The effect of afforestation as a restoration measure in a degraded area in a Mediterranean environment near Lorca (Spain)

Anja M.W. de Wit & Leo C. Brouwer
Department of Physical Geography, Utrecht University,
PO Box 80.115, 3508 TC Utrecht, the Netherlands
Email: A.deWit@frw.ruu.nl

Abstract

In parts of Spain which suffer from desertification, afforestation has taken place to supposedly reduce the effect of land degradation, notably erosion. In a marl limestone area near Lorca, south eastern Spain, the effects of afforestation on overland flow and erosion processes are studied. The natural vegetation in the area consists mainly of *Stipa tenacissima* (perennial grass) and *Pinus halepensis*. In 1983 *Pinus halepensis* have been planted on terraces, which were created with heavy machinery.

The first results of the study indicate that surface runoff after heavy rainfall is increased and consequently erosion is enhanced in the reforested areas. This unwanted effect is due to a number of causes. Most importantly the creation of the terraces was done very rough and preferential flowpaths were created because the bulldozer created tracks perpendicular to the contour lines. Secondly on north facing slopes the originally present, fairly well developed natural vegetation was destroyed. Since vegetation cover as well as the presence of a humus layer, are important factors on reducing erosion risk, this has lead to an initial increase in erosion. Thirdly the growth rates of the *Pinus halepensis* are slow that in 1997, fourteen years after planting the trees sometimes have reached no greater heights than 80 cm and the coverage percentage is still very low. Thus in this case the negative impacts on erosion of afforestation in the first 14 years after planting are greater than the gains. This was mainly due to wrong implementation.

Introduction

South-eastern Spain is about the driest area in Mediterranean Europe with an average annual rainfall of less than 300 mm. Despite the small annual amounts of rain, individual rainstorms may be heavy with very high rainfall intensities (Imeson and Emmer[1]). Such events may lead to considerable erosion.

Part of the study area was afforested with the aim to combat desertification by means of reducing erosion rates. During the operation artificial terraces were created with a bulldozer, which were planted with *Pinus*

halepensis. The expected effects were increased water infiltration on the terraces, less surface runoff and less erosion than in the previous situation. However, the actual effects were not known in this area. In this paper, the runoff response from two small catchments differing in forested area are evaluated.

Study area

The study area is located in the south-eastern part of Spain, in the region of Murcia near Lorca (figure 1).

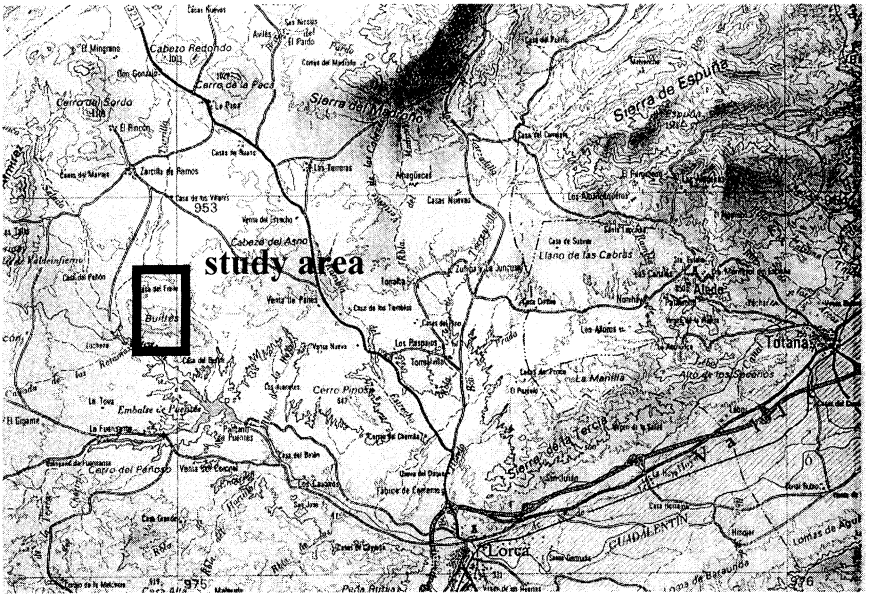


Figure 1: Location map of the study area.

