EROSION STUDY PROJECT CORDOBA (SPAIN)

FINAL REPORT

"The rain in Spain is mainly in the Plain"
"Lluvia de Enero para el venero"

EROSION PROJECT
STEERING COMMITTEE

Wageningen, 1978

Acknowledgements

The Erosion Project Steering Committee expresses its gratitude for co-operation and hospitality to:

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CHAPTER I INTRODUCTION

Erosion of cultivated lands is an ever growing problem in the world of today. The present situation shows that 30% of the world's exploited soils is suffering to more or less severe erosion.
The attention paid to this problem by the Agricultural University at Wageningen, Netherlands, is coordinated by the Erosion Study Group, in which are represented the Departments of Land and Water Use, Soil Science, Forestry and Civil Engeneering.
During the last six years three Erosion Project Studies have been carried out in Spain, in coöperation with the Spanish Soil Conservation Service (SCS), a department of the Institute of Nature Conservation (ICONA). The first study took place in Armenteros (prov. of Salamanca), the second one in Hornos, (prov. of Jaén). For the variety of projects it was judged useful to initiate a third study in a large scale, mechanised farming area, where social problems are less predominant, and an economic evaluation seems possible.
On recommandation of the SCS, the province of Córdoba was selected. After consulting the local authorities, a project area was pointed out in the Campiña of Córdoba.

The purpose of this Erosion Study Project is:
- to analize the factors influencing the erodibility and erosion hazard
- to determine soil losses and predict their long term effects on agriculture
- to design measures and conservation plans for the Project area
- to evaluate costs and benefits in order to find out the best solution to the erosion problems in the Campiña.

The Erosion Study Project was set up in three phases:
1) First Phase: a preliminary reconnaissance, in order to find a Project area, which is representative for the Campiña as a whole, and to obtain general information concerning climate, topography, hydrology, vegetation, and socio-economic data. In this stage the rainsimulation equipment was also tested. This reconnaissance was done in November 1975 (2 weeks).
2) Second Phase: A geological and pedological survey and inventory of land-use and agricultural practices. This stage took place in May 1976 (2 weeks).
3) Third Phase: in this stage supplementary data were collected, analized and worked out into two Soil Conservation Plans. An evaluation of plans and projects was made. This phase took one month for fieldwork in Spain (november 1976), and one year for compilation in Wageningen.

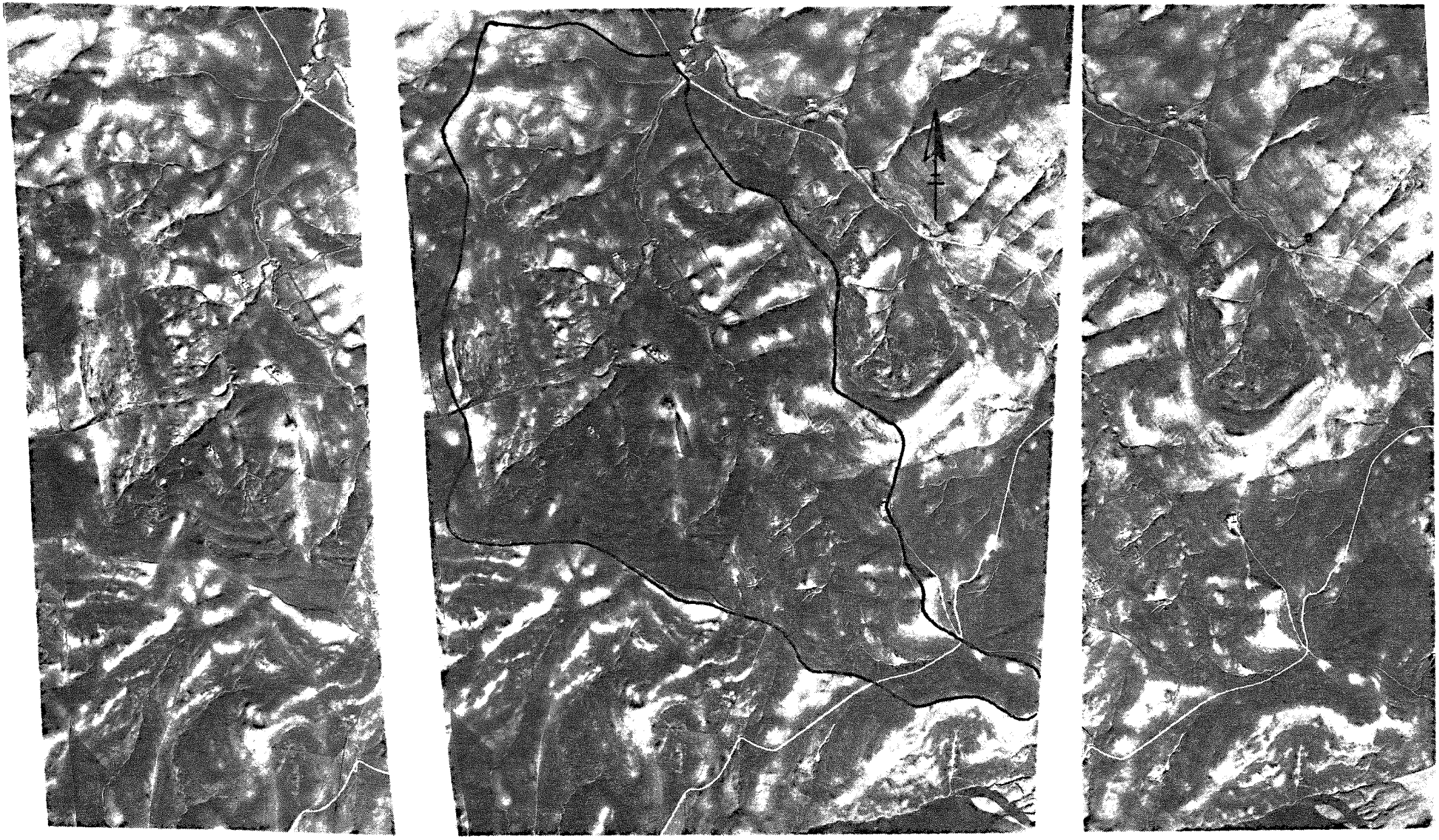

Fig. 1.1 Stereoset of the Pilot Area

Because of the predominant role of large-scale arable farming in the Campiña and the lack of forest and natural vegetation, the department of Tropical Agronomy was invited to join the Study Project; the Forestry department only participated in the Third Phase.

After each of these stages a project report was brought out (in Dutch). The aim of this Final Report is to summarize the whole Study Project. The set up of the Study Project can be found in the grouping of chapters in this report:

Chapter II contains general information of the Project area, as it has been collected in the first phase.

Chapter III to VI describe the inventory surveys for each discipline.

The goals and measures of the Soil Conservation Plans are dealt with in Chapter VII and VIII, whereas in Chapter IX an evalution is made of the economical and social feasability of these plans.

Conclusions are in Chapter X.

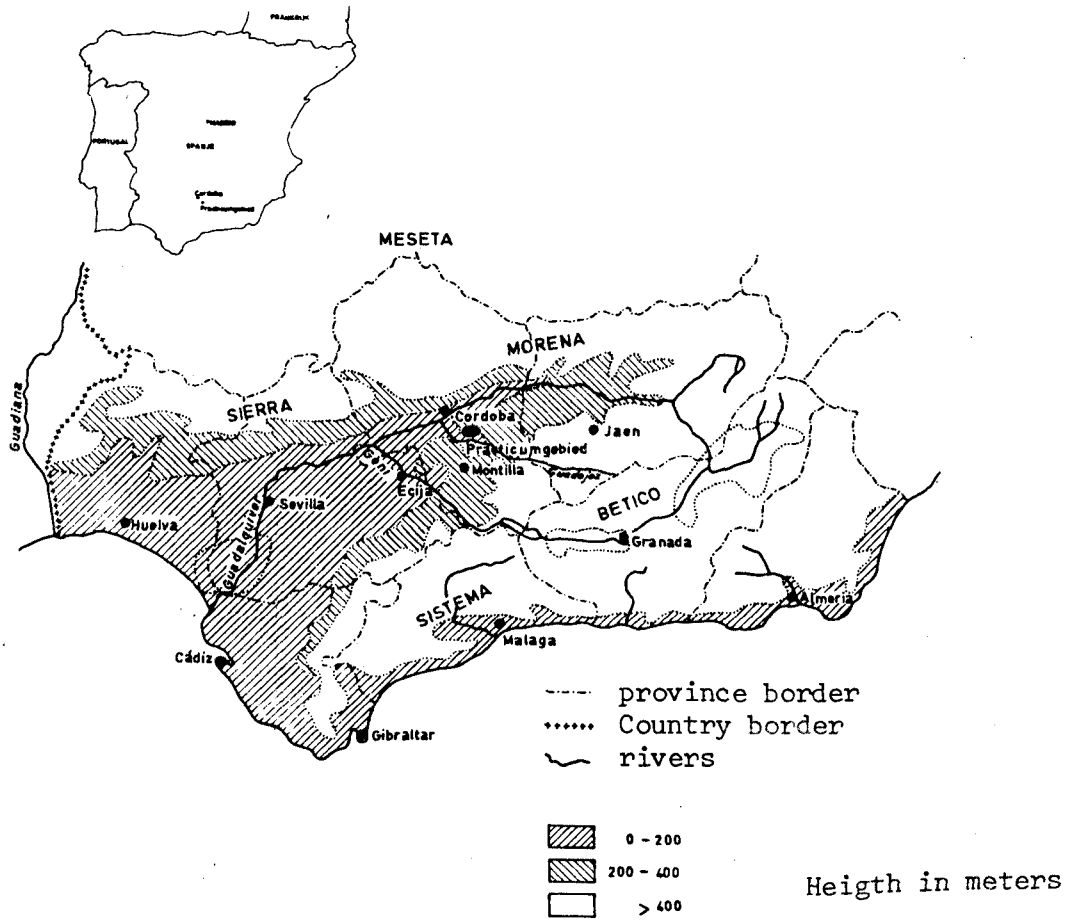

Fig. 2.1 Location of the Project Area

CHAPTER II GENERAL DESCRIPTION OF THE PROJECT AREA

2.1 Location and Topography

The Campiña of Córdoba is located in the western part of Andalucia. It is situated in the lowlands between two mountainous ridges: the Sierra Morena on the northern bank of the Guadalquivir valley; and the Betic System in the South. Westward it is limited by the province border of Córdoba.
This Project Study concentrates on the homogenous wheatlands in the centre of the Campiña, an area of about 200.000 ha within 11 municipalities, including Córdoba.
The Project Area is defined by the cover of 7 aerial photographs (1965); it is about 6000 hectares, and is regarded to be representative for the Campiña. Within this area, the catchment of one watercourse (Arroyo de los Camareros) was studied in more detail. This Pilot area amounts to 525 ha's (Figure 2.1).
A detailed map of the Pilot Area is given in Map I.
The landscape of the Campiña is characterized by an endless rolling topography, with only some isolated farms or scattered villages. The area is fully cultivate and almost tree-less.
The Campiña gently slopes from South-East to North-West. The main drainage pattern is situated in this direction. Heights vary from 400 to 200 metres above sea level. The Guadalquivir basin lies about 100 metres lower. The average slope of the Project Area amounts to 11%, whereas slopes generally don't exceed 40%.

2.2 Accessibility

The main roads in the Campiña are the E 25 (Córdoba-Madrid) in the North and the N 331 (Córdoba-Granada) in the South.
The Campiña itself is crossed by some paved or semi-metalled country roads; whic are not too good. The access roads to the farms often are unmetalled. In the Pilot Area the access road to Campiña Bajo 1, 2 and 3 is unpassable for several days after a rainstorm. The parcels mostly are reached over land. With the prese tractors no problems occur, as far as no gullies cut off the way.

2.3 Climate

According to the KÖPPEN-classification the Campiña has a mediterranean climate (Cs), with temperate humid winters and dry hot summers.
Some important climatic data are given in Table 2.2. The average monthly temperature is between 10 and 28°C, but the difference of absolute max. and min.

Table 2.2 Some climatic data of Córdoba (1931-1960), and calculated evaporation

	j	f	m	a	m	j	j	a	s	o	n	d	year
mean temperature (°C)	9,1	10,7	13,5	16,3	19,4	24,4	27,9	27,6	24,3	18,6	13,6	9,6	17,9
abs. max. temp. (°C)	24,8	27,8	29,2	35,4	39,4	41,6	44,6	44,0	40,0	36,5	27,6	20,8	44,6
abs. min. temp. (°C)	-4,7	-6,0	-1,0	3,0	3,0	9,0	12,0	11,2	9,8	2,0	-1,2	-3,0	-6,0
mean air humidity (%)	77	70	69	62	58	48	41	43	51	64	74	78	63
mean precipitation (mm)	88,4	66,8	110,4	60,4	50,1	12,2	2,6	3,4	22,9	86,0	76,5	84,6	664,3
do., project area (mm)	75,0	58,3	92,1	53,4	45,4	16,0	8,6	9,2	24,3	73,2	65,8	72,1	593,4
E_o (Penman) (mm)	30	47	78	113	148	189	232	206	138	85	42	26	1334
E_p (Turc) (mm)	43	51	73	99	127	156	179	173	139	97	61	43	1241

temperature is extremely high: during summermonths day temperatures above 40°C are not uncommon. In winter temperatures below 0°C occur frequently.
Rainfall data are collected from 4 meteorological stations nearby the Project Area. The average yearly rainfall amounts to 600 mm. However, this amount may vary widely every year. Rain is concentrated in a few months; summer rainfall occurs, often in the shape of heavy rainstorms.
Maximum daily rainfall was estimated by plotting the rainfall data of two stations (Vill d.C. & Bujalance) into a log-normal distribution.
According to ELIAS (1963) the ratio between the total amount of rain and duration could be determined for various return periods (Table 2.3). From the station El Origuero some pluviograms were available. However, too many data were lacking to determine rainfall intensity during heavy showers.
The evaporation was calculated from meteorologic data of Córdoba, by means of PENMAN'S and TURC'S formulae (Table 2.2).
Although only Córdoba data were available, it may be concluded that water deficits of 600 mm yearly occur; in june there can already be a shortage of 200 mm; (dependent from the available moisture in the soil).

2.4 Socio-Economic Aspects

As a result of the historical frontier line during Moorish Occupation (1240-1492), the population of the Campiña is concentrated in few villages.
Demographical statistics show that the population of the Campiña decreased the last 15 years (app. 10%), due to migration to the cities and emigration to European countries (30%) as foreign labourers.
The working population of the Campiña in the agricultural sector since 1900 diminished from 72% to 42% and is still decreasing. In 1970 23% of all Spanish workers finds employment in agriculture. Industry is established in Córdoba-city only. The economic developments of Spain during the last years cannot well be seen in the Campiña.
Most agricultural labourers live in the villages, and work only partially on the farms. Casual labour is used for the thinning of beets and sunflower and the harvest of olives, beans & cotton.
On the farm live only a few regular personnel such as tractor drivers and the manager. The owner of the farm mostly resides in town (Córdoba, Granada, Madrid). He takes decisions about investments and the choice of crops.

Table 2.3 Maximum short period rainfall (mm) at various return periods.

	Return Period (years)		
duration	2	10	25
24 hr	43	60	70
1 hr	18	25	29
5 min	5	7	8.25
1 min	1.0	1.4	1.65

Table 2.4 Farm size distribution (1962)

Farm size (ha)	number of farms	(%)	Total Superficies (ha)	(%)	mean superficies (ha)
0 - 10	15 900	70.0	48 600	8.0	3.06
10 - 300	6 496	28.6	322 600	53.1	49.66
300 - 500	168	0.74	62 800	10.3	373.81
500 - 1000	103	0.45	69 000	11.4	369.90
> 1000	47	0.21	104 500	17.2	2223.40

Land tenure is historically grown. In the Middle Ages most land was property of the Church or the Nobility. In the 19th Century a considerable landreform was started, which caused in the Campiña an expropriation of 11% of the cultivated area, mostly around the villages.
As a consequence of the Land Reform Act of 1931 many landholders sold enormous areas to their former tenants, who made themselves to a new Owners Class.
At the moment much land is being sold to banking houses for investment purposes.
Table 2.4 summarizes the land tenure-distribution of the Campiña in 1962. The 1972 - data are almost equal. In spite of the changed ownership, the land distribution hardly shows any change since 1300 (LOPEZ, 1974).
The small farms are usually situated around the villages, where farmers have other jobs as well. The mean farm size in the Pilot Area is about 180 ha.
As to leasehold tenure in the Campiña, 25% of the area is leased; the greater part of which is cash tenancy. Share tenancy seldom occurs (3%). About the height of rent only little data are available; but it varies from Ptas 1300 to 20.000 per ha (in the irrigated Gualdalquivir valley).

CHAPTER III SOIL INVESTIGATIONS

3.1 Geology

The Iberic peninsula consist of a paleozoic core, the Hercynic Massive (at present the Central Meseta), surrounded by mountain ranges (such as the Sierra Morena and the periferic mountain ranges, separated by depressions). During the Mezozoicum and in the early Tertiary (Eocene) these depressions were filled with thick layers of sand, lime and marl which became folded during the following alpine orogenesis. Sedimentation in the depressions continued during the Oligocene and the Miocene.
The Campiña is situated in one of the mentioned depressions, the Betic Depression, which is the basin of the present Guadalquivir River. This river has deposited floodplains at different levels in the Quaternary as well as in Holocene periods as is witnessed at present by terrace remnants at 5 different levels.

