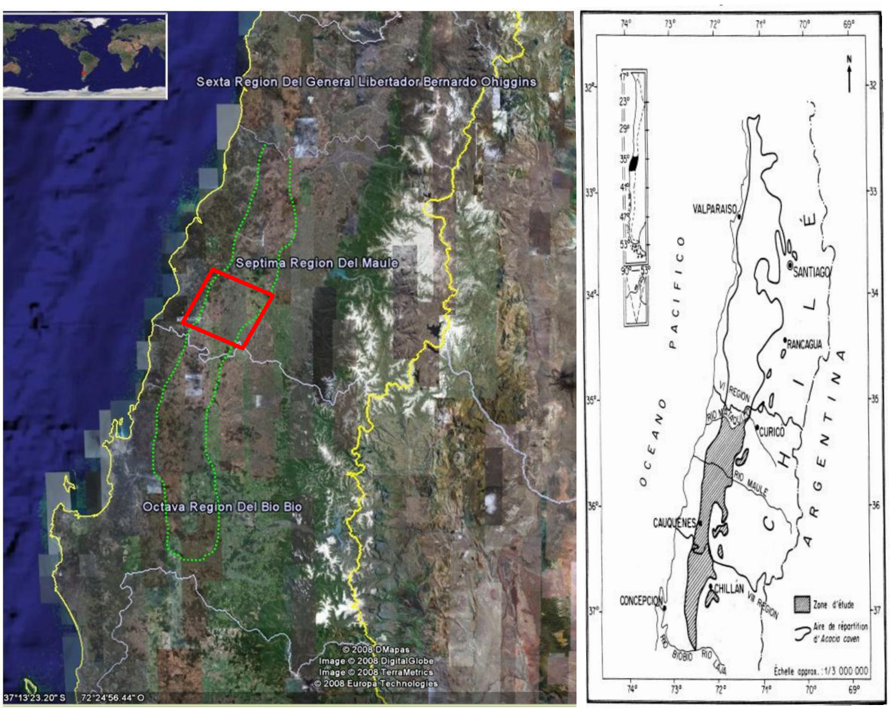
Secano Interior, Chile

Highlights of work carried out in the DESIRE Project
Based on research at INIA, Chile

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

- **Coordinates:**
  Latitude: 35°57' S
  Longitude: 72°23' W
- **Size:** 9097km² (1699km^2 simulation zone)
- **Altitude:** 92 – 180 m (simulation zone)
- **Precipitation:** 550 – 1200 mm
- **Temperature:** 5° – 29°C
- **Land use:** cereals, forest plantations, grass and shrubland
- **Inhabitants:** ca. 300,000 farmers
- **Main degradation processes:** water erosion
- **Major drivers of degradation:** inappropriate land management, soil mining, destruction of natural woodland vegetation



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

Mediterranean dryland areas of central Chile have been subjected for more than four centuries to a heavy destruction and degradation of natural resources. Most of this 2 million ha is occupied by a traditional agricultural system that combines livestock activities with the production of cereals, in soils with high slope. As a result of the prevailing land use systems, about two thirds of "secano interior" soils are badly eroded, and soil organic matter and fertility are very low in many places. At macro regional level, the erosion has provoked environmental imbalances, like siltation of rivers and ports, and serious problems of floods as much as rural level as in the cities. As a result of this historical process it has been produced strong environmental, economic and social imbalances. Indeed, these are the areas of the country with the greatest concentration of rural poverty and the worst quality of life and social inequity.

Geographical description

Erosion is the main cause of degradation of the soils in Chile, in particular in the secano interior dryland area. Due to the topographic conformation of the country, with two large mountain ranges along the country, the Coastal mountain range close to the Pacific Ocean and the Andes mountain range, and the rain intensity and distribution, which is highly concentrated in winter, water erosion is the most important form of soil degradation. With a territorial area of 75.49 M ha, 46% (34.491 M has) are affected by erosion of different degrees; 7% of soils presents a severe erosion, while 27% are highly eroded, 44% moderately degraded and 22% are in state of light erosion degree .

Erosion and some control strategies used in the study area

Geomorphology and soils

There are three types of geomorphological units with three corresponding soil types that affect the "secano interior" and Central Valley: granitic (Maule and Cauquenes Series), metamorphic (Pocillas Series) and vertisols (Quella clay soils). The first two, of Paleozoic origin, are found primarily in the coastal foothills, and include considerable topographic diversity. In contrast, the latter, dating from the Upper Cretaceous or early Tertiary, stretches some 30-100 km westwards from the Andes, depending on latitude. All three soil types are acidic (pH 5.8-6.2), highly susceptible to erosion, and characterized by chronic deficiencies in organic matter, macro- and microelements.

