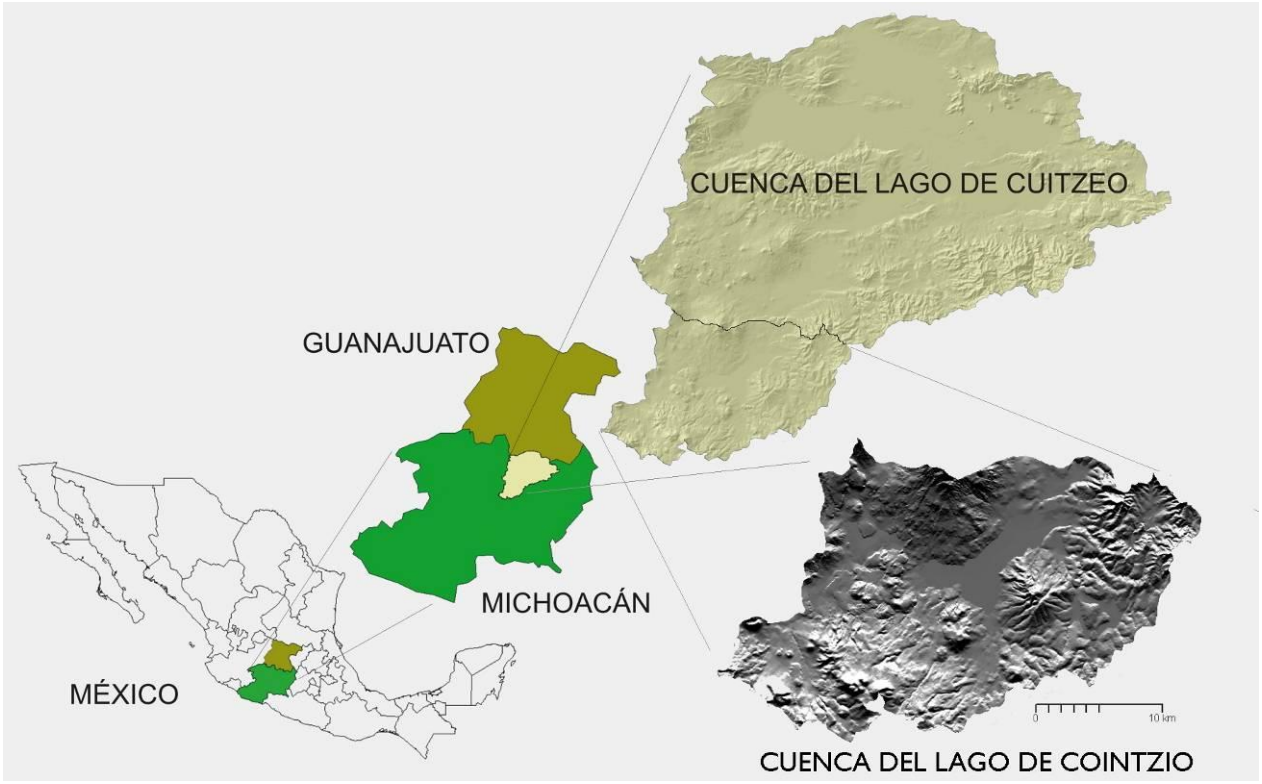
Cointzio, Mexico

Highlights of work carried out in the DESIRE Project
Based on research by IRD

General information

The Cointzio watershed is located between 19º23''et 19º38' North, and 101º10'and 101º34' West. It covers a surface of 650 km^2 and is correspond to the south western part of the Cuitzeo lake watershed of 4 000 km^2.



The Cointzio catchment experiences soil erosion, deforestation, grazing, etc., which also affect water quantity and quality. There are steep slopes and some highly erodible soils. The local customs that encourage overgrazing, as well the removal of crop residues for use as animal food, and burning of remaining residues, have tended to make erosion worse. The benefits of conservation tillage, and a global approach to conservation practices, will be demonstrated and tested.

