chemical analysis results of the irrigation water used in 2009 and that used in 2010 shows that the latter has lower EC, pH, Ca^{+2}, Mg^{+2} and Cl^{-} anion concentrations but a slightly higher SAR (Sodium Adsorption Ratio, a measure for suitability of water for irrigation, higher means less suitable). These value make the fresh well irrigation water acceptable for irrigation according to international standards.

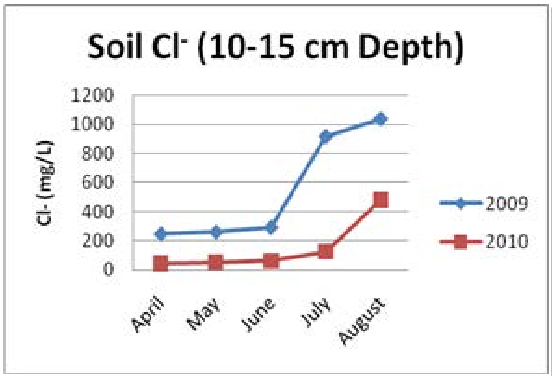
Analysis of the soil samples shows that the EC, SAR and Cl^{-} content in the soil in 2009 is clearly higher than in 2010, indicating a positive effect of using fresh groundwater even after one season. This depends on the general moisture content: the values all increase towards the driest month of August when the difference is less pronounced. The differences in the subsoil are less clear because of fluctuations in 2010 The SAR is even higher at soil depth 60-70 cm in 2010. The overall result shows that the improved irrigation water seems to have positive impact on almost all the parameters. The Wheat yield improved: 3.4 ton/ha in 2009 versus 4.2 ton/ha in 2010.

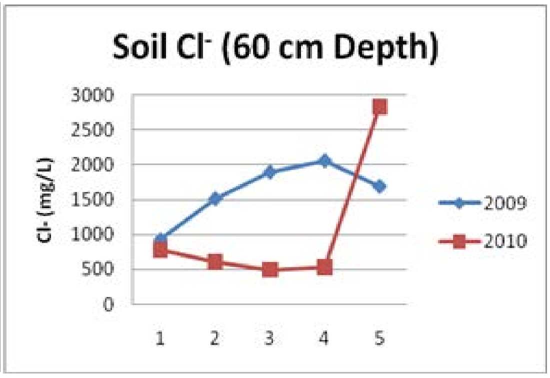






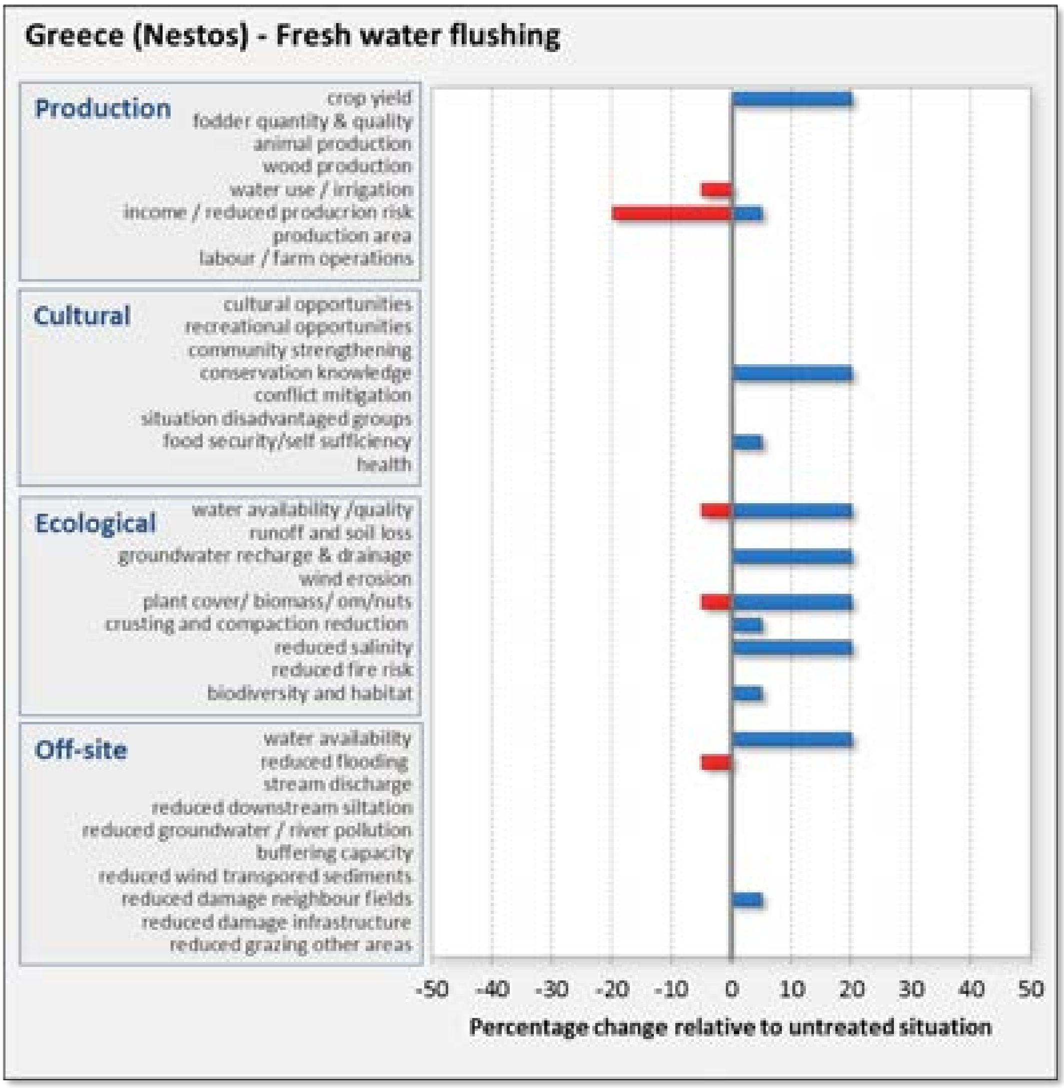






HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

All groups of stakeholders were interested in the results of freshwater transport technology, especially the farmers. The evaluation indicates a medium positive effect overall: there is an increase in crop yield, but at the same time there are also increased costs because of installing an irrigation system that brings water from the streams or wells further inland to the coastal zone. Also using while the groundwater wells have relatively fresh water, there are still elevated salt contents. There are also clear improvements in soil structure and organic matter, from observations on the fresh water field. The yield and crop quality of these fields is a lot better (see photo below).

The total cost of this technology must be taken under consideration before implementation. The reactions of stakeholders were very positive and they were keen on implementing the technology if financial aid is given. All stakeholders expecting the transport of fresh water from the nearby river Nestos.

Photographic illustration of crop growth under the surface water FW (left) and groundwater irrigation GW (right).

CONCLUSIONS

Irrigation with fresh water shows an immediate positive result in both soil degradation indicators as well as in crop yield, and fresh water technology is popular and ready to be accepted in principle. However the cost of installing the irrigation systems is too high for the farmers at the moment. Moreover, the fresh water wells are maybe not a solution in the long run. Heavy use of this water might well induce a further encroachment of saline sea water further inland. This leaves the water of the river Nestos system, but it is not clear if the river system can handle such an increased use of its freshwater and how this will affect the surrounding area.

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6 TURKEY – KARAPINAR: MINIMUM TILLAGE

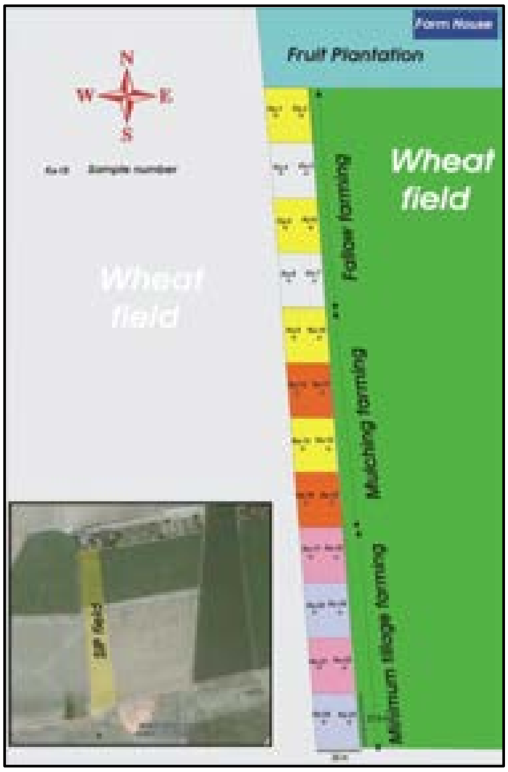
The Karapınar area is the most arid part of Anatolia in Turkey, which suffers from wind erosion due to unfavorable soil and climatic conditions. Also the area knows intensive use of ground water resources for irrigation. Earlier ground water well measurement showed that annual drop reaches 8-10 m. Farmers mostly prefer cereals, maize and sugar beet as irrigated crop types.

Ploughing often results in fine particles that are removed by the wind. Direct drilling has already been introduced as an alternative. An experiment was carried out to test the effect of minimum tillage and stubble on wheat (Ekiz bread wheat) without irrigation. Sediment moved by wind erosion itself is very difficult to measure so the experiment concentrated on the suitability of these tillage forms.

THE EXPERIMENT: MINIMUM TILLAGE AND STUBBLE MULCHING

The technologies tested are minimum tillage (MT), stubble fallowing (SF) and ploughed stubble fallowing (PSF), near the settlement of Apak Yayla. They are designed in a strip farming plan on the crop yield of Ekiz bread wheat (*Triticum aestivum* var. Ekiz). For each technology four rows of parcels perpendicular to the dominant wind direction were made of which one is active this year and other fallowed. The following parameters were measured at the times indicated in the table below.

- Sprouting number /m^2 and branching number (in the early and late sprouting period)
- Grain yield, number of grains in ear, weight of 1000 grains, height of plant, harvesting index and # of grains in m^2 (in the harvesting period)



Observations are done on two different locations on each parcel and are averaged later. Unfortunately there were no means to measure physical soil parameters but only crop related parameters (yield related).

RESULTS

Sprouting and branching are used to calculate the density of the wheat plants per m². The three technologies resulted in considerable variations in term of sprouting observations. Minimum tillage has the highest sprouting intensity but lower branching number while the ploughed stubble fallowing is optimum for both sprouting intensity and branching number. The inter-annual variation is high.

	2010		2011		Average	
Technology	Sprouting number/m2	Branching number	Sprouting number/m2	Branching number	Sprouting number/m2	Branching number
ploughed stubble fallowing	280	3.2	413.0	2.6	346.5	2.9
stubble fallowing	268	3.0	433.0	2.3	350.5	2.6
minimum tillage	313	2.4	411.0	1.8	362.15	2.1

Grain yield and height of plant is the best for stubble fallowing while the number of grains in ear and weight of 1000 grains do not considerably vary. In terms of harvesting index and number of grains in m², minimum tillage and stubble fallowing have clear advantages upon ploughed stubble fallowing (see table below).

Income is based on grain and straw yield, whose amount varies significantly according to the technology applied. From the viewpoint of net economic income, the Stubble farming has clear advantage compared to other technologies (Table below) with a net income of %44. The other two technologies are close to each other.

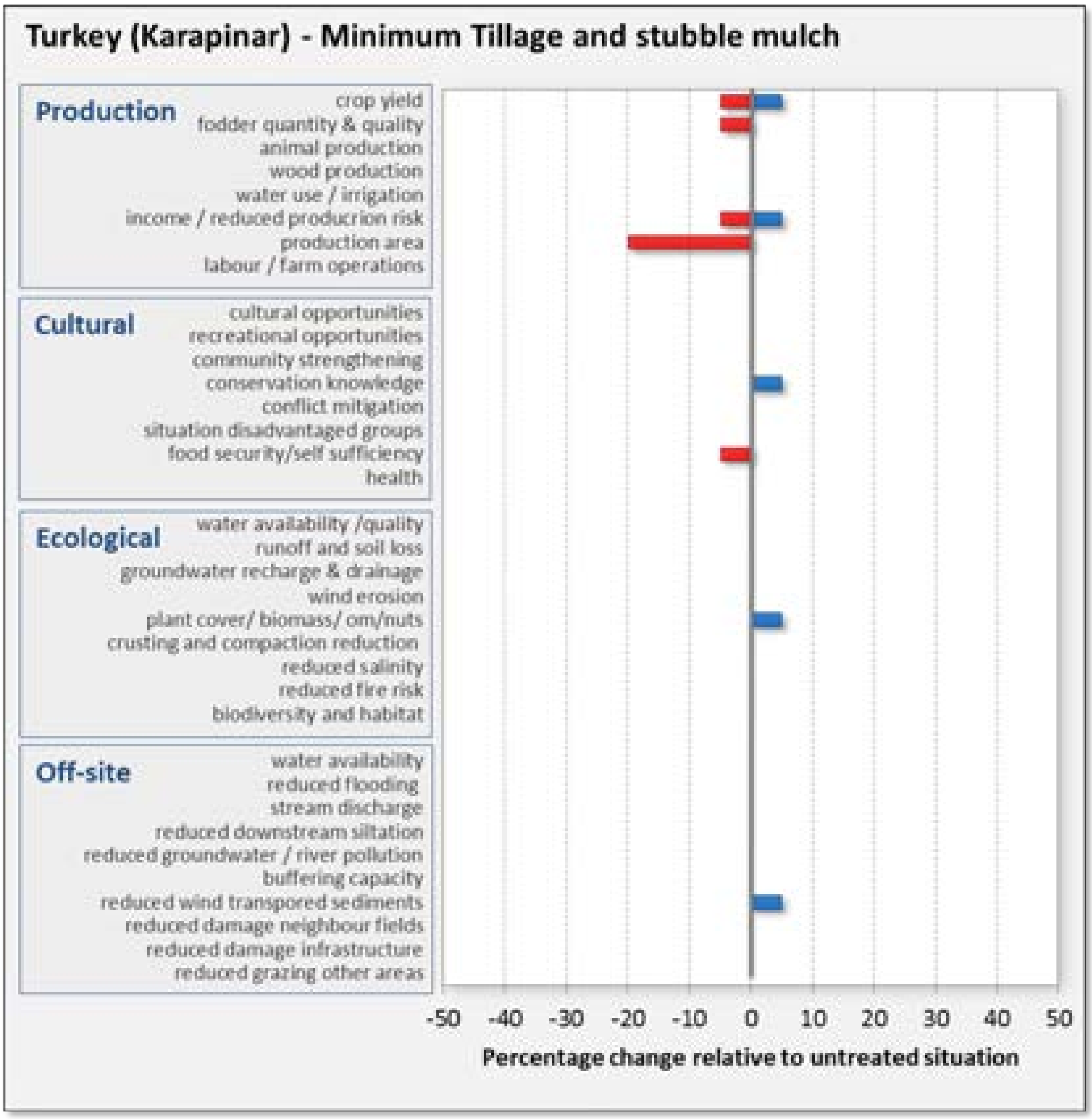
Profuct	2009				2010			
	Yield (kg/da)	Quantity (kg)	Unit price (TL/kg)	Income	Yield (kg/da)	Quantity (kg)	Unit price (TL/kg)	Income
wheat (minimum tillage)	449	512	0.5	256	376	429	0.65	279
wheat (stubble farming)	518	590	0.5	295	562	641	0.65	417
wheat (ploughed stubble farming)	464	529	0.5	265	422	481	0.65	313
Straw (minimum tillage)	965	1100	0.1	110	537	612	0.2	122
Straw (stubble farming)	1053	1200	0.1	120	787	897	0.2	179
Straw (ploughed stubble farming)	1009	1150	0.1	115	591	674	0.2	135
TOTAL INCOME				1161				1445

In terms of wind erosion, it was observed that the stubble farming and minimum tillage have less visual wind erosion than the ploughed parcels.There are however no measurements for this.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.

Both treatments are evaluated at the same time as they are one large experiment.



STAKEHOLDER'S OPINIONS

Stakeholders are passively involved in the division of the area into technology parcels and the ploughing and sowing operations as observers. The presumed efficiency and expected results of technologies applied in the field were discussed. The owner of the experimental field executed the agricultural activities himself (ploughing, fertilising, etc.) throughout the season.

Stakeholders generally approve the effectiveness of the technologies tested. The yileds are comparable although slightly lower. However the treatment includes a fallow period which for the irrigated areas is not present. Thus land is taken out of production which is considered very negative. This is not compensated by the net gain in income of the treatment because of lower labour and operational costs. This will be different for each farmer, depending on the degree of mechanization. The end result is therefore that the technology is not readily accepted because the benefits are not sufficiently clear cut. This may change if irrigating with groundwater becomes too costly. The experiment shows that rainfed agriculture is possible in principle while having a positive effect on wind erosion (at least visually).

CONCLUSIONS

- Minimum tillage and stubble fallowing have clear advantages in terms of yield parametres of the Ekiz bread wheat in Karapınar hotspot. Minimum tillage particularly positively effects the sprouting intensity but not the branching number.
- The variations in yield parametres are probably explained in terms of removal of nutrient topsoil by wind erosion. It seems that minimum tillage and stubble fallowing decrease the shear stress of the wind and hence reduce the wind erosion.
- Contrary to vegetative parameters, the harvested product (both for grains and straw) is the maximum in stubble farming followed by ploughed stubble farming.
- Basic obstacles agains the wider application of technologies are considered the lack of specialised machinery and required knowledge for minimum tillage and the decrease of net income due to fallowed parcel each year.

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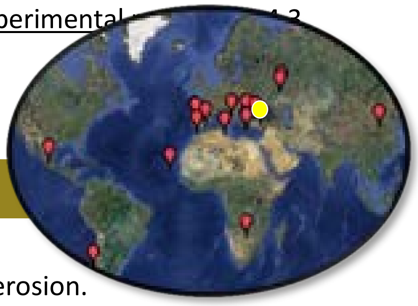


7 TURKEY – ESKESHIR: TERRACING & CONTOUR TILLAGE

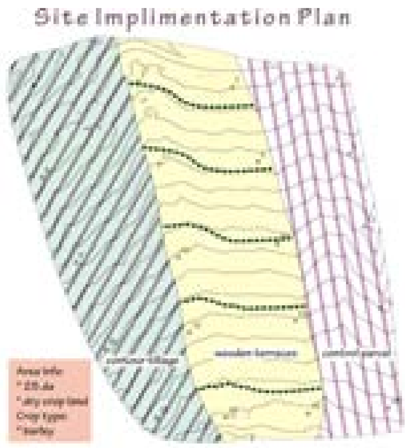
The hill slope areas near Eskisehir suffer from soil erosion.

The area is semi -arid, soils are shallow, stony and organic matter content is low. Land use is rainfed wheat with occasional fallow periods. Late spring and early summer rainfalls are particularly erosive.

Experiments were carried out that interrupt the runoff and help increase infiltration and thereby increasing soil moisture storage. The overall objective is to decrease surface runoff and to reduce soil losses.

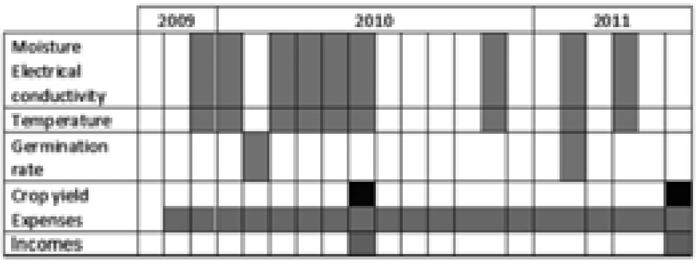
THE EXPERIMENT: TERRACING AND COUNTOUR TILLAGES

Two technologies (contour ploughing and terracing) were investigated for water retention and crop growth against the conventional cultivation practice during the period December 2009 and July 2011.



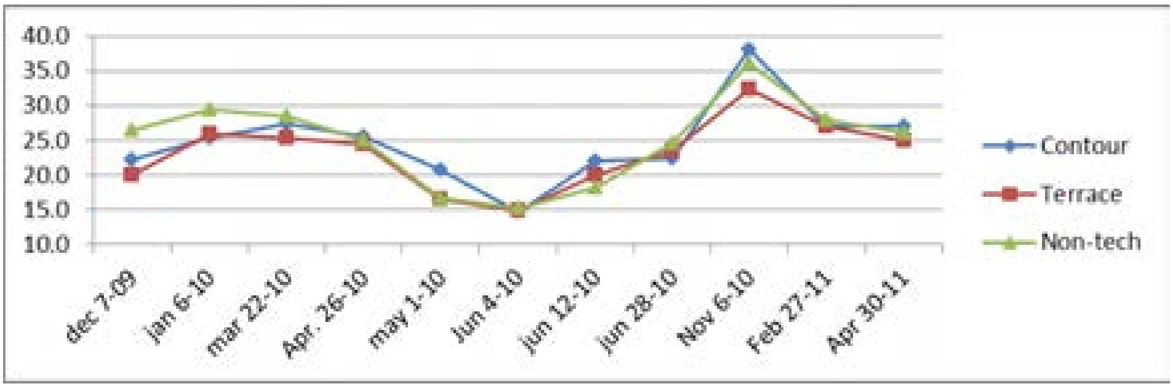
Terracing in this context means that shallow levees were made along the contour lines (dashed lines in the drawing to the left). Poles are hammered on top and branches are woven between them This potentially stops the sediment and slows down runoff and when left continuously, a sloping terrace would eventually form. The tillage between these fences is along the contours. The left hand plot was done with contour ploughing only. The right hand plot uses the conventional tillage along the slope as it gives the longest seed lines.

Soil parameters such as moisture content and electrical conductivity were measured regularly with a portable TDR at pre-defined locations (12 per plot), apart from germination rate and crop yield observations (see table below). Germination rate is determined by counting the individual sprouts in m^2 once within January in the early sprouting period. Crop yield assessment was made during the harvest at the end of growing season.



RESULTS

The result shows that the water content (WC) of the soils vary seasonally. During the monitoring period (Nov 2009 – June 2011) contour tillage technology results in a slightly higher WC (Figure below). Terracing gives second best results though non-technology area exhibit higher WC in the winter months. The differences might also be caused by soil variation. In any case, the differences are not significant, certainly not in a sense of crop water availability.

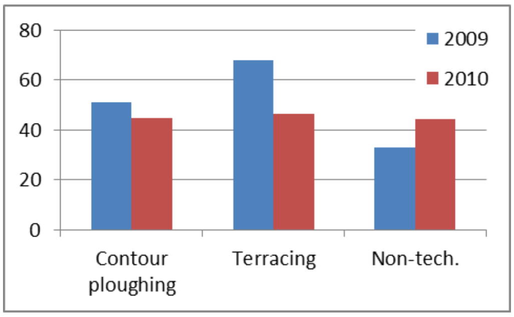


Average moisture content (12 measurementsper moment per treatment) during the experiment.

It appears that during the first year, seed germination rate was the highest in the terraced plot as compared to contour and conventional tillage, while in the second year these differences were not observed. This shows that inter-annual variability is sometimes large and not all effects should be contributed to the technology.

Finally, crop yield in the terrace and contour tillage plots is increased by 2-3 times. While this can be explained by a better germination in 2009, there is no clear explanation for 2010. There might be moisture differences deeper in the soil that are not detected.

During the two years there were no direct erosion events on the plots, However a neighbouring unprotected field showed heavy rills which were seen on the experimental slope.



Germination rate winter Barley in January in sprouts/m^2

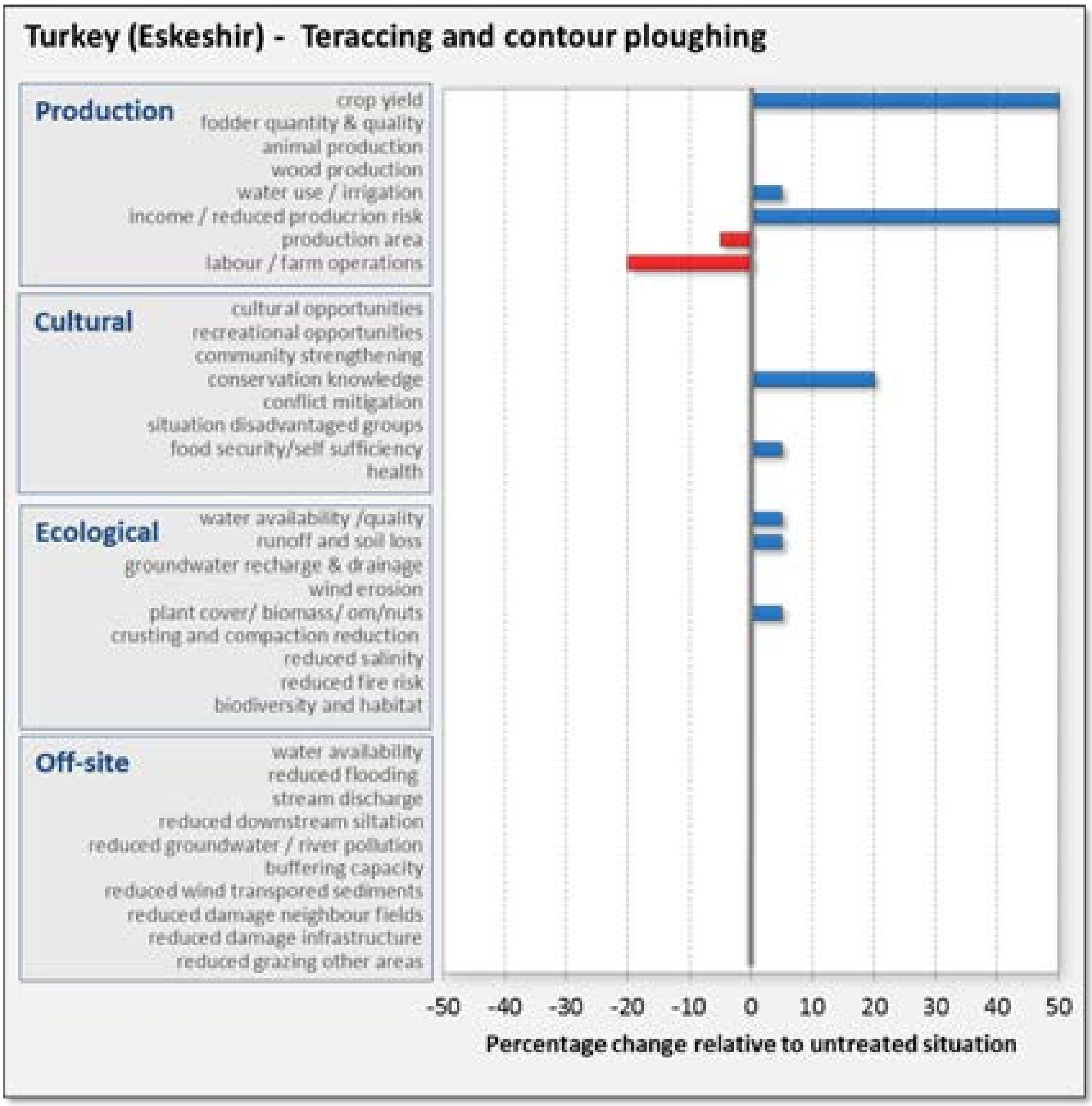
Harvest / collection date	technology	Area (ha)	Crop type	Quantity (kg/ha) 2009	Income (per ha) 2009	Quantity (kg/ha) 2010	Income (per ha) 2010
07-07-10	Terrace	1.15	barley-grain	1652	634	1304	501
07-07-10	Terrace	1.15	straw	609	61	635	63
07-07-10	Terrace Total				*(293)* **695**		*(512)* **564**
07-07-10	Contour tillage	0.82	barley-grain	756	290	1829	702
07-07-10	Contour tillage	0.82	straw	366	37	762	77
07-07-10	Contour tillage Total				*(293)* **327**		*(574)* **779**
07-07-10	Control	0.8	barley-grain	375	144	313	120
07-07-10	Control	0.8	straw	188	19	313	31
07-07-10	Control Total				*(271)* **163**		*(558)* **151**

Summary of yields in kg/ha, expenses (between brackets) and income for the two years. Monetary unit is Turkish Lyra. Note that there is an initial expense to create the levees of 2170 TL.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.

NOTE: the evaluation outcome was nearly the same for both technologies. The only difference is that for contour ploughing alone the negative judgment of farm operations is less severe. Creating and maintaining the levees is considerable more effort than the tradional tillage.



STAKEHOLDER'S OPINIONS

The stakeholders meeting showed the importance of bringing solutions to this degradation trend which threats both the environment and the farmers' income. The farmers experience shows that barley is the most appropriate crop for the terrace and the contour ploughing technologies. Stakeholders were passively involved in the construction of wooden terraces as observer. In the last harvesting season, stakeholders visited mutually the implementation area and discussed the technologies. By using their own experiences they found that barley crop in terraced and contour

ploughed spots are more robust compared to control parcel. Stakeholders mostly think that due to low rainfall rates throughout the growing season 2009 and lack of fallow in our application radically decreased the effectiveness of the technologies applied. In a wider sense they believe that the population is becoming older due to intense migration of young people to big cities for economic reasons, which puts an extra stress on implementing technologies at a larger scale.

Terracing involves additional costs and possibly loss of some land whereas contour ploughing can be widely applied without much effort. Also it is seen as a slight loss of land. The field however has to be wide enough because contour ploughing might create many short tracks and turns of a tractor, which causes a yield loss. Generally it needs only cost for fuel use which is similar to traditional ploughing. However some training is needed for implementing in steeper slopes. Also smaller tractors with more manoeuvre capability will be better in cultivating terraced land.

CONCLUSIONS

Contour ploughing and terracing seems to have a slight increase in top soil moisture due to reduced runoff but this depends on the seasonal rainfall. The technology helps in improving soil condition and crop growth as well as increased yield benefits. The yields over two years were much higher in the experiments than in the control plot, even while the rainfall was very different between the years.

Regarding relatively smaller costs involved in contour ploughing, the technology is applicable in wider hill slope areas of semi-arid Central Anatolia. The levees with fences were considered less advantageous because of initial costs and loss of agricultural area, for little gain.

Main bottleneck for the easy application of technologies seems sociological (lack of enough young farmers) and economic (prices etc.) rather than scientific.

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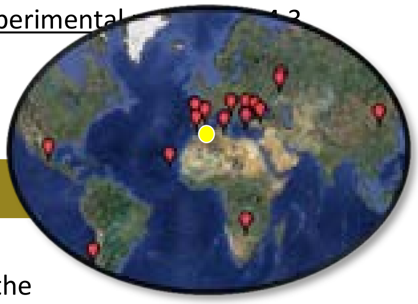


8a MORROCO – MAMORA: GULLY STABILISZATION

The North West of Morocco has areas with extensive gullying of the agricultural lands. High pressure agriculture and overgrazing, combined with occasional heavy rainfall, causes severe land degradation.

An additional problem is sedimentation in the drink water reservoirs downstream. For farmers in the area, annual crops for food production and livestock for immediate income is vital. Conservation measures must improve their situation or they will not be acceptable.

THE EXPERIMENT: PLANTING BUSHES TO STABILIZE GULLIES

A good way to stabilize gullies and prevent further erosion is planting shrubs. The species must be able to survive dry years, and *Atriplex halimus* was chosen and planted in 2009 in a regular pattern across the gullies. *Atriplex* is a Mediterranean species and adapted to the climate, but initially the plants were irrigated to protect them from drought. The gully area is fenced to keep out animals. The experimental plot has been isolated for two years after which controlled grazing took place. Apart from stabilization the species can be used as a fodder, and fencing of the area is expected to cause rangeland restoration.

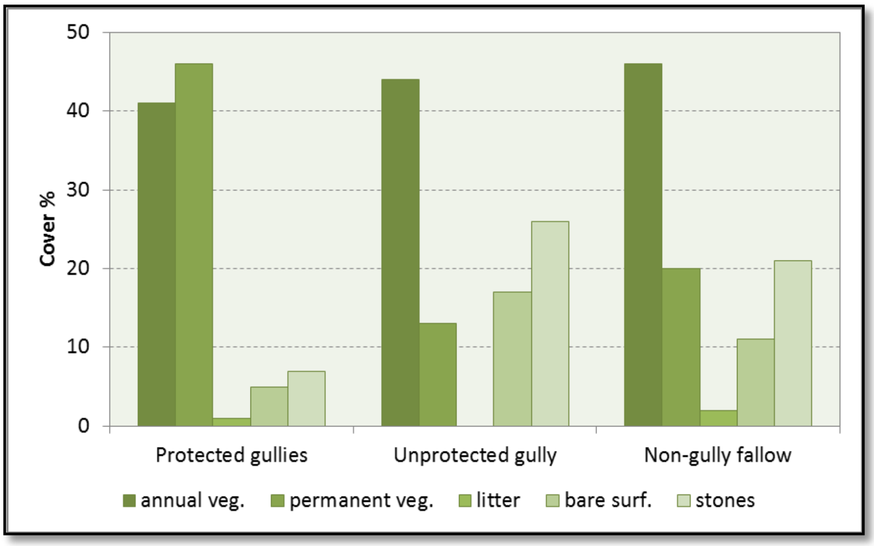
This long term experiment was started in 2008 where weather conditions, biomass, soil moisture and soil properties are monitored.

Variable	2007	2008	2009	2010	2011
Meteo		→	→	→	→
Discharge		→	→	→	→
Vegetation			→	→	→
Soil Moisture			→	→	→
Soil Properties			→	→	→
Yield				●	

Atriplex halimus

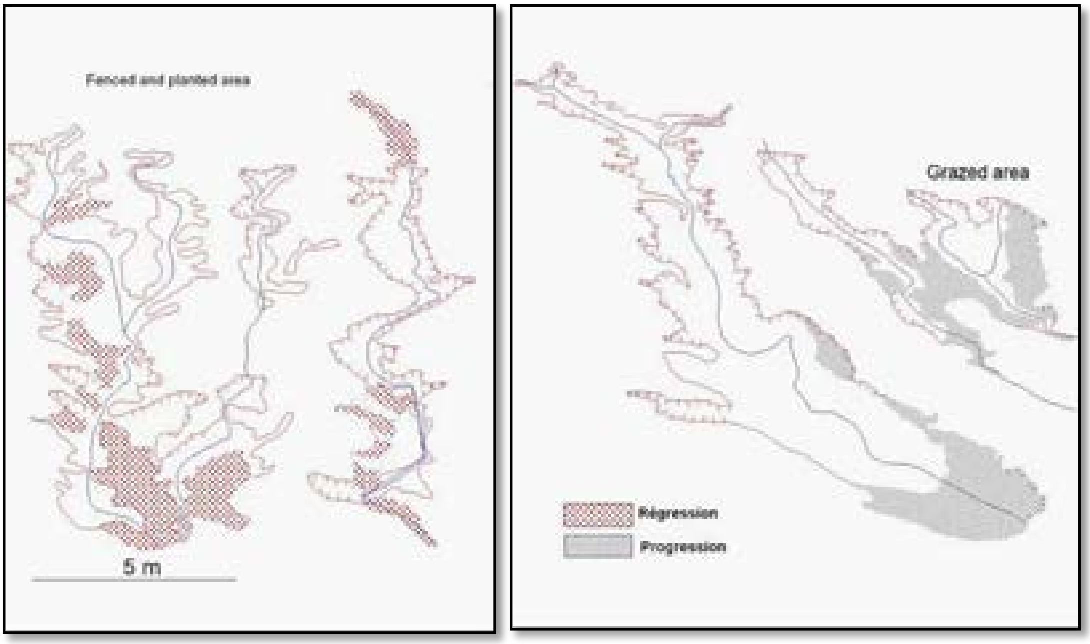
RESULTS

The experiment has clear effects both on the biomass increase and the gully stabilisation. Biomass of both annual grasses and perennials has increased considerably from 360 kg/ha to over 1200 kg/ha. Also the quality of the vegetation has increased, with good grass species, making this a viable source of fodder. The number of grass species was 20/m^2 on the 'atriplex' plot as opposed to 10/m^2 on the fallow plot. Expressed in cover % the cover was more permanent (see figure below). Experience shows that in a dry year the *Atriplex* survives and provides a minimum biomass, while in a wet year there is a combination of grasses and *Atriplex*. The effect on sediment loss needs longer monitoring at catchment level, but no forther gully change has been observed in the plot.



Cover % of the trhee plots: while the cover of annual grasses is about the same, the perennials give a good alround cover and protection.

Soil moisture seems to be higher in the Atriplex plot although this may differ from season to season according to rainfall. The soil was less compacted in th plot. Effect on other factors such as soil organic matter need longer monitoring to evaluate. The establishment of this plot however also brings costs. An analysis of the costs and benefits in terms of fodder gives the following estimates. The prices are relative to currency changes.

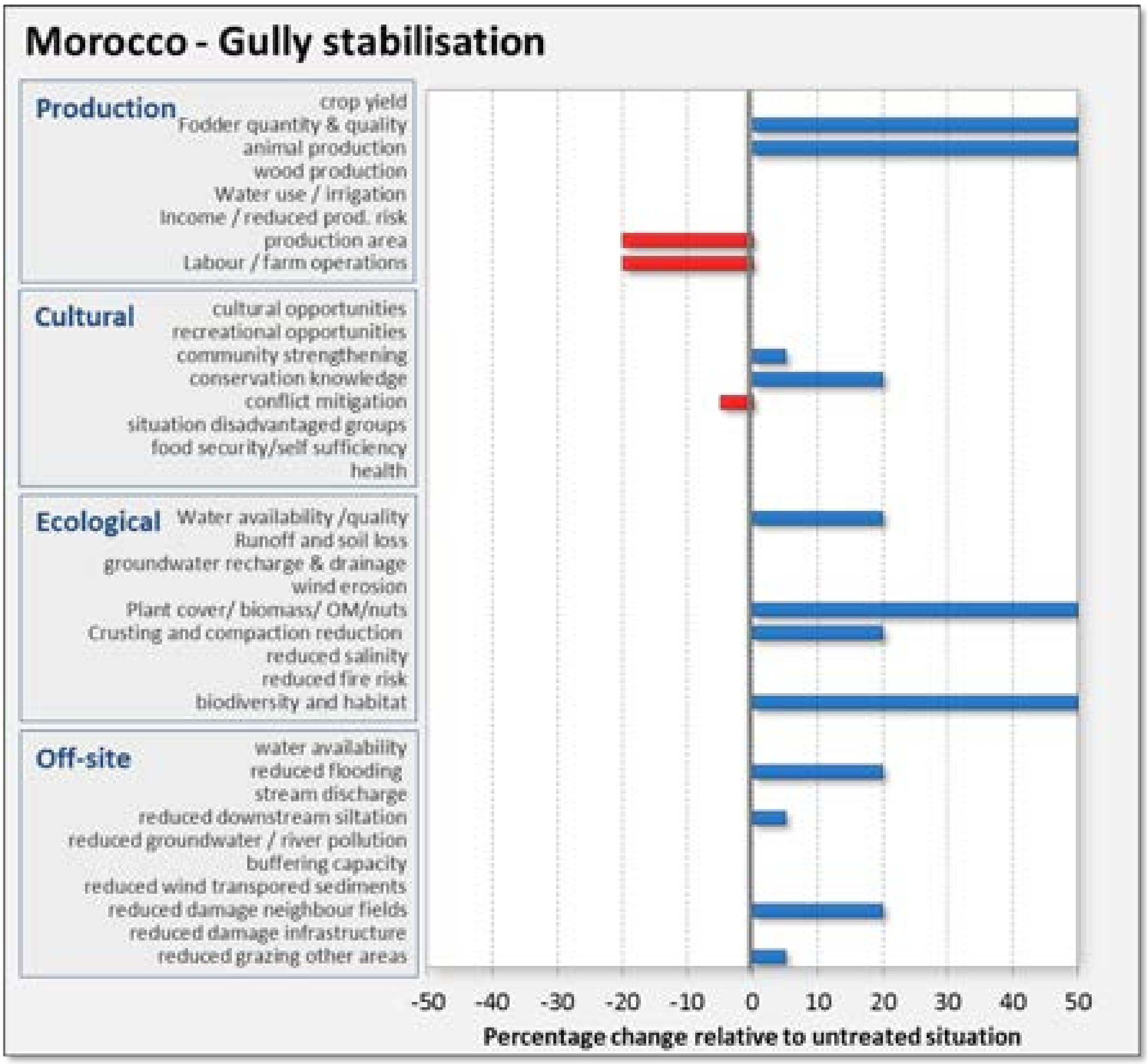


The effect of 2 years of fencing showing a decrease of the gully area (left) by gradual collapsing and filling in (marked as regression) as opposed to the reference area (right) where the gully area that has increased (marked as progression).

Input/ha	Euro	Output/ha	Euro	Euro
Plants	405	Fodder yield 1rst year	0	
Holes	810	Improve in site	135	
Fence	587	Improve downstream	135	
Irrigation	720	Total outputs 1rst year	270	
			0	-2252
		Fodder + ecosystem services	405	-1442
		Fodder + ecosystem services	405	-1307
		Fodder + ecosystem services	540	-767

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

The results of the experiment are positively regarded. However the farmers point out that a large scale fencing and planting of the degraded lands in the region is impossible for them, without financial compensation for time and subsidized equipment and materials. An initial set aside period of 2-3 years would mean a substantial (temporary) loss of grazing land.

The initial investments are approx. 2x as high as the combined 3 year returns in this experiment. The farmers are spectators at the moment, until the long term effects are clearer and more convincing. The general knowledge on land degradation is improving however, because of these experiments.

CONCLUSIONS

On a small scale the experiments are successful. The area is degraded in places but apparently a natural restoration seems possible when the areas are protected from grazing, at least temporarily. There are indications of a decrease in erosion while at the same time the fodder quality and quantity increases. Thus it can be beneficial for farmers. On the long run a further stabilization of the slopes is expected.

This positive effect is off-set by a large initial investment in time, labour and money. This would make a large scale adaptation of this measure impossible, and fencing areas that are otherwise open for grazing may have also social and cultural implications. Also initially the area is set aside causing a decrease of grazing land of a few years. A viable approach could be to establish several of these experiments in strategic and visible locations both to combat erosion and to promote acceptance and increase understanding.

A long term effect of a larger availability of fodder might be that a reduction in pressure on other ecosystems, such as the forested areas that are now overgrazed.

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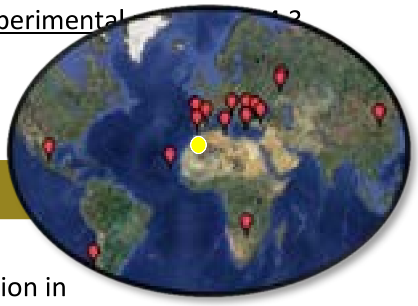
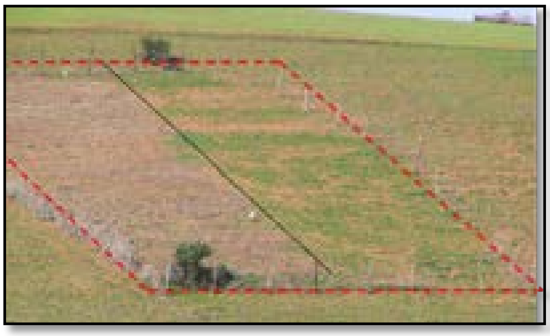


8b MOROCCO – MINIMUM TILLAGE

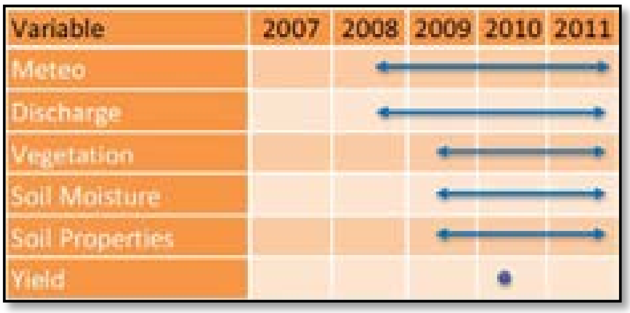
The North West of Morocco is characterized by a strong variation in seasonal rainfall from year to year. Ploughing is done at the first rains after September and with sufficient rainfall there will be a moderate harvest in February (mostly Wheat and Barley). If the crop fails it is used for fodder. For farmers in the area, annual rainfed crops for food production and livestock for immediate income is vital. There are no additional water sources and water conservation measures could help in this situation.

THE EXPERIMENT: TERRACING AND COUNTOUR TILLAGES



Ploughing is a necessary tillage operation to open the soil and eliminate weeds. However it also destroys the natural soil structure that is more stable and it may cause excessive evaporation and compaction may result in runoff and erosion. The experiment compares a minimum tillage plot (left hand side) with conventional tillage to see if the water availability increases. Also a third plot was established: fallow with grazing (the normal practice). Additionally the minimum tillage plot was covered with natural mulch and residue. This should protect the soil from water and wind erosion and limit direct evaporation.

The soil is very stony and direct seeding was not possible, a seedbed was prepared with a shallow tillage operation. Also minimum tillage requires the application of herbicides for weed control. The first year light grazing was permitted; the second year the plot remained closed.

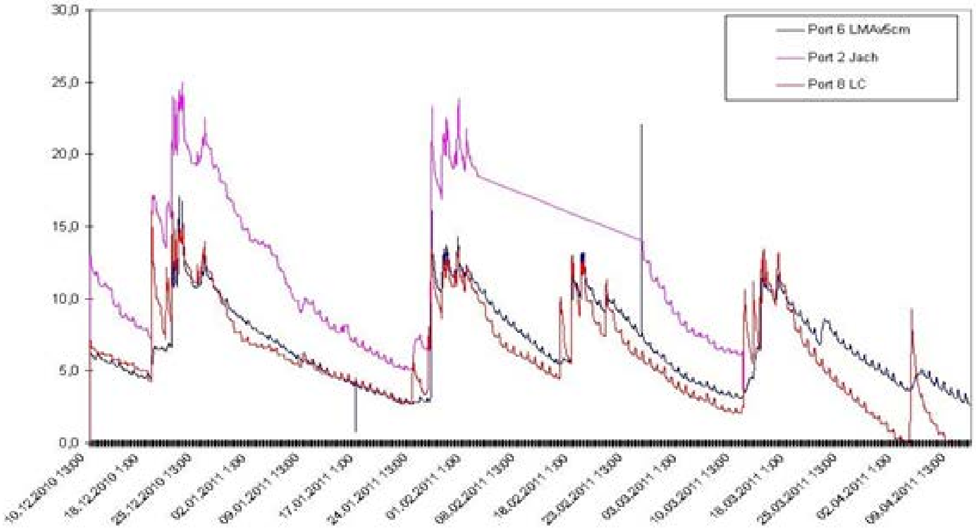


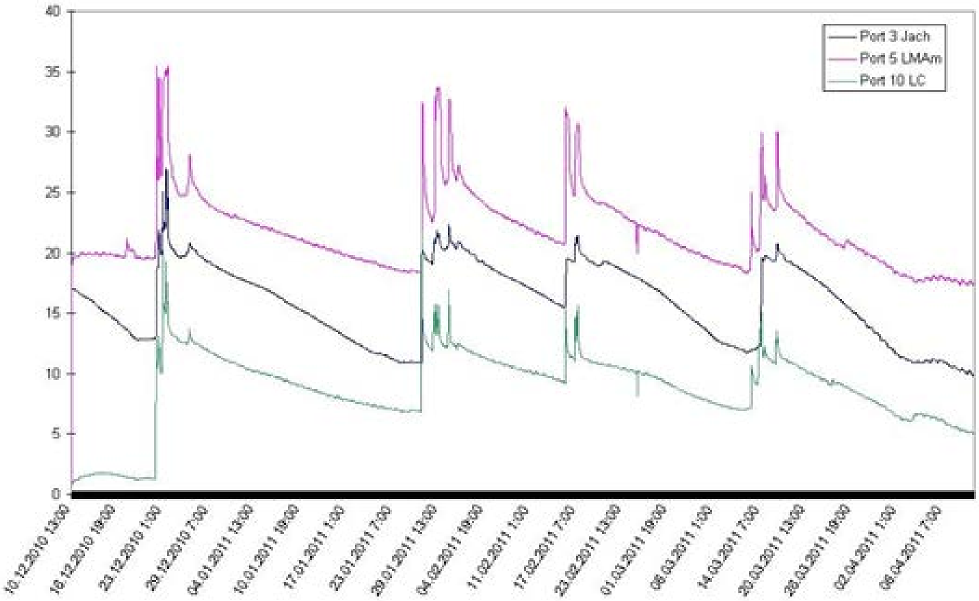
This 2 year experiment was started in 2009 where weather conditions, soil moisture and soil properties are monitored, as well as yield parameters. Several sets of TDRs were used for soil moisture monitoring at 5, 15 and 30 cm depth.

RESULTS

The experiment did not give clear results in water availability throughout the two year monitoring. In some periods the minimum tillage plot had more water, in some it has less than the fallow and normal tillage plots. The graphs below show the growing season from sep 2010 to april 2011, at 5 cm depth (top) and 30 cm depth (bottom).

The sensors near the surface show that the fallow plot is wettest (indicated with 'Jach') while the minimum and conventional tillage moisture contents are not significantly different (indicated resp. with ‘LMA’ and ‘LC’). The moisture content at 30 cm depth is markedly higher for the Minimum Tillage (LMA) and similar for conventional tillage and grazed fallow. An explanation for this is in the effect of surface cover. The fencing and mulch caused a much higher vegetation density in the minimum tillage plot, causing more interception of rainwater and a dryer soil near the surface Possibly the mulch and cover caused interception of rainwater. This prevented in fact infiltration which takes place on the fallow plot, and so that becomes wetter. The treatment seems to work for the deeper soil, where the minimum tillage is wetter than the fallow and the conventional tillage (which is driest). It is however not clear if this is a result of fencing and vegetation, or of the tillage itself.





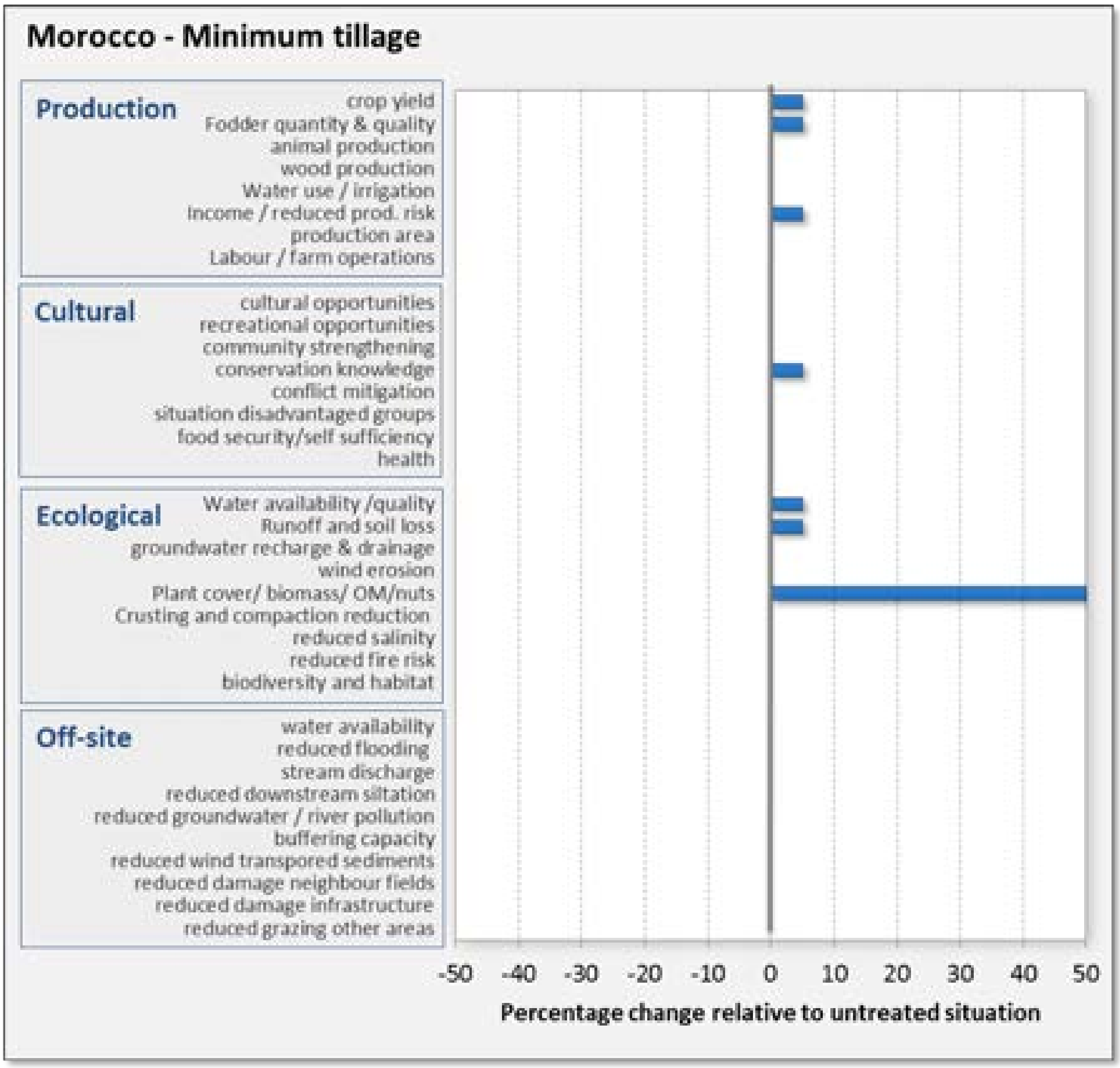
Moisture contents at 5 cm (top) and 30 cm (bottom) for the plots fallow+grazing (jach), cobnventional tillage (LC) and minimum tillage (LMA), for the growing season 2010-2011.

It is important to note that the soil on which the plot was established was not suited for minimum tillage. It is an old river deposit and very stony compared to other soil types in the region. The stoniness prevents the seeds from establishing properly which results in a loss of yield. Seeds are also more easily accesible to birds. Therefore some form of tillage is necessary in these circumstances. A different soil type with finer material may repond better to the measure.

A main effect may be the fencing, which prevents grazing pressure and gives therefore higher yield results. A slight increase in yield is recorded: 545 kg/ha of Barley on the minimum tillage plot compared to 505 kg/ha on the conventional plot. The amount of straw was 1230 kg/ha and 1100 kg/ha respectively.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

The farmers are not very convinced by the results. The small increase in grain yield and straw yield (used for fodder) was offset by the necessity for fencing in this experiment, which is seen as very negative. There is no visible improvement of the soil, and the location was not appropriate for minimum tillage because of the stoniness. Also there might not be sufficient material for mulch in this dry environment, which could increase pressure on natural areas for mulch production.

CONCLUSIONS

The experiment does not give clear results yet (although 2 years is short for a natural soil structure to re-establish). The increase in yield may be a result of the fencing, decreasing the grazing pressure. Also, minimum tillage as a conservation measure was not correct for this soil type: the stoniness hinders proper seed establishment. On a different soil type (also present in the area) the results might be better. As a positive effect a clear increase in water availability, especially deeper in the soil and later in the season, is observed.

There are strong cultural objectives against fencing (apart from the costs). Traditionally there is free range grazing as a strategy for survival. At the same time there is an increasing tendency of fencing in the region to confirm ownership. It is clear that Large scale application of minimum tillage would mean a complete revision of farm management, with controlled grazing (with or without fencing), harvest of fodder instead of grazing of stubble, etc. It is difficult to estimate the effects. The negative pressure on natural areas (forests) may actually increase when animals are excluded from some areas, while the better managed areas show a positive ecological effect(less runoff, better soils etc). In any case it is clear that a large scale management change has influences beyond the immediate change in tillage, and there must be a strong economic incentive before such changes would take place.

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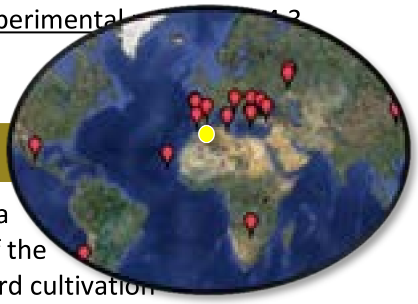


9a TUNESIA – ZEUSS KOUTINE: WATER HARVESTING

The Zeuss Koutine area in Tunisia suffers from over exploitation of the aquifers, and extension of orchard cultivation at the expense of natural grazing lands. Severe long drought periods reduce soil water content to levels where olive plantation can suffer enormously. Traditional water harvesting techniques (Jessour and Tabias) are used for the improvement of water content of soil. Replenishment of groundwater aquifers are ensured through the recharge structures (gabion check dams and recharge wells). However, current cropping levels versus water availability may not be sustainable. The experiments are geared towards monitoring water levels, as the water harvesting techniques are well established.

THE EXPERIMENT: MONITORING WATER LEVELS OF TRADITIONAL SYSTEMS

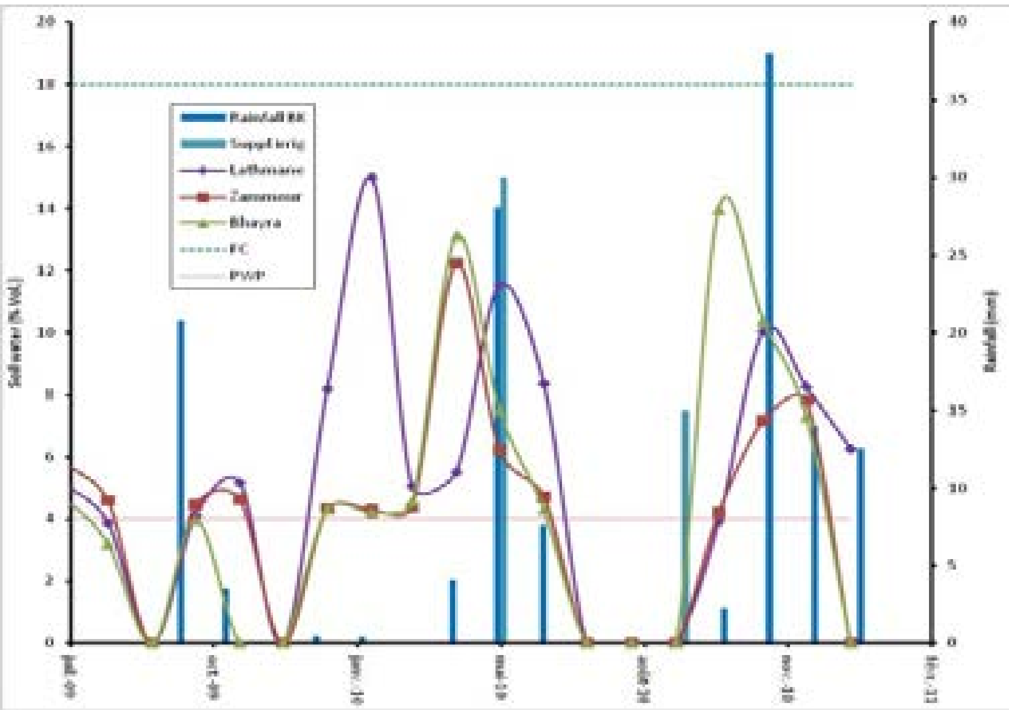
Jessours and Tabias are variations of a system of water harvesting whereby checkdams along flat valley floor capture the runoff water and sediments from the surrounding slopes (called impluvium). In the central flat area behind small dams dam (Tabia) fruit or olive trees are grown. Ratios of surrounding Impluvium versus cropped area vary from 6 to 20. The differences between the tabia and the jessour systems are that the former contains two additional lateral bunds (up to 30 m long) and sometimes a small flood diversion dyke (Mgoud). Besides their water harvesting qualities, these systems also have a positive effect on soil erosion and groundwater recharge.

At three sites, gravimetric methods were used to monitor soil water at different depths: 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. The piezometric level of aquifers and rainfall were monitored by the Water Resources Division of the Ministry of Agriculture in Medenine since the 1990. Apart from rainfall also irrigation supply was monitored.

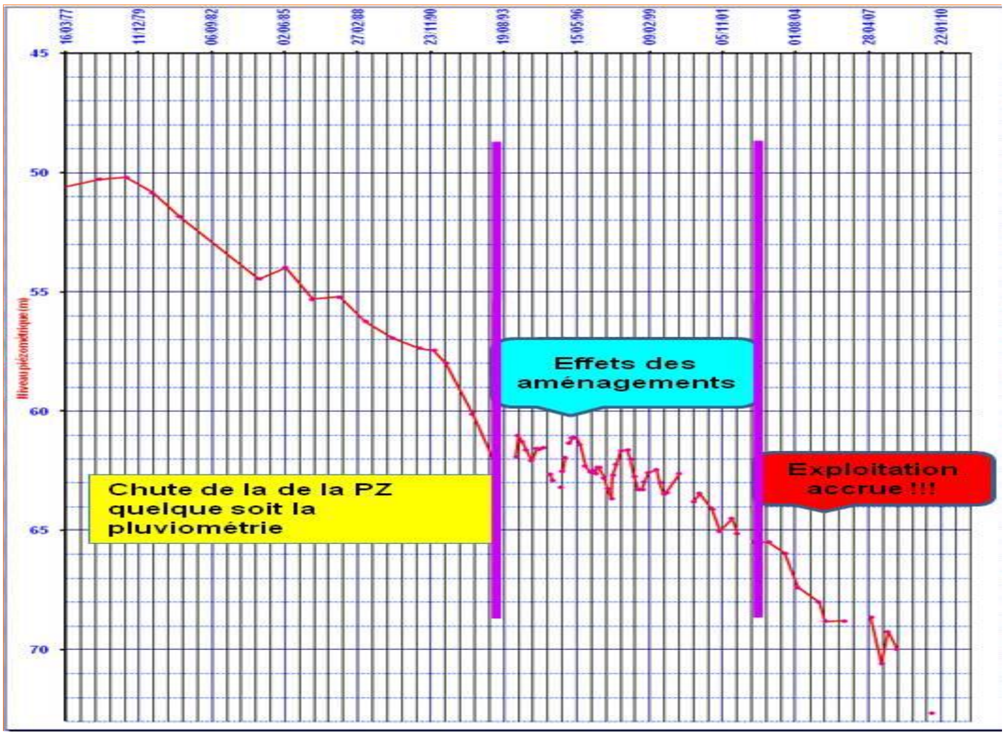
RESULTS

The observation period lasted for one and half year which was an exceptionally dry period. No runoff was recorded from the impluvium and the only supply of water was the rainfall itself. Consequently, the soil water content was very low in the three sites especially during the summer time which did not reach the field capacity throughout the period (see graph below).

The monitoring year happened to be exceptionally dry. The total recorded rainfall was 132 mm in Béni Khédache while the average annual rainfall is around 220 mm. Due to high spatial variability of rainfall and due to logistic reasons the monitoring of soil water was discontinued.

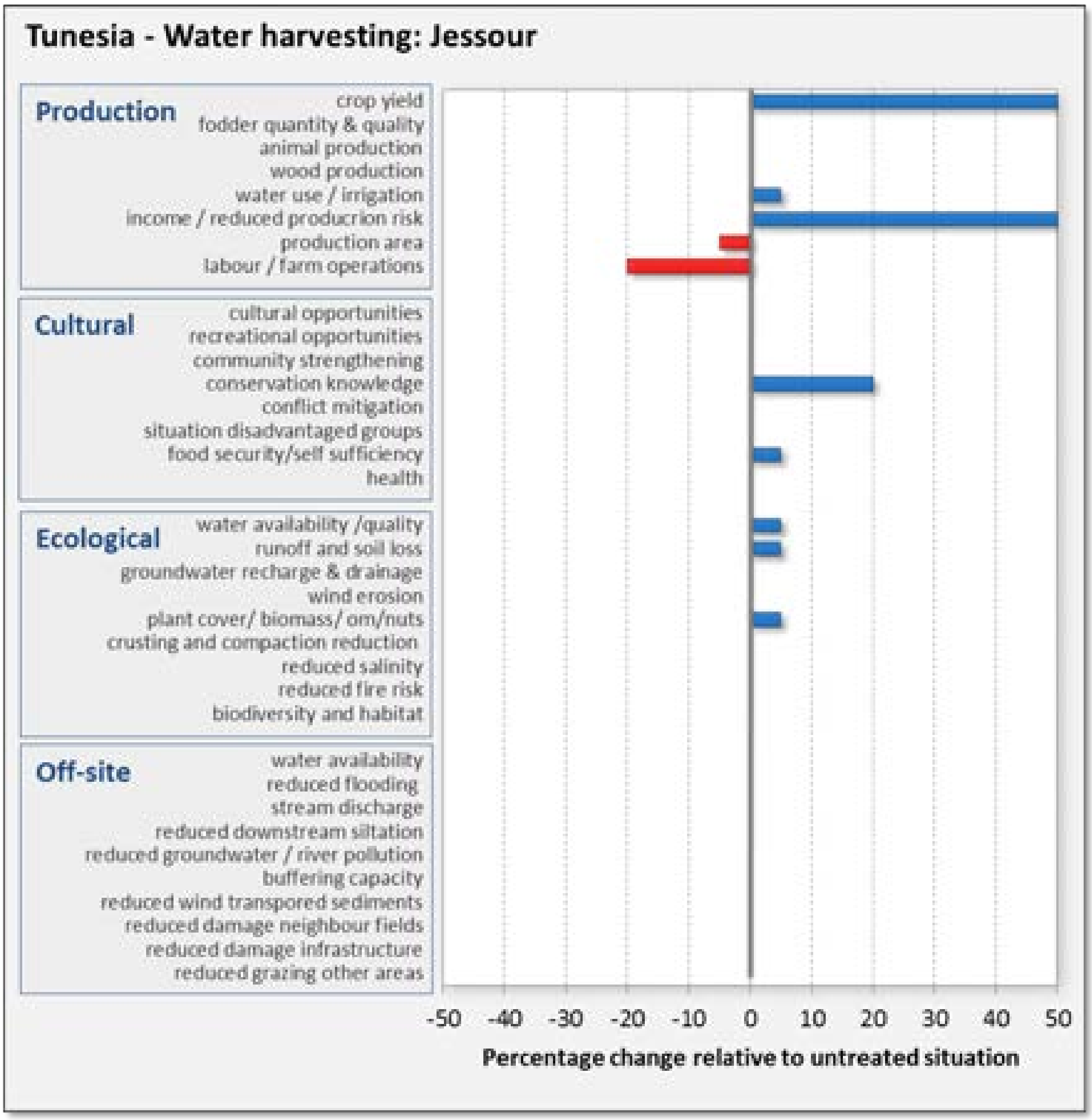


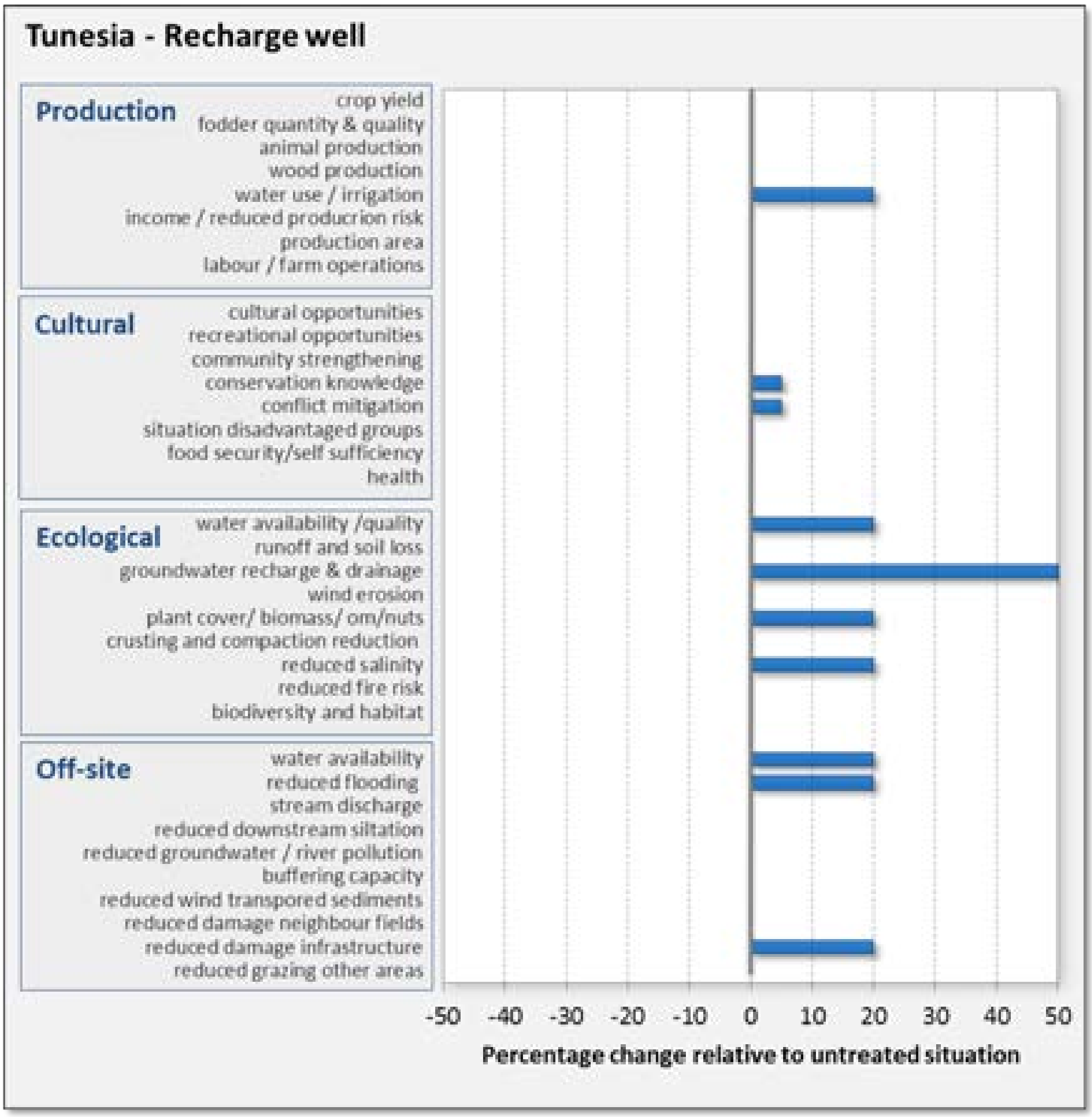
Irrigation from groundwater was supplied 2 times to prevent Olive crop failure. The use of irrigation water can be seen directly in the lowering of the local aquifer system (see below). There is no reaction of the groundwater to the rainfall as this is evaporated entirely. These systems are local and react fast to pumping and are therefore vulnerable. They are replenished by wide check dams across the valleys but in the dry years of the experiment this did not occur.



HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.





STAKEHOLDER'S OPINIONS

The stakeholders meetings show the technology as well adapted technique for the environment (90% of the land user families have applied the technology).

The evaluation shows that the Jessour/Tabia is evaluated positively and without there would be a severe risk of crop failure. This is offset by maintenance to the dyke system and some loss of production land (flat valley floor is used for checkdams). The recharge well is positively evaluated for its bio-physical effects and effect on available irrigation water, but has no direct production value.

CONCLUSIONS

The water harvesting technique increases farmer's income and it is very popular. The system is fragile and crop failure cannot be prevented without outside assistance in very dry years. A wider hydrological research is necessary to see how resilient the groundwater system is.

The technology is well known by the local population but training is necessary for the younger generations to make them aware of the wider setting.

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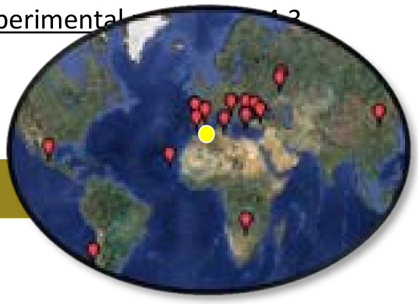


9b TUNESIA – ZEUSS KOUTINE: RANGELAND RESTING

The Zeuss Koutine area in Tunisia area suffers from the exploitation of pastoral land. Ever since the ground water has been exploited by means of drilling a lot of pastoral land was converted into irrigated cropland or orchard. This has increased the pressure on the remaining land causing over grazing and associated soil erosion problem. An experiment was carried out to improve plant cover and biodiversity in the grazing areas aiming at minimizing land degradation.

THE EXPERIMENT: SET ASIDE A PART OF COMMUNAL GRAZING LANDS

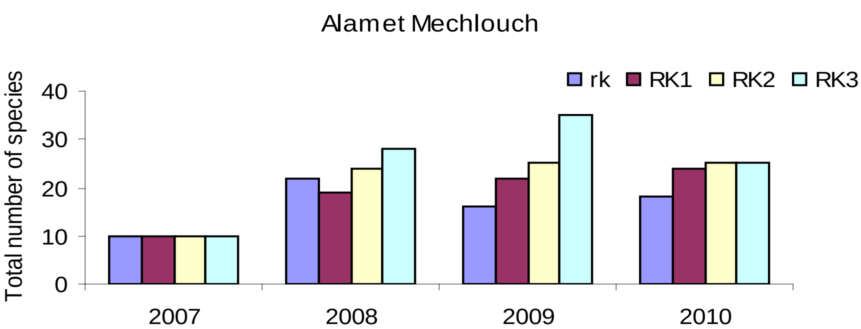
The resting technique was carried out on three sites (Alamet Mechlouch, Beni Ghezaiel and Sidi Makhlouf) within four management modes: RK3: rested rangeland, RK2: moderately degraded rangeland, RK1: overgrazed rangeland, rk: abandoned cultivated rangeland.

Several transects of 20 m long each, were established in the different representative plant communities of the target rangeland, and used to determine plant cover parameters according to the points-quadrats method.

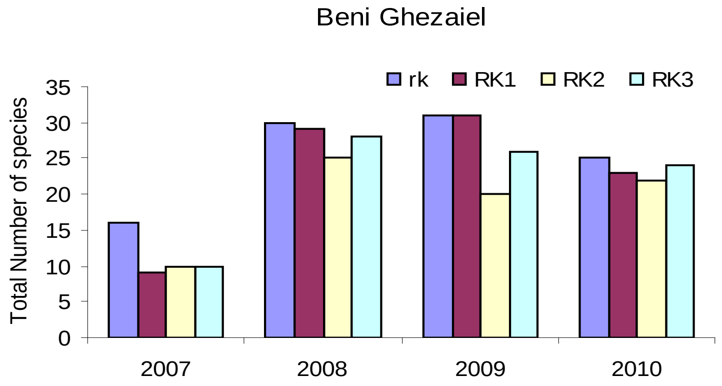
The monitoring concerned the evolution of some descriptors (global plant cover, specific frequencies, flora richness, the plant density and the range biomass production as well as the grazing capacity). The experiment was conducted during four years: spring 2007 (initial state), spring 2008, spring 2009 and spring 2010.

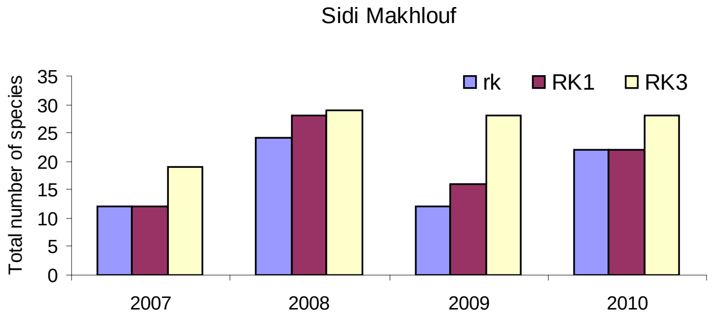
RESULTS

The experiment shows that there is an increase of plant species when the plots are rested for several years. The the number of species already doubles from 10 to >20 in the first year of resting and fluctuates after related to lacel circumstances. The degraded plots (RK2) have the lowest species number (see figures below). In all the sites, the beneficial effect of resting on plant diversity is clear.

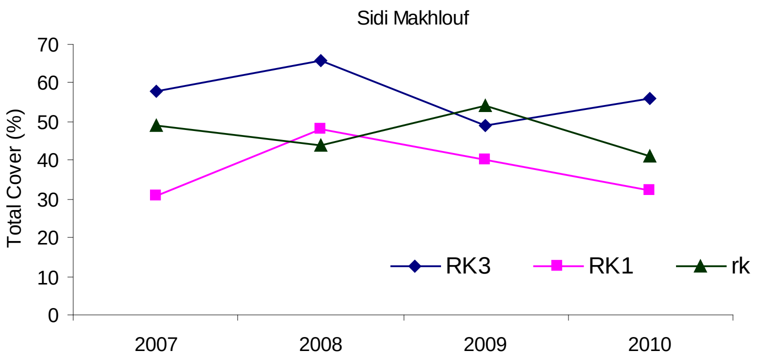


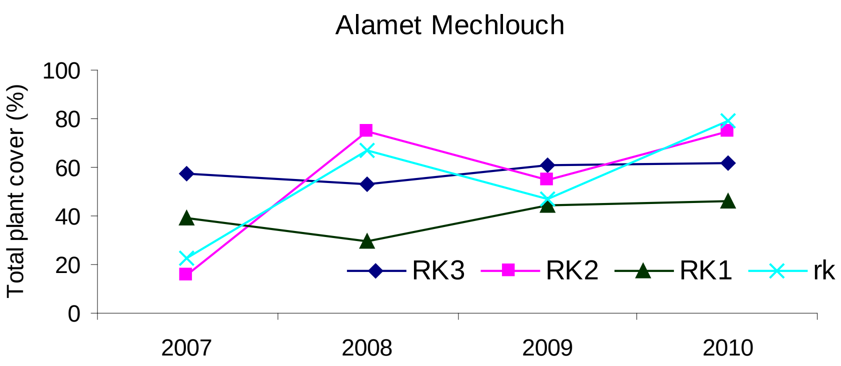
This effect may be hidden by the climatic conditions of the year. In rainy seasons, annual species are very abundant also in degraded sites.

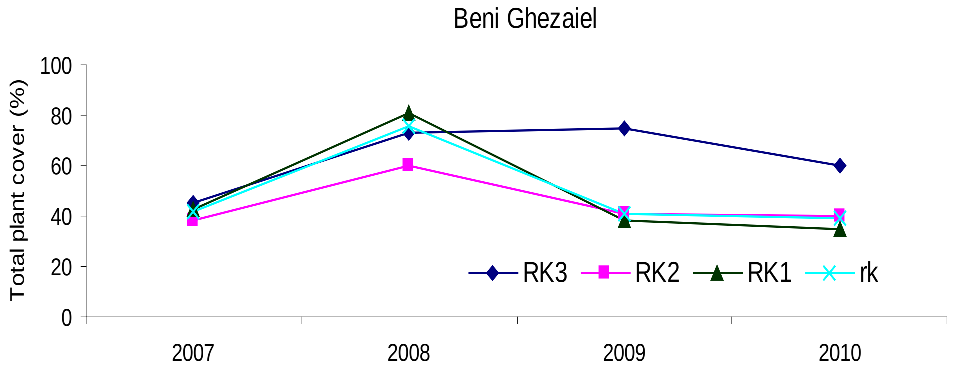




The resting technique also helps in improving the total plant cover (see figures below). This is more obvious in dry periods when only perennial cover can be observed.







HOW WELL DOES IT WORK?

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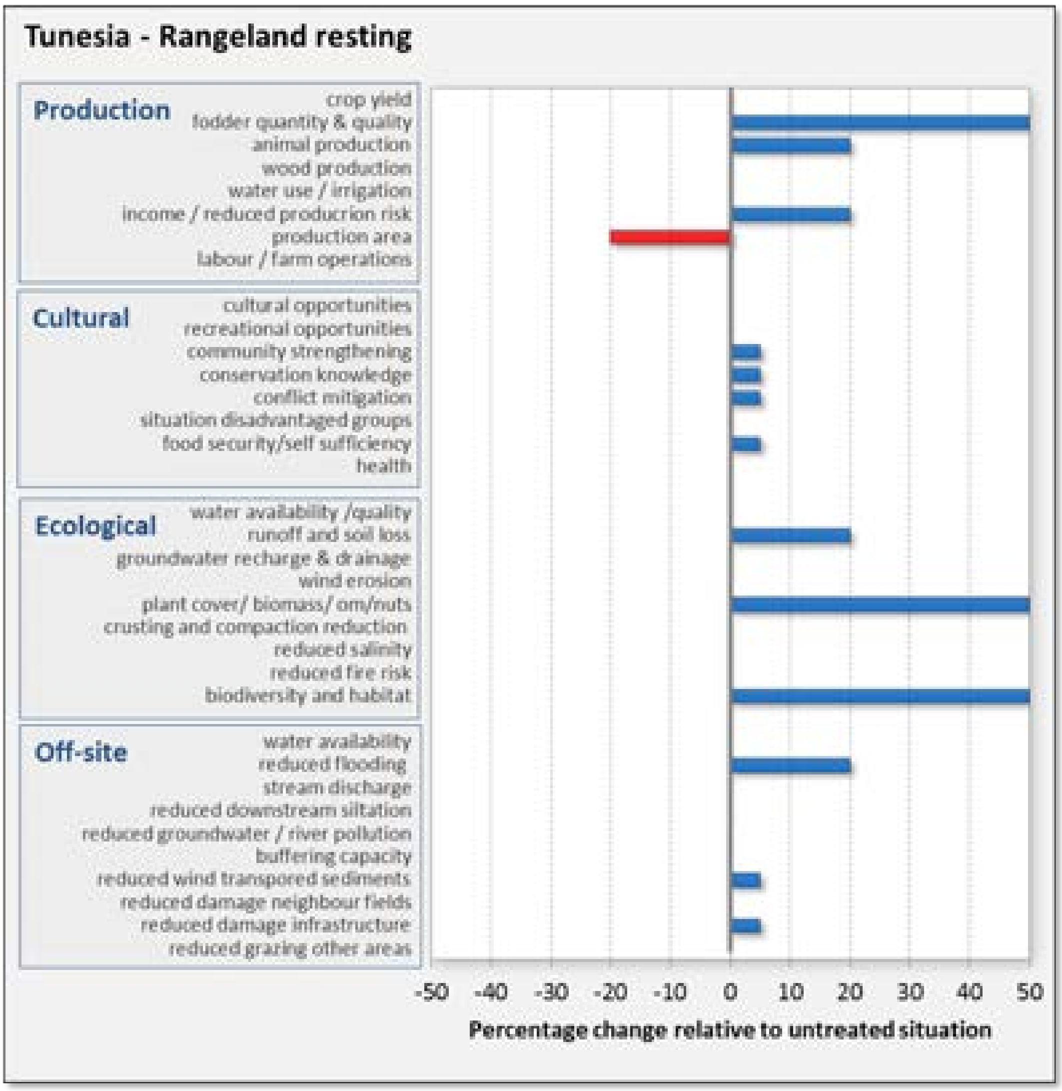

STAKEHOLDER'S OPINIONS

The stakeholders meetings show the technology as well adapted technique for the environment. About 10% of the land user families have applied the technology with external support and 1% of the land user families have applied it without external support. This support is needed because resting means land is taken out of production temporarily and with current animal stocking levels this means either subsidy in the form of fodder or an increased risk of overgrazing the remaining area.

CONCLUSIONS

The rangeland resting technology helps increase plant cover and plant biodiversity, especially in dryer years, as compared to conventional grazing land. In wetter years the degradation is less visible, so resting is especially beneficial for resilience: recovery in dry years.

To make the technology successful and sustainable it has to be accepted by the people. It could mean change of grazing culture (planning of resting areas which is agreed upon by the community and adapting to less grazing areas. This needs management of the communal lands and in the beg7inning possibly extra subsidy for fodder .

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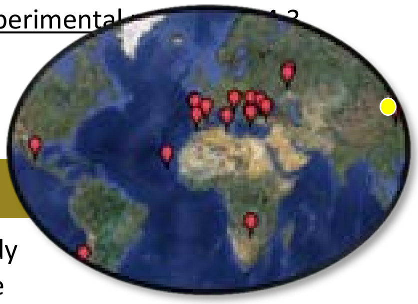


10 RUSSIA – DZHANYBEK: DRIP IRRIGATION

The “Dzhanybek” study area is situated on the territory of Pallasovsky District, Volgograd Region, which is a dry steppe area situated at the left bank of lower part of Volga River valley. The climate of has a number of negative characteristics (drought, dry hot winds, dust whirls etc.) but also positive factors as warm summers and high radiation allows the valuable agricultural cultivation (horticulture, vegetables, cereals, fodder).

The irrigation of crops in this region (situated at about 100 km from Volga River and very scarce local resources of fresh water) was stopped in early 2000 due to increasing of costs for water delivering strongly linked to high price for energy. Working equipment was sold, the old units finally broke down. Water storage capacities at the territory were absolutely dry for already 4 years from beginning of project activities. Before, they were used to be filled with snowmelt waters. Unprofessional vegetable farming for domestic use is also under threat. High evaporation and shallow groundwater lead to salinization of the soil. This and declining water resources affects people's income by decreasing food production. Nowadays the main income of the stakeholders is agricultural production from their garden plots (fruits and vegetables), growing cattle (sheep and cows). There is a big agricultural conglomeration – farm “Romashkovsky”. A number of people are working in this farm and their salary depends on its production.

The young generation is leaving rural areas due to level of life and possibilities to find more income in the urban area. Lack of information about sustainable land management, climate instabilities and weak institutional support with low financial support from the governmental organization making life of people in this region difficult.

The experiment focusses on testing drip irrigation as a water conservation practice while generating a viable crop yield.

THE EXPERIMENT: DRIP IRRIGATION OF TOMATOES TO CONSERVE WATER

Field trials were carried out aiming to test drip irrigation technologies in different field conditions and sources of irrigation water. The groundwater in this region is the receiver of surface water (in general after snow melting) and the depth and concentration is determined by the micro-relief. Under micro-depressions the surface of groundwater is convex with depth about 2 - 5 m and mineralization about 0,3-1,4 g/l. Under micro-elevations the surface of ground water is concave with depth about 3 - 9 m and mineralization about 4-17 g/l. It has to be used with care.

The setup was to have (1) experimental plots at micro depressions within agricultural fields with the use a fresh ground water stored in between soil surface and salty ground waters, (2) experimental plots at garden of householders at villages with the use of municipal water delivery system and (3) experimental plots within natural pasture near location of temporary summer habitation of shepherds with water transported in tank or cistern.

At each experimental site a drop irrigation networks were assembled of hose pipes of drop irrigation

Installing drip irrigation lines in Tomato plots

(produced by “Rosinka”) for each rank with the distance 0.3 m between the droppers, a output from tank/cistern was installed on about 1 meter height to water distribution system.

The experimental plots irrigated by drip irrigation technology were established and monitored during growing seasons from 2007 till 2011 at the same time and at the same fields in parallel with experiments with furrow irrigations. They were equipped with 4 boreholes providing access to capacitance soil moisture sensors measuring soil moisture till 40 cm. During all five experimental seasons a continuous drip irrigation applications were proceeded and data on soil moisture were recorded as well as meteorological parameters were recorded by automatic weather station located near these plots.

Underground storage tank of snowmelt water for drip irrigation. The meltwater forms a sweet water lens on top of the brakkish groundwater.

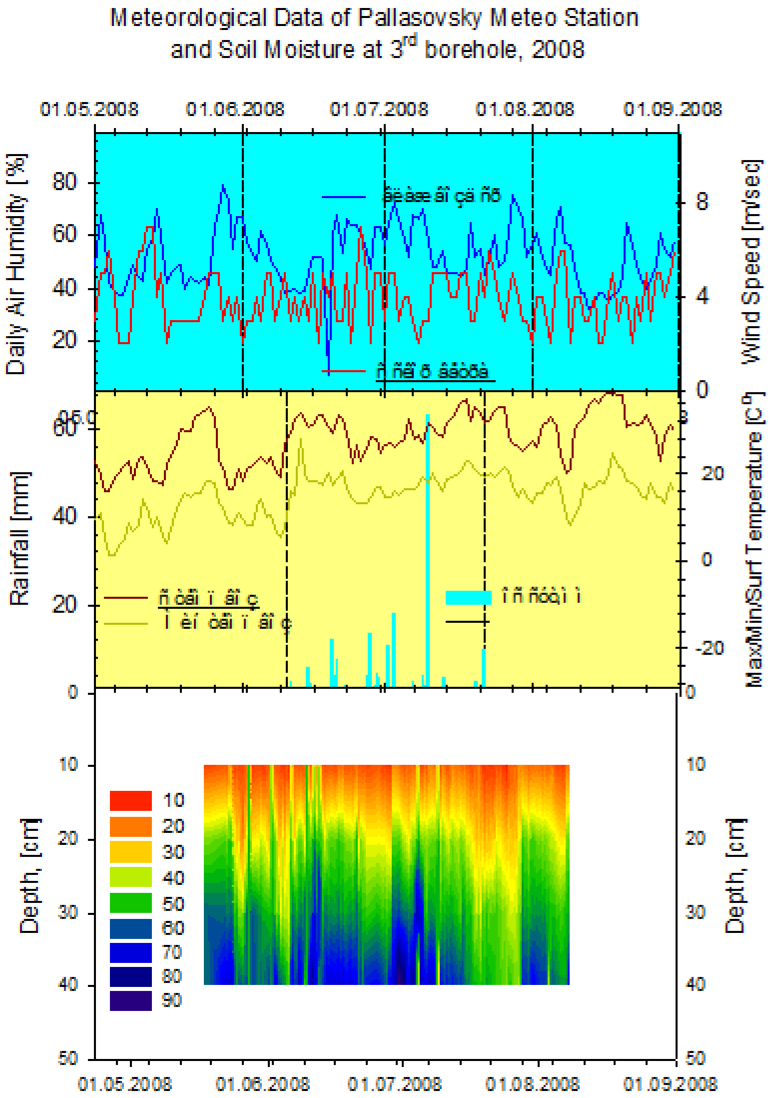
Variable	2007			2008			2009			2010		
	Vi	VII	VIII	Vi	VII	VII	VIII	VII	VIII	Vi	VII	VIII
Soil Moisture												
Electrical Conductivity												
Air Temperature												
Germination Rate												
Growth quality												
Soil chemical analysis												

RESULTS

During the monitoring period of 5 years a water regime under drip irrigation was recorded in total during 21 months. It was shown a positive water regime without development of preferential flow to deep soil layers and ground waters. Amounts and timing of furrow irrigation changed depending on weather conditions. Irrigation dozes during vegetation period was about 3600-4050 m^3/ha (May-10 - 15 days with 400-500 m^3/ha, June- 20 - 25 days- 1000-1100 m3/ha, July- 20 - 25 days 1100 -

1200 m^3/ha; August – 15-20 days – 800-900 m^3/ha; September – 5 - 10 days – 300 - 350 m^3/ha). The actual use of irrigation water by drip irrigation was estimated at 2000 m^3/ha. At the same time this increases the water available for other uses (by roughly 30-50%). Effect on salinity was too early to tell.

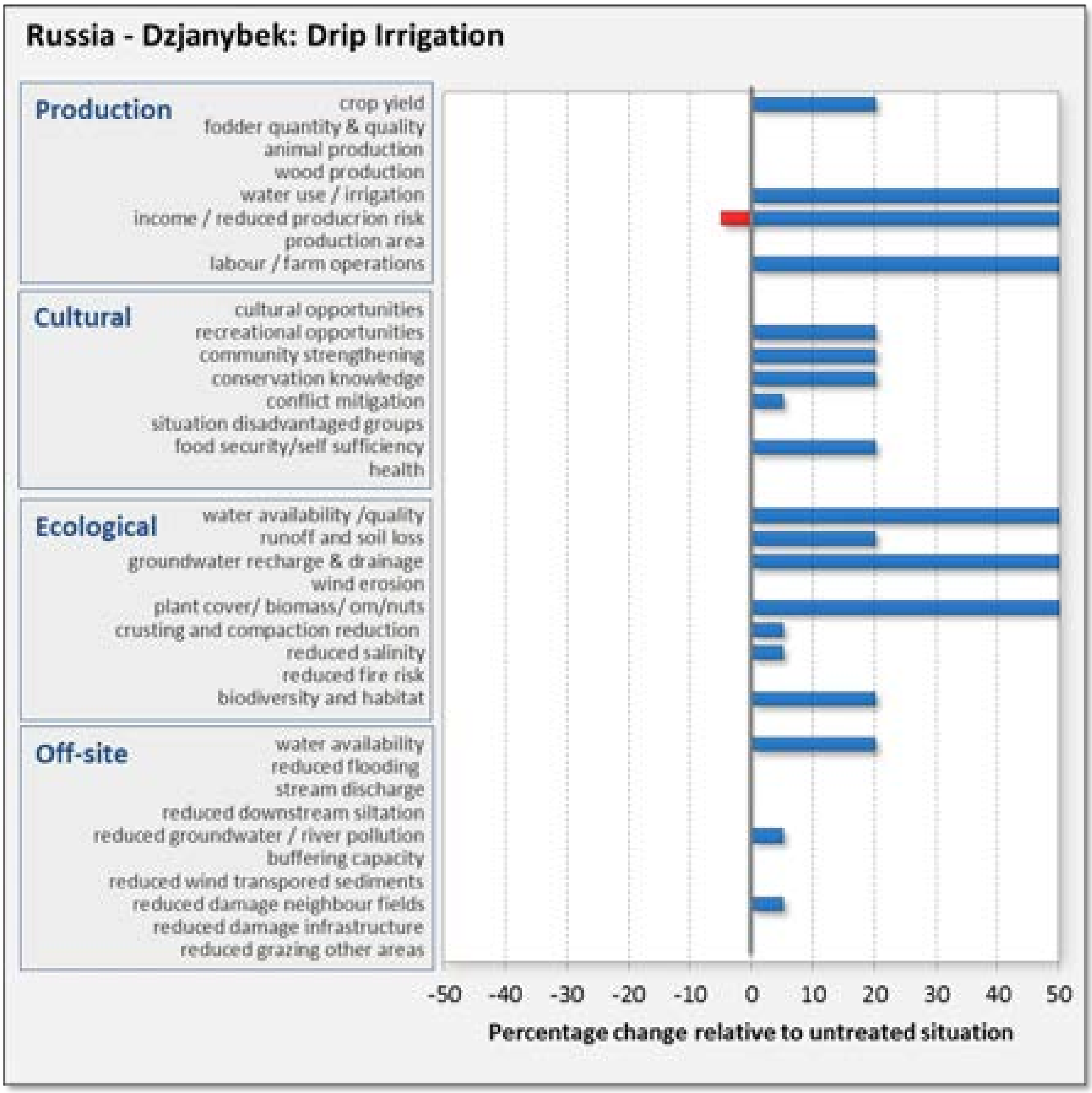
Consequently the drip irrigation has a very large effect because of the more precise application, shorter supply lines and decrease in evaporation. Vegetable yield increased form 4 to 6 tone/ha while the workload decreased from 2hours to 1 hour per day.



Measurements during growing season of 2008 year soil moisture in the root zone of the tomato plot of the Sobolev family (Romashky village of Pallasovsky District, Volgograd region, Russia)

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

A lot of farmers and experts and administrations shown interest in drip irrigation technologies using considerably small amount of water that is very important in this region with scarce fresh water resources. The stakeholders feel it should be more advertised in newspapers. The decrease water use for tomatoes is directly linked to the availability of consumption water for households. They would like this to be more controlled and introduction of drip irrigation would raise this awareness. Drip irrigation is a profitable irrigation practice since it provides opportunity to get fresh vegetables with a small amount of applied water and workload, but implementation and maintenance costs are high obstacles for large application of it.

However, the main bottleneck is the cost of installing drip irrigation systems. Without subsidy this technology will not be broadly used.

CONCLUSIONS

- In highly dry areas of Volgograd and Saratov Regions it is possible to cultivate tomatoes and other vegetables with drip irrigation method. The use of drip irrigation allows changing the cropping patterns that encourages land cultivation.
- Drip irrigation is very adaptable to the soil conditions and local sources of fresh water.
- System of drip irrigation can be successfully located and used as at the small holdings so at farms of different type of ownership.
- Using drip irrigation, more productive appeared to be tomato sorts that are grown in Volgograd Region, their productivity made up 50-60 t/ha.
- Vegetables of these sorts were also the best according to biochemical analysis. The sweetest (sugar contents - 3,74%) was the Dar Zavolgia.
- Drip irrigation is more conservative in water use and increases water availability for households.
- Initial Investments to install drip irrigation systems are the main bottleneck.

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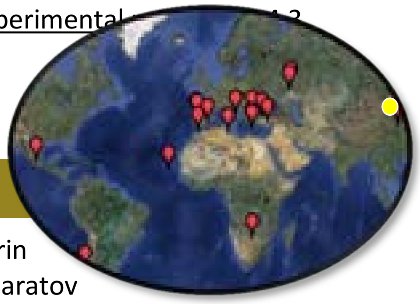


11 RUSSIA – NOVY: DRIP IRRIGATION

The Novy study site coverin g Marksovsky Region of Saratov Oblast is situated at left bank of Volga River, and has a semi-arid climate. A long warm and dry summer with little rainfall every second year makes an extensive rainfall based agriculture practically impossible. Considerable land use changes have taken place over the last 40 years while first large irrigation system been constructed based on sprinkler irrigation use. This has caused regional ground water rising and secondary salinization appearing, as well as of developing of zones suffering of local runoff and water erosion by excessive irrigation.

The collapse of the Soviet Union and increased socio-economic crises with rising prices of energy (pumping water from the Volga river), the use of irrigated land at Marksovsky Region diminished more than 5 times from its original size. Sprinkler irrigation was partly replaced by furrow irrigation, which is less expensive (no pumping) but has a low efficiency. as much water is lost because of low infiltration rates. This in fact generates soil erosion in the furrows and sedimentation of agrochemicals in nearby ponds.

Drip irrigation has a much better controlled application of water below the surface, which conserves water and prevents erosion.

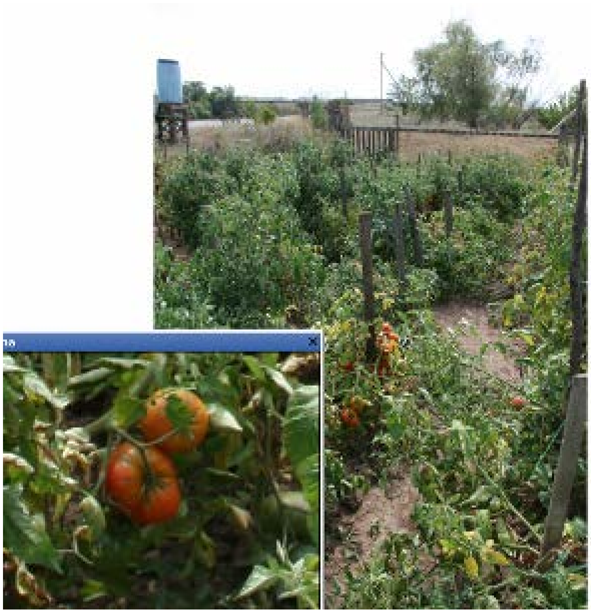
THE EXPERIMENT: DRIP IRRIGATION TO CONSERVE WATER AND PREVENT EROSION

Field trials were carried out to (1) investigate the causes of negative impacts of both sprinkler and furrow irrigation technologies on the land and water resources and their degradation as well as (2) to test new and adapted irrigation technologies aiming to improve irrigation impact on these resources by making it environment neural or friendly.

Furrow irrigation leading to erosion

Both aims were achieved by dealing with experimentations and precise monitoring of soil moisture and water fluxes developed at plot and field scale with farm conventional sprinkler irrigation and spatially variable irrigation rate (like alternative to conventional one) of alfalfa, furrow and drip irrigation (like alternative to furrow one) irrigation of tomatoes.

The experimental field scale plots irrigated by furrow technology were established in 2008 and monitored during two irrigation seasons from June till August 2008 – 2009. These plots were located at the irrigated areas of agricultural farm specialized on vegetables. These experimental fields were equipped with 10 boreholes providing access to capacitance soil moisture sensors to measuring soil moisture till



Experimental plot with drip irrigation of tomatoes at Shishkine family backyard.

100 cm and 3 weirs established at one furrow with aim to measure water discharge at the beginning, middle and end parts of it. During both experimentation seasons 6 irrigation applications were proceeded and data on soil moisture, water discharge at furrows were recorded.

The experimental plots irrigated by drip irrigation technology were established at the same time and at the same fields in parallel with experiments with furrow irrigations. Their were equipped with 4 boreholes providing access to capacitance soil moisture sensors measuring soil moisture till 40 cm. During season of 2010 an experimental plot with drip irrigation was established at garden of one householder at Mikhailovsky village. During all three experimental seasons a continuous drip irrigation applications were proceeded and data on soil moisture were recorded as well as meteorological parameters were recorded by automatic weather station located near these plots.

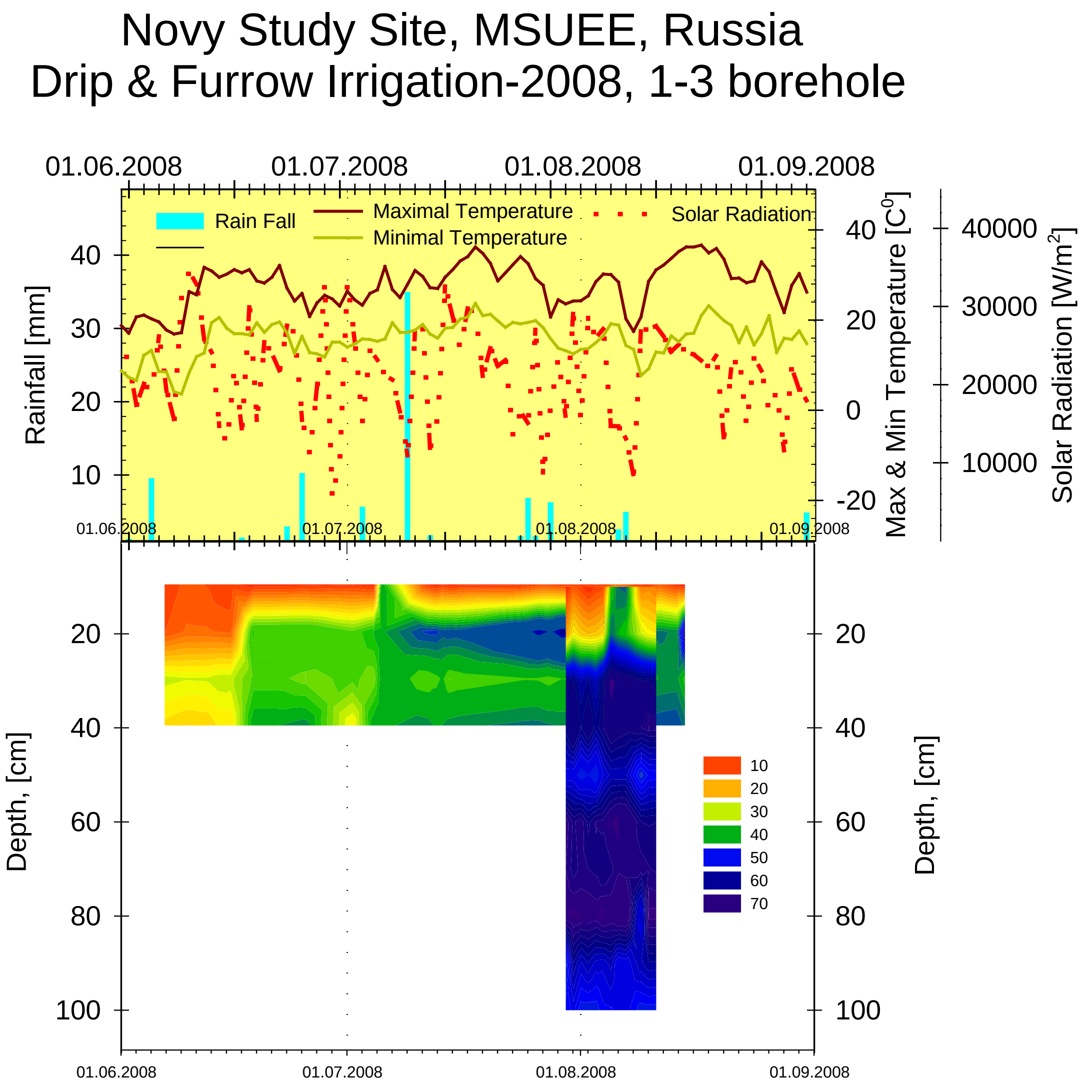
Variable	*2007*			*2008*			*2009*			*2010*		
	Vi	VII	VIII	Vi	VII	VII	VIII	VII	VIII	Vi	VII	VIII
Soil Moisture												
Electrical Conductivity												
Air Temperature												
Germination Rate												
Growth quality												
Soil chemical analysis												

RESULTS

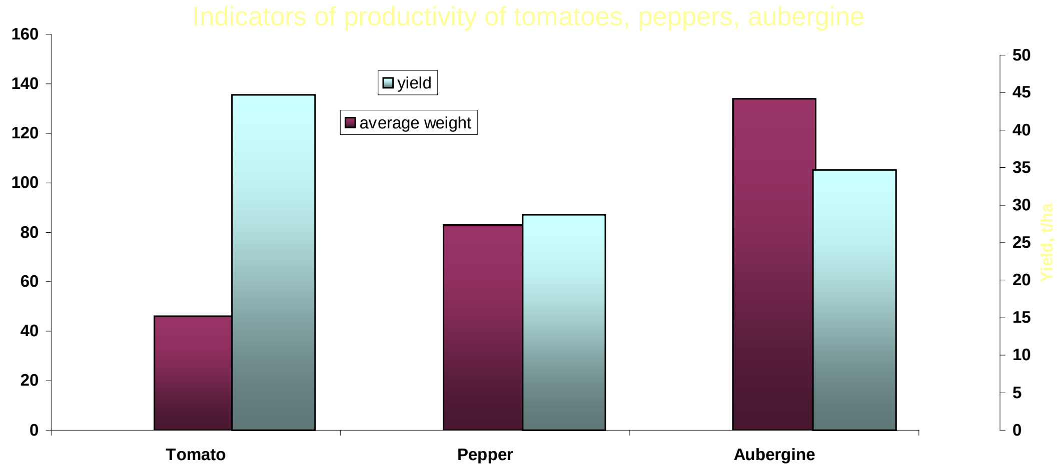
During the monitoring period of 3 years, a total of 7 events of water irrigation by furrow irrigation were recorded. By this monitoring results it was shown high negative impact produced by water flowing in furrow on soil and down lading water objects as well as by infiltrated water raising ground water levels. Impact was produced by water erosion in furrows, chemicals used for plan nutrition and preferential flow to deep soil layers and ground waters.

During the monitoring period of 3 years a water regime under drip irrigation were recorded in totally during 11 months. It was shown a positive water regime without developing runoff, formation of water erosion and preferential flow to deep soil layers and ground water.

A comparison of amount of water used for both technologies of irrigation at the same meteorological conditions shows that furrow irrigation uses 5-7 times more water than drip irrigation with similar crop yields.

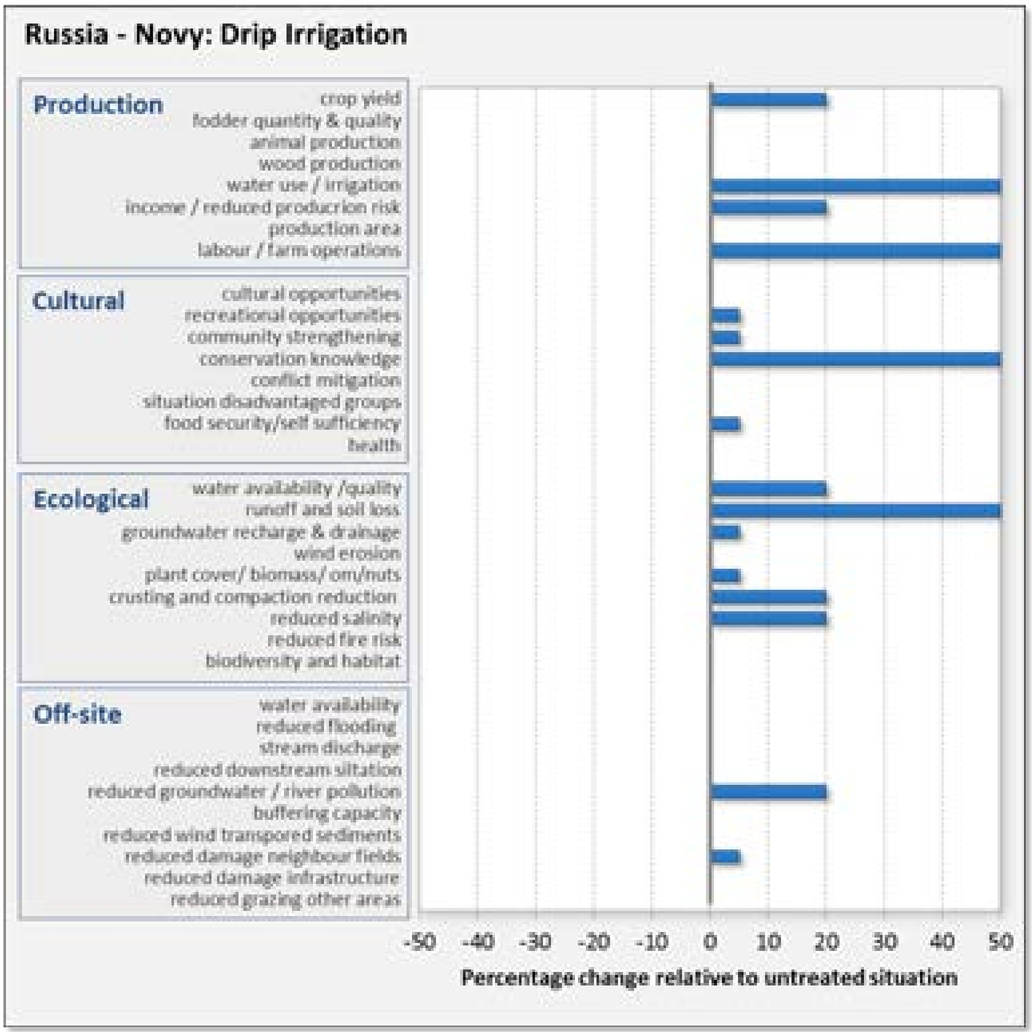


Comparison of soil moisture events measured simultaneously at drip irrigated plot in the range of 0 – 40 cm and at furrow irrigation plantation in the range of 0 – 100 cm



HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

A lot of farmers and experts and administrations shown interest in SLM technologies to protect the land, the interest in advanced irrigation technology. Drip irrigation is profitable compared to furrow irrigation practices since it does not increase the yield, but considerably reduce amount of applied water and workload. Despite the implementation and maintenance costs, the drip irrigation may increases the benefits in water consumption as well as land and water resources protection against degradation and pollution.

CONCLUSIONS

The traditional furrow irrigation of vegetables is a technology with high and inefficient water use: about 20-30% of water is absorbed by roots of growing plants and about 70-80% is lost, causing erosion. This obviously has an impact on the environment.

Drip irrigation technology improves the moisture regime and water availability in soil root zone by a permanent slow input that can be adjusted to seasonal and diurnal variation of water consumption of plants during growing season. Yields under both techniques are very similar.

However, Additional funds should be available to purchase drip irrigation systems. Not all farmers have access to a functioning system so for a large scale application considerable investments would be needed. A special regional drip irrigation supporting program is needed as well as an environmental protection program. Furrow irrigation systems could be taxed and excluding from the list of subsidy of energy needed for water transportation. This subsidy could instead be used for installation of drip irrigation systems.

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➜ This project has been funded by the European Commission DG Research-Environment Programme
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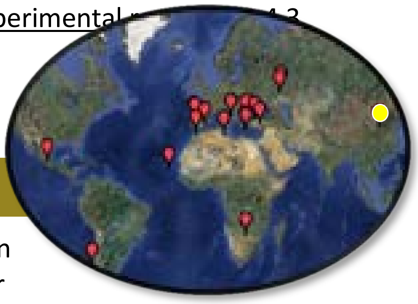
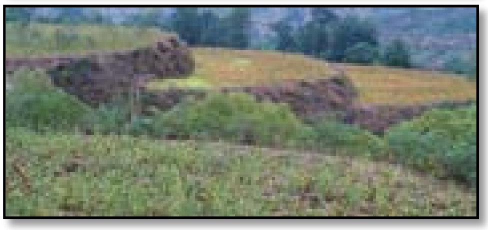


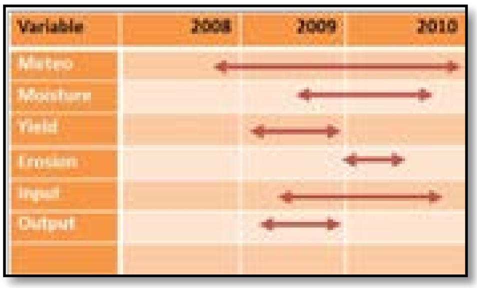
12 CHINA – KELAIGOU: CHECKDAM AND TERRACES

On the Loess plateau area in the Yan river basin in China, severe soil erosion is common. This results in deep gully and badland formation on the steeper slopes. To rehabilitate gullies, check dams have been constructed. These limit runoff and sediment delivery downstream and increase water availability for maize. The slopes can be stabilized with terrace constructions. Because of annual rainfall fluctuates between 400 and 1100 mm (average 560 mm), water can be a limiting factor in this region. Soil water conditions are monitored and compared to crops on the slopes, as well as runoff and erosion under different land uses. The erosion is especially important downstream while the conservation measures are tought to be important on site (because of soil moisture increase).

THE EXPERIMENT: CHECKDAMS FOR WATER HARVESTING

Check dams were constructed in an area covering 6.27 ha in the Mazhuang watershed, Basota country, Yanhe basin, Yan'an which is located in the Loess plateau (top left photo). In the same catchment 18,2 ha are under bench terraces (middle phoyo). The experiment is to see the effect of check dams and terraces on soil moisture, soil erosion and surface runoff. This area was compared with sloping cropland (24.5 ha, bottom photo). Surface runoff was assessed with a rainfall simulator with a rain intensity of 55 mm/hr. Data was gathered using 2 rainfall events lasting 30 and 60 minutes.



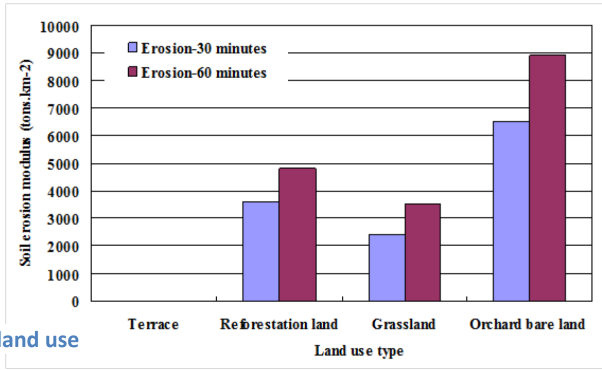


Soil moisture was measured 3 times (before planting field crops in April, mid-august and after harvesting in October). Experiment started in 2009 and data for 2 years are available. The auto weather station was set up in this watershed. The metrological data, soil moisture, yield, soil erosion, input and output of agriculture were monitored.

RESULTS

The results indicated an increase of soil moisture because the runoff from the up-stream area is detained by the check dams. This also results in minimizing soil losses from the fields. The result is based on 2010. The orchard with a bare soil shows twice as much soil erosion as the experiments under forest and on grass land. Terraces and check dams have of course no runoff because of the flat slope.

Total cost involved in the cultivation in check dam land and on terraces is higher because there is simply more surface to plant (see Table below). But the net income is also higher on the flatter areas because of better yields in all the 3 land use types: the yield of check-dam land, terrace, slope crop land is 7800, 4500, 2400 kg per hectare respectively.



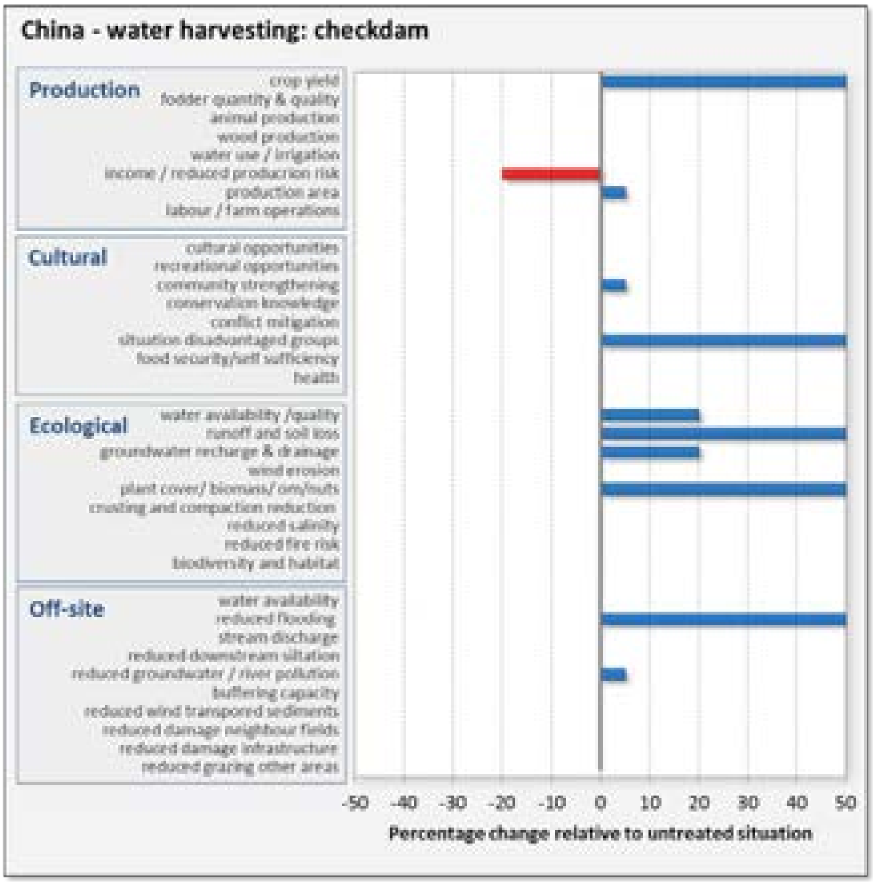
Soil loss in ton/km^2 under various land use

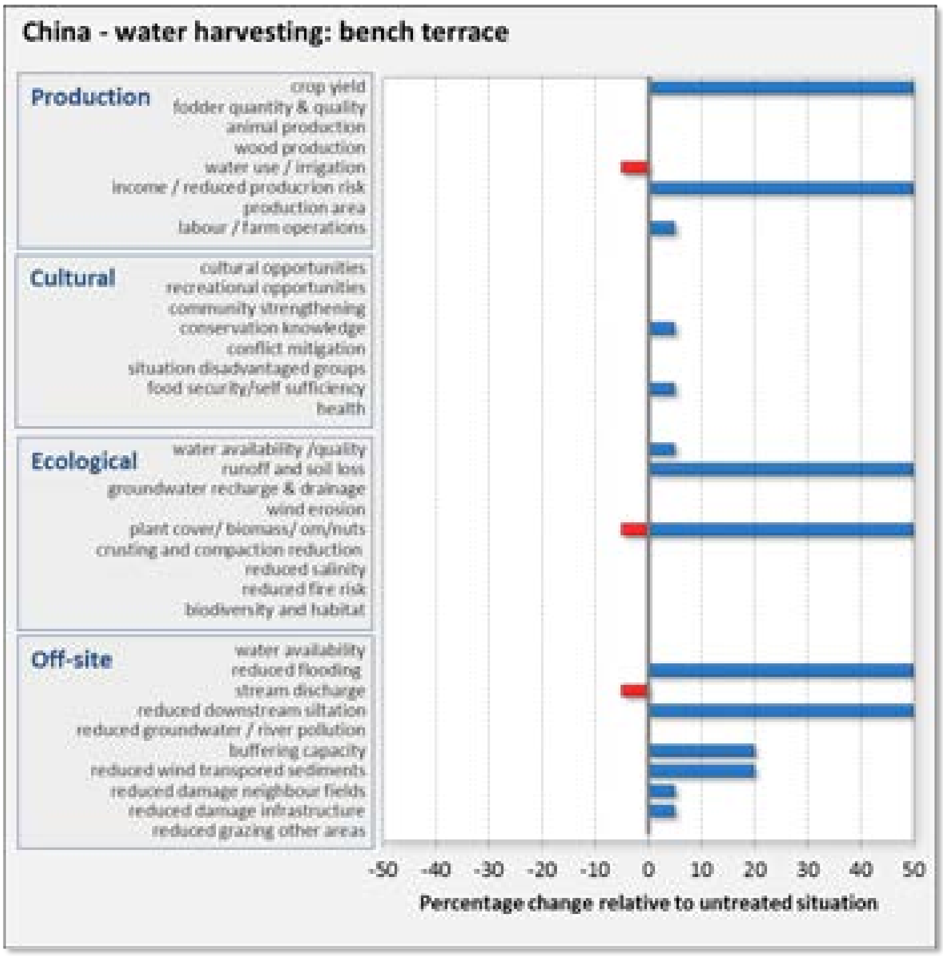
Land use	Seeds	Chemical Materials*	Tillage And planting	Direct input	Labor	Labor cost	Total Input Including Labor	Yield	Value	Net income without labor	Net income with labor
	Yuan	Yuan	Yuan	Yuan	Day	Yuan	Yuan	kg	Yuan	Yuan	Yuan
	a	b	c	d=a+b+c	e	f=e*50**	g=d+f	h	v=h*1.85***	v-d	v-g
Check-dam land	525	4575	525	**5625**	105	5250	**10875**	7800	14430	**8805**	**3555**
Terrace	420	2700	525	**3645**	90	4500	**8145**	4500	8325	**4680**	**180**
Slope Crop land	300	1800	525	**2625**	75	3750	**6375**	2400	4440	**1815**	**-1935**

** Chemical Materials: fertilizer, pesticides and herbicide; ** Price of corn: 1.85 Yuan RMB per kg; *** Price of labor days: 50 Yuan*

HOW WELL DOES IT WORK?

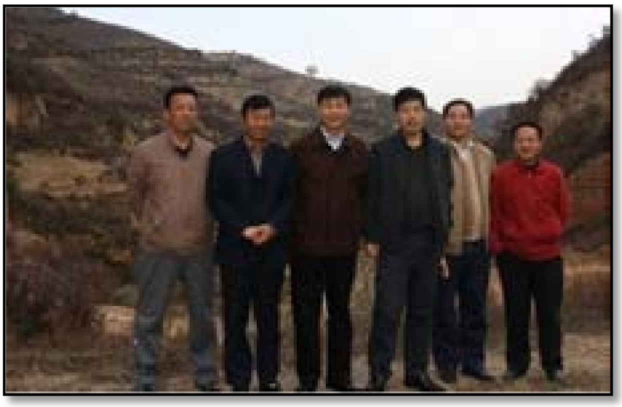
The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.





STAKEHOLDER'S OPINIONS

The stakeholders here include local farmers, village head Soil and Water Conservation Bureau and Agriculture Bureau of Baota County. Farmers have clear planting plans with simple crops such as maize, millets, potatoes and beans. They have a desire to improve the income of the land and they think the soil and water conservation is a very good approach to improve the agricultural conditions (Photo 5). Since the yield of slope land, terrace and check-dam are higher, they would like the local government to invest more to build high quality land.



CONCLUSIONS

Combatting erosion is possible in many ways and especially interesting tomitigate problems downstream. Measures that drastically improve the onsite circumstances, such as terracces and checkdams are interesting because they xcreate flat land with favourable conditions. This is shown by substantially incerased yields. In fact rainfed agriculture with staple food crops on slopes is hardly profitable because of the low yields.

However constructing and maintaining check dams and terraces is expensive. Since Cropland is in short supply (0.1 ha per capita) it is impossible for most people to do this themselves. Therefore they are interested but also regard is as something unobtainable. Many farmers find an income in other types of work such as road and building construction.

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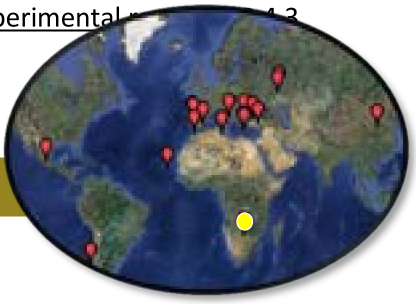


13 BOTSWANA – BOTETI: BIOGASS INSTALLATION

The Boteti study area has overgrazing as the degradation challenge. The extent of overgrazing in pastures, woodland and settlements is fragile to critical. Firewood collection adds to the range degradation, thus alternative energy in the form of biogas has been proposed by the stakeholders. Firewood is the main source of energy, not only in common households but also in schools and communal centers.

Since cattle is one of the main sources of income, biogass might be a valuable alternative. The generated gas is expected to reduce heavy firewood use and even promote socio-economic activities which will reduce poverty – perceived to be one of the main drivers of land degradation other than droughts.

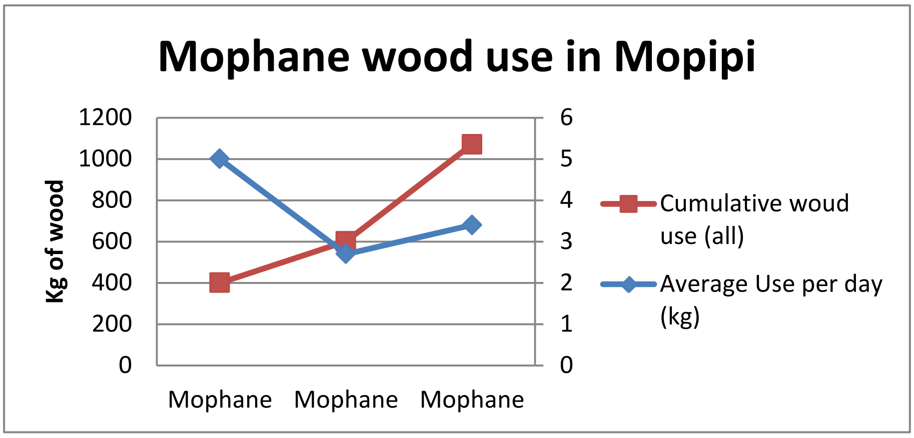
THE EXPERIMENT: BIOGASS TO CONSERVE BUSHLAND

At the very bottom is a digester, in which the cow dung is fed. The fermentation yields gas, which collects in the tank above. Pipes are used, to collect the gas for various uses e.g. cooking, heating and lighting. The amount of cow dung input, is measured, against the volume of gas generated. A biogas tank has a movable cover that adjusts to the amount of gas produced. Different design exist, and this design with the above gorund feeder pipe was maybe not the most easy. Alternatives are buried gas tank with a cover level to the surface and a feeder canal where water and dung are mixed are also at surface level. In any case biogass is relatively new in Botswana with only a few examples existing in the country.

RESULTS

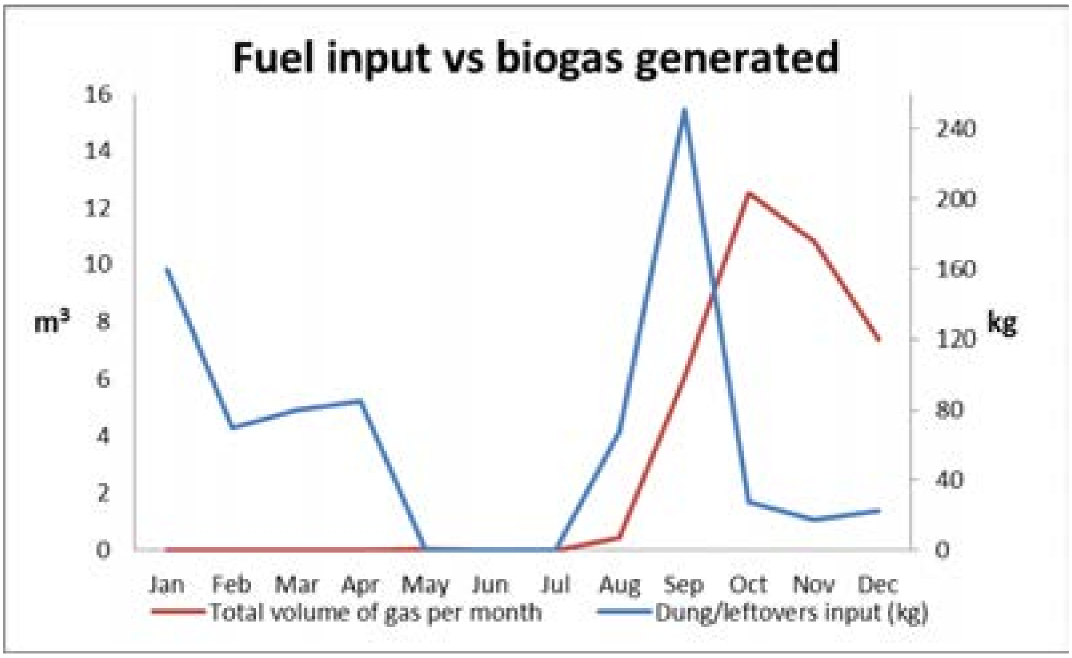
In the experiment the amount of fue lwood gathered by the village was monitored, and its use compared to the use of biogas (in cooking and heating activities of the household connected to the tank). There is sufficient cow dong present to use biogas on a larger scale.

The cumulative increase in firewood demand is apparent in households (see figure below). The same pattern applies for the local schools, where firewood demand is creating local conflicts over the resource. The Department of Forestry and Range Resources has conducted studies in the area, in response to the firewood and general degradation concerns.



Cow dung may be collected at water points, kraals and cattle posts. The distances to these vary, hence the costs. Within walking distance 10-50kg may be collected e.g. in a wheel barrow; but further away, donkey carts and vehicles may be used, which take on more cow dung quantities e.g. 250-450kg per load. However, as the experiment proceeded, food leftovers were introduced as the fuel. The response of the biogas was more immediate. The locals then introduced food leftovers from the secondary school to fuel the biogas. This has remained a very successful intervention – the results being very positive for August to December, 2011 (see below).

NB: 1kg cow dung produces 0.06m3 gas, which can feed a family of 4-6 (at 3 meals per day) for about 4 days.

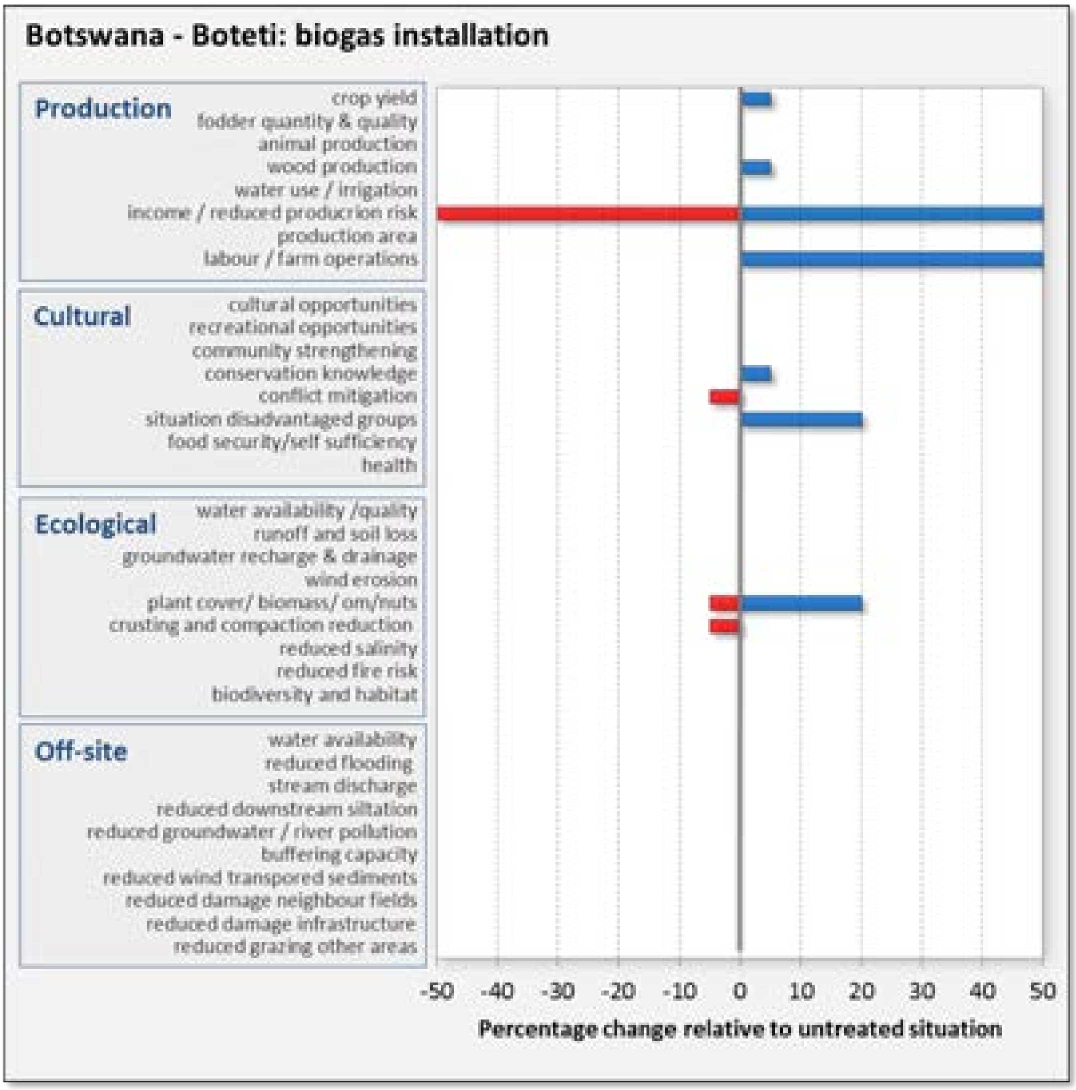


Challenges

a) Lack of transport to collect dung/leftovers from the secondary school which has offered to provide the leftovers. The school is about 3km away.
b) Transport of bio waste when from far becomes a bottleneck quickly
c) When schools are closed (limited leftovers) thus the biogas fuel (leftovers) are scarce. The biogas tank rises minimally, as a result.
d) The loose/free movement within the digester of the biogas tank and its lightness (not heavy), reduces the much needed pressure to push the gas towards the stove. Thus cooking is rather slow when using the stove. The top can be weighted down.

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

The impact of the biogas is too early to show, but schools, villagers – have all expressed interest, citing the limited energy sources as a major challenge. Interest ranged from using the gas for: cooking, powering a generator to produce electricity, to larger scale like providing energy for cooking i.e. to replace 19 truckloads that are needed every 3 weeks for each secondary school in the area.

CONCLUSIONS

The biogas is running well, and the results are beginning to show i.e. how much gas is generated from what quantity of cow dung or food waste. This will be the first time in Botswana, where exact performance measurements are done.

The impact of the biogas, is too early to show, but schools, villagers – have all expressed interest, citing the limited energy sources as a major challenge. Interest ranged from using the gas for: cooking, powering a generator to produce electricity, to larger scale like providing energy for cooking i.e. to replace 19 truckloads that are needed every 3 weeks for each secondary school in the area. However, the uptake of the biogas technology in the country is quite an expensive enterprise. Limited trained personnel and service providers, remain key challenges. For the poor households, the starting capital of around €600 is too steep. This is despite biogas being a feasible energy source in other countries. The few commercially run biogas plants in Botswana e.g. Cumberland Hotel (uses kitchen leftovers) and the Richmark (uses chicken waste) have shown high success, with high capital returns. The plants are economic viable, and lead to alternative energy sources, away from coal generated electricity.

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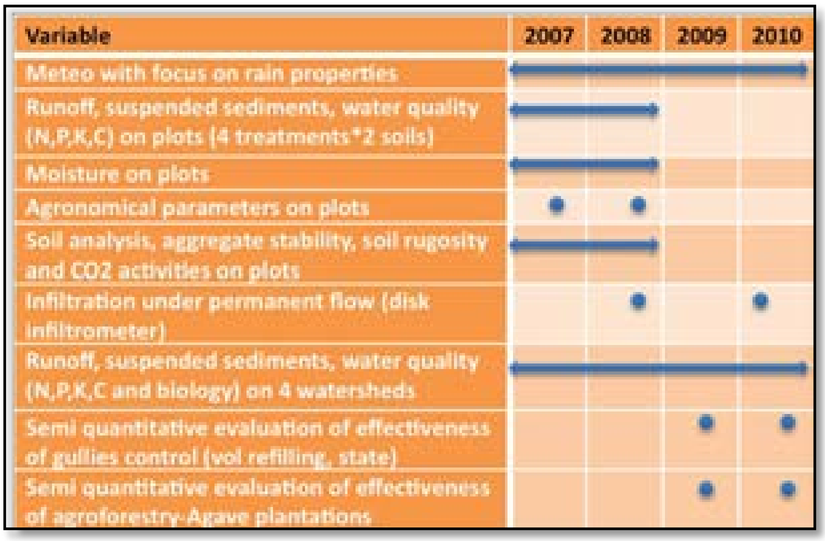
14a MEXICO - COINTZIO: CROP ROTATION

In the Cointzio basin, land degradation is mainly due to free grazing of cows. To avoid this, a global solution must be searched and must be adapted to different environmental situations. Due to the critical economic situation of farmers, men and women can act only with subsidies (local projects), managed by political authorities. The Cointzio basin has different kinds of soil erosion due to the type of climate (temperate semi-humid with a 6 months rainy season), soils and geomorphology as well as land uses (some mechanized farming, mainly rainfed agriculture with free grazing cattle, forest, recent avocado plantations). Apart from the land degradation, the downstream effect is the refilling of the Cointzio dam used for drinking water of the capital of Michoacán, as well as occasional severe flooding. One of the techniques tested is the effect of crop rotation, including minimum tillage, on sediment losses.

