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Soil survey and land evaluation for planning, design and management of irrigation districts

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SUMMARY - To achieve a sustainable agriculture in irrigated lands irrigation and drainage projects must be soundly planned and designed. In these planning and design phases soil surveys are essential to assess the irrigation suitability of the lands of new projects or for land reclamation purposes in rehabilitation projects. These surveys are sequential: by means of exploratory surveys an inventory of land resources can be achieved; through reconnaissance surveys and semi-detailed studies irrigation suitability can be assessed; finally, detailed soil surveys are applied for irrigation and drainage design purposes.

Key words: Soil survey, land evaluation, irrigation suitability.

RESUME - En vue d'une agriculture durable dans les terres irriguées, les projets d'irrigation et de drainage doivent être planifiés et conçus de façon très rationnelle. Lors de ces phases de planification et de conception, les études de sol sont essentielles afin d'évaluer la viabilité de l'irrigation dans ces terres faisant l'objet de nouveaux projets ou d'interventions de mise en valeur des terres dans le cadre de projets d'assainissement. Ces études sont séquentielles ; un inventaire des ressources foncières peut être dressé à l'aide d'études préliminaire ; la viabilité de l'irrigation peut être évaluée par des études de reconnaissance et semidétaillées ; et finalement, des analyses détaillées du sol sont requises pour la conception de systèmes d'irrigation et de drainage.

***Mots-clés**: Etude du sol, évaluation des terres, viabilité de l'irrigation.*

Introduction

Land reclamation by means of irrigation and drainage has contributed to rural development through an increase of land productivity and farmers income.

In arid and semi-arid regions irrigation makes agriculture possible in areas otherwise unproductive and unpopulated due to their unfavourable natural conditions. In temperate regions complementary irrigation maintains regular production during the dry season.

In temperate humid regions land drainage has been an efficient mean for increasing crop production and to decrease farming costs. In irrigated lands agricultural drainage is indispensable to avoid the permanent hazard of waterlogging and salinization; in fact, approximately half of the 280 Mha of irrigated lands in the world need agricultural drainage (Lesaffre, 1990).

The importance of irrigation and drainage in the Mediterranean region can be remarked with some figures from Spanish agricultural statistics: the irrigated area, which nowadays amounts to 3.2 Mha and

15% of the total arable land, provided in 1988 50% of the total agricultural output (González Ferrando, 1988). That means productivity of irrigated agriculture is six times that of rainfed farming, even though not all irrigated lands have already reached their potential production. Similar figures come from the USA where 25% of the value of all crops produced comes from 24 Mha of irrigated lands, which are some 10% of the land farmed (Van Schilfgaarde, 1990).

Meanwhile, many developing countries are becoming food importers, whilst they were self sufficient in the past. This is due to the fact that the rate of growth in acreage under irrigation has dropped in the last decade, whereas population is increasing rapidly. In the period 1980-85 the world average percent growth has been only 8%, when in the seventies was 26% (Albertson and Bouwer, 1992).

Therefore, irrigation and drainage projects, if soundly planned and constructed, are fundamental to ensure crop production in arid and semi-arid regions and a very important way to maintain a regular production in temperate areas.

However, deficient irrigation and drainage projects may have negative effects to the environment through deterioration of natural resources: soil losses due to erosion derived from poor water management, waterlogging and soil salinization because insufficient drainage and deterioration of the quality of the surface water and groundwater, due to the salinization and pollution of the drainage water by agricultural chemicals or by mobilization of toxic elements from the soil. These inconveniences sometimes make a conflict between irrigation development and environment preservation.

Therefore, future increases in food production to supply a growing population must result from new irrigation projects technically and environmentally well planned. However, since new land suitable for irrigation and water of good quality are scarce resources rehabilitation of irrigated projects, through modernization of the irrigation systems, efficient water management and reclamation of waterlogged and salt affected lands, must be an urgent need to achieve a sustainable agriculture.

To achieve these goals, soil surveys are essential in the planning and design stages of irrigation projects, either for land evaluation to assess the irrigation suitability of new lands, or for land reclamation to achieve sustainability in rehabilitation projects. These studies are sequential and cover a wide range of purposes and levels of intensity: exploratory surveys for the inventory of land resources, reconnaissance surveys for land classification to assess the feasibility of new irrigation projects or to identify problem areas in irrigated lands and detailed surveys for design and implementation of new irrigation schemes and for the rehabilitation of irrigated areas.

