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Study of Techniques to Increase Water Resources and Run-Off in Semiarid Regions. The Case of the Canary Islands and Israel

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Abstract

Semiarid regions and some oceanic and Mediterranean islands, have the singularity of using the same traditional water exploitation like small dams made from local materials that intercept streams when it rains (run-off harvesting), in the other hand when the land is sloping plots are used. These environments , from around the world, have things in common as torrential rainfall pattern. For this reason they have problems with water erosion and soil conservation. Another point is that in islands and regions with semiarid climate the availability of freshwater is scarce, forests, that can grow in these environments have a crucial role in the regulation of water resources in several ways, they encourage the infiltration, conserve soil and if forests are at some altitude could take advantage from the fog precipitation, this is a typical case in oceanic islands and in some inland areas. In our case studies, there are some hydraulic strategies to increase water and reduce erosion, which occur in some territories such as the Canary Islands in Spain and the semiarid Negev in Israel (and many others in Middle East), where the role of these technologies is conserve soil (traditional techniques mainly), to increase water and finally generate development to the community, forests, agriculture, flora and fauna. In the case of Canary Islands another important factor to understand the water resources regulation in the islands is the fog precipitation. In the Canary Islands this effect occurs from the 600 meters, powered by vegetation adapted to this type of precipitation, also this phenomenon has been observed in the Sahara desert in Africa coast.This paper discusses the peculiarities on each case, highlighting the ability of the traditional techniques to improve the hydrological cycle on lands with scarce of water resources.

Keywords: Run-off harvesting, reforestation, horizontal rain, scarce water resources, semiarid climate, surface hydrology.

1. Introduction

Surface runoff and soil erosion are, in general, natural phenomena associated with hydrological, geological, and ecological processes. The relationships between forest and climate conditions, and their effects on runoff, soil erosion has an effect on water recollecting systems, principally at the semiarid regions.

Runoff and soil erosion processes on forest-cover watersheds depend on the type and kind of vegetation, and the physical and chemical characteristics of the catchment terrain. The forest terrain could be formed of deep (>1.5 m, below the main root zone depth of the trees) or shallow (<1.5 m) soil that covers the bedrock, or bedrock exposed to the atmosphere. The bedrock could have a very low permeability or it could be full of extensive cracks through which the water can flow freely. All

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of these parameters can significantly affect the hydrology and the soil erosion processes in the forest (Bredemeier).

Soil erosion by water, involves two main processes: detachment of soil materials from the surface soil by raindrop impact and surface runoff shear; and transport of the resulting sediment by raindrop splash and overland flow (Baver er al., 1972).

2. Materials and Methods

The Canary Islands are an Atlantic Ocean archipelago, belongs to Spanish Kingdom, is located off the northwest coast of Africa. The island of Fuerteventura is 95 km off the African coast. The islands are volcanic in origin as the region of Macaronesia. Its climate is subtropical, though modified by altitude and slope north or south. This climatic variability leads to a rich biodiversity that, together with the rich landscape and geology.

The geological history of the islands is very complex. There are several lava washes phases that give a typical volcanic relief. During major glaciations, the Canaries had a more arid climate that favored the occurrence of erosion and debris on the slopes and ravines. Gullies and ravines are characteristic of the Canary Islands; it is casual channel where water flows are directed present on the islands. Its route is short, and usually has a straight profile. His bed is carpeted with debris washed away.

As basic features climate in the Canaries have the following factors, first is conditioned by the proximity of the African continent, whose effects are manifested in the archipelago when a hot Saharan air invasion, with winds from the East or Southeast, trailing towards or haze Islands airborne dust from Africa. Rainfall occurs irregularly and is of a downpour. Have a very clear pattern in which the altitude is decisive. Lanzarote and Fuerteventura, flat islands, have strongly marked features of arid, with rainfall of less than 100 mm on the coast and 300 mm in the interior. In general all the Coasts of the islands collect rainfall below 300 mm. Gradually Rainfall increases with altitude.

The Negev covers an area of 1 million hectares in the south of the country, and in a majority of this is classified as desert or as semi-arid.

The long summer are hot a dry. The average winter rainfall ranges from 200-300 mm in the central and western Negev, 100-150 in ramat Hanegev with an altitude of 400 meters to about 30 mm in the Arava valley that can be defined as arid zones. Due to scarcity of water, in the ancient times, agricultural in the Negev was based on run-off harvesting and today used to create forest in the Negev principally to make the Negev green near populated centers. Planting based on run-off harvesting are undertaken in areas where the annual rainfall is between 80-200 mm: in undulating loess areas and chalk and limestone slopes.