Climatic limitations

Six months of drought (October to March) render the relatively high annual rainfall of the study area far more difficult for rainfed farming than would at first appear. Rainfall is concentrated in the mid-winter months of June and July. High levels of run-off occur from the structurally degraded and compacted soil surface. Aridity decreases from north to south. In the northern limit the annual rainfall is less than 300 mm per year, while the southern boundary reaches to 1000 mm annually. Long term average of the minimum temperatures of the coldest month (July) is 4.8 °C and of the maximum temperatures of the warmest month (January) is 29 °C. In Cauquenes, where the experimental sites have been placed, mean annual rainfall is 695 mm with six month (October to March) of drought period.

Land use.

Agriculture in the Chilean "secano interior" has long suffered from low inputs and dependence on a limited number of crops (cereal, livestock husbandry and viniviticulture). Cutting, burning and plough agriculture over the last four centuries have led to dramatically degraded soils and landscapes of stikingly low bio- and ecodiversity. An anthropogenic formation called "espinales" occupies most of the area (Figure 5), the arboreal stratum of which is comprised a single, spiny legume tree species, *Acacia caven* (Mol.) Mol. The herbaceous stratum consists of a wide variety of Eurasian and other non-native annuals that have virtually replaced all native forbs and grasses in the area.

Over the last 40 years, the coastal foothills, as well as an increasing percentage of hillside of the "secano interior" have been sold to forestry companies who create industrial scale plantations of *Pinus radiata* and *Eucalyptus spp*., with the help of government subsidies. This is contributing to the trend of homogenization of landscape and depopulation of the region. Rural exodus is increasing steadily in the "secano interior" and small and medium-sized farm require new options in the areas of mixed farming, woodlot forestry and new crops in order to survive.

Institutional and political setting

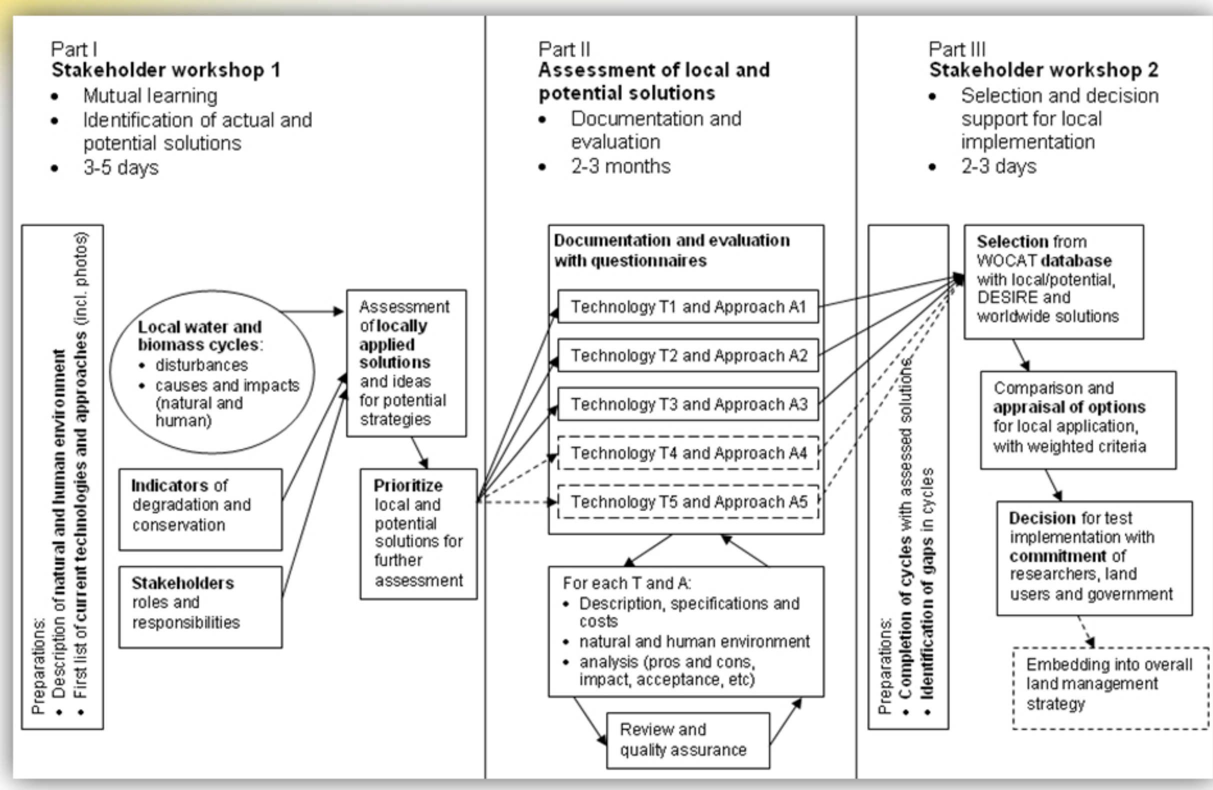
In Chile the Agricultural and Livestock Service (Servicio Agrícola y Ganadero, SAG) has a mission to protect, maintain, conserve and increase the condition of the renewable natural resources, base of the agriculture production including the associated environment and biodiversity, promoting the sustainability of this sector. To reach this objective SAG and the Institute of Agricultural Development (INDAP) designs and applied strategies and environmental instruments to avoid or mitigate the adverse effects on the renewable natural resources, like water, air, soil, biodiversity and wildlife, generated by the activities of different productive sectors, and at the same time, support the environmental sustainability in the agriculture field and in the associated productive sectors. In particular, the SAG and INDAP implement programs of recovery of degraded soils and contribute with subsidies to the farmers for the recovery of the eroded and degraded soils and for the implementation of conservationist practices of soil management. This program has five work lines:

a) soil conservation practices: to avoid physical soil losses. Among such practices are: minimum o zero tillage; dune control; contour lines; establishment of forestry cover, infiltration ditches; organic matter or compost incorporation; and practices that contribute to improve water holding capacity of the soil.
b) crop rotation: the general purposes of rotations are to improve or maintain soil fertility, reduce erosion, reduce the build-up of pests. Crop rotation also means that succeeding crops are of a different genus, species, or variety than the previous crop. The planned rotation sequence may be for a two- or three-year.
c) phosphate fertilization: encourage the use of phosphate in soils, in order to recover the levels of natural fertility, c) soil pH correction: encourage the incorporation of the necessary lime dose to the soil to change the level of pH until a value of 6.0, to reduce the aluminum saturation, and
d) pastures establishment: encourage the establishment or regeneration of a permanent vegetal cover on degraded or fragile soils.

Relevant end-users / stakeholder groups

Two fundamental and key user institutions are **INDAP** and **SAG**. Both institutions have a mission to attend technically and financially to the Chilean farmers with regard to soil conservation and rehabilitation. In particular in the Mediterranean region INDAP and SAG develop programs for recovery degraded soils, fomenting tools for soil conservation like the construction of simple structures for erosion control at farm level, cover crops and sown pastures, and the plantation of trees with agro-forestry purposes.

The Centre of Education and Technology (**CET**), has the mission of help small farmers to increase their life quality improving their technology, agriculture productivity and sustainability of natural resources. The CET has an active role on the articulation of rural organizations with county authorities, research centers and state institutions, in order to have influence on the design of new polices related with rural life. A number of NGOs are available in the secano interior working with small farmers, like Agraria, Grupo de Investigaciones Agrarias (GIA), among others. The large majority of the land in the “secano interior” is private therefore farmers and forest companies will be the final users.



Researchers talked with local people and policy makers, and together they decided on the best options for sustainable land use. In the DESIRE Project the three Parts to WOCAT methodology were developed as outlined above. This provides decision support for choosing technologies suited to the local environment that includes social, cultural and economic factors as well as physical science.

In every DESIRE study site researchers and stakeholders held two workshops to arrive at their selection of approaches and technologies. At the first workshop stakeholders learned about how degradation happens, and how to avoid it.

Meetings of researchers with stakeholders were used to help break the cycle of desertification. Together they discussed and tried out suggestions to find the best ways of reducing the incidence and impact of the chosen technologies while addressing goals for sustainability.

- **Technology 1**: No tillage with subsoiling. No tillage preceded by subsoiling consists of the use of a subsoiler at a 50 cm depth every 5 years before performing no tillage agriculture. This technology mitigates water erosion that occurs with the traditional tillage.

Zero tillage machine drawn by oxen. Seeding of lentils in the rainfed area of Ninhue County . Photo by Carlos Ruiz

- **Technology 2**: Crop rotation with legumes. These systems combine phases of legumes of different lengths, in which N is fixed and accumulated in the soil, followed by phases of cereals where accumulated N is extracted. In this new rotation four legume-wheat rotations were compared to a monoculture crop rotation (wheat followed by oat). The legume species are: narrow-leaf lupin (*Lupinus angustifolium*); yellow lupin (*Lupinus luteus*); Peas (*Pisum sativum*); and a fodder mixture of vetch (*Vicia atropurpurea*) + oat.