The Cointzio watershed has a temperate semi-humid climate with a rainy season from June to October and 3 type of soils and land uses distributed among the landscape: Luvisols irrigated and highly mechanized agriculture in the plain, Acrisols with a moderate to low mechanization for a survival agriculture on the hills and Andosols mainly covered by forest over ±2300 m. Cattle are everywhere,

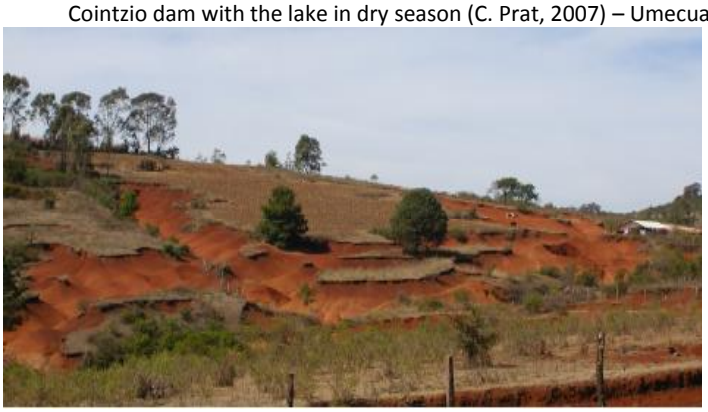
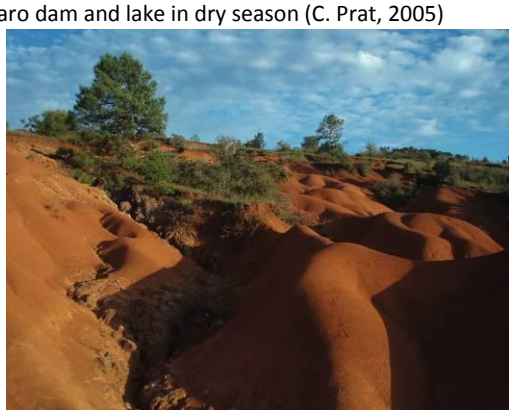
without any real control. Since 2007, avocado plantations with drop irrigation have been established on Andosols.

Mexico is a country with severe erosion problems. The topographic characteristics and rain intensity in the country promote a high risk of erosion, especially on hillside land. 61% of the area dedicated to annual crops in the country is located on greater than 4% slopes. The watershed of Cointzio is like a small plain surrounded by mountains. The outflow of the basin is controlled by a dam, built 70 years ago, which created a lake used for irrigation and drinking water for Morelia, state capital of Michoacán. Another consequence of erosion is the siltation of lakes and reservoirs. Moreover, sediments can adsorb contaminating or eutrophic substances, reducing water quality even more.

In association with the federal and national laws on water, climate, agriculture, etc, programs have been developed to reduce the land degradation and promote a sustainable development. These give a political legitimacy to work in this area, as well as possibilities to find easily stakeholders supports and funds for stakeholders.



Cointzio dam with the lake in dry season (C. Prat, 2007) – Umecuaro dam and lake in dry season (C. Prat, 2005)

Atecuaro landscape with Acrisol strongly eroded and dividing corn fields (Prat C., 2004 and 2008)



In some case (here Potrerillos), when the soil is eroded, the “tepetate” (volcanic tuf) is appearing. Due to its physical and chemical properties, nothing can grow naturally (C. Prat, 2007 and 2009)



New avocado plantations on upper part of the watershed, with drop irrigation, Atecuaro (C. Prat, 2008) – Pine resine extraction, Atecuaro(C. Prat, 2004) - Illegal deforestation (pines), Atecuaro (C. Prat, 2007).


Traditional mixed culture (corn-zucchini-bean) fields on Acrisols on piedmont, El pedregal (C. Prat, 2008) – Drainage channel in the plain (C. Prat, 2008)


Cattle grazing a corn field let in fallow, during the dry season (C. Prat, 2007) - Herbicide application in intensive corn production on plains (C. Prat, 2007)

Existing practices on land and resource uses

The traditional system of agriculture is based on maize, beans and marrow association during one year and the second year it is used as fallow that the cattle graze freely. In case of mechanization, or with Cambisols and Andisols where beans do not grow, monoculture of corn is also usual.

During the last 15 years, 90% of the bulls with yokes have disappeared in Michoacan. In the plains, the main part of the work is mechanized, and a high quantity of fertilizers, pesticides, etc… is used. For the other areas of the basin, tractors prepare the fields for the sowing. Then, sowing and fertilization are done by hand. The corn mounding is done by hand, or more often, with a yoke of horses. In some case, a second fertilization is applied.

Due to low corn prices, farmers focus more and more on animals feeding. That is because, farmers are more interested to produce green material instead of seeds, since they are using plants to feed animals during the dry season.

Animals can go nearly everywhere, from the forest to the fields when they have been harvested or when they are in fallows. But, the main cause of land degradation is due to overpopulation of animals grazing freely which is producing overgrazing. This point is the MAIN cause and problem of land degradation in all the Cointzio watershed.