The project area is situated on the deposits of the Late Miocene and has remnants of the first (highest) quaternary terraces and possibly also the second (Fig. 3.1). The late Miocene consist of alternating layers of marl and sandstone which are

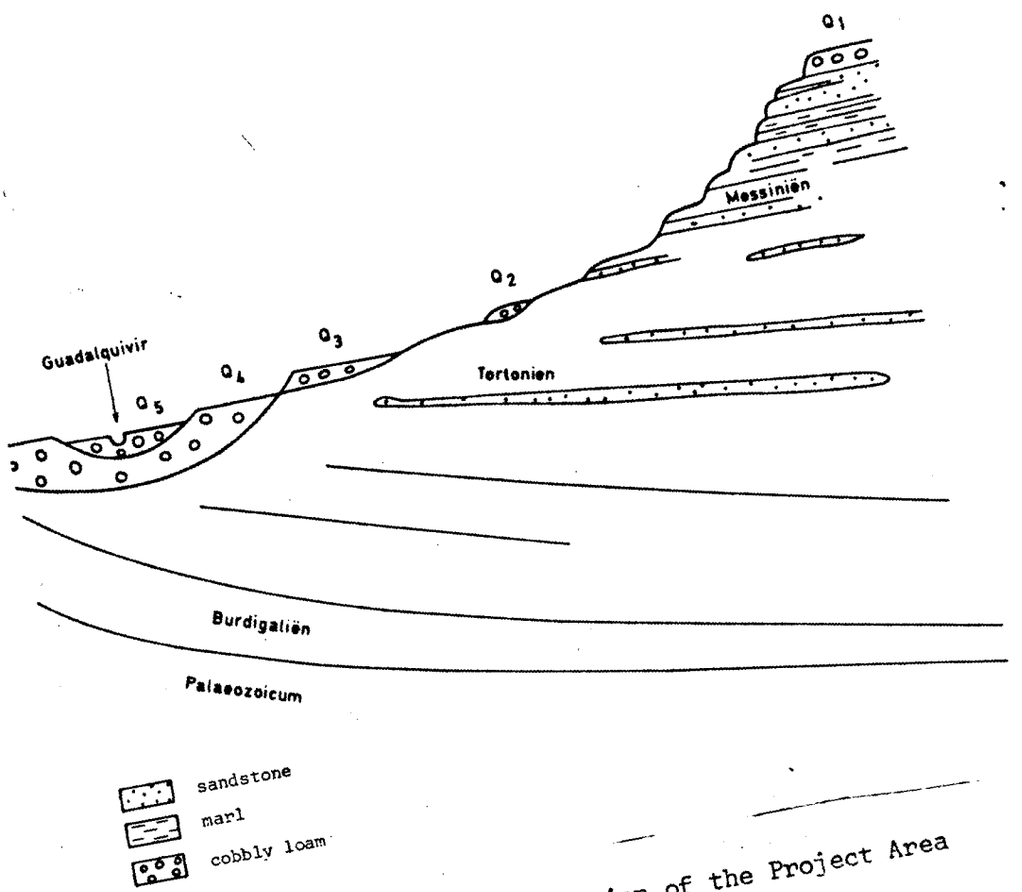

Fig. 3.1 Geological cross section of the Project Area

still nearly horizontally stratified. The upper part of these sediments can be divided into two slightly different formations:
The Upper Tortonien, consisting of blue-gray clayey marl with relatively thin, discontinuous layers of lenses of sandstone and The Messinien, consisting of alternating layers of clayey marl and sandstone of almost equal thickness. The Messinien is on top of the Upper Tortonien. The transition between both formations is gradual and is found in the project area at a level of about 200 m above sealevel.
The quaternary river terrace remnants consist of reddish gravelly clay with boulders.

The geomorpology of the area is the result of the occurrance of these layers as well as erosional effects. The slopes in the Upper Tortonien and Messinien Formation are at various levels interrupted by a steeper "shoulder" of hard sandstone layers in the soft clayey marl. The valleys in Upper Tortonien are not symmetric, however, because of the interrupted or lens-shaped form of the sandstone layers.
The rolling topography of the project area is the result of geological erosion in soft parent rock.
Accelerated (or manmade) erosion has started mainly after the introduction of mechanized traction after Worldwar II, when mixed farming was replaced by pure arable farming. The resulting erosion, mainly gully erosion, and sedimentation, has modified the geomorphology of the area considerably. Landslides occur in the zone of transition between the Upper Tortonien and the Messinien because of the increase of gradient there and the accumulation of moisture through the permeable sandstone strata saturating the marl in that zone.

3.2 Soil Map

The soil studies were carried out in two periods.
In april 1976 a reconnaissance survey was conducted in the project area.
As a result a provisional legend could be produced and a preliminary soil map, mainly based on photo interpretation was drawn up (Stuurgroep Erosie 1976).
During the second stage, a final, detailed soilmap scale 1 : 10.000 of the pilot area could be produced based on some 500 augerings, 15 soil profile studies, field-observations and aerial photo interpretation (Map 2).

Table 3.2 Legend of the Soil Map

M soils on Marl

M1 Deep, dark calcareous clay. Gently sloping or sloping topography

M2 Moderately deep, dark calcareous clay, here and there shallow dark over pale calcareous clay. Gently sloping or sloping topography

M3 Pale calcareous clay, sloping or steep topograpny

S soils on Sandstone

S1 Pale yellowish calcareous loam moderately deep or deep, locally shallow over sandstone. Sloping or steep topography

S2 Pale yellowish calcareous clayloam or loam. Sloping or steep topography

C Colluvial Soils

C1 Very deep, dark calcareous clay. Flat or gently topography

C2 Dark or pale calcareous clay. Irregular, sloping topography

Q Soils on Quaternary deposits

Q Reddish brown gravelly and clobby loam. Flat or gently sloping

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* dark: more than 2.5 YR 5/3
pale: lighter than 2,5 YR 5/3
(Japanese edition of
Munsell Colors)

Shallow: < 15 cm
Moderately deep: 15-50 cm
Deep : 50-100 cm
Very deep: > 100 cm.

Soil formation on the clayey marl parent material in the project area (designated as M-soils), has resulted in soil profiles with a dark gray, granular A-horzion over a deep C-horizon with cracks and slickensides. Such profiles are generally classified as Vertisols.
The described soil formation is most prominent in the least sloping zones as above a sandstone outcrop and in depressions and valley bottoms where colluvial soil has accumulated. The steeper zones on clayey marl have a lighter coloured surface soil and the soil profile has vertic features only.
The soils on Marl have been mapped in 3 units on basis of depth of the dark surface soil over a pale subsoil.
The soils developed on the sandstone outcrops and slightly below (designated as S-soils) are coarser textured and have a yellowish colour as result of mixing with the limonite rich sandy weathering products of the sandstone. The soils have locally a subsoil of yellowish sand. These soils have no vertic features.
S-soils are mapped in two units differentiated on the nature of the subsoil:
S 1 has a sandy or sandstone subsoil, S 2 soils don't have sand within 1.20 m depth.
Colluvial soils are soils developed on colluvial deposits in valleys and depressions. These soils are mostly "cumulic" i.e. the surface soil became deeper and deeper because of sedimentation of dark and pale, erosional products from higher areas. The surface soil therefore is often stratified. The colluvial soils are mapped in two units, differentiated on basis of formation:
C1 soils are very deep dark, "natural" soils whilst C2 soils are accumulated by the activity of man, who has filled up and levelled gully-affected areas with farm machinery.
A very small portion of the pilot area has soils, developed on remnants of the first quaternary terrace. The parent material is gravelly and cobbly loam. The soil is reddish brown. These soils were mapped in one unit, Q_1.
Table 3.2 shows the legend of the Soil Map 1 : 10.000.

The described soils occur in the field in a certain characteristic sequence, (Fig. 3.3), correlated with topography and parent material. This pattern is very clear on aerial photographs because the granular dark topsoil of the vertisols reflects little light and shows extra dark on the photo, whereas the sandy patches near the sandstone outcrops show extra light because of their lighter natural colour tone combined with reflection as result of slaking and crust-formation.

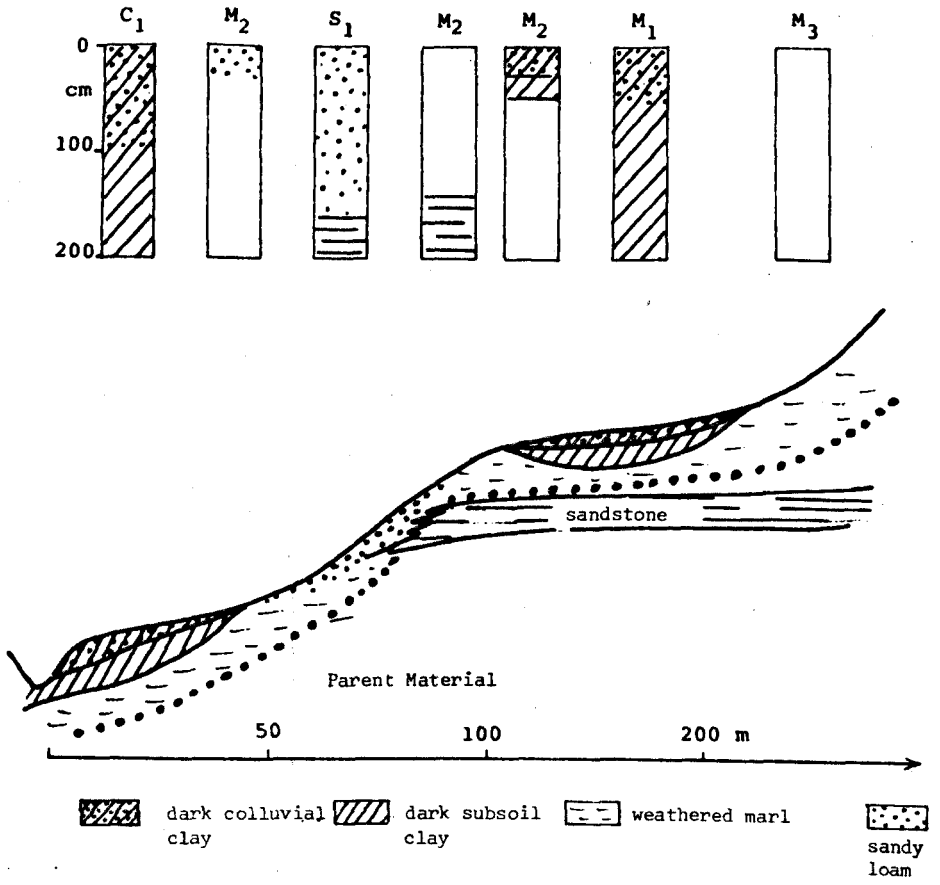


Fig. 3.3 Characteristic sequence of soil profiles

The soils of the project area have been classified according to the U.S. Soil Taxonomy (1975), and the FAO/Unesco classification (1971). The Soil Moisture regime of the area is Xeric. On basis of the described soil profiles, all soils of the area have ochric, or a mollic epipedon (surface horizon) and a cambic (subsurface) horizon. On basis of these features the Soil Mapping Units were classified as follows:

M1 and C1	predom.	Typic Chromoxerert
M2	"	Vertic Xerochrept
M3	"	Aquic Xerochrept
S1 and S2	"	Typic Xerochrept
Q1	"	Calcixerollic Xerochrept
C2	Complex	Vertic and aquic Xerochrept.

3.3 Soil analysis results

Soil samples for chemical and physical analysis were taken at different stages of the project for different purposes. A summary of the analysis results is given below and reviewed in Table 3.4.

The mechanical analysis was carried out on soil samples treated to remove organic matter but not calcium carbonate. A limited number of samples was treated with HCl to remove $CaCO_3$ as well. Soil texture was determined with the pipette-method. It can be concluded that

1) Most M soils are silty clay (both top and subsoil)
2) Most S soils are clayloam (topsoil) or sandy loam (subsoil)
3) Calcium carbonate is mainly in the silt and sand fraction of the soil
4) The Marl parent material contains no sand. Hence the sand from the M-soils is originating from the sandstone soils.

The percentage calcium carbonate of the samples was determined by the method of Scheibler. Contents vary little and seem well distributed over the soil profile. All M, S and C soils are highly calcareous (25-40%).

The quaternary soils contain less (23%).

The organic matter content of the surface soil hardly exceeds 1%.

The subsoil contains no organic matter at all. The dark surface soil colour is caused by dispersed organic matter, a common characteristic of vertic and vertisols.

Soil permeability tests indicate that permeability of wet soil is extremely low.

Fig. 3.5 Desintegrated slaking crust after rainstorm

The submersion test of EMERSON indicates slaking for all samples but no dispersion, even if treated to simulate soil tillage. So, according to this test, aggregate stability is moderately high (Class 4).
Field observations show that the aggregates desintegrate into very small micro aggregates but do not easily disperse into primary particles (Fig. 3.5).
WISCHMEIER'S erodibility factor K was estimated by use of a nomograph for medium textured soils (W, 1971).
The following values are obtained from it:

M soils: K value approx. 0.10 short tons/acre .er. index
C soils: K value approx. 0.15 " " "
S soils: K value approx. 0.16 " " "

Application of this nomograph is doubtful, however, to the highly calcareous and heavy montmorillonitic clays of the M and C units.
It we take into consideration the vertic properties of the M and C soils, including their tendency to form impermeable plough pans, and the susceptibility of S-soils to surface crusting after rain, it is suggested to modify the above values into 0.15 for M and C soils and 0.25 for S-soils (non-metric).
These values are accepeted as a basis for calculations of total soil loss elsewhere in this report.
In addition to the described tests, fieldobservations and aerial photographs may help in assessing soil erodibility in the project area.
Some conclusions can be drawn from this observation:

1) There is a moderately strong erosion hazard, mass-movements, sheet and gully erosion, in the steeper (i.e. higher) areas not only because of slope, but also because the more erodible S soils are predominant in those areas (Messinian formation).
2) In the less sloping areas erosion may only occur in time of exceptional rainstorms.
3) Gully-erosion commonly starts in the transitional zone between the Upper Tortonian and the (steeper) Messinian formations. Small landslide scars may act as starting point for a gully.

3.5 Soil suitability for agriculture

Differences in soil suitability in the Project Area are caused mainly by differences in slope and relief.
The suitability of the M-soils in general is mainly determined by their physical properties: they have a heavy clayey texture, high lime content and, due to the

Table 3.6 Soil suitability for various crops

Soil type	Winter Crops	Summer Crops	Olive	Almond	Pinus	Eucalyptus
M1 less than 20%	I	III	V	V	IV	III
M1 steeper than 20%	V	V	V	V	IV	IV
M2 less than 20%	I	III	V	V	IV	III
M2 steeper than 20%	V	V	V	V	IV	IV
M3 less than 20%	II	IV	V	V	IV	III
M3 steeper than 20%	V	V	V	V	IV	IV
S1 less than 20%	III	IV	III	IV	II	III
S2 steeper than 20%	V	V	IV	IV	III	IV
C1 less than 20%	I	I	V	V	IV	II
C2 less than 20%	II	II	V	V	IV	III
C2 steeper than 20%	V	V	V	V	IV	IV
Q	III	IV	II	III	II	III

clay mineral montmorillonite, much swelling and shrinking, with a changing moisture content. The suitability of the S soils is limited by their steepness. The soils have been classified for their agricultural suitability according to a system as described by BEEK EN BENNEMA (1972) and FAO (1976).
According to this system the soils were assessed on basis of the following land-qualities:

- oxygen availability in the root-zone
- nutrient availability
- resistance to soil erosion
- suitability for mechanized agriculture
- moisture availability.

For each of the mapping units in combination with slope class, the above land-qualities are assessed in terms of good(1), moderate(2) and bad(3) as well as the possibilities for improvement of the landqualities under the prevailing economic and technical conditions.
The question of crop choice is dependent on the prevailing landutilisation type and climatic criteria. If these data are known, the suitability of soils for various crops in relation to its requirements can be listed in 5 classes (Table 3.6). From this table some general conclusions can be drawn:

1)- Almost every soil type is suitable for winter crops
2)- Only Q- and S soils are suitable for olive trees
3)- The steeper areas are only suitable for tree crops.

CHAPTER IV CROP INVESTIGATIONS

4.1 Introduction

During the second phase an inquiry was made into the farm management in the Project Area.
Most of the farmers established some hesistance in giving information, especially concerning yield and farm-economics. Some managers refused cooperation at all, not having the permission of the owner. Thank to Mr. Christobal Lovera's support, 8 holdings could be inquired in and around the Pilot Area.
Moreover field investigations were undertaken to estimate crop yields and the relationship of yields with soil moisture and erosion.
In the third phase information of special subjects was obtained by means of informal conversations and in a visit to the INIA in Córdoba.

Table 4.1 Crop yields of various crops on the inquired farms

Farm	wheat (kg/ha)		sunflower (kg/ha)		sugar beets (ton/ha	
	1974	1975	1974	1975	1974	1975
Camarero Bajo 1	4730	1630	815	1020		
Camarero Bajo 2		1300		570		
Camarero Bajo 3		2120		1300		
Camarero Alto		1630		815		
Calderito Bajo	3260	815	1220	815		
Calderito Alto	3900	850				22
El Rubio	4075	1630	490	163	16	5,5
Enciñeno y T.	3590	2450	815	440		

4.2 Rotation and Crop choice

From the 16th Century till the beginning of the 20th Century a three course rotation was commonly applied, with subsequently one year of cereals, fallow with weeds (pasto), and bare fallow.
On the fallow pasture some livestock was held (mostly sheep).
In the 20th Centure an intensification took place of cereal cropping, due to:

- the new type of farm owner, who was anxious to increase his yields by innovation of farming methods
- the possibility to apply fertilizers, which made organic manuring superfluous
- the development of mechanical labouring and the introduction of tractors, which could reclamate the submarginal areas without much difficulty. Guaranteed prices for wheat and other products facilitated decisions about crop management and mechanization.

As a result the farming system changed into a two course rotation, with wheat as main crop, and various rotation crops. It is characterized by an exhaustive use of the area, a very high rate of mechanization, and a crop choice based on farm-economics exclusively.
Rotation crops were firstly beans (Vicia faba) used for fodder, and chick peas (Cicer arietinum). In the 50's maize and cotton were added, which required a great labour force for harvest. At the moment sugarbeets (Beta vulgaris) and sunflower (Helianthus annuus) are the favorite rotation crops. Safflower (Carthamus tinctorius) also occurs, but the area under this crop is decreasing. Stockfarming has disappeared completely except on some specialized farms in the river valleys.