THE EXPERIMENT: CROP ROTATION SYSTEMS TO COMBAT EROSION

Different rotation systems were tested on plot level during 5 years on 8 erosion plots at 2 sites (Acrisol and Cambisol andic) with Traditional corn/ Fallow/Corn with organic fertilization and Corn or cereal with no tillage and crop residues. Climate, soil and water erosion, soil properties and agronomical parameters were surveyed. Measurements included were:

- Agro-meteorological data was registered in the field (La Cortina watershed) at every 30 minutes for Temperature (max, min), Wind (speed direction), Humidity and UV Solar radiation. Rain was recorded in 3 places (La Cortina, La Cienega, Potrerillos which are own catchments followed) by tipping bucket method (every 0.2 cc with a second precision) from which rain volume, intensity, kinetic energy and erosivity were calculated. Historical agro-meteorological data from of 5 meteo-stations in the Cointzio catchment were also used.
- Runoff was measured (1 min registration and 1 mm precision) in 3 sub-catchments and also at the outlet of the Cointzio catchment for 5 years. *Note that the catchment results are reported in the annex of deliverable 4.3.1.*
- Sediment traps were designed and installed in the 3 small catchments. The sediment samples are collected after every rainfall event. In the case of the basin outlet, suspended sediment concentration was assessed from the turbidity.
- Infiltration was measured in Andosols and in Acrisols with 4 kind of treatments (natural-Forest; ploughed, lower part of furrows one year after corn cultivation and higher part of furrows also one year after corn cultivation).



RESULTS

The effect of crop rotation on infiltration, runoff generation and sediment production were tested. The discharge from the Cortina and Potrerillos watershed in 2010 seems to have nearly the same values (4 and 6 m3 s-1). The discharge from the Huertitas sub-watershed was a little lower than the other two. Since this catchment is 3 times smaller than the other catchments the Heurtitas sub-watershed can be considered more degraded.

Infiltration measurements show that it is very high in Andisols as compared to the Acrisols (3 mm/h). Crop rotation seems to have not much effect in infiltration rates. But, it can have differences within the same crop rotation system, for example infiltration on the ridge of the furrows and at the lower parts can be very differen (Table 1). This variation must be taken into count in the modeling and interpretation of runoff and soil erosion.

Table 1: Hydraulic conductivity obtained in the Andic Cambisol of sub-watershed of La Cortina (Y. Grusson, 2010)

K (mm/h)	Follow-Ridge	Follow-Furrow	Ploughed	Forest
Maximum	70,92	36,36	84,60	44,28
Minimum	12,46	26,75	2,39	20,41
Average	41,69	31,55	43,50	32,35

Rainfall was nearly 50% higher in in 2010 as compared to 2009 which resulted in higher sediment concentration with the highest concentration in the sub-watershed of Poterillos (Table 2).

Table 2: Comparison of maximum, minimum and median sediment concentration in the 3 catchments (Y. Grusson, 2010)

	Huertitas			La Cortina			Potrerillos		
Year	2009	2010	2010 values at 25 cm	2009	2010	2010 values at 25 cm	2009	2010	2010 values at 25 cm
Maximum	55,4	55,6	44,7	7,8	47,8	13,4	125,7	224,4	157,27
Minimum	0,0	1,0	1,0	0,0	0,2	0,2	0,1	11,0	11,00
Median	2,2	13,0	8,3	0,5	4,6	1,8	8,0	44,0	33,18

The two catchments generated high sediment yields (Huertitas, 900–1500 t km^{-2} y^{-1}; and Potrerillos, 600–800 t km^{-2} y^{-1}). The sub-watershed of La Cortina generated a rather low sediment (30 t km^{-2} y^{-1}). At the scale of the entire Cointzio basin (630 km^2), it was not possible to derive any direct relationship between rainfall intensity and sediment concentration. This can be explained by the high spatial variability of rainfall and due to vegetation growth throughout the season. Erodible sediment availability on hill slopes was identified as the main factor controlling suspended sediment delivery. The occurrences of numerous active gullies in Huertitas and Potrerillos provided a constant sediment source linked to the river network, which explains the high SSY recorded at both stations. At the sub-watershed scale, a combination of various parameters was responsible for sediment control. Peak discharges during floods were found to be significantly associated with exported loads; discharge proved to be a controlling factor when sediment was not lacking.

HOW WELL DOES IT WORK?

No evaluation results were given so this analysis cannot be done

STAKEHOLDER'S OPINIONS

The agro-climatic measuring instruments, rain gauges, water level and sediment trap installation were located in the farmer's fields. The farmers took care of the instrument and in some case, they also helped to take samples, and do some measurements. As the farmers were paid, they were interested. But they don't see a direct interest for themselves because our results are interesting at a watershed scale and not really at individual farm level.

If the regional authorities want to stop sedimentation of the dam, an integrated policy is needed. An analysis at catchment level is also being done and is reported in the annex of deliverable 4.3.1

CONCLUSIONS

- Minimum tillage, good ground cover, fertilization and organic residue incorporation are the key solutions to reduce soil erosion.
- To control free cattle grazing, the economic situation of the farmers has to be taken into account.
- Farmers involvement is possible if program brings money to do concrete actions.

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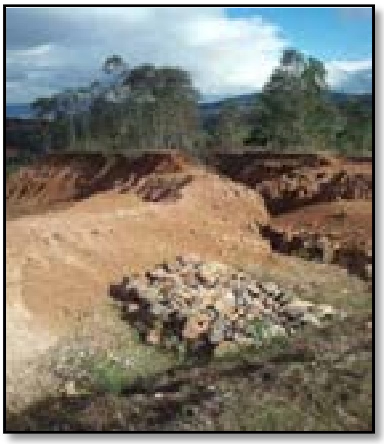
14b MEXICO - COINTZIO: GULLY CONTROL

In the Cointzio basin, land degradation is mainly due to free grazing of cows. To avoid this, a global solution must be searched and must be adapted to different environmental situations. Due to the critical economic situation of farmers, men and women can act only with subsidies (local projects), managed by political authorities. The Cointzio basin has different kinds of soil erosion due to the type of climate (temperate semi-humid with a 6 months rainy season), soils and geomorphology as well as land uses (some mechanized farming, mainly rainfed agriculture with free grazing cattle, forest, recent avocado plantations). Apart from the land degradation, the downstream effect is the refilling of the Cointzio dam used for drinking water of the capital of Michoacán, as well as occasional severe flooding. One of the techniques tested is the gully control.

THE EXPERIMENT: GULLY CONTROL TO LIMIT SEDIMENT DELIVERY

To control gullies, stone dams (gabions) were constructed involving local stakeholders. It was funded by the Mexican Ministry of Environment and Natural Resources (SEMARNAT) since 4 years. Identification and location of the stone dams constructed in the last decade in the Cointzio watershed are available in a spatial database (GIS) of SEMARNAT. Semi-quantitative evaluation of the effectiveness of stone dams to control gully erosion was carried out by measuring the volume of sediment trapped and the status of the installation as a whole.



RESULTS

The semi cantitative evaluation of the stone dams build to control gullies show the following resuslts:

- 90% of this dams are in good condition 4 years after construction
- 80% of the check dams have very few or no sediments at all. The remaining 20% check dams have 10 to 20% of their capacity filled by the sediments. Usually, the first check dam located at the upper stream in a series of check dams is filled by the sediment (10-20% filling) meaning that constructing one check dam can control gully formation. However the area tested is on volcanic tuffs material and not on very degraded soil.

HOW WELL DOES IT WORK?

No evaluation results were given so this analysis cannot be done

STAKEHOLDER'S OPINIONS

Evaluation and effectiveness of control of gully erosion by small dams was discussed with some farmers. They are interested in soil conservation works but they consider that the dams are probably not so useful.

CONCLUSIONS

For the construction of check dams it needs good studies especially to identify the critical areas. Check dams should be constructed starting from the upper part of the watershed. 80% of the check dams have very few or no sediments at all. The remaining 20% check dams have 10 to 20% of their capacity filled by the sediments. The location of gully control and the influenc downstream has to be apstially analyzed in a watershed context.

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14c MEXICO - COINTZIO: AGAVE AGROFORESTRY

In the Cointzio basin, land degradation is mainly due to free grazing of cows. To avoid this, a global solution must be searched and must be adapted to different environmental situations. Due to the critical economic situation of farmers, men and women can act only with subsidies (local projects), managed by political authorities. The Cointzio basin has different kinds of soil erosion due to the type of climate (temperate semi-humid with a 6 months rainy season), soils and geomorphology as well as land uses (some mechanized farming, mainly rainfed agriculture with free grazing cattle, forest, recent avocado plantations). Apart from the land degradation, the downstream effect is the refilling of the Cointzio dam used for drinking water of the capital of Michoacán, as well as occasional severe flooding. One of the techniques tested is the agro-forestry of newly established agave plantations.

THE EXPERIMENT: AGAVE AGROFORESTRY TO IMPROVE SOILCOVER

The degraded lands are planted with local agave for making alcoholic beverage (Mezcal) and fodder production in association with trees in 5 ha of land. The wild agave seeds are planted in different density together with trees. Semi quantitative evaluation of the agave plantation is carried out at the beginning of the rainy season.

Variable	2007	2008	2009	2010
Meteo with focus on rain properties	━	━	━	━
Runoff, suspended sediments, water quality (N,P,K,C) on plots (4 treatments*2 soils)	━	━		
Moisture on plots	━	━		
Agronomical parameters on plots	●	●		
Soil analysis, aggregate stability, soil rugosity and CO2 activities on plots	━	━		
Infiltration under permanent flow (disk infiltrometer)		●		●
Runoff, suspended sediments, water quality (N,P,K,C and biology) on 4 watersheds	━	━	━	━
Semi quantitative evaluation of effectiveness of gullies control (vol refilling, state)			●	●
Semi quantitative evaluation of effectiveness of agroforestry-Agave plantations			●	●

RESULTS

Land remediation of the degraded soil by planting local agave (*Agave inaequidens*) in combination with trees (agro-forestry) can be used as fodder for cattle consumption and also for the production of Mezcal (alcoholic beverage).

Since agave plantation started recently (2010) in Mexico, no concrete result related to remediation of degraded soil is available. Suggestions to improve the agroforestry are the creating of 4 production centers in the basin of Calabozo-Potrerillos considering the distance between the communities, the soil type, the population size and the territory of communities as follows:

- S. Coapa Rafael, San Rafaelillo, El Bañito, Yerbabuena vieja
- The Maiza, La Yerbabuena, S. Andrés Coapa
- Potrerillos and
- Chihuerio, S. Miguel Coapa

This site number may be reduced according to the available resources but should not be less than 2 sites. In addition, suggestions for seedbed preparation, greenhouse and planting distances are suggested as follows:

1. Seedbeds for the Agaves and trees (per site)
   a. 1 place of 10 x 10 m for the Agave and another one of 5 x 5 m for trees
   b. Appropriate substrate of forest soil with compost earthworms (is possible)
   c. Water available for irrigation by gravity
   d. Fences against animals

2. Greenhouses (per site)

   a. 1 place of 50 x 50 m (1/4 ha) to 200 000 Agaves and 1 place of 21 x 36 m (1/4 ha) for 60 000 trees.
   b. Appropriate substrate of forest soil with compost earthworms (is possible))
   c. Water available for irrigation by gravity
   d. Fences against animals
   e. Nursery with greenhouses involves full-time 2 people per site per year.

4. Agaves transplantation for soil restoration with native maguey and production (After one year in the greenhouse or directly by transplantation of wild plants

   a. Planting density maguey: / ha 1.5 * 1.2 m = 2.218 plants
   b. Density of planting trees / ha: 3 * 3 m = 1.090 plants.

5. Transplantation of agaves for living borders
   a. Agave planting density on the line every 0.20 cm-= 5 plants / linear meter.
   b.

HOW WELL DOES IT WORK?

No evaluation results were given so this analysis cannot be done

STAKEHOLDER'S OPINIONS

Evaluation and effectiveness of the Agave plantation have been discussed during workshops and directly on the field with some farmers. Farmers are interested to do some actions against soil erosion. For the Agave plantation and project, there is a lot of expectation.

CONCLUSIONS

Agave plantation is a productive undertaking under agroforestry practices. It sustains biodiversity, generate work and remediate soils.

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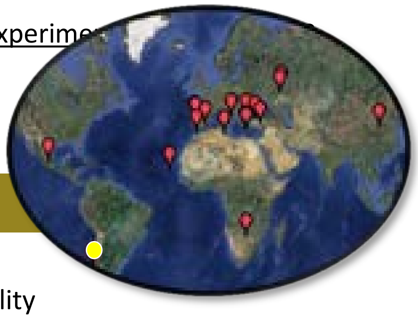


17a CHILE – SECANO INTERIOR: CROP ROTATION

In the dry Secano interior in Chile, farmers face problems of soil fertility depletion which affects the sustainability of traditional crop production. Another problem associated with fertility depletion is erosion because of periods in the crop rotation cycle where the soil is bare. Experiments were carried out to introduce crop rotation with legumes to replace wheat mono culture and to solve the problem of soil fertility depletion, while at the same time providing a better soil cover and also improving the soil structure, which improves infiltration.

THE EXPERIMENT: IMPROVING SOIL FERTILITY

Two experiments were carried out to see if monoculture wheat cultivation can be replaced by crop rotation with legumes.

Experiment 1. Four legumes species (peas, white lupine, yellow lupine and *Vicia faba (*a bean species) are tested in rotation with the traditional wheat crop. The experimental design is randomized block with four replications with plot size of 4x5 m.

Experiment 2. Two mixtures of annual legumes and different length of the period of pasture in rotation with wheat in a randomized block with four replications with plot size of 6x6 m.

Assessments on Crop and Pastures: Natural abundance of ^{15}N, ^{15}N isotope dilution, photosynthetically active radiation (PAR) intercepted by the crop, dry matter production (above-ground and root) and grain yield biomass, in all treatments and in pasture, seed production, botanical composition, seed hardness, and seed bank and regeneration capacity for self-seeding.

Soil Assessments: in situ N mineralization, leaching of nitrates and volatilization of ammonia.

Variable	2007	2008	2009	2010
Runoff	↔	↔	↔	↔
Sediments	↔	↔	↔	↔
Nutrient losses	↔	↔	↔	
Yield	↔	↔	↔	↔
Soil Moisture	↔	↔	↔	↔
Physical indicators	•		•	
Biological indicators				•
Soil compaction	↔	↔	↔	↔

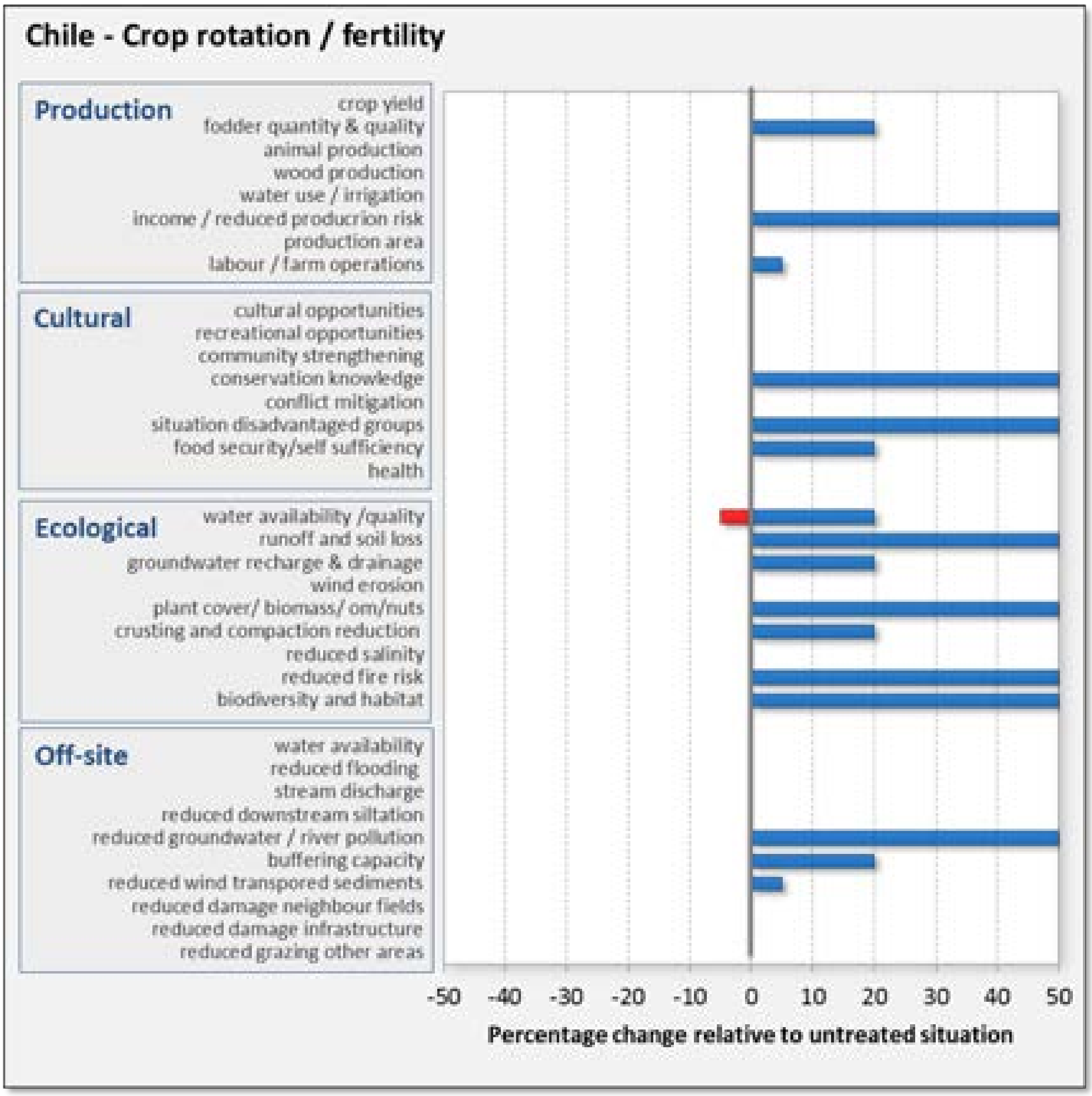
RESULTS

The yieldof the normal wheat with fertilizer a[[;icayion is about 30% higher than any of the treatements. Of those the treatments woth Lupine perform the best. However, with crop rotation with legumes, the production cost of wheat is decreased by more than 70% since farmers do not need to buy fertilizers, saving of up to 100 kg N/ha is possible by using legumes in the crop rotation. Also, farmers get diversified source of income by selling legumes in addition to wheat.
The biomass of wheat crop when it is rotated with legume is similar to its biomass when it is cultivated with fertilizer. But the crop yield is low (1.5 $t.ha^{-1}$) which is nearly half of the yield when it is cultivated with fertilizer.

Treatments	Legumes (Year 2008)		Wheat after legumes (year 2009)			
	Biomass	N fixed	Grain yield	Yield	Saving in fertilizer	Saving in dollars
	T ha^{-1}		T ha^{-1}	%	k Urea ha^{-1}	\$ ha^{-1}
L. angustifolius	10.9 b	0.157 b	2.6 b	79	277	376
L. luteus	5.4 d	0.139 b	2.5 bc	75	263	357
Pisum sativum	13.2 a	0.184 a	2.4 bc	72	252	342
Pasture Mix 1	1.6 e	0.017 c	2.2 cd	66	231	314
Pasture Mix 2	1.4 e	0.015 c	2.3 c	69	242	328
Cereal + N	7.7 c	-	3.3 a	100	0	0

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

- Stakeholders think that their quality of life will be improved because of diversified income source. The farmers have more products to sell in addition to wheat
- It also allows complementarity between crop production and livestock.
- The weakness of the technology is the difficulty in marketing the new products.
- There is also lack of appropriate machinery for harvesting the legumes.
-

CONCLUSIONS

This technology helps decrease production costs of wheat since fertilizer is not applied.

It helps carbon sequestration and thus minimises greenhouse effects. It also helps improve soil conditions by increased surface cover and soil organic matter.

The main bottleneck of the technology is the difficulty in marketing the new products. There is also lack of appropriate machinery for harvesting the legumes.

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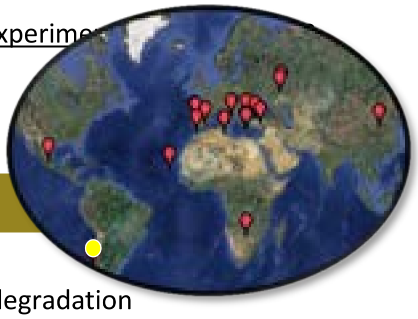


17b CHILE – SECANO INTERIOR: NO TILLAGE

In the Secano interior there is a problem of soil erosion and soil degradation caused by the Mediterranean type of climate (heavy rainfall in winter) and inappropriate land management practices. Experiments were carried out on the experimental farm to decrease surface runoff and soil losses and to improve soil water availability for growing crops.

THE EXPERIMENT: NO TILLAGE

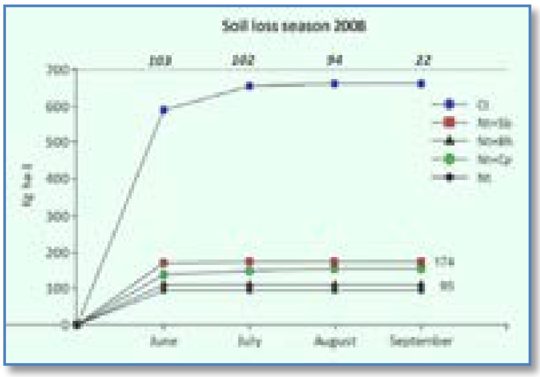
An oat-wheat crop rotation was established and the following tillage systems were evaluated:

(i) no tillage (Nt);
(ii) no tillage with subsoiling (Nt+Sb), which consisted of a subsoiler at 40 cm depth, every 40 cm perpendicular to the slope, before sowing;
(iii) no tillage with *Phalaris aquatica* barrier hedges (Nt+Bh) at 12.5 m distance;
(iv) no tillage with contour ploughing (Nt+Cp) every 12.5 m with a 1% slope to remove water from the plot; and
(v) conventional tillage with animal plowing (Ct) . Plot size was 1000 m^2.

The experiment started in 2007. For each rainfall event data on surface runoff, sediments and nutrient losses were collected using runoff storage tank. Data on rainfall and soil parameters (pH, Nitrogen, phosphorus, organic matter, bulk density, aggregate stability, soil water content, etc.) was also collected.

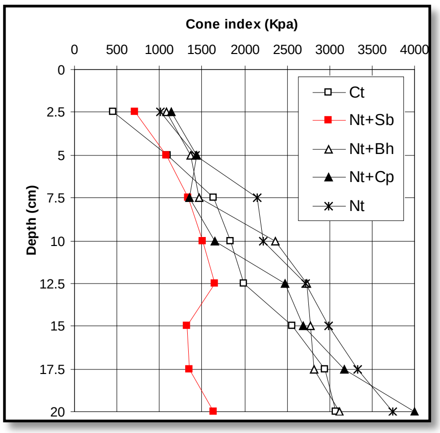
Variable	2007	2008	2009	2010
Runoff	←	—	—	→
Sediments	←	—	—	→
Nutrient losses	←	—	→	
Yield	←	—	—	→
Soil Moisture	←	—	—	→
Physical indicators	●		●	
Biological indicators				●
Soil compaction	←	—	—	→

RESULTS

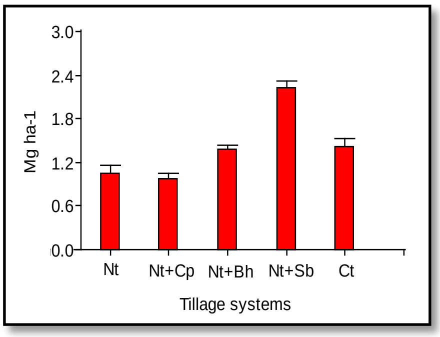


The results indicated that soil loss for all the treatments was less than 1 ton ha^{-1}. The result also shows that the runoff coefficient was more than 50% in the conventional tillage while in conservation tillage it was between 20-30%.

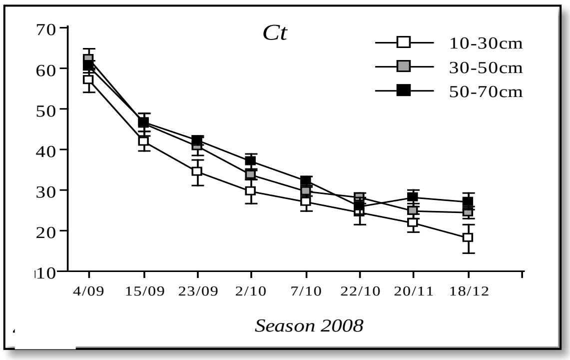
The study on soil compaction shows that in the second year, soil penetration resistance increased from 500 to 1500 kPa in all tillage system at a depth of 2.5-10 cm of depth. In soil depths 10-20 cm soil penetration resistance exceeded 2000 kPa in Nt, Nt+Cp, Nt+Bh, and Ct tillage systems. While in the no tillage and subsoiled treatment (Nt+Sb) it was significantly lower (1500 kPa). In the third year, soil penetration resistance in Nt+Sb remarkably increased to over 2000 kPa below 15 cm of depth, while the rest of the conservation treatments exceeded this threshold at 10 cm. The high values in soil compaction are also explained by the presence of high percentage of clay in B horizon (18 to 100 cm). They could inhibit root development.

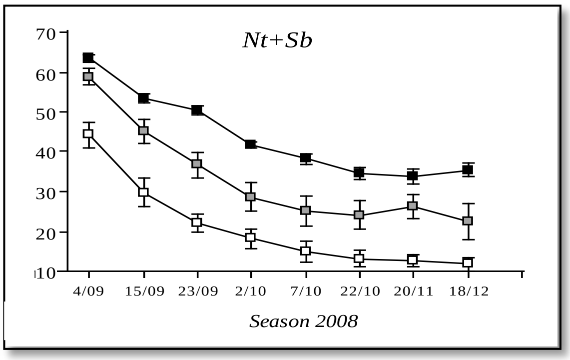


In the first year of the study (2007), oat grain yield and biomass production of Nt+Sb was significant (p<0.01) higher than the rest of the treatments, while Nt+Cp and Nt obtained the lowest productivity. In 2008, (more humid year) the highest wheat productivity was observed in the Nt+Sb and Ct treatments, and the lowest in Nt. Finally, in the third year oat crop production was higher in the Nt+Sb, Ct and Nt+Bh treatments compared to Nt.



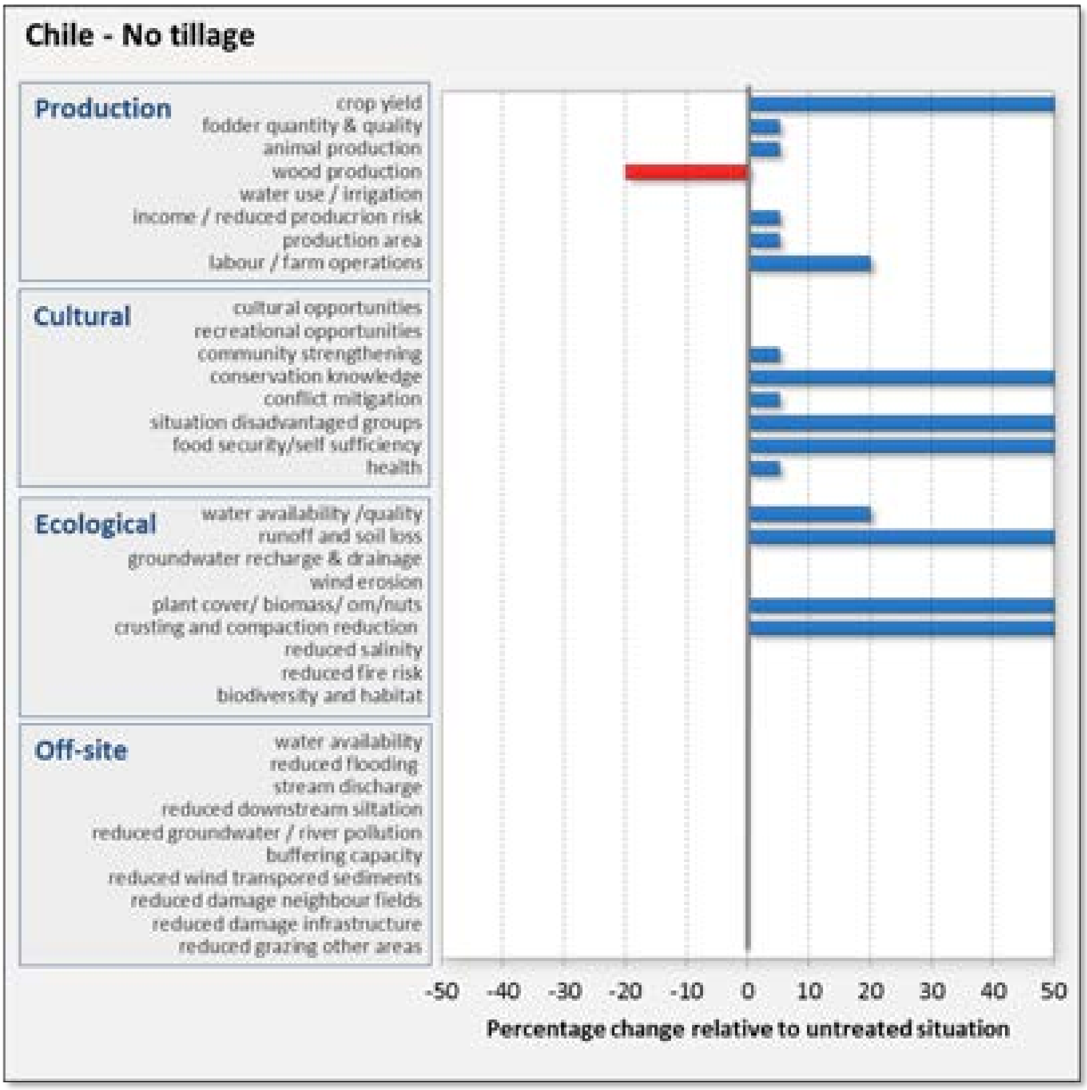
The result also showed that conservation systems preserve more soil moisture in the profile than traditional tillage (see graphs below). The crop residues left on the soil surface minimize evaporation loss and enhance infiltration.





HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

A lot of farmers visited the experimental sites during 2008-2009. The stakeholders think that their quality of life will be improved because of diversified income source. The farmers have more products to sell in addition to wheat

in 2010 a new project was established where the farmers adopted no tillage with sub-soiling and contour ploughing with barrier hedge in a wheat – oat crop rotation

CONCLUSIONS

The no tillage with sub-soiling reduces soil loss by more than 70% of the soil loss as compared to conventional tillage.

Also the runoff coefficient is reduced in the no tillage and sub-soiling practices. In addition, it increases soil cover and soil organic matter.

The crop yield of no-tillage is is slightly lower than conventional syillage although with subsoiling, the yield is actually higher. No Tillage saves on certain operations but there are additional farm costs for herbicides and including also additional use of farm machinery for removing the weeds and for sub-soiling will be required.

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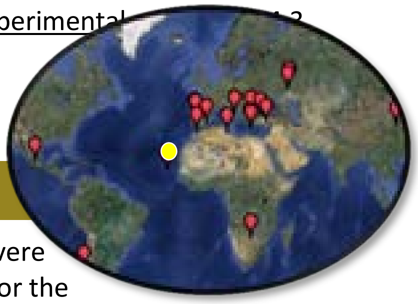
DESIRE



18 CAPE VERDE – RUNOFF BARRIERS WITH PIGEON PEAS

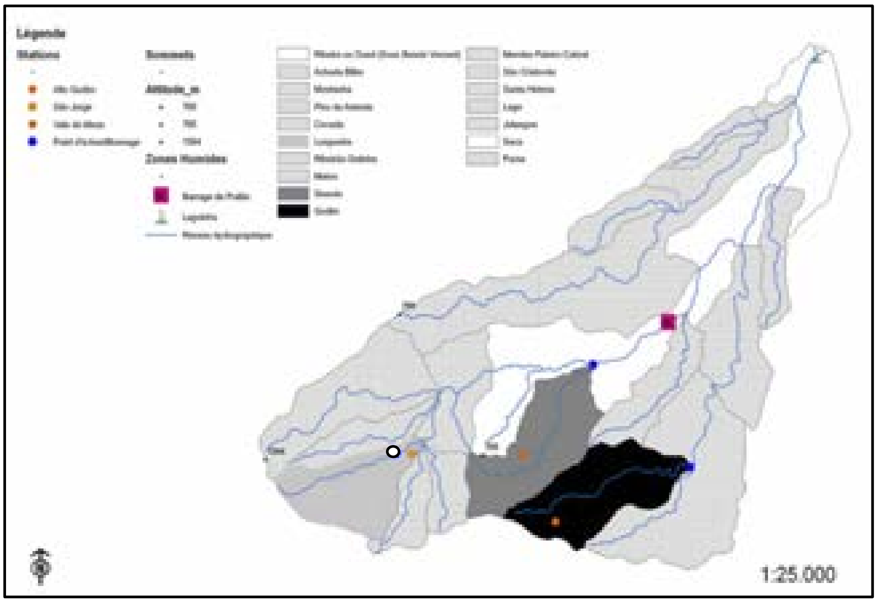
Cape Verde has been facing to severe environmental problems impact for the people living in the island. In order to control desertification (drought, strom runoff, erosion) the government has been taking actions regarding biodiversity conservation, ecosystem management and better valorisation of water resources. Slanting terraces as a form of conservation are widespread, but in the dry climate vegetation cover is low and the terraces do not always have the desired effect. The experiment aims at improving the system with vegetation barriers.

THE EXPERIMENT: LINING TERRACES WITH PIGEON PEAS

The experiment was carried out in a sub-watershed which is located in the Ribeira Seca, Santiago island to see if vegetative barrier can be used in order to increase surface cover and reduce runoff. Pigeon pea was planted as vegetative barrier in about 330 ha land (see photo left). The advantage is that pigeon peas maintain a high cover as dense bushes and can also be used as animal fodder. The experiment included pruning of the bushes, which provides additional fodder.

To evaluate the effects of the technology the hydrologic behavior was monitored in the outlet of two sub watersheds (Longueira and Serrado). At the outlet of the Longueira subwatershed runoff flow and suspended sediment load (with sampling bottles) was measured for the period 2005-2009. For the period 2009-2011 only runoff flow was measured.

In the fields, vegetation cover, organic matter and rock outcrops were estimated using 25 m transects. In addition, leaf area index and soil hydraulic conductivity were measured. Assessment of soil erosion and erosion risk for pigeon pea cultivation with and without pruning was estimated using the PESERA model. The pigeon pea were not sown in contour lines to form barriers as planned, but were planted in pits together with maize and beans to cover more soil.



RESULTS

The maximum runoff from the subcatchment did not change much (5-6 m^3/s) while the annual precipitation varies. This is related to the variability and type of rainstorms recorded.

	2007	2008	2009
Annual Precipitation San Jorge (mm)	389.3	370.0	652.7
Number of days with rainfall (From August to October)	13	23	36
Max Instantaneous Runoff (m^3/s)	6.68	5.77	6.07
Erosion by water ($t.km^{-2}$)	211.3	540.2	115.7
Yield Fodder (tons)	51.43	72.00	60.00

The result obtained from running erosion model (PESERA, see table below) shows that 58 km^2 of land with erosion rates greater than 10 $t.ha^{-1}.yr^{-1}$ was reduced to 42 km^2 in pigeon pea cultivation without pruning, indicating a reduction of 27,6% . With respect to biomass production the pigeon pea cultivation plays an important role not only in the fight against desertification and erosion, but also in improving the income of animal raisers. The result also shows the increase of biomass production (varies between 1410 and 1450 kg / ha) in more than 90% of the study area.

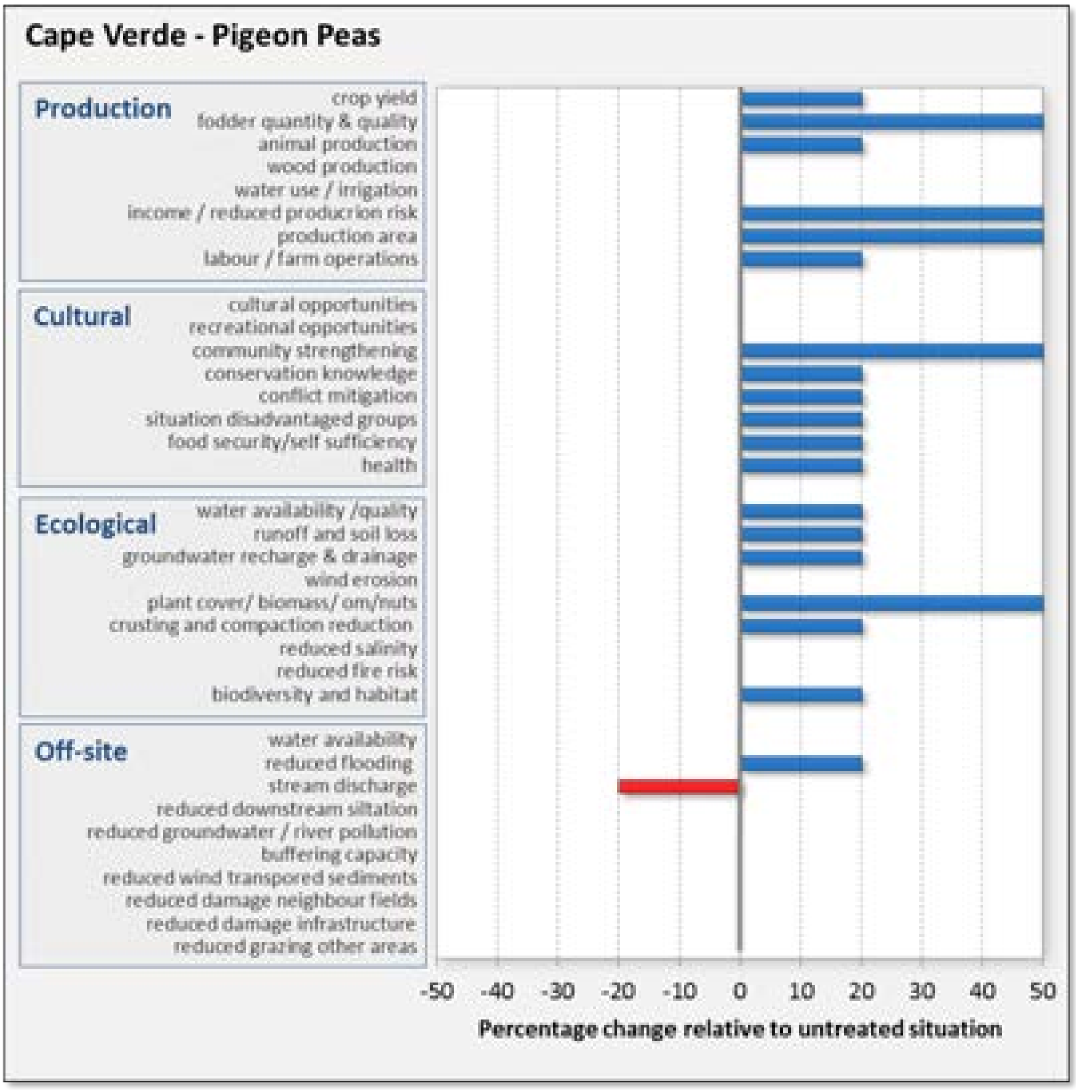
Pigeon pea with pruning		**Pigeon pea without pruning**	
Area (km^2)	Soil loss ($t.ha^{-1}.yr^{-1}$)	Area (km^2)	Soil loss ($t.ha^{-1}.yr^{-1}$)
20.4	> 20	12.7	> 20
37.6	10 – 20	29.7	10 – 20
11.7	5 – 10	25.0	5 – 10
1.5	2 – 5	3.6	2-5
0.3	0 -2	0.5	0-2

Data on runoff, erosion rate and suspended sediments are available for only 2010 and partially for 2011 (see table below). Using only one year data is not sufficient to make any firm conclusions to assess the effect of pigeon pea plantation on controlling runoff and soil losses.

Variables	2010*[1]					2011**				
	8	9	10	11	12	8	9	10	11	12
Run off max inst. ($m^3.s^{-1}$)	0	3.42	1.75	0	0	N/A	N/A	N/A	N/A	N/A
Mean Suspended sediment ($g.l^{-1}$)	0	4.0	2.80	0	0	0	7,88	0,23	0	0
Erosion ($t.km^{-2}.yr^{-1}$)	0	5.25	2.50	0	0	0	N/A	N/A	0	0
Soil cover (%)	60	80	85	85	80	83	86	90	94	94

HOW WELL DOES IT WORK?

The results are evaluated from a production, socio-cultural and economic point of view. The bars express the estimated or measured percentage of change with respect to the reference situation. This change can be positive (blue) or negative (red). Note that this evaluation is based on the experiments, on the long term experience of the coordinating team in this area and on consultations with the farmers.



STAKEHOLDER'S OPINIONS

Stakeholders were involved since the beginning of the project. They were involved in selecting and implementing the technology. The stakeholders seem to be convinced that the cultivation of pigeon pea and afforestation with fruit trees help in combating land degradation. This was shown by the workshop organised with them.

Stakeholders evaluate the technology as very positive in terms of production and other effects that relate to a higher income. They only negative aspect is that conserving water upstream might cause water shortage downstream.

CONCLUSIONS

This technology helps improve vegetation cover which helps in reducing surface runoff and soil erosion. Whether applied as terrace barrier or more mixed with the traditional Maize crop in an intercropping pattern crop yield is increased and supplemented with fodder supply from pruning of the pigeon peas.

When applied in the entire catchment it should be noted that downstream water supply might be affected. This may have consequences for a dam was built downstream with a reservoir for irrigation which may have less inflow of water.

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7. General conclusions

The following main conclusions can be drawn at this stage. Note that cross cutting issues between sites are investigated in deliverable 4.5.1. nevertheless a number of important conclusions can be drawn:

i) **There are few best practices to be found: each situation is unique in its context. The three categories, bio-physical, economic, and socio-cultural are equally important to understand final results.** It is clear that all situations are different, and that the success of a particular technology depends entirely on the local context. All evaluations are positive to very positive in terms of bio-physical effects and neutral to positive in terms of productivity and economic effects. However at the same time stakeholders are reluctant to try out or continue a particular technology, often for very clear reasons. Without this dual approach (analysis and evaluation) such considerations would never surface. In that sense the approach can be called a success, because it clearly points out bottlenecks or directions of action for policy makers.
The clearest benefits are those where water harvesting is concerned in situations where water is a bottleneck for production, and also fencing and rangeland resting gives very clear benefits in rangeland quality and fodder quantity, in a relatively short time (1-2 years). More complex experiments such as minimum tillage sometimes have clear positive bio-physical and economic effects but re culturally difficult: minimum tillage field look “messy” and abandoned and give an impression of bad farming. Measures that only result in erosion control but offer no other benefits are the least interesting. Soil loss in itself very gradual and is rarely seen as a problem.

ii) **Experimental fields/plots form a very good basis to discuss technologies with farmers, although the general interest varies per site, they exist at a “stakeholder scale”**. Results are directly visible and on a scale that links closely to their socio-economic life. This does not always result in acceptance of course, that depends on the degree of success. Subtle success or results in a context of desertification alone are certainly not enough to convince stakeholders, there must be clear economic benefits above traditional ways of land use. However, if on a site a political decision would be made to subsidize conservation technologies in an area, this approach of stakeholder based field scale implementation has the clear advantage of promoting involvement.

iii) **An integrated approach is necessary and there is a difference in an implementation on a plot or field, and a large scale implementation in a site.** From a scientific point of view plot studies are of limited value because of the impossibility to upscale directly and the need for integrated catchment research. These results confirm that but also point out in which direction an integrated approach would have to go. An approach that is technology driven and looks only at biophysical aspects is not useful, as is an approach that is only social in context (since farmers deal with the bio-physical reality every day). In several sites this is actually done so that background knowledge is available and plays an important role in evaluating the results (background catchment research is done in Spain, Portugal, Crete, Morocco, Tunisia, Russia, Mexico and Cape Verde).

iv) **Large scale implementation of technologies often means a drastic change in the way people are doing farming and this can only happen if the economic benefits are clearly there**. If these benefits are the same as the traditional way of farming or even if costs are slightly lower, this is not enough to stimulate major changes. The impression is that benefits that cut down in costs (labour and fuel) are not so positively judged as an increase of income, but this was not investigated in a structural way. Certainly if the benefits are not immediately clear or only seen after a few years (such as is the case with minimum tillage and set aside rangeland control) there is little incentive to change, unless major subsidies are provided as support. An integrated approach is needed. There may be unforeseen domino effects that might be expected: for instance conservation of the degraded gully area in Morocco to protect both the soil and a downstream artificial lake, might cause cattle to start grazing in an adjacent protected forest area. Or for instance the use of fresh water for irrigation in Greece might be available only to certain farmers, causing an inequality in the area because of the vicinity to the river.

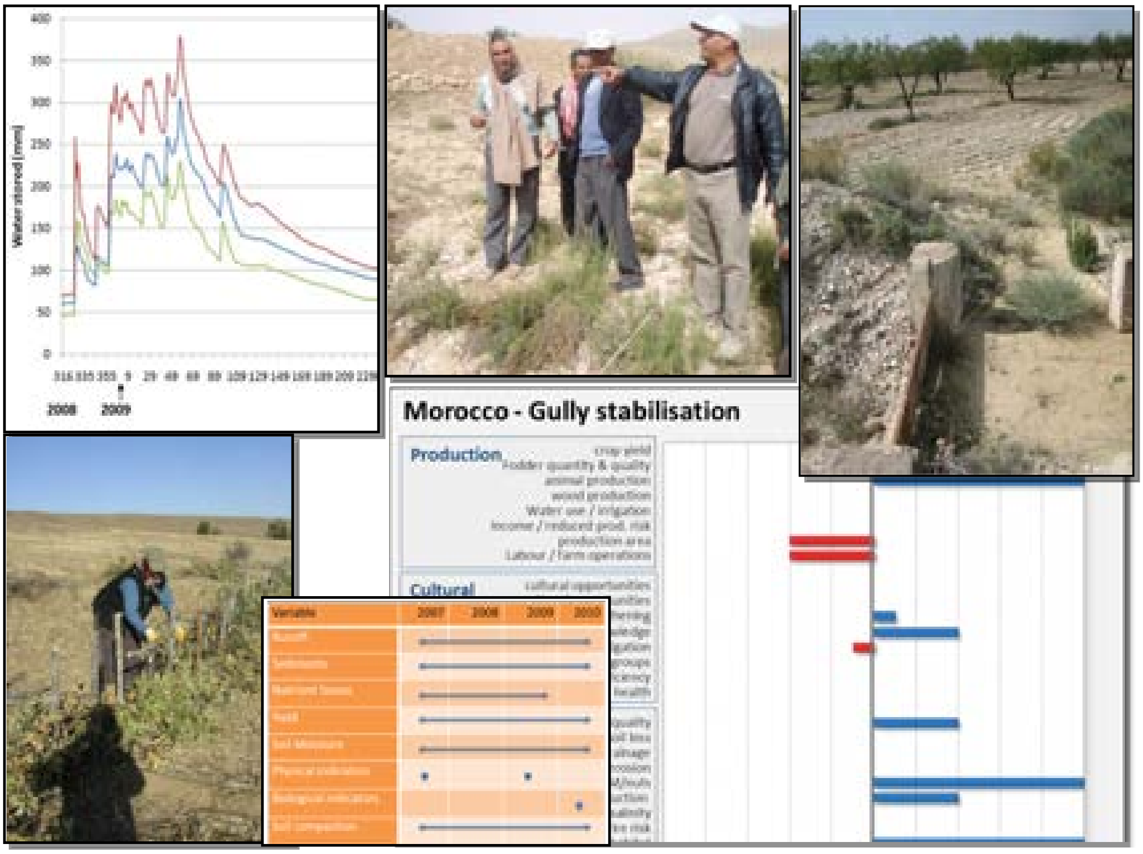
v) **The main socio-cultural effect seems to be a better understanding of desertification and conservation, but these are still very complex processes.** However, this "understanding" should not be taken for granted, some stakeholders seemed to think the effect of a technology was permanent even after the technology was abandoned. Clearly in several cases agricultural extension work and schooling would be very beneficial. Only areas where the technologies have been introduced long ago or no agriculture is feasible without them (such as for instance water harvesting techniques in Tunesia, Boquera irrigation in Spain, drip irrigation in Russia) are really successful. Controlled grazing and rangeland management is successful if the decrease of grazing area is compensated by subsidy during the first years.

vi) **In areas where the productivity is not very high and farming does not offer perspectives for the future there is little incentive to change methodologies drastically or go for whole scale protection of areas**. There are usually one or two major constraints that prohibit the wide scale implementation of a technology on the site. The cost factor is usually the main bottleneck: implementation and maintenance of technologies are too much to be carried by the farmer's community alone. Sometimes the technology gives a clear increase in yield in which case this is less of a constraint, sometimes the economic benefits translate in lower production costs compared to conventional operations but this seems less interesting then a direct yield increase.

Deliverable 4.3.1 (annex)

WB4 - Implementation of conservation technologies at stakeholder level

Results of field experiments - *ANNEX*



January 2012

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ITC

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Contents

INTRODUCTION

This report is the annex to Deliverable 4.3.1 of Work Package 4.3 of the DESIRE project. It contains the scientific reports of each study site, describing the experimental results of the implementation technologies implemented at plot and field level. The summaries of these findings combined with the evaluation results of the questionnaires are in the main report of deliverable 4.3.1 (for a full description of the methodology, see that report). Tab;e 1 shows the functional groups in which the experiments can be organized.

		1	2			3		4			5		6			7
Site number		Minimum tillage	Mulch / residue /stubble	Green cover	Rotation/crop type	Contour ploughing	Woven fences/runoff control	Water harvesting	Terrace (bench)	Check dams	Fresh water irrigation	Drip irrigation	Gully control/Fodder	Rangeland management	Biogas	Fire break/prescribed burning
1	Spain	X	X	X		X		X								
2	Portugal															XX
4	Greece Crete	X1		X1										X		
5	Greece Nestos										X					
6	Turkey Karapinar	X	X													
7	Turkey-Eskisehir					X	X									
8	Morocco	X1	X1										X			
9	Tunisia							XX						X		
10	Russia Dzhanybek											X				
11	Russia-Novy											X				
12	China								X	X						
13	Botswana														X	
14	Mexico	X			X								X			
17	Chile	X			X	X	X									
18	Cape Verde						X1		X1							

Table 1. (1) Minimum tillage; (2) Soil cover management; (3) Runoff control; (4) Water harvesting; (5) Irrigation management; (6) Rangeland management and fodder production; (7) Forest fire management.

1 SPAIN - GUADALENTIN

Responsible partner

Partner 6 – Estacion Experimentqal de Zonas Aridas (Joris de Vente, Albert Solé-Benet, Jorge López-Carratala, Carolina Boix-Fayos)

1.1 SITE INFORMATION

Given the severity of the land degradation and desertification problems, and taking advantage of the long history of research projects, the Guadalentín basin in south-eastern Spain was selected as one of the study areas in DESIRE. The focus of most DESIRE research in Spain has been on the sub-catchment of the 'Rambla de Torrealvilla', which is considered to be representative for large parts of the Guadalentín basin. The Guadalentín basin covers an area of about 3300 km². The 'Rambla de Torrealvilla' is a tributary in the headwaters of the Guadalentín upstream of Lorca, and covers about 250 km² (Figure 1 & 2).

During the last two decades, the Guadalentín basin has been the study area for many studies dealing with land degradation. Examples are the projects MEDALUS, DESERTLINKS, MEDACTION, and RECONDES funded by the EU, but also various Spanish national research projects have focused on parts of the Guadalentín basin. One of the reasons for the broad interest in the Guadalentín is that land degradation is generally considered severe in large parts of the basin due to a combination of the Mediterranean climate, characterised by dry summers followed by intense autumn rainfall, an often steep topography with fragile soils on highly erodible lithology's. Moreover, initiated by political and socioeconomic changes, important land use changes have taken place over the last centuries, which have formed an important driver for further land degradation.

Soil erosion by rills and gullies are amongst the main causes of land degradation in the Guadalentín. Apart from the natural conditions favouring soil erosion (i.e. topography, climate and lithology), high soil erosion rates are often triggered by frequent tillage, uncontrolled land abandonment and improper reforestation techniques. Another land degradation problem is soil salinization due to overexploitation of aquifers. Measures to combat land degradation problems have been applied for over 100 years. Some of them have been successful, while others have failed.

Fig. 1: Location of the Guadalentín drainage basin in Spain.

The climate in the Guadalentín varies from semi-arid to sub-humid Mediterranean, with mean annual precipitation between less than 300 to more than 500 mm, and an average annual temperature between 12 and 18°C (1971-2000). Droughts, centred in summer commonly last for more than 4-5 months. Annual potential evapotranspiration rates larger than 1000 mm are common. The dominant soil types in the Torrealvilla study area are Regosols, Fluvisols, Calcisols, Gypsisols and Leptosols (FAO, 2006). Leptosols dominate on the steeper slopes of the limestone outcrops, whereas Calcisols, Gypsisols and Regosols are mostly found on the flatter terrain. Calcic and petrocalcic horizons are common in these soils. The experimental plots are located on Calcisols and Regosols under relatively gentle to moderate slopes between 5 and 15 %.

Vegetation in the Guadalentín is highly disturbed by centuries of human influence. Semi-natural ecosystems include shrublands with dominance of *Stipa tenacissima*, *Rosmarinus officinalis* and *Anthyllis cytisoides*. Forests are dominated by *Pinus halepensis*. The main land use at present in the Guadalentín includes under rain fed conditions almonds and herbaceous crops, and under irrigation orchards with citrus, various vegetables, greenhouses and also almonds are sometimes irrigated.

A detailed study of land use changes since the 1950's within the Torrealvilla catchment performed within DESIRE (Nainggolan et al, in review) shows that more than 72% of the study area has undergone significant land use changes over the past five decades with pronounced effects on landscape composition and structure. This study also showed that afforestation, land abandonment and agricultural intensification are the three main types of land use change occurring in parallel.

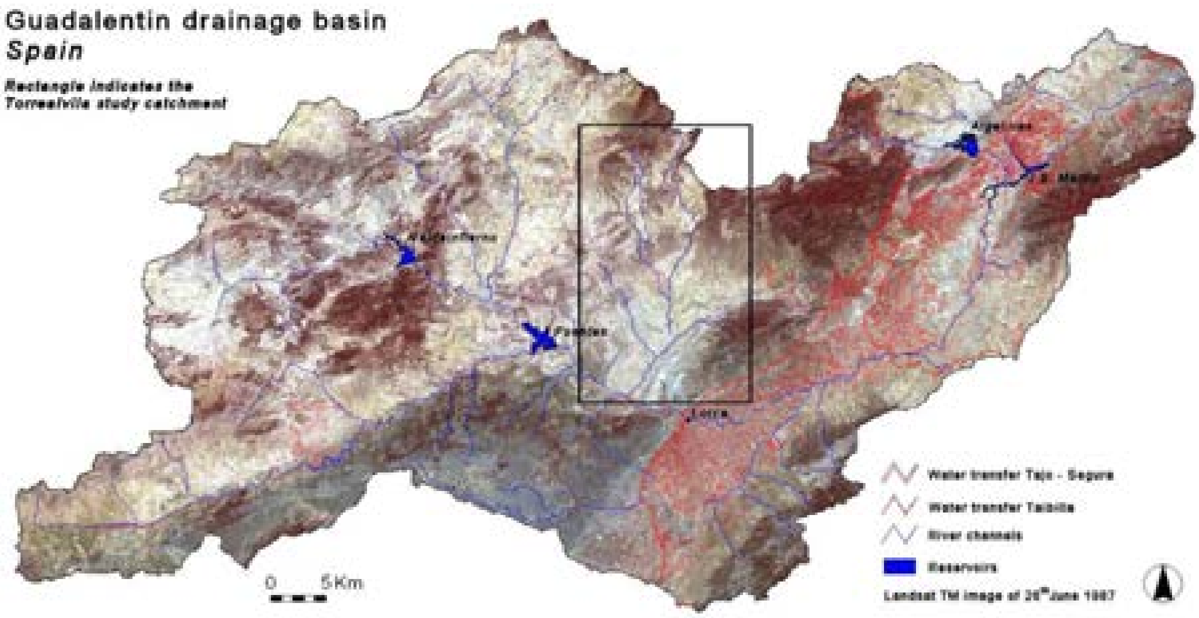

Fig. 2: Overview of the Guadalentín drainage basin and Torrealvilla subcatchment in SE-Spain.

1.2 INTRODUCTION

The main forms of land degradation in the Torrealvilla subcatchment are caused by water erosion and drought. As became apparent during the DESIRE stakeholder workshops, farmers are generally more concerned about a lack of water than about soil loss. Therefore, the DESIRE field trials were designed to provide information on the possibilities of a more efficient use of water by preventing evaporation (i.e. straw mulch) and by collecting surface runoff through traditional water harvesting techniques (i.e. *boquera*). Moreover, an assessment was made of the potential of various technologies (i.e. reduced tillage, straw mulch, green manure and water harvesting) to improve soil properties, increase infiltration, increase soil organic matter and reduce surface runoff and soil erosion by water.

So, the overall objective of the field trials was to assess the effectiveness of different Sustainable Land Management (SLM) measures to reduce soil erosion and increase soil water content, and to assess the crop yield and farm profit after correction for possible extra costs for implementation and maintenance of the SLM measures. This economic part of the evaluation was considered crucial since an effective but expensive or yield reducing method will not be acceptable for stakeholders. In the DESIRE stakeholder workshops it became very clear that the first consideration for implementation of any SLM measure is its short-term profitability rather than any long-term prevention of land degradation. Therefore, following the stakeholders' recommendations, monitoring of the SLM measures was done according to economic and ecological criteria.

1.3 Trial layout

Field trials were performed in the upper part of the Rambla de Torrealvilla, in the area of the 'Los Alagüeces' farm (Fig. 3). The owner of this land with over 1000 hectares, kindly provided access to his land and participated actively in the implementation and monitoring of the experiments. Field trials were conducted under the two main land use types within the study area: rain fed cereals and almond orchards. In total five SLM measures were monitored in three field sites (Fig. 3). The three field sites were selected at short distance from each other (<1 km). Field site A is an almond field without terraces where reduced tillage and green manure technologies were applied. Field site B is a terraced Almond field. Here, in one terrace the effect of a traditional water harvesting system (*boquera*) was monitored and compared with another terrace without a *boquera*. In a third terrace, also without *boquera*, straw mulch was applied to study the effect on reduced evaporation losses. Field site C is a cereal field where the effect of reduced tillage was compared with conventional tillage operation with a mouldboard plough. Annex I provides a detailed description of soil types and chemical compositions of the three field sites. Table 1 provides an overview of the period of monitoring of the different SLM measures as well as the meteorological data from the meteorological station that was installed at the Alhagüeces farm in august 2008.

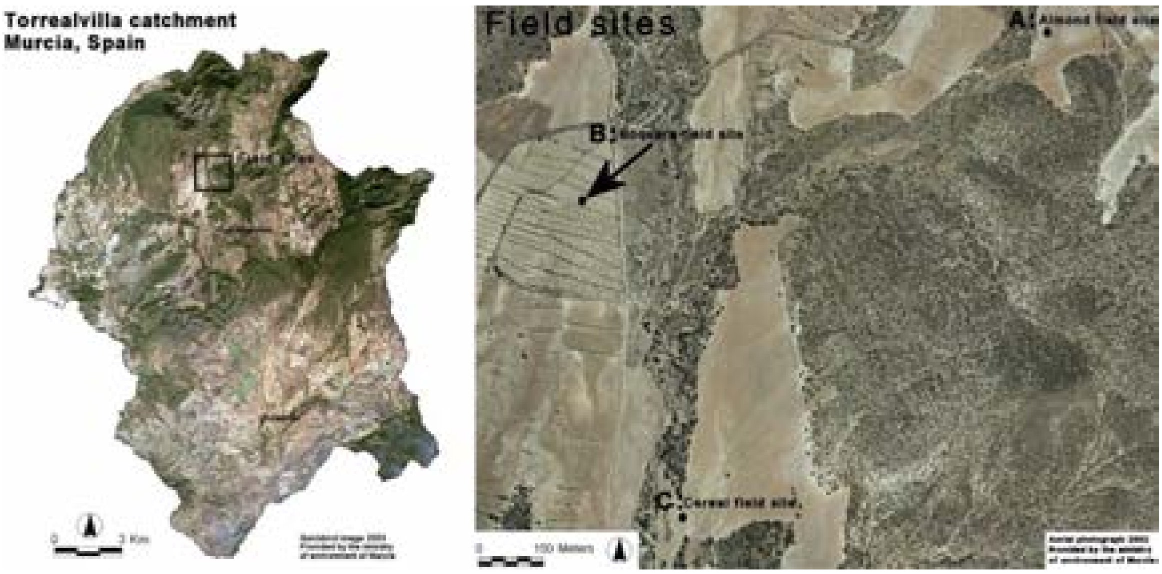

Fig. 3: Location of the field sites within the Torrealvilla catchment. A: almond field with green manure and reduced tillage experiments. B: Almond fields with a *boquera* and organic mulch treatment. C: cereal field with reduced tillage experiments.

Meteorological data

An automatic weather station was installed at the Alhagüeces farm that measured rainfall every 5 minutes, as well as air temperature and humidity, wind speed and direction and stored data on a datalogger.

Table 1: Overview and timeline of monitoring and implementation activities at the Alhagüeces experimental farm.

	2008	2009	2010	2011
Meteorology	**			
Farm logbook	**			
Site A				
Seed green manure	**	**	**	**
Soil water (Θ)		**		
Runoff		***		
Erosion		***		
Almond harvest		**	Damaged by frost	Damaged by hail
Site B				
Soil water (Θ)		**		
Mulch cover		***		
Boquera inflow		**		
Almond harvest		**	Strongly reduced by frost	Damaged by hail
Site C				
Runoff		***		
Erosion		***		
Cereal harvest				**

Field Site A: Reduce soil and water loss in Almond orchards

On this sloping almond field (Fig. 4) two SLM measures were implemented aiming to reduce soil and water loss and increase soil fertility: green manure and reduced tillage. These SLM measures were compared to conventional tillage operation (control condition). In the green manure field, a mixture of barley and vetch (*Vicia sativa)* was seeded in autumn and ploughed into the soil in spring. The first time this green manure was seeded was in autumn 2008, and this was repeated each following year. Like the field with a reduced tillage treatment, this field was ploughed only twice a year, whereas the field under conventional tillage was ploughed between 3-5 times per year, which is the common practice in the study area.

Fig. 4: Overview of Field site A, indicating the location of the open runoff plots

To monitor the effect of the treatments on ecological criteria, three replica open runoff erosion plots (Gerlach type) were installed in each treatment, giving a total of 9 runoff plots (Fig. 4). To determine the exact contributing areas to the open runoff plots, a terrestrial laser scanner (TLS) was used to construct a high resolution digital elevation model. Furthermore, soil moisture of the upper 20 cm was measured about every month at 30 random points in each field with FDR equipment. After every event, runoff and soil loss were measured by collecting the water and sediments from the Gerlach runoff plots and storage tanks.

To evaluate the economic impact of the SLM measures, all farm operation costs of each treatment (ploughing, implementation, seeding etc.) were registered in a logbook, and the harvest was determined individually per treatment.

Field Site B: Increase available water in almond orchards

Field site B (Fig. 5) consists of a cascading system of flat terraces that allowed comparison of 2 SLM measures with control conditions. Originally all of these terraces were irrigated from a traditional water harvesting system, called *boquera* in Spanish. A *boquera* is a system where during rainfall events that result in flow through a nearby ephemeral stream (rambla), this water is (partly) diverted to the nearby terraced fields through a series of man-made gateways and cprresponding channels (i.e. *acequia*s). Because of lack of maintenance of these channels in field site B, nowadays, only a few of the monitored terraces can still benefit from the inflow of water. In one of those terraces that still receives water from the *boquera* during flow events, a probe was installed that registers water height in the *acequia* channel with a high accuracy (1 mm) at a 20 seconds interval. By using the Mannig equation, the water height was converted into an estimated volume of water. In another terrace, without additional inflow of water from the *boquera*, a straw mulch (~15cm thick) was applied under the canopy of the almond trees after the spring rainfall since spring 2009. In a third terrace, also without additional water inflow, normal production scheme was used as a control plot. In all three plots soil water content was registered hourly at 35 cm depth, and about monthly for the first 20 cm with FDR equipment. The *boquera* and control fields were ploughed 3-5 times per year, whereas the field with straw mulch was ploughed only twice a year.

To evaluate the economic impact of these SLM measures, all farm operation costs of each treatment (ploughing, construction, maintenance, mulching, etc.) were registered in a logbook, and the harvest was determined individually per treatment.

Fig. 5: Field site B with the inlet of the *boquera-acequia* to the Almond field (left) and the straw mulch below the Almond trees in the adjacent terrace (right).

Field Site C: Reduce soil and water loss in a cereal field

Field site C is a cereal field where reduced tillage was compared with a conventional tillage regime. Under conventional farming practice winter wheat is seeded in October-November after the autumn rains. In February grains are greening, maturing in May and harvested in June. Crop residues are left on the field as mulch or for post-harvest grazing by cattle until September, when the fields are ploughed with a mouldboard plough for seeding in November or left fallow for one year. In our experiments, both under conventional tillage and reduced tillage, each year of cereal production was followed by one year of fallow. Under conventional tillage, the land was ploughed 5 times in two years, one of which with a mouldboard plough. Under reduced tillage, the land was ploughed only three times in two years with a disc or chisel plough and never with a mouldboard plough.

Fig. 6: Overview of Field site C indicating the location of runoff plots under conventional tillage and reduced tillage regime.

To monitor the effect of the treatments on ecological criteria, three replica open runoff-erosion plots (Gerlach type) were installed in each treatment, giving a total of 6 runoff plots (Fig. 6). To determine the exact contributing areas to the open runoff plots, a terrestrial laser scanner (TLS) was used to construct a high resolution digital elevation model. After every event, runoff and soil loss were measured by collecting the water and sediments from the Gerlach runoff plots and storage tanks.

To evaluate the economic impact of these SLM measures, all farm operation costs of each treatment (ploughing, implementation, seeding, etc.) were registered in a logbook, and the harvest was determined individually per treatment. Since each harvest is followed by a fallow year, only 1 cereal harvest was obtained during the monitoring period.

1.4 Analysis and Results

Meteorological data

Fig. 7 presents the average rainfall and temperature as were registered at the Alhagüeces meteorological station since 2008. Over the three years of monitoring an average annual rainfall of 292 mm was recorded, however, with a high variability between years. A maximum of 340 mm was registered in the first year and a minimum of 222 mm in the last year of monitoring. Fig. 8 shows the average maximum rainfall intensity that was measured over the three years of measurement. Rainfall intensity is represented by the Imax30 and Imax5, which refer to the maximum rainfall intensity (mm h^{-1}) during 30 and 5 minutes respectively. These graphs show that most rainfall occurs in autumn and spring. While March was on average the wettest month, the highest rainfall intensity was recorded in May. On average, air temperature is highest in July and lowest in February, whereas occasionally until March temperatures below zero were registered.

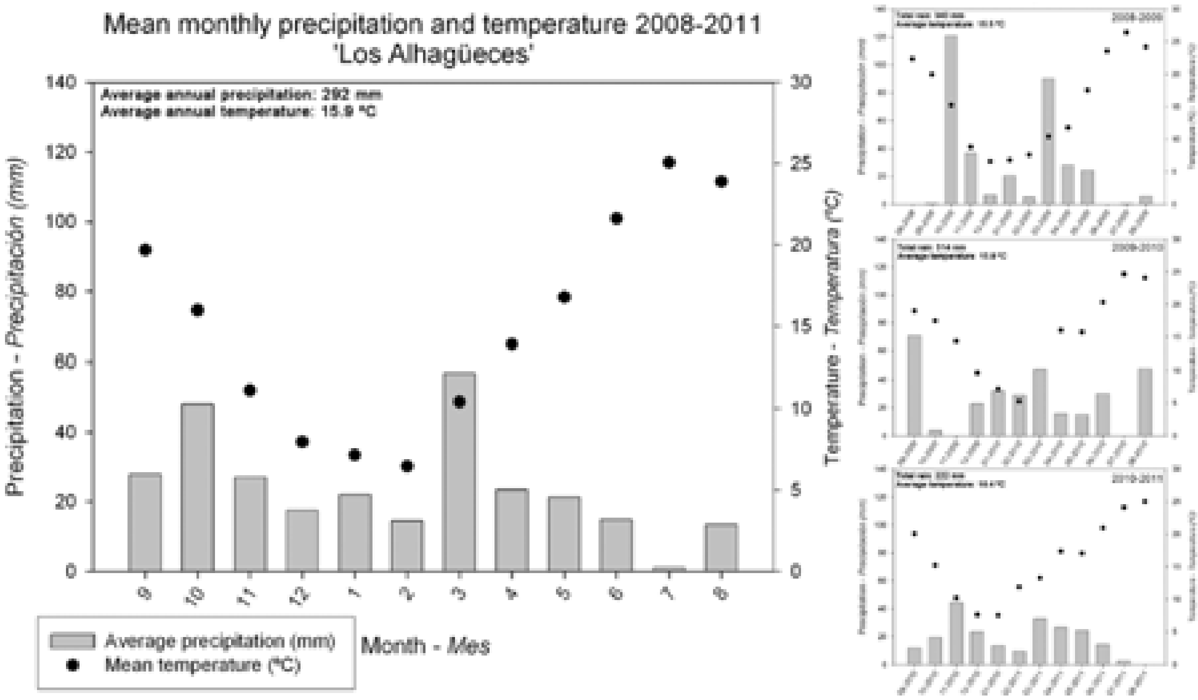

Fig. 7: Summary of meteorological data registered at Alhagüeces meteorological station 2008-2011.