Conservation tillage and its effect on water erosion and soil indicators

Using legume-cereal crop rotation for rehabilitation of soil fertility:

Technology 3: Agroforestry systems. Under Mediterranean climate of this part of Chile, water availability for woody species, especially in the first summer, is a key factor in the survival, growth and successful establishment of trees. The use of conservation systems of soil and water management allows a more favorable water balance, increasing water infiltration into the soil and availability for the development of agroforestry species.

Agroforestry species used were cork oak (*Quercus suber*), Quillaja (*Quillaja saponaria*) and a fodder tree called tagasaste (*Chamaecytisys proliferus*). This species showed the highest growth in height, crown diameter and trunk diameter. Among conservation structures, infiltration trenches favour the development of tree species, but are expensive and less efficient in retaining water in the profile, compared to subsoiling with ridges. This structure has shown an increase in moisture content over the infiltration trench between 0-70 cm deep.


System of multipurpose planting trees planting on infiltration trenches(left)

System of multipurpose planting trees on subsoil tillage ridge (right)

Stakeholder workshop

The strategies were evaluated based on the economic, environmental and social benefits that different technologies could offer. A very important set of criteria was all about economics, productivity, profitability and market access. Also, farmers and technicians who participated in the workshop have evaluated environmental criteria. Primarily they chose those technologies that are more profitable and more efficient in terms of control of erosion and mitigate land degradation. With regard to the potential for adoption of the technologies, the main issues that were highlighted by the farmers and technicians were related to:

1. Access of economic incentives for the adoption of conservationists practices. To Include the technologies developed in DESIRE as part of the incentive program for the Recovery of Degraded Soils managed by the Agriculture and Livestock Service (SAG) which implies:
   - Adjusting incentives according to timing of the expenses and investments.
   - Conditioning incentives to the adoption of the technologies
2. Generating a participatory approach for further transfer and dissemination of the results, which implies considering the production systems and the goals of the farmers
3. Developing an adoption model with local leadership - coordination between institutions - long-term institutional commitments.
4. Training for technicians to support the adoption of the technologies.
5. Evaluating the economic and social impact of the soil conservation practices

It is a problem to improve the rate of adoption of strategies. Funding or providing mechanization is the main obstacle for adopting zero tillage and subsoiling. The solution could be to create and promote small companies of agricultural machinery, managed by farmers themselves. Two examples already exist in the countries of San Carlos and Ninhue.

Representatives of the National and Regional of the Soil & Conservation Program were present in the workshop (German Ruiz from SAG, David Aracena from INDAP). They undertook to incorporate the technologies developed in the DESIRE project to the Integrated System to Recovery Degraded Soils (ISRDS) in order to improve the management plans that are funded to farmers. In addition, the Ministry of Agriculture of Chile, through the Agricultural and Livestock Service, committed to continue supporting research and transfer of technology in the Soil Conservation practices, once the DESIRE project has finished.

Feedback from participants

About the workshop, the comments received by the participants were generally very positive. Farmers and technicians highlighted the importance of these types of workshops in which they can give their opinions regarding to the policies and tools of soil conservation, which are promotes by the Ministry of Agriculture in the region and in the country. They expressed the lack of discussion forums on the topic and the necessity to participate in the decisions that involve them directly. In this respect the DESIRE project was an excellent opportunity to make known their views regarding the national program of soil conservation and the way they think, that such might be more effective.

Regarding the project itself, participants highly valued the fact of having participated in the project from the beginning. This greatly facilitated the discussion of the results. They assessed the quantity and quality of the results, especially concerning the technologies on non tillage, subsoiling and the new crop rotations. This aspect will greatly facilitate the extension of the results. In fact the end of the workshop discussion turned around how incorporate effectively the technologies developed in the project, as part of the tools that the State funds. In this respect the farmers requested more transfer of technology, but through a participatory model with local leadership and many more co-ordination between Institutions and institutional commitment to longer term. They also detected weaknesses in the training of technicians, the only way to ensure the adoption of the technologies. They also emphasized the need to evaluate the Economic and Social Impact of the soil conservation practices

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.