4.3 Crop data

Wheat is the main crop in the Campiña since long. Almost 50% of the Project Area is seeded every year. The Campiña can be considered to be the "Wheat Belt" of Spain.
Yields vary, depending of the yearly rainfall, from 4000 kg/ha in a good year (1974) to less thans 1000 kg/ha in a bad year (1975). (Table 4.1). There are also great differences between farms.
However, a correlation between the total amount of rain in the growing season and the yield could not be discovered. A rainfall of 350-400 mm is considered to be sufficient for a good yield, provided that it is well distributed over the season :

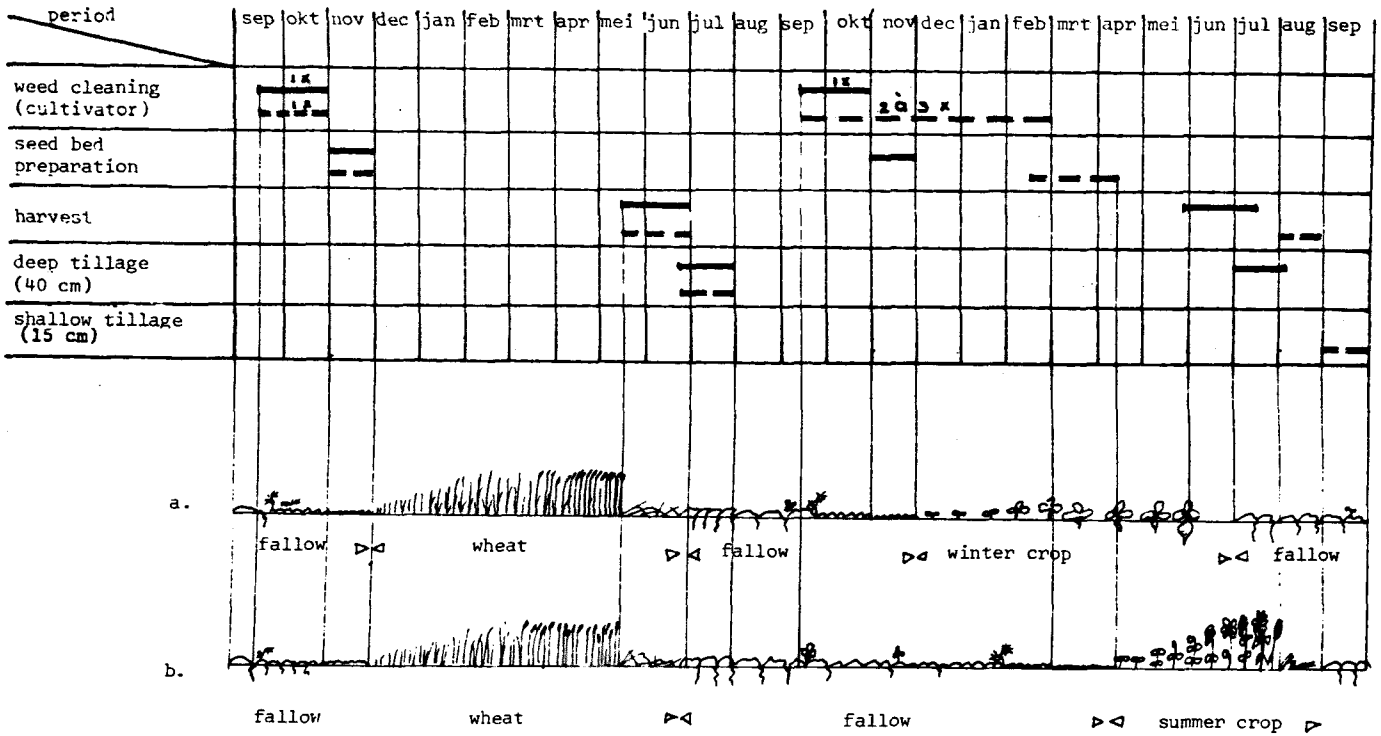
Table 4.2 Assumed production and benefits for various crops

	Yield		Net Profit
	kg/ha	ptas/ha	ptas/ha
Wheat	2000	20000,-	5000,-
Sunflower	750	11000,-	4000,-
Sugar beets	15000	60000,-	10000,-

100 - 150 mm before seeding
50 - 100 mm between germination and tillering
100 - 150 mm between tillering and flowering
ca 50 mm during seed production

The effects of water deficits on plant growth depend heavily on the time in which such water deficits occur.
Field investigations in april 1976 did not show any correllation between the 1000 grain weight and the actual soil moisture content. Admittedly other factors had influenced this relationship (such as inequal fertilizing).
Pests of lice and capsid bugs are controlled by spraying the crop from aeroplanes. A problematic weed is the wild oat (Avena fabua) which is combatted against by hand. The wheat race T85 is sensitive to mildew (Odium sp.).
Quaranteed prices for wheat amounted to 9.3 ptas/kg (1975). As to production costs the only available data are given in LEON & RUIZ, (1975), where marginal production (variable costs only) is calculated for one farm. The assumptions of production, and production costs and net benefits used further on in this report, are summarized in Table 4.2.
Sunflower has been introduced in 1968, in order to increase the edible oil production. Spanisch agricultural policy aims to substitute the consumption of olive oil, which has a great export value, by other vegetable oils. The sunflower area is grown up to 50% of the rotation crops since, and has ousted the sunflower completely. The only type of sunflower grown is the Peredovic-variety.
The yields of sunflower vary greatly from year to year and per farm (see Table 4.1). The deep and extended rooting system guarantee an effective water use. However the crop is sensitive for water deficits during growth: 450 mm is the minimum need in the growing season. On experimental fields of the INIA, yields of 2000 - 2500 kg/ha are reached; In farming practice yields over 1000 kg/ha must be possible. Field observations showed a retarding growth on the steeper slopes; it is probably explained by the lower water availability in the sandy layers.
The effect of fertilizers on sunflower yields is negligible, according both to literature as to field investigations.
In sunflower no pests or diseases occur until now, and weed problems are not serious. Because of hazard for downey mildew (Plasnospora h.) it is advised to limit sunflower growing to once every four years.
The harvest of sunflower is fully mechanized, which makes the crop attractive compared to other labour-intensive rotation crops.

Sugarbeets are grown on irrigated as well as unirrigated lands. In the Campiña the yields vary a lot due to the available rainfall. The moisture need amounts to 550-700 mm. The sugar content of the beets lies between 16 and 22%.
Weed control is done by chemical methods (grasses) and by hand, it takes place twice in the growing season. Pests don't occur frequently. Harvest is done mechanically.
Because of the yields that may be expected sugar beets are a very risky crop. In the Pilot Area no beets are grown, due to the poor transport facilities on unmetalled roads. Moreover the crop is sold by contract, which is not very attractive to the farmer.
Chick peas are not a very popular crop in the Campiña. The yields decrease when grown too often on the same parcel. Yield data are only known from one farm, where an average was reached of 815 kg/ha. The main diseases are footrot (Fusarium orthoceras) and rabia (Mycosphaerella rabiei), the latter of which is disastrous, and hard to combat. The crop is harvested fully by hand, which makes it inattractive to the farmer.
Horse beans are affected by broomrape (Orobanche sp.) in such manner, that no benefits can be expected as long as no resistant varieties have been breeded. The only way to combat this parasite is the "Siciliano" method: to plough the crop just before the flowering of broomrape.
Cotton was commonly grown in the 50's and the 60's, but at present is limited to irrigated areas only. The short available growing season owing to the low soil temperatures in spring is one reason. The increasing picking wages is the other one. Moreover the crop is very sensitive to erosion and was often damaged therefore.
Olive trees occur in the Project Area on the Quaternary Terraces only, where soil is not subject to the strong swelling and shrinking. In the other part of the Campiña, olives are planted on a large scale (31% of the cultivated area in 1970). Despite high picking wages and lowering World Market prices, this area is still increasing. Farmers consider planting of olives to be a stable investment. Since 1966 guaranteed prices are given.
Other rotational crops that may form an alternative for the sunflower and safflower is the oilseed rape (Brassica napus var. olifera), which is a winter crop. In Sevilla experiments have been set up with this crop, which promised good results. Its water consumption in the growing season is about 530 mm; so it is expected to fit in the climatic conditions even better than sunflower does. It's also a good soil-conservating crop due to the high degree of density, directly after germination.



a. ═══════ : with winter rotation crop (beets)

b. ========== : with summer rotation crop (sunflower)

Fig. 4.3 Present Cultivation System and Field situation.

Crop choice is limited mainly by the climatic conditions, therefore the enlargment of the assortment of rotation crops is not simple.

4.4 Tillage practices

To the tillage machinery of each of the inquired farms belong:

- a share plough with 2 to 5 shares for medium-deep tillage (40 cms)
- heavy springtine or rigid-tine cultivators
- light Danish cultivators (trade mark: Kongskilde)
- disc harrows of various sizes.

Some holdings disposed of subsoilers (50 cm deep) and Cambridge rollers for seedbed preparation.

Most tillage labour is done by track-type tractors (Caterpillar), to minimize slip an tilt hazard on steeper slopes. The power needed is 50 hp - 130 hp, depending on the tillage equipment.

After the wheat harvest (in june) the straw and stubble are burnt; sometimes the straw is bundled in bales and held for cattle or sold. In july, when the soil is still moist, it is ploughed deeply (40 cm) or subsoiled. During autumn the soil is crumbled by means of the cultivator or the disc harrow 1-5 times, to combat weed growth. Bij doing this the cracks in the soil are filled up with the fine surface material.

The rotation winter crop is sown from october to february dependent on the first rainfall. Summer crops are sown in the period between march and may. Sometimes the soil is crumbled again immediately after sowing, which is even worse for the erodibility of soil. After the harvest of rotation crops the haulm is crushed two times by the disc-harrow and turned in by two workings perpendicular to each other. After some weed clearing the soil is ready for sowing the main crop (Fig. 4.3).

Soil tillage is only practicable in a small soil moisture range. After rainfall it is onworkable because of its stickyness, after a long drought it is too hard to plough upon.

4.5 Stockfarming

In order to investigate the possibilities for stockfarming in the Project Area, an inventory was drawn up of the existing stock farms in the surroundings. They are concentrated near the population centres of Santa Cruz, Espejo and Castro del Rio. The live stock held was composed of pigs, sheep, goats or cattle, for diary as well as meat production. The occurrance of stock farms in this area

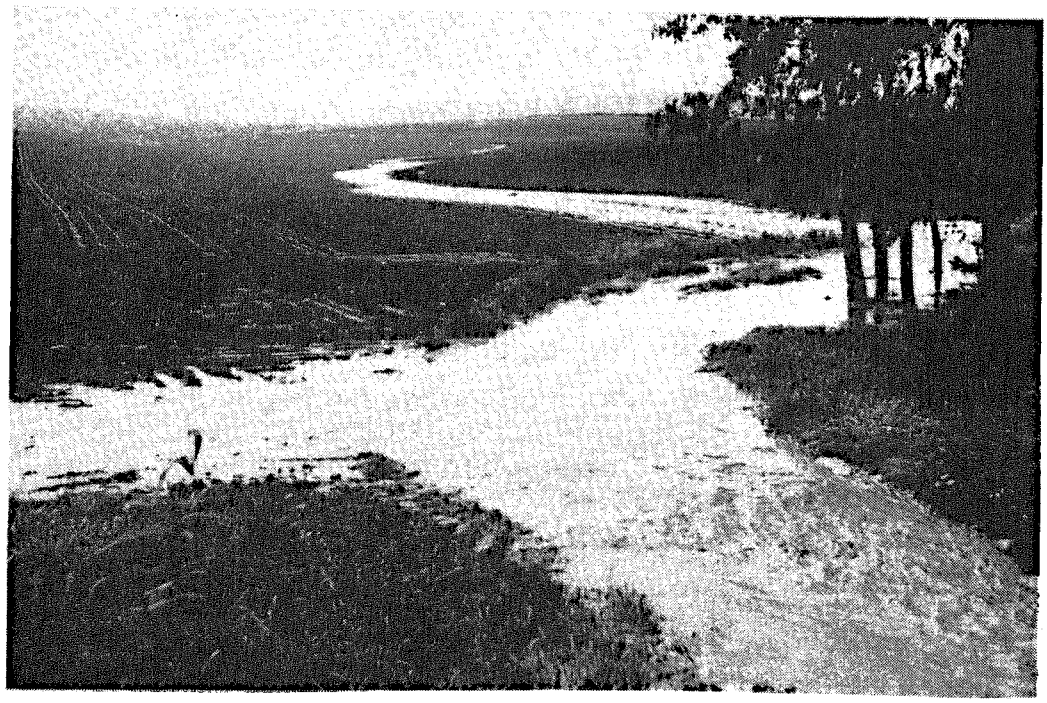


Fig. 4.4 Erosion damage on bare fallow fields in the Project Area.

is explained by the labour supply in the villages, the soil suitability and the possibility for irrigation. They are mostly situated on sandy or gritty soils, which are tread solid during the wet season, (while the soft clay soils may cause hoof-infections).
Feeding takes place on pastures, on wheatlands after harvesting or on fallow pastures, during the wet season. In summer additional fodder is required (e.g. horse beans), unless the farmer disposes of irrigated areas or of pastures elsewhere (e.g. in the Sierra Morena). The sheepherds too are grazing in the Sierra Morena during summer.
Grassland amelioration would be possible, but never guarantees a food production all over the year. Stock farming is economically not more attractive than arable farming; it is mostly based on the personal interest of the farmer. It may be concluded, that stockfarming, however attractive from a erosional point of view, generally can not be applied in the Project Area.

4.6 Erosion damage

In the inquiry some questions were stated about the occurrance of erosion in the Campiña. Sheet-erosion was not felt as a problem; the farmers declared that the ripening of eroded soils takes only a few years. Because of the thick homogenious layer of Marl soil loss is not felt as a permanent damage. During heavy rainstorms of may 1976, we saw great mud streams coming down along the bare parcels (Fig. 4.4). These were blocked however in the lower part where crops were grown. The same remarks were made as to landslides on the steeper areas. These are too steep to tillage mechanically, but some farmers try to level out the slope by earthmoving.
The most harmful form is gully-erosion; the cutting of the parcels bu gullies is an obstruction for the large scale cultivation. They are eliminated by ploughing repeatedly or by special earthmoving machinery. According to statements of the farmers gully erosion had not occurred since 6 years. They estimated the water deficits to be of greater harm to the yields than the degradation of soil fertility due to erosion.
During the 3rd phase an inventory was made of the small-scale farms near the villages, to find out if small parcels are less erodible than bigger ones. Theoretically, one might expect so, because of the smaller slope length, the more intensive tillage and the variety of crops. The inventory showed, however, that 1) smaller farms have also taken into cultivation the steeper and more erodible areas; 2) that contouring is not always applied, because the long side

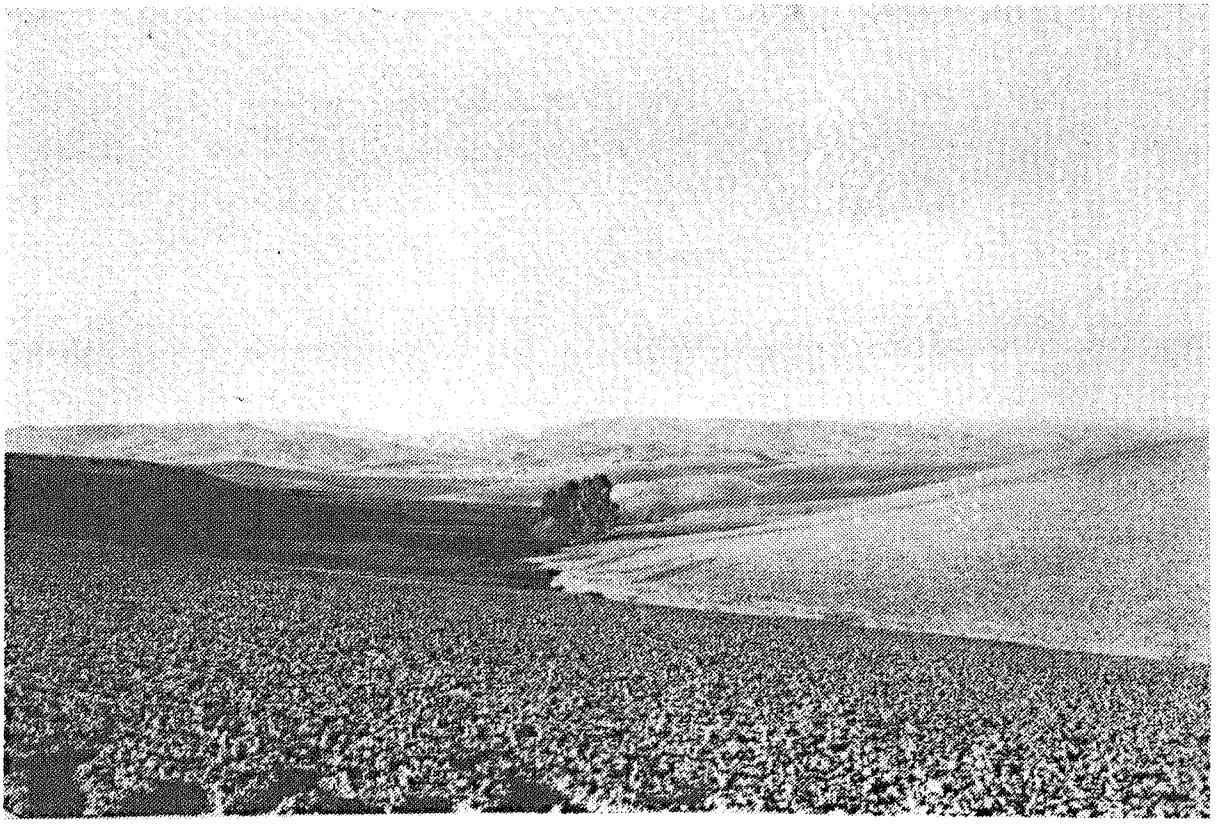


Fig. 5.1 View on the Pilot Area with scarce vegetation.
On background the Sierra Morena

of the parcel lies uphill; and 3) that the crop choice is rather homogeneous owing to the planting of olives everywhere. It may be concluded, that reallotment of parcels without other measures does not guarantee a lowering of erosion hazard.