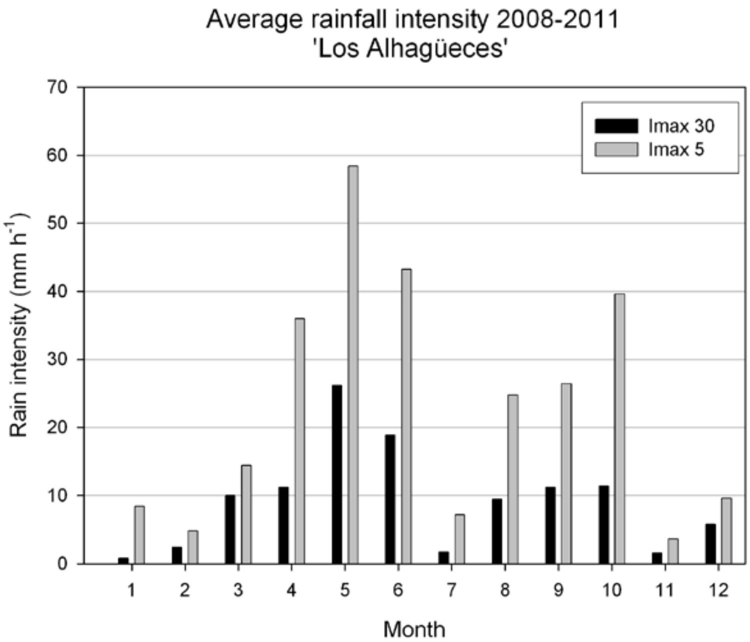

Fig. 8: Average maximum rainfall intensities measured at the Alhagüeces meteorological station from 2008-2011.

Field Site A: Reduce soil and water loss in Almond orchards

Regarding the ecological evaluation criteria, Fig. 9 shows the soil and water loss under green manure, reduced tillage and control conditions as measured in the erosion plots in field site A, after 2 years of monitoring and 18 events. These results show that soil and water loss by runoff and erosion under reduced tillage and green manure treatment were reduced with about 60% as compared to a conventional tillage regime.

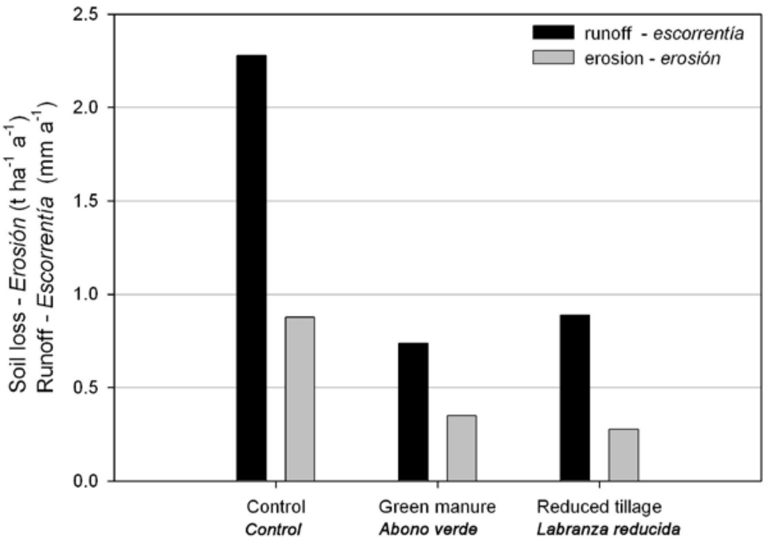

Fig. 9: Soil and water loss from sloping almond fields with green manure, reduced tillage and control conditions.

Monitoring of soil water content did not show consistent differences between the different treatments (Fig. 10). Differences were very small, and if there were differences, in general soil moisture tended to be even higher under reduced tillage and green manure treatment than under control conditions, possibly due to the effect of dew formation on plants below the almond trees.

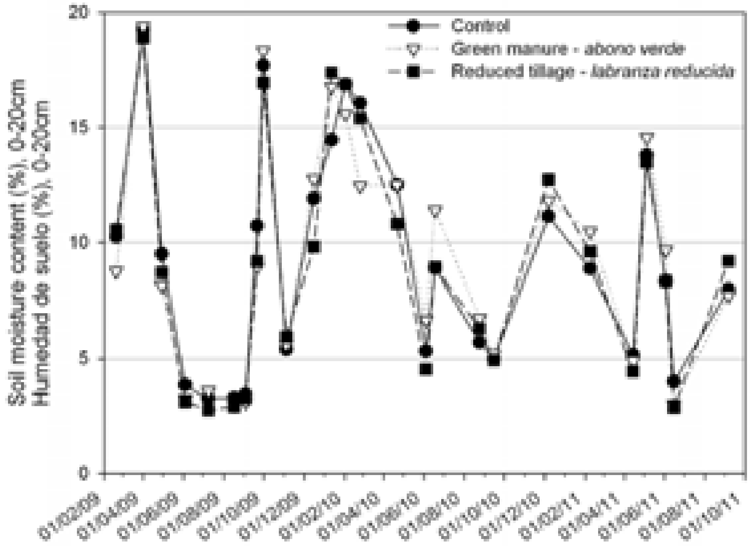

Fig. 10: Soil water content from 0-20 cm depth under green manure, reduced tillage and conventional tillage.

Unfortunately, due to frost in spring 2010 and hail in late summer 2011, we only obtained data on the almond harvest for 2009 (Fig. 11). These data point towards an increased almond yield in the field with green manure of 40% compared to the other two treatments. Given the high inter-annual variability in almond harvest and the expected increasing positive effect of green manure on almond yield with time makes reliable economic assessments difficult. Nevertheless, based on available data and only including those costs and benefits that differentiate between treatments (so, not considering costs that are common to all treatments), Table 2 gives a summary of an economic cost benefit assessments of the three treatments based on all activities and prices recorded in the farm logbook (e.g. gasoil use, tractor hours, man hours etc.). This summary indicates that green manure results in increased economic benefits, whereas reduced tillage does not affect the economic benefits as compared to conventional tillage.

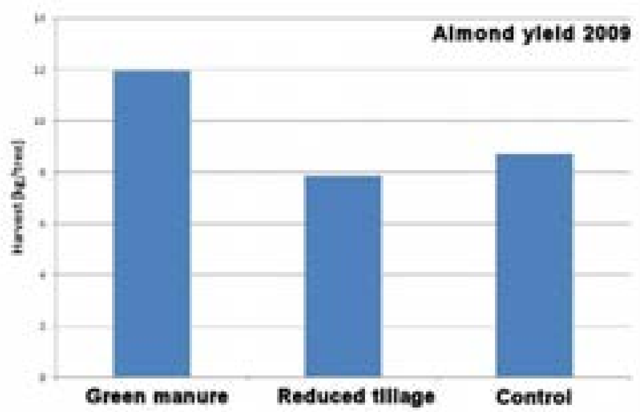

Fig. 11: Almond harvest field site A for 2009

Table 2: Overview of costs and benefits of SLM measures in field site A, without taking account of costs that are common to all treatments.

	€/ha/a	Green manure	Reduced tillage	Control
Income	*Yield*	€1927,-	€1268,-	€1404,-
Costs	*Ploughing*	€60,-	€60,-	€120,-
	Seeding	€70,-		
Gross benefit		***€1797,-***	***€1208,-***	***€1284,-***

Field Site B: Increase available water in almond orchards

The objective of SLM measures in field site B was to increase (*boquera*) or maintain (mulch) soil water content, and thereby increase almond harvest. Over the monitoring period of 2 years, a total of 13 events with water entering through the *boquera-acequia* system were recorded. By these events, the *boquera* provided over 550mm of additional water to a field of 10 ha. This means that with a mean annual rainfall of about 300mm, the total available water for this field was almost triplicated.

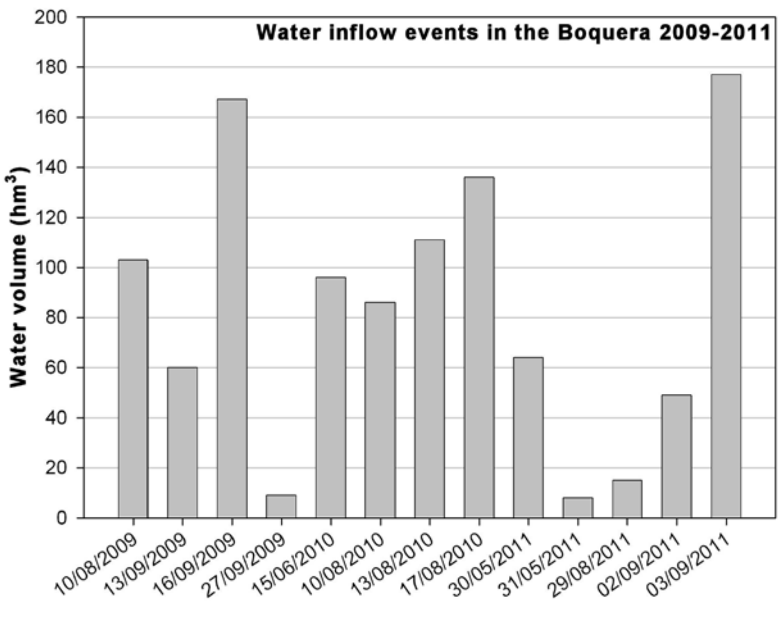

Fig. 12: Volumes of water collected by the *boquera* in 13 events between August 2009 and September 2011.

Fig. 13 shows the soil water content for the upper 20cm of soil, and Fig. 14 at 35 cm depth for the field with additional water from the *boquera*, for the field with Mulch and for the control field with conventional treatment (no additional water from the *boquera*, no mulch). These Fig.s show that in the *boquera* field superficial soil water content was about 24% higher than under control conditions. However, at greater depth (35 cm) soil water content under control conditions was generally higher than under both SLM treatments. With a mulch treatment, soil moisture content was similar or sometimes even slightly lower than under control conditions in the upper 20 cm, whereas at greater depth soil moisture content under mulch was almost always lowest of the three treatments.

These sometimes surprising differences in soil moisture may partly be explained by textural differences between the soils. Therefore, these results still need to be corrected for differences in pF values and wilting points. Nevertheless, it may also very well be that depositional crusts that developed on the *boquera* fields, due to the extremely high sediment concentration of inflowing water, impede deeper infiltration of incoming water. Besides, the incoming water enters in such large volumes that a large part of this water does not have time to infiltrate and flows out of the terrace at its drainage outlet. With respect to the Mulch, a possible explanation for the relatively low soil water content is that under the relatively low rainfall volumes the straw mulch acts as a sponge and impedes infiltration to the soil. Moreover, recent research suggests that straw mulch may become water repellent and prevent infiltration to the underlying soil layers.

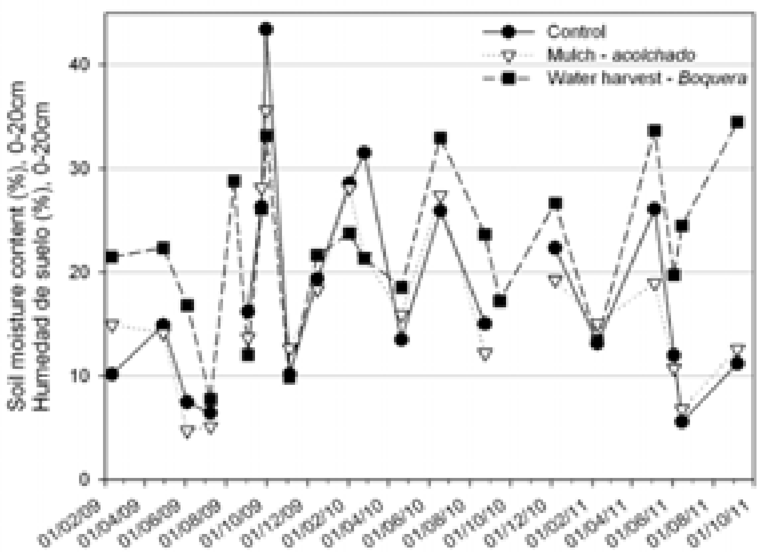

Fig. 13: Soil moisture content for the upper 20cm of soil in Field Site B.

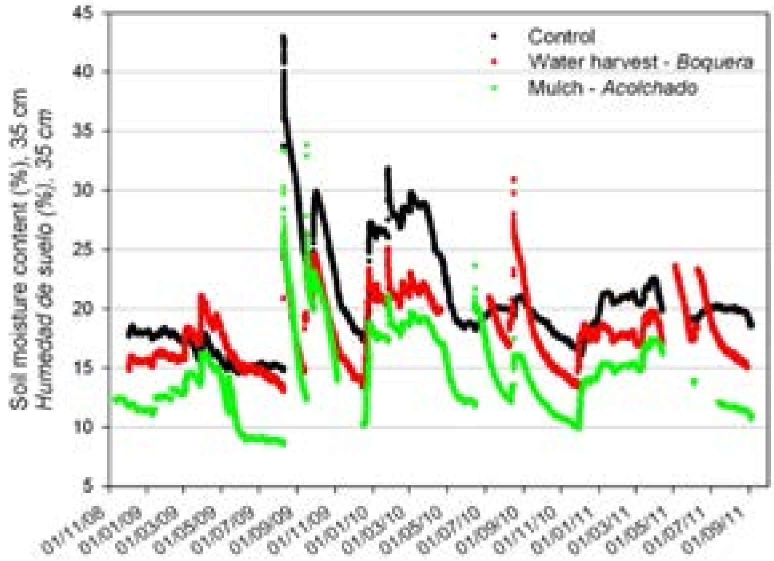

Fig. 14: Soil moisture content at 35cm depth in Field Site B.

Due to hail in late summer 2011, we only obtained data on the almond harvest for 2009 and 2010 (Fig. 15). Besides, the harvest of 2010 was strongly reduced because of frost in spring 2010. Nevertheless, these yield data indicate that the harvest in the *boquera* doubles the harvest under conventional treatment and under Mulch. The summary of economic implications (Table 3) indicates that despite its implementation and maintenance costs, the *boquera* increases the benefits enormously (52%) while mulching is not profitable compared to conventional procedures since it does not increase the yield.

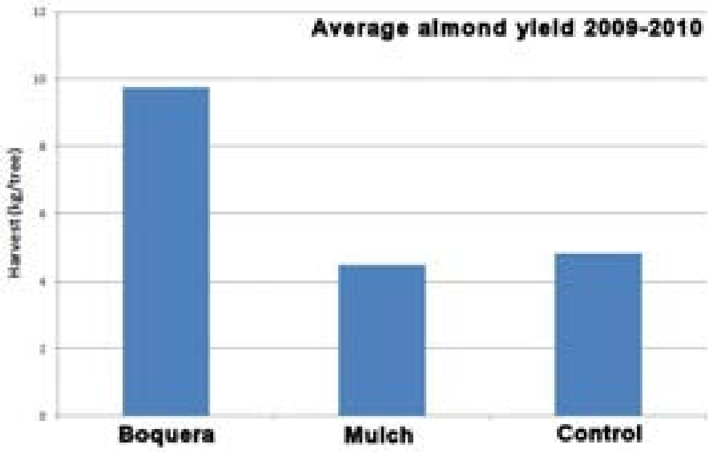

Fig. 15: Average almond harvest in field site B, based on data from 2009 and 2010.

Table 3: Overview of costs and benefits of SLM measures in field site B, without taking account of costs that are common to all treatments.

	€/ha/a	*Boquera*	Mulch	Control
Income	*Yield*	€2368,-	€1393,-	€1368,-
Costs	*Ploughing*	€120,-	€60,-	€120,-
	Initial-maintenance	€350,-	€520,-	-
Gross benefit		***€1898,-***	***€813,-***	***€1248,-***

Field Site C: Reduce soil and water loss in a cereal field

Under reduced tillage of cereals a clear decrease in soil loss (56%) and water loss (30%) due to runoff and erosion was observed as compared to conventional tillage (Fig. 16). These data are based on 2 years of monitoring in which 18 events were registered. It is expected that the reduction in soil and water loss may be higher on the longer term when soil organic matter content in the soil under reduced tillage increases. While these are important reductions in runoff and erosion, it must be noted that erosion rates and especially runoff rates and average runoff ratios are relatively low under both treatments. The data clearly indicate that the main volume of soil and water loss occurs during a few large events.

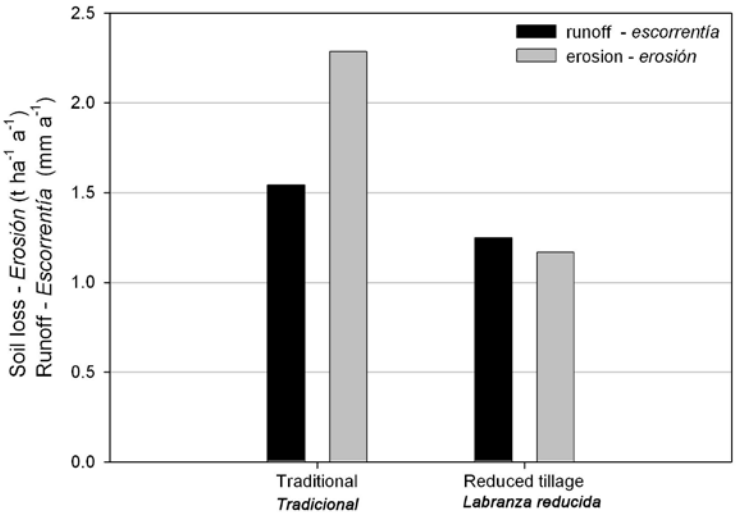

Fig. 16: Soil and water loss due to runoff and erosion under reduced tillage and conventional tillage of cereals (average after 2 years and 18 events)

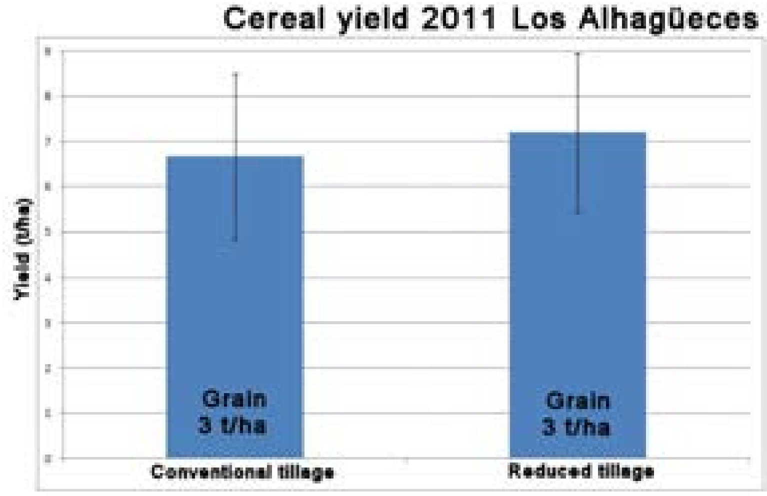

Fig. 17: Cereal yield in 2011 under two treatments and after two years of monitoring. Indicated are total yield of straw and grain (bars), and grain only. The bars indicate standard deviations of three measurements of 1 m^2 taken in each treatment.

Fig. 17 shows the cereal yield as measured in 2011. Since there is only 1 harvest every 2 years, this corresponds to the yield per 2 years. With an average cereal yield of 3 tonnes per hectare of grain in both treatments, the reduced tillage results in a 12% higher profit due to a reduction in operation costs for ploughing (Table 4). It is expected that on the longer term, harvest under reduced tillage will increase due to an increasing organic matter content of the soil.

Table 4: Overview of costs and benefits of reduced tillage versus conventional tillage of cereal (field site C), without taking account of costs that are common to both treatments.

	€/ha/a	Reduced tillage	Conventional tillage
Income	*Yield*	€315,-	€315,-
Costs	*Ploughing*	€45,-	€75,-
Gross benefit		***€270,-***	***€240,-***

1.5 INVOLVEMENT OF STAKEHOLDERS

Stakeholders were involved in the selection, implementation and monitoring of SLM measures from the start of DESIRE in various ways. First of all, during the workshops of DESIRE WB3, stakeholders decided which measures to implement and where they should be implemented. Following this, the selected SLM measures were implemented on the land of one of the participating farmers. This farmer, the land owner of the Alhagüeces farm, had a considerable involvement during the implementation and monitoring of the SLM measures throughout. Besides, several other farmers from the area were also involved for ploughing activities, almond harvest, and installation of monitoring equipment in the field. The land owner also documented all his farm activities and related costs and benefits in a farm logbook.

After 1 year of monitoring a farm demonstration day was organized during which all field installations and preliminary results were demonstrated and discussed with a large group (>25) of invited stakeholders representing farmers, regional policy makers, NGO's and scientists. This led to lively discussions and all participants showed high interest in the monitoring and in this kind of field meetings.

After 2 years of monitoring a last stakeholder workshop was organised during which all monitoring results were presented to a group of 18 stakeholders, representing farmers, regional policy makers, NGOO's and scientists. In this workshops, and based on the monitoring results, stakeholders were asked to prioritize SLM that should be considered for further dissemination. Moreover, stakeholders were asked how best to achieve this dissemination during the remainder of DESIRE and beyond.

Fig. 18: Field demonstration day at the Alhagüeces farm.

1.6 Discussion and conclusions

Most of the SLM measures selected by stakeholders and tested in DESIRE are effective and feasible. Most measures are beneficial regarding ecological and economic criteria, which is a prerequisite for sustainability. Some measures (i.e. mulch) require adaptations and further research before they can be recommended for wider application. Moreover, an important conclusion is that sustainable land management requires implementation of a package of SLM measures rather than only 1 or 2 specific ones. Some measures can only effectively be applied under certain conditions (e.g. *boquera*), and not each measure is beneficial for all ecological or economic criteria. Another important result of DESIRE and the SLM test implementation is that farmers now know very simple methodologies to make their own experiments or trials in their fields.

To reduce soil and water loss, increase soil fertility, and increase almond yield, green manure proved to be effective and feasible. It leads to less soil and water loss and a higher yield. Soil water content was not reduced and might even benefit during some periods of the year. Since operation costs do not significantly increase, the profit is also higher than under conventional production. Reduced tillage of almond orchards also reduced soil and water loss, but yield was not increased, at least not after 2 years of monitoring. Nevertheless, operation costs are lower, so if the yield is maintained at least at the same level there is also an economic benefit compared to conventional treatment.

A traditional *boquera* water harvesting system was found to be very effective to increase almond yield, and notwithstanding the implementation and maintenance costs, resulted also in an important economic benefit. The large volumes of water from the *boquera* triplicated the annual available water from natural rainfall in the study area. There are however also some considerations to be made. First of all, the implementation of a *boquera* is limited to locations near ramblas with enough runoff during rainfall events. Furthermore, during those events, often the volume of incoming water is so high that a large fraction of it gets lost and runs downslope. This is also reflected in a relatively small increase of soil water content in a *boquera* as compared to the control conditions. The water collected by a *boquera* may therefore be used much more efficiently by storing it in reservoirs from which the water can be used for irrigation when it is most needed and using up to date drip irrigation techniques. The optimal design and feasibility of such storage systems requires further research.

A straw mulch to prevent evaporation losses did not result in an expected increase in soil water content and increased crop yield and reduced the economic benefit with 35%. There are various possible explanations for this. It may be that straw is not working properly for this purpose and a different mulch type is required that assures infiltration but prevents evaporation losses. However, a second problem of applying mulch is that it is relatively expensive in terms of material and labour needed to put it on the fields. Therefore, alternative mulch types also need to be relatively cheap and easily applied with existing and already available machinery.

Reduced tillage of cereals showed to result in an important decrease of soil (56%) and water loss (30%) by runoff and erosion. After the relatively short period (2 years) of monitoring with only 1 harvest, no effect was observed on cereal yield. This may be different after more years of monitoring. Nevertheless, even if yield is not affected by this treatment, a higher benefit was achieved because of less operation costs under reduced tillage. Longer term monitoring is still required since most soil and water loss occurred during the low frequency high intensity events. These events is where the main difference will be made

Altogether, although we should not expect miracles, the monitoring results during two years of DESIRE research show that there are various opportunities to slightly increase economic benefits and at the same time provide increased ecological services by protecting and maintaining soil and water resources under rainfed agriculture in semi-arid conditions. For these reasons, these measures have a relatively high level of acceptance amongst stakeholders. This requires important further efforts of dissemination of project results and continued involvement of stakeholders.

REFERENCE

FAO, 2006. World reference base for soil resources 2006. A framework for international classification, correlation and communication. World Soil Resources Reports, 103. FAO, Rome, 128 pp.

Nainggolan, D., de Vente, J., Boix-Fayos, C., Termansen, M., Hubacek, K., Reed, M.S. In review. Afforestation, land abandonment and agricultural intensification: Competing trajectories in semi-arid Mediterranean agro-ecosystems.

Annex 1

a. Soil descriptions

Field A

Profile at the left of the plot “green manure”. Profile orientation; N. Soil tilled up to 27 cm depth over a more or less recalcified marl. Surface stoniness from medium to high. Three horizons and 3 correponding soil samples were taken.

- 0-10(15) cm: Horizon Ap; some rock fragments (RF) up to 20 cm diameter; weak, crumby structure; friable; many very-fine roots crossing the horizon; some macropores of lombricus; between clear and diffuse, undulated boundary. Sample A1.
- 10(15)-22 cm: Horizon AC; some RF; from weak granular to weak crumby structure; friable; many very-fine roots crossing the horizon; some medium root; some rounded macropores (lombrics); quite similar to the surface horizon but wetter; clear, regular boundary. Sample A2.
- > 22 cm: Horizon C-R; recarbonated marl color cream, with some hard RF, calcareous. Sample A3.

Field B

Profile excavated in the “mulch” sector, near the wall of the upper terrace bank. Between two almond trees; other plant cover: weeds.

- 0-15(20) cm. Horizon Ap; surface rock fragments (RF) around 20-40%; clay loam; fresh to slightly wet; fine crumby structure; friable; poor macro-porosity of biological origin; some worms (lombrics); abundant fine roots crossing the horizon mass; regular, gradual boundary. Sample B1.
- 15(20 – 38 cm: Horizonte ApC, plough layer; texture …with 20-30% RF; massive to fine, weak subangular blocky structure; moderately hard; abundant nodules or concretions of $CaCO_3$; very fine roots less abundant than in the previous horizon; some large root under decomposition; poor macroporosity in general; presence of worms (lombrics); regular, gradual boundary; sample B2.
- 38-50 cm; loamy sand texture with RF > 30%; Peak, fine subangular blocky structure; very friable; very small nodules or concretions made of $CaCO_3$; abundant very fine roots crossing the horizon mass; some large root under decomposition; regular, gradual boundary; sample B3.
- 50-70 cm; Sandy texture with abundant RF (>60%); without soil structure; not cemented; abundant very fine and fine roots crossing the horizon mass; some large roots (from almond trees); regular, gradual boundary. Sample B4a.
- 70-90 cm; identical features as above except that this horizon contains a higher content of RF. Sample B4b.

Field C

Profile in one of the excavations for the runoff-plots deposits, the most extreme at the right, looking upwards.

- 0 - 12(17) cm: Horizon Ap; some RF; between dry and fresh; granular structure; very friable; fine roots crossing the horizon; high porosity; some cracks from the surface reach up to 20 cm depth; macropores (fissure type) abundant and those of biological origin less abundant; no biological activity directly detected; clear, undulated boundary. Sample C1.
- 12(17) - 22(27) cm: Horizon Ap; possible plow pan? from massive horizon (no structure), to weak sub-angular blocky structure; roots crossing the horizon; some very fine and fine pores; no biological activity directly detected; clear, undulated boundary. Sample C2.
- 22(27) - 48(55) cm: Horizon AC; neat blocky structure; no friable; very fine abundant pores; some very fine roots; worm casts; diffuse, regular boundary. Sample C3.
- 48(55) - 74(80) cm: Horizon C2; moderate blocky structure; somewhat friable; abundant, very fine pores; some very fine and medium roots; no biological activity observed directly; diffuse, regular boundary. Sample C4.
- 74(80) – 110 cm: Horizon C3; weak blocky structure; friable; abundant, very fine and fine pores; few very fine and fine roots; diffuse, regular boundary. Sample C5.
- > 110 cm: Horizon C4; close to the marl (parent material). Sample C6.

b. Soil Analyses (essential soil variables)

sample	depth	RF	Sand	Silt	Clay	texture	pH	EC	SAR	CO3	active lime	OM	C/N	N tot
	cm	*%*	*%*	*%*	*%*			*mS/cm*		*%*	*%*	*%*		*%*
A1	0-10(15)	27.4	20.1	34.2	45.7	clay	8.5	1.11	1.02	39.42	8.27	2.99	6.93	0.25
A2	10(15)-22	15.1	40.5	27.7	31.8	clay loam	8.6	0.77	2.33	20.06	16.70	3.01	9.70	0.18
A3	> 22	32.4	30.0	20.6	49.4	clay	8.8	0.68	2.01	72.64	5.21	2.08	12.1	0.1
B1	0-15	55.5	34.4	25.5	40.1	clay loam	8.7	0.52	3.92	52.31	13.60	1.18	7.6	0.09
B2	15(20)-38	52.5	32.4	26.3	41.3	clay loam	8.3	0.66	2.31	46.41	4.18	0.21	1.21	0.1
B3	38-50	58.4	36.2	27.9	35.9	clay loam	8.7	0.63	4.03	44.44	13.65	0.21	1.52	0.08
B4a	50-70	71.9	35.5	30.5	38.0	clay loam	8.8	0.64	2.31	47.90	12.68	0.83	5.35	
B4b	70-90	97.2	37.7	27.3	35.0	clay loam	8.6	0.78	4.16	32.69	2.08	0.19	1.11	
C1	0-12(17)	19.0	9.3	25.9	64.8	clay	8.9	0.58	1.70	27.50	20.79	0.48	3.09	0.01
C2	12(17)-22(27)	15.3	7.3	28.2	64.5	clay	9.0	0.56	2.90	69.37	17.75	1.24	0.72	0.08
C3	22(27)-48(55)	10.9	10.5	33.9	55.6	clay	8.5	1.44	3.41	31.35	1.04	0.47	3.02	0.09
C4	48(55)-74(80)	14.1	11.1	33.3	55.6	clay	8.9	2.26	9.02	69.52	19.87	0.31	1.79	0.1
C5	75(80)-110	47.5	25.7	20.6	53.7	clay	8.3	3.64	11.90	72.19	17.71	0.18	1	0.1
C6	> 100	47.8	16.8	26.3	56.9	clay	7.8	5.40		68.25	18.68	0.14	0.8	0.1
	RF = Rock Fragments													

c. Soil Analyses (other soil variables)

Sample	depth	K	P	CEC	Ca2+	Mg2+	Na+	K+
	cm	*mg/kg*	*mg/kg*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*	*meq/100g*
A1	0-10(15)	400.2	< 4	28.7	24.6	2.9	0.1	1.0
A2	10(15)-22	250.0	< 4	33.2	30.3	2.0	0.1	0.6
A3	> 22	69.6	< 4	27.1	24.9	1.9	0.1	0.2
B1	0-15	214.2	< 4	8.5	4.5	2.9	0.2	0.9
B2	15(20)-38	59.4	< 4	9.3	5.7	3.4	0.1	0.2
B3	38-50	41.0	< 4	6.5				
B4a	50-70		< 4	13.2	9.9			
B4b	70-90		< 4	7.2				
C1	0-12(17)	237.0	< 4	9.2	5.0	3.6	0.1	0.6
C2	12(17)-22(27)	142.0	< 4	15.2	10.6	4.0	0.2	0.4
C3	22(27)-48(55)	103.8	< 4	20.4	13.7	6.1	0.5	0.3
C4	48(55)-74(80)	102.2	< 4	25.3	16.5	7.2	1.3	0.3
C5	75(80)-110	160.0	< 4	15.8	7.8	5.4	2.2	0.4
C6	> 100	185.8	< 4	21.7	9.9	8.6	2.8	0.5

d. Bulk densities of surface horizons

(six samples per treatment, results are in Kg L^{-1})

Field A (no significant differences among treatments)

Green manure: 1.095 ± 0.01

Reduced tillage: 1.08 ± 0.04

Control : 1. 07 ± 0.02

Field B (little differences among treatments)

Boquera:	1.11 ± 0.02
Mulch:	1.02 ± 0.02
Control :	0.95 ± 0.02

Field C (little differences among treatments)

Conventional tillage	1.01 ± 0.05
Reduced tillage	0.92 ± 0.01

2 PORTUGAL

Responsible partners

Partner 7 - University of Aveiro (site 1 Mação)

Partner 18 - Coimbra Higher School of Agriculture, and

Partner 4 - University of Wales (sites 2-4 near Góis and Miranda do Corvo)

Further collaboration with partner 1 Alterra and partner 14 – Wageningen University.

Overview

The main form of land degradation is water erosion and solute- and sediment-related nutrient losses after fire. Apart from trying to prevent wildfire, the remediation techniques are intended to reduce erosive runoff and limit erosion. Both prevention and remediation solutions will be assessed in selected catchments, as follows:

Site 1 (Caratão catchment near Mação) is focused on reforestation and mitigation techniques such as corridors and strips. The Mação Region suffered massive fires in 2003 and 2005, and now more than 70% of the municipality has been burnt. Natural degradation and regeneration, together with mitigation techniques are being assessed at this location.

Site 2 (Vale Torto catchment near Góis) is more focused on the use of prescribed fire as a wildfire prevention tool. The Vale Torto area is a shrubland area where prescribed fire was carried out on February 20th 2009 as an experimental fire (broadly equivalent to a prescribed fire near the catchment boundaries but hotter towards the main drainage line), and where the impacts will be assessed for at least 2 years after the fire. The area was burned by several fires in the 1970s and the early 1980s. In the early 1990s, the common land was burned using prescribed fire to provide grazing areas for the surrounding villages. It has not been burned since. An unburnt catchment of similar size is being monitored for discharge and bedload sediment trapped behind the gauging station v-notch weir.

Site 3 (Camelo catchment near Góis) is similar in many respects to Vale Torto catchment in that it has similar rainfall, geology, topography, soil and vegetation cover. It was subject to wildfire in July 2008, and so provides a useful comparison to Vale Torto in terms of assessing the degree to which prescribed fire causes less erosion than wildfire. Monitoring began before the first erosive rainfall events.

Site 4 (Moinhos, near Miranda do Corvo) is a catchment affected by wildfire in September 2009. It comprises both *Pinus pinaster* and *Eucalyptus globulus* plantations. Monitoring to assess the effectiveness of post-fire mitigation measures began in October 2009. The main aim is to test remediation techniques following wildfire. After an initial period to establish the patterns of soil erosion at the different sites, the effect of the following treatments are expected to be assessed: leaving timber waste in different available quantities on the surface, and allowing pine needlefall onto the soil from the scorched tree canopy.

2A - MAÇÃO STUDY SITE

Partner 7 - University of Aveiro

2.1 INTRODUCTION

The Mação Region suffered massive fires in 2003 and 2005, and now more than 70% of the municipality has been burnt. Natural degradation and regeneration, together with mitigation techniques are being assessed at this location.

Forest is the dominant land use, consisting dominantly of *Pinus pinaster,* with some *Eucalyptus globulus.* An important part was burned recently and gave way to regeneration stands and shrubs, where the regeneration failed.

Preventive Forestry is composed by a set of measures applied to forest stands, shrubs and other spontaneous species to protect forest against fires. These measures deal with forest stands composition, structure and location, aiming to reduce fire risk and to increase vegetation resilience to fire.

Preventive Forestry measures represent an important instrument against forest fires, but the removal of vegetation tends to expose bare soil to the erosive effects of rainfall. Rainfall simulations were used to assess erosive processes, such as runoff and sediment loss.

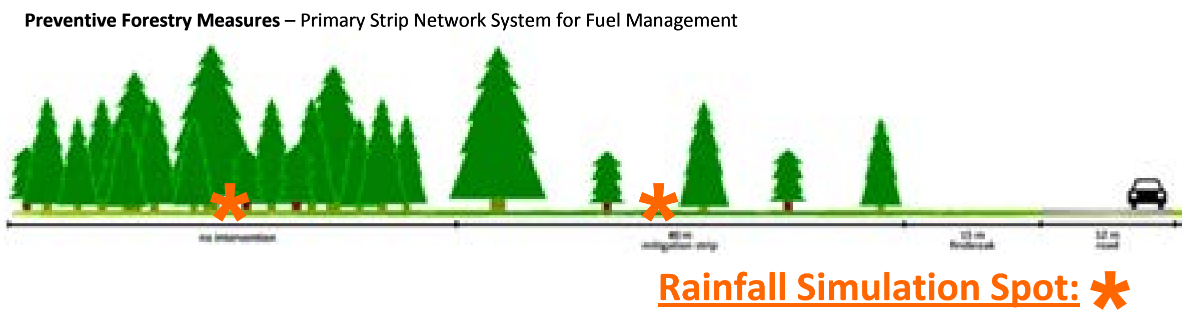

Fig. 1 – Rainfall simulation spots

2.2 TRIAL LAYOUT

For the rainfall simulation experiments, a Sprinkler Rainfall Simulator developed by Cerdá *et al.* (1997) was used. The rain was produced at an intensity of 45 mm/h (local extreme event type). Run off was measured from a 0.26 m^2 plot in the centre of the target area. A rainfall simulation event was done at the dry season and another at the end of the wet season (work in progress).

Table 1 – Description of cover type, slope at rainfall simulations sites

Pinus pinaster				***Eucalyptus globulus***				**Shrubland**			
Mitigation strip		No intervention		Mitigation strip		No intervention		Mitigation strip		No intervention	
Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat	Sloped	Flat
3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies	3 replies

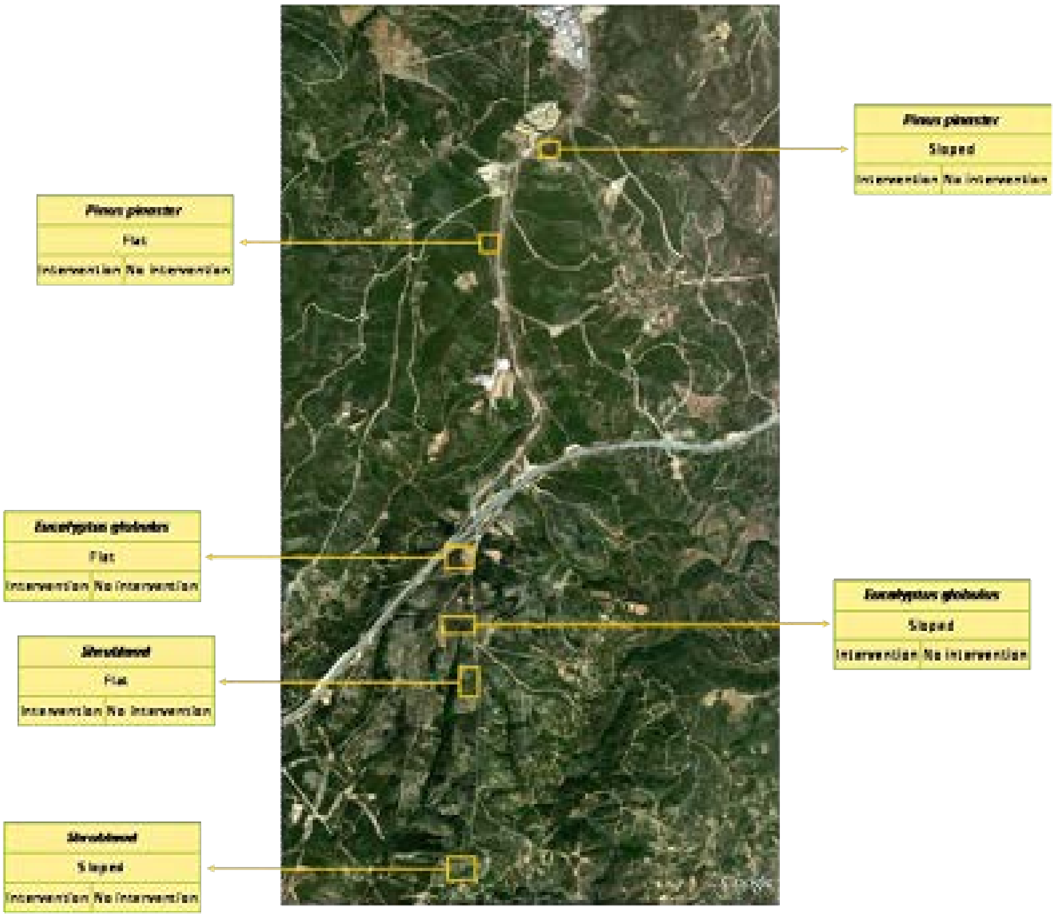

Fig. 2 – Plots location

Listing of indicators measured:

- Texture analysis, slope, soil water repellency, soil humidity, runoff volume, soil organic matter content and sediment loss.

Include time graph of measurements from the poster: example:

Table 2 – Timetable

Variable	2009	2010	2011
Field site slection	●		
Field data		←———	———→
Lab analysis		←—	—→
Statistical analysis		←—	————→
Meteorological data	←————	————	————→

2.3 Analysis and Results

The selection of this method is related to the fact that can substitute natural rainfall, achieving better control over the test, as well as a replica of the same conditions at different locations. It is possible to compare different parts of the Primary Strips Network System for Fuel Management, due to the control of rainfall characteristics, facilitating the development of research.
As mentioned, the type of the simulator is a sprayer, and was constructed following the model of Cerdà *et al.* (1997).

Biophysical results:

<u>Dry Season</u>:

- Rainfall simulations in flat Shrubland and sloped Eucalyptus sites resulted on the highest cumulative sediment losses; Shrubland did not have vegetation cover and Eucalyptus is located on a stony ground (>90%).
- Flat Eucalyptus and Pine sites led to insignificant soil losses.
- The influence of slope only had a significant impact in Eucalyptus sites.
- Sediment loss on flat Shrubland was higher than on sloped Shrubland.
- There was small variation of sediment loss on flat Pine and Eucalyptus sites throughout rainfall simulations.
- Sediment loss on flat Shrubland site was higher in the first 20 min but decreased significantly until the end of the simulations; the presence of high peaks may be explained by micro relief water accumulation.

Socio-economic results:

- Increase knowledge among researchers and local stakeholders about the effects of the mitigation strips technology on soil erosion and/or conservation.
- Promotion of future opportunities for dissemination and further developments under the suitability of this technology.
- Due to high implementation and maintenance costs, this technology requires the full support from public entities (as well as specific technology capacity).

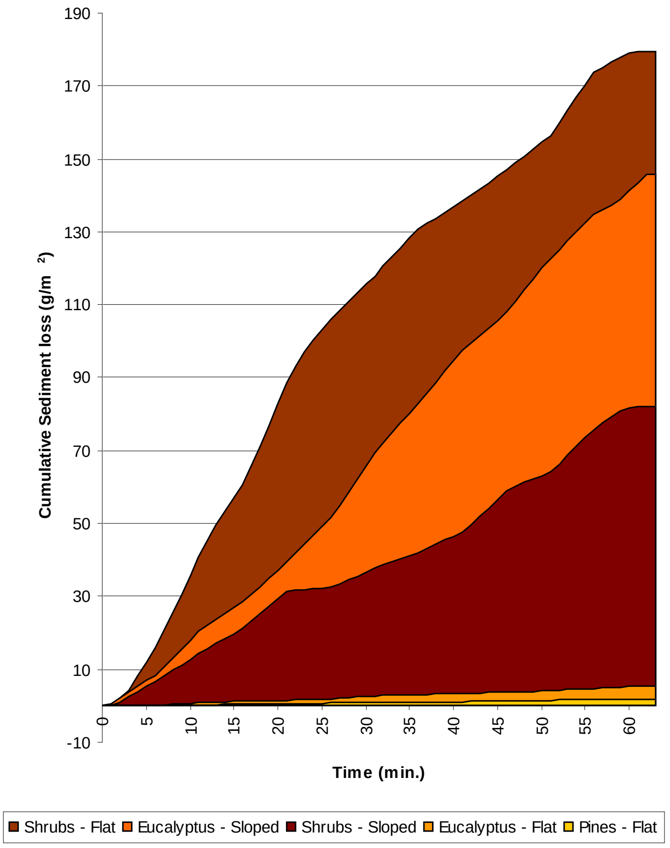

Fig. 3 – Mitigation Strips Area – Cumulative Sediment Loss

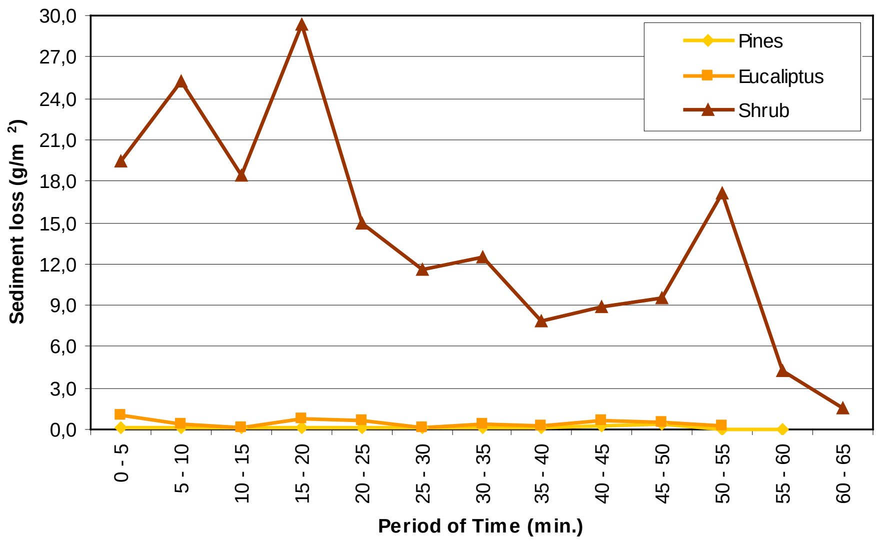

Fig. 4 – Mitigation Strips Area – Sediment Loss in Flat Sites

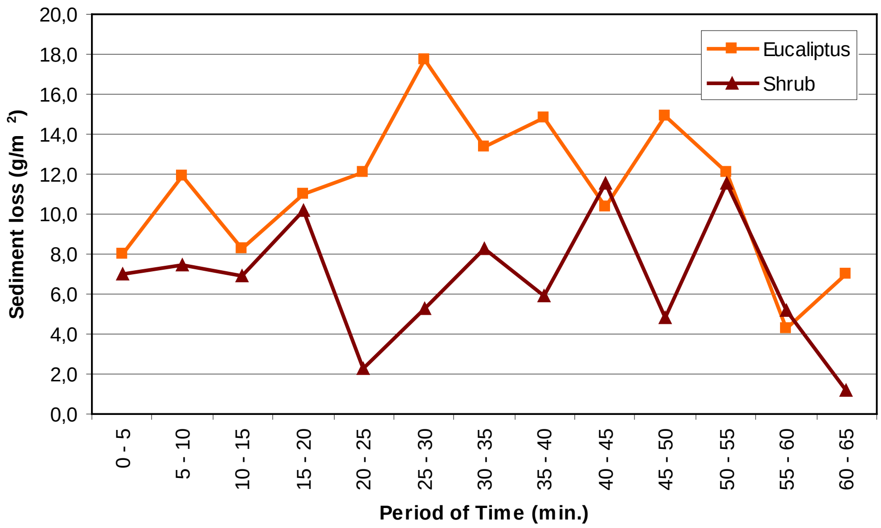

Fig. 5 – Mitigation Strips Area – Sediment Loss in Sloped Sites

Figure 6 - Simulation Plot (flat)

Figure 7 - Sprinkler Rainfall Simulator developed by Cerdà

Figure 8 - Soil layers in pine site - no runoff occurred

2.4 INVOLVEMENT OF STAKEHOLDERS

All the stakeholders were involved in close collaboration between researchers of University of Aveiro and local technicians from GTF (Forestry Technical Office of the Municipality of Mação) and Aflomação (Forestry Association of Mação) – for the selection and assessment of field-test areas.

Eng.º António Louro (Vice-President of Mação Municipality): “What happened here was the consequence of a large number of forest fires. It was related to a new landscape that we created during the last century which resulted in the death of agriculture and invasion by forest. This landscape, together with the climate conditions typical for this region was completely unsustainable. It ended in an enormous tragedy and huge waste of resources. The tragedy is related to the loss of income and livelihood of the local population which in the last decades was the forest. And along with that loss we are now losing the population. DESIRE creates a strong link between the academic world and local reality. For us that’s very good because it brings knowledge from the academic world straight to the field.”


Figure 9 and 10 – Stakeholders & scientists involvement: selection and assessment of field-test areas

2.5 DISCUSSION AND CONCLUSIONS

- Preliminary Rainfall simulation results showed differences according to cover type and slope.
- The technologies can be applicable to other areas, but extra financial support is needed to local authorities and stakeholders.

REFERENCE LIST/LITERATURE

Cerdà, A., Ibáñez, S., Calvo, A. (1997) Design and operation of a small and portable rainfall simulator for rugged terrain. Soil Technology 11 (2), 161-168.

2 B - GÓIS STUDY SITES

2.1 INTRODUCTION

The main objective was to assess soil degradation due to erosion rate measurements and associated nutrients losses along the time after the fire. The main aim is to evaluate prescribed burning techniques currently used as a landscape management technique to prevent fire. To this end, wildfire areas and prescribed burnt areas were assessed to measure the differences among the two types of fire.

2.2 TRIAL LAYOUT

After the visit to some areas recently burned by several wildfires, Camelo wildfire, in Castanheira de Pera Municipality, was selected, according with geology, slope, soil erosion features, soil water repellency and fire intensity. To study the real impact of the fire, another non burned catchment (Vale Torto, located in Góis Municipality) with similar geology, relief, soil, vegetation and climate was selected. After almost one year, Vale Torto was submitted to an experimental fire to evaluate fire impact on soil degradation and hydrological properties and to compare the impacts of different fire intensities. Since prescribed burning is a wildfire preventive tool, largely applied in Portugal, Podentes study site, in Penela Municipality, was also selected for the study. The Podentes site is located in a limestone area, where the soils, vegetation and bedrock are very different from the study areas located in the Central mountain range, which are dominantly schist and quartzite. Since the Camelo study area presented several problems, mainly due to the logistics involved and the small burned area, we took the opportunity presented by a wildfire in Miranda do Corvo Municipality, to perform additional tests. Moinhos 2009 wildfire had a wider burned area and had several management techniques that were absent from previous forest burned areas, such as terraces, which represented an additional challenge, since they are very difficult to monitor. In January 2010, needles were applied and monitored in a hillslope plot, at Moinhos study site, as an erosion mitigation technique, to simulate the natural pine needles fall from scorched pine canopy. In January 2011, logging wastes from a burned (wildfire) and slashed eucalyptus area were applied (and are being monitored) in a terrace plot, also at Moinhos study site, as another erosion mitigation technique. In Fig. 1 the location of the four study sites from ESAC are shown.

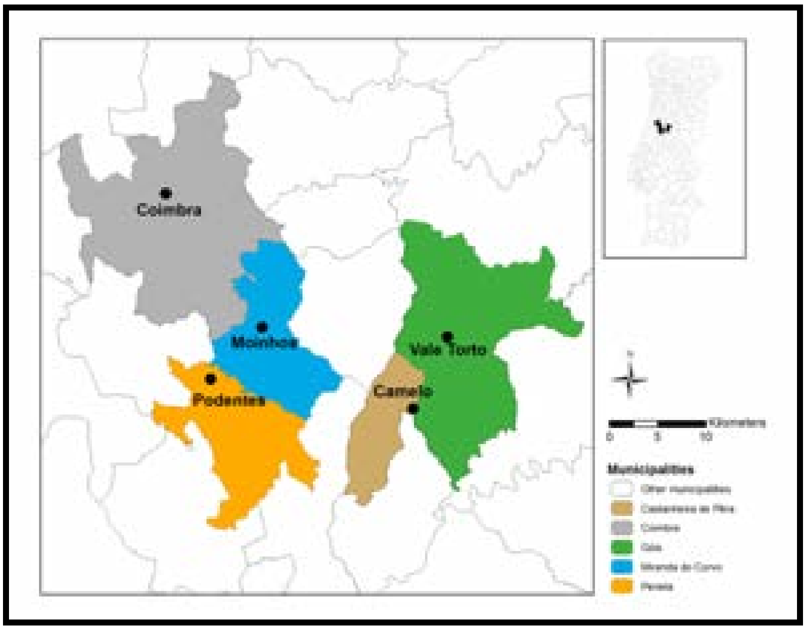

FIG. 1: ESAC study sites location.

The research focused on three study sites in central Portugal: Camelo burnt in a wildfire in early summer 2008 (Photo 1); Vale Torto, submitted to an experimental fire in February 2009 (Photo 2); and Podentes subjected to a prescribed fire in April 2009 (Photo 3). The Camelo wildfire affected a small (3.3 ha) catchment comprising scrub vegetation representing a fuel load of 65 t/ha. It has steep slopes (c. 25º) on schist bedrock with water-repellent, thin (<10cm), stony soil and a mean annual rainfall of 1000 mm. Vale Torto is a 9 ha catchment a few km NE of Camelo. It has similar geology, relief, soil, vegetation and climate, but a lower fuel load (23 t/ha). In Podentes, the forestry service burned a smaller area (2 ha) on calcareous bedrock with shallow-angled slopes (from 5º to 10º) and a wettable and stony soil, but thicker (<20cm). The rainfall is similar to the other sites but, although also comprising scrub vegetation, the species differ from Camelo and Vale Torto (mainly *Quercus coccifera*, *Pitacia lentiscus* and *Arbutus unedo*).The fuel load was measured at 70 t/ha. Finally, in Moinhos, an area of 95 ha burnt in September 2009 (Photo 4). It is an area of schist bedrock, with a mean annual rainfall of 1000mm, steep slopes, and where heavy machinery built terraces to prepare the soil for the eucalyptus plantations. By the time they were burned, the Eucalyptus were already with 10 years and a thick understory and litter layer were visible.

Prescribed fire is a new approach to the degradation problem posed by wildfires. In fact, prescribed fires are part of our legal body, according with the Law Decree 156/2004, the Law 12/2006, the Law Decree 124/2006 and ordinances 1060/2004 and 1061/2004. Despite the legal acceptance of this management technique, it has not been fully validated by scientific knowledge, for the Portuguese conditions. For this reason, trials were performed at Vale Torto and Podentes.

Photo 1: Camelo site, affected by wildfire in July 2008.

Photo 2: Vale Torto atchment during experimental burning on February 20th 2009.

Photo 3: The Podentes prescribed fire, in April 2009.

Photo 4: Moinhos study site, after September 2009 wildfire.

2.3 METHODOLOGY

Several techniques were used to monitor degradation processes following forest fires and prescribed fires (Table 1). In order to assess the impact of fire on soil physical properties and on the hydrological and erosional response, intensive field work was carried out. The methodologies used in the different study sites were the same, but with some adaptations according with the effort spent in each study site and the available resources.

Table 1: Chronogram of wildfires and prescribed fires and of the different monitoring activities made in the study sites of Vale Torto, Camelo, Podentes and Moinhos.

	2009												*2010*											
	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
1		*(a)*		*(b)*				*(c)*																
2																								
3																								
4																								
5																								

1 – Prescribed fire at (a) Vale Torto and (b) Podentes and wildfire at (c) Moinhos
2 – Overland flow and runoff at all sites (Moinhos after October 2009)
3 – Soil erosion monitoring (Moinhos after October 2009)
4 – Soil moisture monitoring (Vale Torto only)
5 – Soil water repellency monitoring) (Vale Torto and Podentes only)

A database was constructed with the data collected in the experiments carried out in each study site. It was performed as follow:

- Camelo

Several soil samples were collected and analysed for nutrients in the burned and in the surrounding unburned areas immediately after the fire. To estimate the amount of biomass that had burned, three vegetation plots (1×1m) were collected in the unburned area. To compare the hydrological and erosional responses, rainfall simulation experiments (model Cerdá *et al.*, 1997) were carried out immediately post-fire, in both burned and unburned sites (Fig. 2), and repeated along the time. The simulations were performed for 1 hr on small plots (0.25 m^2), at a rainfall intensity of 45 mm/hr. Soil moisture content was measured every minute, and overland flow volume at 5-minute intervals. Sediments transported by overland flow and their organic content were also measured. A sediment fence installed in a footslope location (contributing area of 589 m^2) was installed and monitored along the time (Fig. 2). The sediments were collected and weighted, and a sample was saved for nutrient analysis, periodically along the time. In order to assess vegetation recovery, repeat-vertical-photography in plots with 0.25m^2 were performed along the time.

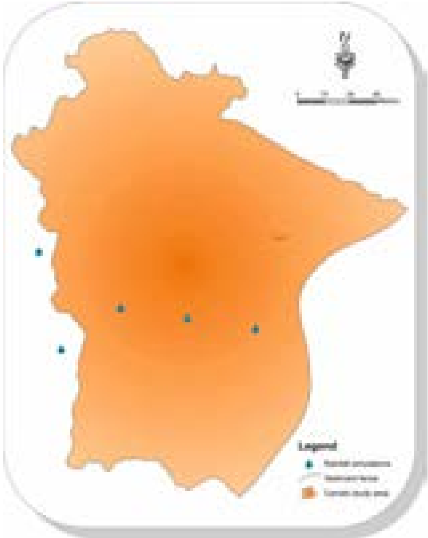

Fig. 2: Camelo study site: burned area extent and location of the performed experiments.

- Vale Torto

As in Camelo study site, several soil samples were collected and analysed for nutrients before the prescribed fire, immediately after and one year after. Six rainfall simulations were performed in different time periods before and after the fire. Five sediment fences (Photo 5) were installed to assess the erosion rates before the fire and reinstalled with three additional ones after the fire (Fig. 3). A micro-catchment weir was also considered for runoff and sediments data collection (photo 6), and measurements were also performed at catchment level, to provide the spatial integration of hydrological and erosion processes. An 8*2m bounded plot, draining to a modified *Gerlach* was also used. The vegetation recover was also monitored through repeat-vertical-photography in plots with $0.25m^2$ and visually through $4m^2$ plots.

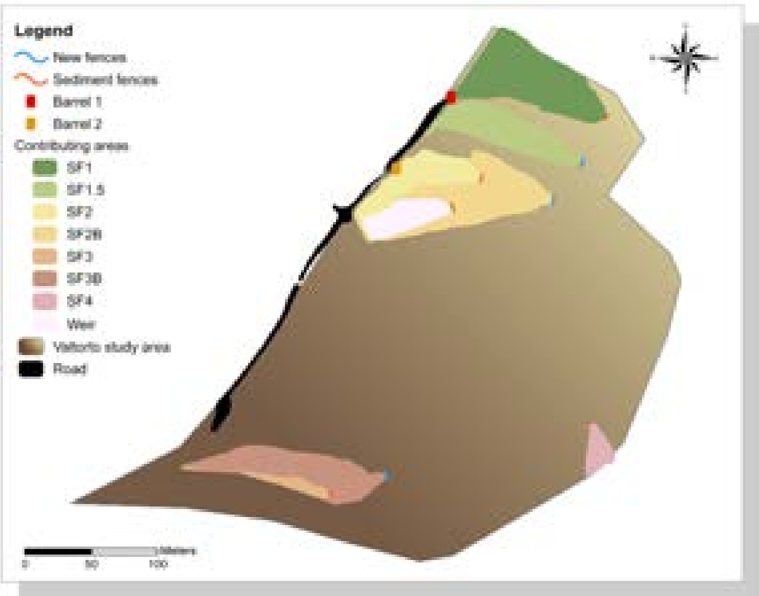

Fig. 3: Vale Torto catchment: location of sediment fences and of weir pool sub-catchment and their contributing areas.

Photo 5: Sediment fences, Vale Torto.

Photo 6 - Weir pool sub-catchment, Vale Torto.

During the prescribed fires, thermocouples were used to monitor soil temperature during the burning, to allow the cross analysis with the properties and processes after the fire.
To assess soil water repellency (hydrophobicity) an experimental design consisting on the detailed monitoring of grids was used. Field data were obtained from 2 grids, one in burned area and another in the adjacent unburned terrain. Each grid comprises 54 points (for each point we consider 5 readings), and the monitoring program use a different 'clock' position around each point for each survey, to enable the sampling of fresh soil at each measurement occasion.

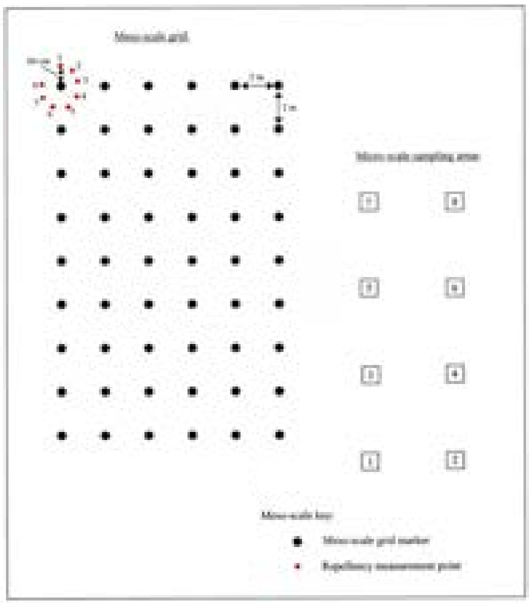

Fig. 4: experimental design of the soil water repellency grid (left); and measurement of hydrophobicity at five points, along a mini-transect (marked by the white tube), in the burned grid, at Vale Torto, in march 2009 (photo).

- Podentes

In Podentes, several techniques were used to monitor degradation processes following prescribed fires, namely point assessment of soil properties, such as infiltration capacity and soil water repellency. Soil water repellency was assessed depending on the shrubland type, slope orientation and soil depth. During the fire, the soil temperature was assessed with the same methodology used in Vale Torto. A set of rainfall simulations was performed in burned and unburned areas, during different monitoring campaigns.

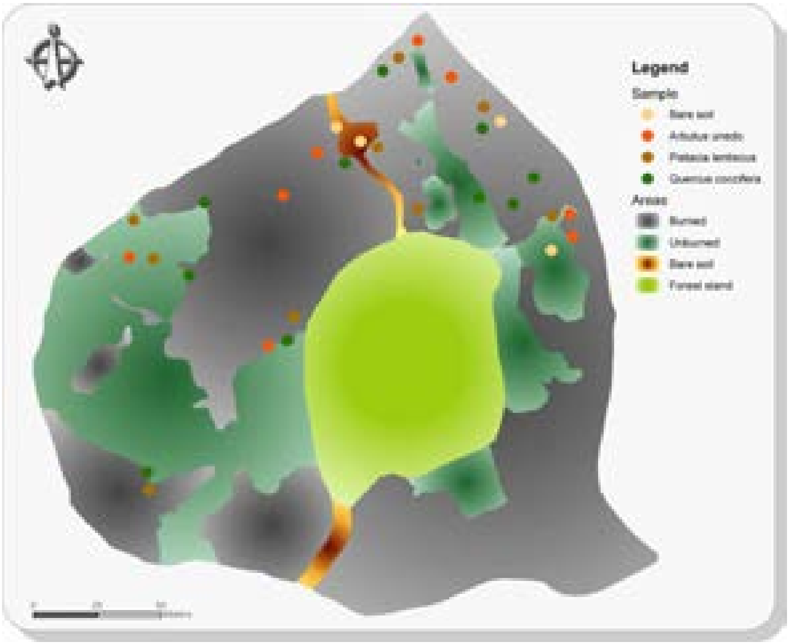

Fig. 5: Map of the prescribed fire area in Podentes.

- Moinhos

In Moinhos, the land degradation has been assessed through sediment fences installation and periodic monitoring. Two plots 8*2m were also installed and needles were applied in one plot (the other one worked as a control plot) as a treatment and erosion mitigation assessment. Logging wastes from a burned (wildfire) and slashed eucalyptus area were also applied in a terrace plot, as another erosion mitigation technique.

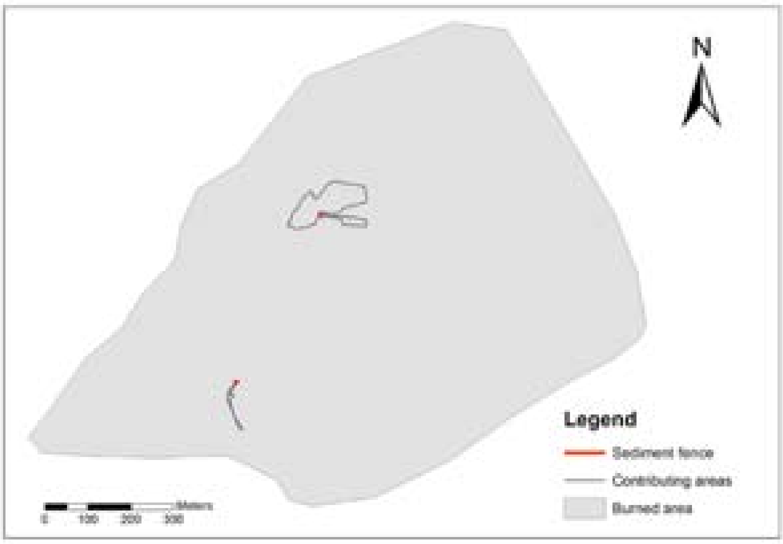

Fig. 6: Moinhos study site: burned area extent and location of the sediment fences and respective contributing areas.

2.4 Analysis and Results

Considering the large amount of data collected and analysed, we will present only a part in this report.

According with the grid methodology system of repeat hydrophobicity measurement used at Vale Torto, the results (presented in Fig. 7 a,b,c) show different patterns of water repellency, following the experimental fire. In fact, right after the fire (on 20th February 2009), there is a marked increase in the soil water repellency that is not shown by the unburned area. The unburned area only presents marked soil water repellency patterns following a long (12 days) dry period. Right after fire, the prescribed burned area shows some moderately repellent spots.

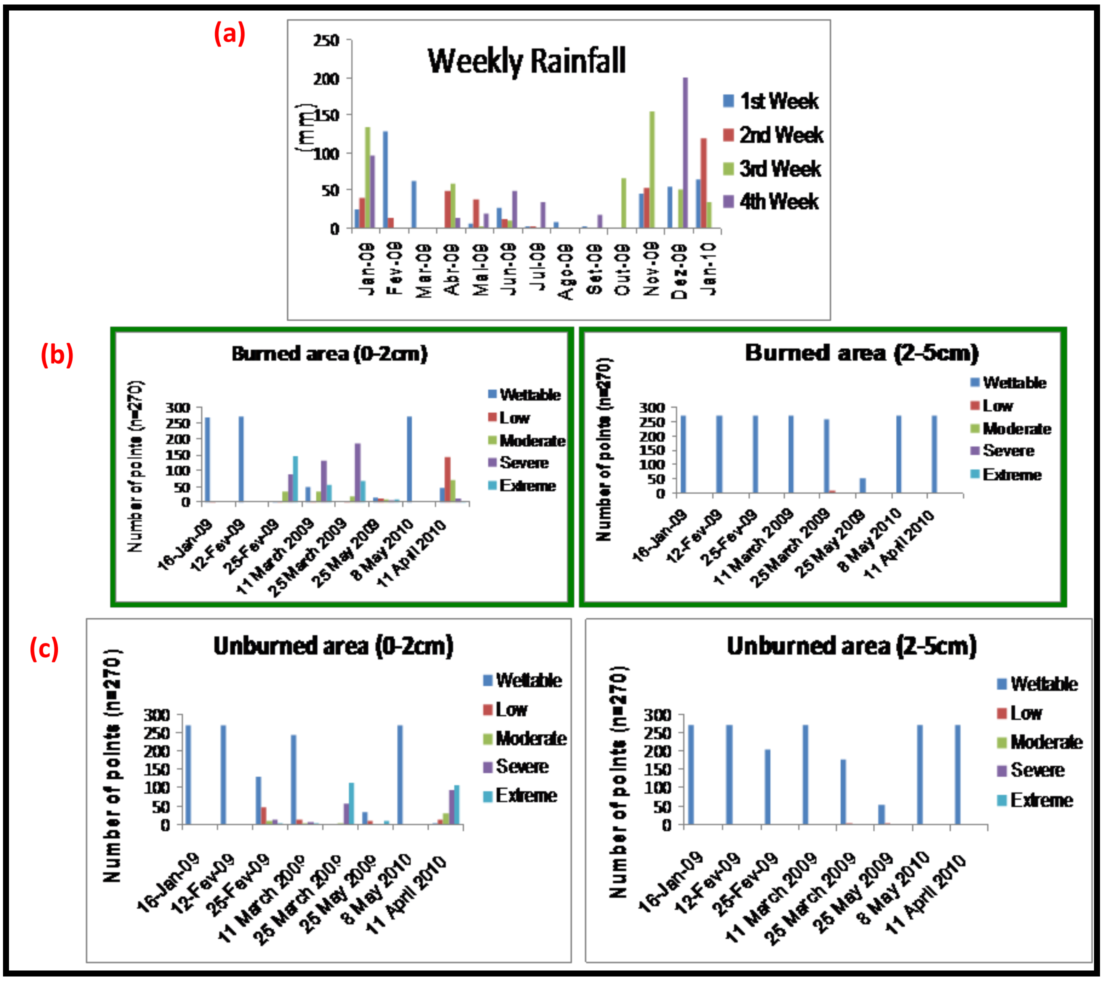

Fig. 7: rainfall (a) and soil water repellency for burned (b) and unburned (c) areas, in vale torto.

