1 TRADITIONAL AGRICULTURAL PRACTICES IN THE CANARIES AS SOIL AND WATER CONSERVATION TECHNIQUES

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Abstract

The islands of Lanzarote and Fuerteventura in the Canary islands (Spain) are among the most arid regions of the European Union, bordering on desert conditions. The unfavourable conditions –climate, soil, sparse vegetation and lack of water- are conducive to degradation processes leading to desertification. Dryland farming is ruled out because of these environmental conditions. Down the years local farmers have developed agricultural techniques to conserve soil and water and allow a small amount of cultivation without irrigation. These systems involve either the covering of soils with volcanic materials, which act as a mulch, or the harnessing of what little run-off water exists. The present work describes the main systems, focusing mainly on the first type just described. The properties of the mulched and unmulched soils are compared: moisture content at different depths, evolution over time, temperature, effects on salinity-sodicity, etc. All the results obtained point to the technical effectiveness. These systems are in decline today not so much for reasons of effectiveness but due to socio-economic factors.

Keywords: Soil and water conservation structures, volcanic mulch, traditional farming systems, conservation agriculture

1.1 Introduction

Arid and semi-arid zones account for approximately one third of the earth's surface and affect some 16% of the population (UNESCO, 1995). The climates and soils of these zones are an impediment to agricultural production, whilst at the same time leading themselves to desertification processes. Down the years soil and water conservation techniques for farming have been developed in such parts, many of them being valid models of sustainability (Gale *et al.*, 1993; Chesworth *et al.*, 1994; Kamar, 1994; Doolittle, 1998; Nachtergaele *et al.*, 1998). Examples of these agricultural systems can be found in the arid parts of the Canary Islands (Fernández Caldas and Tejedor, 1987; Jiménez *et al.*, 2002).

The Canaries are an archipelago in Spain and comprise seven islands, with a combined area of 7,541 km^2 and maximum height of 3,718 m.a.s.l. The islands' climate is extremely varied due to a number of factors, notably the trade winds, relief, orientation of the mountain ranges and altitude. In the more mountainous islands, the northern side is humid and cool, due to the influence of the trade winds, whereas the southern side is arid and warmer, as are the flat islands (Fuerteventura and Lanzarote).

Lanzarote, which is 846 km^2 in size, is the eastern-most island in the archipelago, lying a mere 125 km off the western coast of Africa. It is also the least mountainous of the islands, reaching a maximum height of 670 m.a.s.l. Its official population, in 1995, was 76,413 inhabitants although the real figure is 113,360 due to tourism, making for a population density of approximately 134 inhabitants per km² (Hernández, 1999). The island receives one and a half million visitors every year and tourism has fast become the mainstay of the local economy, to the detriment of other sectors such as agriculture.

The island has suffered major volcanic eruptions that have resulted in emissions of abundant pyroclastic materials, a circumstance that has propitiated the development of farming techniques based on the use of these materials as mulch. The present work examines these practices mainly in the island of Lanzarote. First, the characteristics of the environment in which these agrosystems are used will be described. Then, a discussion will follow on their design features and show how they enhance some of the properties of the soils.

1.2 Environment

1.2.1 Climate

The climate parameters are typical of a very arid climate. Annual rainfall tends to be less than 150 mm with considerable variations from year to year. Rain falls during the winter months and the greatest amounts of water come from torrential south-easterly and south-westerly storms. Average annual temperature is around 20°C-21°C with notable differences during the course of the day (sharp falls in temperature at night). Winds are strong and constant year-round, with an average speed of 20 km h^{-1}. Sunshine is plentiful, with an annual average of 7.8 hours per day. The evaporation rate is high, at approximately 2000 mm in evapometric tank. Relative air humidity is also high with a daily average in excess of 70%, an important circumstance given the possibility of condensation water uptake and its role in the operation of the agrosystems described here.

On the basis of the different climate indices, the climate of the study zone is classified as Desert (Lang index), Hyperarid (De Martonne) (Porta, 1994), and semi-arid tropical Mediterranean (Papadakis, 1960). The years during which the soils in the agrosystems were monitored (March 1998-April 2001) were particularly dry. In a representative weather station the annual rainfall collected was 72.6 mm in 1998, 98.0 mm in 1999 and 47.1 mm in 2000.