CHAPTER V FORESTRY INVESTIGATIONS

5.1 Inventory of vegetation

In November 1976 (Third Phase) an inventory was made of the existing vegetation and tree plantations. Because of the scarcity of both natural vegetations (Fig. 5.1) - i.e. plant assemblies which established itselves and developed spontaneously - and plantations, the surroundings of the Project Area were included in the inventory. The objective was to make a reconstruction of the original vegetation and to gain information about the performance of different tree species in this region. The vegetations have been described and classified according to the BRAUN-BLANQUET method.

Natural vegetations in the Campiña can only be found where arable farming is impossible, as on steep slopes, in the deep permanent gullies and channels, and on parcel boundaries and roadsides. Only in the Monte de la Morena there still existed various stages of degeneration of the original forests: (1) a small wood of holm oak (Quercus ilex) with wild (?) olive (Olea europaea), (2) a dense scrub ("matorral") of kermes oak (Q. coccifera), mastic tree (Pistacia lentiscus) and other shrubs, and (3) grassland with scattered holm oaks. A few hedges, rich in species, were found outside the Pilot Area. These vegetations are threatened by burning after the harvest and overgrazing, parts still are being converted in arable land. Woody vegetation in gullies and along the Rio Guadajoz may include as natural elements elm (Ulmus sp.), white poplar (Populus alba), black berries (Rubus spp.) and tamarisk (Tamarix gallica).

Tree plantations also are very rare in the Campiña. They serve to check gullies and gully heads, to offer some shadow to cattle and in one case for firewood. The main species planted are eucalypts (Eucalyptus cf camaldulensis) and aleppo pine (Pinus halepensis). On farm yards one sees mulberries (Morus spp.), fig (Ficus carica), tree of heaven (Ailanthus glandulosa), acacia (Robinia pseudo-acacia), and a few other fruit trees and ornamentals.

5.2. Original vegetation

It was not a simple task to make a reconstruction of the original climax

vegetation of the Campiña based on the few and degraded relic vegetations present in the area. Moreover these vegetations are nearly confined to certain sites, as steep slopes in sandstone, which are not representative for the region. Nevertheless the species encountered give indications for the vegetation which originally covered the area. It is concluded that formerly on dry soils forests prevailed belonging to the alliance Quercion Ilicis with some affinity to the Oleo-Ceratonion (both of the order Quercetalia ilicis). This forest was dominated by the holm oak; the shrub layer consisted of kermes oak and mastic tree with - mainly on open places - several vines (Rubia peregrina, Lonicera implexa, Clematis flammula). Near watercourses vegetations of the Populion albae predominated, with willow (Salix spp.), elms and poplars.

5.3 Afforestation effects and possibilities

The deforestation of the Campiña and subsequent convertion into agricultural lands has been a process of many centuries. In the last decades the last remnants of woody vegetation were nearly completely exterminated. The farmers consider woods and trees for several reasons inconvenient or even detrimental to the agricultural production. Reforestation of certain areas therefore would meet with strong objections. For this reason the effects of forest and natural vegetation on the agricultural crops are briefly summarized.

- Trees and shrubs may function as breading ground for birds. Both seed and insect eating birds will settle, so that the total effect on crop growing is not well predictable. Crop diseases are not spread by the natural plants, as often stated; on the countrary, natural vegetation can serve as a buffer for the spreading of crop diseases. The hazard for the outbreak of disastrous pests and diseases is decreased by a variation in ecosystems.
- There will be a competition for light and soil moisture between planted trees and agricultural crops in a narrow bordering zone. On the other hand trees will function as a windscreen, especially if underplanted with shrubs, so that the evapotranspiration may decrease over a distance equal to many times the height of the trees.
- Trees may form obstacles for agricultural activities, as ploughing and spraying by airplane. This should be borne in mind when areas and species to be planted are considered.
- Afforestation is an excellent soil conservation measure where applied on steeper slopes and in gullies and gully heads. The permanent covering of the soil by shrubs and herbs is the best defence against erosion.

- Besides afforestation has a scenic and recreational value. The presence of woods and natural vegetation enhances the value of the landscape and increases the game stock.

It may be concluded that reforestation of certain areas with high erosion hazard, as steep slopes, and the planting of roadsides and farmyards offers considerable advantages.

The choice of tree species is limited by climatic and soil conditions. The soil suitability for various tree species was evaluated and summarized in Table 3.6. Tree planting especially deserves consideration on the steeper, sandier areas, which are less suitable for agriculture. Afforestation on vertic marl-soils will be hampered by the continuous swelling and shrinking, that may damage the tree's rooting system.

The following species are considered:

on dry soils: Pinus halepensis, P. pinea, Eucalyptus cf. camaldulensis;

on moist soils: Populus alba, some Populus nigra varieties, Ulmus sp., Salix spp., Eucalyptus cf. camaldulensis.

Quercus ilex is not recommended as a first tree crop because of its slow juvenile growth. However, woods of this species could be established in a well-developed pine plantation by underplanting or sowing.

CHAPTER VI HYDROLOGIC AND EROSIONAL INVESTIGATIONS

6.1 Hydrology

The drainage of the Campiña is provided for by the two rivers Rio Genil and Rio Guadajoz. Besides, a lot of drainage gullies convey water during rain periods only. They have moulded a dendritic pattern in the homogeneous marl of the Campiña. All these gullies and rivers are strikingly situated in NW-SE-direction, and all drain into the Guadalquivir. The Pilot Area is formed by the catchment area of one of these gullies, the Arroyo de los Camareros.

During the First Phase a topographical survey was made of the Pilot Area in which a longitudinal section and many cross sections are compiled. The main gully has a length of 4200 m, and a fall of 96 m. The profile of the gradient is parabolic, which points to some equilibrium between discharge and gully slope. In the Third Phase a more detailed description was given of the nature and size of erosion features in the drain gullies, to serve as a base for improvement measures. In this description attention was paid to the slope, depth, shape of the cross

Fig. 6.1 Rainsimulator

section, vegetation cover, and erosion and sedimentation features of the profile. The cross sections show a great variety of shapes. On some spots gullies have very deep incised below the surface level, which is coupled with caving and erosion of the side slope. In other places the gully has disappeared completely by sedimentation or by deliberately ploughing (in particular the side drains). Within the gully system some structures are built: 4 road culverts and one bridge were measured.

During the Third Phase flow velocity equipment was tested in order to measure the peak discharge of the Pilot Area. Unfortunately there was no discharge at all during the field period.
Some water samples of the Rio Guadajoz and Guadalquivir were taken and data were collected about the mud transport of these rivers. From these scarce facts no conclusions could be drawn concerning the influence of the Campiña watershed on the total silt discharge.
From deep augerings down to 2.5 m during the Soil Survey the information was obtained that the groundwatertable lies far beneath the surface level, even in the gullies. Water wells are supplied by means of shafts that are constructed in the water conducting sandstone layers. This water is used for some irrigation on very small scale (0.1 ha) , and for drinkwater. Some farmers told, that last years drinkwater deficits occurred during summer months.
Because of the difficulty with doing groundwater observations in the Pilot Area and the little potentials for irrigation, no further attention is paid to groundwater problems. The measures carried out in the Soil and Water Conservation Plans may have however a positive effect on the water table in the wells.

6.2 Rainsimulation and infiltration measurements

In order to obtain data about the behaviour of the soil during heavy rainstorms, various field experiments have been set up.

In november 1975 and 1976 8 rainsimulations have been carried out with a table-form rainsimulator above micro plots of 0.5 m^2 (Fig. 6.1). A detailed description of the rainsimulation-equipment is given by SPAAN (1977).
Rain was simulated in different intensities (1-3 mm/min) and on different situations of soil type, slope and soil tillage condition. During the rainsimulations the following observations were taken:

Tabel 6.2 Rainsimulation results

SITUATION				PRECIPITATION			RESULTS							
							Runoff				Infiltration			Sediment
simul. nr.	soil	slope	tillage	Tot (mm)	time (min)	inten-sity	Tot (mm)	%	R_i (mm/min)	%	Tot (mm)	%	I (mm/min)	(g/l)
1	S_2	20%	shallow	81	28[1)]	3.0	23.3	28	1.5	50	58	72	1.25	2.0
2	S_1	30%	shallow	49	105[2)]	3.24	14.0	29	1.4	43	35	71	1.0	14.0
3	M_3	8%	shallow	56	54[2)]	2.33	20.0	36	1.2	53	36	64	0.8	3.3
4	M_1	6%	deep	118	105[2)]	2.72	11.6	10	0.5	18	106	90	1.47	-
5	S_1	8%	deep	70	100[2)]	2.69	21.8	31	1.0	37	48	69	0.55	4.25
6	S_1	9%	grass covered	81	105[2)]	2.79	19.0	23	1.6	57	62	77	0.68	0.0
7	M_1	6%	shallow	71	34[1)]	2.08	14.4	20	1.0	48	56	80	1.0	10.0
8	S	8%	shallow	95	90[1)]	1.05	30.0	32	0.4	44	65	68	0.6	-

1) continuous rain

2) intercepted rain

- the instantaneous runoff (R_i) at the end of the simulation
- the total runoff (R_{tot}) at the end of the simulation
- the sediment content of the runoff water at various moments
- soil moisture profiles before and after the simulation.

Results are summarized in Table 6.2. Conclusions could be made only tentatively because of the little amount of experiments and the great variety in soil situations. It could be seen however, that

- the infiltration on M-type soils is highly influenced by deep tillage, but fewly on S-type soils; it amounts to 0.5-1.5 mm/min.
- infiltration is lower on S-type soils and on steeper slopes.
- runoff % appears to be dependent from tillage practices only.
- no silt transport occurs on grassland. On arable land no conclusions could be drawn about the sediment content.

In addition to the rain simulations infiltration tests with a ring-infiltrometer were carried out. Even the duplo observations show great differences in infiltration rate, probably due to the presence of cracks in the subsoil.
The infiltration tests on shallow cultivated soils showed a complete stagnation after a quick saturation of the ring. This phenomenon can be explained by the occurrance of an impermeable plough pan, which obstructs free infiltration to the subsoil.
In general the infiltration rates measured with the infiltration rings were considerably higher than those measured with the rainsimulator, owing to the slaking effect of the latter's rain drops.
For the projects's purpose the rainsimulating data seemed to be preferrable to the infiltration ring data.
Table 6.3 shows the infiltration criteria, which are set up after comparison of these data with literature. The simulation tests gave no reason to distinguish into more than 2 soil types. The higher infiltration rate on grass-covered soils is explained by the rainfall-protecting effect of vegetation, which prevents slaking on S-soils, and by the higher permeability due to the root-channels on both S and M-soils. The infiltration rates for grasscovered soils are valuable for a full cover only, and are to be reduced when the soil is partly covered.
For the determination of soil losses larger runoff plots have been installed (Fig. 6.4). Unfortunately no runoff at all occurred, even not after several days with a 25 mm rainfall. The prediction of soil losses therefore had to be

Table 6.3 Estimated infiltration rates (mm/min)

Soil type	tillage	slope class		
		0-10%	10-20%	>20%
M	shallow	1.0	0.9	0.8
	deep	1.5	1.4	1.2
	grass-covered	1.1	1.0	0.9
S	shallow	0.6	0.5	0.45
	deep	0.6	0.5	0.45
	grass-covered	1.0	0.8	0.6

Fig. 6.4 Installation of runoff-plots

based on theoretical calculations only. It may be concluded, however, that erosion merely occurs later on in the season, when the soils are wet and swollen.

6.3 Peak Discharge

The peak discharge of the Pilot Area was calculated with the "Curve Number Method" and with the "Unit Hydrograph Method", according to U.S., S.C.S. Handbook (1964).
The present soil condition of the Pilot Area is regarded to be straight row, of a poor hydrologic condition, soil group C. Because large areas are not covered with winter crops, the Curve Number of the Pilot Area was estimated at 90 for bare fallow land.
The peak discharge was calculated for a 1- and 2-hours rainfall with a return period of 10 years. (29 mm and 34 mm respectively). The peak discharge for the Pilot Area as a whole amounts to 15.3 m^3/s. When the Pilot Area is devided in more catchment areas the discharge is 21.1 m^3/s, due to the nearly simultanuous arrival of the peaks from the various catchment areas.
Calculations with COOK'S method and the Rational Formula give much higher peak discharges: up to 40 m^3/s. These methods are less suitable for larger catchment areas. It may be concluded, however, that with the present gully dimensions, the Pilot Area will be liable to flooding in times of high rainfall.

6.4 Sediment Analysis

Sediment samples were taken from the gully-bottom, from eroded banks, and from the rain simulation plots, the texture of which was analized at the Soil Laboratory in Wageningen. Some representative samples are shown in Table 6.5.
The composition of the gully bottom sediment is growing coarser downstream. In the upper course the texture is hardly different from the field, while near the bridge the percentage > 50 µ amounts more then 40%.
As might be excepted, the composition of the bank slides shows no difference with the field texture. The sediment coming from the rain simulation plots has a slightly finer composition on M-soils, and is considerable finer on S-soils. It is obvious, that only the silt and clay fractions is washed away, although non-dispersed aggregates were also visible in the runoff material.

Table 6.5 Texture Analysis of Sediment samples

Origin	Grainsizedistribution (%)			
	<2μ	2-16μ	16-50μ	>50μ
Arroyo de los Camareros:				
field surface	51.4	20.2	17.7	10.7
upstream bottom	52.8	25.9	16.1	5.2
midstream bottom	31.5	13.5	20.8	34.2
downstream bottom	28.8	12.0	15.3	43.9
Bank Slide near La Pangia:				
upslope	51.6	20.0	13.2	15.2
downslope	47.1	24.1	16.5	12.3
Rain simulations:				
M-soil, field	53	23	8	16
sediment	61	23	7	9
S soil, field	35	23	9	33
sediment	54	32	7	7

6.5 Soil Mechanical Investigations

For soil mechanical determinations an undisturbed sample of ca 10 kg was taken out of a M1-type soil in the Pilot Area. In the soil laboratory this sample was devided in various parts to be analized.
Results are representative for this soil type only; statements concerning the soil mechanics of the whole area should be based however on more samples.
The bulk density (γ_d) was determined sixfold at a soil moisture percentage of 30% and amounts (on base of dryweight) to 12 800 $\pm$ 900 $N.m^{-3}$.
The density of the solid phase (γ_s) was determined fivefold by means of a pyknometer. For γ_s a value was found of 26 300 $\pm$ 400 $N.m^{-3}$.
The porosity (p) of the soil can now be calculated from these data, and amounts to 0.51 $\pm$ 0.04 (at a soil moisture of 30% only!). The bulk density of saturated soil is 17 900 $N.m^{-3}$, demonstrating the swelling character of the soil (viz.§ 2.3).
ATTERBERG'S values of plasticity are important to the workability of the soil.
The upper plastic limit (Θ_L) was determined with CASAGRANDE'S equipment and with the cone-penetrometer, and amounts to 59% $\pm$ 2% moisture content by volume.
The lower plastic limit was stated at 29 $\pm$ 3%, so that the Plasticity Index $Ip = \Theta_L - \Theta_p$ is equal to: 30% $\pm$ 4%.
According to CASSAGRANDE'S Unified Classification the soil is classified as a plastic CH-type.
The shearing strength was measured with triaxial tests with cell pressures of 0.5, 1.5 and 2.9 $N.cm^{-2}$ (after a 24 hours consolidation).
For COULOMB'S equation was found:
$s = 0.38 + 0.21\ \sigma'$ $N.cm^{-2}$,
so that the angle of shearing resistance is equal to $\phi = 11.9^{\circ}$.

With these data the stability of slopes could be calculated, using TAYLOR'S (1967) sliding surface method. Figure 6.6 shows the relation between the critical height of a slope and slope angle at soil mechanical equilibrium (with a factor of safety F = 1). From this figure it may be concluded that for slopes of 1 : 2 (which is common for new excavations) a height of 2.85 m is allowed. On steeper side slopes (which occur in the gully banks) a height of 1 meter may already cause bankslides.

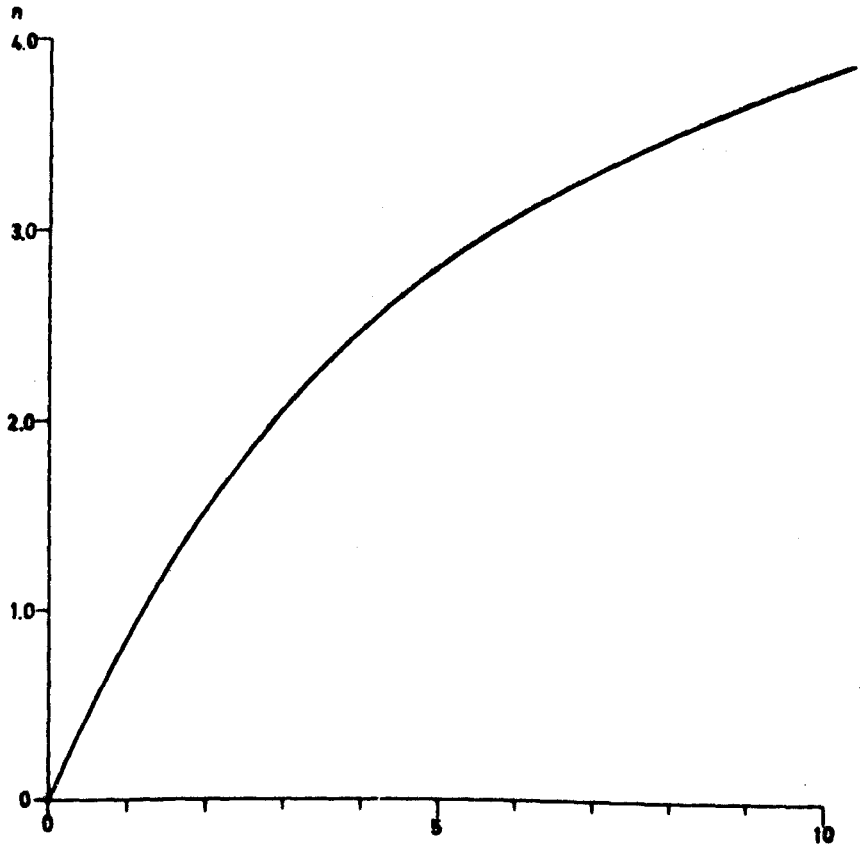


Fig. 6.6 Stabile slope height at various angles of slope (1:n).