The avocado production in Mexico took place first around Uruapan city, at 100 km to the west of Morelia. But since the last decade, the boom of the "green gold" promoted by this culture is arriving also in the Cointzio watershed. If tree plantation is good against soil erosion, the avocado plantations during the first years present a lot of problem in relation with the soil and water contamination. For the plantation, the soil is deeply plowed (50 cm!). As soils have andic properties, exposed to dry conditions, they lose all their structure and holding water capacity and so, they are very susceptible to be eroded. To avoid plant competition for water and space, producers use huge quantities of herbicides. Fertilizers and fungicides are also used. These elements can be moved down with the runoff, contaminating rivers. The use of drip irrigation, at least during the first years of the plantation, can be a big problem due to the water volume used, often without any permission. If the avocado plantations continue to increase so much, people down the river will have problem with the water, in terms of quantity and quality.

Existing laws and policies for land and water resource management

There are plenty of laws and policies for land and water resource management, but unfortunately, only a few are really applied. Policies exist at the level of the nation, the state, the watershed and the municipality. The "integral management plan of natural resources of the lake of Cuitzeo", defined in 2008 and accepted in 2009 by authorities, is the new guide line for the sustainable development in Cointzio watershed.

DESIRE research

There have been 2 main scales for 2 kind of tests:

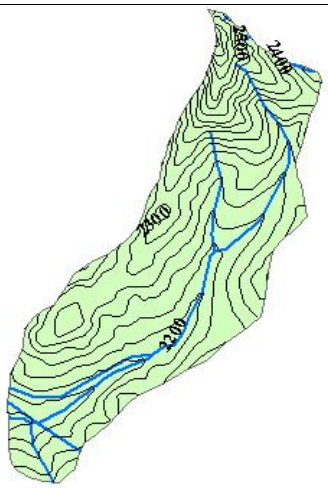
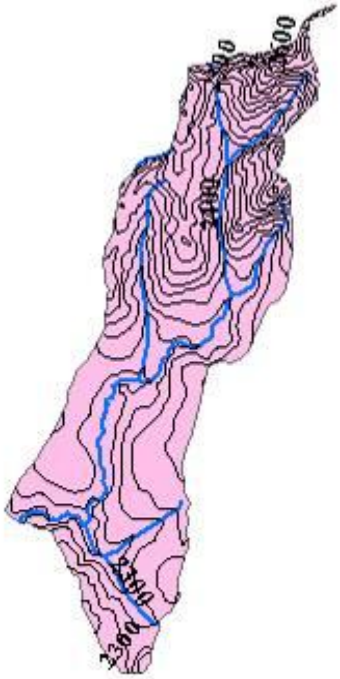
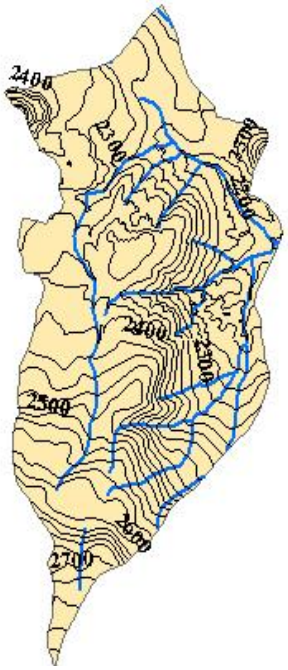
- Farmer plot scale for testing agronomic options (2004-2008)
- Watershed scale for testing and evaluate land use managements (Since 2007)

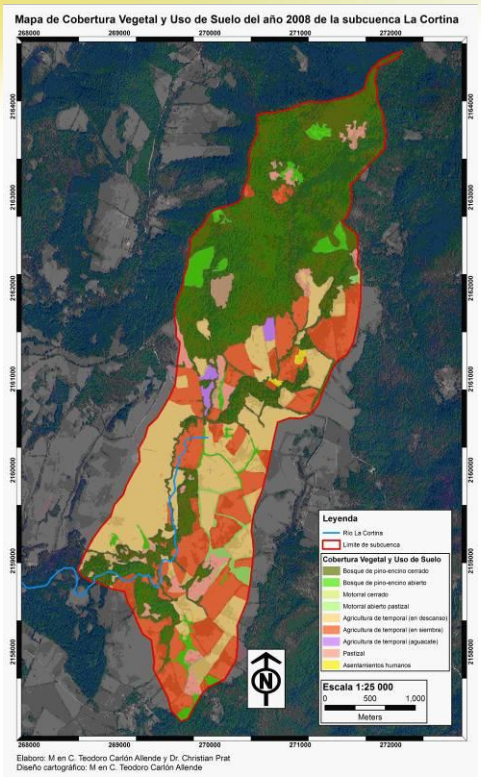
These tests have been conducted according to the soil type (Andosol or Acrisol), the land use (Agriculture, Forest, Pasture) and focused on small farmers, with low to moderate mechanization, with usually no irrigation, low incomes and school level education. Data were collected in the fields and from archives of administrations.