Planting techniques have been developed to achieve two essential objectives: deep root penetration and the maximum use of water that can be made available to the plants. The most valuable technique to create a forest in the semiarid Negev is harvesting of run-off water and using it to irrigate trees (Nachmias, 1989).

3. Study of Water Harvesting Techniques in The Canaries

The *Maretas (Canaries)* is a water collection system that has two working types. First type, has an impermeable surface with a slope oriented to a point to water collection and finally this water is storaged in a buried tank. The second way is to build a water channel (0, 5 by 0,5 m) from a ravine that when it rains, the water flows from the stream by the channel to a tank, without sediments due to a sand removal.

The hydraulic structures called *Gavias (Canaries)* are techniques to run-off harvesting, they are used in the island of Fuerteventura and Lanzarote. *Gavia is* located into a ravine. *Gavia* is basically a small earth dam,(Figure 1) it is built with local materials. Earth dams are placed transversely to the stream and store rain water (when it flows), then water infiltrate slowly into the land. Also earth dams retain nutrients it was carried by water from the upper parts of the island. *Gavias* maintenance contributes to hold the soil, preventing fertile sediment runoff transported to sea (Santamarta, 2008).This technique is similar to Guadi in Israel.

Figure 1. Volcanic pyroclastics used to increase water holding capacity to improve water availability in the reforestation. Lanzarote Island, Canaries, Spain (Santamarta Cerezal, 2007).

The *Natero (Canaries)* in its operation and its construction is similar to *Gavias*, because they are small earth dams, but smaller than the *Gavias*. The *Natero* are located in the upper parts of the island. It dam is one meter high, built with local stones, sometimes there is a spillway to mitigate flash flood (when it´s heavy rain).There is a small space available to cultivate one tree or another crops like potatoes. This traditional technique is built in both kind of islands, Western and Eastern.

Enarenados (Canaries) fundamentally, this is a thick layer of pyroclast volcanic material. Pyroclastic layer can be naturally occurring (due to a volcanic eruption) or may be artificial, built by farmers from the island. The pyroclastics are very porous, they store water, especially from the dew, is an extra supply of water for crops (potatoes, vines...) including forest restoration as seen in Figure 2. This technique is also used on the continent (Southern Spain).

In the Canaries this volcanic ash is used to ensure the humidity at the start of reforestation due to low water in the eastern islands with rainfall close to 150 mm per year.

4. Horizontal Rain, A Study Case in The Canaries

Cloud formation is a thermodynamic process depending on pressure, specific volume and temperature of the air. When these conditions are favourable, water vapour in the air condenses in small drops forming a cloud. The ability of the liquid drops to remain suspended in the air depends on the speed and agitation of the mass of air that carries them. A simplified measure of the speed and agitation of the wind is the kinetic energy. If the kinetic energy of the air carrying the cloud experiences a sudden decrease, the drops may not be able to remain suspended and the consequence is the precipitation of liquid water.

This situation occurs in some forest ecosystems where the tree canopy acts as a barrier to the clouds. Water drops are collected on the leaves resulting in the so called “horizontal rain”. As we will see further in this document, horizontal rain from clouds of fog has a supreme importance in forest ecosystems where other forms of precipitation are not abundant.

Since clouds appear at a height of hundreds of meters from the ground, they need to be intercepted by a forested mountain range to yield horizontal rain. We have an important example in the western Canary Islands (Spain), where this phenomenon occurs at altitudes ranging from 800 to 1,500 meters from sea level. This type of rains accounts for 75 % of the precipitation that recharges the aquifers and feeds the forests of these islands (Santamarta and Seijas, 2010).

The water quantity deposited in the forest by these rains depends on the cloud density. Cloud density varies from 0.05 g/cm^3 in slightly dense clouds to 3 g/cm^3 in very dense clouds (Schemenauer and Cerecera, 1987).

Figure 2. Fog collectors in Lanzarote Island, Canaries, Spain (Santamarta Cerezal, 2008).

Water capture efficiency depends on the forest structure and tree species, as shown in the studies of Kämmer ,1974, who studied the different effects of Laurus azórica and Erica scoparia on the quantity of precipitation from horizontal rain in the Canary Islands. The results of the experiment demonstrated that a needle-shaped leaf such as those of Erica scoparia receives more water than a broad leaf such as those of Laurus azorica in spite of the latter having a larger area because the air flows in the vicinity of a broad leave is turbulent. As a result, the smaller drops bounce off the turbulent layer without having the chance to make contact with the leaf. Needle-shaped leaves present a more aerodynamic form and there is no turbulence. This is also the case of Pinus canariensis, the most common conifer in the Canary Islands, whose leaves are composed of three needles. Woods of these conifers are a more efficient captor of water resources than the wide-leaved *Laurisilva*, which is the other type of forest ecosystem present in the Macaronesia region. Generalizing for the European forests, precipitation from horizontal rain is expected to be more significant for conifers than for angiospermas, speaking in general terms (Santamarta and Seijas, 2010).