CHAPTER VII PROBLEMS AND OBJECTIVES

7.1 Erosion problems in the Campiña

In the foregoing chapters different erosion problems of the Campiña were already indicated and argued, in particular the factors influencing the rate of erosion (climate soil erodibility, topography, cultivation practices, and land use). Globally the harms felt in the Campiña due to erosion processes can be devided into 5 major features:

- The occurrance of surface runoff, which causes the loss of soil, seed and fertilizers; surface runoff predominantly occurs on S-type soils, in fallow periods, and in crops that don't cover the soil completely (§ 3.4).
- Lowering yields of wheat and sunflower owing to the water deficits in the growing season (Ch. 4).
- Dissection of the arable land, caused by gully erosion, caving, and incision of gully heads. At greater discharges the downstream area is flooded (§ 6).
- A scenic and ecological degradation of the Campiña as a result of progressive reclamation and burning of natural vegetation areas (§ 5).
- Inaccessability of the farms in times of exessive rainfall, due to the mentioned flooding of gullies, and to the bad condition of the access roads (§ 2).

7.2 Objectives of the Soil Conservation Measures

All these erosion problems are caused by natural circumstances as well as by human activities. The aims of the soil conservation measures can be grouped into the following types of objectives:

1) Protection of the land against soil loss by water erosion
   - reducing the direct runoff
   - slowing down the flow velocity on the field
   - preventing the transport of soil, seed, fertilizers and crops
   - maintaining the natural fertility of soil
   - preventing mass movements and landslides.
2) Conservation of moisture for crop production
   - enlarging the infiltration rate
   - increasing the water storage
   - reducing the amount of direct runoff.

Table 7.1 Diagram of possible effects of measures on Soil Conservation

+ positive effect
- negative effect
? effect unknown

Objectives:	Measures: Soil (Mechanical) measures: terracing	contour farming	levelling	deep ploughing	Engeneering measures: side slopes	check dams	vegetation	Tillage practice: crop choice	stubble farming	deep tillage	zero tillage	strip cropping	Forestry measures: natural vegetation	afforestation	Farming system: reallotment	stock farming
1) Soil protection:																
direct runoff	+	+	+	+				+	+	+	+	+	+	+	+	+
flow velocity	+	+	+	+				+	+	+	+	+	+	+	+	+
soil transport	+	+	+	+				+	+	+	+	+	+	+	+	+
soil fertility			-					+					+	+		+
2) Moisture conservation:																
direct runoff		+	+	+				+	+	+	+	+	+	+		+
infiltration capacity		+		+				+	+	+	+	+	+	+		+
water storage		+	+	+				+	+	+	+	+	+	+		+
3) Gully Control:																
peak discharge	+	+	+	+	+	+	+	+	+	+	?	+	+	+	+	+
flow velocity					+	+	+									
side slope stability					+		+									
4) Natural and Scenic objectives:																
scenic attractiveness	?				?	?	+	+	+			+	+	+	?	+
stabilizing of the natural ecosystem	+						+	+	+		+	+	+	+		+

3) Protection of the land against incision and flooding
   - decreasing the peak discharge
   - slowing down the flow velocity in the gully system
   - stabilizing the longitudinal and side slopes
4) Restoration of the landscape and ecological balance of the area
   - extending the scenic attractive areas
   - applying a floral and faunic diversification
5) Improvement of the external and internal accessability
   - making an all-weather connection possible.

The objectives are thus described in specific quantitative targets, which will be evaluated afterwards..
For realizing the objectives, a lot of measures are available of a mechanical, civil engeneering, tillage-practical and landusing nature. Table 7.1 shows a cross-diagram of possible effects of measures on the targets mentioned.
This schedule has been the basis of the working method of the Erosion Study Project: First the effect and feasability of some particular measures has been investigated (e.g. the application of stockfarming in the Campiña). After that 2 alternative Soil Conservation Plans have been developed, each of them based on a package of measures of different nature: Plan I applies technical measures only, leaving the present management system unchanged; Plan II incorporates the change of landuse, crop rotation and tillage practices.

Socio-economic factors which may influence the erosion hazard (such as land tenure, market prices, costs of mechanisation), are held to be external prepositions, that cannot be changed. One should realize, however, that with the change of the socio-economic situation (e.g. land reforms), the erosion problems in the Campiña could be resolved in a completely different way than is proposed in the presented Soil Conservation Plans.

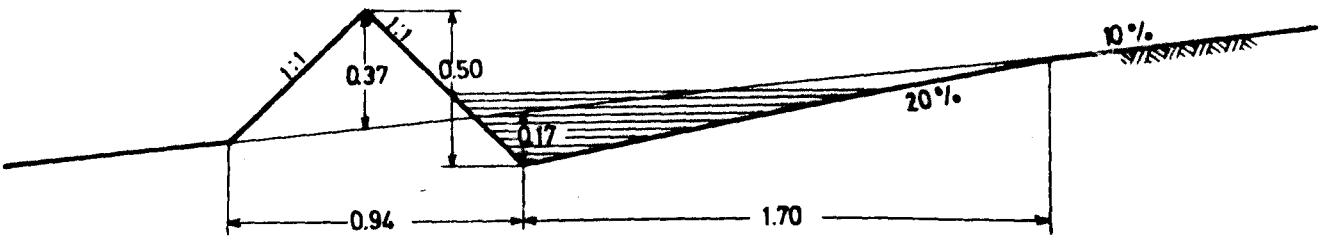
CHAPTER VIII SOIL CONSERVATION PLANS

8.1 Description of the Plans

As described in Chapter 4.6 erosion is not felt as a serious problem by the farmers in the Campiña, and an erosion-conscious tillage is not practised. It was judged useful therefore to develop a Soil Conservation Plan that does not interfere very heavily in the present management system, in order to have

Plan I

Scale 1 : 25



Characteristics:		
	ridge heigth	0.50 m
	water depth	0.25 m
	width	2.64 m
	excavation volume	0.15 m^3/m
	discharge capacity	0.10 m^3/s

Plan II

Characteristics:		
	ridge heigth	0.50 m
	water depth	0.25 m
	width	2.50 m
	excavation volume	0.17 m^3/m
	discharge capacity	0.10 m^3/s

Fig. 8.1 Terrace types on a 10% slope.

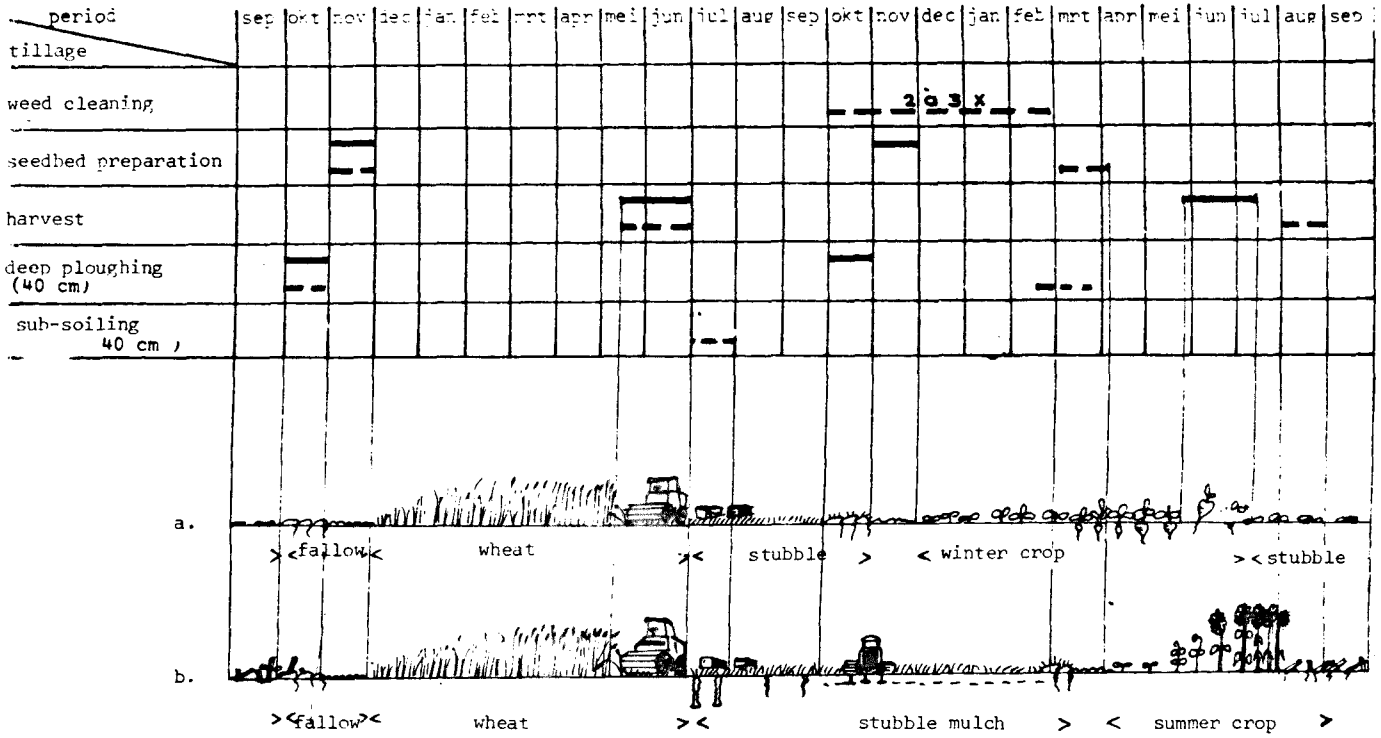
a chance of succeeding. On the other hand, we liked to develop a plan which is more profound in taking measures; this offers the possibility to find out the difference in effects of these various points of view.

The starting point of Plan I is, that erosion control measures should be taken without changing the present farming system. The crop-rotation and cultivation area will stay equal to the present situation. The erosion control measures will be of a mechanical nature only: they are determined by the soil condition and topography, and should be economically feasible anyhow.
The main erosion control measure applied is the construction of terraces. Their function is:

- control of overland flow by discharging the runoff before it grows hazardeous
- catchment of eroded sediment, which would flow downstream otherwise
- moisture conservation as a result of the slower discharge of runoff water.

The utilized terrace is a so-called "narrow-base" type ("Granadina"), which consists of a narrow grass covered ridge, and an upslope channel, that forms part of the cultivated land (Fig. 8.1). Downslope of the scarce natural areas, a diversion terrace of the same type is constructed. They all have a slight longitudinal slope in order to divert the runoff water and to prevent landslides caused by saturation of the terraces. The calculation of terrace distances and dimensions is done in 8.2.
The presence of terraces will urge the farmer to cultivate in one direction; however, contour cultivation is recommended not only on the terraced areas, but especially on slopes less than 5%.
As can be seen in Table 6.3, the infiltration rates on deep-ploughed lands are higher than on shallow cultivated lands. It is recommended therefore to do one deep tillage every year instead of the numerous shallow cultivations, not only because of the erosion hazard on fine crumbled soils, but also as a moisture conservation measure. Terrace calculations are based on the present cultivation system however, since a change in cultivation practice cannot be guaranteed in Plan I.

The starting point of Plan II is to minimize the erosion amount to a stated limit of 40 ton/ha. For that purpose technical as well as crop measures and change of landuse are concerned. As a result the present farming system will be changed considerably.



a. ═══════ : with winter rotation crop (sugar beets)

b. ========== : with summer crop (sunflower)

Fig. 8.2 Cultivation system and Field situation in Plan II.

As to landuse measures all areas steeper then 20% will be taken out of cultivation. In accordance with the soil suitability and superficies, these areas are designated for afforestation with various species or natural grass-vegetation. The areas taken out of cultivation should be bought by and stay under the care of the Government. Their total superficies amounts to 58.5 ha, which is 11.3% of the Pilot Area.
In addition to this measure, a reallotment should be carried out in order to obtain regular parcels for arable farming. The net area per farm is equal before and after the reallotment. Existing farm boundaries are maintained as far as possible. Where a reallocation of the farm area is needed, it is laid along natural boundaries such as gullies and forest areas.
The cultivation area is still used for the present wheat crop rotation, but cultivation practices will be changed. To minimize the erosion hazard it is recommended to leave the stubble on the field after the harvest, until the new crop is sown, and to replace the many shallow weed cultivations by one deep ploughing tillage plus seedbed preparation before the winter crop, or by subsoiling the stubble in the case that a summer crop is sown. This system is scheduled in fig. 8.2. The straw can be removed off the fields like before since the decay of straw would require more N-fertilizers.
Even when stubble mulch farming is applied, on slopes > 10% additional technical measures are necessary to shorten the slope length. After preliminary calculations it was decided to abandon strip cropping, and to construct terraces of a slightly different type: in Plan II a narrow base type terrace with grass-covered ditch and sideslopes of 1 : 2 is used (Fig. 8.1). The advantage of these type to the farmer is its stability, even if constructed under a steeper longitudinal slope; the larger superficies taken out of cultivation may be a disadvantage.
For both plans a gully control programme was designed. All terraces and diversion ditches should drain into a permanent channel. Therefore existing gullies will be stabilised and be brought on the right dimensions; where necessary drainage gullies are ploughed in, or new vegetated waterways have been designed.
To improve the accessability of the Project Area, and to ensure the transport of other crops (esp. sugar beets) during the rainy season, the present access road to the farms Camarero Bajo 1, 2 and 3 will be reconstructed. There was no reason to change the existing alignment; in Plan II the road is extented to open up the new forest area. The road improvements consist of application and compactance of a surface layer of sand and stone dust, the construction of permanent fords in the main gully and the digging of roadside ditches.

Table 8.3 Estimated values for the HORTON-MANNING formula

Soil type		k_M	v_c	(r-i) values for slopes 5%	15%	25%	35%
M	fallow	30	0.30	0.40	0.50	0.60	0.70
S			0.15	0.80	0.90	1.00	-
M	stubble	20	0.45	0.30	0.40	0.50	-
S			0.30	0.70	0.80	0.90	-

The final lay out of the two Plans is drawn in Map 3 and 4. The next paragraphs will deal with some detailed calculations of these plans.

8.2 Terrace spacing and soil loss

Terrace intervals have been determined by means of 2 formulae: Firstly the maximum space in which no rillerosion by runoff water occurs, is calculated with the HORTON-MANNING formula (1). Secondly, the soil loss within this distance is determined by WISCHMEIER'S soil loss equation (2). If the calculated soil loss exceeds the tolerated amount, the terrace intervals are adapted conformably.

The HORTON-MANNING formula emanates from the critical runoff velocity:

$$V_c = K_m^{0.6} . (r-i)^{0.4} . \ell^{0.4} . \cos \alpha^{0.4} . s^{0.3} \qquad (1)$$

in which

V_c	=	critical flow velocity	(m/s)
K_m	=	Manning's roughness coëfficient	($m^{1/3}/s$)
$(r-i)$	=	precipitation minus infiltration rate	(m/s)
$\ell \cos \alpha$	=	length of slope	(m)
s	=	slope gradient	(m/m)

The various estimations used for this equation are summarized in Table 8.3. The design-rainfall occurring once every 10 years is derived from meteorological data (Table 2.3) and amounts to 1.4 mm/min. The infiltration rates for different soiltypes and slope classes are obtained from rainsimulations and literature (Table 6.3).
From the diagram of HJULSTRÖM it was concluded, that erosion will occur at a surface flow velocity of 0.3 and 0.15 m/sec on M and S soils respectively. The critical velocity is higher on covered fields, due to the earth-fixing function of vegetation. With known values for V_c, $(r-i)$, s, and cos α, the critical slope length (ℓ) can be calculated.

WISCHMEIER'S soil loss equation has been applied to calculate the total sediment runoff due to splash-, sheet- and rill erosion.

$$A = R.K.L.S.C.P. \qquad (2)$$

with:

A =	Average soil loss	(t/ha.yr)
R =	Rainfall factor	(Erosion-Index-Unities, E.I.)
K =	Erodibility of Soil	(ton/ha. E.I)
L =	Slope length factor	(-)
S =	Slope gradient factor	(-)
C =	Crop management factor	(-)
P =	Conservation practice factor	(-)

In determination of these factors the original Anglo-saxian unities were used, and converted in metric unities afterwards.

The soil erodibility (K) was stated in § 3.4 on 0.15 for M soils and 0.25 for S soils. For lack of continuous rainfall records the erosivity of rainfall (R) was estimated with the empirical formula

$$R = 4.3 \times 10^{-5}. a.b.c + 26 \qquad (3)$$

a = average annual rainfall (mm)
b = max. 24 hours rainfall for 2 years return period (mm)
c = max. 1-hour rainfall for 2 years return period (mm)

For the Project Area a R-value of 46 E.I.-unities was found.

The crop rotation factor (C) was calculated, by weighing the crop cover with the proportional Erosion Index during the year. This was done for different crop rotation systems, with and without stubble mulch cover. It could be concluded that:

- the C-factor for the present situation in the Project Area amounts to 0.6
- by diminishing the number of tillages this can be reduced to 0.5
- rape seed and sugar beet rotations are more favourable than sunflower
- stubble mulch farming reduces these values with 50%.

As a result of these calculations the C-value was stated at 0.6 for fallow rotation systems (present situation and Plan I), and 0.3 in stubble mulch systems (Plan II).

