4 RUNOFF HARVESTING SYSTEMS IN THE CANARIES

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Abstract

Soils in arid regions are characterised by a lack of water, a circumstance that acts as a barrier to dry crop farming. The islands of Fuerteventura and Lanzarote are among the most arid zones in Europe. The general climate features are as follows: extremely arid, annual rainfall of below 150 mm, potential evapotranspiration above 2,000 mm and average annual temperature around 20 °C. A traditional farming system, known locally as *gavia* (-water harvesting technique) has been developed in these islands, allowing a diverse and productive form of agriculture that uses no irrigation.

Monitoring of soil moisture in two field plots was conducted over a 3-year period. It was compared with an adjacent plot that received no runoff during the study period. Sampling was carried out once per month, every 10 cm to a depth of one metre, and moisture was measured using the gravimetric method. In both field plots, the differences between the runoff harvesting and the plots with no runoff is noteworthy. The gavias act as natural mulch and only the soils where the system is used had sufficient available water in the root zone to enable crops to be planted and achieve a level of production which would not be possible in the non-treated soils. The percentage of humidity is above the wilting point during the rainy seasons and for a few months subsequently. In the adjacent plot the humidity percentage remains below the wilting point year-round.

These differences in the soil moisture content affect the salinity and sodicity of the soils. Indeed, while natural soils adjacent to the gavias may be classified as saline-sodic, this problem is not present in the soils within the gavias. This trend in salinity and sodicity is the same in all the systems, in very different situations.

Thus, this system seems to be very efficient in reducing soil salinity and sodicity, even in the zones near the sea. Hence the interest in preserving this traditional agricultural system for the conservation of two valuable resources in the Canary Islands: water and soils. However though, the gavia system is in decline today. Its minor economic worth does not reflect its cultural, landscape and environmental importance.

Keywords: soil moisture, arid soils, dry farming, anthropic changes, runoff harvesting, gavia, water conservation, soil conservation, saline soils

4.1 Introduction

Runoff occurs as a result of intense rainfall and poor soil infiltration, characteristics that are very common in arid and semi-arid tropical regions (Reij *et al.*, 1988). Surface water can be harnessed for agricultural use if channelled and directed to cultivation plots surrounded by small walls. This traditional dryland farming system is known locally in the Canaries as gavias and dates back to the period of conquest by the Spaniards, although no exact date can be given (Roldán, 1968). Although present on other islands in the Canaries, where some remains can still be found, they are most widespread nowadays in Fuerteventura (Quirantes, 1981). It is estimated that an area of approximately 3,800 hectares is taken up by gavias (MAPA, 1989).

The most important crops grown are winter cereals. Although in terms of yield and economic worth the system's importance is negligible, its conservation and operation clearly play a major role in combating desertification, particularly in such an arid part. Indeed, the gavias are a system for soil and water conservation, as the present paper seeks to bring out.

4.2 Presentation of study zone and system

4.2.1. Area description

Our study was conducted in soils in Fuerteventura and Lanzarote (in the Canary Islands, Spain), that are located 115 km off the West Coast of Africa. These islands are among the most arid in the European Union with the following climate features: annual rainfall below 150 mm; torrential rain which falls very heavily and briefly; high potential evapotranspiration (in excess of 2,000 mm in an evaporimeter tank); a daily average of around 8 hours sunshine; annual average temperature of around 20 °C, with considerable differences between night and day; high relative air humidity (> 70%) and strong winds (Torres, 1995).

Rainfall events with an intensity up to 10mm in 24 hours represent 66.5% and 66% of total rainfall, respectively, whereas those with an intensity of over 50 mm in 24 hours represent just 0.6% and 0.7% of the total for each island (Marzol, 1988). Water resources are extremely limited and 90% of all water used comes from seawater desalination.

4.2.2 Description of the gavias system in the Canaries

The gavias system, which was designed to collect runoff in arid zones of the archipelago, has given rise to small-scale dryland farming. The gavias are located near flat zones, usually on foothills, and are oriented perpendicular to the steepest sloping area generating the runoff. They are frequently close to small watercourses, small ravines, from which runoff can be collected. The systems comprises cultivation plots, protection walls *(trastones),* runoff water entry *(torna),* excess water exit *(desagüe)* and a water channel *(caño)*

The plots are completely surrounded by earthen walls between 50-80 cm high, although sometimes these can be up to 1.25 metres. Water enters via an opening at ground level in the part that receives the runoff initially. This opening may simply be a lowering of the wall, a part made of stones and *aulagas* shrubs (*Launaea arborescens*) and even, on occasions, a cement and stone construction with a wooden gateway that is raised and lowered as required.