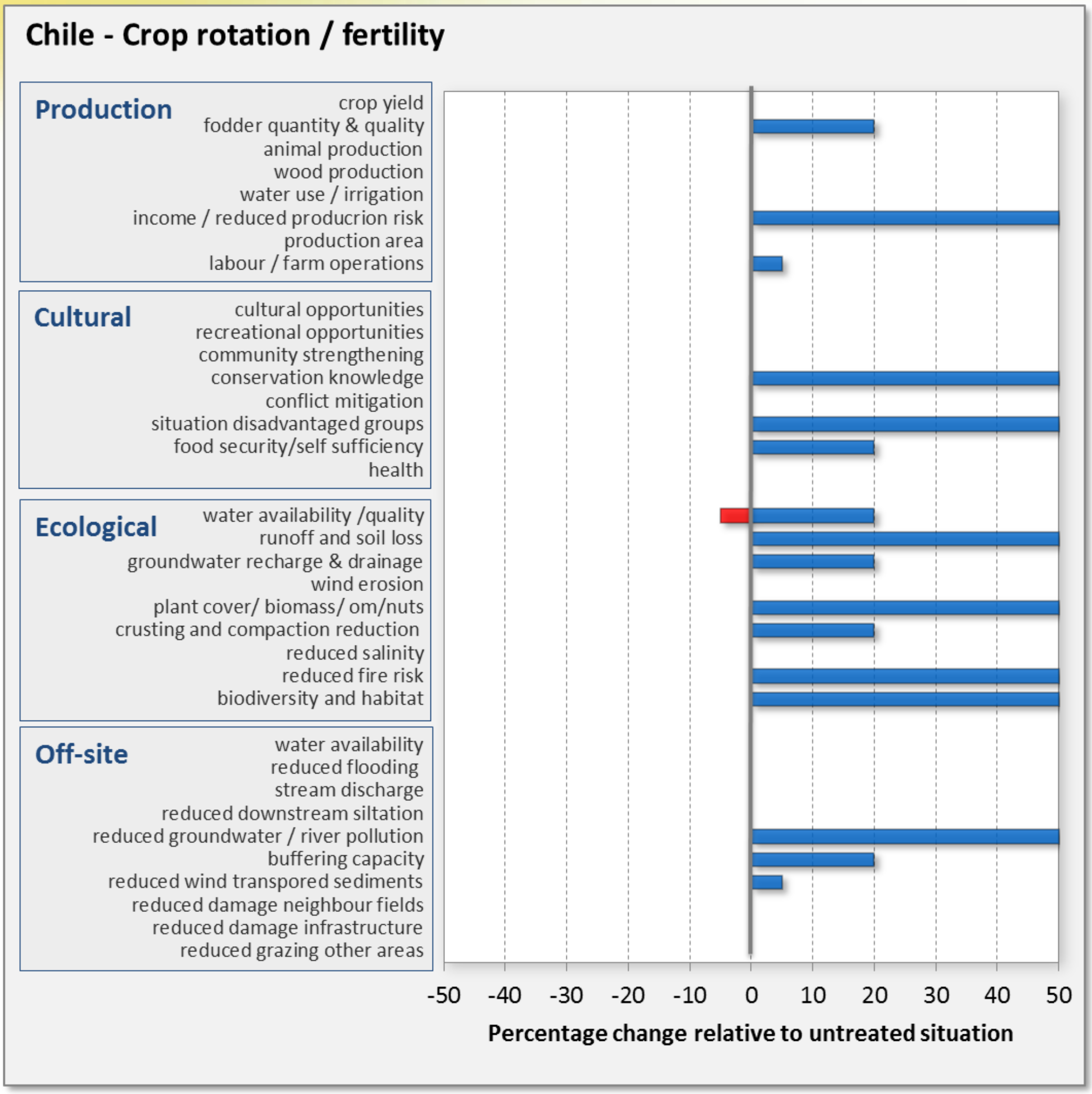
Experiment 1. Four legumes species (peas, white lupine, yellow lupine and *Vicia faba (*a bean species) are tested in rotation with the traditional wheat crop. The experimental design is randomized block with four replications with plot size of 4x5 m.

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.

The yield of the normal wheat with fertilizer was about 30% higher than any of the treatements. Of those the treatments woth Lupine performed 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.

EVALUATION

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 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.

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.

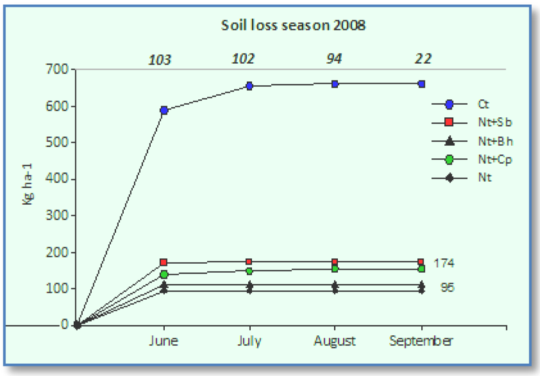
THE EXPERIMENT: NO TILLAGE

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.