The results revealed that, during pre-fire wet periods, the soil was wettable in both grids, and immediately after the fire, the burned soil was with moderate to severe hydrophobicity, much higher than in the unburned area (wettable or with low hydrophobicity). The burning intensified surface soil hydrophobicity (compared with the unburned control), probably due to enhanced drying and the <100ºC surface soil temperatures during the fire. However, one month and 1 year after the fire, the results showed lower values in the burned area, possibly caused by a reduced input of repellent substances in the burnt area.

As expected, soil hydrophobicity tended to disappear during prolonged wet periods and to re-establish during dry periods. However, the main conclusions are that soils are naturally strongly water repellent, even if not burned, and that this characteristic is observable in depth along the shallow soil profile. The values immediately after the fire show hydrophilic characteristics in the top layer, as a result of the combustion of organic matter and the formation of ashes.

In the Podentes prescribed fire, taking advantage of species patches, an analysis to various ash types on soil water repellency was performed, namely for P. lentiscus, A. unedo and Q. Coccifera (Fig. 8). Measurements were made for the NE and SW slopes and show some differences related with aspect and specie, as shown in Fig. 8, with the SW slope showing somewhat less repellency.

In addition, infiltration rate and capacity were measured before and after the prescribed fire, by means of minidisk infiltrometer (MDI), in Podentes study site. MDI measurements were performed at the soil surface for the different shrubland species: Quercus coccifera, Pistacia lentiscus, A. unedo and on bare soil. N means north orientation, and S means south orientation (Table 2).

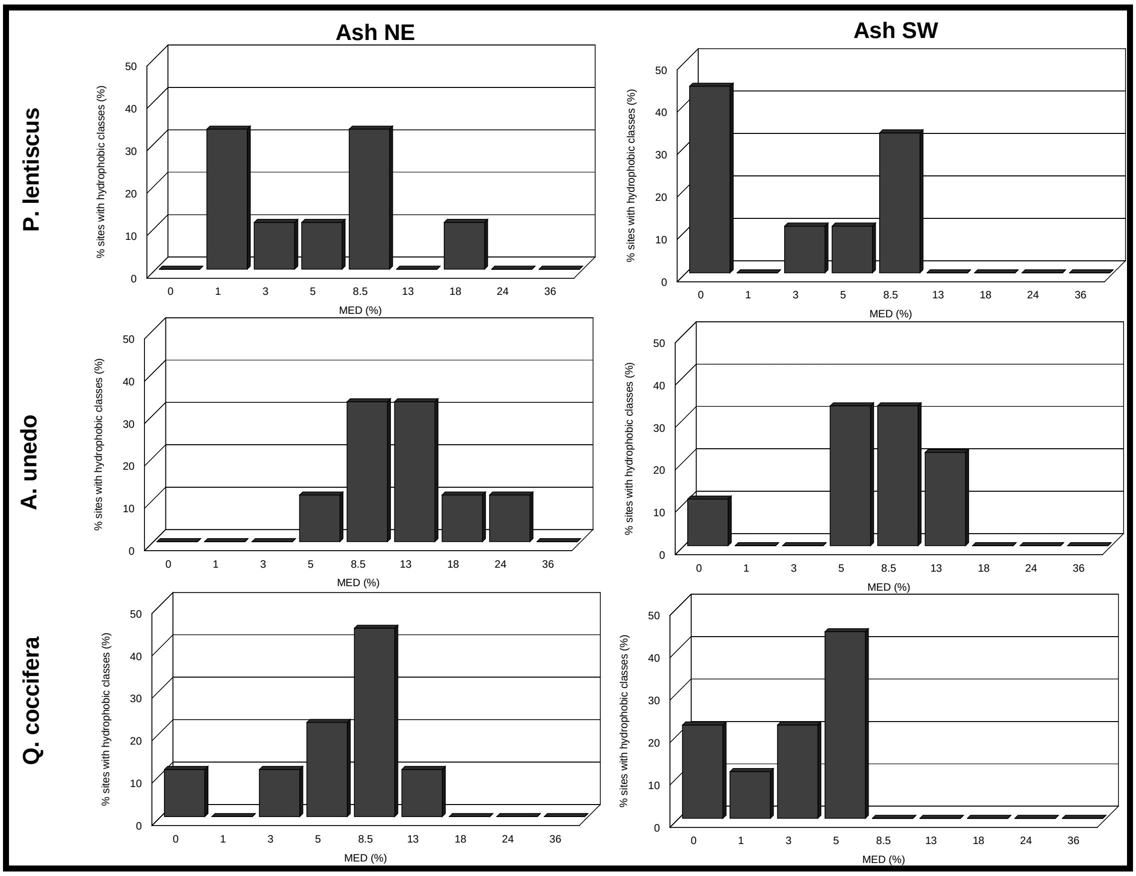

Fig. 8: soil water repellency (med method) for different ashes resulting from various plants combustion at the podentes prescribed fire

Table 2: infiltration rate and infiltration capacity, before and after the prescribed fire

	Infiltration rate (mm/h)			Infiltration capacity (mm/h)		
	Burnt	**Unburnt**	**ratio**	**Burnt**	**Unburnt**	**ratio**
Bare soil		7.50			13.85	
Q. coccifera S	10.45	13.80	0.76	30.26	30.56	0.99
P. lentiscus S	15.05	22.39	0.67	29.64	31.13	0.95
A. unedo S	7.99	12.09	0.66	11.89	32.45	0.37
Average	**11.16**	**16.09**	**0.69**	**23.93**	**31.38**	**0.76**
Q. coccifera N	25.47	41.03	0.62	26.87	46.13	0.58
P. lentiscus N	28.94	29.42	0.98	30.25	31.76	0.95
A. unedo N	16.23	24.57	0.66	16.62	30.10	0.55
Average	**23.55**	**31.67**	**0.74**	**24.58**	**36.00**	**0.68**
Whole area	**15.81**	**21.14**	**0.75**	**21.94**	**29.14**	**0.76**

The higher peak temperatures were observed in the hillside NE among hillside SW, which is related with the different fuel load content. The low fire impact promotes a slight to moderate soil water repellency in the ash layer. The A. unedo ashes showed major hydrophobic behavior among the other species. After the low intensity fire, and with a 25% of soil water content, slight water repellency was obtained at the soil surface. This fact implies, at least, at short term, the alteration of the soil surface hydrological properties (Fig. 8).

Fire produced decreases in soil water infiltration rate and capacity (25%). Major reductions of infiltration capacity rates were observed under the burnt A. unedo, which agrees with the finding of high values of soil water repellency under that specie (Fig. 8). According with these results, different behavior could be related with the litter and root exudates supplied by the different bush species. However, further research on soil organic matter composition in soil aggregates is necessary to confirm this conclusion.

The results indicated that, despite the temperatures intensity, the different vegetation species have an important role in the short term soil water repellency and infiltration (mainly infiltration capacity) and, subsequently in hydrological processes. Prescribed fire should be used carefully as a tool to prevent wildfires, since it may affect some soil properties and hydrological characteristics, at least, at the short term (Table 2).

Considering the rainfall simulation experiments results, the fire type and the geology are important parameters to consider hydrologic and erosion changes (Fig. 9).

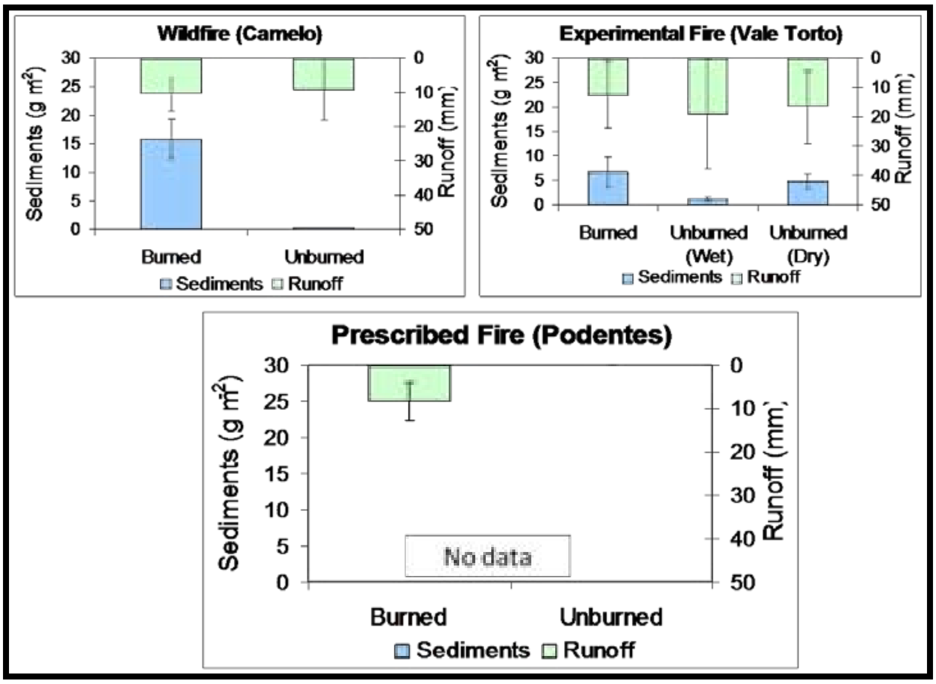

Fig. 9: rainfall simulation results in camelo, vale torto and podentes study sites, immediately after the fire and in the unburned areas.

The results point out the higher infiltration capacities on limestone comparing with the schist bedrock. On schist sites, the fire had no discernible impact on runoff, and the average runoff coefficients for the burned sites were 24% Camelo, 29% Vale Torto and 8% Podentes. However, despite de absence of runoff changes, the increase of soil loss after the fire in the schist study sites is more significant, especially in the wildfire area: 3.8 g m^{-2} vs 0.1 g m^{-2} in the wildfire area and 1.6 g m^{-2} vs 1.2 g m^{-2} for the experimental area. Nonetheless, considering the Vale Torto results (Fig. 10), the increase in soil erosion immediately after the fire was not very marked, particularly compared with the erosion rate in unburned areas recorded during dry periods.

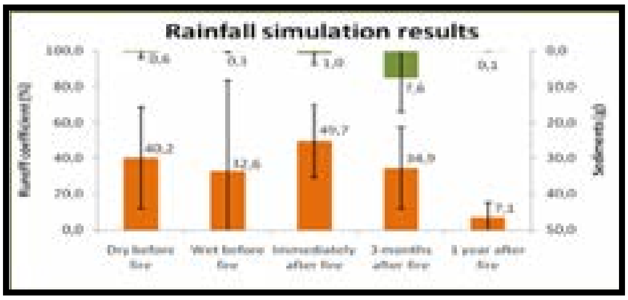

Fig. 10: rainfall simulation results obtained in vale torto study site along the time.

The results presented on Fig. 10 demonstrate that despite the expected increase in erosion rates after the fire, the erosion peak doesn't necessary happen immediately after the fire. The same results were validated with the sediment fences (Fig. 11).

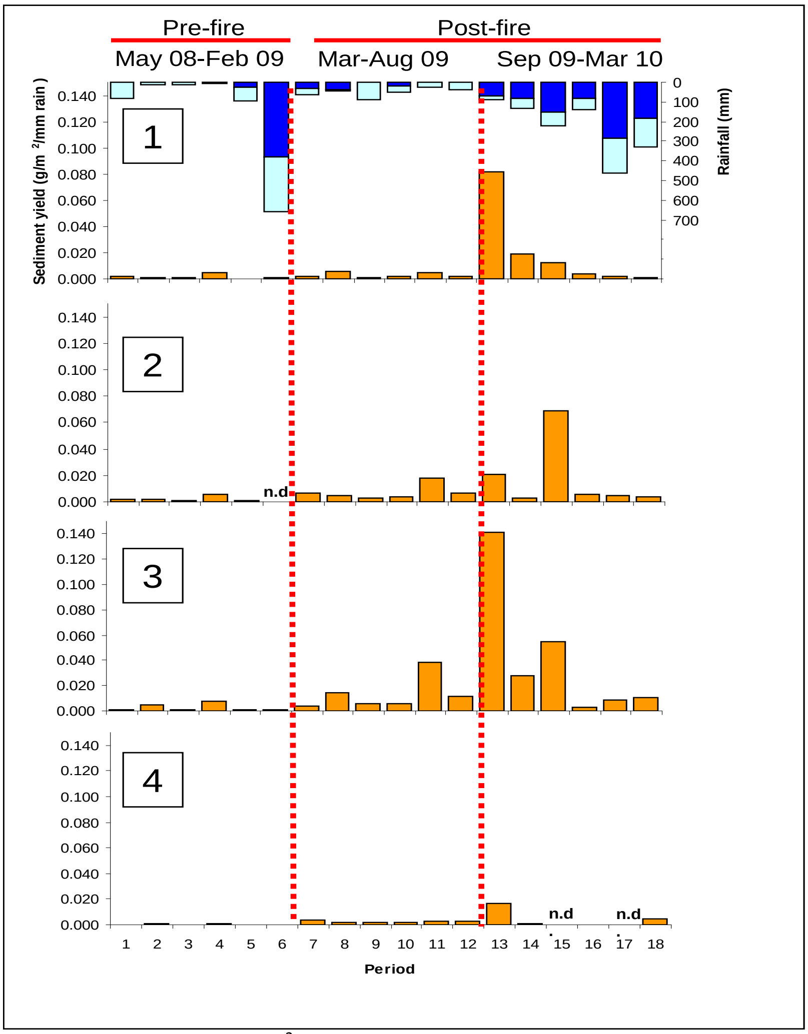

Fig. 11: soil erosion expressed as sediment per m^2 of contributing area collected from the sediment fences in vale torto for periods of different lengths (orange bars) together with rainfall amounts (dark blue and light blue compound bars), for the period of may 2008 – march 2010. For rainfall, dark blue represents the amount falling as daily events ≥ 20 mm, and light blue as rain falling in daily amounts <20 mm. (n.d. = no data).

The soil erosion results for Vale Torto sediment fences show that post-fire erosion, for the periods 7-18,presented a distinct increase compared with pre-fire periods (1-6). However, there is a difference in the size of this increase, which rises from 2-5 times pre-fire values overall for the first 4 months after fire up to June 2009 (periods 7-12), to 8-15 times for July 2009 - March 2010 (periods 13-18). The latter coincides with autumn-winter 2009-10, which was particularly wet. Rain fell not only in high amounts but also at higher intensities (up to 62.2 mm daily) in this interval. Although pre-fire period 6 has the highest rainfall total (652.3 mm), with a fairly high proportion (55%) of daily events of rainfall ≥20 mm and a maximum daily rainfall of 49.6 mm, soil erosion recorded for each fence was lower than or similar to Fig.s for post-fire periods. The generally high erosion Fig.s in periods 13 to 18 compared with periods 7-12 do coincide with high rainfall totals, but it is probably rainfall intensity rather than quantity that is critical. For example, whereas the hourly rainfall amount equaled or exceeded 5 mm on just 3 occasions during periods 7-12, it did so on 25 occasions in periods 13-18, with 6 of these equaling or exceeding 10 mm and 1 equaling or exceeding 15 mm in period 15. There is some evidence of a decline in erosion in periods 13-18 for fences 1 and 3. This is thought to reflect reduced availability of easily removed sediment, charred debris and ash, a converse increasing exposure of a protective stone cover and an increasing vegetation cover.

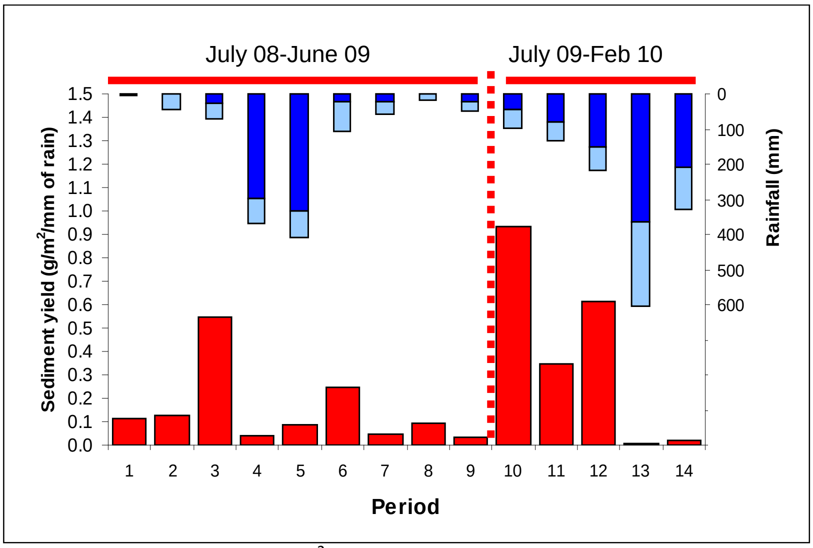

Fig. 12: soil erosion expressed as sediment per m^2 of contributing area collected from the sediment fence in camelo catchment for periods of different lengths (red bars) together with rainfall amounts (dark blue and light blue compound bars), for the period of july 2008 to february 2010. For rainfall, dark blue represents the amount falling as daily events ⩾ 20 mm, and light blue as rain falling in daily amounts <20 mm.

For the wildfire from Camelo study site (Fig. 12), there are some similarities but also differences comparatively to the Vale Torto experimentally-burned catchment. The soil losses per unit contributing area are on average 1-2 orders of magnitude higher (2.2 t/ha for the first year after the wildfire, and 3.6 t/ha for the whole 19-month monitoring interval up to March 2010) compared with post-fire Fig.s at Vale Torto. It is difficult to demonstrate categorically that this difference is caused by the difference in fire characteristics, but in most respects (geology, soil characteristics, slope gradient) Camelo and Vale Torto appear similar. The main difference seems to be the nature of the fire and the size of the fuel load (65 vs 23 t/ha, respectively). Similar to results from fences 1 and 3 at Vale Torto, those at Camelo show an overall decline in the quantities of soil collected for the last few periods despite large quantities of rainfall and some high intensity. As suggested above, this is thought to result from a combination of sediment 'exhaustion', development of a stone armour and vegetation recovery.

The erosion measured after both the experimental fire and wildfire can be compared with the long-term records of soil erosion on long unburned terrain at the Vale Torto site. The results from both the sub-catchment weir pool (0.028 t/ha/yr) and the small bounded plot (0.016 t/ha/yr) are similar and are 1-2 orders of magnitude lower than the post-fire erosion results.

In addition, a lysimeter approach to assess fire impact on soils started during 2010. One lysimeter was ordered and largely tested before the experiments started. During the experimental lysimeter fire (Photo 7), flame temperature was assessed using an infrared heat sensor, that shows temperatures reached values over 700ºC. The top ash temperatures took more than 15 minutes to reach values below 50ºC .

Photo 7: On the left the initial lysimeter during preparation and, on the right, during the burning.

30"			3'		
	34	34		538	560
	34	34		496	616
	34	34		681	711
	34	158		641	625
1'			5'		
	34	34		117	166
	34	34		300	505
	34	177		299	651
	410	367		599	471
1'20"			8'		
	80	461		158	160
	102	696		228	205
	70	642		405	325
	353	608		463	223
2'20"			15'		
	487	423		115	120
	628	753		90	95
	651	702		290	180
	622	707		260	75

Fig. 13: flame and ash temperatures during the burn.

Despite the high temperature reached on the flames, the top soil (0-2cm depth) temperature varied spatially, and despite the average temperature was around 250ºC, in some places it reached 450ºC (Fig. 14). At the sub-surface soil layer (2-5cm), the temperature reached during the fire was around 60ºC.

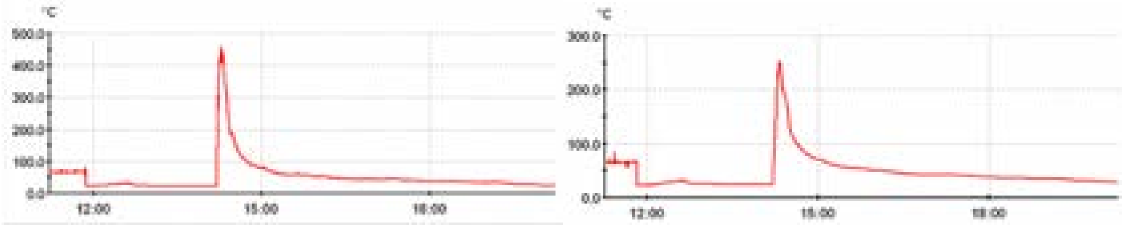

FIG. 14: TEMPERATURE VARIATION DURING LYSIMETER BURN AT TOP SOIL LAYER.

Fig. 14 present the maximum temperatures monitored by thermocouples at the top soil layer, where we can notice that some locations exceeded 400ºC while others showed less than 300ºC of maximum temperature.

After the first lysimeter construction and experimental tests, five additional lysimeters were ordered. Since January 2011, the lysimeters are being prepared for the assessment of the impacts of post-fire mitigation techniques. They were full with a gravel and sand layer and covered with a top layer of 10 cm soil (collected in a pine tree forest area) (Photo 8). All the lysimeters are placed to simulate a 15º slope and will be covered with representative vegetation from a pine tree plantation. They are currently covered with fabric before the experiments starts, to conclude their installation and allow starting all of them at the same time and in the same conditions. A calibration period will be followed, for the pre-assessment of the experimental conditions. In the end of March 2011, the vegetation of four of the six lysimeters will be burned. A monitoring period will follow the burning, according to the following experimental design: 2 unburned lysimeters as controls, 2 burned lysimeters without post-fire mitigation measures and 2 burned lysimeters with post-fire mitigation techniques applied.

Photo 8: A lysimeter after soil placement and before the cover with litter (left) and the lysimeters being homogenized before the calibration period that will be followed by the burn (right).

2.5 INVOLVEMENT OF STAKEHOLDERS

Prescribed burning is increasingly used as a tool for landscape management, in order to increase diversity and reduce forest fire risk. To perform prescribed burning, one has to get approved in a special fire management course, the means to perform it are only possible with the involvement of local authorities, which became involved in the Vale Torto experimental fire.

The stakeholders were responsible for getting all the permits and perform the prescribed burning. They followed up the recovery of the burn area.

Prescribed fire is probably the most cost effective technique for landscape management, it is an old practice that was forbidden during 60 years, and therefore has the adherence of local stakeholders.

2.6 Discussion and conclusions

The main conclusion steaming from the work performed is that prescribed fire is in fact a management technique with less degradation impacts when compared with wildfires, and therefore there is a scope for the use of prescribed fire as a landscape planning tool to prevent the occurrence deleterious wildfires.

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3 GREECE - CRETE

Responsible partner

Partner 9 – Agricultural University of Athens (AUA)

Overview

Location 1 - Augeniki

Here runoff and erosion are monitored on an agricultural field covered with a systematic olive grove. The field is located on a moderately steep slope (slope gradient 17%), moderately deep soil (soil depth 55-65 cm) and prone to surface water runoff and tillage erosion. Rills of water erosion were observed after a heavy rainfall occurring in the area in November 2008. Furthermore, changes in soil color on the surface horizon are present in the same field due to tillage erosion. Water stress to the growing plants is also a major issue in the area since water for irrigation is not available. SWCs tested in plots include: (a) no tillage, no herbicides application, (b) no tillage herbicides application for reducing soil erosion and increasing soil water availability. The control plots have been tilled perpendicular to the contour lines which is the normal ploughing direction. An automatic monitoring system for soil erosion, soil moisture content, and soil temperature has been installed in the field for the above mentioned SWCs techniques. Meteorological variables are measured at the same field using an automatic station. The experimental station is remotely controlled from the laboratory of Soils in the Agricultural University of Athens.

Location 2 – Agia Barbara

Here overgrazing is monitored on a range land. The field is located on a steep slope (slope gradient 23%), moderately deep soil (soil depth 45-60 cm) and prone to surface water runoff erosion. Rills of water erosion are observed in places where runoff water is concentrated. Water stress to the growing plants is also a major issue in the area especially in the south-facing slopes since the soil water storage capacity is relatively low. SWC tested in plots include controlled crazing for reducing soil erosion. The control plots are overgrazed. An automatic monitoring system for soil erosion, soil moisture content, and soil temperature has been installed in the experimental field. Meteorological variables are measured at the same field using an automatic station. The experimental station is remotely controlled from the laboratory of Soils in the Agricultural University of Athens.

3A Crete 1 – Augeniki study site

3.1 Trial layout

In November 2008, a field experiment was established at a private olive grove near Augeniki village, 18.5 Km southwest of Heraclion city, Crete, Greece, at the coordinates of 35° 11′28.15′′ N 25° 01′ 22.47′′ E and 360 m above sea level. The field included a systematic cultivation of non-irrigated olive trees planted in 1980, and covering an area of 2 hectares. The field is located on a moderately steep slope (slope gradient 17%), moderately deep soil (soil depth 55-65 cm) and prone to surface water runoff and tillage erosion. The experiment installed in the upper zone of the field, where six closed runoff plots were established. Each plot was 3 m wide and 5 m long (15 m^2) with the long side perpendicular to the contour lines.

The field experiment included the following three and management practices (LMP) (treatments) prevailing in the area with two replicates (Fig.1): (a) no tillage – no herbicides application, (b) no tillage – herbicides application, and (c) tillage operation – no herbicides with soil cultivated perpendicular to the contour lines at depth 20 cm using a disk harrow. At the bottom of each plot there was a small drainage ditch and a tube leading surface water runoff to six dipping buckets and six soil sediment traps corresponding to the three LMPs with their replicates.

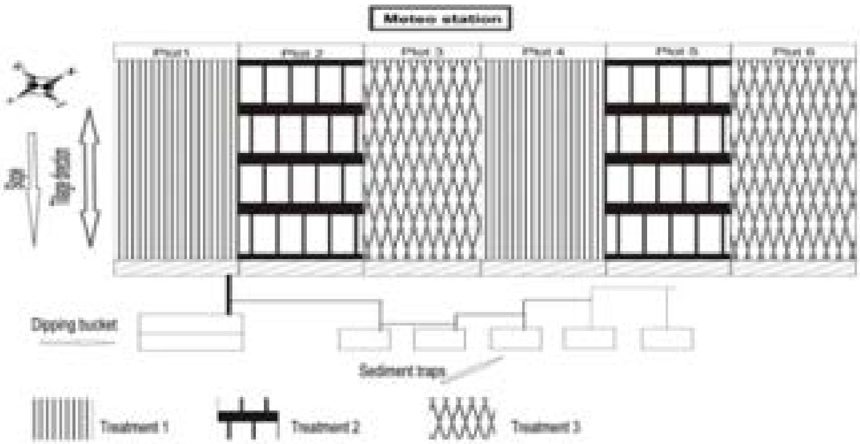

Fig.. 1. Experimental layout of three treatments with two replicas in the experimental field site Crete 1-Augeniki

Meteorological and soil data were recorded in an automatic data logger station (Campbell Scientific Ltd-CR10X) using various sensors installed in the plots of the experimental field (Fig. 2). The data logger was remotely controlled through GSM system from the laboratory of Soils in the Agricultural University of Athens. Specifically, the amount of rainfall was recorded by a dipping bucket rain gauge (Casella London Limited) and stored every 5 minutes. Open pan evaporation was recorded electronically every 6 hours with stainless steel standard pan evaporation meter. Also, wind speed (Campbell Scientific Ltd-A100R), air temperature (Rotronic-MP101A), relative humidity (Rotronic-MP101A) were measured every minute and recorded after averaging every hour. Net solar radiation was measured by a net radiometer (Campbell Scientific Ltd-Q*6). In each plot two time domain reflectometers (TDR-Campbell Scientific Ltd-CS615) were installed for measuring the volumetric soil moisture content at soil depths of 20 and 40 cm. Soil temperature was measured at 10 cm soil depth by a soil thermometer (Campbell Scientific Ltd-PT100). Runoff of each plot after a rain event was collected and the amount of sediments were measured. These runoff containers and ditches were cleared of sediment after each runoff event.

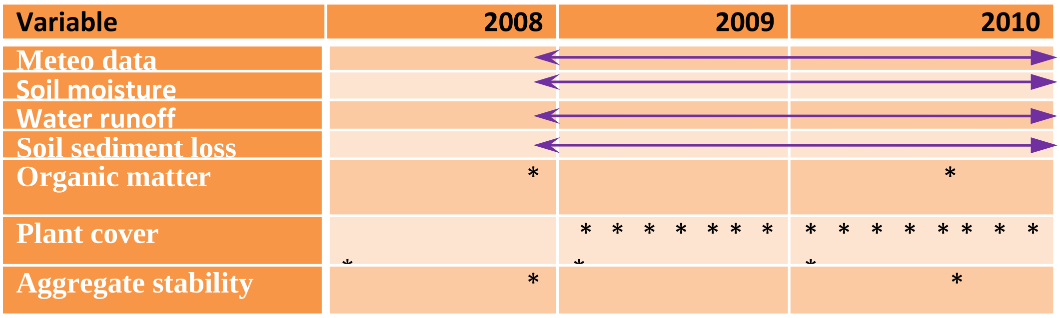

Fig. 2: Time graph of measurements conducted in the Crete 1 – Augeniki experimental filed site

Temporary soil water storage in the upper 50 cm soil layer for the various treatments was determined by using the volumetric soil moisture content measured in the depths of 20 and 40 cm. Soil aggregate stability, particle size distribution, and soil organic matter content were measured twice during the execution of the experiment (12/11/2008, and 30/9/2010). Soil samples were collected from the soil layer 0-25 cm from the six plots (treatments and replicates) and analyzed for particle size distribution of the <2mm fraction by the Bouyoucos hydrometer method (Gee and Bauder, 1986). The wet sieving technique by Yoder (1936) was used for the determination of the mean soil weight diameter of the soil aggregates. Organic carbon content was measured using the modified Walkey-Black wet oxidation procedure (Nelson and Sommers, 1982). Plant cover was recorded periodically throughout the period during which field observations was carried out. The TERON methodology was used for the calculation of soil losses due to tillage erosion for the tillage land management practice. Data were analyzed per year from September to September the following year.

The following indicators were monitored related to land degradation and desertification: soil moisture, soil temperature, water runoff, sediment loss, rainfall, potential evapotranspiration, air temperature, aggregate stability, soil organic matter content, plant cover.

3.2 Analysis and Results

The total amount of rainfall falling in the first year was relatively high (924.3 mm rain) about twice the average value of the area (average 512 mm), while the following year was particularly dry with an amount of 370.8 mm of rain. These oscillation in rainfall are typical of the Mediterranean climate prevailing in the study site of Crete. Even though there were significant differences in the amount of annual rainfall, four to five major rainfall events have been occurred in both study years generating overland significant amount of water runoff. As it was measured in both years, major runoff events have occurred late fall to middle winter (Fig. 3). This period is crucial for soil erosion since soils are not adequate covered due to long dry summer period.

Land management practices applied in the olive grove and amount of rainfall falling during the study period have greatly affected surface water runoff and sediment loss. As Fig. 4 shows, the highest amounts of annual water runoff have been measured in the soil subjected to tillage operations with 44.7 mm and 7.9 mm, corresponding to the first and second year of study, respectively. Water runoff was greatly reduced to about 4 times compared to tillage under the land management practices of no tillage and no tillage-herbicides application. The lowest values of water runoff were recorded under the no tillage land management practices since soil was fully covered with the annual growing weeds during the crucial period of soil erosion. The percentage of rainfall lost as surface water runoff was ranged form 2.2-4.8% in the LMP of tillage operations, while these values were lower than 1.8% of the total amount of annual rainfall in the other LMPs.

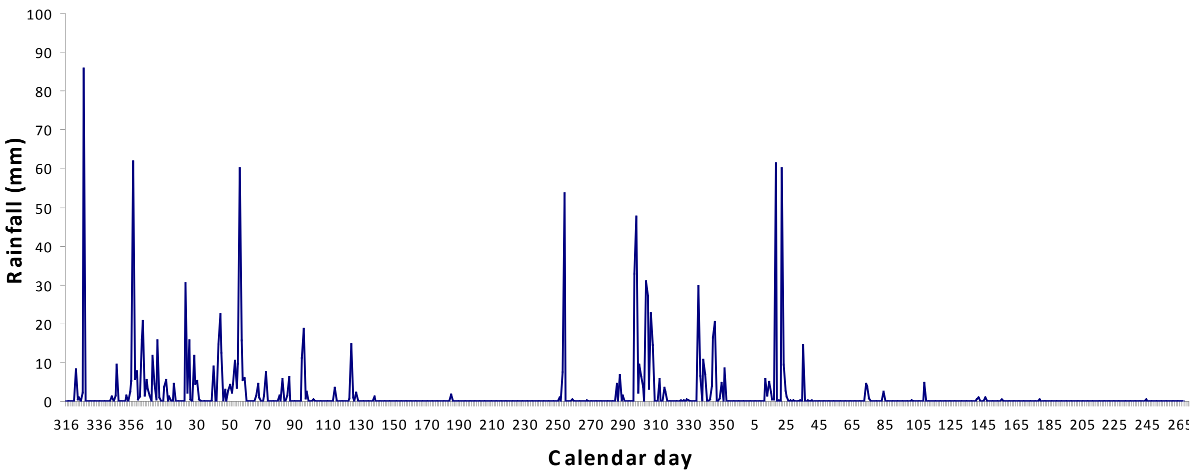

Fig. 3: Change of daily rainfall with time recorded in the experimental field site of Crete2-Augeniki study site

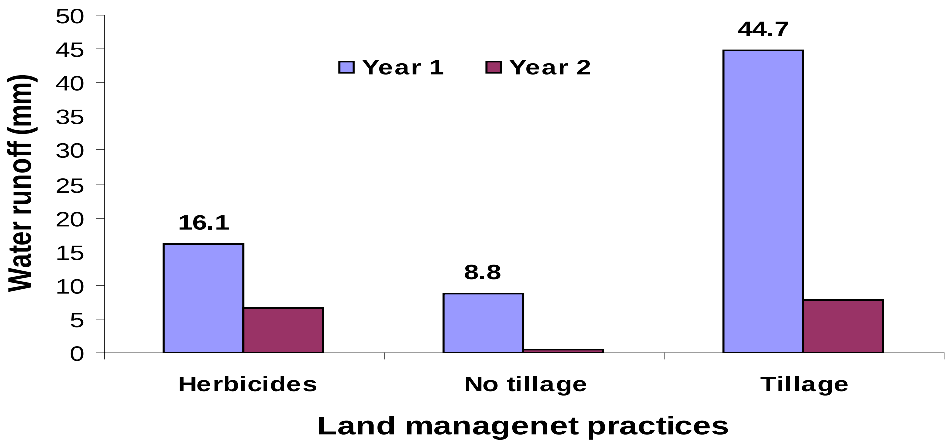

Fig. 4: Annual water runoff measured under various land management practices in the olive grove

Annual sediment loss shows similar trends with water runoff in the various land management practices. As Fig. 5 shows, sediment loss was higher in the tillage LMP applied in the olive groves and especially the first year of measurements when high amounts of rainfall occurred. Sediment loss in this management practice was ranged from 44.2 to 255.9 kg ha^{-1} yr^{-1} for the two year period of measurements. Annual sediment loss was greatly reduced even in nil values for the other land management practices greatly contributing in protecting a sensitive area to land degradation and desertification. The measured soil erosion rates due to surface water runoff in the period of two years are relatively low for the study area. Therefore, LMPs have to be considered in other processes affecting soil and water conservation in the area, as well as the cost of crop production. Tillage erosion is very important in the area and especially for the sloping land. The estimated annual soil loss by tillage using the TERON methodology is 3.7 mm of soil. This value corresponds to a soil displacement of 407 t ha^{-1} yr^{-1}. Such soil displacement forms the upper parts of a hillslope (convex and linear part) and deposition in the lower concave part of the slope results in high rates of degradation of the cultivated hilly areas.

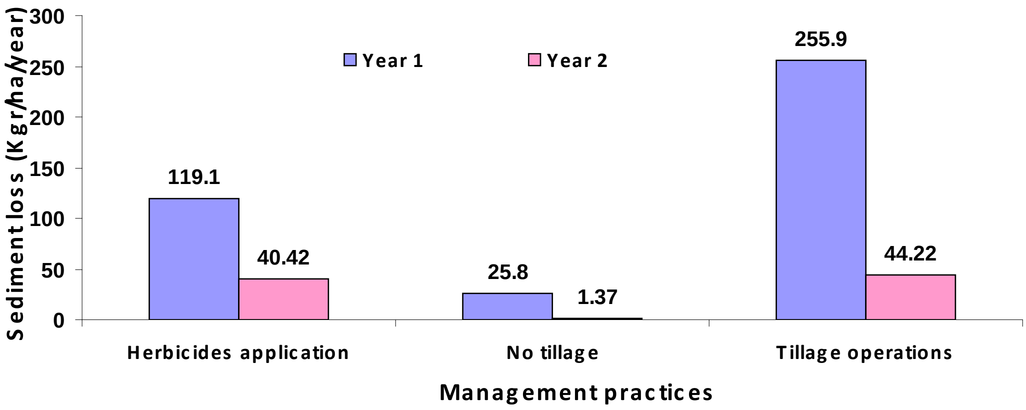

Fig. 5: Annual sediment loss measured under various land management practices in the olive grove

Land management practices have affected surface water runoff and therefore soil water stored into the soil. As Fig. 6 shows, soil water stored was higher during the whole period of study in the no tillage-no pesticide application land management practice. As it is expected the presence of weeds in the olive grove extract soil water available for the growth of olive. Considering that the rooting system of the existing weed (*Oxalis sp*) is growing in the upper 15 cm soil layer, and getting dry during middle of spring after rainfall is diminished, the soil water adsorption is not so important for the growing olive trees. In addition, the presence of weeds fully covering soil surface, greatly reduces both soil water evaporation and water runoff, and conserves soil water stored into the soil. The removal of weeds by applying herbicides have reduced soil water stored into the soil during the whole period, since upward capillary rise of soil water is not interrupted. The tillage land management practice reduces such water movement and conserves higher amount of soil water than the land practice of herbicides application.

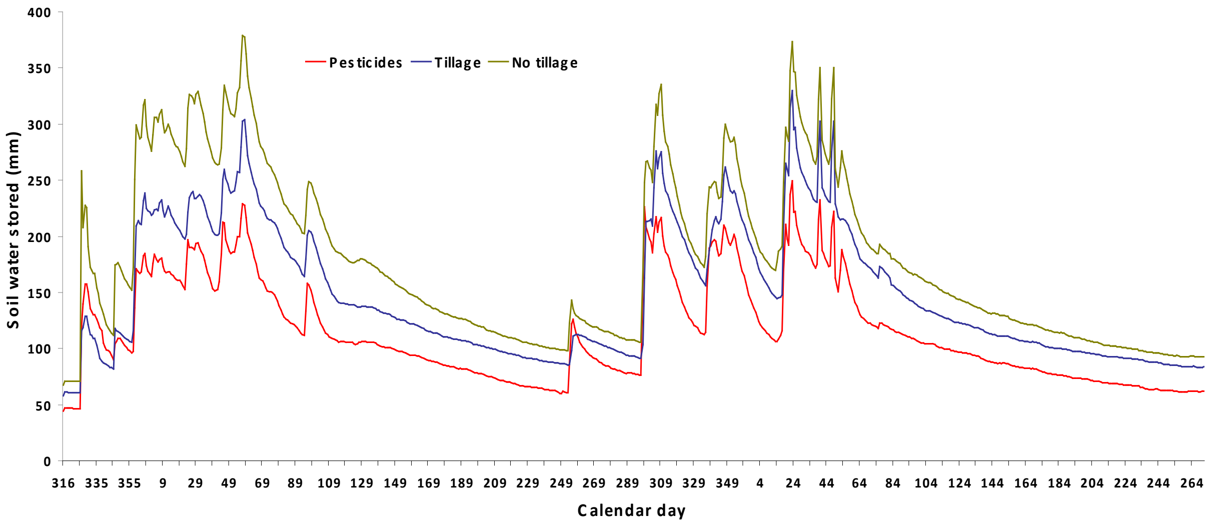

Fig.. 6: Change of soil water stored in the upper 50 cm with time measured in the various land management practices in the olive grove

Land management practices greatly affect land degradation and socio-economic characteristics of the people. Based on the existing socio-economic conditions of the study site of Crete, the net revenue form a systematic olive grove under the no tillage-no pesticide application land management practice is estimated in 1588 euro per hectare, while the man-power required is 281 hours per hectare. As it is expected the other land management practices reduce net income and the required man power is higher. Under the tillage and no tillage-herbicide land management practices, the net revenue is estimated in 1454 and 1370 euro per hectare, respectively, while the required man-power is 296 and 298 hours per hectare.

3.3 INVOLVEMENT OF STAKEHOLDERS

Local stakeholder has offered his field for installing instruments and monitoring different land management practices, as well as has participated in the installment of the monitoring instruments. Many of local farmers have visit the monitoring site and observed the work carried out. They have many times discussed the issue of desertification and the measures for protecting the land from further degradation in local meetings. They have considered the applied land management practices and included in the agricultural program of “Integrated Land Management of Olive Groves” for receiving higher subsidies.

The benefits of applying the proposed no tillage or minimum tillage land management practices are related to: (a) lower cost production of olive oil, (b) higher income due to the application of integrated land management of olive groves for protection of the environment. The application of no-tillage or minimum tillage land management practices did not require additional cost for implementation. Several stakeholders have accepted this type of land management practice. The main reaction is the lack of knowledge transfer by the Greek Ministry of Agriculture on new sustainable land management practices and decreasing cost production and protecting the environment. The expectations from the proposed technology in olive groves are: (a) expansion in larger areas thought the study site of Crete , (b) protection of the environment due to reduction in soil erosion and increase in soil water storage.

3.4 DISCUSSION AND CONCLUSIONS

The effect of land management practices on soil erosion and land degradation in an olive grove has been assessed by conducting experimental measurements for a period of two years (2008-2010). The obtained data have shown that the no tillage – no herbicides application land management practice compared to the other techniques derived nil sediment loss (1-25 kg ha^{-1} $year^{-1}$), lowest water runoff (0.4-8.8 mm $year^{-1}$), highest amount of water stored into the soil, lowest soil temperature, highest biodiversity, lower desertification risk, lowest olive oil cost production. The herbicides application showed the lowest amount of water conserved into the soil and intermediate values of water runoff (6.7-16.1 mm $year^{-1}$) and sediment loss (40-110 kg ha^{-1} $year^{-1}$). The tillage land management practice showed the highest sediment loss (44-250 kg ha^{-1} $year^{-1}$) and surface water runoff (7.9-44.7 mm $year^{-1}$), the highest desertification risk, intermediate amount of rain water conserved into the soil. While water erosion appears not so important for land degradation in the study field site and for the two years period, tillage erosion caused by the used implements for cultivating the land is the most important process of land degradation and desertification. The average soil loss due to tillage erosion has been estimated in 3.7 mm per year.

Other indicators important on land protection such as soil organic matter content and aggregate stability was related to the applied land management practice. Aggregate stability and organic matter content was higher for about 30% in the soil under no tillage – no herbicides application. The estimated Pieri (1989) soil crusting susceptibility index is 2.3 for the soil under tillage, while this index 3.2 for the no tillage – no herbicides application.

The proposed sustainable land management practice of no tillage – no herbicide application has already applied in many cases in the Crete study site. This type of management is favored in the last decade by the local farmers due to the low olive oil price and reduced farm income. Considering that the olive fruit production has decreased for about 35% in the area in the last 3 decades, farmers have realized the importance of no tillage or minimum tillage in protecting olive groves from land degradation and desertification, and conserving water resources, as well as reducing the risk of low land flooding.

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3B CRETE2 – AGIA BARBARA STUDY SITE

3.1 DESCRIPTION OF THE SETUP OF THE EXPERIMENT

In December 2008, a field experiment was established at a private grazing land near Agia Barbara village, 23 Km southwest of Heraclion city, Crete, Greece, with coordinates: 35^{o} 08′35′′ N, 24^{o} 59′ 24 02′′E and 880 m above sea level. The field is located on a steep slope (slope gradient 23%), moderately deep soil (soil depth 35-45 cm) and prone to surface water runoff due to overgrazing. The experiment installed in the upper zone of the field where four runoff plots were established. Experimental plots are located in a field of 4 hectares, 10 m^2 each, corresponding to two treatments with two replicas located on a random plot design. The field experiment included the following two land management practices (LMP) (treatments) prevailing in the area (Fig.1): (a) sustainable grazing (SG), and (b) overgrazing (NSG). At the bottom of each plot there has been installed a small drainage ditch and a tube leading surface water runoff to four dipping buckets and four soil sediment traps corresponding to the studied LMPs with their replicates.

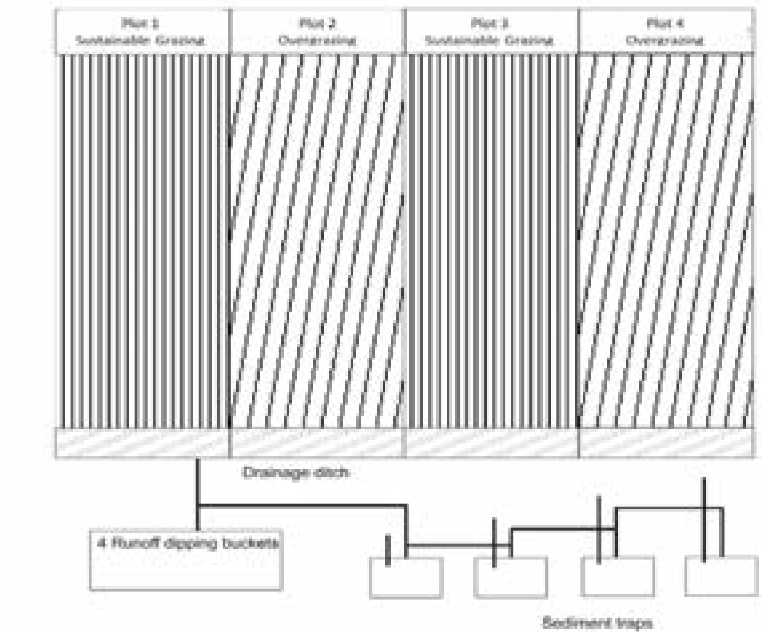

Fig. 1. Experimental layout of two treatments with two replicas in the experimental field site of Crete2-Agia Barbara

Meteorological and soil data were recorded in an automatic data logger station (Campbell Scientific Ltd-CR10X) using various sensors installed in the plots of the experimental field (Fig. 2). The data logger station was remotely controlled through GSM system from the laboratory of Soils in the Agricultural University of Athens. Specifically, rainfall amount was recorded by a dipping bucket rain gauge (Casella London Limited) every 5 minutes. Wind speed (Campbell Scientific Ltd-A100R), air temperature (Rotronic-MP101A), relative humidity (Rotronic-MP101A) were measured every minute and recorded after averaging every hour. Net solar radiation was measured by a net radiometer (Campbell Scientific Ltd-Q*6). In each plot a time domain reflectometer (TDR-Campbell Scientific Ltd-CS615) was installed for measuring the volumetric soil moisture content at soil depth of 20 cm. Soil temperature was measured at 10 cm soil depth by a soil thermometer (Campbell Scientific Ltd-PT100). Water runoff from each plot was measured using dipping-bucket gauges. These metallic containers were cleared of sediment after each runoff event.

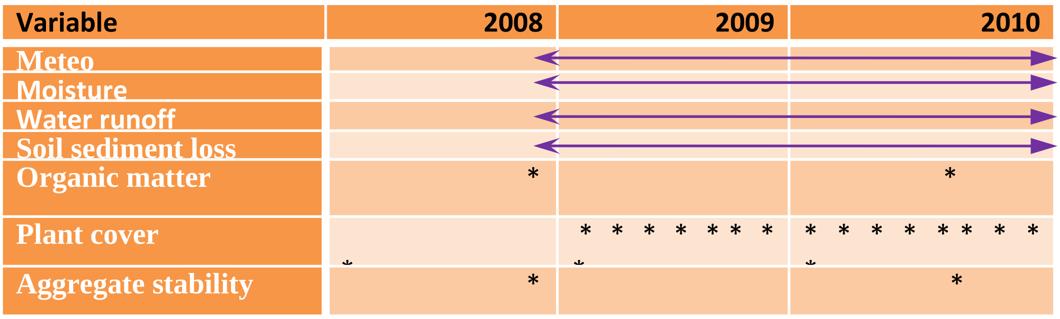

Fig. 2: Time graph of measurements conducted in the Crete2–Agia Barbara experimental filed site

Soil aggregate stability, particle size distribution, and soil organic matter content were measured twice during the execution of the experiment (12/11/2008, and 30/9/2010). Undisturbed soil samples were collected from the surface A-horizon (0-25 cm depth) from all experimental plots (treatments and replicates) and analyzed for particle size distribution of the <2mm fraction by the Bouyoucos hydrometer method (Gee and Bauder, 1986). The wet sieving technique by Yoder (1936) was used for the determination of the mean soil weight diameter of the soil aggregates. Organic carbon content was measured using the modified Walkey-Black wet oxidation procedure (Nelson and Sommers, 1982). Plant cover was recorded periodically throughout the period during which field observations were carried out. Data were analyzed per year from September to September the following year. The following indicators were monitored related to land degradation and desertification: soil moisture, soil temperature, water runoff, sediment loss, rainfall, potential evapotranspiration, air temperature, aggregate stability, soil organic matter content, and plant cover.

3.2 Analysis and Results

The amount of rainfall measured during the study period of year 1 and year 2 was 520.0 mm and 625.3 mm, respectively. As Fig. 3 shows, the greatest amount of rainfall has been fallen from late fall to middle winter. During that period 10 rain important events have occurred inducing incipient ponding and different run-off volumes were measured in the different plots. The considerable great variation in the total run-off reflects the paramount importance of surface conditions on run-off generation and land degradation. The existing annual and perennial vegetation and the plant residues have covered about 85% of the soil surface in the soil under sustainable grazing, preventing raindrop splashing, formation of surface crusting, and minimizing the velocity and the amount of run-off water. During the first two weeks of January 2010 there was rain almost every day causing saturation of soil and generating subsoil lateral water flow and overland runoff. The total amount of rainfall measured during that period was 158.3 mm generating 14.3 mm and 5.8 mm of water runoff in the corresponding overgrazed and sustainable grazed land management practices.

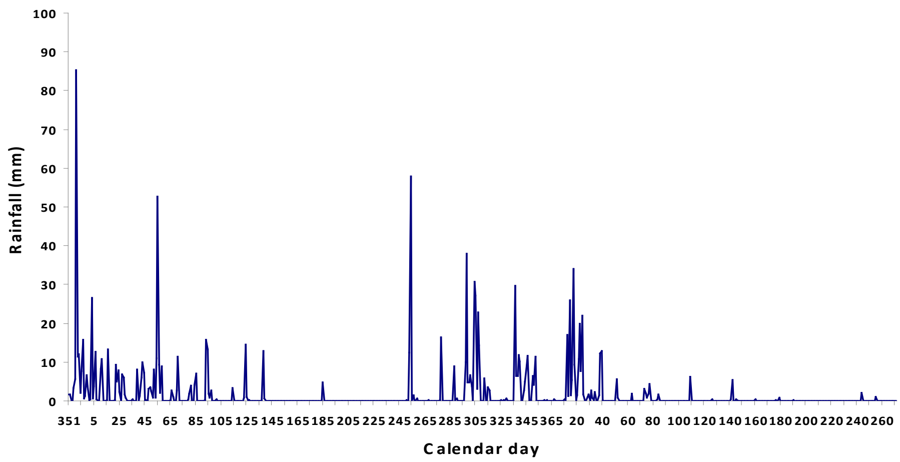

Fig. 3. Daily amount of rainfall measured in the Crete2-Agia Barbara experimental station in the period from December 2008 to September 2010

Degradation of vegetation by grazing animals, accompanied by decrease in plant cover and deterioration of surface soil aggregates, favored surface water runoff generation and soil loss in the overgrazed land. As Fig 4 shows, surface water runoff was higher more than 2 times in the overgrazing plots during the study period of two years. A total amount of 43.7 mm and 28.0 mm of water runoff was measured in the overgrazed plots during years 1 and 2, respectively. These values have been reduced to 18.0 mm and 7.4 mm, respectively in the sustainable grazing plots. Water runoff was 8.4% and 4.5% of the falling annual rainfall in the overgrazing plots during the years 1 and 2, respectively. These values have bee reduced to 3.6% and 1.1% in the sustainable grazing plots.

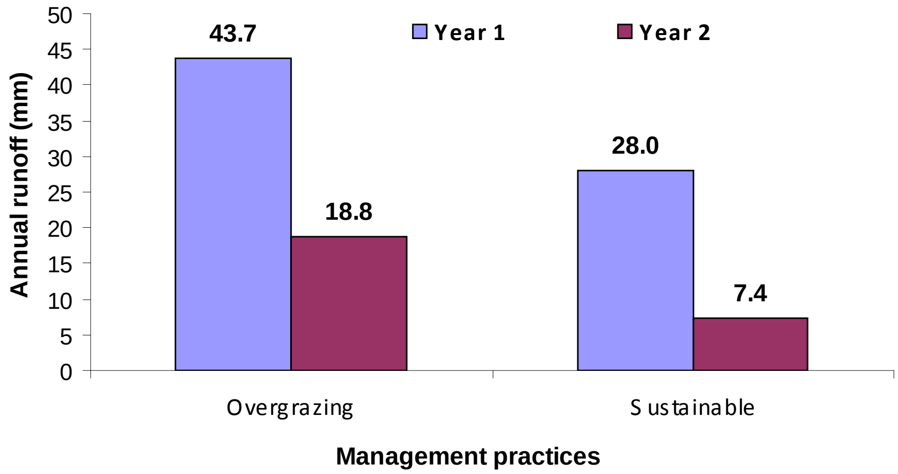

Fig. 4: Annual runoff measured in experimental plots under different grazing intensity in the Crtete2 study site

As water runoff, sediment loss was similarly affected by grazing intensity. As Fig. 5 shows, sediment losses in the overgrazed plots were 352.3 kg ha^{-1} yr^{-1} and 142.6 kg ha^{-1} yr^{-1} during the study years 1 and 2, respectively. Sediment losses measured during the same period in the sustainable grazed plots were about 2.5 times less than in the overgrazed plots. Even though soil erosion in the overgrazed land is higher than the sustainable grazed land, rates of soil erosion can be considered as low. This can be attributed to the physical condition of the vegetation and soils in the study site. The broad area has been overgrazed in the past and less- or non-palatable plant species have been dominated such as *Genista acanthoclados, Poterium spinosum, Euphorbia acanthothamnos, Thymus capitatus, Anthylis hermaniae, Phlomis fruticosa,* etc. Considering that the soil are relatively shallow (soil depth less than 40 cm), and the area has a long dry period (May to October), plants have been grown a very dense rotting system for combating water stress and plant competition, restricting soil particle detachment by overland water flow and reducing soil sediment loss.

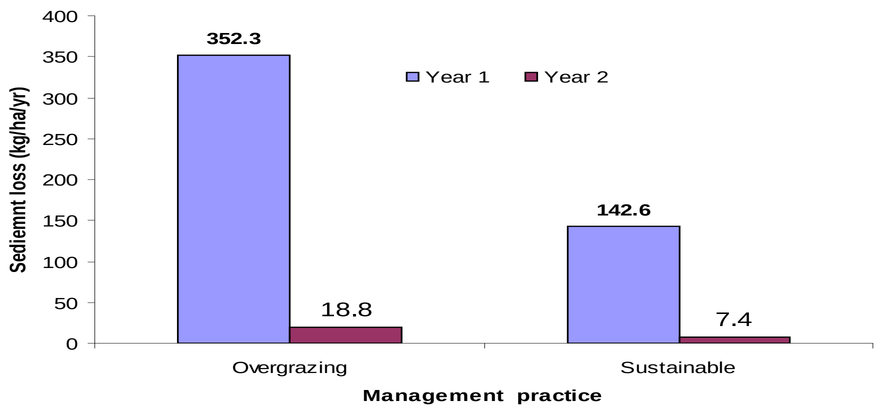

Fig. 5: Annual sediment loss measured in experimental plots under different grazing intensity in the Crtete2 study site

Grazing intensity affects soil erosion and soil water storage. As Fig. 6 shows, the overgrazed soil had a higher amount of soil water stored into the soil especially during the first year of study, even though a higher amount of rain water has been lost as runoff. This can be attributed to the removal of a great part of the growing palatable plants by the animals, reducing water transpiration. No significant differences in soil water storage have been observed between the different grazing intensities in the second year. This can be attributed to: (a) the wetter winter occurring in the second year, and (b) the delay of arrival of grazing animals in this area from the low land in spring. Furthermore, it has to be pointed out the reduction of soil water evaporation in the sustainable grazing plots, showing some temporal higher amounts of water storage into the soil during the winter period (Fig. 6).

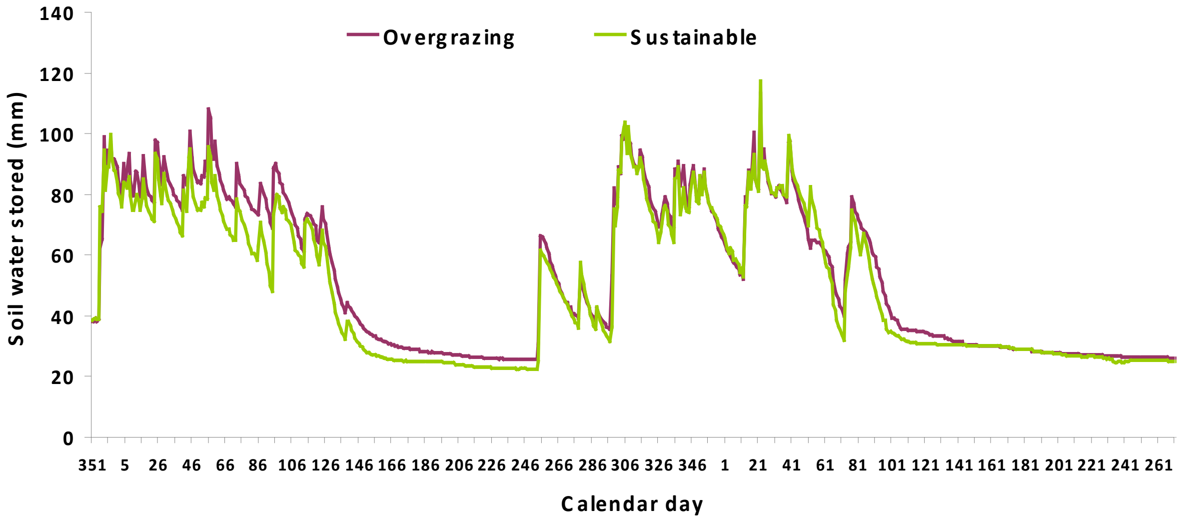

Fig. 6: Change in soil water stored into the soil with time measured in experimental plots under different grazing intensity in the Crtete2 study site

3.3 Involvement of stakeholders

Local stakeholder has offered his field for installing instruments and monitoring different land management practices. Many of local farmers have visit the monitoring site and observed the work carried out. They have many times discussed the issue of desertification and the necessary actions for land protection from degradation and desertification in local meetings. Local farmers are aware of the impacts of land desertification in the area and the necessity for applying immediately measures against it. They have realized the importance of applied sustainable grazing in the broad area, but the main constrain is the conditions of EU subsidies allocation which is based mainly on the number of productive animals. The benefits from actions against desertification are related to: (a) the protection of the wide environment in the area, and (b) the conservation of natural resources and the increase in rain water stored into the soil and supplying water to springs and to the aquifer in the lower Messara valley.

The application of sustainable grazing require additional funds for compensating the reduction of number of animals according to sustainable carrying capacity or to buy additional feed for keeping the animal out of the land for a certain period. The cost is estimated in 7 Euro per animal per year for removing the extra number of animals from the land. Few stakeholders have accepted this type of land management practice by expanding their activities in other sectors of the local economy. The main problem and reaction is the lack of adequate funds for supporting farmer's income. The expectations from the proposed technology in grazing land are: (a) limited expansion of the technology in larger areas under the existing economical conditions, (b) protection of the environment if sustainable grazing is applied in the whole grazing land of the island of Crete.

3.4 Discussion and conclusions

Overgrazing is considered as the main cause of soil erosion, land degradation and desertification in hilly areas of Crete study site used as pastures. The obtained results showed that under sustainable grazing surface water runoff was 7.4-28.0 mm per year, compared to 18.7-43.7 mm per year in the overgrazing plots, while sediment loss was 0.007-0.14 t $ha^{-1}year^{-1}$, and 0.018-0.35 t $ha^{-1}year^{-1}$, respectively. Under overgrazing conditions, organic matter content was 35% lower and the average soil temperature 2.3^{o}C higher compared to sustainable grazing. Soil moisture content was higher in the overgrazing soil due to lower plant cover but the total rain water stored into the soil was lower compared to the soil under sustainable grazing. Mean values of soil penetration and shear strength were higher under overgrazing conditions. Finally, desertification risk was assessed as high in both cases but the desertification indices for sustainable grazing was lower indicating lower vulnerability to desertification if sustainable grazing is applied.

Desertification of grazing lands and landscapes caused by grazing animals is a complex process affecting both vegetation and soil characteristics. Overgrazing results in removal of palatable plant species followed by less- or no-palatable ones dominating in the grazed land. Under such conditions, farmers put deliberately fires for distinguished unpalatable plant species causing severe problems of soil erosion and land degradation. Besides overgrazing, undergrazing can also cause desertification due to the growth of high amount of flammable biomass affecting ignition of wildfires and leading to high erosion rates and degradation of the land. In addition, undergazed and not burned areas can be invaded by woody species resulting in loss of biodiversity due to high plant competition. Therefore, a sustainable grazing of the pasture land is considered the best land management practice for protecting such areas from desertification. Even though grazing land in the island of Crete is highly degraded in many places, it is necessary, farmers to remain in the land keeping sustainable number of animals for (a) protecting the land, (b) providing the market with high quality of products, and (c) supporting local culture and their income.

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4 GREECE - NESTOS RIVER BASIN, MAGGANA

Site coordination:

Partner 15 – DUTH Democritus University of Thrace

4.1 SITE INFORMATION

The coastal region of the East Nestos River Delta has limited freshwater supplies. For irrigating the fields ground water is pumped although the quality is moderate at best. Data from previous projects and the DESIRE project revealed the intrusion of seawater into the coastal aquifers of the region under consideration. Groundwater level is usually between 1-3m below soil surface while the electrical conductivity varies from 2 to 7 mS/cm in accordance to the season and the distance from the sea.

The area is situated in the coastal region of the East Nestos River Delta (Xanthi, Greece). The altitude is below 5 m from MSL and the distance from the seashore < 4 km. Groundwater is over-exploited and the water quality has been devastated by seawater intrusion and an increasing salt content. The use of such waters for irrigation purposes during the last 40-50 years resulted in significant land degradation and desertification.

A local-traditional technology applied by the farmers is the transportation of freshwater from local streams inland. This technology has significant benefits concerning productivity and land preservation; however, in some cases (sodic soils) the degradation processes are enhanced. There is also a significant cost charged to the farmers due to the continuous operation of diesel (oil) pumping stations. The local water policy (Decision of the Prefecture, Xanthi, Greece) prohibits the transportation of water from superficial sources in a distance > 500 m. As a result it is not possible for the local enterprise to install an electrical supply system (for agricultural-irrigation purposes) in case one field is situated at a higher distance.

The DESIRE project aims at policy level to promote the local technology of freshwater transport in a broader-district area. This can take place by a carefully designed central transportation network system receiving freshwater from the Nestos river. Major dams (Thesauros, Platanovrisi) are already in operation in the river and there is a provision for irrigation water supply in the broader Xanthi region.

A major objective of the DESIRE project in field level is to demonstrate i) the beneficial effects of freshwater irrigation in a region traditionally irrigated by brackish groundwater, ii) the drawbacks related to the degradation of sodic soils upon application of freshwater, and iii) promising amelioration strategies.

Field studies planning

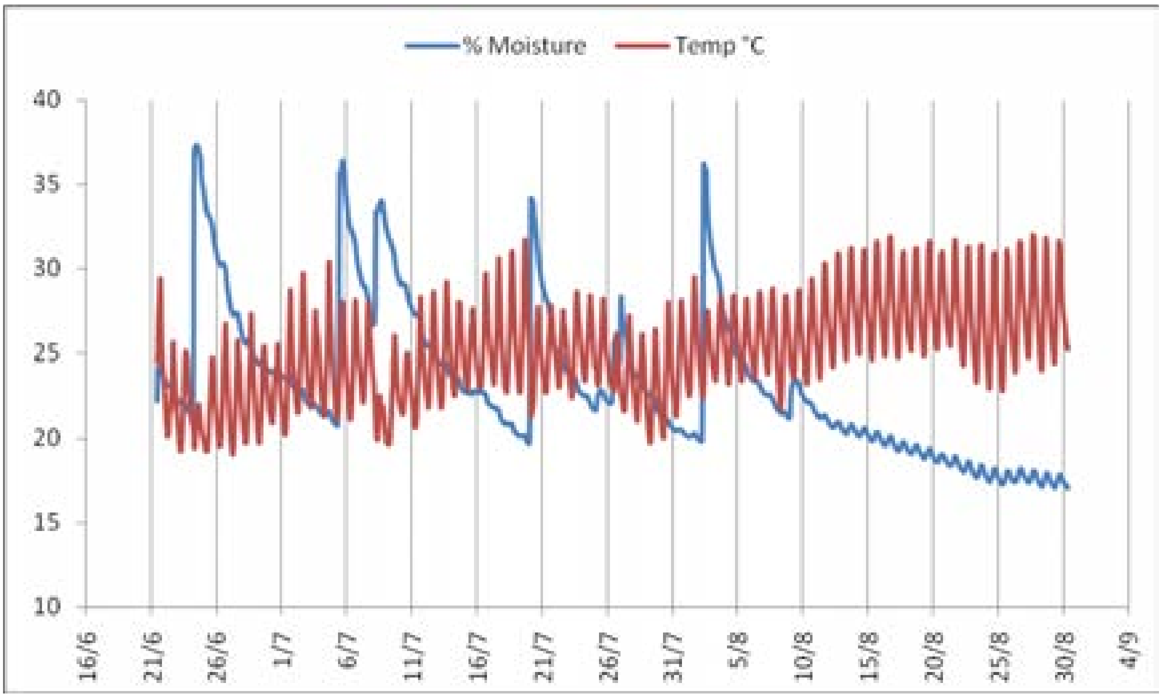
Experiment was carried out in three fields: A corn field which has been irrigating with freshwater from a local stream for the last 10 years from a local stream ("Megalomaxairo") was selected as reference for the study. Other two fields consisted of one which is traditionally irrigated with saline groundwater and another one which is irrigated by a nearby well with improved water quality.

During the crop season (2010) local authorities involvement and cooperation contributed to freshwater transportation in the groundwater irrigated field. In this case the short-term effects on productivity increase and desertification mitigation was studied in combination with different amelioration strategies (deep ploughing, gypsum addition).

Strategies incorporating structural measures (new drainage canals, installation of subsurface drainage pipes, decline of groundwater level, etc) was not performed within the merits of this project unless appropriate contribution by the local authorities is available and this will be decided for the third cultivation period (2011).

4.2 Trial layout

A nearby well with improved water quality, compared to the one that was used last year, was selected for irrigation. Then, an electric powered pump & two sprinklers were installed for irrigation. Finally moisture, temperature & EC sensors were installed (Fig. 1). The measurements are depicted at the graph below (Graph 1). All the rain or irrigation events can be distinguished.



Graph 1. Moisture and temperature fluctuation graphs (year 2010).