Miocene and Tertiary marls and limestones which have been uplifted in the Pliocene are the dominant parent materials. Quaternary erosion processes determined the present relief. Soils are shallow and vulnerable for land degradation processes. North facing slopes are generally covered by *Pinus halepensis* stands and south facing slopes by *Stipa tenacissima*, a perennial grass with a patchy distribution. High potential evapotranspiration rates on the south slopes inhibit the development of a vegetation with a good ground cover here.

In the early eighties, the Forest Hydrologic Restoration (FHR) programme was initiated by the Autonomous Communities (Regional Governments) of Spain. This occurred in the framework of the National Plan of

Erosion and Desertification Control, meant to combat the problems with land degradation in Spain (Rojo Serrano[2]). As a result of the FHR, the study area was partly afforested in 1983 with *Pinus halepensis* on artificially created terraces. The main goal was to improve the water infiltration on hill slopes. Due to presumably increased infiltration rates on the terraces, more water could be stored in the subsoil and the growth of the vegetation was expected to be improved (Martínez de Azagra Paredes[3]).

To test these assumptions, two small adjacent catchments, differing in afforested area but similar in parent material were studied (table 1).

	Catchment A	Catchment B
total surface area (ha)	13.9	16.2
afforested with *Pinus halepensis*	51%	14%
natural occurrence of *Pinus halepensis*	42%	54%
covered by *Stipa tenacissima*	7%	32%

Table 1: Selected characteristics of the studied catchments.

At the outlets of the two catchments, sharp crested V-notch weirs were constructed and discharge through the weir was monitored since late 1995. Precipitation was measured with various rainfall gauges within and near the catchments and the precipitation intensity was measured with a tipping bucket.

Within the afforested areas, local overland flow on the terraces and at the footslopes was measured by monitoring total discharge in ditches along the slope. Simple devices (crest stage tubes) were used to establish locally if overland flow occurred during an event.

Results

Between November 1995 and May 1997 only four events occurred that lead to discharge in one or both catchments. Catchment A had four times runoff and catchment B only in two occasions.

Figure 2 presents the rainfall characteristics and resulting discharge at the catchment outlets for two events in spring 1997. Discharge responded quickly to high intensity rainfall, with in catchment A a delay of the peak discharge of about 15 minutes in both cases. Catchment B responded similar to catchment A for the 20 April event both in timing and magnitude of peakflow. During the 31 May event the peakflow was much smaller in catchment B, and the peak was a little delayed. Absolute amounts of peakflow were 44 and 56 l s^{-1} in catchment A for the 20 April and 31 May event respectively, and 43 and 26 l s^{-1} for catchment B. The total duration of runoff was in the order of 1.5 hour in both catchments for these two events.