Analysis and Results

Land uses of small catchments

Land uses (types) were compared, in terms of their localization in the catchment in regards to the main drain, and the evolution during the last five years, at the field scale. This was to understand better the runoff and soil erosion as well to try to predict evolution and consequences in term of water use and soil erosion.

		
Huertitas Catchment (2,8 km^2)	*La Cortina catchment (10,1 km^2)*	*Potrerillos-El Calabozo catchment (10,6 km^2)*



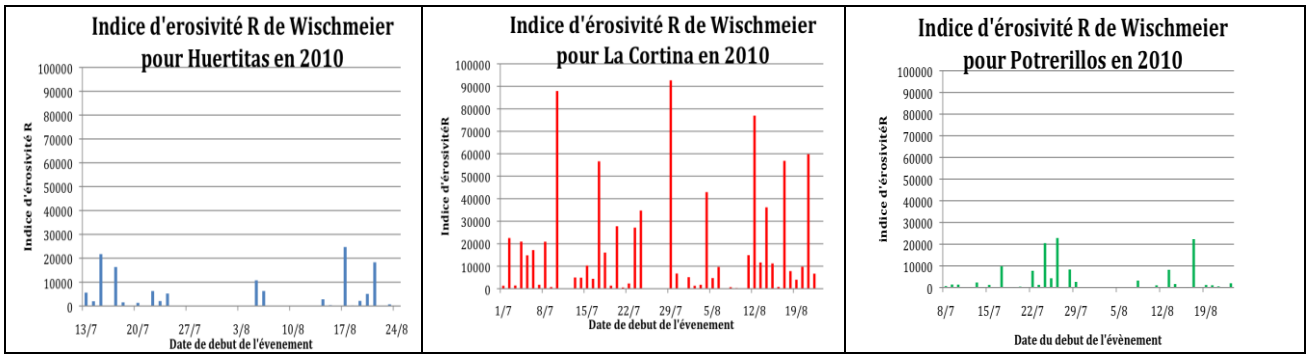
Map of land use in 2008 of La Cortina watershed (Carlon and Prat)

It was clear that the land degradation was 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.

Acrisols with gullies can be treated with Agave plantations and gully control, meanwhile Cambisol and Andosol can uses agricultural sytems adapted like no tillage, with improvements or limits to the avocato plantations, the new “green gold” of México. These plantations consume a lot of water and have high potential for erosion and water contamination.

Remediation programs in the Cointzio catchment.

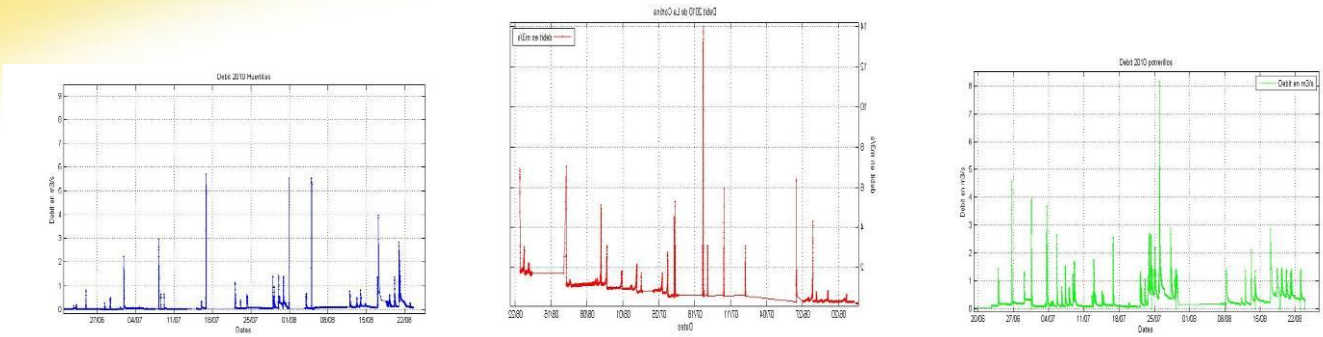
To understand the effectiveness of the official program of land remediation by reforestation, gullies control, no tillage etc. we started with SEMARNAT to collect this data and locate it in a GIS.