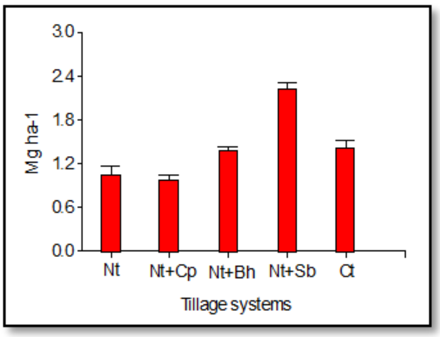
RESULTS



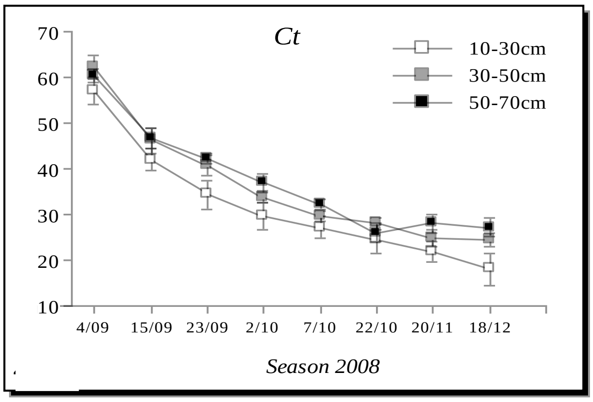
The results indicated that soil loss for all the treatments was less than 1 ton ha^{-1}. The result also shows that the runoff coefficient was more than 50% in the conventional tillage while in conservation tillage it was between 20-30%.

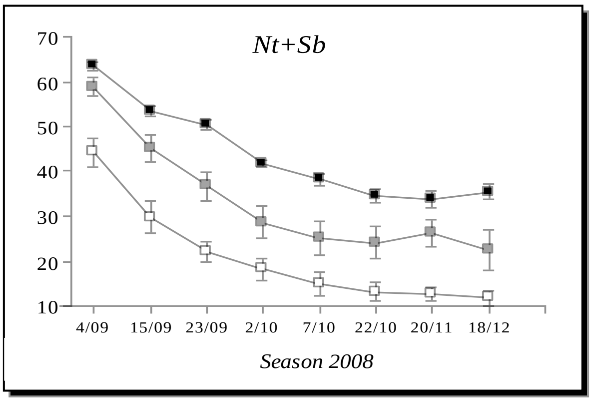
The study on soil compaction shows that in the second year, soil penetration resistance increased from 500 to 1500 kPa in all tillage system at a depth of 2.5-10 cm of depth. In soil depths 10-20 cm soil penetration resistance exceeded 2000 kPa in Nt, Nt+Cp, Nt+Bh, and Ct tillage systems. While in the 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.





EVALUATION

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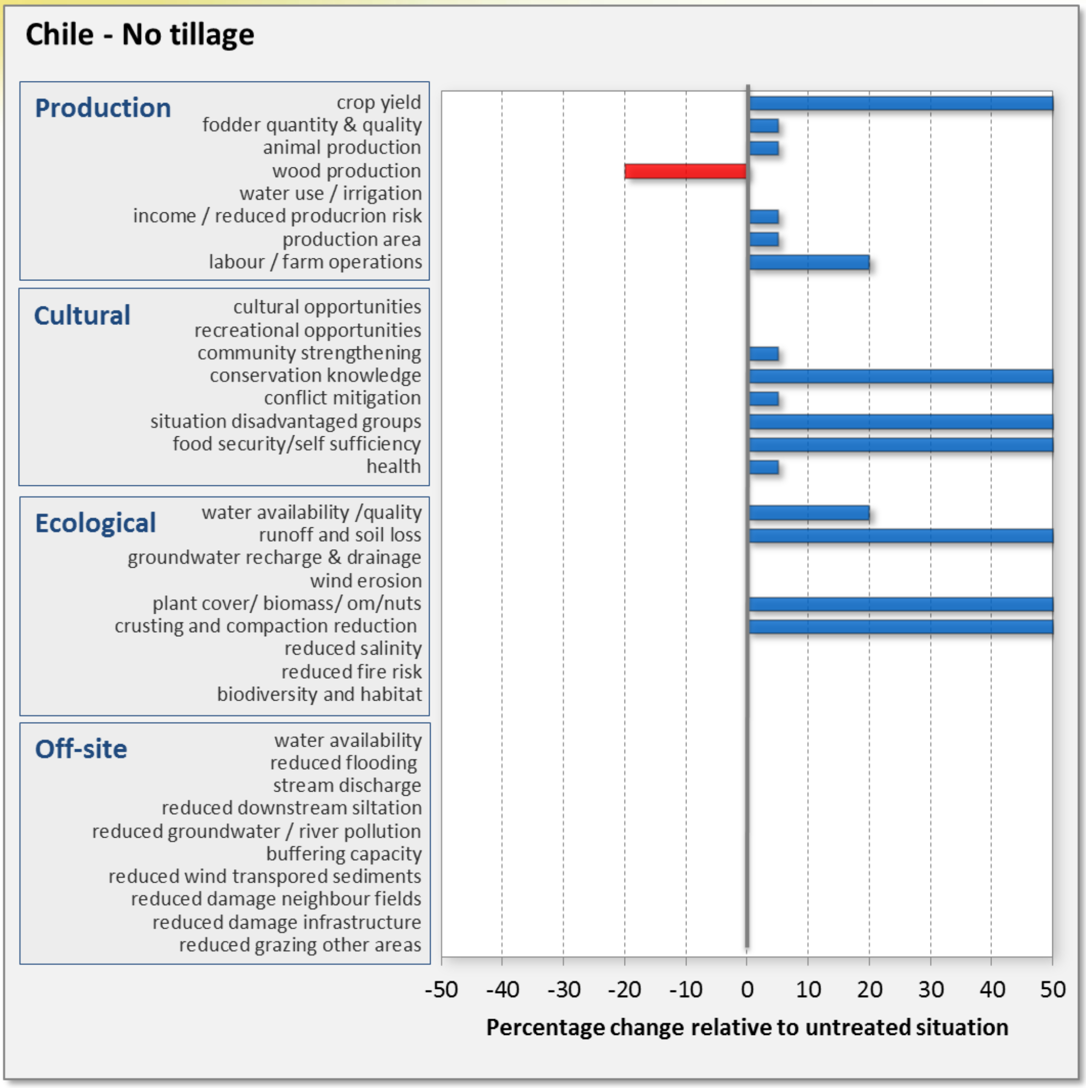