Excess water can be diverted to another gavia located lower down. This can be achieved by simply lowering the height of the protection walls, which can be reinforced with stones and cement. The height of this lowered part can be between 15-70 cm, but is most commonly 30 cm. The water outlet has to be at least twice as wide as the entrance so that the gavia can evacuate its water automatically without giving time for the wall to be damaged. In other cases, excess water is diverted towards a small ravine located to the side (Tascón, 1997). Where runoff water does not reach the gavia directly, water from nearby small ravines can be brought in using a rudimentary channel, consisting of just earth, or earth reinforced with stone or even cement.

Generally speaking, gavias are grouped in a terraced-like formation, known locally as a 'rose'. If the water intake exceeds the amount envisaged by the design, the walls can be severely damaged and considerable quantities of both water and soil are lost. The gavia system requires annual upkeep, for the most part rebuilding of walls and cleaning out the runoff channel structures. These jobs require considerable labour because they are, by necessity, manual and the plots are very small. The arrangement of the gavias rules out machinery in most cases. Without the work, the deterioration caused to the structures by runoff during heavy rain would be irreversible. The expression '*gavia bebida*' (literally 'imbued gavia') is used in Fuerteventura to denote cases where water has saturated and infiltrated the gavia.

Once the water has entered the system the soil is tilled to break the capillarity and conserve moisture (mulch effect), and then seeding takes place. The main traditional crops grown are winter cereals (wheat, barley, oats and corn), as well as lentils, chickpeas, and beans. Other crops, such as saffron and potatoes, are also grown, albeit to a lesser extent. The system can be viable in 5-6 years out of every 10, which is the usual frequency with which the gavias are filled.

4.2.2. Systems studied

Two systems with different characteristics were chosen, one on Fuerteventura (field-plot 1) and the second on Lanzarote (field-plot 2). In the latter case, there are very few hectares of farmland under this type of cultivation system.

Field-plot 1 is located on a north-eastern coastal plain in Fuerteventura, less than a kilometre from the coast. It comprises two terraced gavias with earthen walls, which receive runoff water channelled from an adjacent basin (Photo 1). The gavia is situated at the bottom of a watercourse, which has enabled it to accumulate large amounts of fine materials, giving it a depth of around a metre, compared to the 50 cm of neighbouring soils. The plains representative soils outside the gavia presented a petrocalcic horizon at about 50 cm depth, which prevented us from taking deeper samples of the adjacent natural soil (Fernández Caldas *et al*, 1987). The soil is highly carbonated and generally presents a balanced texture. Surface stoniness (with stones and basaltic and calcareous gravel) is high (80-90%), a circumstance that reduces erosive processes. Erosion is low and of the sheet type. Around 63 hectares of crops receive runoff water from a water basin of 1,079 ha. Hence the crop area/catchment area ratio is 1:17. The studied gavia measures 0.34 ha. The walls and the water outlet are 50 and 30 cm high respectively. Lentils and corn are normally grown. Two harvests were obtained during the study period.

Field-plot 2 is located in the central part of Lanzarote. It comprises a system of three gavias, which have been terraced using stone walls. The gavias receive runoff water channelled from a catchment area at the foot of a volcano (Guanapay Mountain). The natural soils adjacent to the gavia present a highly developed argillic horizon, with some carbonatation (Fernández Caldas *et al*, 1987). They are very prone to water erosion, with abundant gullies. Around 0.21 ha of crop-growing area receive water from 7.6 ha of catchment area, giving a ratio of 1:30. The most frequent crops are corn and barley. Planting took place twice during the study period.

4.3 Field and laboratory

For the monitoring of soil moisture, samples were taken over a period of three years, approximately once per month, every 10 cm to a depth of one metre both in the plot used for cultivation as well as in the one not used thus. Volumetric water content was calculated by the gravimetric method, taking into account apparent density.

To study salinity-sodicity characteristics a profile was studied out within the system and another in the adjacent natural soil. Samples were taken every 10 cm throughout the full depth of the soil.

Bulk samples were allowed to air-dry and the soil 2-mm mesh sieved for laboratory analysis. Retained moisture at 1500kPa was estimated by pressure-plate extraction, using a porous ceramic plate (USDA-NRCS, 1996).