Fig. 1. Sensors and logger installation

Soil sampling every month, from April 2010 until August 2010, took place. Relevant laboratory measurements of EC, pH, Moisture and Chemical analysis of the samples were conducted.

Table 1. Composition of Irrigation water

Variable	2008	2009	2010
Meteo Data	√	√	√
Moisture			√
Groundwater Level	√	√	√
Groundwater EC	√	√	√
Soil EC		√	√
Soil pH		√	√
Soil Chemistry		√	√
Yield		√	√

4.3 Analysis and Results

Before seeding, grinding of crop residues (corn) from the previous season (2009), soil ploughing to a depth up to 40 cm and soil milling (counter sinking) of the surface soil (up to 25 cm) was performed by the farmer using appropriate equipment (Fig. 2 of 3rd year report). Nitrogen (N) fertilizers were applied before seeding and the amount ranges from 20 to 25 kg/1000m^2 depending on the cultivation and seed type. The irrigation period was 4 months and the corresponding quantity was about 20.000 m^3 of water for the study field (from April 2010 to early August 2010). The field was seeded with corn on 22 March 2010.

Chemical analysis of the irrigation water used, are shown in Table 1 and a comparison with 2009 irrigation water in Table 2. From the data presented it is evident that the groundwater used in year 2010 has lower EC, pH, Ca^{+2}, Mg^{+2} and Cl^- anions concentration, but a little bit higher SAR. The chemical parameters of the 2010 irrigation water render it acceptable for irrigation.

Table 2. Comparison of Irrigation water between 2009 and 2010

Parameter	2009	2010
EC (μS/cm)	2350	1912
pH	7.67	7.2
SAR	2.41	2.85
Ca^{2+} (mg/L)	424	246
Na^+ (mg/L)	175	194
Mg^{2+} (mg/L)	84	63
K^+ (mg/L)	10	15
Cl^- (mg/L)	470	295

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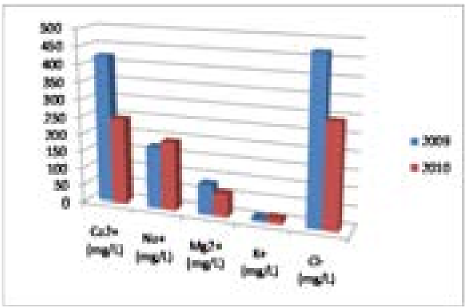


Soil sampling was performed on 23 April, 14 May, 21 June, 20 July and 30 August 2010. During each sampling campaign five (5) samples were obtained at close intervals from soil depths 0-5 and 5-10 and three (3) samples from soil depths 10-15 and 15-20 using undisturbed sol cylinders. This procedure was conducted randomly at three points of the study field. Consequently, a total of sixteen (16) samples were obtained from soil layers 0-5, 5-10, 10-15 and 15-20 cm (Fig. 2). At the same locations grab samples were obtained from deeper soil layers 40-50 and 60-70 cm using a hand auger. The soil samples were emptied into plastic bags, sealed, and transported to the laboratory.

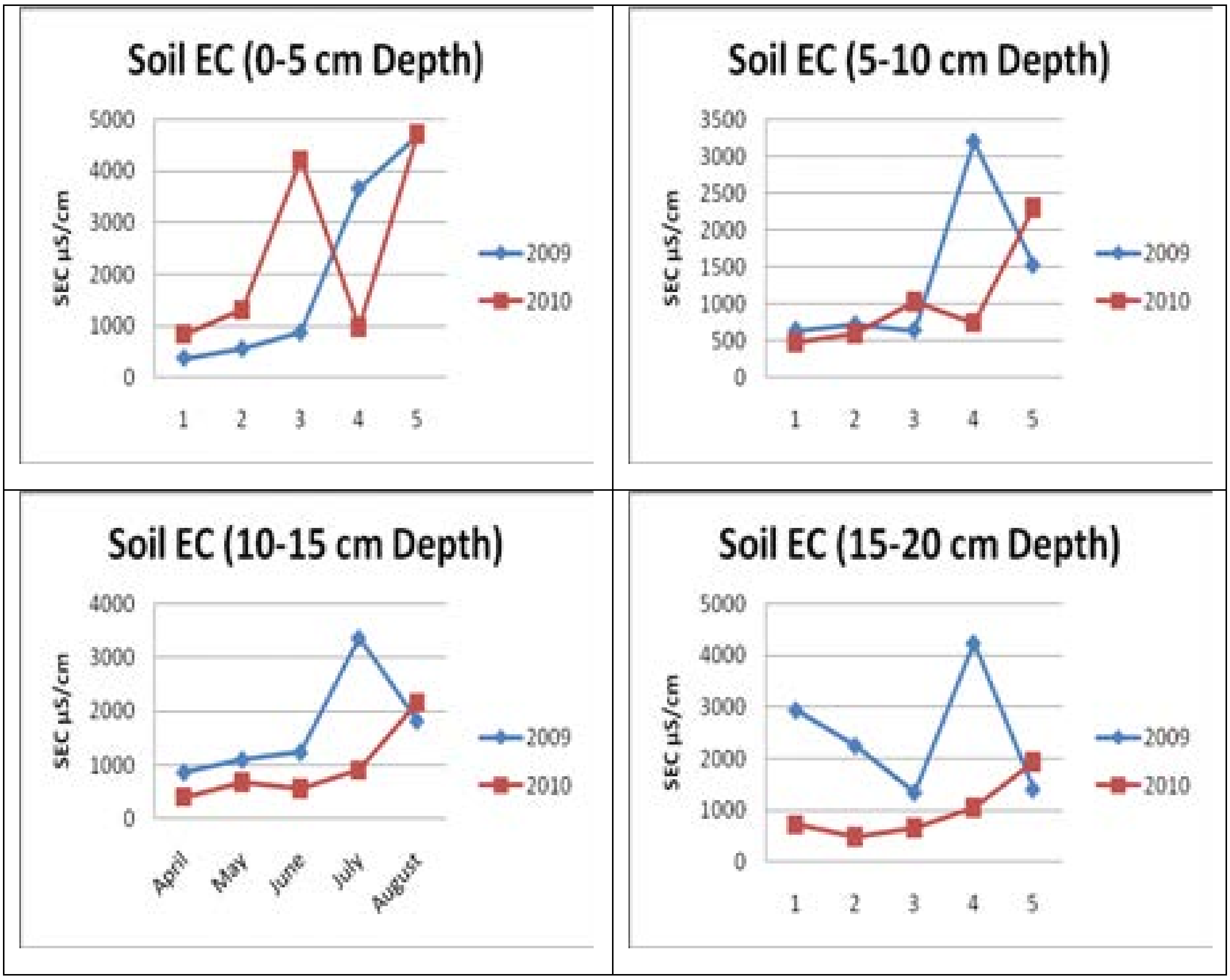
Fig. 2. Soil sampling.

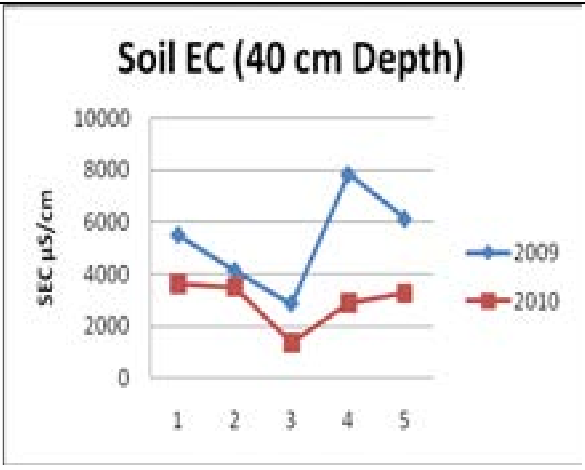
In the laboratory, field moist samples were weighed and subsequently air-dried for a period of approximately 7 days, until the weight was stabilized. The air-dried samples were weighed again the soil moisture content and dry bulk density were calculated. Accordingly, the pH and the EC of the soil determined according to standard procedures (1 part distilled water/1 part soil) (Richards, 1975). The liquid from the 1:1 paste was removed by filtration and chemical analysis was performed according to APHA (1998) (Fig. 3).

Fig. 3. Preparation of the samples for analysis.

In the next tables all the comparisons between year 2009 and 2010 results are depicted.

Table 3. Soil EC/Depth/Study year





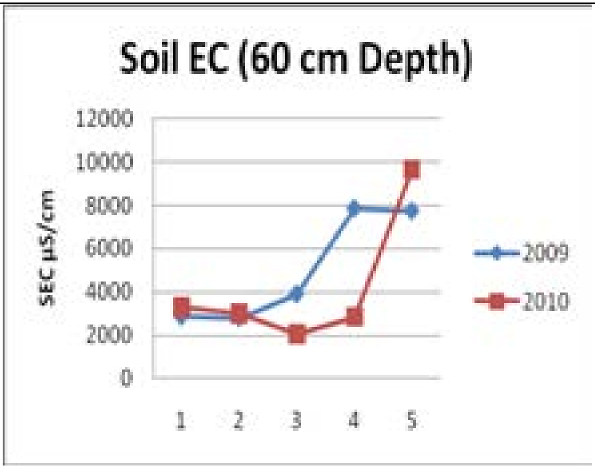
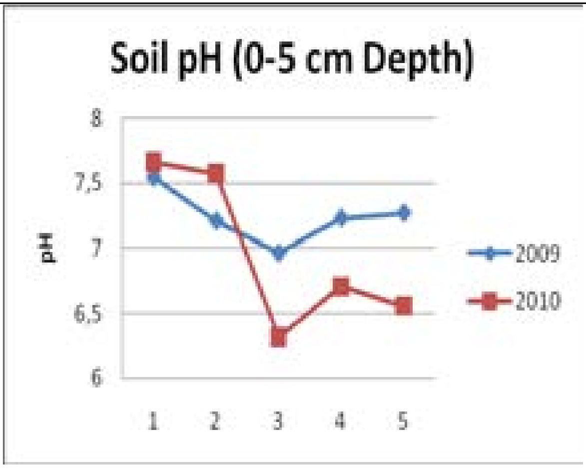
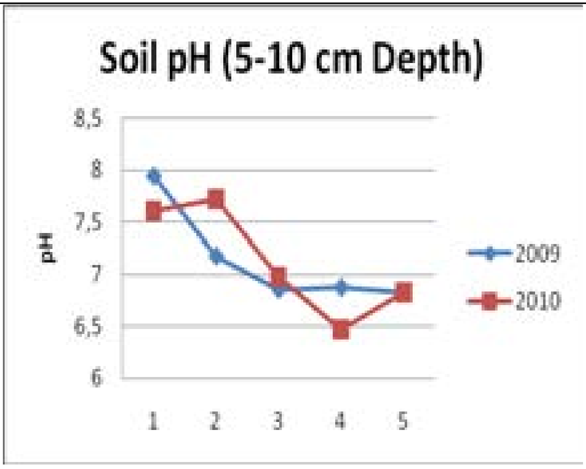
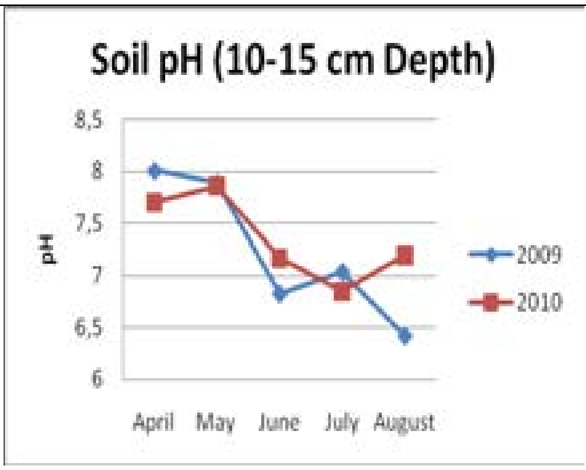
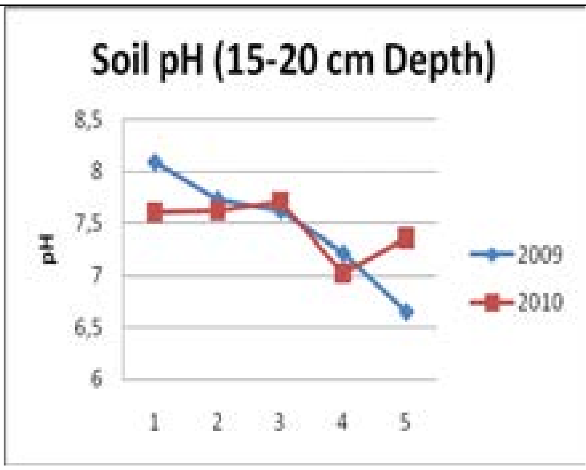


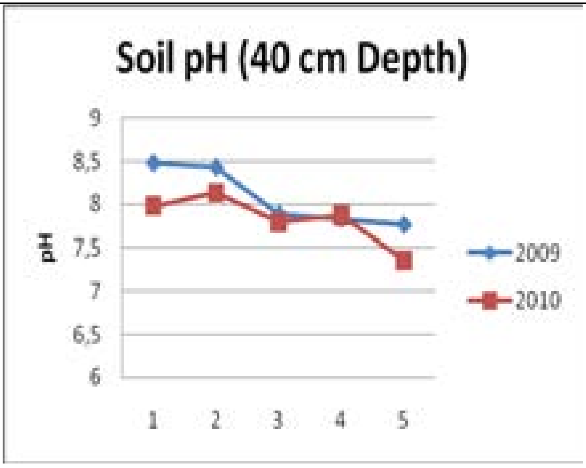
Table 4. Soil pH/Depth/Study year











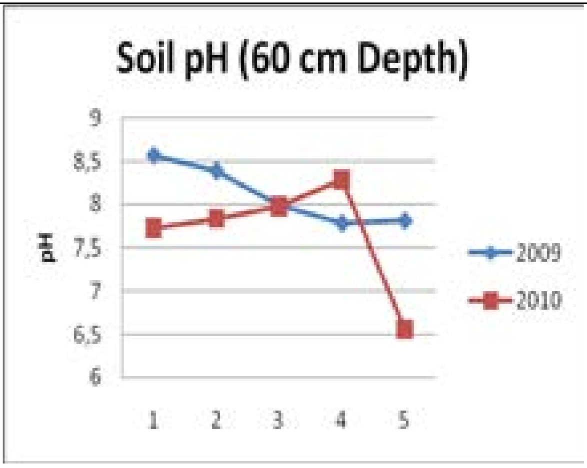
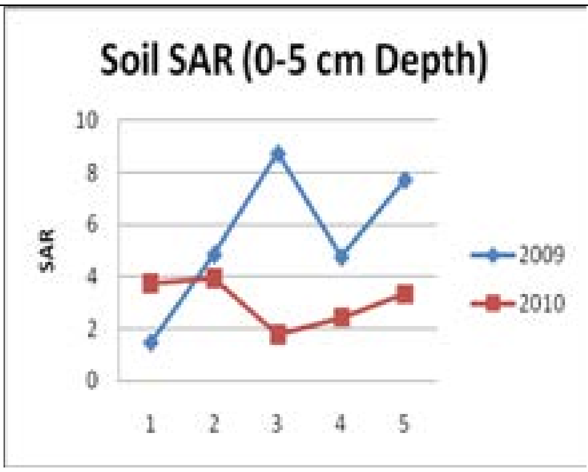
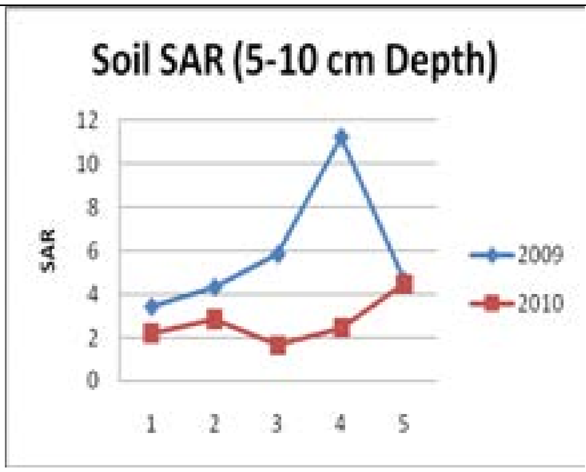
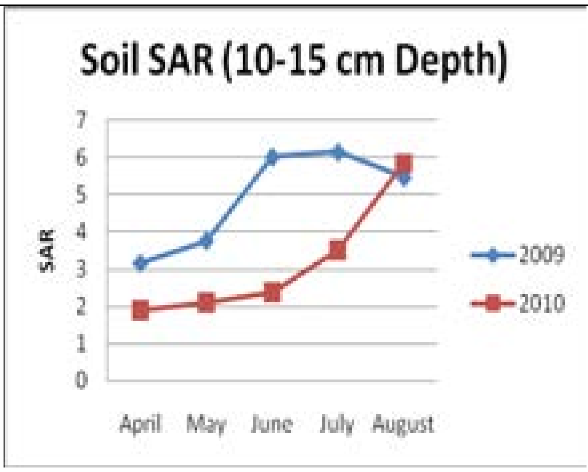
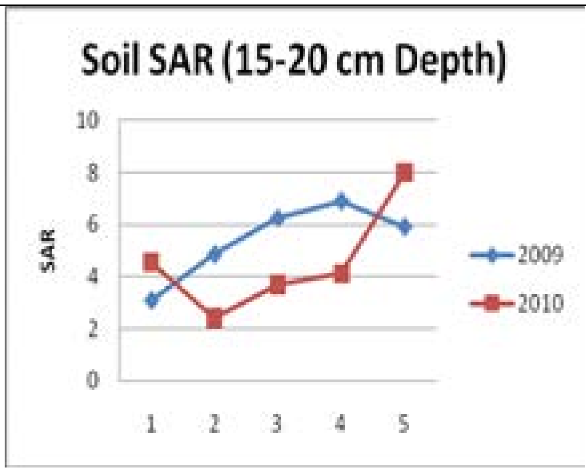


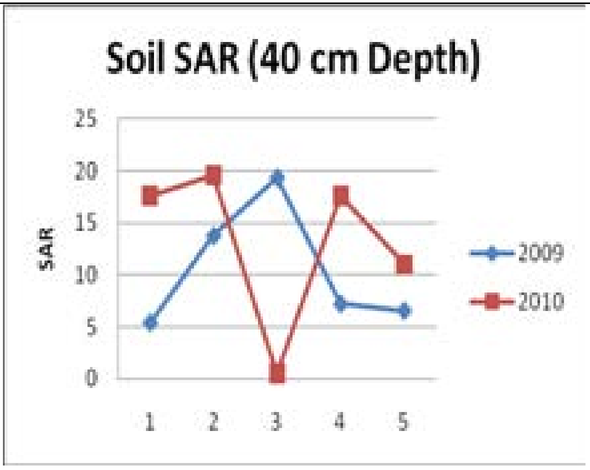
Table 5. Soil SAR/Depth/Study year











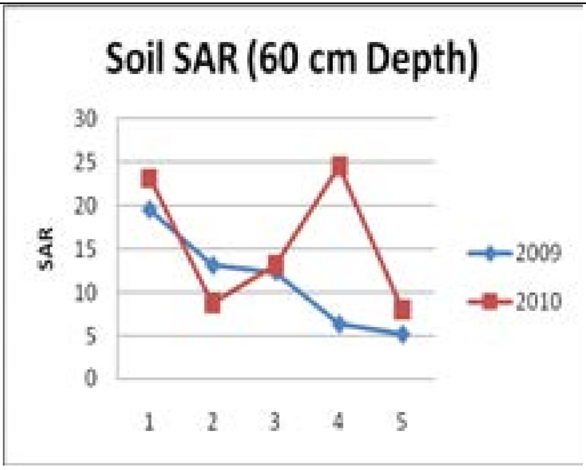
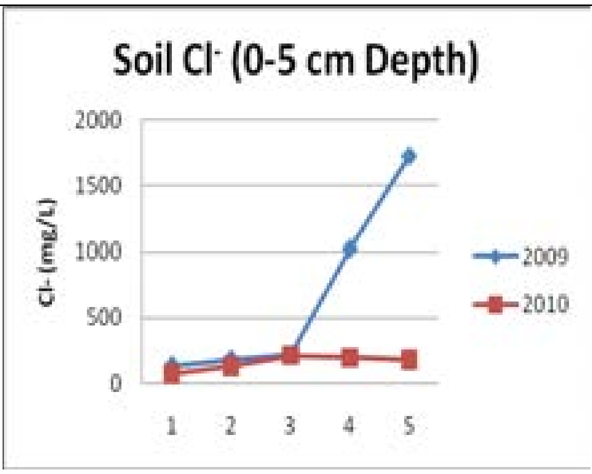
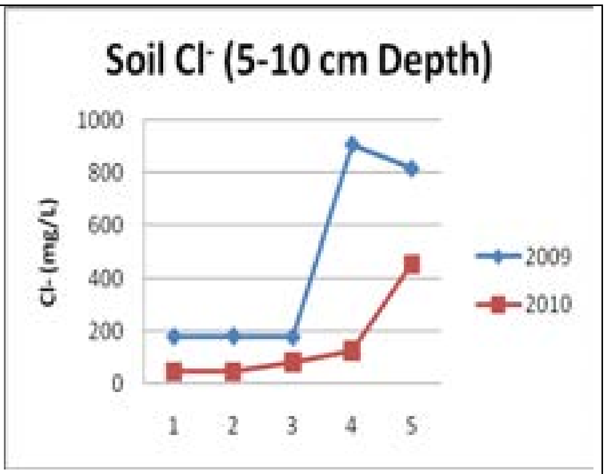
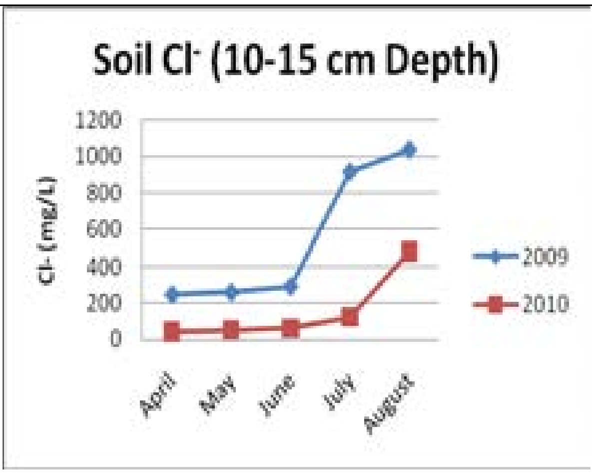
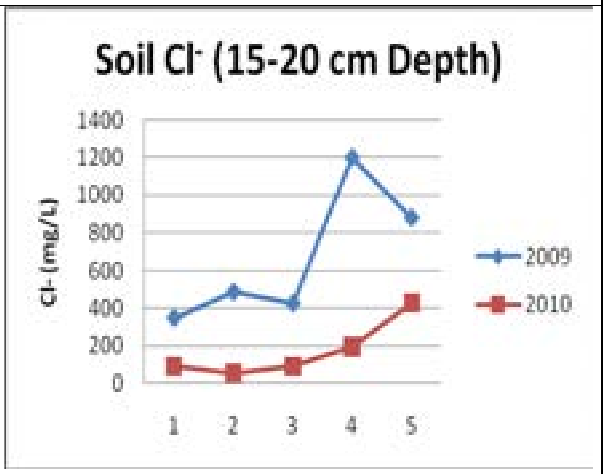


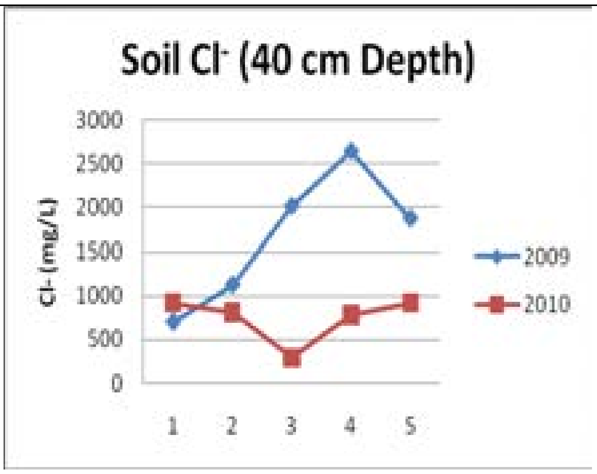
Table 6. Soil Cl⁻/Depth/Study year

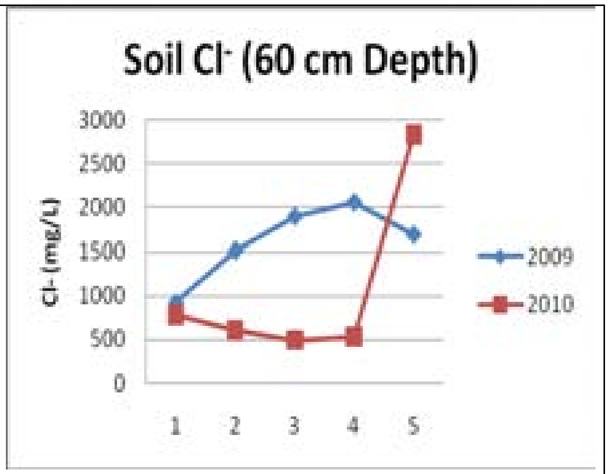












To conclude, from all the above charts it is clear that the overall improved irrigation water quality seems to have a positive impact on almost all parameters and layers.

4.4 Involvement of stakeholders

All groups of stakeholders were interested in the results of freshwater transport technology, especially farmers. Many more farmers are now seeking funding for applying freshwater irrigation, throw water transport from the nearby stream or from deeper boreholes, which are located northern from the study area.

All stakeholders expect the transport of fresh water to take place from the nearby river Nestos when some environmental protection issues are resolved.

Fig. 4. In situ discussions with stakeholder/farmer

4.5 Discussion and conclusions

Even throw it wasn't feasible to use fresh surface water, the overall improved irrigation water quality seems to have a positive impact on the yield. The benefits on the yield should have been better if surface fresh water had been used.

The reactions of stakeholders were very positive and they were keen on implementing the technology if financial aid is given.

All stakeholders expect the transport of fresh water to take place from the nearby river Nestos when some environmental protection issues are resolved.

The technology of fresh water transport is simple and easy to use. It is applicable to areas where the groundwater is saline due to various reasons.

The total application cost of this technology must be taken under serious consideration before implementation.

The only problem for the implementation of this technology is the increased cost of the whole construction (installation of underground water pipe system, electricity poles, electricity voltage transformer and the electrical pump).

5 TURKEY – KARAPINAR

Site coordination

Partner 10 - Eskisehir Osmangazi University (EOU)

5.1 INTRODUCTION

Karapınar area is the most arid part of Anatolia and still greatly suffers from wind erosion due to unfavored soil texture and meteorological conditions though intensive use of ground water resources. We designed an experimental setup in the strip farming plan to test the effect of wind erosion upon wheat crop (Ekiz bread wheat). Technologies applied are minimum tillage, ploughed stubble fallowing and stubble fallowing. Area of each technology is further divided into 4 parcels 2 of them are sowed this year with a left (i.e. fallowed) parcel in between.

The site is generally considered an area that is the most prone to the wind erosion in Turkey. But after the import of drilling technology by farmers of the region this problem in croplands are greatly reduced though the same problem still persists in very poor pasturelands.

The experimental plot area is very close to the Apak Yayla settlement. It is an irrigated cropland with low organic matter content and prone to wind erosion due to unfavorable texture of soil. Soils are typically thin (25-30 cm) and sand grade with very low clay and organic matter content. In a larger scale excessive groundwater exploitation forms another urgent problem. Earlier ground water well measurement showed that annual drop reaches 8-10 m. Farmers mostly prefer cereals, maize and sugar beet as irrigated crop types.

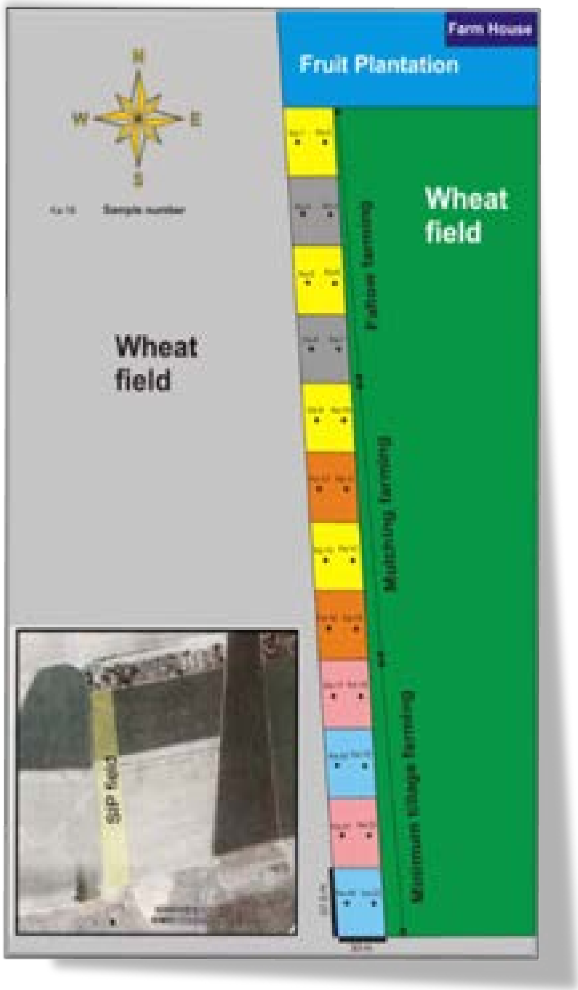


Figure 1: Implementation plan for the Karapınar hotspot.

5.2 TRIAL LAYOUT

Early (at the time of sprouting) and late (just before and after harvesting) vegetative observations were made to compare the effects of three technologies (minimum tillage (MT), stubble fallowing (SF) and ploughed stubble fallowing (PSF), all designed in strip farming plan) on the crop yield of Ekiz bread wheat (*Triticum aestivum* var. Ekiz). For this aim, we designated a trial plan seen at the right. It consists of three technologies. Each technology further includes four rows of parcels perpendicular to the dominant wind direction, one is active this year and other is kept fallow.

The following parameters were measured at the times indicated in the table below.

- Sprouting number /m^2 and branching number (in the early and late sprouting period)
- Grain yield, number of grains in ear, weight of 1000 grains, height of plant, harvesting index and # of grains in m^2 (in the harvesting period)

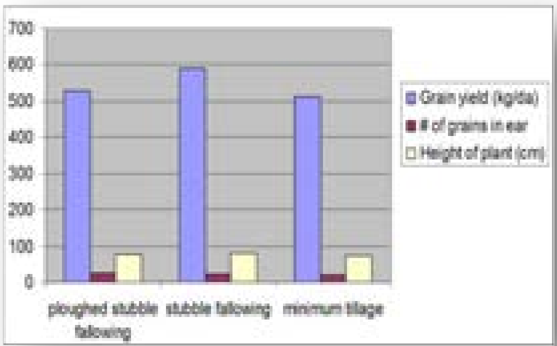
Observations are done on two different locations on each parcel and are averaged later.

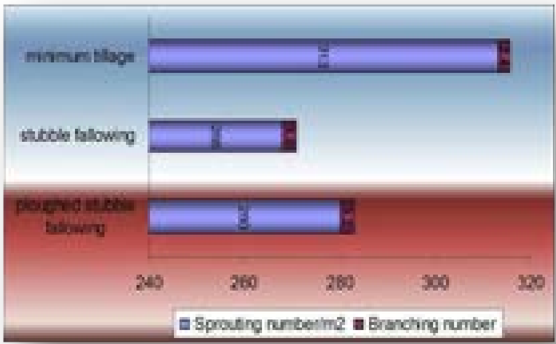
Table 1: Timing of observations in the Karapınar hotspot

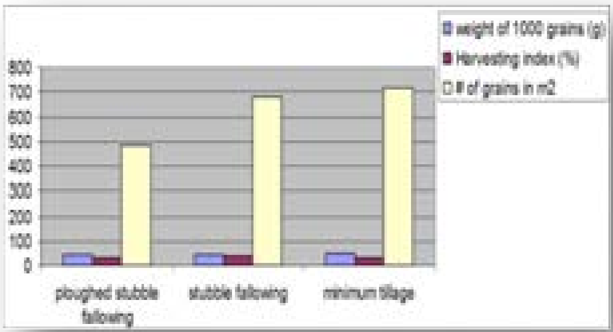
Time of measurement	Variable	2009	2010
Early and late sprouting period	Sprouting number/m2		
	Branching number		
Harvesting period	Grain yield		
	# of grains in ear		
	Weight of 1000 grains		
	Height of plant		
	Harvesting index		
	# of grains in m²		

5.3 Analysis and Results

Three technologies applied resulted in considerable variations in term of sprouting observations. Minimum tillage is the best in sprouting intensity while the ploughed stubble fallowing is optimum for both sprouting intensity and branching number.







Grain yield and height of plant is the best for stubble fallowing while the number of grains in ear and weight of 1000 grains do not considerably vary.

In terms of harvesting index and number of grains in m^2, minimum tillage and stubble fallowing have clear advantages upon ploughed stubble fallowing.

Figure 2: Change of various vegetation parameters through the observation period.

A brief socio-economic analysis of the applied technologies is also carried out. The basic spending is directly related with the agricultural activities such as ploughing, fertilizing etc., since none of the technologies requires pre-investment (Table 2). Since the plot sizes are equal, the expenditures are also equal.

Table 2: Details of spending for each technology

Date	Activity*	Input	Quantity	Unit	Total costs (local currency)	% borne by land user**
10/10/2009	Ploughing	Oil, machinary, manpower		ha	400	100
10/10/2009	Sowing	Oil, machine, seed		ha	200	100
25/02/2010 30/03/2010	Fertilising	DAP	200	kg	140	100
		Humic acid	100	kg	300	100
		Sulfur	100	kg	100	100
		Urea	150	kg	105	100
		Amonia nitrate	200	kg	120	100
		Zinc sulfate	20	kg	40	100
		Liquid humic acid	5	lt	25	100
		Oil, manpower			200	100
30/11/2009	Weed control	Pesticides			30	100
		manpower			70	100
15/04/2010 15/05/2010	Irrigation	Electricity, manpower			250	100
08/07/2010	Harvesting	Combine harvester	1	machine	80	100
15/07/2010	**Transport to the market**	**Truck renting**	**1**	**truck**	**150**	**100**

Table 3: Productivity and outcomes of each technology applied (plot area for each technology=0.45 ha).

Harvest/collection date	Output (product)	Quality (grade)	Quantity	Unit	Qty sold	Unit	Unit price (local currency)
08/07/2010	wheat (minimum tillage)	%15	512	Kg	512	Kg	0,5 TL/kg
	wheat (stubble fallowing)	%15	590	Kg	590	Kg	0,5 TL/kg
	wheat (ploughed stubble fallowing)	%15	529	Kg	529	Kg	0,5 TL/kg
	Straw (minimum tillage)		1100	Kg	1100	Kg	0,1 Tl/kg
	Straw (stubble fallowing)		1200	Kg	1200	Kg	0,1 Tl/kg
	Straw (ploughed stubble fallowing)		**1150**	Kg	**1150**	Kg	0,1 Tl/kg

Incomes are two types, grains and straw whose amount vary significantly according to technology applied (Table 3). Stubble fallowing (mulching) yields the maximum amount of grains as well as the straw, while the minimum tillage produced the minimum values for both parameters.

From the viewpoint of net economic income, the Stubble farming has clear advantage compared to other technologies (Table 4) with a net income of %44. The other two technologies are close to each other.

Table 4: Comparison of net income rates of various technologies applied (fallowed parcels considered).

Technology	Spending's (TL/per ha)	Outcome (TL/per ha)	Net outcome rate (%)
Minimum tillage	736	813	9.4
Stuble farming	736	922	20.1
Ploughed stuble farming	736	843	12.7

5.4 Involvement of stakeholders

Stakeholders participated as observers in the division of the area into technology parcels and the ploughing and sowing operations. We discussed all together about the presumed efficacy of technologies applied in the field. The owner of the field where experiment was carried out executed himself the agricultural activities (ploughing, fertilizing, etc.) throughout the season.

Stakeholders generally approve the effectiveness of the technologies tested but think that fallowed parcels between the ploughed and sowed fields radically decrease the benefits of technologies.

Figure 3: DESIRE experts are discussing the advantages of different technologies applied with two stakeholders.

5.5 DISCUSSION AND CONCLUSIONS

▸ Minimum tillage and stubble fallowing have clear advantages in terms of crop yield of the Ekiz bread wheat in Karapınar hotspot. Minimum tillage has positive effects on the sprouting intensity but not the branching number.

▸ The variations in yield parameters is probably explained in terms of removal of nutrient topsoil by wind erosion. It seems that minimum tillage and stubble fallowing decrease the shear stress of the wind and hence reduce the wind erosion.

▸ Contrary to vegetative parameters, the harvested product (both for grains and straw) is the maximum in stubble farming followed by ploughed stubble farming.

▸ Basic obstacles for wider application of technologies are the lack of specialized machinery and required knowledge for minimum tillage and the decrease of net income due to fallowed parcel each year.

6 TURKEY - ESKİŞEHİR

6.1 SITE INFORMATION

Since the area is situated in the mountainous northern part of the Eskisehir hotspot where slope gradients and precipitation are relatively high compared to elsewhere, our basic goal here is to decrease water erosion. Due to the long-lasting nature of this problem together with non-existence of any previous prevention initiative, soil profiles are thin, stoniness is high and organic matter content is low. Dry-farming fields in vicinity are exhibiting severe rill erosion which has been facilitated by further wrong practices such as slope parallel and abnormally deep ploughing.

The experimental plots are situated in a south-facing relatively steep (15-20 %) slope which is separated by some dry valleys. Downstream, similar fields are extending while upstream a road is cutting through all fields perpendicular to slope to form a natural terrace (see photo below). Rill activity in the selected field in vicinity is salient although deep ploughing partially masks it.

6.2 INTRODUCTION

Widespread hillslope fields in the Eskişehir area with a semi-arid climatic setting suffer from water erosion. We divided the SIP area into 3 parts, one is non-technology, i.e. downslope ploughing, and others are contour ploughing and terracing (contour ploughed). Terraces constructed in the fall 2009, are made up of wooden poles woven by thiny plant branches and supported by earth. The width and length of terraces are 30 m and 60 m respectively. There are 6 individual terraces constructed on the hillslope.

6.3 TRIAL LAYOUT

Two technologies and a control field are investigated in terms of water retention and crop quality in the cropping season between December 2009 and July 2010. Water content (WC) and electrical conductivity (EC) of the soils are positively affected after the spring rainfalls but not before this time. Contour ploughing resulted the most water content followed by terracing. With respect to germination rate, terracing is the best technology followed by contour ploughing. Although the evaluation of growth data belonging to 3 different periods is not terminated, it can be qualitatively stated that both technologies positively affect growth quality too.

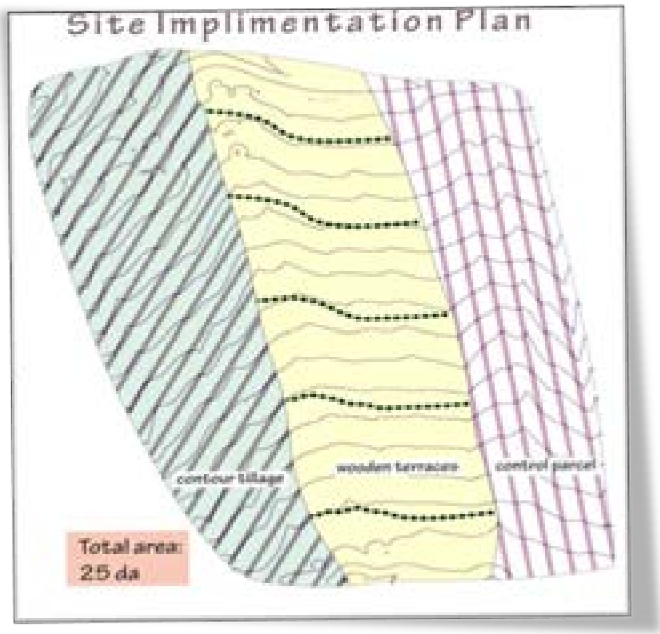
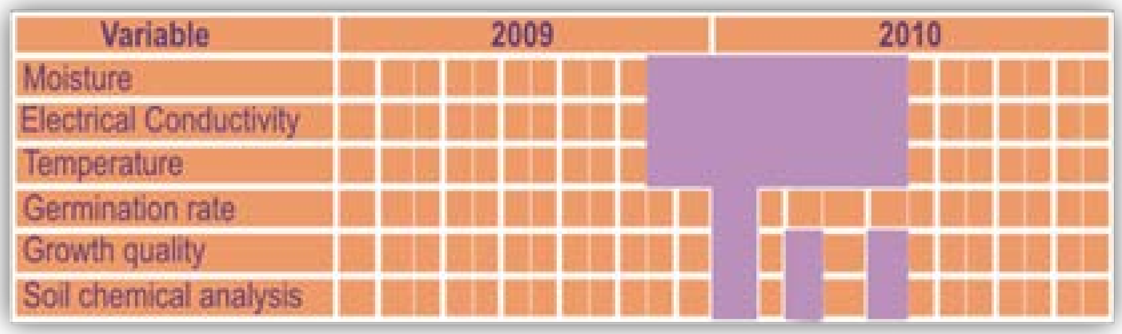


Figure 1: Implementation plan for the Eskişehir hotspot.

Throughout the growing season we made TDR measurements (Water Content, Electrical Conductivity and Temperature), germination and growth quality observations (table 1).TDR measurements are made by a portable instrument at pre-defined locations of enough number (12 measurements for each technology) and representativeness. Germination rate is determined by counting the individual sprouts in m^2 one time within January in the early sprouting period. Growth quality assessment was made as length and weight measurements of the crop (barley) in three different periods through the growing season (table 1).

Table 1: Timing of the observations in the Eskişehir hotspot



6.4 Analysis and Results

Water content (WC) and Electrical Conductivity (EC) of the soils significantly vary according to the different technologies applied in a similar way. Between December 2009 and March 2010, measurements in control parcel surprisingly yield higher WC probably due to less effective germination of the barley seeds underneath the soil. During and after the sprouting period (early Spring afterward) technologies begin to show effect so that the Contour Ploughing is the best and Terracing is significantly better compared to control parcel. In terms of EC measurements, results are similar but less significant. Germination rate measurements show distinct variation according to technologies applied. Sprouting is the most in terraced area followed by contour ploughing.

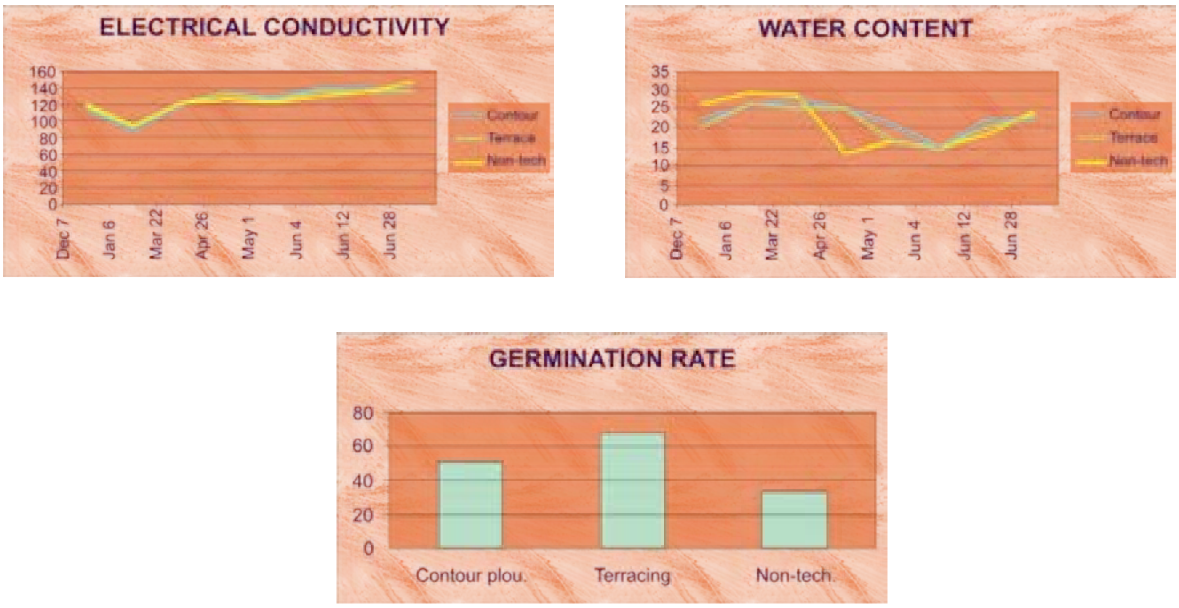


Figure 2: Change of electrical conductivity, water content and germination rates through the observation period.

We also made a brief socio-economic analysis of the technologies including spending and outcomes. Cost of agricultural activities as well as the investment of the technologies are summarized in the table below. They comprise terrace construction (the basic cost), cultivation, fertilization and other secondary spending's related to harvesting . Except the cost of terrace construction, all other expenditures were done by the farmer himself.

Table 2: Expenditures made in the cropping period 2009-2010

Date	activity	input	quantity	Unit	Total cost(local currency)	% borne by land user
15/10/2009	Terrace construction	Wood, manpower	300	M	2500	0
25/10/2009	Cultivation	Fertilizer (20-20-0 NPK composed)	255	Kg	166	100
		Fuel	17	Lt	51	100
		Seed	544	Kg	208	100
10/3/2010	Fertilizing	Fertiliser (%26 NH4NO3)	255	Kg	102	100
		Fuel	0.5	Lt	25	100
10/4/2010	Herbicide	Herbicide	17	Gr	7	100
		Fuel	0.5	Lt	25	100
07/07/2010	Harvesting	Combine harvester	1	Machine	119	100
07/07/2010	Transport to market	Truck renting	1	Truck	90	100

Incomes are calculated according to technologies and shown below. It is obvious that terraced (also contour ploughed) plot has the maximum productivity followed by contour tillage technology. In the evaluation of the outcome Fig.s, the inequality of the surface area of the each technology should be regarded.

Table 4: Outcomes of each technology applied

Harvest date	Output (product)	Area (ha)	Quality (grade)	Quantity	Unit	Income	Unit	Unit price (local currency)
07/07/2010	Barley (Terraces)	1.15	%12	1900	kg	730	tl	0.384 tl/kg
	Barley (cont. till.)	0.82	%12	620	kg	238	tl	0.384 tl/kg
	Barley (control)	0.8	%12	300	kg	115	tl	0.384 tl/kg

The table below compares the amount of incomes and spending for each technology. It can be concluded that the benefits of of terracing is outpacing the other technologies, but the construction of terraces requires significant investment.

Table 5: Comparison of incomes and spending for each technology applied

Technology	investment (per ha)		Income (per ha)
Terracing and contour tillage	Construction	2500	634
	cropping	286	
Contour tillage	cropping	286	290
Control plot	cropping	286	144

6.5 INVOLVEMENT OF STAKEHOLDER

Stakeholders were passively involved in the construction of wooden terraces as observer. We discussed all together about the presumed efficacy of technologies applied in the field. The owner of the field where experiment took place and several other stakeholders were actively involved in the agricultural activities (ploughing, fertilizing, etc.) throughout the cropping season. The Stakeholders think the effectiveness of the applied technologies is decreased due to low rainfall rates during the last growing season.

Figure 3: One of the project experts is discussing with a stakeholder about the effectiveness of the terraces.

6.6 Discussion and conclusions

This experimental season is generally suitable for trial except the lack of fallow. This causes significant decrease in productivity due to limited water content of the soil. But the present data allow us a comparison of technology efficiencies.

▸Two technologies applied caused better soil and crop growth parameters as well as increased yield benefits. It is suggested that terracing increased water content of soil by decreasing runoff distance. Results showed that contour ploughing is also effective in similar way.
▸ Considering the fact that the cost involved in terracing and particularly the contour ploughing is relatively small, productivity is substantially very high. For this reason, these technologies are applicable in wider hillslope areas of semi-arid Central Anatolia.
▸ Main bottleneck in front of easy application of technologies seems sociological (lack of enough young farmers) and economic (prices etc.) rather than scientific.

7 MOROCCO - SEHOUL REGION

Site coordinator

Partner 11 - University of Mohamed V, UNESCO Chair (UM)

Also cooperating (PhD)

Partner 21 - Faculty of Geoinformation Sciences and Earth Observation, University of Twente, The Netherlands

7.1 INTRODUCTION

The Sehoul region is located under sub-humid to semi-arid conditions; it is on the border of a cork oak forest, which means a quite stable environment. The area is affected by desertification due to many reasons as follows:
The cork oak forest is in a poor condition, due to overgrazing, wood cutting, forest diseases and climate change impacts on regeneration.

- The cities' growth and the need for space for activities and transport.
- The increasing pressure over the natural resources, namely soil and water posed by more intense agriculture systems, which are adopted to answer to the proximity of the Rabat-Salé urban market needs.
- The soil is a made of a thick sandy leached horizon, which corresponds to old dunes developed in the region during a dry period of the upper Pleistocene; the humid conditions of the Holocene permitted the forest growth and the surface stabilisation; the current retreat of the forest creates again conditions for desertification, with the appearance of local dunes in the places affected.
- The deficit of water and the competition between agriculture, urbanization and tourism on this resource.

The existing agro-system in the Sehoul region is often inefficient and the Sehoul environment is characterized by soil erosion and land degradation, with spatial differentiation in term of processes. Following the Wocat workshops and the assessment with the Wocat tools, the choice was for implementing experiments in order to improve the annual cultivations and restore the badlands. The objective is to conserve the agro-pastoral tradition, to improve the yield and the farmers income and to mitigate the degradation processes.

The main objective is to identify existing and new strategies, capable to prevent or mitigate land degradation and to experiment those strategies with some required techniques of measurement, in order to be able, after some years of experimentation to assure for these successful strategies a high and fast rate of dissemination among local stakeholders. The field work programmed for the monitoring of these techniques and approaches aims to determine their efficiency, in term of land degradation mitigation, social benefits and farm’s yield increase.

7.2 TRIAL LAYOUT

Two experiments were carried out: one experiment was for stabilizing the gullies and the other one for improving the soil condition. They are described as follows:

Experiment A

Experiment was carried out to protect slopes affected by gullies and rills by planting fodder trees (A*triplex*). The objective is to demonstrate that the grazing areas can be more productive (with a higher biodiversity) and at the same time less eroded if the soil cover is protected and improved.

Experimental plot of land of 5000 m^2 was selected corresponding to an ancient fallow land which became gullied. The plot of land was planted by A*triplex halimus* and was put under fencing since April, 2009. The plantation was made in strips of 6m of distance with an objective to stabilize ravines and restore the biodiversity. The density of the plantation is 760 plants / ha which has a success rate of growth of 89,5%. The plot was irrigated every 20 days during the early stages of the plants.

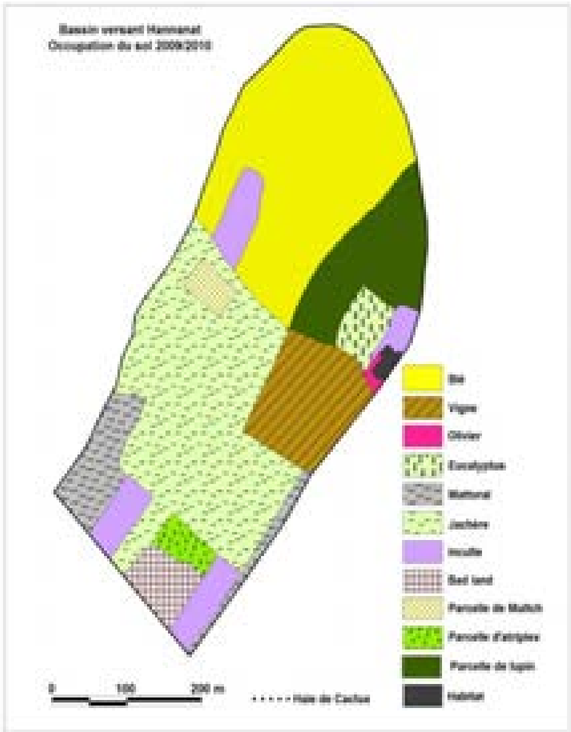
We chose *Atriplex halimus*, because it is adapted to this environment of scrawny grounds. It is the fodder shrub which tolerates well the conditions of aridity of the ground and which can contribute to the valuation of the marginal and degraded grounds and to the improvement of the vegetable and animal productions in deprived regions. The plant possesses a system of roots very developed which allows it to use the water supply of the ground and to form a dense network retaining the soil.

- The *Atriplex* plants were brought from a tree nursery of the region of Bni Mellal
- digging of holes of plantation
- organized by a metallic fence
- plantation of shrubs
- irrigation in the pipe from a tank, every 20 days, in June, July and August
- the stake it defense is going to continue 2 years.

The monitoring concerned several parameters:
- the covering of the herbaceous vegetation, its biomass and the floristic biodiversity,
- evaluation of the fodder production : mineral part, organic part, fat, nitrogen matter, cellulose, and digestibility in vitro of the organic matter;
- soil state surface: soil moisture, resistance to penetration, cohesion, rate of pebbles on the surface and of the encrusted parts.
- Observations on the gullies transversal profile and on the steepness of the banks.

Experiment B

Experiment was carried out to improve soil condition on steep slopes under cultivations using minimum tillage with crop residues from previous harvest. The main objective is to reduce evaporation and the soil disturbance by animal grazing. The experiment was carried out on a field of size 500m^2, with the aim of a better management of the lands.



Time graph of measurements:

Variable	2008	2009	2010
Meteo	<--	----------------	-----------------
Discharge		----------------	-----------------
Vegetation		----	----------
Soil Moisture		------	--------
Soil properties		------	--------
Yield			x

7.3 Analysis and Results

7.3.1 Treatment of gullies by plantation of Atriplex

The results of the monitoring during one year show that the planting of Atriplex helps in the stabilization of gullies. It has several advantages:

- Increase of the covering rate by herbaceous plants and of the degree of the soil protection; the rate of surface covered by herbaceous increases from 57% in the eroded fields to 87% in the planted plot, during spring.
- Improvement of the quality of the herbaceous vegetation, with an increase of the permanent species, 3 times, after one year.
- Improvement of the floristic biodiversity: in the *Atriplex* plot, the number of species is 2 times the one in the non-protected slopes. The *Atriplex* plot under fencing is recorded with high number of plant species (27 species) in spring, 2010 against only 10 species in fallow land.
- Increase of the vegetation biomass: the total palatable biomass has increased from 360 kg/ha to 1235, after management.
- Improvement of the quality of fodder: the rate of nitrogen matter increased from 34 to 190 kg/ha and the rate of cellulose from 63 to 211 kg/ha.

- Increase of the fodder production, from 127 fodder units per ha to 694, which represents a rate of 72%.
- Improvement of the soil surface. In the atriplex plot a higher soil moisture is recorded than in the non-protected slopes. Also soil compaction and cohesion are reduced in the atriplex plot.
- The observations made during the intense episodes of rain in 2010 show that in the *atriplex* plot more rain is infiltrated into the soil resulting in less runoff. This process appears through the profiles of the gullies which already show less steepness and more sharp banks.

The planted slope compared to the land in fallow on the other side of the basin

Atriplex plantation offers a good opportunity for both fodder production and soil conservation. The main factor responsible of this trend is the plot fencing during the phase of atriplex growing and herbaceous recovering. Less animal pressure on the vegetation cover and on the soil is then the solution for stabilization of gullies and for ecosystem stability. Once the gullies are stabilized less water will arrive downstream in the main channel, which will decrease the risks of dissection and the risks of siltation in the SMBA dam down the slope.

Economic analysis

Inputs/ha	Moroccan currency (Dh)	Outputs /ha	Moroccan currency (Dh)	
Plants	-4500	Fodder yield 1rst year	0	
Holes	-9000	Improve in site	1500	
Fence	-6520	Improve downstream	1500	
Irrigation	-8000	Total outputs 1rst year	3000	
1rst year balance	- 28020		6000	-22020
2nd year		Fodder + ecosystem services	4500	-17520
3rd year		Fodder + ecosystem services	4500	-13020
4th year		Fodder + ecosystem services	6000	-7020

7.3.2 Soil improvement by mulching and minimum tillage

The practice contributes in:

- restoring the plant covering of grounds and their biological activity, in particular the microorganisms and the fauna of grounds.
- restoring soil condition in particular their structure and their capacity to store water, thanks to the improvement of their surface state and thus by increasing their infiltration capacity.

The experiment was carried out using three plots:

1 - A field used as a fallow plot which is grazed after crop harvest and also grazed in the year which follows.

2 - A field which is fenced after crop harvest and which is cultivated in conventional plowing by the tractor, along the contour lines in December, 2009;

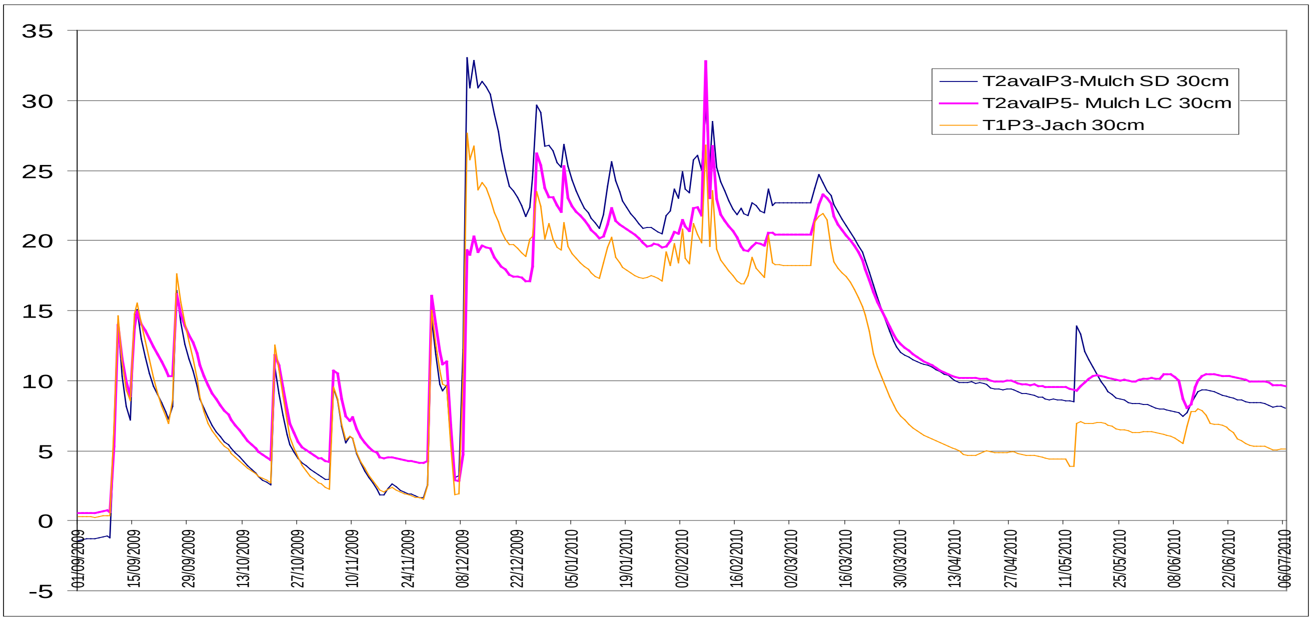
3 - A 3rd field which is fenced after crop harvest and which is with minimum tillage and with the application of a grass herbicide in December, 2009. The seeds were sown directly using a seed drill with animal harness. Unfortunately all the seeds could not be sown due to shallow soil (rocky ground) and the exposed seeds were consumed by migratory birds. Nevertheless, the harvest was better in the portion of the direct sowing, not consumed by birds, compared with the result of the conventional plowing.


Herbicide in December

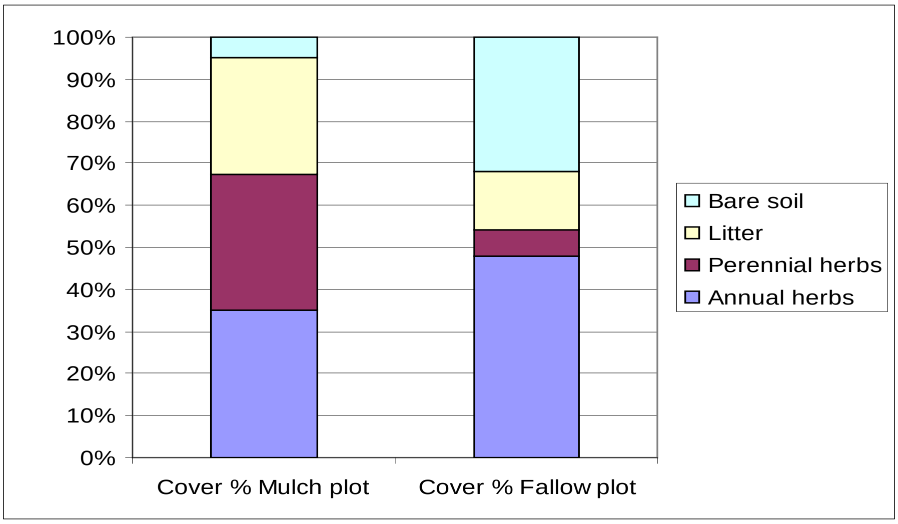

Direct seeding


A weak result in spring


A yield of about 5.4 qx/ha



A better evolution of soil moisture I, the mulch – direct seeding field compared to the grazed fields and to the conventional tillage (measurements by TDR fixed in the soil at 30cm depth for the whole rainy season).



Types of soil surface cover in the mulch plot and in the grazed fallow field

7.4 Involvement of stakeholder

The involvement of farmers was promising during the workshops organized in 2007 and 2008. But we observed much less enthusiasm when we proposed to install experiments in the field.

The involvement of technicians (Agriculture and forests) was very weak during all the phases. There is a pessimistic perception due to precedent failures.

To solve the situation a contract was made with a farmer, against incentives and financial support, to be able to install experiments in the field.

Waiting for real benefits in term of yield and fodder, the farmers are more in a position of spectator, than a position of facilitating the dissemination of ideas and experiences.

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8 TUNESIA - ZEUSS KOUTINE

Site coordination:
Partner 12 - Institut des Regions Arides (IRA)
In collaboration with Partner 14 – Wageningen University

8.1 INTRODUCTION

The rapid and remarkable evolutions of the production systems and natural resource exploitation increased with the exploitation of groundwater aquifers by drillings and fast extension of fruit trees orchards at the expense of natural grazing lands after the privatization of collective tribal lands. In this context, the spatial agrarian system complementarily disappeared and replaced with other interconnected and adjacent production systems. Those systems are marked by a competition for the access to the natural resources, especially for land ownership and water use. In addition, climate variability and climate change will add other constraints for the already vulnerable eco and agro-systems.

The selected monitoring sites represent the main encountered problems in the region namely: water scarcity and rangeland degradation. Water harvesting techniques (Jessour and Tabias) are used for the improvement of water content of soil and thus evapotranspiration of plants and trees. Replenishment of groundwater aquifers are ensured through the recharge structures (gabion check dams and recharge wells). Rangeland degradation is cured using the rangeland resting techniques.

8.2 TRIAL LAYOUT

The monitoring at the level of the Jessour/Tabias concerned: First, the soil water content is determined monthly using the gravimetric methods at different soil depths: 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm (Fig. 1). Due to the lack of rainfall and with the help of DESIRE project, some farmers in the Lathmane site performed supplemental irrigation by supplying their olive trees with water during the month of March/April 2010. The water is brought in cisterns by tractors from the neighboring wells. And second, the olive leaf stomata conductance of the two main used varieties: Zarrazi and Chemlali using a Decagon promoter (Fig. 2). This monitoring started in 2009. The piezometric level of aquifers and rainfall were monitored by the Water resources division of the Ministry of Agriculture in Medenine since the nineties.

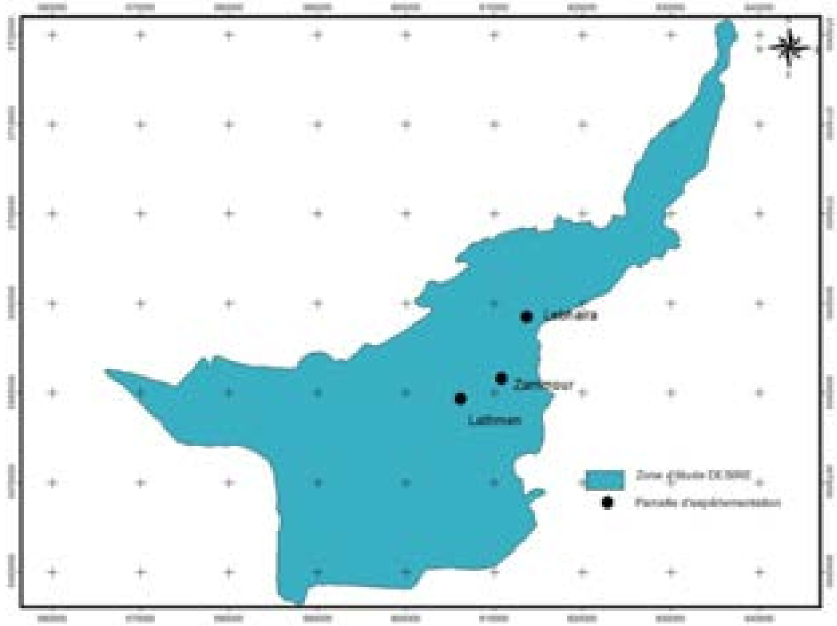


Fig. 1. Soil water monitoring sites.

Fig. 2. Soil water sampling (left) and leaf resistance measurement (right).

The resting technique activity was s carried out in three sites (Alamet Mechlouch, Beni Ghezaiel and Sidi Makhlouf) within four management modes: RK3: rested rangeland, RK2: moderately degraded rangeland, RK1: overgrazed rangeland, rk: abandoned cultivated rangeland. Several transects of 20 m long each, were established in the different representative plant communities of the target rangeland, and used to determine plant cover parameters according to the points-quadrats method .The monitoring concerned the evolution of some descriptors (global plant cover, specific frequencies, flora richness, the plant density and the range biomass production as well as the grazing capacity). The experiment was conducted during four years: spring 2007 (initial state), spring 2008, spring 2009 and spring 2010.

Fig. 3. Rested and overgrazed sites in the Stipa tenacissima rangelands (up) (3) and field monitoring measurements (bottom).

8.3 Analysis and Results

Soil water

The evolution of the soil water content in three sites is presented in Fig. 3.

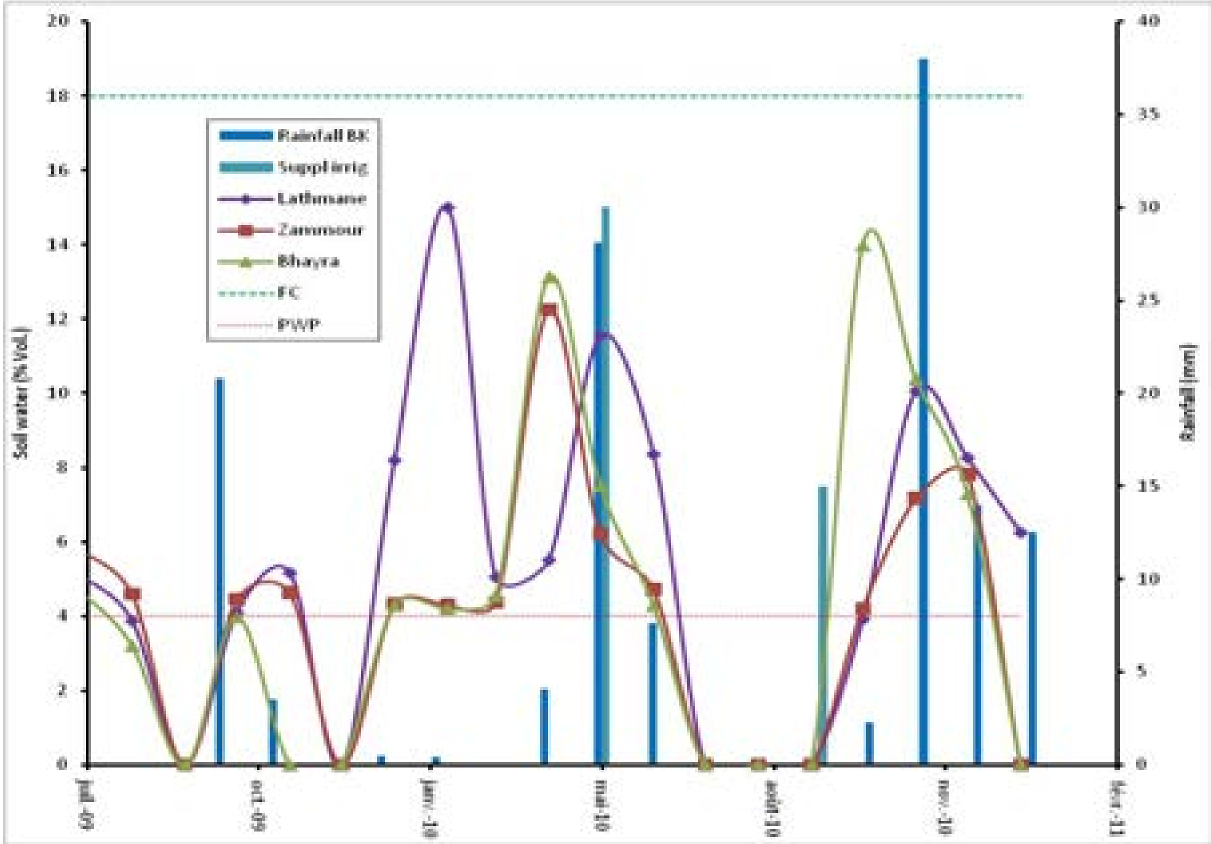


Fig. 3. Evolution of the soil water content in the monitoring sites.