The Conservation practice factor (P) is dependent from the tillage practice and from the slope gradient. For countourfarming within terraces the following P-values are taken:

Slope (%)	5	15	25	35
P-value	0.5	0.8	1.0	1.0

Table 8.4 Estimated Soil Losses in the present situation (ton/ha.year)

Soil type	Slope length (m)	Slope Class (%) 5	15	25	35
M	150	40	190	340	540
	350	60	290	530	840
S	150	65	320	580	910
	350	100	490	890	1400

Table 8.5 Definite Terrace Spacings and (within brackets) estimated Soil Losses (ton/ha.year)

PLAN I Soil Type	0-10%	10-20%	Slope Class 20-30%	30-40%
M	225 (24)	100 (125)	30 (155)	15 (173)
S	30 (15)	30 (114)	15 (183)	-

PLAN II Soil Type	0-5%	5-10%	10-15%	15-20%
M	3000 (22)	500 (42)	100 (51)	50 (55)
S	265 (11)	160 (39)	50 (60)	16 (52)

Table 8.6 Estimated Curve Numbers in the Pilot Area

Soil Type	Field situation	small areas (terrace)	(terraced) larger areas
M	fallow	84	77
	stubble	80	74
	nat.vegetation	78	70
S	fallow	90	83
	stubble	85	80
	nat. vegetation	83	75

With these factors known, the erosion losses for each slope length and gradient could be determined. Table 8.4 shows the estimated soil losses in the present situation. The average soil loss in the Pilot Area amounts to 240 ton/ha. Reversely, the critical slope length at various slope gradients can be determined, once the maximum acceptable soil loss being stated.
Table 8.5 shows the terrace intervals chosen out of the two calculations with formulae (1) and (2), and (within brackets) the corresponding soil losses. In Plan II a soil loss of 60 ton/ha was the utmost limit. In Plan I a minimum terrace interval of 15 meters was held.
The application of stubble mulch allows a larger terrace interval in Plan II. Nevertheless the average soil loss amounts to 40 ton/ha, against 100 ton/ha in Plan I.

8.3 Peak discharge

The calculation of the discharge for the new situation is done again (as in 6.3) with the Curve Number Method, with a few modifications due to the infiltration rates obtained from the rainsimulation tests.
The time of concentration of a catchment area is determined with the formula:

$$T_c = \frac{4.320 \ \ell^{0.8} \ \ (\frac{1000}{CN} - 9)^{1.67}}{9000 \ . \ \bar{y}^{0.5}} \qquad (4)$$

in which T_c = time of concentration (h)
ℓ = length of overland flow (m)
CN = curve number (-)
$\bar{y}$ = mean gradient of the discharge area (%)

The Curve Numbers have been estimated according to Table 8.6. Note that different values are used for small and larger areas.
The total peak runoff (Q_p) is calculated by

$$Q_p = q \ . \ Q.A. \qquad (5)$$

in which q = peak discharge of one unit area ($m^3.s^{-1}.km^{-2}.mm^{-1}$)
Q = direct runoff (mm)
A = superficies of the catchment area (km^2)

The peak discharge q is directly derived from a empirical relationship with the concentration time T_c.

The direct runoff (Q) can be derived from empirical graphs (US SCS, 1955) or from direct runoff measurements, e.g. with the rainsimulator. In this report the estimated infiltration rates (Table 6.3) are used for this purpose. The value of Q is calculated then with

$$Q = (r-i)\ T_c \qquad (3)$$

in which r is the rainfall for a certain return period (from table 2.3). The design return period is 10 years for crop measures and terraces, and 25 years for gully structures.
Peak discharges could not well be calculated with other formulas (such as the Rational Formula, and COOK'S Method) for lack of runoff data during the field periode. Determination of the runoff coëfficient therefore was not possible. The Curve Number Method seemed to be most suitable for calculating the peak discharge based on estimations and micro runoff measurements.
The peak discharge of terraces with a 10 years-return period varies from 2 l/s (on S soils) to 400 l/s (on M soils).
The peak discharge of the catchment area once every 10 years is reduced from 21.6 m^3/s in the present situation to 7.35 m^3/s in the First Plan and to 6.0 m^3/s in the Second Plan. For a 25 years return period these values are 10.9 and 9.2 m^3/s respectively. The lower peakdischarge in the Second Plan is due to the afforestation areas and the stubble mulch farming system.

8.4 Design of terrace dimensions

The cross section of terraces was calculated with MANNING'S formula:

$$Q = k_m \cdot F \cdot R^{2/3} \cdot S^{\frac{1}{2}} \qquad (6)$$

in which

Q	= design discharge	(m^3/s)
k_m	= roughness coefficient	$(m^{1/3}/s)$
F	= wetted area of the cross section	(m^2)
R	= hydraulic radius	(m)
S	= longitudinal gradient	(m/m)

The critical flow velocity in the terrace ditches $v = \frac{Q}{F}$ was fixed at 0.6 m/s and 0.4 m/s on bare M- and S soils respectively (field terraces of Plan I) and 1.0 and 0.75 m/s in grass-covered terraces (Plan II and diversion terraces). Firstly the maximum gradient of the terrace ditches at the critical flow velocity was computed.
The next step was the aligment of terraces on the map in such way, that the maximum gradient was not exceeded, and that regular parcels were created as

Table 8.7 Terrace length and superficies

		length (m)	per ha (m)	superficies (ha)	%
PLAN I	Field terraces	71800	143	8.3	1.6
	Diversion terraces	2650	5	0.3	0.1
	Total	74450	148	8.6	1.7
PLAN II	Field terraces	18250	35	6.5	1.3
	Diversion terraces	5100	10	2.0	0.4
	Total	23350	45	8.5	1.7

Table 8.8 Some data of the gully system

		PLAN I	PLAN II
Present length	(m)	8000	8000
Improved	(m)	3300	2800
New constructed	(m)	9400	5000
Structures:			
Gaviones		28	38
Gaviones communes		10	-
Stone ridges		9	-
Weirs of fertilizer bags		8	100
Rastrillo's		-	180
Shrub checks		166	-

far as possible. Finally, out of the various dimensions two standard-type-terraces were chosen, each of them with a safety margin of at least 1.5 in the First Plan or an overheight of 0.25 m in the Second Plan. (Fig. 8.1).

The total length and superficies of terraces in the pilot area is summarized in Table 8.7. The length of terraces in Plan II appears to be reduced to one third of the length in Plan I, because of the application of stubble mulch. The superficies occupied by the terraces is almost equal in both plans, due to the broader vegetation cover in the ditches of Plan II.

8.5 Design of the main drainage system

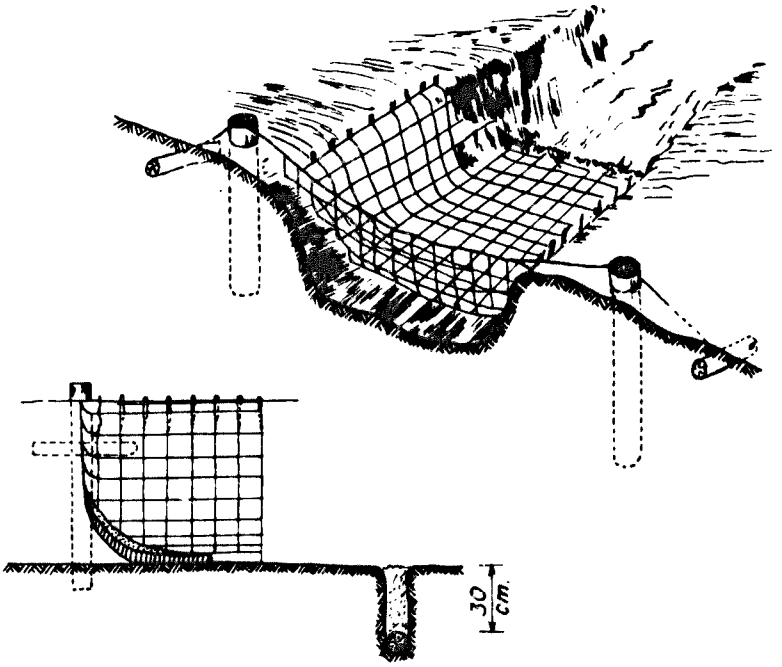
For dimensioning purposes the main drainage system was divided in a number of channel sections, in which a constant discharge is supposed. For each of the channel sections the catchment area is determined on the plan maps, and the actual dimensions are derived from the cross sections measured in the first phase.

The calculation of required gully-check measures was also done with the MANNING-formula (6). For Q the peak discharge of a 25-years return period was taken. The maximal permissible velocity in the canals was stated at 1.0 m/s in grass-covered and 2 m/s in paved waterways.

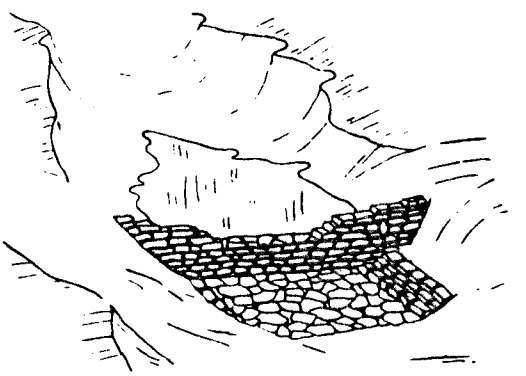
The dimensioning of existing channels starts with the calculation of the flow velocity at the actual circumstances. Unless it exceeds 1 m/s, no gully check structures are necessary. If the stream velocity is higher than allowed, the effect of excavation of the cross section and increasing the roughness is investigated firstly. If these measures still are insufficient to lower the velocity, the longitudinal slope should be changed.

The construction of new channels is different for both plans: In Plan I normal drainage ditches of a trapezoidal shape are used, in order to loose as little arable land as possible; in Plan II grassed waterways of a width of 5 m and side slopes 1 : 5 have been applied. The calculated longitudinal gradient is compared with the field slope in order to find out whether drop structures are necessary.

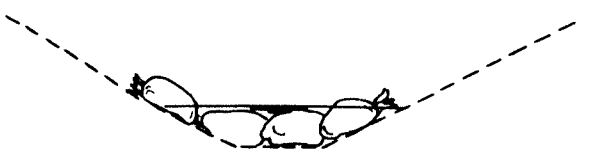
The choice of the type of drop structures is dependent on the location of the drop, the required head loss, and the availability of materials. In Plan I presumably shrub checks are used in the side gullies, and wire dams ("gaviones") and wire bags ("gaviones communes") in the main gully.



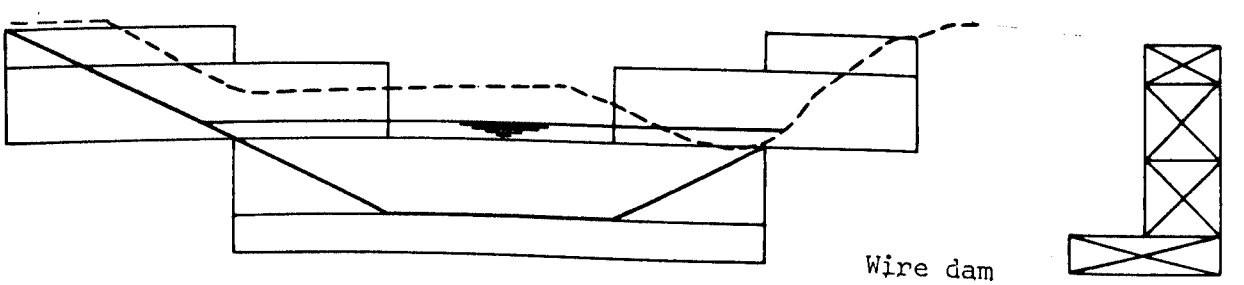
wire net
(rastrillo)



stone ridge



Fertilizer bags



Wire dam
(gavion)

Fig. 8.9 Some gully structures

In the side gullies of the Second Plan also wire nets ("rastrillos") and weirs of half-filled fertilizer bags are applied. In fig. 8.9 some of these structures are represented. Concrete construction works should not be used, in view of the vertic properties of the soil, which may cause cracks in the structure.
The stabilizing of side slopes should be realized by sowing grasses (e.g. Canary grass; Phalaris canariensis). In the larger sections the roughness can be increased by the planting of shrubs (Tamarix, Syllibium marianum and Rubus sp.p). Obstruction of the channel is not likely and may rather be an advantage for the filling up of the rastrillos.
Gully heads in Plan I have to be protected by planting trees, thus preventing the farmers to plough in. In Plan II most of the gully heads are situated in the areas taken out of cultivation, so that no supplemental protection works are needed. The present culverts and bridge do not need improvement. In some places paved fords have to be constructed. The channel section 25 m before the bridge will be paved and cleaned up. After the bridge a dissipator is placed to reduce the stream velocity back to 1 m/s.
Some quantitative data are summarized in table 8.8. The total length of the drainage system increases from 8 000 m in the present situation to 17 000 m in Plan I and 12 500 m in Plan II. The side gullies in Plan II are discharging larger catchment areas because of the little amount of terraces (See Map 4). As a result of the higher peak discharge of the side gullies more drop structures are needed in Plan II. The gully control measures are drawn in Map 5 and 6.

CHAPTER IX EVALUATION

9.1 Cost calculation

In order to make an economical evaluation an attempt was made to estimate the costs and benefits of both soil conservation plans. This was a hard job to do, because not much financial information was available, in particular concerning the benefits. The inquiry dit not provide market prices and costs of inputs of various crops. For calculations the data of Table 4.2 were used, giving the gross market prices and the net profits of each crop.
Earthmoving costs could be derived from the Hornos Project Report (ICONA, 1976). Additional prices which were not available have been estimated on the base of Dutch prices, with a correction for Spanish circumstances (e.g. labour costs). The costs and benefits of the soil conservation plans are reviewed in Table 9.1.

Table 9.1 Summary of costs and benefits (ptas)

		PLAN I		PLAN II	
		Pilot Area	per ha	Pilot Area	per ha
1)	INVESTMENT COSTS:				
	Land Purchase	-		1.167.500	
	Reparcelling	-		75.000	
	Terrace construction	2.280.000	4427	725.000	1408
	Gully control	2.500.000	4855	2.580.000	5010
	Road construction	500.000	972	721.000	1490
	Afforestation	-	-	680.000	
2)	MAINTENANCE COSTS:				
	Terraces	97.000	188	65.500	127
	Gully check structures	17.500	34	32.500	63
	Vegetation	42.500	83	32.000	62
	Road	34.700	67	50.000	97
3)	ASSOCIATED COSTS:				
	Areas out of cultivation	10.000	19	146.250	284
	Terraces	43.000	83	32.500	71 *
	Headland and border effects	131.000	254	37.300	82 *
	Drainage system	20.660	40	17.920	40 *
4)	BENEFITS:				
	Rill erosion	50.000	97	71.000	155 *
	Tillage costs	75.000	146	66.600	146 *
	Water conservation	367.500	750	342.750	750 *
	Flood control	17.500	33	17.250	33
	Road improvement case a	10.000	21	10.000	21 *
	case b	210.000	580	210.000	580 *

* Accrued to the cultivation area only (457 ha).

The costs could be classed under the following heads:

1) initial investments for land purchase and construction works. The purchase costs of the land taken out of cultivation have been estimated on the base of the production level of 1 000 kg wheat per ha with a net profit of 2.500 ptas/ha (which equals the higher land rent in the Campiña). Capitalized at a discount rate of 10% for an infinite period this results in an ha price of 25.000 ptas.
   Reparcelling costs, including transfer costs and the clearing away of field boundaries, are stated without further specification on 75.000 ptas.
   Construction costs for terraces have been calculated for the different terrace types separately, and vary from 2.610 to 3.360 ptas/100 m.
   Construction costs include the staking out and sowing of grasses.
   The construction of the drainage system contains the excavation of water-courses, the construction and materials of gully check structures and the planting of vegetation. The road construction costs are compiled of material costs (sand and concrete mortar) and machine costs (road rolling and cutting out of roadsides).
2) recurrent maintenance costs. These consist of yearly inspection and lopping of terraces and gullies, and the repair of terraces and structures at the end of their technical lifetime. The maintenance of the access road consists of adjustment of the cross section and cleaning of roadside ditches.
   The costs are estimated at 12.50 ptas/m.
3) associated costs of land and production losses. Landlosses on the areas taken out of cultivation for afforestation, terraces and gullies, are estimated at 5.000 ptas/ha year, being the net profit of that less productive area. Losses due to border and headland effects, caused by the terraces, are appreciated at the production value of 20.000 ptas/ha year. Extra tillage costs due to differences between terrace intervals and the working width of machines, estimated at one extra passage per terrace, amount as well to 20.000 ptas/ha year.