In the case of oceanic islands, we can speak about Canary Islands, Cape Verde, Madeira, Hawaii and some others coastal areas with significant mountains, where the effect of horizontal rain from the trade winds increase the availability of water in the ground, this is very strong point in two ways, first, it increases the vegetation and its diversity, on the other hand, the horizontal rain or fog precipitation increases infiltration (which is also aided by the vegetation roots). Infiltration is also favored by the permeability of the volcanic soils. All these issues are good things for the island aquifers.

Also the horizontal precipitation through fog collectors allows the option of availity water near crops or forest restorations. There are experiences in this direction for example in Lanzarote islands (Canaries) (Figure 3).

Figure 3. Earth dams, to intercept surface water, called *Gavias* in Fuerteventura Island, Canaries, Spain (Santamarta, Cerezal 2007).

Table 1. Rainwater collected from fog precipitation , on the island of Lanzarote (Canary Islands) at 500 m MSL, Fog water collection was measured with artificial catchers. From Jun 2008 to Jun 2009

Station numbers	Amount of water by m^2 of Fog water collector
Nº1	178,99 L/m^2
Nº2	1.119,87 L/m^2
Nº3	1.226,15 L/m^2
Nº4	214,92 L/m^2
Nº5	116,28 L/m^2
Average	469,02 L/m^2
Rainfall average L/m^2	150 L/m^2

5. Forest Hydrology Study of Water Harvesting Techniques in Israel

A *liman* (Israel) is an earth structure builds up in depressions with a flat bottom and a dam in from of it carrying trees(Figure 4). These receive run-off water trapped to a designed depth by a "threshold" at the entrance to the by-pass. The liman provide the means of growing trees in low rainfall areas, where watering by other than run-off harvested from a higher catchment would be out of the question because of the cost, and were trees would have little chance of survival without some concentration of the light winter rainfall. The ratio of catchment to effective area (the bottom of the area) may be as high as 100:1.

Contour ridging (Israel), on slopes, the ground may be formed around the contour with the soil ridges for the young trees. With the slope normal to the planting ridges, the trees receive the run-off from the ground above to the next ridge. The flat gradient of the ridged planting lines should allow for each tree to receive a good soaking when rain is heavy enough, with run-off at minimum (Moshe, 1989).

Contour strips (Israel), are used to planting on slopes where there is little risk of erosion or where the soil is so thin that is impossible to blade it in ridges. These strips are cultivated along the contours to a depth of 30-40 cm. No change in the natural gradient is made between the cultivated strips, untouched strips of ground are left, the width of which depend on the tree spacing required.

Molehills (Israel) is the plant technique used in hilly country(Figure 5). A pit is broken up by hand, then a trench dug uphill to collect run-off, the soil from this is placed at the worked pit, and a top of this mounds flattened. The young tree is placed in the centre of the mound, to be irrigated by the run-off collected in the trench. The number of "molehills" varies from 1,400-2,000 qhectare, depending on the percentage of rocks.

Figure 4. Liman in the Negev desert, Israel (Santamarta Cerezal, 2009).

Figure 5. Molehills in the Negev desert, Israel (Santamarta Cerezal, 2009).

6. Conclusions

These traditional water techniques are used for over 100 years, today are effective for the increasing in runoff, as well as for soil conservation. These techniques could be a first step to plan and restoring degraded areas with strong erosion processes in soils and semiarid areas of the Negev in Israel and some island areas with semiarid climates in the zone of Macaronesia, where the availability of freshwater is scarce

The techniques currently are used to run-off harvesting in semiarid regions, these water works are based on those which is described in this paper, in this direction, at the moment many traditional techniques are rescued from the past to use it at the present like the *Gavias* in the Canary Islands and the Liman in the Israeli case, and even now are used for forestry.

The role of these techniques are in twofold: on one hand, the regulation of both kind of water resources (surface and underground water resources) and on the other hand , the erosion control and soil conservation, which is one of the big problem in this kinds of ecosystem.

In the Canary Islands, convective rain (horizontal rain or fog precipitation) takes a key role by doubling (more or less, depends on the author) the conventional rain in some cases. The main factor of this rain is the existence of a special winds regime (trade wind mainly in oceanic islands or coastal winds in mainland) and the relief, that are the two limiting factors.Techniques reviewed in this paper related to the fog rain, have applicability in other semiarid regions, with similar environmental characteristics, in fact, it used in countries like Chile, Spain, particularly on the Mediterranean coast there are feasibility studies.

These systems have inexpensive cost and it could be part of efficient forest or water government policies to regulate water resources and control erosion.

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