1.2.2 Geology

Like the other Canary Islands, Lanzarote is of volcanic origin and has suffered the most prolonged recent eruptions (1730-36) during which the greatest amount of materials in the archipelago's recent volcanic history were given off (Carracedo *et al.*, 1998). The pyroclasts and outcrops emitted covered a substantial part of the island's soils and led to the birth of these striking systems, *arenados*, thanks to which dryland farming is possible here. Predominant are basaltic materials dating back to between 1824 (last eruption) and the later Miocene.

Aeolic formations are also abundant in Lanzarote. These are organogenic calcareous sands, which were blown inland from coastal areas and, during the Quaternary period, covered the soils of the central part of the island (Fuster *et al.*, 1968). These sands, known locally as *jables*, a term derived from the French word *sable*, have also given rise to another agrosystem, described here also and called *jable* as well.

1.2.3 Soils

The chief factors responsible for the origins and dynamic of Lanzarote's soils are aridic moisture regime, scarcity of vegetation and the age of the geological materials. Other contributing factors are, in the majority of cases, contamination by aeolian dust from the Sahara Desert, degradation processes, human actions and human pressure on the territory. As a result of all these factors, the soils present very specific characteristics, such as low organic matter content and low biological activity, alkaline reaction, horizons with accumulations of carbonates, soluble salts, sandy-loamy surface texture, modified soil surfaces: desert pavement, sealing crusts, etc. However, considerable variations in the texture of the deep horizons, structure, depth of profile, types and amounts of the saline accumulations etc, are found from one soil to another, especially with regard to the age of the materials, topography and erosion (Fernández Caldas *et al.*, 1987). The soils found on the island are, according to the Soil Taxonomy 1999 (Soil Survey Staff, 1999), and the nearest equivalent in other classification system (FAO, 1998), as follows:

Table 1.1. *Soils*

SOIL TAXONOMY, 1999	*WRB (FAO, 1998)*
Vitritorrands	Vitric Andisols
Calcitorrerts	Calcic Vertisols
Argids, Calcids, Cambids	Luvisol, Calcisols, Cambisols
Psamments, Fluvents, Orthents	Arenosols, Fluvisols, Leptosols/Regosols

These soils were clearly formed in different climatic conditions. The origins of the fersiallitic soils with deep clayey alterations and the Vertisols, which are normally underground, appear to be associated with a warm climate with clearly distinct wet and dry seasons. The distribution of carbonates in the soil and the erosion and colluviation processes are associated with subtropical semiarid climatic conditions, while the current, more arid climate triggers deeper carbonisation in existing soils and contributes to processes of degradation rather than formation. Tephra mulch brings about a change in the soil moisture regime, which switches from aridic to udic in some cases (Tejedor *et al.*, 2002a).

1.2.4 Water

Due to the arid climate and other factors, water is in very short supply in Lanzarote. Indeed 90% of the water consumed is derived from desalinated sea water. Of the little rain that does fall in the Lanzarote Island, 96% is lost through evapotranspiration, 1% through runoff and some 3% infiltrates. Surface water is collected in reservoirs and by runoff harvesting, while groundwater is extracted from wells, although in this latter case output is low with poor water quality. In the above-described environmental conditions different types of dry farming have evolved.

1.3 Water Harvesting Systems

1.3.1 Systems based on runoff harvesting

The following two systems can be identified:

a) *Gavias*: Systems designed to harvest runoff water. Located in flat or barely sloped parts, usually foothills, and built perpendicular to the highest slope generating the runoff (Jiménez *et al.*, 2002). The system is shown on photo 1 (see photo-page after chapter 3).
b) *Nateros*: Operates on a similar basis as the gavias. Built on the beds of small ravines, they involve the erection of a wall, usually made with earth, perpendicular to the runoff. The wall retains not just the water but also the fine elements carried along with it.

1.3.2 Systems based on surface mulching

Four different systems based on surface muching can be found.