Soil pH was measured in a 1:2.5 soil/water suspension. The electrical conductivity was measured in saturated paste (USDA-NRCS, 1996). The cation exchange capacity was determined after Bower *et al.* (1952). Exchangeable Na and K were extracted with a buffered neutral 1 M NH_4OAc solution, and Ca and Mg by 1 M NaOAc pH 8.2. Solution concentrations were determined by atomic absorption spectrophotometry. Particle size analysis (particles < 2mm) was determined after samples were dispersed in sodium hexametaphosphate solution and shaken on a horizontal reciprocating shaker for 12 h using the densimetric method (Day, 1965). Carbonate contents were determined according to Allison and Moodie (1965).

4.4 Results and discussion

A full weather station was available for field-plot 1, whereas for field-plot 2 rainfall data from a nearby station were used (Table 4.1).

Table 4.1 *Monthly and annual precipitation (mm) for the study area*

Period	*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*	*Total*
Site 1 (1971-2001)	17.2	16.2	13.0	5.4	1.0	0.0	0.0	0.0	2.6	8.5	13.0	22.3	99.2
Standard deviation	27.2	24.3	14.2	9.1	2.7	0.1	0.1	0.0	4.3	14.9	17.2	27.3	51.4
Site 2 (1982-2000)	21.4	15.0	15.7	3.5	1.3	0.3	0.0	0.0	1.7	11.9	19.5	32.4	124.1
Standard deviation	17.8	23.7	14.5	6.2	1.7	0.8	0.0	0.0	2.4	14.8	23.6	34.4	66.9

Monthly and annual variations in rainfall are very high, with the bulk of the rain falling during autumn and winter. Maximum intensities (24 h.) recorded during the study period were 10.2 mm (5/12/98), 21.0 mm (12/1/99), 25.2 mm (13/1/99), and 60 mm (12/3/99) for the station on the island of Fuerteventura (site 1). For Lanzarote the highest daily rainfall recorded was 45.6 mm (5/12/98) and 23.2 mm (27/10/99).

Figures 4.1 and 4.2 show the accumulated water content in 100 cm of soil (gavia and no runoff) on each of the sampling dates, together with precipitation accumulated between sampling.

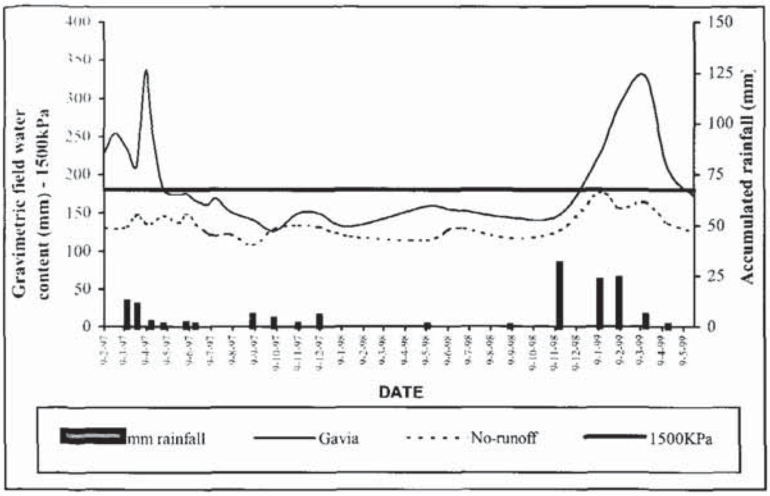

Figure 4.1. *Field-plot 1. Total gravimetric field and 1500 KPa water content in gavia and in no runoff. Effective soil depth:100cm.*