9.2 Benefits

The calculation of benefits was partly based on existing methods, partly new calculation schemes were developed. For reasons of simplicity it was assumed, that the present situation will not improve, neither detoriate without any

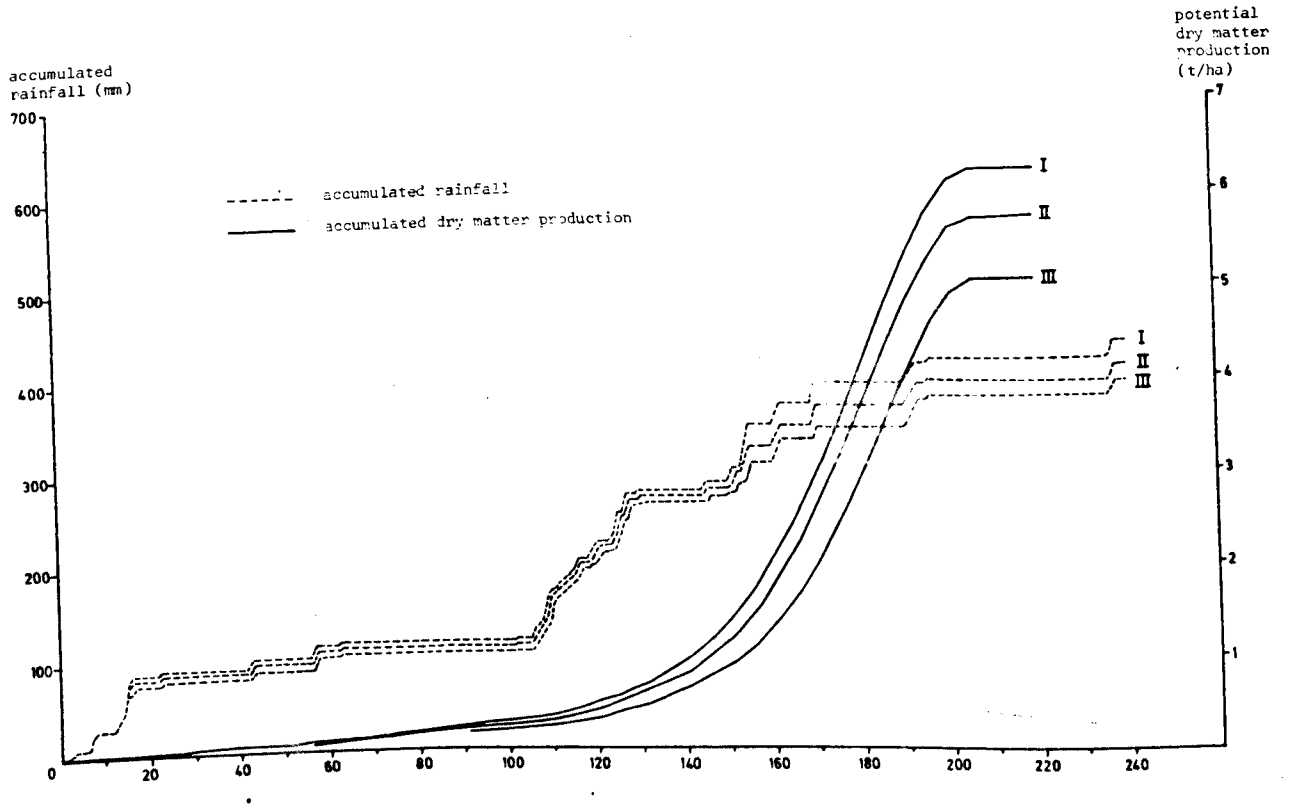


Fig. 9.2 Effect of Water Conservation on Plant Growth in 1968.
case I If all rainfall will be used
case II After water conservation measures
case III Present situation

soil conservation measure. All predicted increments of production and diminishing production losses may thus be regarded as benefits of the soil conservation plans. Secondly, indirect and unweighable benefits, such as improvement of the landscape, and decreasing sedimentation downstream the Guadalquivir, are neglected.
The benefits of the soil conservation plans have been distinguished in 4 categories:

1. Benefits due to soil conservation. These benefits are generated by prevention of furrow and rill erosion, which saves the inputs and production of crops, at a price of 20.000 ptas/ha.
   The additional lowering of tillage costs which would be needed if rill- and furrow erosion occurred, amounts to 1.100 ptas/ha for shallowly eroded fields and 11.000 ptas per kilometer of furrow.
2. Benefits due to water conservation. The increase of production owing to water conservation was calculated with VAN KEULEN'S growth simulation model ARID CROP; which deals with the wheat production in semi-arid climates. For climatic data of 10 years the dry matter production under various assumptions was computed. It was assumed, that presently all precipitation exceeding 20 mm/day runs off from the field, so 13% of the rain falling during the growing season is not disponible for plant growth. If as a result of soil and water conservation measures only the rainfall exceeding 26 mm runs off, this results in a 7.5% increase of dry matter production (because of the heavy influence of extremely dry years, it is preferred to use median values). This means a benefit of 1.500 ptas/ha for each wheat harvest (once in 2 years), and thus yearly benefits of 750 ptas/ha. The simulation of the crop production for an average rainfall year is shown in Figure 9.2.
3. Benefits due to Flood control. This benefit is the prevented damage, that presently occurs by flooding of the drainage gullies. At the present dimensions of the gullies the area flooded in various return periods was computed (Figure 9.3). At the moment an average damage occurs of 1.7 ha per year. By only terracing and field measures this damage could be reduced to 0.6 ha in Plan I and 0.3 ha in Plan II. By only gully control measures the flooded area still takes up 1.4 ha. Just the combination of both measures reduces the damage to zero, The implied benefits, estimated at 20.000 ptas/ha, occurring with a probability of crop presence of 50%, amount thus to 17.000 ptas/year.

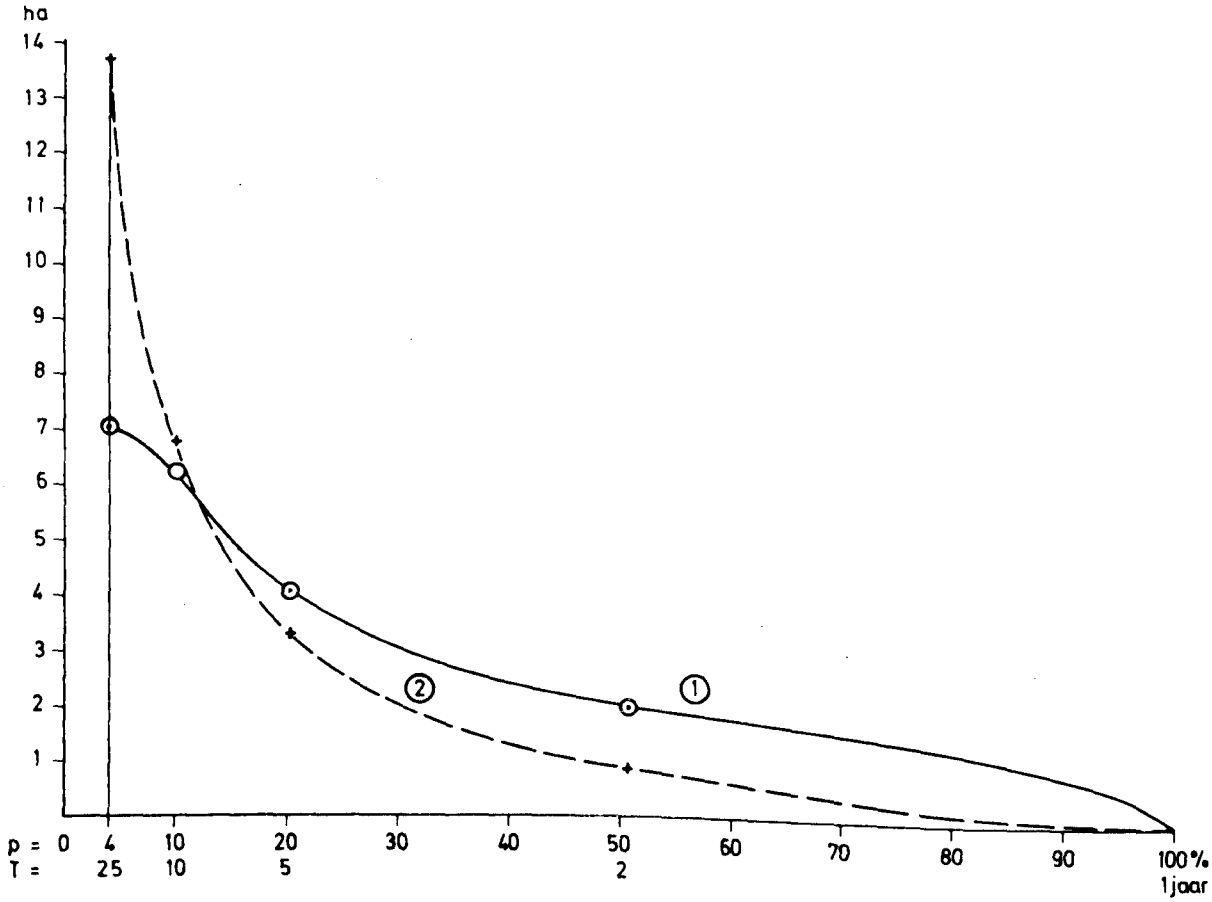


Fig. 9.3 Flooded area at various return periods, according to 2 calculation methods

4. Benifits due to Road improvement. The lowering of transport costs because of the possibility to use trucks instead of tractors and trailers amounts to 2.5 ptas/ton km. The present road utilisation for transport of seed, fertilizers, and harvest products was estimated at 4000 ton.km if sugar beets are grown, and 2400 ton.km, if not. In this case, the possibility to grow sugar beets entails new benefits, which should be accrued to the road improvement. The extra benefits due to the difference in net profits between sugar beet and other rotation crops, are stated on 6.000 ptas/ha over 50 hectares. The extra transport costs for sugar beets amount to 2.5 ptas/ton km over 37.500 ton km. Thus the benefits of road improvement are 10.000 ptas/year in the case that sugar beet growth is already applied (case a), and 210.000 ptas per year if sugar beet growth is made possible by road improvement (case b). Nevertheless, it is not likely that the bad road condition is the only constraint for the growth of sugar beets (cf. § 4.3).
   The scarce road utilisation for forest transport in Plan II does not have any noticeable effect on the benefits.

9.3 Economic Evaluation

The costs and benefits of the soil conservation plans once known, an economic evaluation can be made. The edification of costs and benefits was a reason to distinguish both plans into 3 projects: Terracing and Landuse, Gully control, and Road improvement. Of these projects a national-economic as well as farm-economic evaluation was made. The afforestation of Plan II is dealt with separately.

From the national-economic point of view the best project criterion is the Internal Rate of Return (IRR), which is the discount rate, at which the discounted benefits equal the discounted costs. For simplicity's sake the following assumptions have been made:

- investment costs are all spent in the first year;
- yearly recurrent costs and benefits are assumed to be equal every year, starting from the first one;
- the economical liftetime of the project is regarded to be 25 years (technical lifetime of the measures may be much longer).

The IRR of the various projects are reviewed in Table 9.4. Terracing appears to be favourable in both plans, the most however in Plan II.

Table 9.4 Internal Rate of Return of Plans and Projects

Project		PLAN I	PLAN II
Terracing		8%	26%
Gully Control		-	-
Road Improvement	case a	-	-
	case b	32%	20%
Total Plan	case a	0%	0%
	case b	$3\frac{1}{4}$%	$4\frac{1}{2}$%

Table 9.5 Net benefits (ptas/year) on farm level

Project		PLAN I		PLAN II	
		total	per ha	total	per ha
Terracing		232500	451	373550	817
Gully Control		-	-	-	-
Road Improvement	case a	-	-	-	-
	case b	165300	321	165300	321
Total Plan	case a	123390	240	268500	588
	case b	313390	609	458500	1000

Table 9.6 Grants needed in percent of investment costs

Arrangement		1		2		3	
Plan		I	II	I	II	I	II
Terracing		8	-	54	-	100	-
Gully Control		100	100	100	100	100	100
Road Improvement	case a	100	100	100	100	100	100
	case b	-	-	-	-	100	100
Total Plan	case a	79	41	90	70	100	92
	case b	46	-	73	50	90	50

Gully control and Road Improvement (case a) don't have a positive IRR, because the yearly costs exceed the annual benefits. The IRR of Road Improvement (case b) is remarkably high.
The Total Plan has a positive IRR, but not very high in case b, and extremely low in case a. Compared with an capital interest rate of 10% (the present World Bank criterion) only terracing in Plan II and Road Improvement for both Plans are attractive. The final decision of the Government may depend however on other non-economical considerations.

On farm-economic level the farmer will rather be interested in the annual net benefits of the soil and water conservation measures. Compared with the national-economic evaluation, some costs are not chargeable to the farm, such as: the production loss on the area taken out of cultivation, (for which a compensation is given to the farmer), the extending of the access road to the forest area, and the construction costs of the diversion terraces.
The annual net benefits on farm level are summarized in Table 9.5. The net benefits of Gully Control and Road Improvement (case a) still remain negative. The yearly benefits of Terracing reach the highest level in Plan II. The Total Plan is attractive under all conditions.
With this amount the repayment capacity of the farmer was calculated as percentage of the investments, and the need for subventing. Table 9.6 shows which projects qualify for a grant under 3 arrangements.
The first arrangement implies, that all net benefits are used for repayment of the investment costs. In the second arrangement only 50% of the net benefits should be repaid, whilst in the third one all benefits below 500 ptas/ha accrue to the farmer.
It may be concluded, that under the arrangements 2 and 3 nearly all Projects require a grant. Only Terracing in Plan II remains attractive unsubsidized. Gully control and Road Improvement (case a) always require full subsidizing. So the execution of Soil Conservation works depends heavily on the willingness of the Government to grant; only Terracing in Plan II is economically attractive to the farmer.

Afforestation can be regarded as a independent project of soil conservation, with its own costs and benefits. It must be clear however that the favourable figures of Plan II are mainly due to the withdrawal from cultivation of the steeper areas.

The investment costs include the purchase of the steeper areas, the construction of bench terraces with an angledozer, and the planting of trees or the sowing of grasses. The purchase costs amount to 25.000 ptas/ha, the costs of establishment are 14.500 ptas/ha.
Maintenance costs, only made in the first years, for weeding and the lopping of trees, amount to 900 ptas/ha.
Benefits to be expected are the thinnings every 10 years, and the wood after 80 - 100 years. Estimations of the wood yield have been made for various rotation times.
With these estimations discounted costs and benefits for varying yields, rotation and discount rate were calculated. It could be concluded, that under all assumptions the benefits exceed the costs, and that afforestation is profitable. The IRR at a yearly increment of 3 m^3/ha amounts to 5%, at an increment of 6 m^3/ha to ca 8.5% N.B. The purchase costs were already included in the associated costs of land losses of terracing and therefore have been disregarded in this calculation.

9.4 Feasability of soil conservation measures

From the economic evaluation it is obvious that only a few soil conservation measures are sufficiently profitable, and mostly will be not attractive to the farmer, without grants of the Government. Social and psychological motives may however obstruct the execution as well. The willingness to accept changes in the farm management will depend of the manner in which

a) the responsible people are related to agricultural production and erosion damage, and
b) the proposed measures encroach in the present farming system.

The farming system as well as the relationship of the people with agriculture are historically grown in the Campiña.

a) The landowner is the one who takes decisions concerning investments and crop choice, based on profitability considerations only. Erosion will be a problem to him when it threatens his profit or hampers the management of the farm.
   For the manager the same considerations hold. For him erosion may cause organization problems or decreasing yields.
   The labourers on farm will concern about erosion, when it hampers their activities or threatens the employment potential.

The tenant only concerns short term yield, and an easy contract.
From this picture it could be concluded, that the people who is direct responsible for the agricultural production, is rather interested in the increment of yields than in more soil conservation.
The Government will have an important task to this subject. They should watch over the national patrimony for the benefit of the posterity. The conservation of natural resources is a prerequisite to that. Besides, there may be other national economic reasons for soil conservation (e.g. erosion damage to infrastructural works or villages).
To realize a soil-conservation policy, the Government can dispose of various instruments: extension services, grants and subventions, and legislation measures concerning the farming system. Up to now, none of these instruments have been used in the Campiña. The prohibition (in force since long) on the burning of harvest remnants illustrates poignantly the actual vigour of the law. It is obvious, that a sudden introduction of such measures will meet with some resistance of the farmers. A spontaneous change to soil conservation is not likely therefore.

b) It is beyond doubt, that soil conservation meaures will meet with more difficulties, according as they intervene more heavily in the farming system. Minimizing the number of tillages goes straight against the present practice of clean weeding. The farmer must be convinced of the waterconservation effects of stubble mulch farming in combination with terraces. The introduction of a new tillage practice will require an intensive extension programme. Once convinced by the increasing benefits due to water conservation, other soil conservation measures can be feasible.
Terracing in Plan I is only profitable for the farmer, if grants are given by the Government of at least 50%. However, execution is not likely even then, because of the low net benefits (250 ptas/ha) and the small terrace intervals which may obstruct mechanical tillage. Terracing in Plan II is economically very attractive without any subvention.
When stubble mulch farming is accepted, not much resistance will occur, because of the large terrace intervals.
Gully control measures will never be carried out without a 100% subsidy. Probably the farmers are even less interested when field measures reduce the flooding hazard. If desired, this measure should be financed by the Government completely.

The withdrawal of steeper areas will meet much resistance of the owners, because this measure attacks their autonomy. On the other hand, the designation of steeper areas should be regarded as the clue to soil conservation in the Campiña. The considerable reduction of peak discharge in Plan II is mainly due to the afforestation of highly erodible soils. Presumably legal steps are needed to obtain this area, whereas a reasonable compensation is given. Reallotment of the remaining parcels will not meet with much difficulties after that.

Summarizing the feasability of the Plans one could say that spontaneous introduction of soil conservation measures in the Campiña is not likely. If the Government is prepared to intervene in the present owners relations, the best strategy for developing the Soil Conservation Plan is

- to take legal steps in order to withdraw the areas out of cultivation ,
- to emphasize the waterconservation aspect of the tillage measures,
- to subsidize gully control and road improvement, if desired.

CHAPTER X CONCLUSIONS

1) All recommendations in this report are based on few observations and much assumptions. The execution of Soil Conservation Measures should be preceeded by more longterm experiments regarding the soil erodibility, infiltration rates, and peak discharge, to improve the reliability of the calculations.

2) In behalf of the soil protection in the rainy season winter rotation crops are preferred to summer crops. Early dense crowded crops (such as wheat and rape seed) will better protect the soil than slowly growing species (such as sugar beets).

3) Though attractive from Soil Conservation point of view, stockfarming cannot be recommended because of difficulties in fodder- and water supply during summermonths and the need for alternative pasture lands.

4) The numerous weed-cleaning tillages must be replaced by one deep ploughing tillage just after the harvest and minimal cultivation tillage before sowing. The effect on the waterconservation will then surpass the waterconsumption of weeds.

5) Leaving the stubble on the field after harvest will have a positive effect on both soil protection and waterconservation, by increasing the infiltration capacity and reducing the flow velocity of the runoff water.

6) Crop and tillage measures should be supported with terracing. The application of stubble mulch farming allows large terrace intervals, which facilitates the mechanical tillage, and has an attractive economic return.

7) The withdrawal of the steeper areas out of cultivation is an absolute requirement for minimization of the erosion hazard, and should be regarded as a spearhead for soil conservation plans. Moreover afforestation is economically profitable and means a buffer for crop diseases thank to the variation of the ecosystem.

8) Gully control measures are needed to prevent further incisions and flooding. The costs of construction and maintenance are that high, however, that economical return is not to be expected.

9) Road improvement is necessary to guarantee an all year accessibility of the farms in the Pilot Area. This measure is profitable only when it enables the farmers to grow sugarbeets.

10) The economic evaluation shows that Plan II should be preferred to Plan I, but only terracing is attractive to the farmer.