a) *Natural arenados* are used in areas that have natural presence of tephra and are located near volcanic cones. They are shown on photo 2. The layer of the covering can be quite thick but is most frequently around three metres. For each plant a hole of around 3 metres wide in diameter is dug (to a depth which depends on the thickness of the ash covering) to reach the soil level, where the planting takes place and a layer of manure added on top. The plant is thus in contact with the soil below and is protected from the wind by the hole. Furthermore stonewalls are often erected around the hole. These are semicircular and face perpendicular to the direction of the prevailing wind. Fragments of the basaltic outcrops are used in the walls. This dry farming technique is very common, although it tends to be used only for vines or figs. The most characteristic natural arenado zone, which is used for wine growing, is known as The Geria and covers approximately 2,400 hectares. Some 2 million litres of internationally renowned wine is produced every year here.
b) *Artificial arenados* are made by the farmers in the same way as their natural counterparts in areas not covered by the volcanic materials. Volcanic tephra is placed over the soil, which may be either natural to the area or brought in from other parts, as is the case when the natural soils are too poor for agricultural purposes or are not readily available. The basaltic ash layer varies in thickness between 5-20 cm, with 10-12 cm the most common. Before the soil is covered with the tephra, organic material (usually manure) is added mechanically at a depth of around 10 cm. The average life of the system is approximately 20 years, by which time its effectiveness has diminished due to the tephra mixing with the soil. When this happens, the tephra surface covering is replaced by one that has not been contaminated by the soil. A layer of manure is placed on the ground before the new tephra is laid.
c) Crops grown in *cracks in the lava*. This occurs in parts where the soil was covered by lava outcrops. The farmers use the cracks in the lava to access the soil underneath for growing deep-rooted plants (vines and figs). The soil underneath tends to be superficially contaminated by the tephra, which acts as mulch just as in systems a) and b). Here too, protection against the strong winds exists.
d) Crops grown under *jable*. This form of cultivation takes place in central parts of Lanzarote covered by varying thickness of natural layers of aeolic sands from the sea. Crops tend to be grown in the areas where the sand layer is less than one metre. The procedure for growing the crops is similar to that described above for the artificial arenados: a hole is dug to soil depth, manure is inserted, and planting is done directly in the soil if the sand covering is thin. Where the sand thickness is greater, once the manure is laid the hole is

filled in with sand and the planting is done in the sand, near the surface. Protection against the wind is vital for these sand-grown crops. If no barrier is included, the plant risks ending up buried entirely in the sand. Like the tephras, the surface sand acts as mulch, reducing soil moisture loss. Although the system is less effective, it does nonetheless permit dryland farming of certain crops, such as sweet potato, melon, watermelon and pumpkin.

1.4 Influence of the tephra mulch on soil properties

Having described the main dry farming systems, we will now turn to the influence they have on soil water conservation, salinity-sodicity reduction, soil temperature and erosion control. We will focus on the case of the artificial arenados.

1.4.1 Soil water conservation

We monitored over three 3 years the moisture in the soils covered by tephra and in the adjacent uncovered soils. Sampling was done monthly, every 10 cm to a depth of 1 metre.
Figure 1.1 gives the results obtained in one of the systems, which had a 12 cm layer of tephra. The percentage is given for the moisture content over the three years, expressed as a volume, for each of the depths, together with moisture content at 1500 kPa (wilting point). The chart on the left corresponds to the covered soil and the one on the right to the uncovered soil.

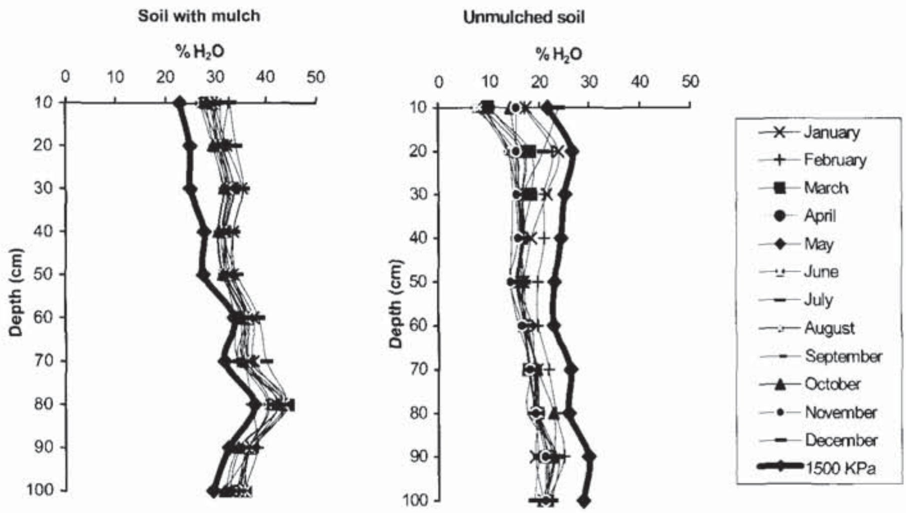

Figure 1.1. *Total gravimetric field and 1500 kPa water content in soil with mulch and unmulched soil*

Moisture in the covered soil remained above the content corresponding to 1500 kPa throughout the year, but below this figure in the uncovered soil (Tejedor *et al.*, 2002b). This circumstance enabled dry farming to be carried out in the former but not the latter.