The observation period, which lasted for almost one and half year, was exceptionally dry. In fact, the total recorded rainfall was 132 mm in Béni Khédache while the average annual rainfall is around 220 mm. Consequently, the soil water content was very low in the three sites especially during the summer time. In fact, it did never reach the FC.

However, it is important to mention that due to logistic difficulties (field visits) and the highly spatial variability of rainfall, the monitoring of soil water was not continuous which did not permit to the team to make the observation in the right time (after rainfall event or supplemental irrigation). On the other hand, many very localized rainfall events could not be recorded.

Therefore, a water balance modeling work is under way and the obtained measurements in addition to collection of informal observations from the farmers will serve as basis for calibration and validation.

Groundwater recharge

The evolution of the piezometric level and the pumping rate of the aquifer are shown in Fig. 4.

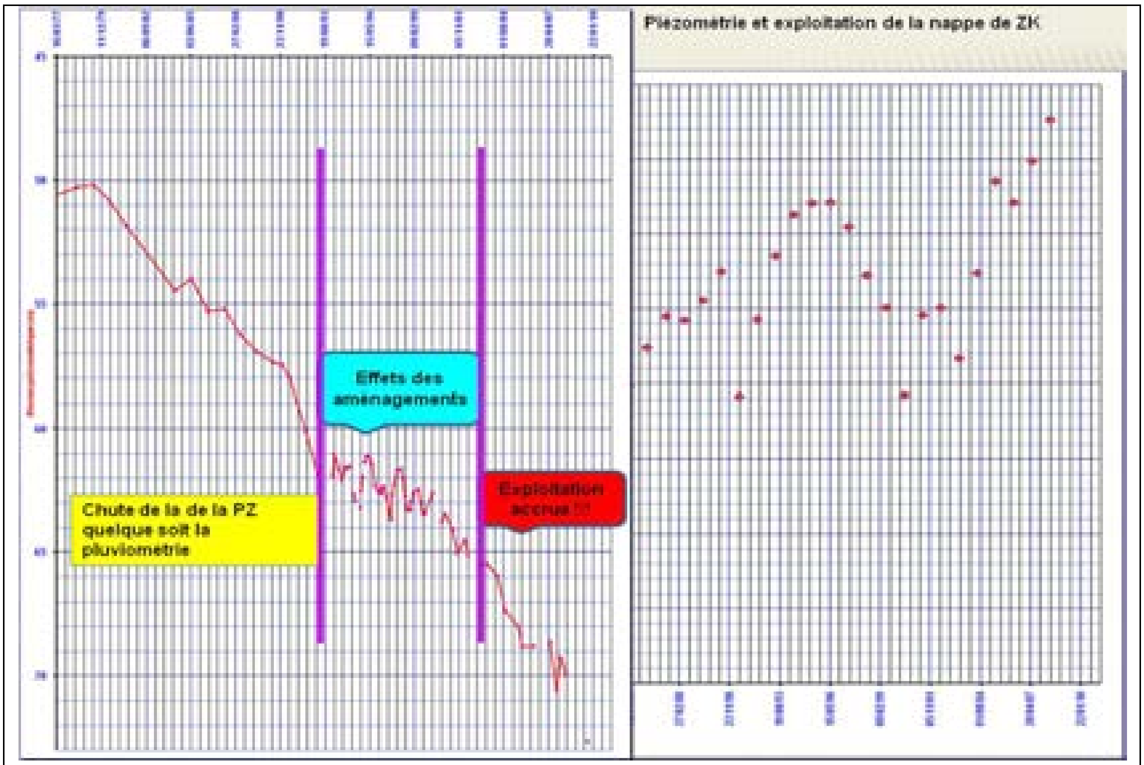
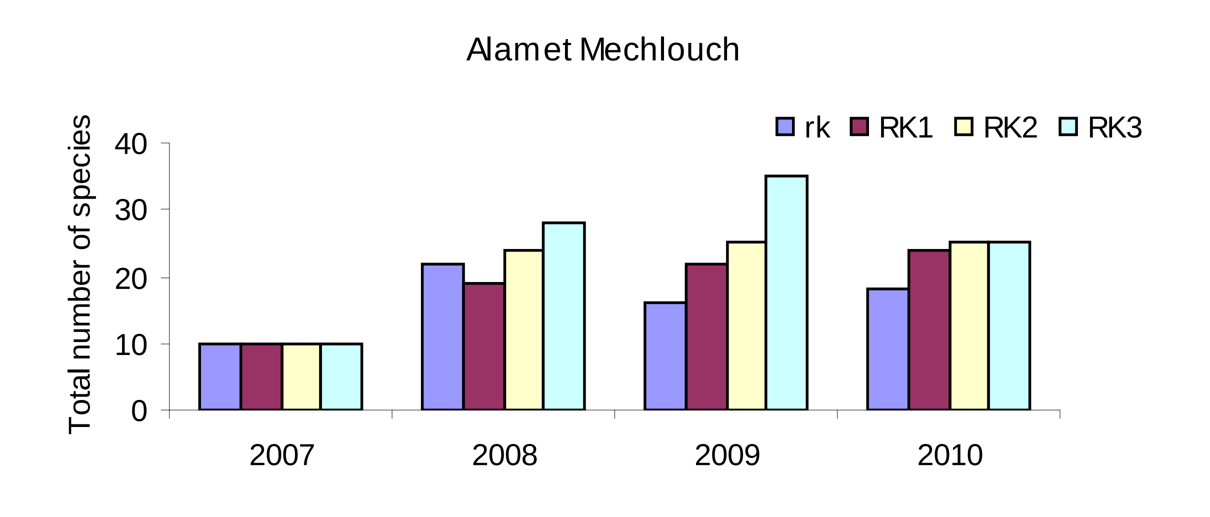


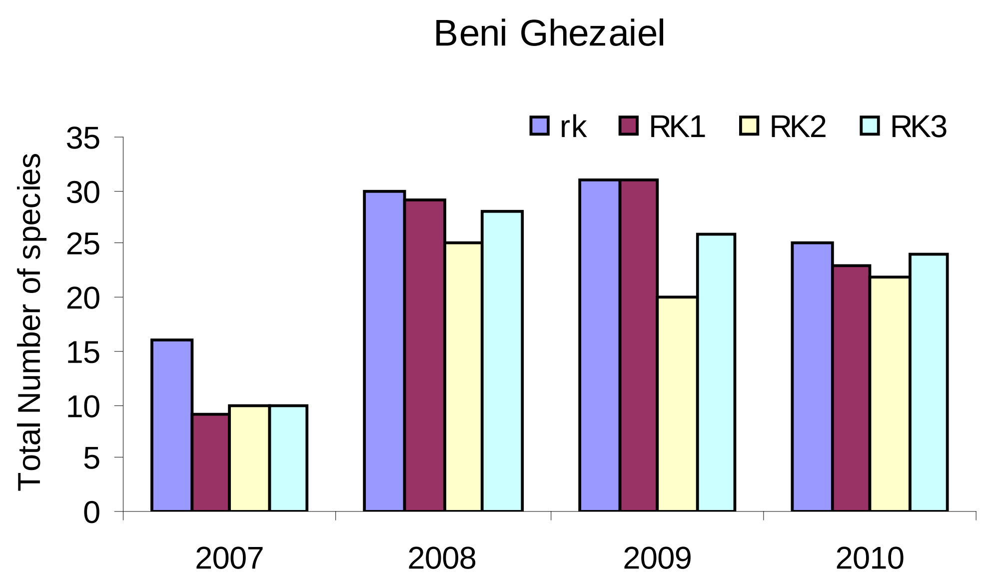
Fig. 4. Water level (piezometric level) and pumping rate of the Zeuss Koutine aquifer.

No runoff was recorded during the observation period (2009-2010). Therefore the PZ continued to drop especially with the continuation of the pumping.

Species richness

The species richness and total plant cover in the range lands monitoring sites are shown in Fig.s 5 and 6.





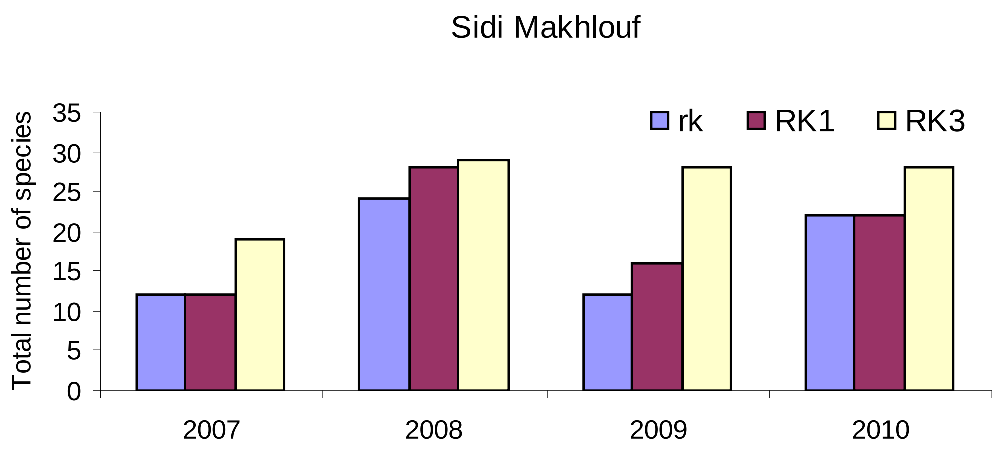


Fig. 5. Species richness.

In all sites, the beneficial effect of resting on plant diversity is clear. This effect may be hidden by the climatic conditions of the year. In rainy seasons, annual species are very abundant mainly in degraded sites.

Total plant cover

Total plant cover was also improved by the use of resting technique. This is more obvious in dry periods when only perennial cover can be observed.

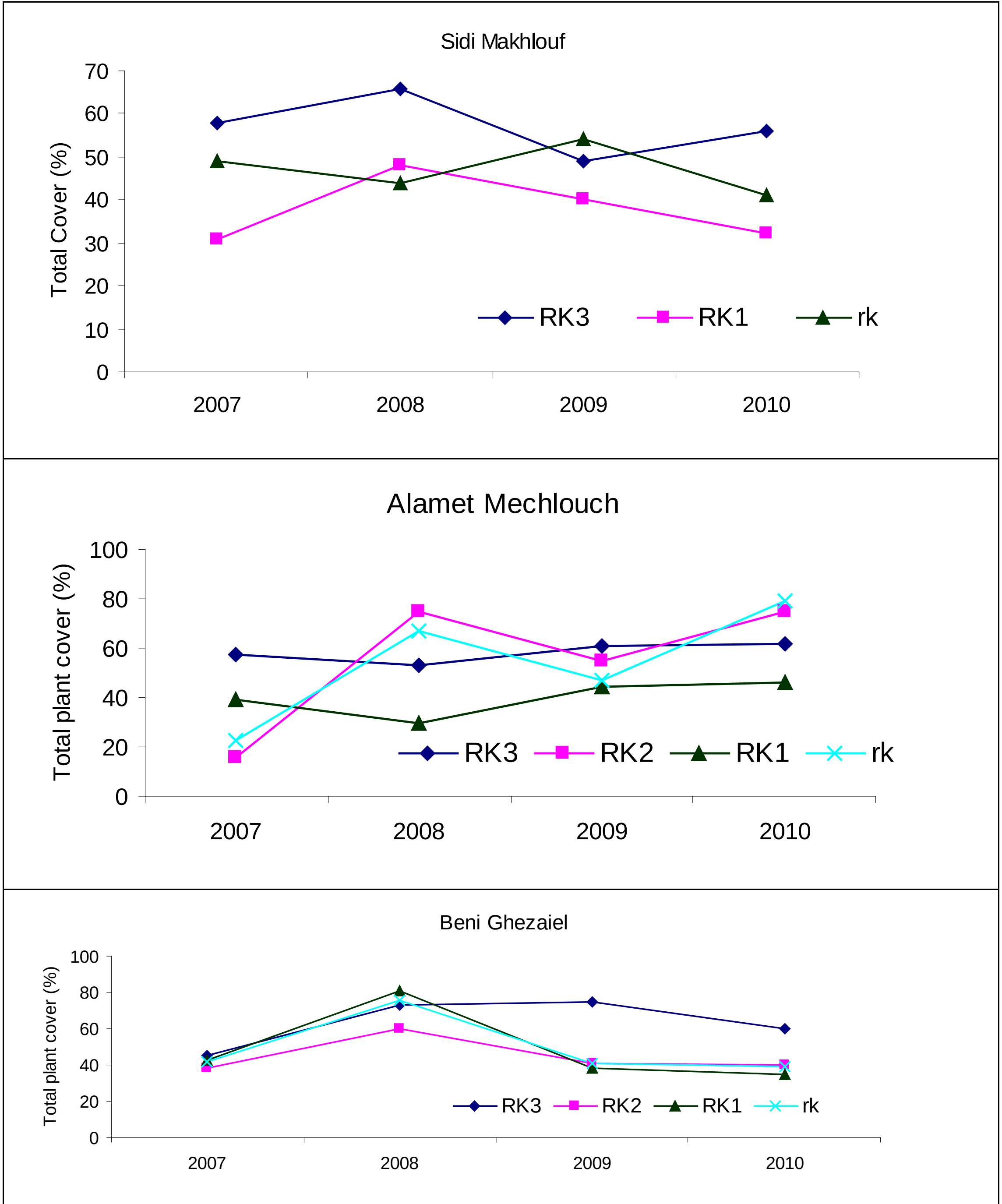


Fig. 6. Total pant cover.

-RK3: rested rangeland
- RK2: moderately degraded rangeland
- RK1: overgrazed rangeland
- rk: abandoned cultivated rangeland (since more than 20 years)

8.4 INVOLVEMENT OF STAKEHOLDERS

The farmers insured the maintenance of their fields amid the exceptionally dry conditions which prevailed. In some sites, they contributed to the supplemental irrigation of their olive trees. The development agency (Agriculture) contributed also in the supplemental irrigation during the dry periods. These combined efforts with DESIRE project resulted in safeguarding the trees from negative effects of prolonged droughts.

However, it is worth to notice that:

- The highly variable rainfall regime and the slow development of local species, typical of drylands, require more patience from the researchers and the other stakeholders.
- Generally, poor farmers are more interested in immediate returns rather than long term benefits.
- Few stakeholders do care about global impacts (off site land degradation, climate change, etc) as their concern about household living priorities.
- Parallel large development programs with consistent budgets, undermine the effects of small scale research projects with relatively very limited financial resources.

8.5 DISCUSSION AND CONCLUSIONS

- The SLM technologies were implemented in close collaboration with all the stockholders who worked effectively together from the phase of planning, through the field execution and the final evaluation of the completed works.
- As farmers are already well acquainted with the technologies, the implementation was relatively a smooth exercise.
- If the simplification of the monitored parameters to the farmers is absolutely necessary to gain their implication, the involvement of the developments agents is rather an easier task.
- The observation period was exceptionally dry (≈ 100 mm). Therefore no major agricultural activities have been carried out. However, it was an opportunity to assess the role of the implemented techniques in coping with drought and consequently also with CC which will become a major concern in the coming decades.

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9 RUSSIA – DZANYBEK AND NOVY STUDY SITES

Several reports are published of the Russian sites: the first one is an agronomic report on the effects of drip irrigation (executed both in the Dzhanybek and Novy study sites), on Tomato crops. This is followed by a site specific report of the two study sites.

9.1 REPORT ON RESULTS OF EXPERIMENTATIONS WITH DRIP IRRIGATION OF TOMATOES

By ZEILIGUER Anatoly, SEMENOV Vyacheslav, ERMOLAEVA Olga, Moscow State University of Environmental Engineering, Moscow, Russia

Today the production of vegetables in Volgograd and Saratov Regions of Russia is mainly concentrated in small farms and private plots. 74% of crop and gross yield of vegetables in the country fall to share of the latest. It can be explained by the fact that in hard economic circumstances the population tries to provide itself with food, especially vegetables. A good alternative to habitually used sprinkler or furrow irrigation technologies now is drip irrigation one. That is more saving way of irrigation used in cropping.

This period in agricultural industry of Volgograd and Saratov Region is characterized by the deficit of all types of resources needed for agricultural production as well as by establishing of various forms of land property. In line with existing rotation of crops that is typical for farming on the land from 500 to 1500ha, there are also farmlands with the square from 50 to 60 ha. Normally, lands with complex landscape and no fertile soils are given for such farms. This factor determines new requirements as to the irrigation technology so to irrigation infrastructure. The system of drip irrigation more fully meets these requirements, because the module principle is more fully realized in it and which gives an opportunity to decrease power consumption and to reduce the term of the cost justification.

Taking water regime in soil rot zone into consideration, we may count as an advantage of drip irrigation the opportunity of optimally robust moistening of root zone, in the context of growth conditions and development of plants that allows to decrease the amount of agricultural water supplied on the contrast with sprinkler irrigation up to 30-50%, and in this case it will decrease water losses for runoff, ground flow and evaporation thus we can cut down the risks of secondary ground water rising and soil secondary salinization. It is necessary to mention agronomic advantages of this type of irrigation connected with the reduce of weedery and the opportunity to provide the supply of mineral fertilizers together with irrigation water (while dieting).

In both Volgograd and Saratov Regions unexpected rise of the temperature in spring time together with wind intensification stipulates the drying up of soil cover. Air frosts during the spring last up to the middle of May, and at the soil surface last about 10 days later. During the period of drought land surface temperature can rise up to 60 degrees. Sunglow lasts enough for south cultivation maturation, in these Regions it is about 2300 - 2200 hours. Strong winds (with the speed of 15-35 meters per sec.) and dust whirls damages agriculture blowing off the fertile upper layer from the land surface. Because of it land structure worsens and the roots system of plants bares. Drought is normal for this region, maximum it lasts 85-90 days. In a sign of droughts the most damaging are dry hot winds.

The climate of both Volgograd and Saratov Region has a number of negative characteristics (drought, dry hot winds, dust whirls etc.) but there such positive factors as great deal of warmth and intensive sun radiation that allows to grow different valuable agricultural cultivation (horticultural, vegetables, grain, feed), and act to raise protein content, gluten, sugar and vitamins in crop production. Longstanding warm and dry autumn helps to take the crop easily.

In the period from 2007-2010 in the frame of DESIRE project the experimentations of the cultivation of vegetables by drip irrigation was established in some following study areas:

- ✓ experimentation station of forestry at Dzhanybek (Dzhanybek study site);
- ✓ vegetable farms of agricultural cooperative “Mildenberger” and “Shagay”(Novy study site);
- ✓ domestic holding plots at Romashky (Mr Missurin family and Mr Sobolev family) and Elton’ villages (Dzhanybek study site);
- ✓ domestic holding plots at Baskatovka (Mr Shshkin family) village (Novy study site);
- ✓ agricultural co-operative farm “Romashkovskiy”.

In the territory of co-operative farm “Romashkovskiy” there already were irrigated fields where such cereal crops as barley, winter rye and spring wheat, corn for silage, alfalfa that gives 4 cuts were grown. The irrigation of these cultivations was performed by sprinkler irrigation machines. But co-operative stopped cultivation of irrigated crop due to increasing of costs for water delivering strongly linked to high price for energy. Working equipment was sold, the old units finally broke down. Water storage capacities at the territory of the agriculture co-operative are absolutely dry for already 4 years. Before they were used to be filled with snowmelt waters. Unprofessional vegetable farming for domestic use is also under thread. So, irrigation crop production brunch stopped functioning at agricultural production of co-operative, that served as feeder for sheep breeding farm that has more than 30 000 animals and is working till now.

Before planting agricultural preparation of trial plot was done. Also, according to the scheme of the experience, assessment and assembling of hose pipes of the system of drop irrigation (produced by “Rosinka”) for each rank with the distance 0.3 m between the droppers, also cistern for 200 liters was installed on 1 meter height to water distribution system. The testing of the created system of drip irrigation was done alongside with pre-irrigation of 250 liters that set a doze of 50 m^3/ha.

Dozes and the time of irrigation changed depending on weather conditions and was set according to the soil moisture, that was measured in 3 holes on 4 depths with the help of PR2 measure instrument.

Irrigation dozes during vegetation period was 3814 m^3/ha (May- 10 days- 454 m^3/ha, June- 24 days- 1090 m3/ha, July- 25 days 1135 m^3/ha; August – 18 days – 817 m^3/ha; September – 7 days - 318 m^3/ha)

During all the vegetation period researches and accounting were done according the methodology of field experiment in vegetable planting and melon-growing that includes:

1) Phenological observations over growth stages of tomato, pepper, eggplant plants: transplanting in soil, flowering, early formation of fruit.
2) Evaluation of population of plants was calculated on every plot in per cents to typical, recommended schemes.
3) Evaluation of growth intensity and biometry of plants was done according to the the methodology of field experiment in vegetable planting and melon-growing
4) Crops accounted by weighing.
5) the selection of soil samples for agrochemical analysis was performed by drilling 5 holes on the depth of 0-20sm and 20-40sm with the further determination of earth humus concentration in % and easy hydrolysable nitrogen in mg/kg – using methods of Turin; labile phosphorus in mg/kg – according to method of Machagin; exchange potassium in mg/kg – in 1 % carbon-ammoniac extract with the further determination on flame photometer; pH on Ph meter; the sum of water-soluble salts in % according to method “ЦИНАО”; unit weight in g/m3 by bottle method.

6) The measuring of soil moisture was performed 2 times a day, everyday with the help of PR2 instrument in 3 observation boreholes, equipped with plastic pipes in the depth of 10, 20, 30 and 40 cm from the surface.
7) The evaluation of tomato fruit quality by determination of contents: dry basis – by drying; sum of sugars – cyanide according to method of Bertran; vitamin C – according to method of Murry; carotene chromatography colon, acidity by titrating of extract with alkali liquor.

Information from Marksovskay and Pallasovskaya state meteorological stations and automated weather station on the moisture o the air, speed of the wind and maximal and minimal day temperatures and on the volume of the fallout were kept and proceeded for analyses. Also there were measured by boreholes with the measuring by instrument PR2, stored and proceeded regimes of soil moisture.

After passing all phonological stages of development the Dar Zavolgia tomato sort was marked (table 1). It flowered 3 days earlier than Novichok sort and 9 days earlier than Volgogradskiy 5/95.To the beginning of the fruit forming stage the Dar Zavolgia and Novichok came together. But at last the Dar Zavolgia began ripening 2 days earlier than Novichok. And only to the end of the 1st decade of august Volgogradskiy 5/95 began to ripe.

It is necessary to mention that in 2nd decade of July because of the heat and dry hot whirls all sorts partly lost their flowers. Green fruits from the south side got sun burns that decreased its venality.

Table 1. Dates of development stages of tomato plants (during 2007 – 2010 years)

Sort	Date of the beginning of the stage		
	Flowering	Fruit forming	Ripening
Volgogradkiy 5/95	21.06 - 25.06	02.07 - 07.07	06.08 - 12.08
Dar Zavolgia	11.06 - 17.06	23.06 - 27.06	01.08 - 06.08
Novichok	15.06 - 19.06	21.06 – 27.06	02.08 – 09.08

Giving evaluation to the dynamics of the changing height of different sort samples of tomato plants we can see little difference between Volgogradskiy 5/95 sort and Novichok in the period of flowering. (table 2).

Up to the ripening stage Volgogradskiy sort was the lowest, it was lower than other sorts for 3,3 cm.

During the period of growing and developing of tomato plant, Novichok led in number of leaves and fruits. To the moment of ripening it got 1,4 times more fruits and 12% more leaves (table 2).

Table 2. Dynamics of plants height, number of leaves and fruits on different sorts of tomato plants (example of 2010)

Sort	Faze									Average weight of the fruit, g	Productivity, t/ha
	Flowering 1-2 trusses			Fruit forming			Rippening				
	Height, cm	Leaves, num	Fruits, num	Height, cm	Leaves, num	Fruits, num	Height, cm	Leaves, num	Fruits, num		
Volgogradkiy 5/95	30,8	24	-	52,7	46	18	58,5	50	21	52	52,8
Dar Zavolgia	35,4	24	-	55,4	46	14	62,3	48	19	55	51,7
Novichok	31,3	25	-	56,0	49	16	61,2	56	28	45	60,2

From three experimental sorts the highest rate of productivity - 60,2 t/ha had Novichok. Volgogradskiy sort and the Dar Zavolgia had no essential difference in productivity, it was 52,8 and 51,7 t/ha (table 2).

Sorts were different in chemical contents. The highest rate of carotene (3,43 mg/%), dry basis (7,44%) and ascorbic acid (20,68 mg/%) were found in Volgogradskiy 5/95, and the sweetest (sugar contents- 3,74 /%) was the Dar Zavolgia. Novichok sort is on the second place in sugar and carotene contents (table 3).

Table 3. Chemical contents of tomato fruits of different sorts.

Sort	Carotene mg, %	Dry matter, %	Sugar, %	Acidity, %	Ascorbic acid, мг%
Volgogradkiy 5/95	3,43	7,44	3,16	0,58	20,68
Dar Zavolgia	3,21	7,05	3,74	0,42	18,48
Novichok	2,64	6,84	3,31	0,41	19,85

During experimentations no illnesses were found on tomato plants. In conditions of Volgograd and Saratov Regions all 3 sorts can be recommended for cultivation using drip irrigation.

During the planting the plot was infested mostly with one year plants, such as Chenopodium album, Poligonum avikulare, Amaranthus retroflexus, Setaria viridis, Solanum nigrum. Among long standing weeds we found Convolvulus arvensis, Lactuca tatarica, Lactuca serriola.

The undertaken researches help to come to the following conclusions:

1. In highly dry areas of Volgograd and Saratov Regions it is possible to cultivate tomatoes with drop irrigation method.
2. System of drop irrigation can be successfully located and used as at the small holdings so at farms of different type of ownership.
3. Using drop irrigation, more productive appeared to be tomato sorts that are grown in Volgograd and Saratov Regions, their productivity made up 50-60 t/ha.
4. Fruits of theses sorts were also the best according to biochemical analysis. The sweetest (sugar contents - 3,74%) was the Dar Zavolgia.
5. taking into consideration weather conditions of the year under review, irrigation norm in drop irrigation method in Volgograd and Saratov Regions.
6. The usage of drop irrigation allows to change species composition of vegetation that encourages land cultivation.

10 RUSSIA – DZHANYBEK STUDY SITE

10.1 SHORT HISTORY OF REGIONAL LAND IRRIGATION DEVELOPMENT

The “Dzhanjbek” study area is situated on the territory of Pallasovsky District, Volgograd Region, RF and geographically belongs to Elton Lake Province of steppe Zavolzhie, which is classified as desertification province of dry steppe, situated at left bank of lower part of Volga River valley.

The climate of Pallasovsky District has a number of negative characteristics (drought, dry hot winds, dust whirls etc.) but there such positive factors as great deal of warmth and intensive sun radiation that allows to grow different valuable agricultural cultivation (horticultural, vegetables, grain, feed), and act to raise protein content, gluten, sugar and vitamins in crop production that helps to take the crop easily.

In this region unexpected rise of the temperature in spring time together with wind intensification stipulates the drying up of soil cover. Air frosts during the spring last up to the middle of May, and at the soil surface last about 10 days later. During the period of drought land surface temperature can rise up to 60 degrees. Sunglow lasts enough for south cultivation maturation, in these region it is about 2300 - 2200 hours. Strong winds (with the speed of 15-35 meters per sec.) and dust whirls damages agriculture blowing off the fertile upper layer from the land surface. Because of it land structure worsens and the roots system of plants bares. Drought is normal for this region, maximum it lasts 85-90 days. In a sign of droughts the most damaging are dry hot winds.

The irrigation of crops in this region (situated at about 100 rm from Volga River and very scarce local resources of fresh water) was stopped in early 2000 due to increasing of costs for water delivering strongly linked to high price for energy. Working equipment was sold, the old units finally broke down. Water storage capacities at the territory were absolutely dry for already 4 years from beginning of project activities. Before they were used to be filled with snowmelt waters. Unprofessional vegetable farming for domestic use is also under thread.

Groundwater in this region being receiver of surface water (in general after snow melting) which dept and concentration has high correlation with micro-relief. Under microdepressions the surface of groundwater is convex with dept about 2 - 5 m and mineralization about 0,3-1,4 g/l. Under microelevations the surface of ground water is concave with dept about 3 - 9 m and mineralization about 4-17 g/l.

The collective farm of Romashki village (50o11,77’ N, 46o40,36’ E) was established in 1944 year and has around 33 300 ha of land. Main production of this farm ise meat, wool, milk and cereals. This farm is one of two biggest farms of sheep breeding in the Pallasovsky district. Crops for arable farming are cereals, mustard and rye. The area has very dry summers with occasional drought. The farm has an extensive history of exploitation of various water sources:

- In the 19th century German settlements developed a huge earth-made system for snow retention to store water melted from snow in soil layer to be used for crop growing during vegetation period time. These systems are now almost degraded and don’t provide a full service.
- Subsequently a surface irrigation system was constructed and abandoned because it was not efficient for nowadays market economy due to high price for supplied water. As a consequence pumping of water in the canal was stopped which stopped also water supply for households, use including gardening.
- Then, water ponds were constructed for local surface water retention of about 1 km^3 capacity and collective use for recreation and for growing of domestic national bird, fish breading and as watering places for livestock. These are almost empty due to increased surface water infiltration.
- A special ground water reservoir was constructed with explosion technology during soviet time (for lifestock), for the use of mix of fresh surface water and mineralized groundwater (about 7-15 g salts/l). During last ten years due to decreasing of groundwater table (for about 2 m at local scale) the capacity declined and provides insufficient water. Some of cited water resource degradation process can be explained by change of seasonal patterns of local climate (i.e. rain during late autumn instead of snow that diminish a depth of frozen soil), longtime drought, and consequences of ruining of irrigation system using .
- During summer time water for domestic use is supplied in the big cistern tracked by car. In such conditions local peoples are very limited in the use of their garden parcel for vegetable growing.

Degradation of land and water resources affects people's income by decreasing food production (yields become lower and lands become abandoned due to salinization of them). The young generation is leaving rural areas due to level of life and possibilities to find more income in the urban area. Lack of information about sustainable land management, climate instabilities and weak institutional support with low financial support from the governmental organization making life of people in this region difficult.

Nowadays the main income of the stakeholders is agricultural production from their garden plots (fruits and vegetables), growing cattle (sheep and cows). There is a big agricultural conglomeration – farm “Romashkovsky”. A number of people are working in this farm and their salary depends on its production.

10.2 FIELD TRIALS

Field trials were carried out aiming to test drip irrigation technologies in different filed conditions and source of irrigation water.

This aim was achieved by (1) experimental plots at micro depressions within agricultural fields with the use a fresh ground water stored in between soil surface and salty ground waters, (2) experimental plots at garden of householders at villages with the use of municipal water delivery system and (3) experimental plots within natural pasture near location of temporary summer habitation of shepherds with water transported in tank or cistern.

At each experimental site a drop irrigation networks were assembled of hose pipes of drop irrigation (produced by "Rosinka") for each rank with the distance 0.3 m between the droppers, a output from tank/cistern was installed on about 1 meter height to water distribution system.

10.3 Field experiments WITH DRIP IRRIGATION TECNOLOGY

The experimental plots irrigated by drip irrigation technology were established and monitored during growing seasons from 2007 till 2011 at the same time and at the same fields in parallel with experiments with furrow irrigations. They were equipped with 4 boreholes providing access to capacitance soil moisture sensors measuring soil moisture till 40 cm. During all five experimental seasons a continuous drip irrigation applications were proceeded and data on soil moisture were recorded as well as meteorological parameters were recorded by automatic weather station located near these plots.

Amounts and timing of irrigation changed depending on weather conditions.

Irrigation dozes during vegetation period was about 3600-4050 m^3/ha (May- 10 - 15 days with 400-500 m^3/ha, June- 20 - 25 days- 1000-1100 m3/ha, July- 20 - 25 days 1100 - 1200 m^3/ha; August – 15-20 days – 800-900 m^3/ha; September – 5 - 10 days – 300 - 350 m^3/ha)

10.4 RESULTS

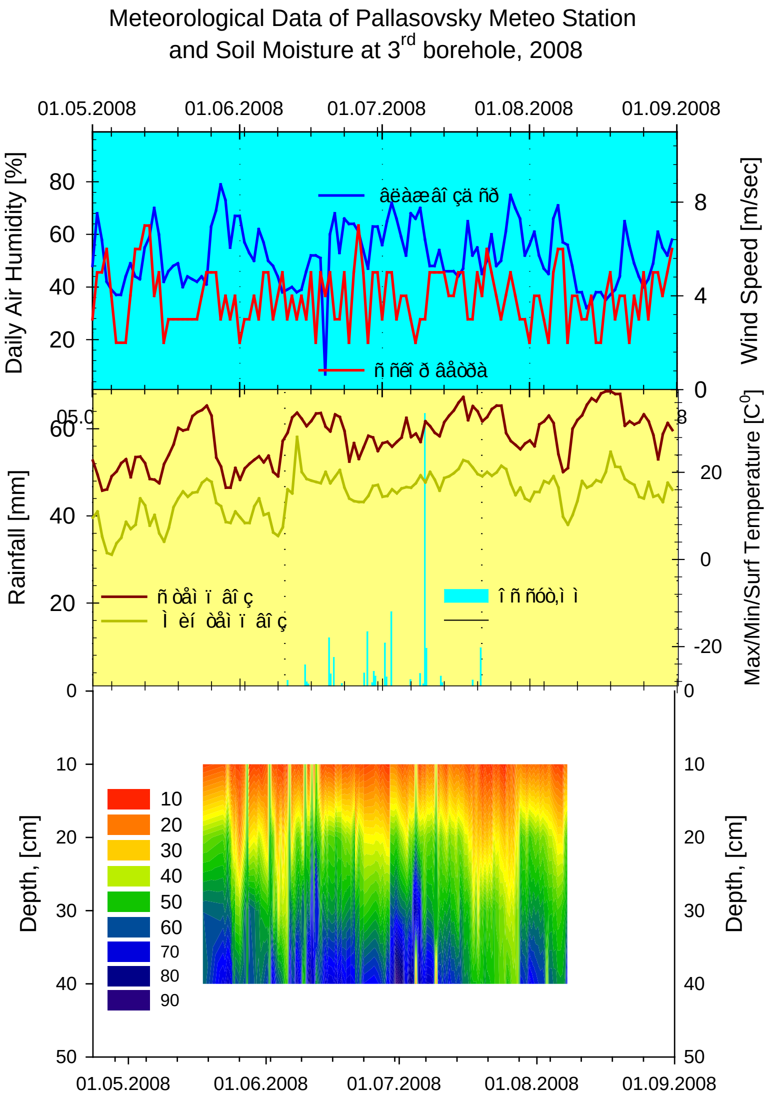
- During the monitoring period of 5 years a water regime under drip irrigation were recorded in totally during 21 months (see figure ???). By this monitoring results it was shown a positive water regime without development of preferential flow to deep soil layers and ground waters.
- During the monitoring period in all experimental plots a good yields of vegetables were obtained.

Plantation of tomatoes watering by drip irrigation at garden of Sobolev family at Romashky village.

Well to lines of fresh water stored in ground after snow melting and used for drip irrigation

Preparation of drip irrigation system with water transported in cistern

Measured during growing season of 2008 year soil moisture at root zone of tomatoes plantation of Sobolev family (Romashky village of Pallasovsky District, Volgograd region, Russia)



10.5 Stakeholder's opinions

- A lot of farmers and experts and administrations shown interest in drip irrigation technologies using considerably small amount of water that is very important in this region with scarce fresh water resources.
- Drip irrigation is profitable irrigation practices since providing opportunity to get frsh vegetables with small amount of applied water and workload, but implementation and maintenance costs are high obstacles for large application of it.

10.6 Conclusions

The undertaken researches help to come to the following conclusions:

7. In highly dry areas of Volgograd and Saratov Regions it is possible to cultivate tomatoes and other vegetables with drip irrigation method.
8. System of drip irrigation can be successfully located and used as at the small holdings so at farms of different type of ownership.
9. Using drip irrigation, more productive appeared to be tomato sorts that are grown in Volgograd Region, their productivity made up 50-60 t/ha.
10. Fruits of theses sorts were also the best according to biochemical analysis. The sweetest (sugar contents - 3,74%) was the Dar Zavolgia.
11. The usage of drip irrigation allows to change species composition of vegetation that encourages land cultivation.
12. The drip irrigation is very adaptable to the soil conditions and local sources of fresh water.

11 Russia –NOVY Study Site

<u>Site coordination:</u>
Partner 26 - Moscow State University of Environmental Engineering (MSUEE)

11.1 Introduction

Since 1990's a new management concept for sustainable utilization of land and water resources for agricultural purposes was introduced these main idea to disintegrate experimental field in some management spaces with no similar properties. Nowadays this concept is known as precision agriculture or site-specific management by contradiction to conventional practices tending to treat a field as a single unit and manage it to optimize the average production as a whole.

From this time this concept starts to receive a great interest among researchers to develop new technologies breaking the field into several sub-units and treating them independently, thereof, the production of each unit can be optimized, rather than treating the entire field as an average (Maohua, 2001). Up to now, the main efforts and applications have been focused on site-specific crop management and has been tested for fertilizers and chemical applications through variable-rate technology.

At the same time water need varies spatially in many fields because of saturated/unsaturated soil hydraulic properties spatial variability closely related to spatial heterogeneity of soil cover, landscape parameters and spatial variability of depth to ground water. Spots of different soil types inside of irrigated agricultural field may have different textures, water holding capacities and infiltration and drainage rates, therefore, the need for irrigation may differ between different zones of a particular field.

Previous generation of irrigation systems have been developed in the base of concept average parameterization of irrigated field and designed to apply the same amount of water through the hole field, without taking soil spatial variability into consideration, therefore, some areas may receive too much water and others not enough within one field. Excessive water application could contribute to surface water runoff and development of small ponds at the surface of irrigated field. From this ponds surface water is reaching deep soil and ground layers as well as ground waters by gravitary pore spaces and/or leaching of nutrients and chemicals to groundwater. Inefficient water application causes reductions in yield quantity and quality, inefficient use of fertilizers and other inputs, and lower overall water use efficiency. The use of precision farming for irrigation water management/scheduling, known as precision irrigation, in order to apply water in the right place with the right amount at the right time, is still in the development stages and requires a lot of experimental works to determine its feasibility and applicability.

It is believed that, improving irrigation system performance to applied water uniformly over the field had received, and still, a great attention in both hands, research and technology or industry, and reached a stage, in which, any further improvements will not significantly increase in profitability. It is important now to shift toward and concentrate on maximization of the net profit from this water through applying it in the appropriate place and quantity.

It is possible to take the advantages of some existing technologies to be adapted for precision irrigation, such as speed-control systems, which are still used for constant speed along the whole field, although it can be used for different speeds. Other option is to take advantage of pulse concept to control single sprinkler (Frassie et al., 1995), single span or small segments along each span (Omary et al., 1997; Camp et al., 1998), through solenoid valves, which are known in irrigation market, but this needs software to control its operation. Therefore, the next generation in irrigation scheduling should be re-defined to have the ability to apply the right amount of water directly where it is needed, therefore, saving water through preventing excessive runoff/leaching is expected. The results have to contribute to the reducing of the use of scarce and high price water resources by the means of right spatial distribution of applied water within irrigated fields that stop losses of applied water by seepage into deep soil/ground layers and ground waters provoking their razing and secondary soil salinization.

Nowadays, this region is characterized by steady tendencies of a climate change aside aridification and formations of shortage of local water resources. Agricultural activities under irrigation are influenced by degradation of land and water resources as well and high final cost of agricultural production due to high water dozes using for irrigation, high price for water pumping & transportation and quite low average productivity. Major land degradation problems in the geographical region called Saratovskoe Zavolghie going along left bank at the middle part of Volga River (Russia) are caused by

- ✓ long time large scale irrigation projects based started since the middle of 1960th based on sprinkler irrigation technology of annual and multiyear forage crops;
- ✓ short time small scale irrigation activities started since middle of 1990th based on furrow irrigation technology of vegetables.

11.2 Trial layout

During 3rd and 4th of DESIRE project years MSUEE team started a research activities aimed at:

- ✓ review the state of precision irrigation for land areas with chernozem (chestnut) soil cover exhibiting alkali zones with low infiltration rates;
- ✓ provide necessary background soil/land information helping to delineate spatially heterogeneous irrigated field into quasi-homogeneous zones;
- ✓ Develop a strategy for application of precision irrigation farming.

✓

A general framework for developing an irrigation application map is presented at Fig.1.

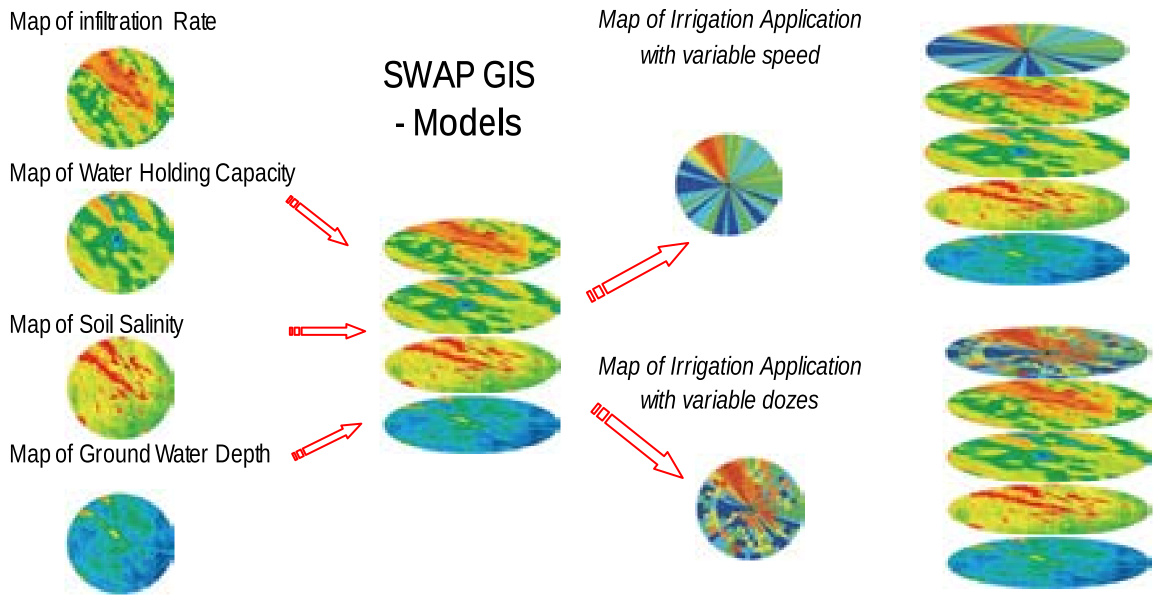


Fig. 1. Framework to develop maps of irrigation applications of variable rate irrigation technologies.

Location of the central point as well as perimeter of irrigated field (using a length irrigation machine span) shown at satellite image The next information needed to delineation of field spatial variability in the border of pivot sprinkler system is originated from the soil maps of irrigated fields. This information is not sufficient to be used for precision irrigation, since these maps provide information about spatial variability at quite large scale by comparison with dimension of quasi-homogeneous polygons.

The next step is to obtain *in-field* information (small scale) with different type of soil sampling techniques for following laboratory analyses and/or special in-field soil properties analyzers like vacuum-infiltrometer dealing with measurements of infiltration rate by capillarity (without surface water dept developing) , soil penetrometers, and/or non-destructive real-time sensors like GPR and/or EM38, providing surrogated properties, such as EC. This was followed by soil sampling, based on the maps produced from this sensor, and correlate the surrogate property with the property in question (EC vs. AWC). Map for the management zones within the field (application map) for the field activity, here irrigation, showing the different quantities (depths) and their location within the field is established. Then a decision must be taken concerning the technologies that must be integrated with the present field machinery or need to be introduced, here, variable-rate technologies. Evaluations for the parameters of this technology, here travel speed and discharge rate, should be done.

Soil Variability Delineation

Soil electrical conductivity (EC) maps were determined without physical contact between the sensors and the soil by use of commercially available dual coil Electromagnetic Induction (EMI) systems (Rhoades, et al., 1989; Hendrickx et al., 1992; Sudduth et al., 1999; Dalgaard et al., 2001; Domsch and Giebel, 2001; Sudduth et al., 2001). An EMI meter, EM38, developed by Geonics Limited, Mississauga, Ontario, Canada, provides fast non-destructive measurements of apparent soil EC. Principle of measurement is described in the above literatures. For soil reconnaissance to quantify EC (mS/m), EM38 sensor, after calibration and in the vertical operation mode, mounted on a PVC-sledge together with a DGPS unit was traveled across the field along the tramlines 5 m apart. The DGPS data were integrated with EM38 data to provide the co-ordinates of each measurement point.

Values for EC and position with sub-meter accuracy for each individual measurement was merged and stored at a rate of 1 sec-1. The reading were logged to a data logger and interpolated using some models using ArcGIS to produce EMI-soil conductivity map.

The presented above procedure of irrigated field delineation was carried out in 3-experimental fields. The resulted maps are showing zones with different soil EC-ranges, and in each zone sample positions were selected depending on the co-ordinates using DGPS. The soil auger-samples to a depth 90 cm from those zones were collected to determine the water holding capacity in laboratory. The same sampling points were subjected to in-situ description for texture using feeling method.

During a field monitoring campaign following variables were measured at both study sites according to shown at table 1 calendar.

Table 1. Variable measured during field monitoring of SLM technologs at both study sites

Variable	*2007*			*2008*			*2009*			*2010*		
	Vi	VII	VIII	Vi	VII	VII	VIII	VII	VIII	Vi	VII	VIII
Soil Moisture												
Electrical Conductivity												
Air Temperature												
Germination Rate												
Growth quality												
Soil chemical analysis												

11.3 Analysis and Results

Water for agricultural and domestic purposes at this region is pumped from Volga River and mounted to uphill areas by networks of pumping stations and open transportation canals in some cases going till hundred kilometers into desert & semi-desert areas. In irrigated areas located near Volga River (maximum about at distance of 20 km) water is pumped from these canals by lateral pumping stations distributing it to pivot sprinkler machines. These machines are carrying out water application at the irrigated field areas of around 40-50ha. At the same time water from open transportation canals is also delivered for small farms cultivating vegetables at field with inclined soil surface providing driving force to carry water flow throughout line of lengthwise furrows with simultaneous lateral soil moistening of seedbed as well as high infiltration into soil/ground profile from furrow beds.

In the frame of FP6 DESIRE 037046 (2007-2011) project aiming to assess main land degradation driving processes in the Saratovskoe Zavolghie region as well as introduce an appropriate innovation technologies after field experimental results it was shown that an extensive irrigation at this region based on sprinkler technology with the rate not adjusted to soil infiltration/retention parameters has provoked a considerable ground water table rising and by consequences secondary soil salinization.

Overall efficiency of irrigated agricultural cropping systems depend on the water needs that vary not just in the time space, but also in within space of irrigated fields. From 1-D (vertical) modeling point of view time variability of crop water needs in one simulated spatial area presented like point-area depend of appropriated parameters at this point-area linking water and energy flows processes called Soil-Water- Atmosphere-Plant (SWAP) continuum. From this concept time variability of crops depends of crop type, crop vegetation state, soil surface aspect, weather conditions, texture & structure of soil profile, amount of available water in the soil root zone as well as amount of nutrient. Spatial heterogeneity (variability) of crop needs within field area of spatial 1-D modeled points depends of the variability of the same parameters but in case of irrigated water application this variability is controlled by spatial variability of field parameters like topography, texture & structure, water holding capacity, as well as soil infiltration and drainage rates. In many case this spatial point variability of key SWAP parameters may be regionalized (homogenized) by assembling of spatial point into quasi-homogeneous spatial zones in the base of some spatial relationships between neighboring point-spaces.

Due to this spatial variability at the same time period the needs for irrigation differ between different spatial zones of a particular fields. While moving irrigation systems apply water at constant rates, some areas of the field may receive too much water and others not enough. Sophisticated technology of water application based on precision irrigation agriculture concept should avoid such spatial disproportions on water receiving by soil root depths by the knowledge of the right spatial places and the right spatial amounts as well as by the means of spatial water application control.

After results of filed experiments it was shown that ground water rising at irrigated areas is originated by considerable irrigated dozes used for irrigation water application and high sprinkling intensities as well as irrigated water losses presumably by preferential flow process descending it into deep soil & ground layers and reaching ground waters. In they turn these losses of applied water applied have been provoked by commonly used technology called "**uniform rate irrigation"** that are not appropriated to complex soil cover structure of irrigated fields due to spatial non-uniformity of key parameters like mezo-topography, water holding capacity and infiltration rate. During water application by such type of technology where the soil intake rate is exceeded, thus causing water run-off with water ponding in micro- and mezo-depressions with following water seepage by preferential flow and as consequence - groundwater rising, secondary salinization/alkalinization leading in their turn to degradation of land & water and environment. At the same time inside of irrigated fields there is development of areas with root zone over or under moistened exhibiting water stress of crop plants and finally provoking low productivity and lost of yield.

11.4 Involvement of stakeholders

The two SLM technologies (drip irrigation for small scale areas and variable rate irrigation for large area) were presented and discussed with different groups of stakeholders from central, throughout regional till local levels during official and not official meetings.

Overall opinion of different stakeholders regarding drip irrigation in place of furrow irrigation is very positive with expectance of high water efficiency under conditions that water price politics should stop no efficient water use.

The stakeholders are very positive regarding non uniform water application (variable rate irrigation) which increases efficiency of water use and for increasing crop yield. If the government stops giving subsidy for water this technology will be even more popular.

Both SLM technologies under field testing in the frame of DESIRE project were included in Concept of Land Reclamation at Russian Federation for the period till 2020.

11.5 Discussion and conclusions

As a practical consequence of this study a new concept of irrigation technology called "**non-uniform irrigation**" is proposed. After this concept this technology should provide site-specific irrigation management by the application of different volumes and/or rates of irrigation water to different areas of a field matching spatial non-uniformity of soil cover structure, water holding capacity of root zone, water infiltration/drainage rates, ground water depths as well as soil salinity/alkalinity.

Experimental results of soil moisture monitoring at field irrigated with the use of “**uniform rate irrigation”** as well as results of computing simulation with scenario of “**non uniform rate irrigation”** with their spatio-temporal interpretation are presented.

The future challenge is to build a rich database in order to formulate a complete decision support system for precision farming, including all field activities i.e. irrigation, fertilization, tillage, plant protection and weed control.

The use of precision agriculture for irrigation water management is still in the development stage and requires a lot of investigation and experimental work to determine its applicability.

The availability of some low-cost data gathering methods, positioning systems and the development in computer programming will help in regulating the depth of water within a field. So the next generation in irrigation scheduling is not just when-how much but when, where and how much to irrigate. A precision irrigation system expected to have the ability to apply the right amount of water directly where it is needed, therefore is saving water through preventing excessive water runoff and leaching. So the suitable technology to control varying amounts of water in direction of traveling and crosswise has to be developed.

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12 China - Yan River Basin

Site coordination

Partner 13 - Institute of Soil and Water Conservation (ISWC), Chinese Academy of Sciences

12.1 Site Information

Kelaigou Village (36°29' 59.20", 109°24' 42.86") is a rural village in the Mazhuang watershed, Liulin Town, Baota County, Yan'an City of Yanhe River Basin. This site is located in the Loess plateau region. The mean annual precipitation is about 567 mm. There are 286 capita in this village, 155 of men, 131 women and 112 of the labor power, in 2009. The land use and cover condition is shown in Table 1.

Table 1 The land use and their brief description

Land use type		Area (ha)	Note
Cropland	Check-dam land	6.27	This is very fertile land in the Loess Plateau. The check dam for land is special in the Loess Plateau because the high sediment concentration in the flood season. Normally, the check dam could be very good quality croplands after 10 to 20 years. The soil here is from land surface of slope with higher organic matter. The seasonal flooding also makes the soil moisture better here. The yield is much higher and stable with great ability of anti-drought disaster. The soil erosion functions of check dam land including of 4 parts: - It is flat and nearly no runoff generation even in summer. - It could detain the runoff and sediment in the valleys to reduce the flash of rivers. - The soil erosion of valleys decrease because the check dam could make the basement of valleys relative stable and the gravity erosion stopped or reduced. - The higher yield makes the local farmers cultivate less land on the slope, especially on the steep slope.
	Terraces	18.20	The terraces in this area are not wide enough to use machine directly. The soil and water conservation functions of terraces are: 1 to reduce the slope gradient and length that increase the rainfall infiltration and runoff generation and 2 the relative higher yields than slope crop land that would makes the local famers cultivate less lands for food.
	total	24.47	
Converted forest (65.93 ha)	Economic crops land	11.33	The crop land was converted into forest in 1999. The subsidies of Economic crops land and Ecological land are different because the government wanted to recover the vegetation for ecological condition. The main aim of conversion is for economic return, but there exists also forest for soil and water conservation.
	Ecological land	54.60	The objective is for soil and water conservation, and there are no economic returns because the logging is forbidden in whole Loess Plateau.
	Total	65.93	
Orchard		40.00	The local government made development plan to plant apple

(40.00 ha)			trees in this area. The quality and yield of apple in this region is good enough. In addition to this, there are also agro-forestry lands in this village. The beans are planted together with young trees.
Grand total		130.40	
Land per capita		0.4559	Since land per capita is very low it is difficult to survive just depending on the land.

12.2 INTRODUCTION

The main soil and water conservation technologies are growing grass, reforestation, terracing and constructing check dams to prevent soil erosion on the sloping areas and preventing the sediment being delivered into the main stream of Yan River and the Yellow River.

The monitoring items include soil moisture and soil erosion, crop yield and health parameters. Weather variables are measured at an automatic weather station set on the roof of one family.

Photo 1 Slope crop land

The area of cropland on the steep slope is very small since the implementation of Grain for Green Project in 1999, so we cancelled the monitoring even the main soil erosion is from the steep cropland.

The mean annual precipitations and evaporation are 560 mm and 1600 mm in this watershed. The precipitation varies greatly among different years and within each season and more than 60% precipitation is in flood season from June to September. The rain storms occurring mainly in summer can induce intensive soil and water loss on the slope that makes the unstable yield even to with no economic return some time.

The experiment carried out in Kelaigou Watershed is mainly for increasing water availability for maize using terrace and check-dam land.

12.3 TRIAL LAYOUT

(a) Four types of land (terrace, reforestation land, grassland and orchard) were selected which were located on steep slope (20 degree slope gradients) facing south. Data was collected as follows: soil moisture data (Before planting in April normally, mid-August and after harvesting in October); data on soil erosion with rainfall simulator (rain intensity applied was 55 mm/hr since adjusting to other intensity was very difficult), 2 storm intensity and 2 rainfall period (30 minters and 60 minters) , double duplications. The simulator and total sediment was dried and weighted (Photo 2 and 3, by Wang Fei).

The test process is: adjusting the simulator, record the runoff generation time, runoff with sediment are taken every 5 minutes, and then measure the weight of bottle, water and sediment, and then separate, dry and weight of the sediment.


Photo2 Simulator


Photo3 Sediment weight


Photo 4 Soil sample taking

(b) In 3 kinds of land (terrace land, slope cropland (maize, millet) and check dam land (maize)) crop yields were measured.

(c) Since water is the limiting factor in this region, terrace land and check-dam land were used to test soil moisture and crop yield with those crops on the slope. The auto weather station was set up in this watershed.

The metrological data, soil moisture, yield, soil erosion, input and output of agriculture were monitored, but some foundational items were not tested. Soil samples were dried with oven drying method, soil erosion was measured using rainfall simulators and movable plots.

The indicators measured include:
For soil erosion: simulating rainfall depth, runoff and sediment, and change into the soil erosion modulus (Unit: tons per square km per events)
For soil moisture: soil moisture by weight
For yield of maize and other crops: the yield and price, the price and input of of seeds, fertilizer, pesticide, labor and so on.

Table 2 The time graph (Green means work time)

Variable	***2009***												***2010***											
Meteo	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Moisture					■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Yield										■	■					■	■	■	■	■	■	■		
Erosion									■	■						■	■							
Input								■	■	■	■				■	■	■	■	■	■	■	■	■	
Output										■	■											■	■	

The land use map of Kelaigou Village (.shp),
Soil erosion is by weight and area,
Soil moisture is by weight of percentage of dry soil.
The yield is in kg per ha, and all the price is in Yuan RMB.

12.4 Analysis and Results

Soil erosion:

The soil erosion of different land uses are very different. During the first 30 minutes, the soil erosion modulus of reforestation land, grass land and orchard (near bare soil surface) is 3600, 2400 and 6500 tons.km^{-2}.event^{-1}(Fig. 1, right). During the whole process of 60 minutes, the soil erosion modulus of reforestation land, grass land and orchard (near bare soil surface) is 4800, 3500 and 8900 tons.km^{-2}.event^{-1}.

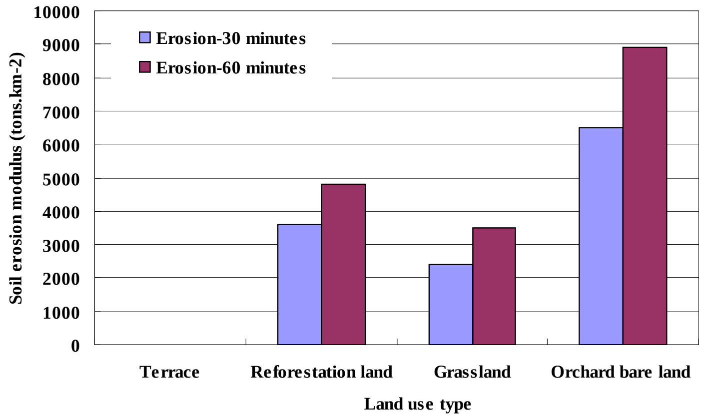


Fig. 1 Soil erosion rate of different land use

When we compared each kind of soil and water conservation practices with of orchard, the terrace has no runoff and sediment generated under simulating rainfall both for 30 minutes and 60 minutes. Reforestation could reduce soil erosion by around 45% and grassland by 62%.

The sediment concentrations of different land uses are very different too (Fig. 2, right). The sediment concentration in the first 30-minute stage is higher than that in the whole process. Except for the terrace with on runoff generation and sediment loss from plots, the sediment concentration from grassland is 57% about that of orchard. The reduction of sediment concentration of reforestation lands is 23.77% and 46.07% respectively.

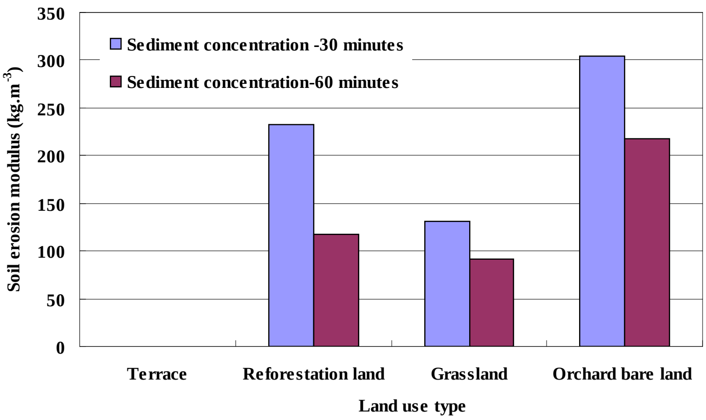


Fig. 2 Sediment concentration of different land use

Soil moisture:

The depth of infiltration of terrace is 20 -30 cm deeper than that on the slope and there were about 30mm rainfall on the top 200 cm soil layer. No runoff and soil erosion in the terraces.

The soil moisture is very plentiful because the runoff from the up-stream could be detained by check dam. It is the sediment tank normally, but in this watershed, there is little sediment from the upstream. The soil becomes muddy from 50 to 60 cm deep. There are no runoff and soil erosion in the monitoring year because the soil is quite dry. In 2009, the soil moisture is not low because of rain.

The input and output of maize planting are surveyed in Kelaigou Village (Table 2). The direct input, labor input and output of three maize lands, check-dam land, terrace, slope crop land, were compared and analyzed. The direct input includes seeds, tillage and planting cost, and the chemicals include fertilizer, pesticides and herbicide. The input of check-dam land is much than that of terrace and slope cropland. The tillage and planting in this region is by man or animal power and the costs are very similar. The fertilizer inputs are very different.

Table 2 the balance of input and output of cropland (by Maize, per hectare)

Land use	Seeds	Chemical Materials*	Tillage And planting	Direct input	Labor	Labor cost	Total Input Including Labor	Yield	Value	Net income without labor	Net income with labor
	Yuan	Yuan	Yuan	Yuan	Day	Yuan	Yuan	kg	Yuan	Yuan	Yuan
	a	b	c	d=a+b+c	e	f=e*50**	g=d+f	h	v=h*1.85***	v-d	v-g
Check-dam land	525	4575	525	5625	105	5250	10875	7800	14430	8805	3555
Terrace	420	2700	525	3645	90	4500	8145	4500	8325	4680	180
Slope Crop land	300	1800	525	2625	75	3750	6375	2400	4440	1815	-1935

Note:
* Chemical Materials: fertilizer, pesticides and herbicide;
** Price of corn: 1.85 Yuan RMB per kg;
*** Price of labor days: 50 Yuan

The labor cost was 50 Yuan per day per person. It is relative lower if we compare with people without skills in the market. 75-105 of labor-days is necessary for each hectare of land.
The yield of check-dam land, terrace, slope crop land is 7800, 4500, 2400 kg per hectare respectively. The difference between check-dam land and slope crop land are more than 200%, and the yield of terrace is 87.5% higher than that on the slope. It is also the benefits of soil and water conservation.
The cost-benefit analysis is very interesting. The local people do not think the labor for planting is a kind of input directly. If we do not consider the input of labor, the net income of check-dam land, terrace, slope crop land is 8805, 4680, 1815 Yuan per hectare respectively. If we consider the labor input, the income is too lower, even they lost something through hard working.
Furthermore, the average cropland is very limited (0.1 ha per capita), and the contribution of land is low for the survival and development of local people.

12.5 Involvement of stakeholder

The stakeholders include local farmers, village head，Soil and Water Conservation Bureau and Agriculture Bureau of Baota County.
1 The local people use the same system normally with clear planting plan because the crops here are quite simple, such as maize, millets, potatoes and beans. They have desire to improve the income of land and they think the soil and water conservation is a very good approach to improve the agricultural condition (Photo 5).
2 The yield of slope land, terrace and check-dam are very different, they wish the DESIRE could influence the local government to invest more to build high quality land.
3 The work of soil and water conservation is well known by the local farmers, and they want to know if there is something new that could be used in their village. Even they pay attention the research more than the soil and water conservation (Photo 6), they can get some useful information and support us to know more about land use and land use change.

4 The average cropland is small (0.1 ha per capita). Most of people do not think it is possible to get more money from the land and their interesting in the project is not high.

Photo 5 Check-dam land survey with local experts

Photo 6 Fix weather station with farmers

12.6 Discussion and conclusion

The terrace and check-dam land are good technologies to reduce the soil and water loss in the research site. It increases water availability for maize through reducing runoff and evaporation from land surface. The check-dam land could use the water from upstream or moisture of former years to improve soil condition.

The technologies could be used in other area of the Loess Plateau. The high quality wide terraces are necessary for planting with machineries. The check-dam should be designed and built according to present condition of less erosion and longer time to form the land.

The land area for each person is very limited in Yan’an City. The local people can get some cereal and food from the land, and it is nearly impossible to improve the livelihood and economic condition.

Terrace and check-dam land could increase the water availability for maize through reduce runoff and evaporation from land surface and using water from upstream or moisture of former years. They could be extended to similar area of the Loess Plateau.

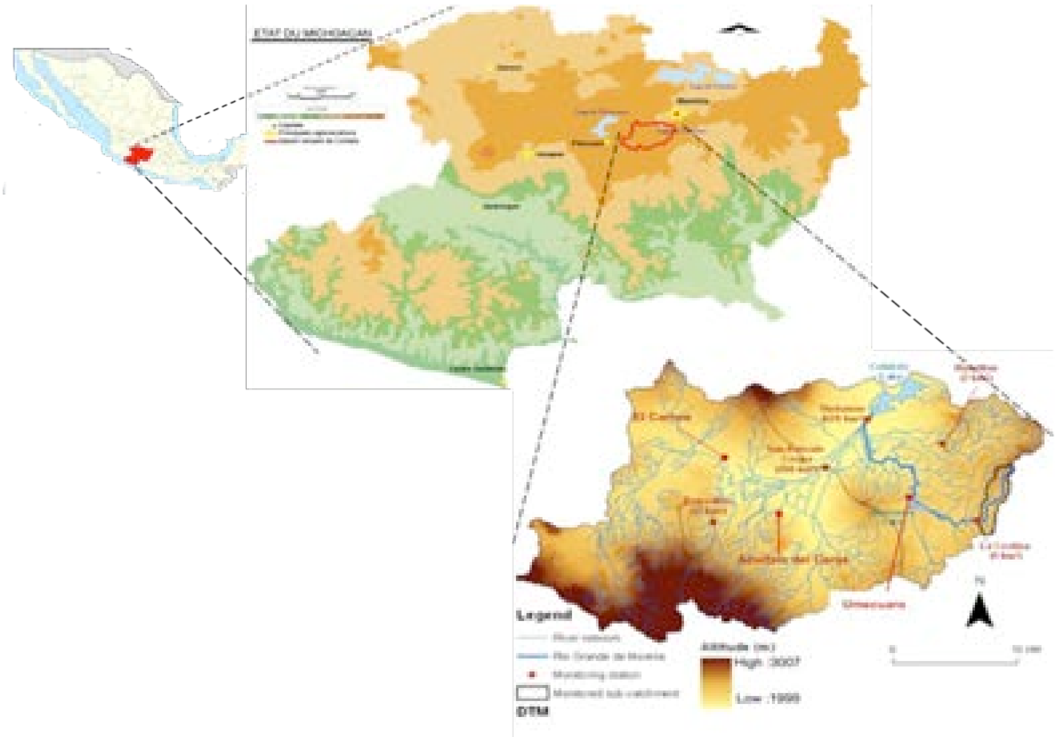
13 MEXICO - COINTZIO WATERSHED (MICHOACÁN)

Site coordination

Partner 22 - Institute de Recherche pour le Developpement (IRD)

13.1 SITE INFORMATION

In Cointzio basin, land degradation is mainly due to free grazing of cows. To avoid this, a global solution must be done and must be adapted according to different environ-mental situation. Due to the critical economic situation of farmers, men and women can act only with granted project, managed by political authorities. The Cointzio basin presents different kind of soil erosion due to the type of climate (temperate semi-humid with a 6 months rainy season), soils and geomorphology (Luvisol on plain, Acrisol on piedmont, Cambisol andico and Andisol upper part) as well as land uses (some mechanized farming, mainly rainfed agriculture with free grazing cattle, forest, recent avocado plantations). The results is the refilling of the Cointzio dam used for drinking water of the capital of Michoacán, dramatic water flooding and land degradation.



13.2 TRIAL LAYOUT

1. Agricultural systems tested during 5 years on 8 erosion plots: 2 sites (Acrisol and Cambisol andic) with Traditional corn/ Fallow/Corn with organic fertilization/Corn or cereal with no tillage and crop residues. Climate, soil and water erosion, soil properties and agronomical parameters survey.

2. Gullies control by filtering stone dams done by local stakeholders and fund by SEMARNAT (Sec. Environment) since 4 years. Inventory of constructions and plotted in GIS, Semi-quantitative evaluation done in the fields in Potrerillos-El Calabozo small basin.

3. Agave agroforestry: degraded lands are planted with local agave for Mezcal and fodder production in association with trees. Transplanting wild agave on degraded area. From seeds of wild agave, production of plants and after one year, planting different density of Agave and trees as well as different form of plantations.