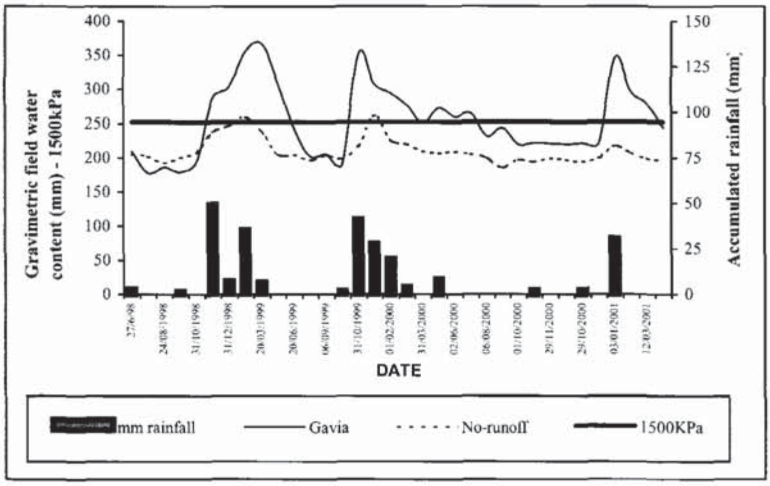

Figure 4.2 *Field-plot 2. Total gravimetric field and 1500 KPa water content in gavia and in no runoff. Effective soil depth:100cm.*

The gavias act as natural mulch. Only in the soils where the system is used was sufficient water available in the root zone to enable crops to be planted and achieve production levels which would be impossible to obtain in the non-treated soils. The percentage of water content was above the wilting point during the rainy seasons and some months afterwards. Differences in water content were noteworthy throughout the year. In the adjacent field-plot (no runoff) the percentage of water content remains below the wilting point throughout the year. The relationship between the accumulated water in the gavia system and in the non-gavia plot was 1.4 (field-plot 1) to 1.2 (field-plot 2).

The gavia soils are more alkalyne than the adjacent natural soils. Of the exchangeable cations, calcium and magnesium predominate in the former, unlike in their natural counterparts, where sodium is more important. The salinity results are shown in the figures 4.3 and 4.4. The behaviour is similar in the two systems, in that the gavia soils are non-saline and the adjacent natural soils are extremely saline.

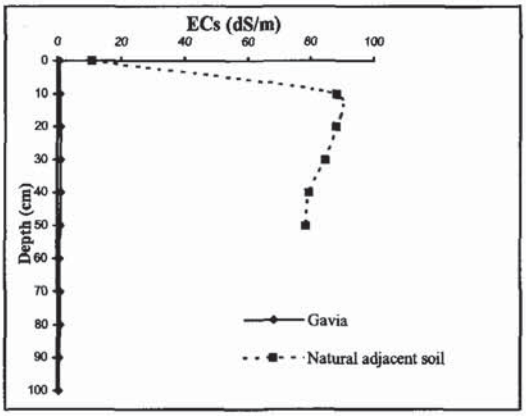

Figure 4.3 *Comparison of salinity in the gavia soil and in the natural adjacent soil in field-plot 1*

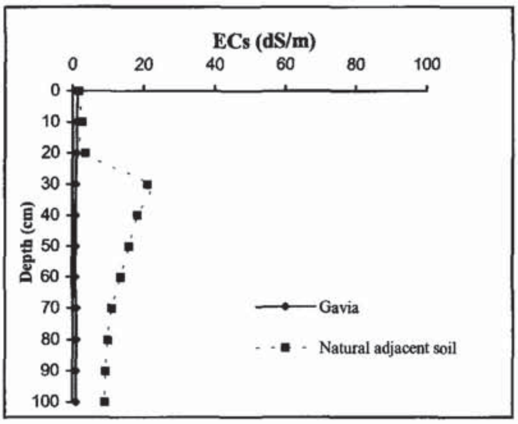

Figure 4.4 *Comparison of salinity in the gavia soil and in the natural adjacent soil in field-plot 2*

Regarding sodicity (Figures 4.5 and 4.6), as can be seen, the gavia soils cannot be considered sodic, unlike their non-covered counterparts, which are extremely sodic.

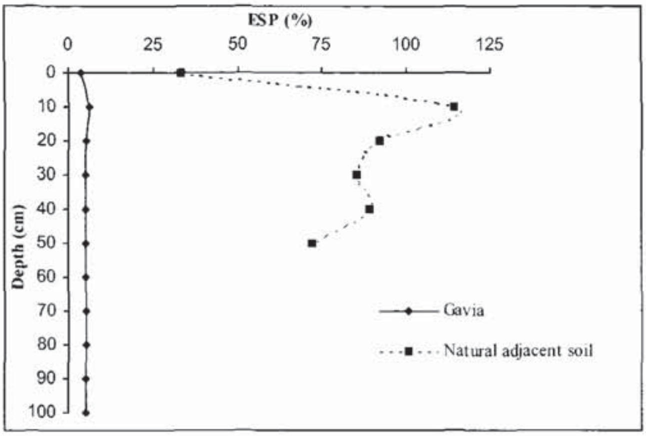

Figure 4.5 *Comparison of sodicity in the gavia soil and in the natural adjacent soil in field-plot 1*