Tephra grain size and the thickness of the covering proved to be extremely important parameters in terms of the results. Experiments with thickness of 5, 10 and 15 cm and three grain sizes (fine, medium and coarse) showed that the finest grains were more effective than the medium ones, and considerably more so than the coarse grain size. Regarding the thickness of the tephra covering, a vast difference was seen between the soils covered with 5 cm and those with 10-15 cm layers, in which behaviour was quite similar. In the latter case medium grain was used. The experiments are near completion and the results will be published at a later date.

The important influence exerted by the tephra covering on soil water conservation is, we believe, due to its physical properties, particularly its porosity, which favours infiltration of the island's scarce rainfall and also helps reduce water loss through evaporation. High environmental humidity and the considerable drop in temperature at night, added to adequate wind speed and the surface size of the tephra, combine to form ideal conditions for condensation, which is in fact seen early in the morning in the form of colour changes in the tephra. The tephra acquires a shiny black colour, which disappears gradually as it dries out during the day. One of the aspects we are working on at present is to estimate the amount of water produced by condensation, as well as the extent of uptake by the soil and the possible insulation effect.

1.4.2 Reducing salinity-sodicity

The tephra mulch exerts a major influence in reducing salinity and sodicity of the soils used for dry farming. Figures 1.2 and 1.3 give the electrical conductivity in the saturated paste (ECs) and exchange sodium percentage (ESP) values in the tephra covered soils and the adjacent uncovered soils. The first 30 cm of soil were used in each case and the soils were those in Fuerteventura where salinisation and sodification process are more pronounced. Each value shown represents the average for the 8 subsamples taken at random in the studied plots.

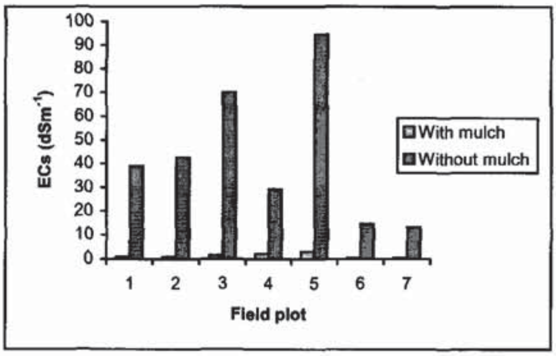

Figure 1.2. *Comparison of salinity in soil with mulch and unmulched soil*

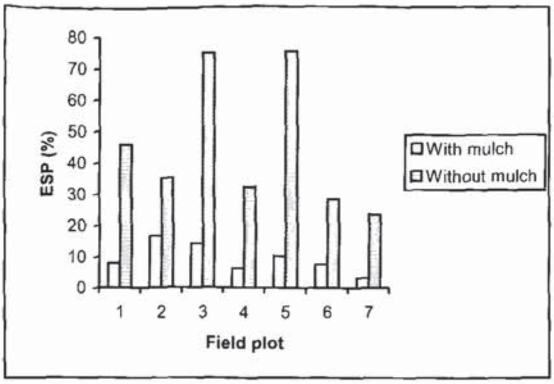

Figure 1.3. *Comparison of sodicity in soil with mulch and unmulched soil*

The non-covered soils are markedly saline-sodic, they present high electrical conductivity values and high percentages of exchangeable sodium. Conversely, when covered with a layer of tephra the same soils have very low ECs and do not reach 15% of ESP. Hence they are neither saline nor sodic (Tejedor *et al.*, 2002c).

The ease with which infiltration occurs and the mulching effect of the tephra layer, as was mentioned, have resulted in soluble salts lixiviation in what was originally a saline-sodic soil losing its salts when covered and the accumulation of the salts is avoided in the root zones. Increased dilution in soils under tephra, ease of Na ion washing and the possible dissolution of calcic salts as gypsum contribute to displacement of exchangeable Na in favour of Ca and hence the ESP values are reduced to limits that can be tolerated by the plants. This accounts for the reduced salinity and sodicity in the covered soils.

1.4.3 Soil temperature

The tephra mulch influences both daily and seasonal soil temperatures. Figure 1.4 gives the result of measurements taken on 6 August 1998, the month with the highest temperature in the year. Measurements were taken in the air, at 5 and 10 cm in the tephra and, in both the covered and uncovered soils, every 10 cm to 50 cm. Measurements were taken at 07:00, 10:00, 13:00, 16:00 and 19:00 h.