Monitoring

Variable	2007	2008	2009	2010
Meteo with focus on rain properties	⟷	⟷	⟷	⟷
Runoff, suspended sediments, water quality (N,P,K,C) on plots (4 treatments*2 soils)	⟷	⟷		
Moisture on plots	⟷	⟷		
Agronomical parameters on plots	●	●		
Soil analysis, aggregate stability, soil rugosity and CO2 activities on plots	⟷	⟷		
Infiltration under permanent flow (disk infiltrometer)		●		●
Runoff, suspended sediments, water quality (N,P,K,C and biology) on 4 watersheds	⟷	⟷	⟷	⟷
Semi quantitative evaluation of effectiveness of gullies control (vol refilling, state)			●	●
Semi quantitative evaluation of effectiveness of agroforestry-Agave plantations			●	●

- Agrometeorological data registered in the field (La Cortina watershed): Registration every 30 min: T (max, min), Wind (speed direction), Humidity, UV, Solar radiation
  Rain registered in 3 places (La Cortina, La Cienega, Potrerillos which are own catchments followed) by event: every 0.2 cc with a second precision. Calculation of rain volume, intensity, energy, erosivity. Agrometorological data from historical registration (per day) of 5 stations in the Cointzio catchment: update and complements of missing data of previous information.
  Used also for WB5 (PESERA)
- Measurements of runoff of 3 small catchments + one of all the Cointzio catchment, followed since 5 years with limnigraph with 1 min registration and 1 mm precision.
- Designed, installation of our own model of sediment traps located every 20 cm high in the 3 small catchments. The sediment samples are taken after every events by local people and analyzed by us after. In the case of the basin outlet, suspended sediment concentration are followed through the measure of the turbidity (every 10 min)
- Campaign of measures of Andosol infiltration using a disc infiltrometer. After make measures on the Acrisol, we test the Andosol with 4 kind of treatments (natural-Forest; ploughed, one year after corn cultivation in the lower and higher part of furrows.
- Identification and precise localization on a SIG, of the different programs of soil restoration done by SEMARNAT since the last decade in the Cointzio watershed. Thanks to this identification, on some works, we did a semi quantitative evaluation of effectiveness of control of gullies erosion done by small stone dams, measuring characteristic of the installations, state and volume of sediment trapped.
- Semi quantitative evaluation of the plantation of Agaves done at the beginning of the rainy season.
- In order to understand the soil erosion and water runoff dynamics as well to replace our field data in their context, we identified for the 3 small watersheds the land use at the field level. We are doing this for the last five years corresponding of the registration period. Then we will correlate parameters to identify the relevant drivers of this process. We will use also some erosion models (Eurosem, hsvm).

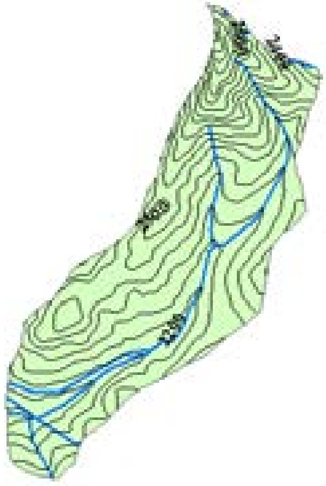
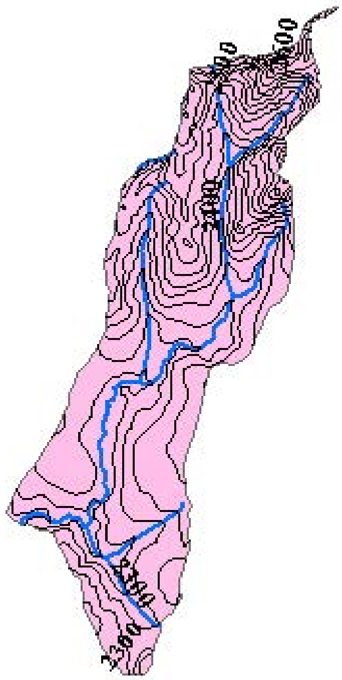
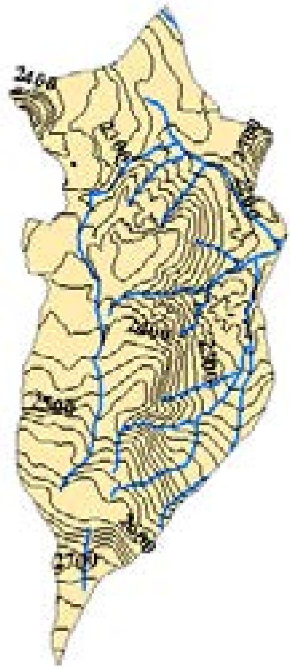
13.3 Analysis and Results

13.3.1 Agricultural systems

The effect on various agricultural systems is tested in terms of runoff, infiltration and sediment production.

Land uses of small catchments

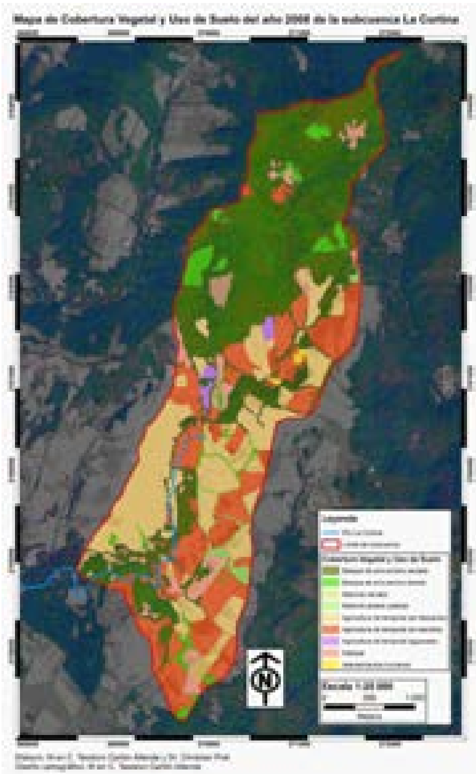
We are comparing the land uses (types), their localization in the catchment in regards to the main drain, and the evolution during the last five years, at the field scale. This is to understand better the runoff and soil erosion as well to try to predict evolution and consequences in term of water availability and soil erosion.

		
Huertitas Catchment (2,8 km^2)	La Cortina catchment (10,1 km^2)	Potrerillos-El Calabozo catchment (10,6 km^2)

	Huertitas	La Cortina	Potrerillos
Altitud (m)	2200-2540	2260-2560	2140-2760
Geology	Andesitic	Andésitic	Andésitic
Hydrology	Temporal	Permanent	Temporal
Climate	Template sub humid with dry season and 6 months rainy season	Template sub humid with dry season and 6 months rainy season	Template sub humid with dry season and 6 months rainy season
Soils	Acrisols	andic Cambisols	andic Cambisols – Acrisols - Indurated volcanic tuffs
Land uses	Mainly grassland, degraded, some rainfed agriculture, few forests, gullies all along the catchment	Mainly forests and rainfeld agriculture with avocado plantation last years	Mainly forests and rainfeld agriculture with avocado plantation last years and gullies at the lower part of the catchment

	Huertitas		La Cortina		Potrerillos	
	Ha	%	Ha	%	Ha	%
Rainfed agriculture (avocado)	0,0	0,0	7,5	0,7	2,8	0,3
Rainfed agriculture (resting)	46,7	17,3	225,4	22,4	142,3	13,4
Rainfed agriculture (cultivated)	5,8	2,1	221,0	21,9	138,4	13,0
Human settlements	1,3	0,5	2,2	0,2	2,1	0,2
Eucalyptus forest	0,0	0,0	0,0	0,0	35,6	3,3
Pine-oak forest open	10,0	3,7	39,0	3,9	81,2	7,6
Pine-oak closed	21,7	8,0	450,1	44,7	269,7	25,3
Gullies	29,1	10,8	0,0	0,0	66,7	6,3
Matorral open grassland	92,9	34,4	12,5	1,2	230,1	21,6
Closed matorral	19,5	7,2	0,7	0,1	12,3	1,2
Pastureland	43,2	16,0	49,0	4,9	83,6	7,9
TOTAL	270,2	100,0	1007,3	100,0	1064,7	100,0

Land use of Huertitas La Cortina and Potrerillos-El Calabozo in 2008 (Carlon y Prat)



Map of land use in 2008 of La Cortina watershed (Carlon and Prat)

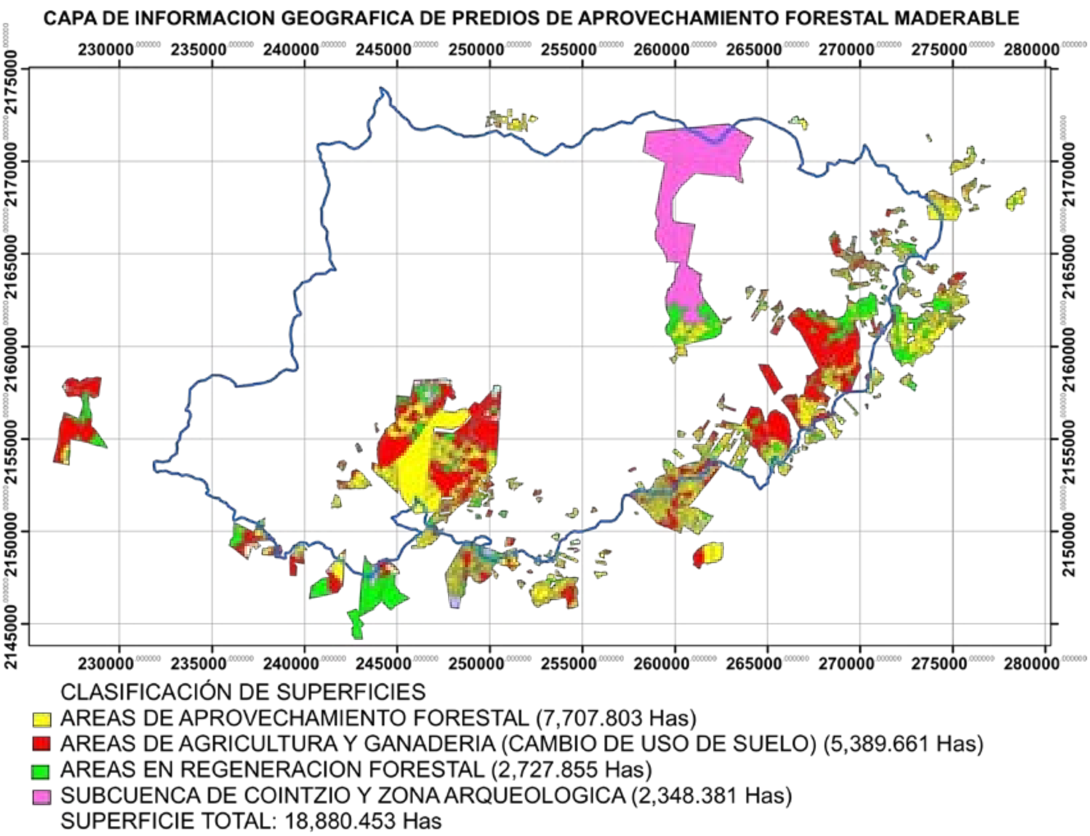
The capture of the land use at the field scale during 5 years is ongoing and will be finish soon to allow the comparison with climatic data and modeling.

It is clear that the land degradation is not the same in the catchments and solutions must be different and adapted to the local reality (environmental and population). All must control cattle which is the main cause of soil erosion.

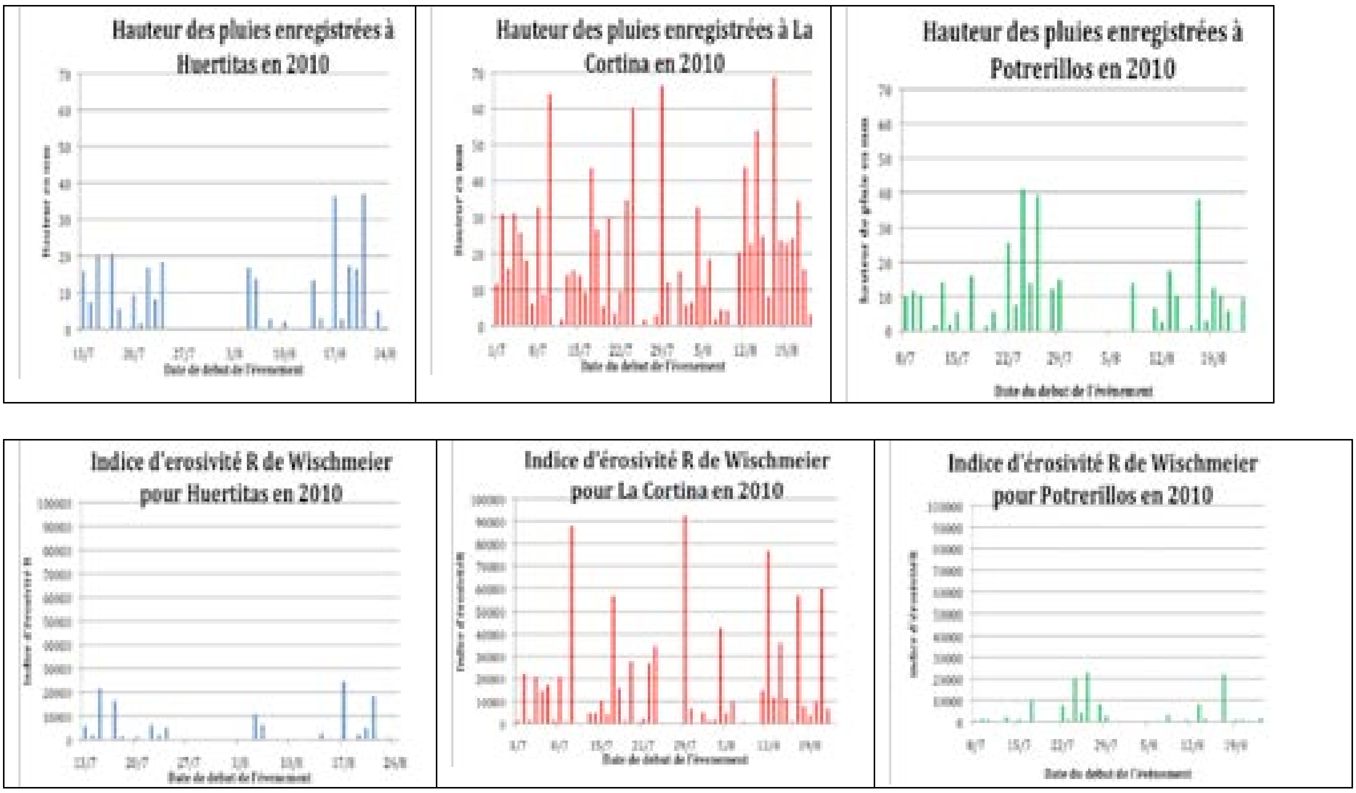
Acrisol with gullies can be treated with Agave plantation and gullies control, meanwhile Cambisol and Andosol can uses agricultural sytem adapted like no tillage and improve (or limit?) the avocado plantations, the new “green gold” of México. These plantations are water consuming and high potential of erosivity and water contamination the first years if actions are not done.

Remediation programs in the Cointzio catchment

To know the effectiveness of the official program of land remediation by reforestation gullies control, no tillage etc. we must know first these programs, where they are, etc. We start with SEMARNAT to collect this data first of the forestation and locate them in a GIS. We will follow this work in 2011 with others topics of land remediation and institutions.



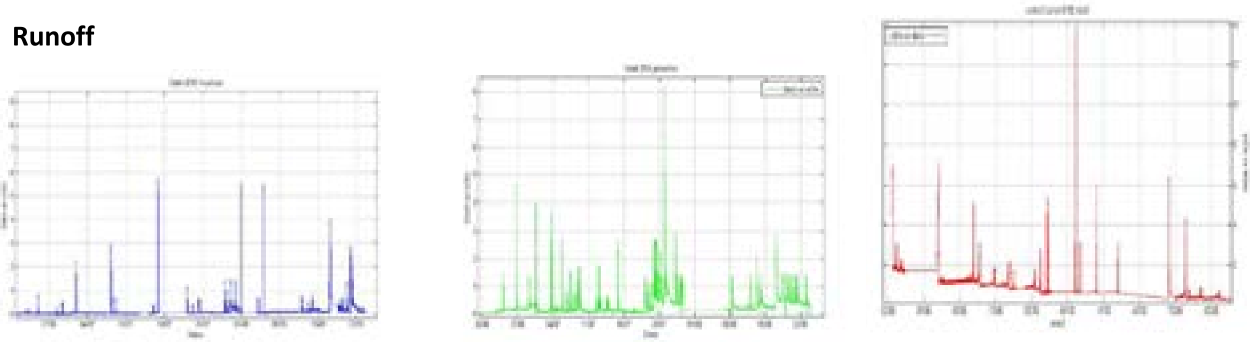
Rainfall



Rainfalls and Wischmeier erosivity index (metric system) for the 3 watersheds in 2010 (here, untill sept 10)

Rainfall was nearly 50% higher in 2010 in regard to 2009 which was quite dry. This is due to the impact of « El niño » event. But there is a strong difference this year between the watershed of Huertita and Potrerillos in regards to Potrerillos in terms of volume and erosivity of rainfalls. This one presents value 2 times higher than the 2 others.

Runoff

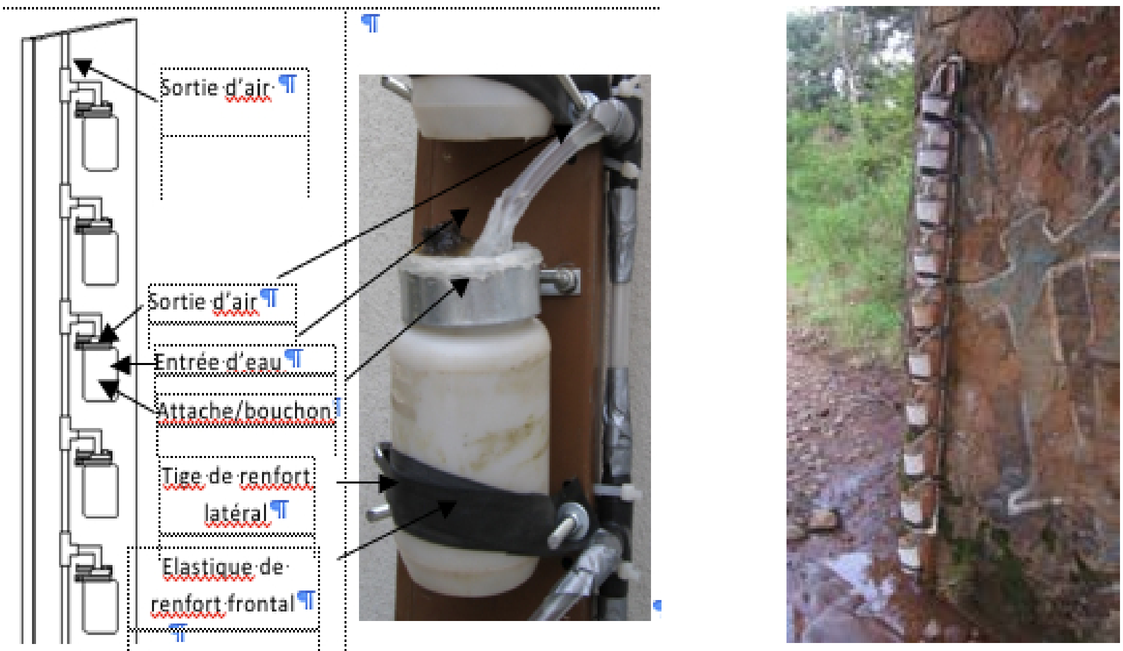


Floods measurments at the outlet of the 3 watersheds in 2010 (here, untill sept 10)

Comparing the three sites between them for the year 2010, we observe that floods from the Cortina and Potrerillos watershed have nearly the same values (4 and 6 m3 s-1), even if the maximum flood flow is higher in La Cortina. The flow rates are obtained Huertitas about them a little weaker than the other two sites, since only the largest floods reach the same throughput thresholds… in spite that this catchments is 3 times smaller than the 2 others, but it is much more degraded

In first approximations for this year, it is possible to see, comparing these flood data with rainfall measures, that the maximum level water match with the higher rainfalls (Huertitas 15/08, 21/08 and 16/08 La Cortina). In the case of Potrerillos watershed, there is a relatively large transfer time since the rain occurs and the flood registered (7 hours delays the 24-25/07). On the contrary, some floods do not correspond with any rainfalls and some rainfalls do not generate floods! These incongruences are due to the extreme localization of the rainfalls (few square kilometers) which are not always registered!

Suspended sediments



Design of trap sediments and installation in the Potrerillos watershed outlet (Y. Grusson, 2010)

This new system funccioned very well with the help of farmers in charge of them.

Watershed	N° Flood	N° flood without registration of trap sediments	Percentage
Huertitas	24	1	4
La Cortina	16	1	6
Potrerillos	17	3	18

The lack of registration of sediments can be due to a double flood when there is not enough time to take samples between both events (Huertitas). But usually, it is due to the lack of reactivity of stakeholders, especially when they are living a bit far from the measurement site, like in Potrerillos
The charge of sediments transported in regards to 2009 where automatic and permanent samplers where functioning and this year, as well between the catchments, present differences (see table below). This can be explained by the difference of equipment and of the energy of floods, stronger in 2010 than in 2009. Obviously, the ideal would be to measures the same sites with both technics.

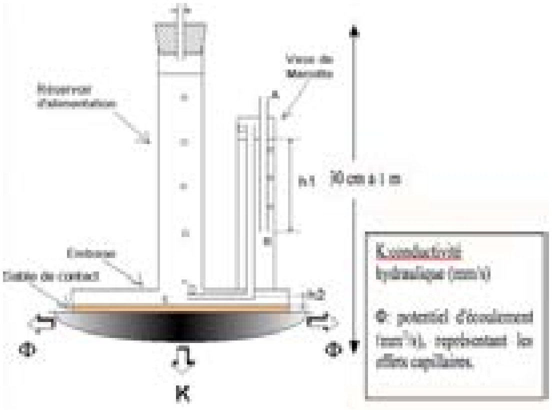
	Huertitas			La Cortina			Potrerillos		
Year	2009	2010	2010 values at 25 cm	2009	2010	2010 values at 25 cm	2009	2010	2010 values at 25 cm
Maximum	55,4	55,6	44,7	7,8	47,8	13,4	125,7	224,4	157,27
Minimum	0,0	1,0	1,0	0,0	0,2	0,2	0,1	11,0	11,00
Median	2,2	13,0	8,3	0,5	4,6	1,8	8,0	44,0	33,18

Comparison of maximum, minimum and median sediment concentration of all floods on the 3 catchments for 2009 and 2010 (Y. Grusson, 2010)

Two catchments exported high sediment yields (i.e., Huertitas, [900– 1500] t km−2 y−1 and Potrerillos, [600–800] t km−2 y−1). In contrast, the third catchment generated a rather low sediment export (i.e., La Cortina, 30 t.km−2 y−1). At the scale of the entire 630–km2 basin, we could not derive any direct relationship between rainfall intensity and sediment concentration. This can be explained by the high spatial variability of rainfall and by the effect of the vegetation growth throughout the season, which provided a protection to the soil against erosive rainfall. Erodible sediment availability on hillslopes was identified as the main factor controlling suspended sediment delivery. The occurrences of numerous active gullies in Huertitas and Potrerillos provided a constant sediment source linked to the river network, which explains the high SSY recorded at both stations. At the subcatchment scale, a combination of various parameters was responsible for sediment control. Peak discharges during floods were found to be significantly associated with exported loads; discharge proved to be a controlling factor when sediment was not lacking. This limit in stream transport capacity preferentially occurred during hydrograph falling limbs. Furthermore, a minimum erosive power was detected in Huertitas and La Cortina, which was regularly reached during floods. In these subcatchments, the role of seasonality was particularly clear, with higher sediment export in the first months of the rainy season. This may be attributed to the growth of the vegetation throughout the rainy season. The rapid succession of several storms was also a cause for high sediment exports, and particularly in Potrerillos. This was associated with a preliminary filling of the channel storage, without the compaction or drying out of particles, which was rapidly followed by a channel flush; but it may also be due to a better connectivity between active gullies and stream channels.

Water infiltration

The infiltrometer is a standard method for determining in situ two phenomenological parameters of the infiltrability, hydraulic conductivity and sorptivity hair on unsaturated soils. These two parameters are used to characterize water movement in soil. Conductivity, K, is a measure of the effect of gravity on the training ground water to the depth through the soil pores.



The measurement system, called TRIM (Triple Ring Has mulitple Infiltrometers Suction) was developed in the Laboratory of Transfers in Hydrology and Environment in collaboration with the Institute HortResearch in New Zealand ([White & Clothier, 1981]; [Thony et al., 1991], [Vauclin and Chopart, 1992])

The method of multi-potential semi permanent regime had been follow. 3 repetitions of 4 locations corresponding to different uses of the same type of soil (Cambisol andic): fallow soil at the top of the furrow, fallow soil in the furrow, soil freshly ploughed with a tractor with disks, and existing soil under forest

a/ Youen Grusson with the disk infiltrometer on Andosol corn field let just harvested (C. Prat 27.04.10)
b/ C. Prat and Y. Grusson doing measures with disk infiltrometer on Andosol corn field let in fallow (P. Bustos 2010)

Results show that the infiltration rate is very high, especially compared to the Acrisols (3 mm/h). The difference between the kinds of land use is surprisingly not so high, in term of average. But, it can present extreme differences for the same system, like for measures done on the ridge of the follow and for the plough. This variation must be taken in count in the modeling and interpretation of runoff and soil erosion.

K (mm/h)	Follow-Ridge	Follow-Furrow	Ploughed	Forest
Maximum	70,92	36,36	84,60	44,28
Minimum	12,46	26,75	2,39	20,41
Average	41,69	31,55	43,50	32,35

Hydraulic conductivity obtain in the andic Cambisol of La Cortina watershed (Y. Grusson, 2010)

13.3.2 Gully control

Semi cantitative evaluation of dams build with stones witout cement to control gullies. They are characterized by:

- Constructions are spread all over the basin
- Done by a succession of small dams made with stones without any cement and located inside gullies
- 90% of this dams are in good state after less than 5 years
- 80% have very few or no sediments captured meanwhile the others one have only from 10 to 20% of their capacity refilled.
- Usually, it is the first one of a serial which is refilled. Apparently, as they have been done as a close succession of dams, the first one located upper stream, can catch some sediments (10 to 20% of refilling) but the other ones do not trapped any sediments. In this situation are they really functioning or not? The answer could really be obtain looking what is going on during rains, but due to security reason (army and narco traffic) it was not possible this year to wait in the fields during the night (rains occur at 90% during the evening and night) to check this point. Anyway, one answer can be also that one: if there is no sediment trapped, it is because there is no sediments eroded! In fact in the area tested, structures have been done on volcanic tuffs and not on degraded soil. That is means that there is not a lot of fine sediments existing and able to be eroded and transported.

For the future, the localization must be better chosen and the strategy must be adapted according to the local situation.

Examples of dams in gullies in EL Calabozo-Potrerillos catchment (photos C. Prat, 2010)

13.3.3 Agave agroforestry

Agroforestry land remediation with local agave (Agave inaequidens) for production of Mezcal (alcohol) and can be also used as fodder for cattle in association with local trees. This is a new trial that was started late as a response to the sudden increase in Agave production as a result of trade agreements between the US and Mexico.

First steps done in 2010: *testing and defining system and people interest :* 5_ha have been concerned. Transplanting wild local agave (A. inaequidens) on degraded area., selection of plants, definition of planting strategy according to the context and objectives.

Strategy defined after test and workshops with stakeholders (start end of 2010)

1. Community Organization
    a. Keeping the organization of workshops with the communities.

    b. Plant production sites.

According to the distances between the communities, the soil type, the population size and the territory of communities, we propose to create 4 production centers of Agave and trees in the basin of Calabozo-Potrerillos which concerned the group of communities:

- S. Coapa Rafael, San Rafaelillo, El Bañito, Yerbabuena vieja
- The Maiza, La Yerbabuena, S. Andrés Coapa
- Potrerillos
- Chihuerio, S. Miguel Coapa

This site number may be reduced according to the available resources but should not be less than2 sites.

2. Seedbeds for the Agaves and trees (per site)
    a. 1 place of 10 x 10 m for the Agave and another one of 5 x 5 m for trees
    b. Appropriate substrate of forest soil with compost earthworms (is possible)
    c. Water available for irrigation by gravity
    d. Fences against animals

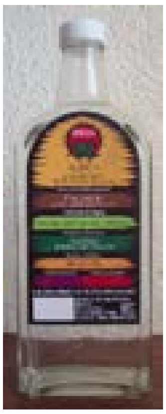
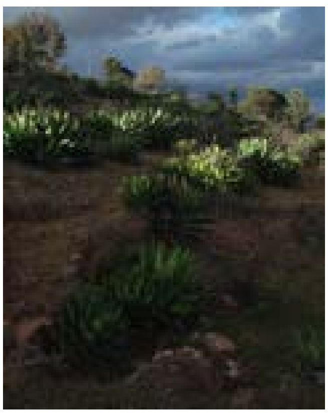
3. Greenhouses (per site)

    a. 1 place of 50 x 50 m (1/4 ha) to 200 000 Agaves and 1 place of 21 x 36 m (1/4 ha) for 60 000 trees.
    b. Appropriate substrate of forest soil with compost earthworms (is possible))
    c. Water available for irrigation by gravity
    d. Fences against animals
    e. Nursery with greenhouses involves full-time 2 people per site per year.

4. Agaves transplantation for soil restoration with native maguey and production (After one year in the greenhouse or directly by transplantation of wild plants

    a. Planting density maguey: / ha 1.5 * 1.2 m = 2.218 plants
    b. Density of planting trees / ha: 3 * 3 m = 1.090 plants.

5. Transplantation of agaves for living borders
    a. Agave planting density on the line every 0.20 cm-= 5 plants / linear meter.


a/ One objectif to reach : commercialisation of certified Mezcal… results in 7-8 years (C. Prat, 2009) b/Area of natural reproduction of local Agave inaequidens (C. Prat, 2010) c-d/ Plantation of Agave by local farmer (E. Rios, 2010), e/Agave transplanted (C. Prat, 2010)

13.4 Involvement of stakeholders

The agroclimate, rainfall gauges, water level and sediment trap Installation are located in the fields of people who are in charge to take care of the equipment. In some case, people are also in charge to take samples, and realize some measures.

As farmers are paid, they are interested to do it. They don't see a direct interest for themselves… because our results are interesting at a watershed scale and not really at individual one.

Note that the institution in charge to collect climatic and hydrological data are not so interested by our results because they are not planned and because, they have a lot of budget restrictions last years and they must give priority to strategic situation (dam refilling, drinking water, flood controls, etc..). In spite of these, they always give us all the help that they can and always received and, finally used, some or our data.

Scientific institutions are obviously the most interested in our results.

Infiltration: Just an IRD action to complete other data

Evaluation and effectiveness of control of gully erosion by small dams as well as the Agave plantation have been discussed during workshops and directly on the field with some farmers. Institutions in charge of remediation are also interested by our results and by the way work with us.

People are interested to do some actions against soil erosion but consider that the dams are probably not so useful. For the Agave plantation and project, there is a lot of expectation.

13.5 Discussion and conclusions

- Minimum tillage, ground cover, good fertilization and organic residue incorporation are some keys to reduced soil erosion.
- Agave plantation in a productive perspective under agroforestry practices, will keep biodiversity, generate works and remediate soils.
- Infrastructural works must be done after good studies to identify critical areas, and must be start from upper to lower part of the waterhed.
- Free grazing cattle is the main cause of soil erosion. But to control it, the **global** farmer situation must be taken into count.
- Farmers involvement is possible if program brings money to do concrete actions.
- Actions can be oriented specifically to men or women or for both
- Administration involvement is possible, when there is program designed for actions where DESIRE can bring some support (and NOT the opposite).

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14 CHILE – SECANO INTERIOR

Site coordination

Partner 27 - Instituto de Investigaciones Agropecuarias (INIA)

14.1 INTRODUCTION

There are two main problems in the Secano Interior: (i) the first identified by the farmers as being one of the most serious problems is due to low sustainability of traditional production system, which is responsible for erosion and depletion of soil fertility, (ii) Second problem is due to soil erosion and land degradation which is caused by the Mediterranean type of climate and inappropriate soil management.

Investigations have been focused on crop rotation and experiments to decrease runoff and soil losses and to improve soil water availability for crops. These tests are being conducted on the experimental station in Cauquenes in central Chile.

14.2 TRIAL LAYOUT

14.2.1 CROP ROTATION EXPERIMENTS

The experiment was carried out in experimental center of the Agricultural Research Institute (INIA), Cauquenes, which is located in the interior dryland of the Mediterranean climatic zone of Chile. The study is being carried out from 2008 to 2011. Two experiments were set up: one on cereal – pulses rotation, and the other on legume pasture – cereal rotation.

Rotation 1: Four grain legumes (peas, white lupine, yellow lupine and Vicia faba) in rotation with wheat were tested. The experimental design is randomized block with four replications. Plot size is 4x5 m.

Table 1. *Rotation with grain legumes through the years*

Treatments	*Years*			
	2008	*2009*	*2010*	*2011*
1	*A*	*T*	*A*	*T*
2	*A**	*T*	*A**	*T*
3	*Ll*	*T*	*Ll*	*T*
4	*La*	*T*	*La*	*T*
5	*P*	*T*	*P*	*T*
6	*A-V*	*T*	*A-V*	*T*

A: Avena sativa (with N fertilization)
A: Avena sativa (without N fertilization)*
Ll: Lupinus luteus
La: Lupinus angustifolius
P: Pisum sativum
A-V: Avena sativa – Vicia faba (green manure)
T: Triticum durum.

Rotation 2: Two mixtures of annual legumes and different length of the period of the pasture are being testing in rotation with wheat (Table 2). The design is a randomized block with four replications. Plot size is 6x6 m.

Table 2. *Rotation with pasture over the years.*

Treatments	*Years* 2008	*2009*	*2010*	*2011*
1	*Lr*	*Lr*	*Lr*	*Lr*
2	*A*	*T*	*A*	*T*
3	*L1*	*T*	*L1*	*T*
4	*T*	*L1*	*L1*	*T*
5	*L1*	*L1*	*L1*	*T*
6	*L2*	*T*	*L2*	*T*
7	*T*	*L2*	*L2*	*T*
8	*L2*	*L2*	*L2*	*T*

Lr: Lolium rigidum
A: Avena sativa
T: Triticum durum
L1: Trifolium subterraneum + Medicago polymorpha + Trifolium michelianum
L2: Trifolium subterraneum + Biserrula penicilius + Ornithopus compressus.

Measurements

Assessments on Crop and Pastures: Natural abundance of ^{15}N, ^{15}N isotope dilution, photosynthetically active radiation (PAR) intercepted by the crop, dry matter production (above-ground and root) and grain yield biomass, in all treatments and in pasture, seed production, botanical composition, seed hardness, and seed bank and regeneration capacity for self-seeding.

Soil Assessments: in situ N mineralization, leaching of nitrates and volatilization of ammonia.

Variable	*Years* 2008	*2009*	*2010*	*2011*
Abundance of natural ^{15}N				
Dilution with ^{15}N isotope				
Mineralization of N in situ				
Leaching of nitrates				
Volatilization of ammonia				
N Balance in crop rotation				
Yield				

Photo: Leaching of nitrates, using capsules of ceramics (lysimeters, 60 cm depth).

14.2.2 Experiments on erosion

An oat-wheat crop rotation was established in 2007. The following tillage systems were evaluated: *i)* no tillage (Nt); *ii)* Nt with subsoiling (Nt+Sb), which consisted of a subsoiler at 40 cm depth, every 40 cm perpendicular to the slope, conducted in 2007 before sowing; *iii)* Nt with *Phalaris aquatica* barrier hedges (Nt+Bh) at 12.5 m distance; *iv)* Nt with contour ploughing (Nt+Cp) every 12.5 m with a 1% slope to remove water from the plot; and *v)* conventional tillage with animal plowing (Ct) . Plot size was 1000 m^2 (Fig. 1).

Monitoring

- On each rainfall event: Sediments, nutrient losses and runoff (Photo 1)

- Soil quality index: soil compaction, Bulk density, aggregate stability, structure, soil water characteristic curve.
- Biological index of soil: Enzymes (FDA, Acid Phosphatase Activity, Arysulfatase, beta-Glucosidase)
- Chemical index: Nitrogen, Phosphorus, pH, organic matter
- Crop rotation evaluations: Biomass, Leaf area, photosynthetically active radiation, grain yield and water use efficiency in C^{13}.
- Monitoring on each season: Soil water content (Photo 2), rainfall

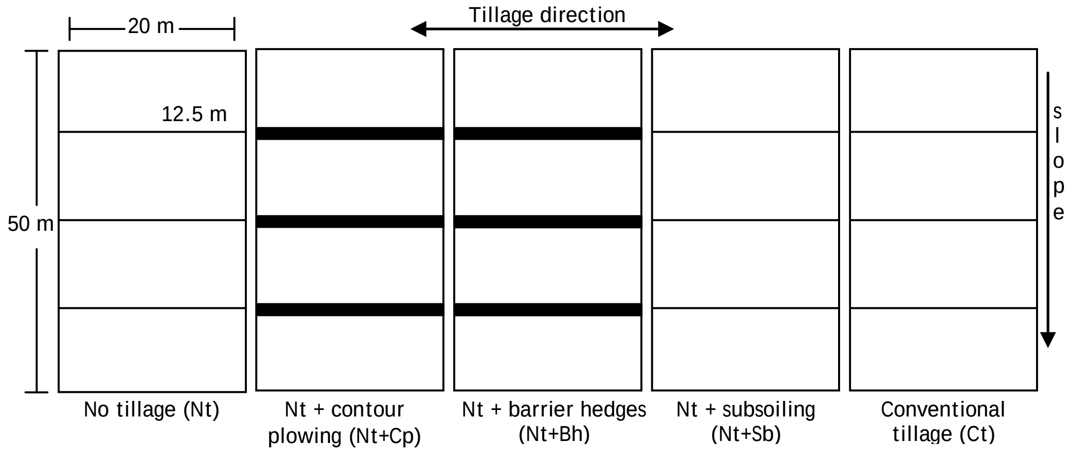

Fig. 1. Map of experimental site.

Variable	2007	2008	2009	2010
Runoff	⟷	⟷	⟷	⟷
Sediments	⟷	⟷	⟷	⟷
Nutrient losses	⟷	⟷	⟷	
Yield	⟷	⟷	⟷	⟷
Soil Moisture	⟷	⟷	⟷	⟷
Physical indicators	●		●	
Biological indicators				●
Soil compaction	⟷	⟷	⟷	⟷

Photo 1. Runoff storage tanks

Photo 2. Soil water content meaurement with neutron probe

14.3 Analysis and Results

14.3.1 Crop rotation experiments

A. *Rotation 1. Four grain legumes (Pisum sativum, Lupinus angustifolius, Lupinus luteus and Avena sativa – Vicia faba (green manure) were evaluated in rotation with wheat.*

Total biomass of wheat in the second year of the rotation

In the wheat crop (second year of the rotation), no N was applied to any of the plots, therefore the year 2009 wheat grown without N application, it is only supplied by the N fixed by legumes grain in the previous year (2008).

Table 3, show the total biomass (root plus shoot) of wheat in the second year (2009). At tillering phonological state of the wheat, no significant differences between the monoculture of cereal with N (wheat, fertilized with 200 U ha^{-1} yr^{-1},) and wheat growing after lupins and peas were found. At the end of advanced tillering, the cereal monoculture with application of N had the highest total biomass (2,469 k ha^{-1}) but at this state it was not different ($P \leq 0.05$) to the crop after lupins and peas.

The highest grain yield was obtained in the monoculture cereal rotation with N application (table 3). A decrease of about 50% in yield occurred in the crop rotation without N supply, whereas when the cereal was grown after legume grain, yields declined only between 21 and 41% depending on the legume crop in previous year (table 3).

Table 3. *Biomass in different states of development and yield of wheat (k ha^{-1}), after different grain legumes.*

Treatments (Crop rotation)	*Phenological stage*				*Grain yield*
	Tillering	*Advanced tillering*	*Shooting*	*Grain filling*	
	k ha-1				
Cereal monoculture + inorganic N	*488 a*[1]	*2.469 a*	*4.177 a*	*12.970 a*	*3.328 a (100%)*
Cereal monoculture + Without inorganic N	*274 b*	*908 c*	*2.158 b*	*8.735 c*	*1.533 c (46%)*
L. luteus - Wheat	*437 a*	*1.933 ab*	*3.674 a*	*9.947 b*	*2.483 b (75%)*
L. angustifolius - Wheat	*470 a*	*2.145 ab*	*4.734 a*	*9.334 b*	*2.623 b (79%)*
P. sativum - Weath	*463 a*	*1.470 bc*	*4.146 a*	*9.965 b*	*2.398 b (72%)*
Avena sativa – Vicia faba (green manure) - Wheat	*285 b*	*1.071 c*	*2.081 b*	*8.275 c*	*1.950 c (59%)*

Total fertilizer in cereal monoculture + inorganic N, was 350 k Urea ha^{-1}. [1]Values with different letter in columns present differences among themselves ($P \leq 0.05$) according to minimal significant difference.

Preliminary Overview of N balance in the rotation

From the N derived from the atmosphere in legumes (Nfda) and N losses by leaching (Nl) and N removed by grain legume (Nlg), it is possible to calculate the N available for the following crop in rotation through the following equation:

$$\text{N balance} = \text{BNF-Nl} - \text{Nlg}$$

N supply due to the FBN by grain legumes in the first year ranged between 139 and 184 k N ha^{-1}. Leaching losses (NL) (60 cm depth) were higher in L. luteus (5.04 k N ha^{-1}) than in L. angustifolius and pea (3.12 and 1.40 k N ha^{-1}, respectively). Other outputs were the N removed by grain legume which ranged between 42 and 66 k N ha^{-1} (Table 4).

From the inputs and outputs of N in the rotational system (table 4), there is a positive balance of N in all tested grain legumes, varying the supply of available N between 88 and 120 k N ha^{-1}.

The balance in the rotation is performed by the contribution made by grain legumes (balance N) and removal of N in cereal grain, which shows a positive balance in all rotations ranging between 47 and 81 k N ha^{-1}, allowing sustainable rotations in the short term (one year of crop rotation), because the extraction of N by the cereal is not made at expenses of the N soil pool, but it is the efficient use of the contribution of grain legumes (Table 4).

Table 4. *Balance of rotation (k ha^{-1}) wheat after different mixtures of grain legumes.*

Crop rotation	*BFN*	*N grain legumes*	*Leaching of nitrates*	*Balance N*	*N grain cereal*	*Rotation balance*
	-------------------------------k N ha-1-------------------------------					
L. luteus - Wheat	*139*	*42*	*5.04*	*92*	*44*	*48*
L. angustifolius - Wheat	*157*	*66*	*3.12*	*88*	*41*	*47*
P. sativum - Weath	*184*	*63*	*1.40*	*120*	*39*	*81*

B. Rotation 2. Two mixtures of annual legumes pastures and different length of the pasture in the system are being tested in rotation with wheat.

Total biomass of wheat in the second year of the rotation

Table 5 shows the total biomass (root plus shoots) of wheat in the second year of rotation (2009); after one year of annual legume pasture. There were observed statistical difference ($P \leq 0.05$) between the treatments with annual forage legumes, compared with cereal monoculture without N, which presented a lower yield of total biomass in all phonological stages analyzed.

The same trend observed in the total biomass expressed in wheat, was observed in grain yield where cereal monoculture without N had a yield of 1,533 k ha^{-1}, while wheat yields after forage legumes, increased their productivity between 43 and 51% depending on the legume crop in the previous year (table 5).

Table 5. *Biomass in different states of development and yield of wheat (k ha^{-1}), after different mixtures of annual legumes.*

Treatments	*Phenological stage*				*Grain yield*
	Tillering	*Advanced tillering*	*Shooting*	*Grain filling*	
	------------------------------ k ha-1 ----------------------------				
Cereal monoculture + Without inorganic N	*274 b*	*908 c*	*2158 b*	*8735 c*	*1533 c (100%)*
Pasture Mix 1 - Wheat	*373 a*	*1004 a*	*3575 a*	*9693 a*	*2193 a (143%)*
Pasture Mix 2 -Wheat	*404 a*	*1070 a*	*3779 a*	*9766 a*	*2313 a (151%)*

Total fertilizer in cereal monoculture + inorganic N, was 350 k Urea ha-1. [1]Values with different letter in columns present differences among themselves ($P \leq 0.05$) according to minimal significant difference; Pasture Mix 1: Trifolium subterraneum + Medicago polymorpha + Trifolium michelianum; Pasture Mix 2: Trifolium subterraneum + Biserrula penicilius + Ornithopus compressus

Preliminary Overview of N balance in the rotation

From the N derived from the atmosphere in legumes (Nfda), subtracting the N removed of N by the forage intake by sheep, plus losses by leaching (Nl) and volatilization (Nv), it is possible to calculate the N available for the next crop in rotation by the following equation:

N balance = Nfda – forage intake by sheep - Nl - Nv.

In Table 6, it is observed the FBN values for both annual legume pastures that ranged between 42 and 49 k N ha^{-1}. In this system, the main losses are from the N extracted by the consumption of the pasture for the sheep which ranged between 3.3 and 3.6 k N ha^{-1}. Secondly, the N volatilization from the feces and urine varied from 0.64 and 0.68 k N ha^{-1} and thirdly the N leaching (60 cm depth) during the growing season ranged between 0.35 and 0.41 k N ha^{-1}.

Therefore, when considering inputs and outputs of N in this rotational system after one year of pasture, the balance was positive, providing between 38 and 44 k N ha^{-1} to the following crop.

The balance in pasture legume-cereal rotation, is performed by the contribution made by the pasture (balance N) and the N removal by the cereal grain, was positive in both rotations, which ranged between 1 and 7 k N ha^{-1}, demonstrating that these rotations are sustainable in the short term, because the extraction of N by the cereal is not made at the expense of the soil pool, but it is the efficient use of input pulses (Table 6).

Table 6. *Balance in crop rotation (k ha^{-1}) wheat after different mixtures of annual legumes*

Crop rotation	*BFN*	*N grain legumes*	*Leaching of nitrates*	*Volatilization of ammonia*	*Balance N*	*N grain cereal*	*Rotation balance*
				------------------------------k N ha-1------------------------------			
Pasture Mix 1	*42*	*3.3*	*0.41*	*0.68*	*38*	*37*	*1*
Pasture Mix 2	*49*	*3.6*	*0.35*	*0.64*	*44*	*37*	*7*

Pasture Mix 1: Trifolium subterraneum + Medicago polymorpha + Trifolium michelianum;
Pasture Mix 2: Trifolium subterraneum + Biserrula penicilius + Ornithopus compressus

14.3.2 Erosion experiments

Temporal and spatial variation of soil water content (SWC)

During the experimental period there was an important variation on annual precipitation. Temporal evolution of total SWC (0-110cm) decreased gradually during crop development in all tillage systems. This is explained by the fact that evaluations were carried out between September and December, period in which rainfall decreases and water extraction by the crop increases. This drying process is dominated by a vertical flow (De Lannoy et al., 2006) in which the development of the plant cover and roots, and water extraction by the crop intervenes, contributing additional variability to the tillage system. In driest years (2007: 372mm and 2009: 535mm), SWC was reduced by 23 to 31%, in which Ct showed the highest decreases in both seasons. However, in a wet year (2008: 768mm) SWC was reduced by 44 to 51% in conservation systems, while in Ct the reduction was 60%. These results showed that conservation systems preserve more soil moisture in the profile than traditional tillage and can be explained because SWC in conservation tillage systems at many semi-arid locations increase with crop residue maintained on the surface, producing less evaporation and greater infiltration (Lampurlanés et al., 2001; Lampurlanés et al., 2001; Jin, 2008; Govaerts et al., 2009). A significant effect ($p<0.05$) was observed between tillage systems and depth in the three years of the study (Table 2). By comparing SWC per strata (10-30, 30-50, 50-70cm; Fig. 2) in the profile during a whole growing season (2008), differences were observed between tillage systems providing two different patterns. In the case of Ct, no real differences were observed between the evaluated depths during sampling time (Fig. 2e). This can be explained because the Ct with animal ploughing inverts and mixes the soil (20-30cm) producing the sealing and crusting of the topsoil with the first rainfall, which reduce infiltration and increase runoff (Lampurlanés et al., 2001; Munodawafa and Zhou, 2008).

Effect of tillage system on soil compaction

Soil compaction evaluations were carried out in the second (2008) and third year (2009) of the study period. The results are presented for the eight soil depths in Fig. 5. In the second year, soil penetration resistance increased from 500 to 1500 kPa in all tillage system at a depth of 2.5-10 cm of depth. Down to 10-20 cm soil penetration resistance changed substantially in Nt, Nt+Cp, Nt+Bh, and Ct tillage systems which exceeded 2000 kPa, compared with the subsoiled treatment (Nt+Sb) which was significantly lower, maintaining an average of 1500 kPa to a depth of 20 cm. In the third year, soil penetration resistance in Nt+Sb markedly increased over the 2000 kPa below 15 cm of depth, while the rest of the conservation treatments exceeded this threshold at 10 cm. These high values in soil compaction are explained by the high percentage of clay in B horizon (18 to 100 cm) and an uniform high bulk density profile (≥ 1.7 Mg m^{-3}; Table 1), which limit root growth due to a) soil water being held more tightly and b) high soil resistance to root growth (Knapen et al., 2007). In addition, several authors have mentioned that an increase in soil compaction, over than 1500kPa, may reduce grain yield (Jung, et al., 2010).

Crop productivity and its interactions with soil water content and compaction
In the first year of the study (2007), oat grain yield and biomass production of Nt+Sb was significant (p<0.01) higher than the rest of the treatments, while Nt+Cp and Nt obtained the lowest productivity. In 2008, (more humid year) the highest wheat productivity was observed in the Nt+Sb and Ct treatments, and the lowest in Nt. Finally, in the third year oat crop production was higher in the Nt+Sb, Ct and Nt+Bh treatments compared to Nt.

<u>Soil loss and runoff</u>
During three years, for each rainfall event were measured runoff, soil loss and nutrient losses. The results indicated that soil loss for all treatments was less than 1 ton ha^{-1}; however, no tillage systems reduced it by more than 73% in 2008 (year with highest rainfall) compared to conventional tillage. Also, the runoff coefficient during the rainfall period (2008) was more than 50% in conventional tillage, while in conservation tillage was between 20-30% in the first month after planting (Fig. 3), and less than 7%.the following month. These results showed the importance of conservation tillage and crop residues to decrease erosion.

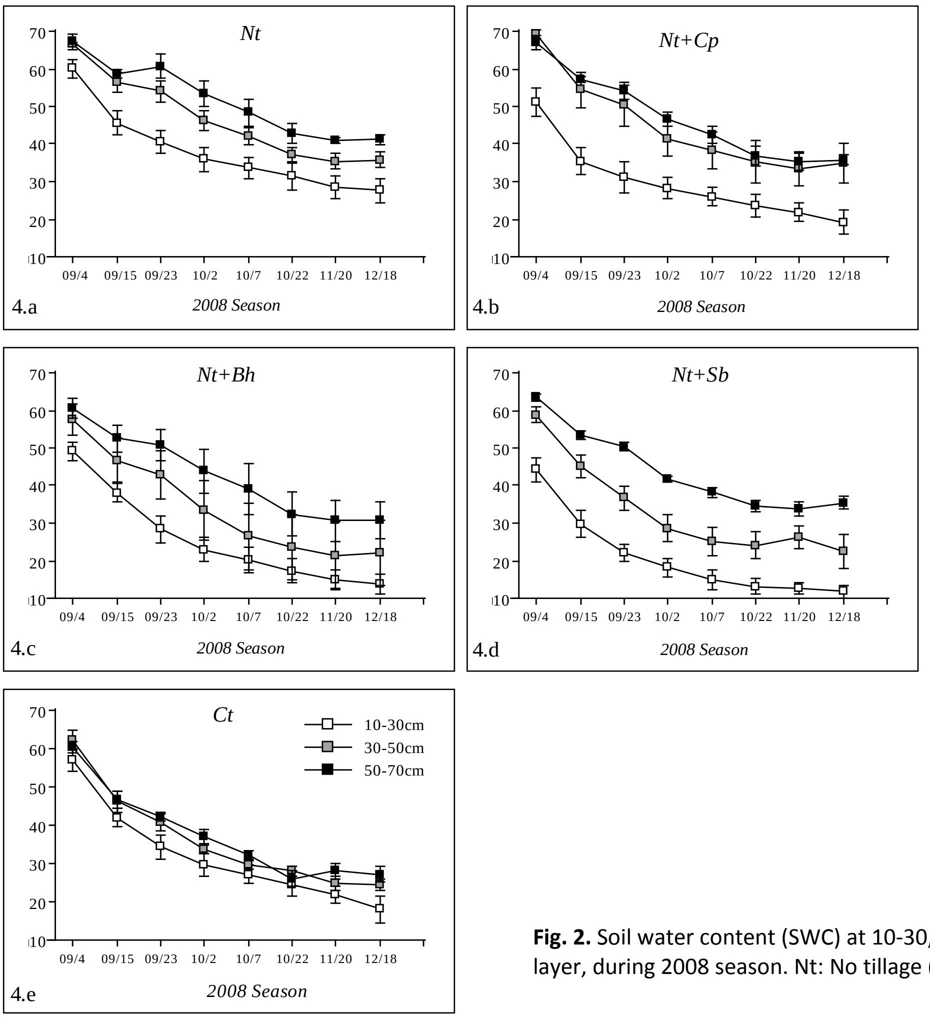

Fig. 2. Soil water content (SWC) at 10-30, 30-50, and 50-70 cm layer, during 2008 season. Nt: No tillage (a); Nt+Cp: Nt+Contour

(e).

ploughing (b); Nt+Bh: Nt+Barrier hedge (c); Nt+Sb: Nt+Subsoiling (d); Ct: Conventional tillage.

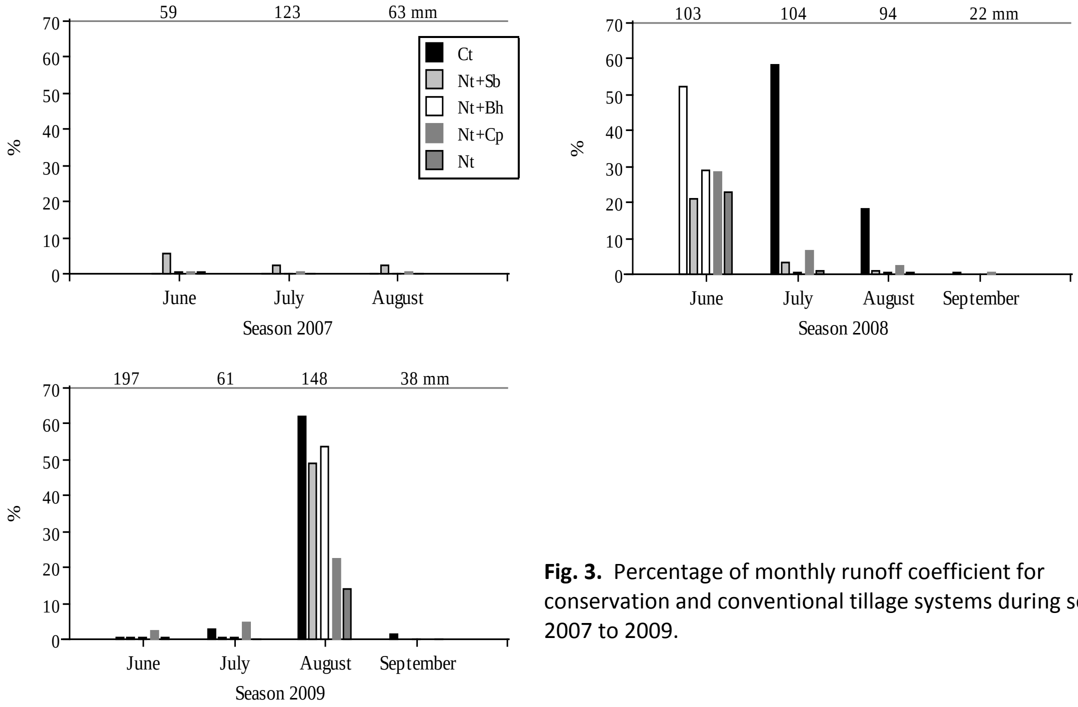

Fig. 3. Percentage of monthly runoff coefficient for conservation and conventional tillage systems during seasons 2007 to 2009.

14.4 INVOLVEMENT OF STAKEHOLDERS

The results obtained in this DESIRE research, are being adopted by the farmers. Based on the results the Ministry of Agriculture through the SAG (Agricultural and livestock Service) has developed and made available to the farmers' financial support for the adoption of such technologies

The results helped to decrease the costs of nitrogen fertilization.

Dissemination to the stakeholders: 200 Farmers and 120 students visited the experiments during 2008- 2009.

Filed day in Cauquenes, October 2010.

Total Biomass in ear emergence in wheat at the second year rotation (Cereal- grain legumes)

Results obtained are being adopted by the Agricultural and livestock Service to generate new policies to farmers.

Also, from the results in DESIRE, a new participative and diffusive project in conservation tillage began with the County of Yumbel. The wheat yield in Nt was 300% highest to Ct. Results were presented in a Field Day with the participation of 400 farmers.

In 2010 a new project (Yumbel County) was established in 30 ha, where the farmers adopted Nt with subsoiling and contour ploughing with barrier hedge in a wheat-oat crop rotation.

Photo: Meeting with stakeholders

14.5 Discussion and conclusions

Using isotopic techniques the contribution of BNF by the legumes (annual pastures and grain legumes) in crop rotations was evaluated. The amount of N provided by the legumes ranged from 42 to 184 k N fixed ha^{-1} yr^{-1}.

In both studied rotations, the saving of N fertilization (k N ha^{-1}) by using grain legumes and / or annual forage in rotation with cereal was higher than 50%, reaching in some cases to 80 % of the total requirement of N by the crop.

The N balance in the rotation with legume pastures was positive for both mixtures. A positive amount of N remains in the soil after one rotation cycle (1 and 7 k N ha^{-1}). The mixture 2 consisting of Trifolium subterraneum var. Seaton Park + Biserrula pelecinus var. Casbah + Ornithopus compressus var. Santorini, was more efficient .

The rotation balance in grain legume-cereal: pea, L. luteus and L. angustifolius were positive, ranging between 47 and 81 k N ha^{-1} after sowing wheat, demonstrating the effectiveness of the contribution of biological N fixation by legumes to cereal.

The results from the erosion experiments indicates a common pattern for the three years, where Nt+Sb and Ct treatments showed the highest yield and the lowest SWC in the profile, especially on Nt+Sb treatment; the subsoiling reduced SWC between 10-30cm depth and favored water extraction by the crop leading to higher productivity particularly in dryer years (e.g. 2007). This investigation suggests that the choice of conservation tillage system without any modification on soil structure will affect crop yield in compacted soils. In addition, in the Mediterranean climate region, the water deficit at the end of the growing season is other limiting factor for cereal production, due to the low water infiltration and low root biomass in compacted soils (Sojka et al., 1993; Hong-ling, 2008; Alvarez and Steinbach, 2009; Vidhana Arachchi, 2009). Therefore, no tillage combined with subsoiling (Nt+Sb) is particularly relevant in these environments where much of crop growth occurs in spring (at the start of the dry season) and is generally subjected to a water deficit during the grain filling-period of cereals (He et al., 2009; Jin et al., 2007). Also, the runoff coefficient during the rainfall period was more than 50% in conventional tillage, while in conservation tillage was between 20-30% in the first month after planting, and less than 7% the following month. These results showed the importance of conservation tillage and crop residues to decrease erosion.

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15 Cape Verde – Ribeira Secca

Site coordination

Partner 28 - National Institute for Agriculture Research and Development (INIDA)

15.1 Introduction

Cape Verde, due to its location in the sub-Saharan region, has been subjected to severe environmental distress, with negative impact for the population. Therefore, since Independence in 1975, the struggle against desertification and its adverse consequences have been one of biggest concern of the people and the Government of Cape Verde. To win the battle against desertification and land degradation the Government, with help from International partners like DESIRE project, has been taking important actions regarding biodiversity conservation, ecosystem management and better valorization of water resources. These actions take into account the progressively scarce rain in Cape Verde as a consequence of climatic change. The contribution of local stakeholders, at all levels, has been crucial to this struggle against desertification. Stakeholders' contribution has included: identification of *in situ* soil erosion symptoms, selection of technologies to combat land degradation due to runoff and flash floods, on-field implementation of technologies, monitoring environmental and socio-economic impacts of implemented technologies.

15.2 Trial Layout

Since the main objective is to reduce flashflood in order to make more water available for crop production, at Ribeira seca study site we worked in a sub-watershed level and not plot scale trials. The two technologies, vegetative barriers with pigeon pea (*Cajanus cajan*) and afforestation with different species of fruit trees, are meant to increase vegetative surface cover, thus, decrease runoff. About 330 ha of pigeon pea, a perennial leguminous crop, and 1000 fruit trees of different species (mango, papaya, avocado, etc) were planted, covering 8 sub-watersheds and involving more than three hundred farmers. To evaluate the effects of technologies, we will monitor the hydrologic behavior in the outlet of the sub watersheds, in which 4 points of measurements are selected: 3 points to the outlet for three sub watersheds and 1 point for 5 other sub watersheds (see sketch map, fig 1).

Fig1. Sketch map showing sampling points

15.3 METHODOLOGY

At outlet level, the indicators measured are ***r***un off, suspended sediment and erosion which are determined by systematically sampling runoff according to the evolution of the water height through flooding or runoff. Water samples are collected in flasks, filtered and the solid obtained is dried and weighed.

At field level, the variables measured include vegetation cover, biomass production of pigeon pea (fodder and fuel wood), maize yield, height of sediment accumulated and erosion symptoms.

Due to the large area to cover, the quantity of pigeon pea seeds to sow was high; thus, we hired two experienced farmers associations (Covada & OASIS) to implement this work during the 2010 rainy season. However, we may enhance that the DESIRE team elaborated an inventory of all beneficiaries (individually), and by localities, in order to have a real framework of acquisition and distribution of the seeds.

Regarding the distribution of fruit trees, we mainly privileged the uplands (more humid), due to the higher rate of fruit set and growth.

The associations had clear instructions of how to distribute and make a proper monitoring of the sowing process, but due to delay in acquisition of the seeds (it was not available on the local market and had to be purchased and shipped from another island), not all instructions were followed as were initially planned. The seeds were only available to the stakeholders towards end of August, and then all other sowing had already been made, and therefore most stakeholders were unable to follow the appropriate instructions, which was to sow in contours lines with the minimum spacing of 6 meters. This fact was only observed when the team started the monitoring and follow-up process. Such phase started a few weeks after the sowing process, since it takes about 15 days for pigeon pea to germinate.

Since it was impossible to evaluate the parameters in the entire study site, we installed yield trial plots in selected localities, to subsequently make an assessment, by climatic zones (humid, sub-humid, semi-arid and arid). Fifty four (54) assessment plots of 7 m x 7 m (49 m ²) were selected in 9 locations. In each location we installed 6 plots, being 3 controls (without pigeon pea) and 3 with pigeon pea crop. Harvesting of the plots is ongoing as well as the evaluation of biomass, yield of maize and beans and fuel wood. Data will be evaluated and analyzed to the scale of study area. All plots have been geo-referenced for future mapping.

15.4 ANALYSIS AND RESULTS

Table 1. Time graph of measurements

Variables	2009								2010[1]				
	5	6	7	8	9	10	11	12	8	9	10	11	12
Run off max inst. ($m^3.s^{-1}$)	0	0	0	0	6.16	2.22	0	0	0	3.42	1.75	0	0

Mean Suspended sediment ($g.l^{-1}$)	0	0	0	0	10.78	8.02	0	0	0	4.0	2.80	0	0
Erosion ($t.km^{-2}.yr^{-1}$)	0	0	0	0	672	32	0	0	0	5.25	2.50	0	0
Sediment accumulation (cm)													
Germination rate (%)									N/A[2]	N/A	N/A	N/A	N /A
Growth quality													
Soil cover (%)									60	80	85	85	80
Treated area (ha) with C. cajan											330		
Biomass Yield ($kg.ha^{-1}$) _C. cajan									N/A	N/A	N/A	N/A	N/A
Production ($kg.ha^{-1}$)_ C. cajan									N/A	N/A	N/A	N/A	N/A
Fuelwood yield (($kg.ha^{-1}$))_ C. cajan									N/A	N/A	N/A	N/A	N/A
Production ($kg.ha^{-1}$)_ Maize									N/A	N/A	N/A	N/A	N/A

[1] These are estimated values; [2] N/A = Values not available at this point

Regarding the hydrological parameters they have been monitored for several years. However, it is very early to compare data for before and after implementation of technologies because the selected technologies (perennial crops and trees) require time (two to three years) to produce measurable impacts at hydrological level. It is important to reinforce that implementation took place in the 2010 rainy season (August to October).

As a result of the late implementation of this phase of project, most of the pigeon pea could not be sowed in contour lines to form barriers as planned, but were planted in pits together with maize and beans to cover more ground. This change may constraint the accurate measurements of some parameters. Therefore, we will present some comments regarding evaluation and analysis of each parameter.

Germination rate (%) We are currently making an assessment of the quantity of pigeon pea seeds made available to the stakeholders, the amount of spoiled seeds, and the amount of seed that was actually sown. This value can only be retrieved further ahead during the dry season;

Growth quality As observed in the field, even though in some places the development is higher, we estimated that the growth quality is acceptable, as the plants average 1 m of height and they are vigorous, and not presenting any sign of pests;

Soil Cover (%) The values presented, were obtained through the technical team best judgment criteria. Usually, before the rainy season plant cover is minimum since farmers collect the forage and clean the field in preparation for the next season;

Biomass & Fuelwood yield (kg.ha^{-1}) C. cajan The biomass & fuelwood of pigeon pea yield will only be assessed toward the beginning of the next rain season, period when the farmers will proceed with pruning;

Production (kg.ha^{-1}) Maize At this point, harvesting is still going on and yield is being evaluated in the 54 sampling plots. The process is expected to be finished in March.



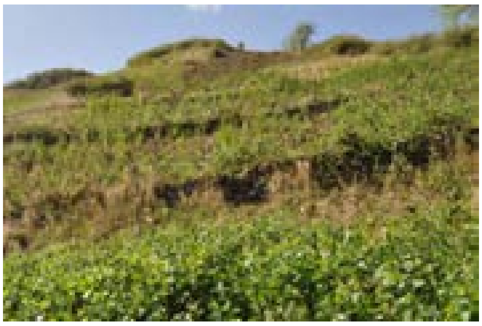

Fig. 2 – Aspects of pigeon pea (Cajanus cajan) plots at 3 stakeholders field in different locations (Chã de Vaca, Ribeirão Galinha e Mato Afonso, (Jan 2011)

Fig 3. Aspect of planted fruit tree

15.5 Involvement of stakeholders

Stakeholders have demonstrated an active and relevant involvement since the beginning of the DESIRE project. Their expectations in terms of outcomes of the projects are also very high. They participated in the first socialization workshop for the project, contributed in the identification of the problems related to desertification and proposed solutions to mitigate them. In the field, they were able to pinpoint and show their fellow farmers what the main constraints were and together they discussed solutions.

Within the framework of the 2nd Workshop, stakeholders enthusiastically engaged in the selection of technologies to combat land degradation and chose two technologies: live barriers of pigeon pea and afforestation with fruit trees. According to them, these techniques would contribute to increase vegetative soil cover and, at the same time, diversify their production and improve their incomes.

The implementation phase of the technologies was the responsibility of stakeholders as NGOS and associations were hired to work for the project during that period. Stakeholders were also called to participate in the evaluation of the technologies.

Fig. 5: Some aspects of stakeholders' involvement (left - two members of Covada farmers associations; center – leader discussing with local people; right – Pigeon pea seed distribution)

Table 2: Stakeholders' involvement

Task	Who
Elaboration of contract to implement technologies	INIDA
Signature of contract	OASIS and Covada
Acquisition of pigeon pea seeds and fruit tree plants	INIDA
Seed and fruit trees distribution	OASIS and Covada associations
Planting of seeds and fruit trees	Local farmers
Follow up on implementation in high altitude zones	Covada association
Follow up on implementation in the low portion of the watershed (low altitude zones)	OASIS
Monitoring of treated areas	INIDA and farmers

15.6 Discussion and conclusions

Since main results from implementation of technologies are not yet available, it is difficult to discuss or draw any relevant conclusions at this point in particularly regarding the hydrological results. Any changes observed between 2009 and 2010 results (hydrological parameters) can hardly be attributed to the effect of the technologies since at the time of measurements the technologies were being implemented. However, we think that real impact will be evaluated in two or three years.

Farmers are optimists that both the cultivation of pigeon pea and plantation of fruit trees within the scope of DESIRE will significantly contribute to protect their soil against erosion, increase crop production and improve their livelihood conditions through more income generation. Farmers are aware of the benefits of pigeon pea crop as: a high protein content grain legume crop, green manure and firewood (woody stems).