CONCLUSIONS

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.

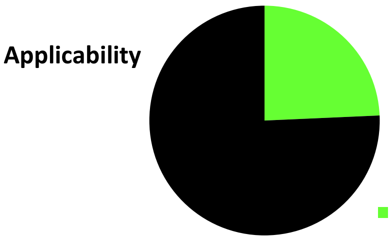
Technology Scenario:

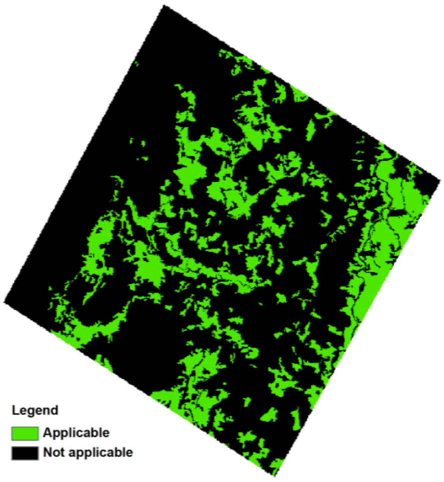
No tillage with sub-soiling (CHL01)

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

Applicability

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

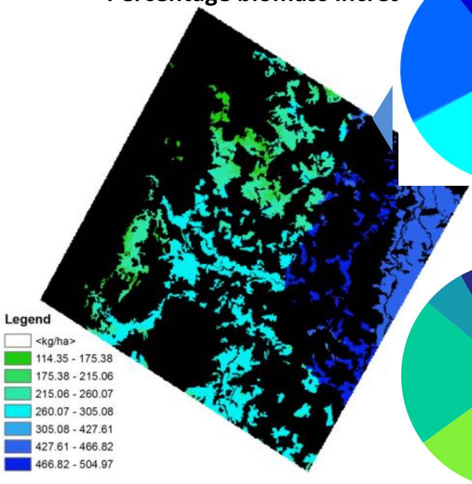


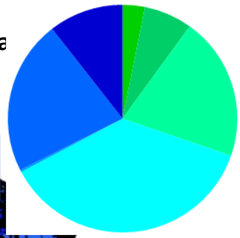


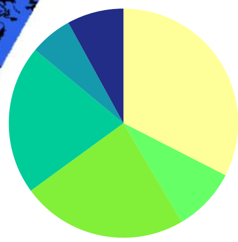
Biophysical impact: increase in biomass

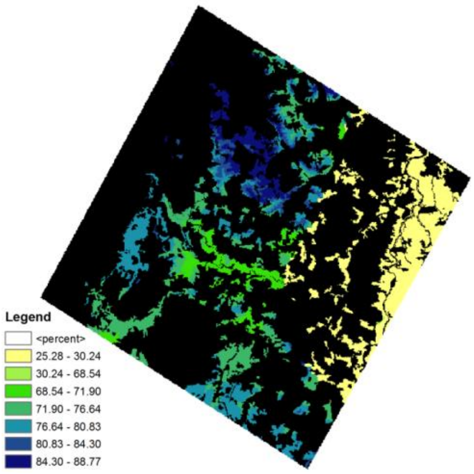
Biomass increase

Percentage biomass increa



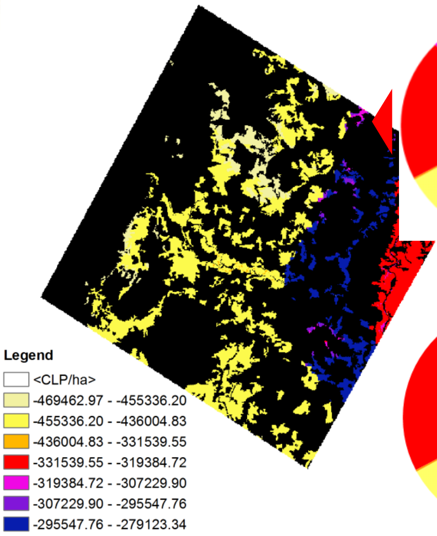




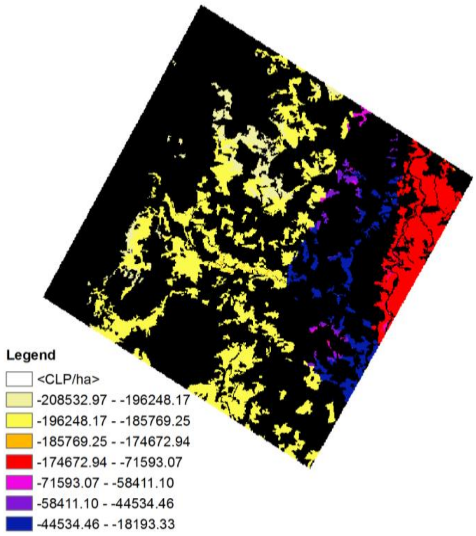


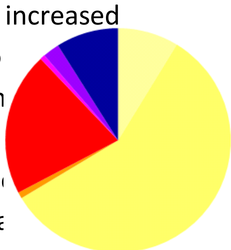
Economic viability

Net profit under traditional tillage system



Net profit under mechanized tillage system





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

Global Scenario:

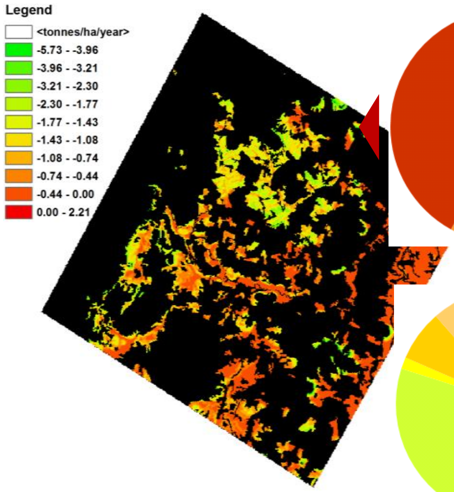
Minimizing land degradation

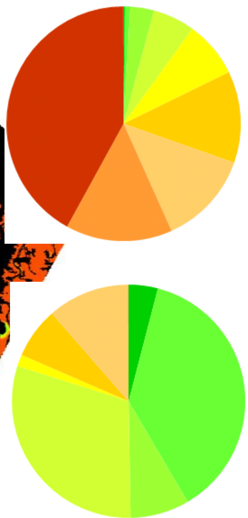
The minimizing land degradation scenario selects the technology with the highest mitigating effect on land degradation or none if the baseline situation demonstrates the lowest rate of land degradation. The implementation costs for the total study area are calculated and cost-productivity relations assessed.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

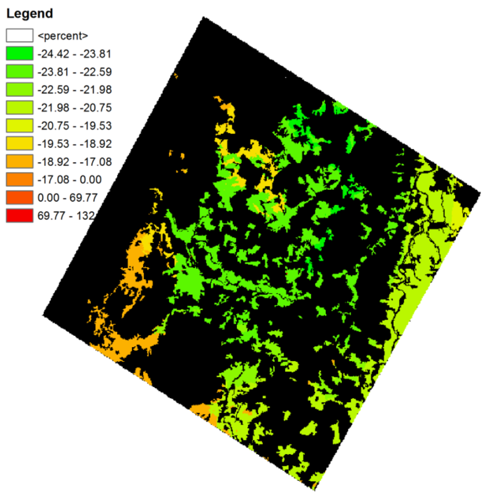
Scope for reduced erosion

Reduction of erosion (negative values)

Percentage of erosion reduction (negative values)







Biophysical impact: erosion reduction

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

CONCLUSIONS

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.

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See: http://www.desire-his.eu/en/secano-interior-chile for full details of DESIRE research