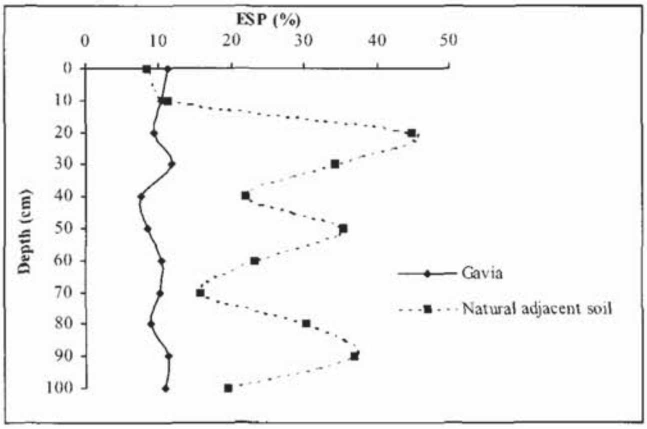

Figure 4.6 *Comparison of sodicity in the gavia soil and in the natural adjacent soil in field-plot 2*

The above tendencies, in the case both of salinity and sodicity, are seen in all the systems studied, despite their different situations. In the light of the results obtained, we can conclude that the gavias are a very effective system in arid regions because they reduce salinity and sodicity in soils, even those located very close to the sea. The washing effect of the system is spectacular, particularly in the case of the gavia situated just a few metres from the sea (field-plot 1).

In such extreme environmental conditions, without irrigation, no crops would be possible if these traditional farming systems did not exist. Gavias are today in decline as farming systems. Their economic worth falls considerably short of their cultural, landscape and environmental value.

References

Allison L.E., Moodie C.D. 1965. Carbonate. P.1379-1396. In C.A. Black *et al.* (ed.) *Methods of soil analysis: Part 2.* 1st ed. Agron.Monogr.9 ASA, Madison, WI.

Bower C.A., Reitemeier R.F., Fireman M. 1952. Exchangeable cation analysis of saline and alkali soils. *Soil Sci.* 73, 251-261.

Day P.R. 1965. Particle fractionation and particle-size analysis. P. 545-567. In C.A. Black *et al.* (ed.) *Methods of soil analysis: Part 1.* 1st ed. Agron.Monogr.9 ASA, Madison, WI.

Fernández-Caldas E., Tejedor Salguero M. & Jiménez Mendoza C. 1987. Soil types in the arid zones of the Canary Islands. *Catena,* 14, 317-324.

Marzol V. 1988. *La lluvia, un recurso natural para Canarias. Servicio de Publicaciones de la Caja General de Ahorros de Canarias.* Santa Cruz de Tenerife, nº130.

Ministerio de Agricultura, Pesca y Alimentación (MAPA).1989. *Ordenación Agrohidrológica de la isla de Fuerteventura. ICONA.* Consejería de Política Territorial del Gobierno de Canarias.

Plan Hidrológico Insular de Fuerteventura. 1999. Boletín Oficial del Estado, nº 105, de 6 de agosto de 1999, 11805-11904.

Quirantes F. 1981. *El regadío en Canarias. Editorial Interinsular Canaria S.A. Dpto.* de Geografía, Universidad de La Laguna.

Reij C., Mulder P., Begemann L. 1988. *Water harvesting for plant production.* World Bank Technical Paper, 91, 1988.

Roldán, 1968. *El hambre en Fuerteventura (1600-1800).* Publicaciones del Aula de Cultura de Tenerife. Santa Cruz de Tenerife.

Tascón Rodríguez C. 1997. *El cultivo en gavias y el cultivo de tomates en invernadero en la isla de Fuerteventura. Análisis comparativo.* Trabajo de Fin de Carrera. Centro Superior de Ciencias Agrarias. Universidad de La Laguna.

Torres J.M. 1995. *El suelo como recurso natural: procesos de degradación y su incidencia en los procesos de desertificación en la isla de Fuerteventura.* Tesis Doctoral. Dpto. de Edafología y Geología. Universidad de La Laguna.

USDA-NRCS. 1996. *Soil survey laboratory methods manual.* Soil Survey Investigations Rep.42, Vers. 3. U.S. Gov. Print Office, Washington, DC.