11) It is not likely that the farmers carry out the recommended soil conservation measures spontaneously. The task of the Government is to stimulate the execution by means of subsidies, extension, and legal steps.
The acquisition of the steeper areas is a prerequisite to further erosion control. In extension the water-conservation aspects of the measures should be emphasized, whereas subsidies are required to finance the non-profitable parts of the plans.

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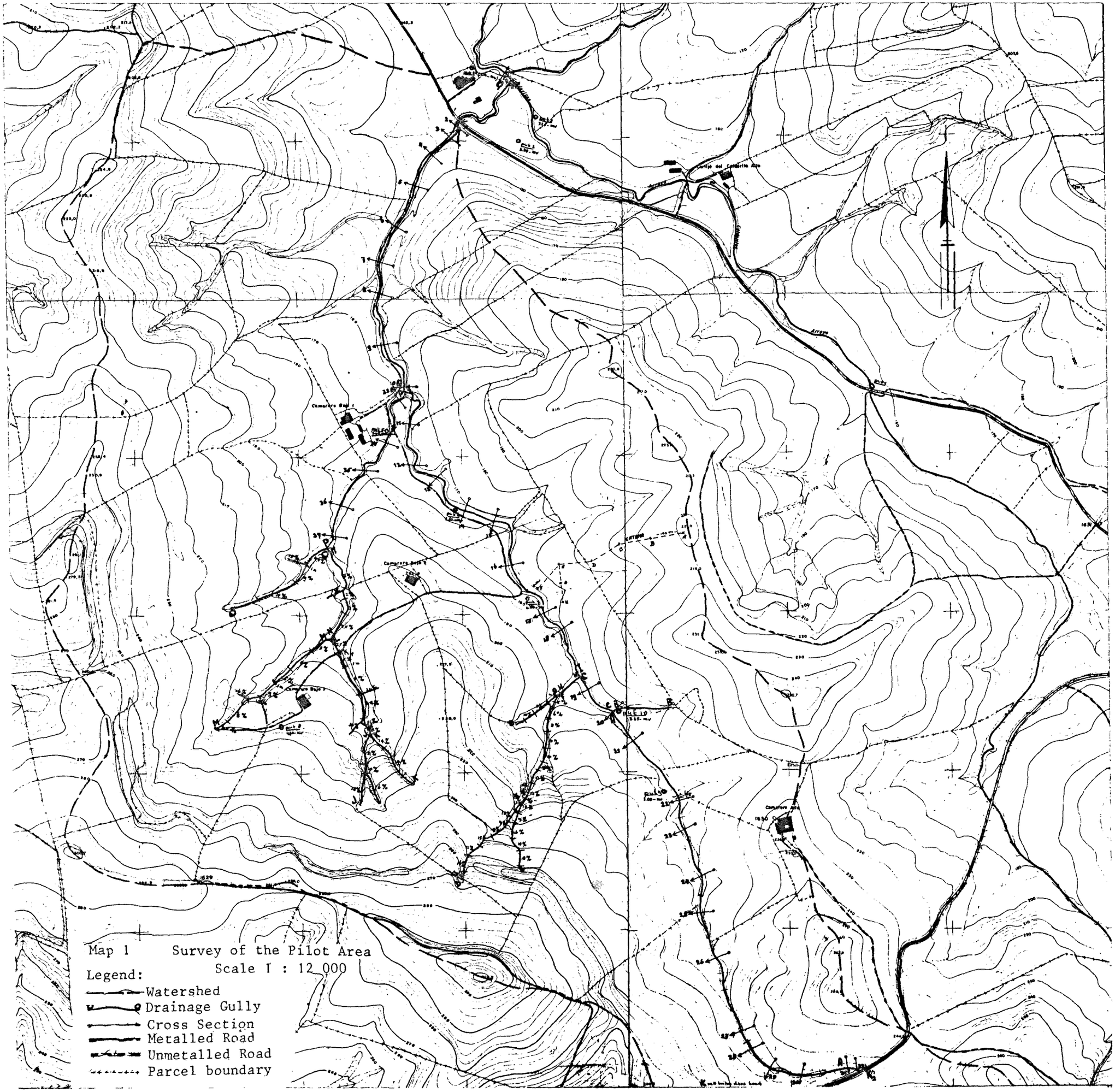
Map 1

Survey of the Pilot Area.


Map 1 Survey of the Pilot Area
Scale 1 : 12,000
Legend:
Watershed
Drainage Gully
Cross Section
Metalled Road
Unmetalled Road
Parcel boundary

Map 2

Soil Map of the Pilot Area.

Calderito Bajo

Camarero Bajo 1.

Camarero Bajo 2.

Camarero B. 3.

Camarero Alto

0 500 m

Map 2 Soil map of the pilot area
Mapa de Suelo del area piloto

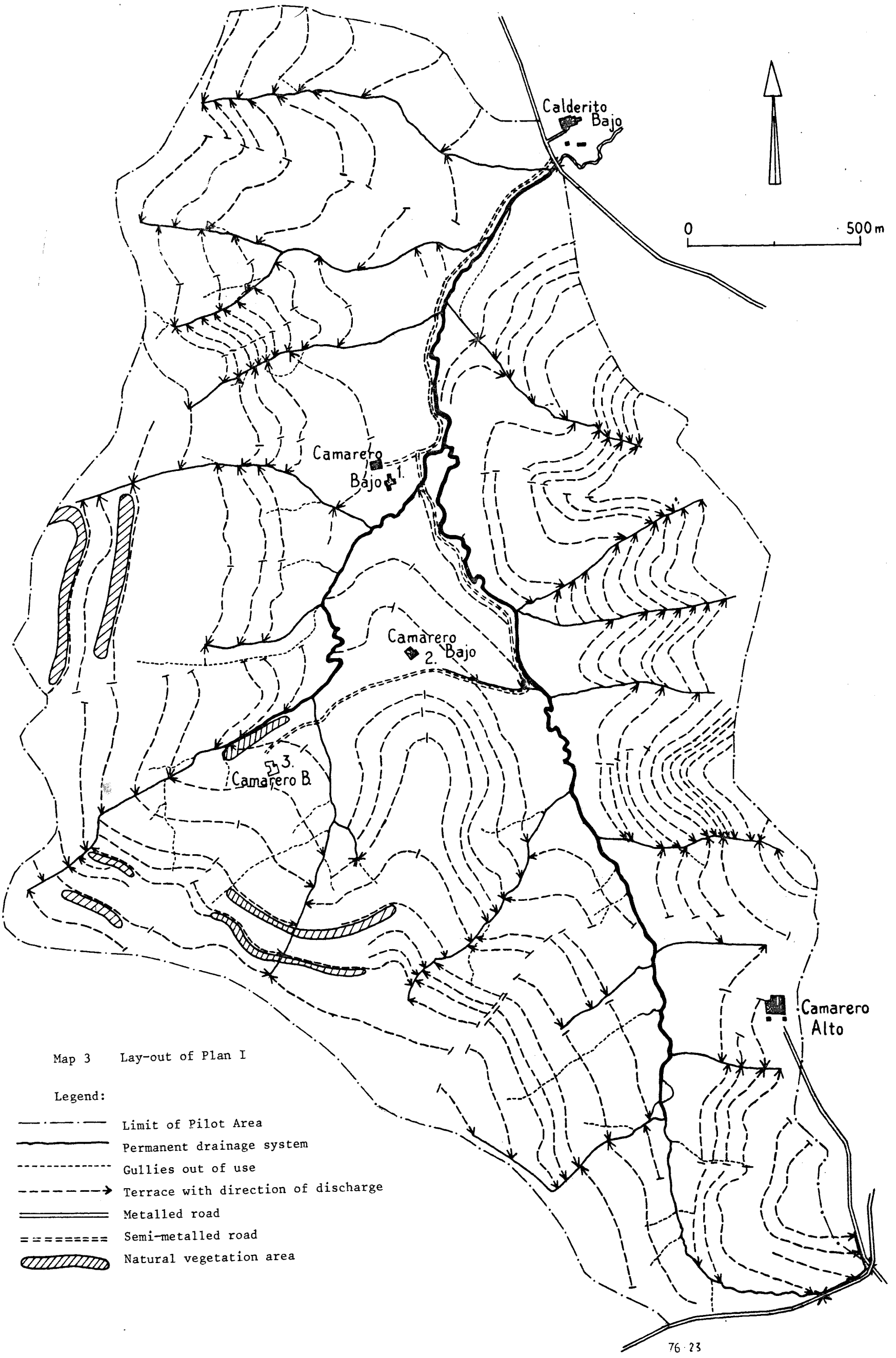
Legend :

- soil boundary
  limite de unidad de suelo
- natural drainage pattern
  red natural de drenaje superficial
- intermittant watercourse
  curso de agua intermitente
- all weather road
  camino afirmado
- un - metalled road
  camino sin afirmar
- border of catchment area
  divisoria de la cuenca
- escarpment
  ladera escarpada
- slope >20 %
  pendiente >20 %
- farmhouse
  cortijo
- location of described profile
  ubicación de perfil descrito

76-25

Map 3

Lay-out of Plan I.



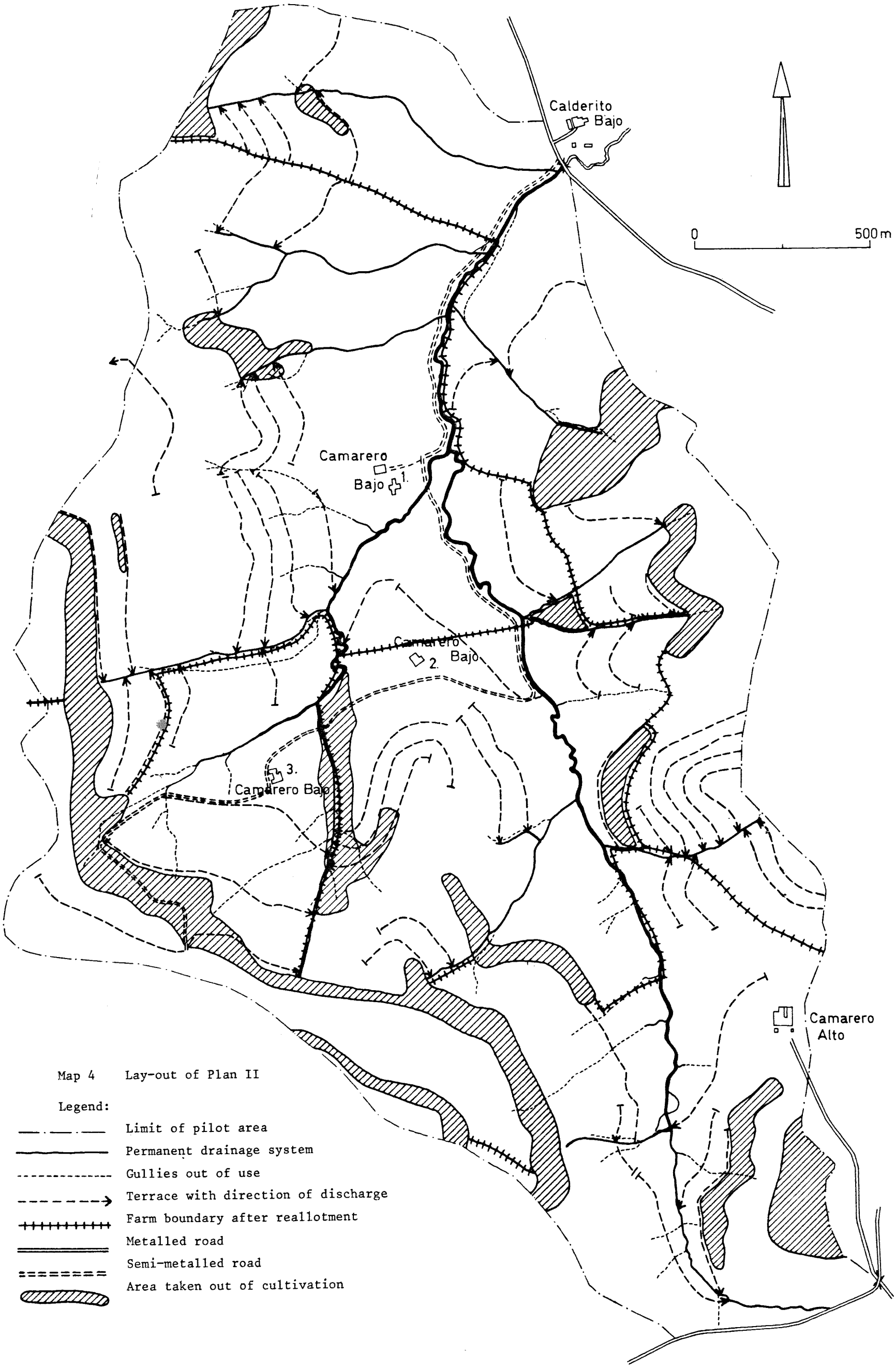
Map 3 Lay-out of Plan I

Legend:

- Limit of Pilot Area
- Permanent drainage system
- Gullies out of use
- Terrace with direction of discharge
- Metalled road
- Semi-metalled road
- Natural vegetation area

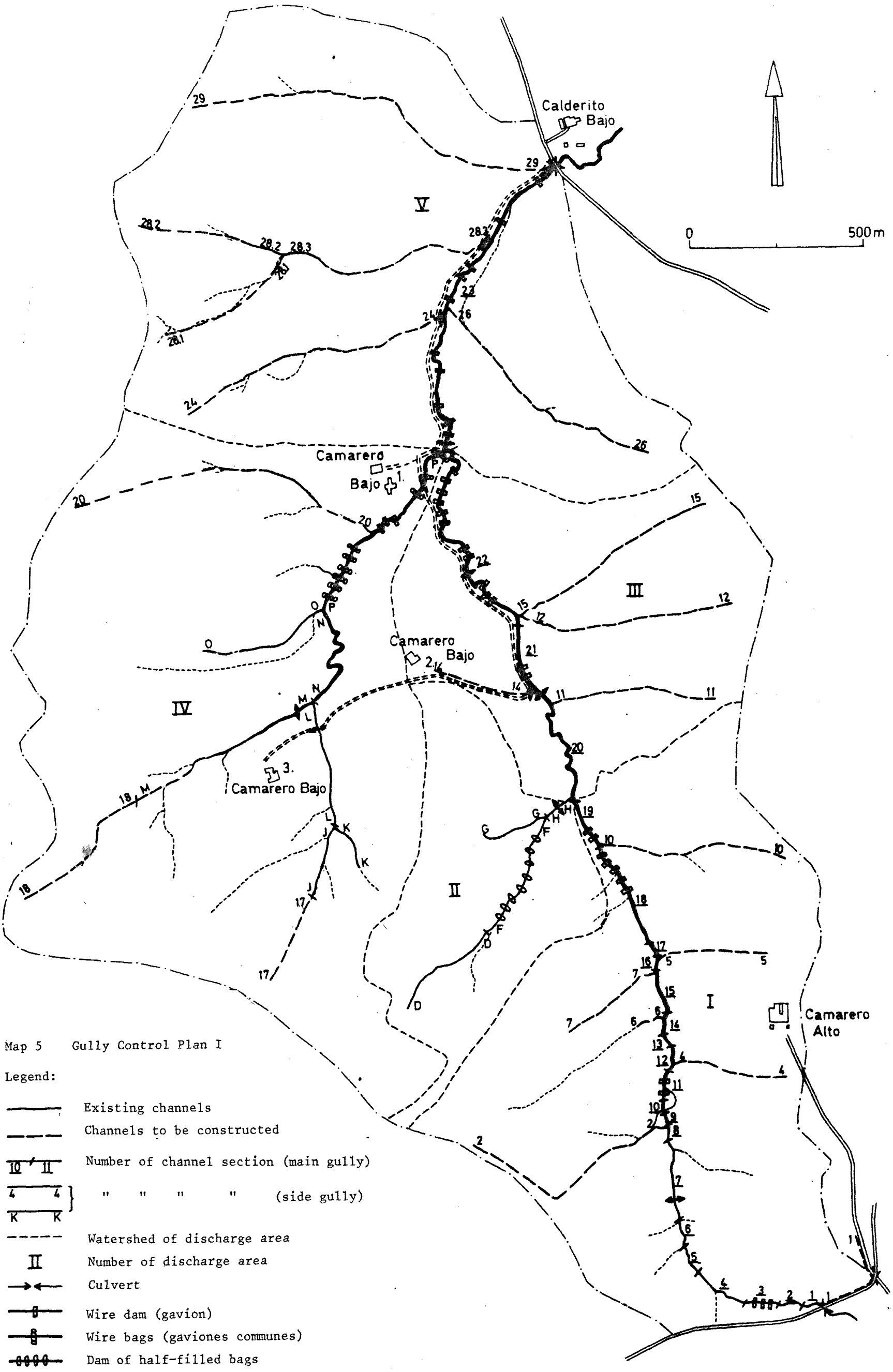
Map 4

Lay-out of Plan II.


Calderito Bajo
0
500 m
Camarero Bajo 1.
Camarero Bajo 2.
3. Camarero Bajo
Camarero Alto
Map 4 Lay-out of Plan II
Legend:
Limit of pilot area
Permanent drainage system
Gullies out of use
Terrace with direction of discharge
Farm boundary after reallotment
Metalled road
Semi-metalled road
Area taken out of cultivation

Map 5

Gully Control Plan I.



Map 5 Gully Control Plan I

Legend:

- Existing channels
- Channels to be constructed
- Number of channel section (main gully)
- " " " " (side gully)
- Watershed of discharge area
- Number of discharge area
- Culvert
- Wire dam (gavion)
- Wire bags (gaviones communes)
- Dam of half-filled bags
- Permanent ford
- Bridge
- Limit of pilot area

Map 6

Gully Control Plan II.

Calderito Bajo

Camarero Bajo 1.

Camarero Bajo 2.

Camarero Bajo 3.

Camarero Alto

V

IV

III

II

I

0 500 m

Map 6 Gully Control Plan II

Legend:

- Existing channels
- Channels to be constructed
- 21 / 25 Number of channel section
- Watershed of discharge area
- II Number of discharge area
- Culvert
- Wire dam (gavion)
- Wire nets (rastrillos)
- Dams of half filled bags
- Permanent ford
- Bridge
- Limit of pilot area