Rainfalls and Wischmeier erosivity index (metric system) for the 3 watersheds in 2010 (here, untill sept 10)

Rainfall totals were nearly 50% higher in 2010 in regard to 2009 which was quite dry. This was due to the impact of « El niño » event.

Runoff

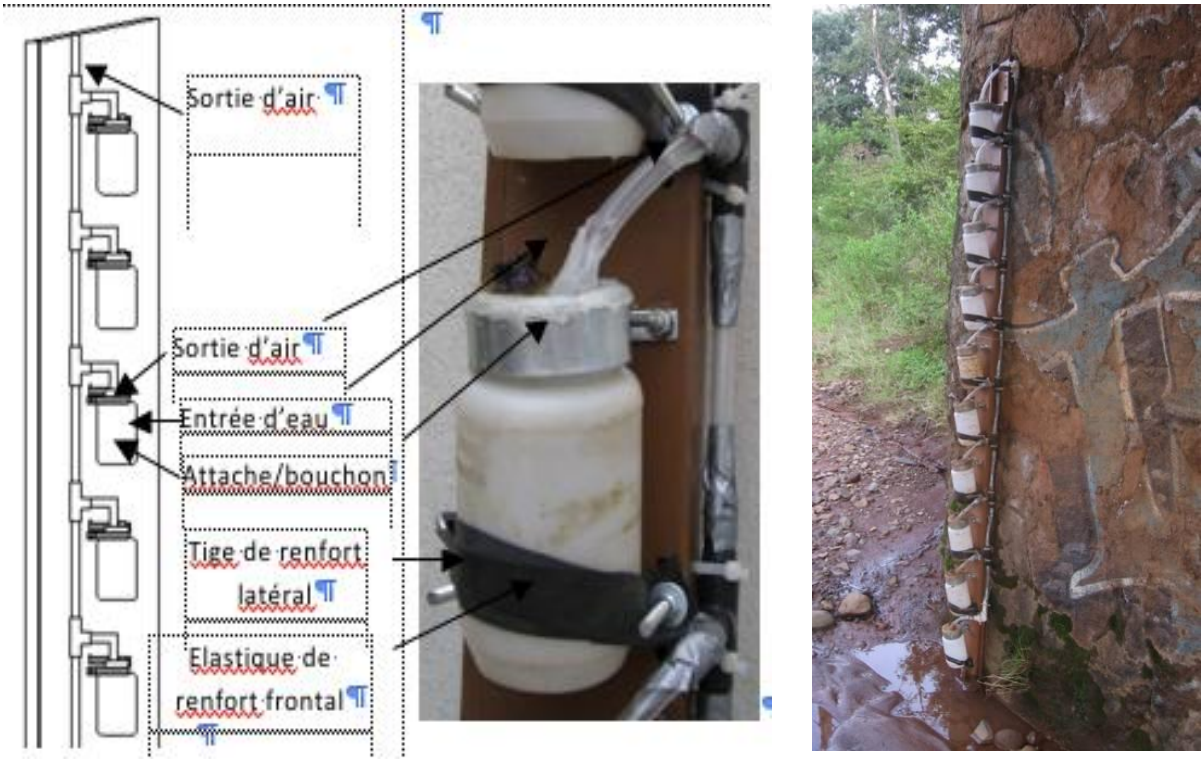


Floods measurments at the outlet of the 3 watersheds in 2010 (here, untill sept 10)

Comparing the three sites for the year 2010, we observed that floods from the Cortina and Potrerillos watershed had nearly the same values (4 and 6 m3 s-1), even though the the maximum flood flow was higher in La Cortina. The flow rates obtained for Huertitas were a little weaker than for the other two sites, since only the largest floods reach it.

Comparing these flood data with rainfall measures, the maximum level water matched with the higher rainfalls (Huertitas 15/08, 21/08 and 16/08 La Cortina). In the case of Potrerillos watershed, there was a relatively large transfer time since the rain occurred and then the flood registred (7 hours delay on the 24-25/07). However, some floods do not correspond with any rainfalls and some rainfalls do not generate floods! This incongruence is due to the extreme localization of the rainfall (few square kilometers) which is not always registered!