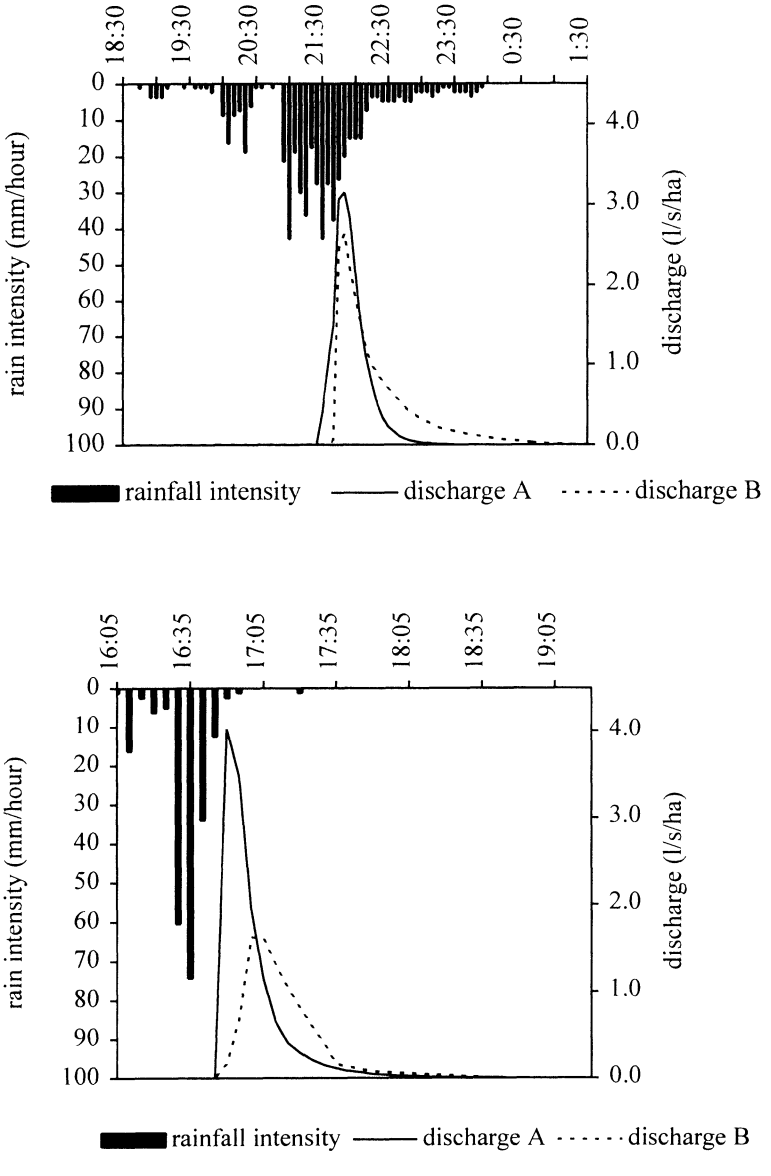


Figure 2: Rainfall intensity and discharge of catchments A (51% afforested area) and B (14% afforested area) on 20 April 1997 (top) and 31 May 1997 (bottom).

In catchment A considerable sedimentation took place upstream of the weir. At another smaller weir located upstream in catchment A, the bed of the approach channel in front of the weir was completely filled with sediment after the events. The two other events that generated runoff in catchment A were somewhat smaller and occurred at 6 May 1996 and 25 March 1997.

The measured discharge in the ditches confirmed that locally the terraces generate considerable runoff. The storage basins in front of the discharge measuring devices contained a lot of sediment after events. Although similar devices were not established within the naturally vegetated areas, visual observations during and after rainstorms suggest that overland flow is less under natural *Pinus halepensis* and *Stipa tenacissima* vegetation. This is confirmed by the occurrence of rills, which are virtually absent under natural vegetation cover, but common at the edges of the artificial terraces. The crest stage tubes were installed in insufficient numbers to establish a relation between vegetation cover and the occurrence of overland flow.

Discussion and Conclusions

The current results suggest that afforestation in this area did not result in the expected effects. On the contrary, overland flow occurred more often and the resulting peak discharge in small catchments was larger in the catchment with a high percentage of afforested area. That the supposedly greater quantities of overland flow indeed generate more erosion was confirmed by i) the frequent occurrence of rills in the afforested area and ii) the fact that after events massive sediment deposition occurred in front of the weir.

Although in the present set-up of comparing two different catchments it cannot be excluded that the difference in response to rainfall events is due to differences in the nature of the catchments. The discharge in the ditches and the obviously greater sediment generation in the afforested areas suggest that indeed the difference in afforested area is the main reason for the observed differences in runoff generation.

Instead of conserving soil, the afforestation seems to have had a negative effect on erosion rates, at least during the first 14 years after planting. A number of conditions may be responsible for this:

- The creation of the terraces was done using heavy machinery. At locations where the bulldozers had not been operating along the contour lines, rill development is frequent. This is the case both on the terraces itself, where they are not completely level, as well as on tracks used to reach higher terraces which are sometimes even perpendicular to the contour lines.
- The natural vegetation on north facing slopes is generally relatively well developed and currently provides better protection against soil erosion than the planted *Pinus halepensis*. Because the topsoil was disturbed due to the bulldozing activities, the soil structure is destroyed and soil organic matter levels are lower on the terraces which probably leads to lower infiltration

rates than under the natural vegetation cover of *Pinus halepensis* and *Stipa tenacissima*.

- The development of the planted *Pinus halepensis* is locally very unsatisfactorily. Sometimes the height of the planted trees is less than 80 cm after 14 years of growth. This leads to a very low canopy cover percentage, locally less than 5% giving obviously little protection against soil erosion.

Thus, the afforestation did not lead to decreased, but on the contrary, to increased erosion rates. This is mainly due to neglicence during terrace construction.

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