Temperature variations during the day in the uncovered soil are considerable up to 20 cm, the temperature reaching 46 °C at 16:00 h. In the covered soils, the temperature remains very even throughout the day and at all depths. The tephra layer exerts, therefore, a major buffering effect. The tephra layer also reduces seasonal temperature differences. Whereas the covered soils show differences between summer and winter of below 6 °C at 50 cm, the difference in the uncovered soils is higher.

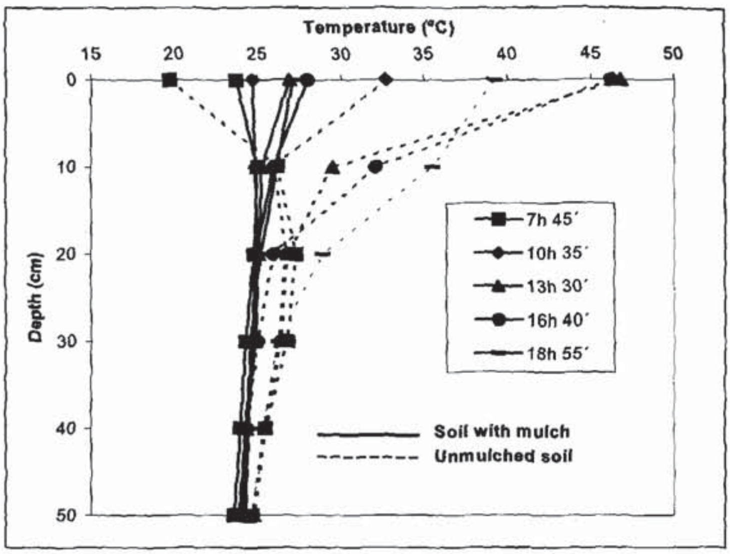

Figure 1.4. *Influence of tephra mulch on soil temperature*

1.4.4 Erosion control

Figure 1.5 compares the infiltration rate curves over time in a soil covered with tephra and in the same soil, uncovered. The study was conducted in a laboratory with a rain simulator, as follows: area 600 cm^2, soil height 15 cm, mulch height 5 cm, slope 6 %, average rain intensity 75 mm h^{-1}. The texture of the soil used was clayey; tephra grain size distribution was: 26.3% < 2 mm, 59.1% 2-6.3 mm, 14.6% >6.3 mm.

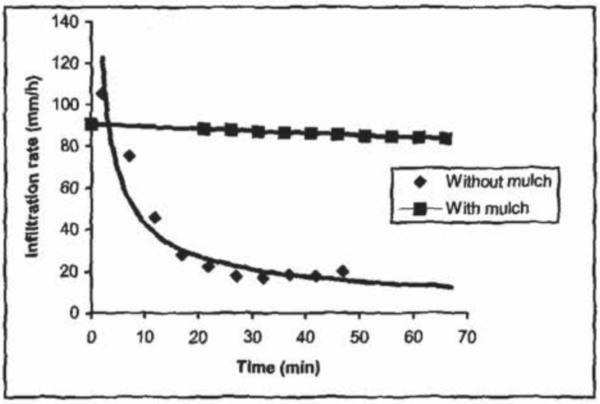

Figure 1.5. *Comparison of the infiltration rate curves in soil with mulch and unmulched soil*

In the uncovered soil the initial infiltration rate is seen to be high but it falls quickly and stabilises at a low value. In the soil under tephra the rate remains high at all times, and runoff is reduced. The system therefore aids soil conservation.

1.5 Production with WHT

The positive effect of the surface layer of tephra in soil and soil water conservation, among other things, is seen clearly in the fact that dry farming is rendered possible, when it would be completely ruled out were it not for the use of the technique. Average production between 1997-2000 for the three main crops was 8,043 kg ha^{-1} for onions, 6,030 kg ha^{-1} for potatoes and 907 kg ha^{-1} for grapes. It is worth noting that the production obtained with this system, using no irrigation, in extremely dry years such as 2000 (47 mm rainfall in the year) was 2,361 kg ha^{-1} for onions, 6,063 kg ha^{-1} for potatoes and 1,775 kg ha^{-1} for grapes. It is striking that under these very dry conditions potato production remained the same and grape production was even higher. The wine produced from the grapes -over 2 million litres per year- is of top quality.

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