Suspended sediments



Design of trap sediments and installation in the Potrerillos watershed outlet (Y. Grusson, 2010)

This new system to trap sediments functioned very well with the help of farmers in charge of them.

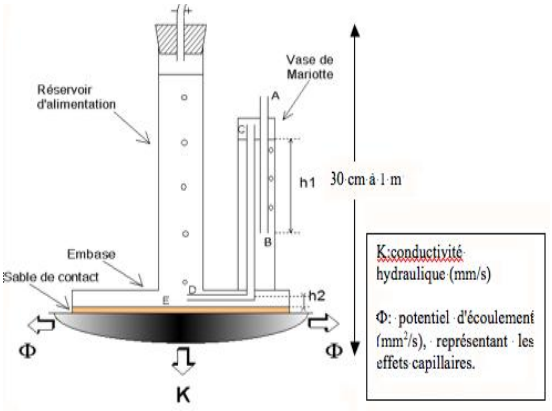
Watershed	N° Flood	N° flood without registration of trap sediments	Percentage
Huertitas	24	1	4
La Cortina	16	1	6
Potrerillos	17	3	18

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, specially when they are living a bit far from the measurement site, like in Potrerillos.

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 dryingout 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)

Infiltration Results

Results showed that the infiltration rate was very high, especially compared to the Acrisols (3 mm/h). The difference between the kind of land use is surprisingly not so high, in terms of averages. 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)

Semi quantitative evaluation of dams built with stones but without cement to control gullies

- Constructions are foundall over the basin
- Achieved by a succession of small dams made with stones without any cement and located inside gullies
- 90% of these dams are in a good state after less than 5 years
- 80% have very few or no sediments captured meanwhile the others have only from 10 to 20% of their capacity refilled. Usually, it is the first one of a series that experiences refilling.
- Apparently, as they have done as a close succession of dams, the first one located up-stream, can catch some sediments (10 to 20% of refilling) but the others do not trap any sediments. In this situation are they really functioning or not? The answer could really be obtained looking what is going on during rains, but due to security reasons it was not possible 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 if there is no sediment trapped, it is because there is no sediment eroded! In fact in the area tested, structures have been made on volcanic tuffs and not on degraded soil.

That means that there is not a lot of fine sediments existing and able to be eroded and transported!

For the future, the strategy must be adapted according to the local problems.

Examples of dams in gullies in EL Calabozo-Potrerillos catchment (photos C. Prat, 2010)

Agroforestry land remediation with local agave (*Agave inaequidens)* for production of Mezcal (alcohol) which can be also used as fodder for cattle in association with local trees

First steps were done in 2010 : testing and defining system and people interest. 5 ha land have been used, by transplanting wild local agave (*A. inaequidens*) on degraded areas, selecting plants, and defining planting strategy according to the context and objectives. The strategy was defined after tests and workshops with stakeholders (start end of 2010)

1. Community Organization
    a. Keeping the organization of workshops with the communities.
    b. Selecting plant production sites :

According to the distances between the communities, the soil type, the population size and the territory of communities, we proposed 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

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

Nursery with greenhouses involve full-time 2 people per site per year.

4. Agave 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 objective 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)

Involvement of stakeholders

- 1-2-3/ The agroclimatic, rainfall gauges, water level and sediment trap Installation were located in the fields of people who were in charge to take care of the equipments. In some case, people were also in charge to take samples, and realize some measures.
- As farmers were paid, they were interested to do it. Scientific institutions were obviously the most interested in our results.

4-Infiltration: an IRD action to complete other data

5-6/ Evaluation and effectiveness of control of gully erosion by small dams as well as the Agave plantation were discussed during workshops and directly in the field with some farmers. Institutions in charge of remediation were also interested by our results. People are interested to do some actions against soil erosion but consider that the dam are probably not so useful. For the Agave plantation and project, there is a lot of expectation…

Conclusions

Small homogenous watersheds (afew km^2) where land use, water level and suspended charge in water were followed, gave at this scale, good information of the water dynamic and existing/possible risks.

- 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 watershed.
- Free grazing cattle are the main cause of soil erosion. But to control it, the global farming situation must be take in to account.
- Farmer involvement is possible if a program brings money to do concrete actions.
- Actions can be oriented specifically to men or women or for both
- Local administration involvement is possible, when there is a program designed for actions where a research project can bring some support (and NOT the opposite).

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See: http://www.desire-his.eu/en/cointzio-mexico for full details of DESIRE research