The aim of this paper is to present the soil survey methods applied by IRYDA in Spain, and to discuss their possibilities of application in other countries of the Mediterranean region. These methods are described in detail in the specific text of the International Course on Irrigation and Drainage (Bardají, 1991).

Exploratory surveys for the inventory of land resources

Purpose

Prediction of water demand is a main topic to take into account in hydrological planning. To determine the present demand of irrigation water in a river basin, geographic information on the actual land use is needed in addition to knowledge on crop irrigation requirements. However, to assess the future demand of irrigation water, potential areas for irrigation development must be established. To identify those lands with irrigation suitability it is needed to carry out an inventory of land resources. With this purpose IRYDA has carried out a soil survey in the Tajo basin for the inventory of lands suitable for irrigation, as a basic contribution for the formulation of the Basin Hydrologic Plan.

Methods

This study consisted of two parts: first an exploratory soil survey of the river basin to map the great land systems at scale 1:400,000 to identify the areas potentially suitable for irrigation; then a reconnaissance soil survey at scale 1:200,000 to subdivide the land systems into geomorphologic units to evaluate finally the land suitability for irrigation on those areas without previous soil information.

The exploratory soil survey began with a photointerpretation study on available aerial prints at scale 1:70,000, although 1:100,000 photographs are more convenient. Once the geomorphologic units were identified and gathered in geomorphologic subsystems and systems, they were checked by means of field itineraries to map the main soil associations and to obtain the main land systems. The land system is an area with a recurring pattern of topography, soils and vegetation, and with a relatively uniform climate (Dent and Young, 1981). These systems are groups of land units geomorphologically and geographically associated in such a fashion that can be easily distinguished in the landscape. In this way the river basin is subdivided into a reasonable number of units which can be systematically studied.

The classification of the geomorphologic units was carried out according to a genetic and morphologic approach, by means of the ITC classification system (Van Zuidam, 1985-86).

The irrigation suitability of these subsystems and systems was evaluated taking into account the climatic characteristics related to the altitude and the soil characteristics related to land qualities affecting irrigation.

After the 1:400,000 map was completed the reconnaissance soil survey to map the soil units included a photointerpretation study and field work with an intensity of 1 observation per 1,000 ha. The ITC system was also applied in this stage.

In those areas with irrigation potential, land suitability for irrigation was evaluated by applying the USBR classification, according to the soil, topography, drainage and climatic characteristics. Thus land classes were obtained and land classes associations where apart from the dominant class other class covers an area greater than 30% of the mapped unit (IRYDA, 1992).

Results and discussion

The Tajo river basin is situated in central and western Spain and covers in Spanish territory an area of 37,210 km^2. In Fig. 1, it can be observed a northern fringe of mountains with acid plutonic rocks, an eastern border with calcareous mountains and again southern mountains with Siluric formations. In the eastern and central part of the basin, calcareous plains and denudational slopes and hills occur. In the west, sandstone and shale peneplains can be found. Piedmonts contact the mountains and the detritic formations. Finally, the Tajo river and its tributaries have formed units of fluvial origin.

In Table 1 the climatic and soil limitations of each subsystem are shown. From these limitations a general approach of the land suitability of each mapping unit can be achieved: the mountainous border has a marked forestry suitability meanwhile the plains and fluvial units have a clearly agricultural suitability. The hills and peneplains have a joint grazing and forestry suitability.

In Fig. 2 a reduced and simplified 1:200,000 map of a part of the basin is shown. In this map a detailed division of the land subsystems into geomorphologic units can be observed.

In Table 2 descriptions of the physiographic units, parent material and soil characteristics are given. These characteristics together with the climatic limitations have been used to assess land suitability. As additional information the actual land use is described.

It is concluded that obviously the irrigation suitability of the mountainous fringe is negligible, meanwhile the suitability of the hilly areas depends on topography. The accumulation systems, if no severely dissected, have good irrigation suitability. The lands of the peneplains are not suitable for irrigation, due to severe soil limitations, although their climatic characteristics are favourable. The fluvial systems and the lands of the plateaus are suitable for irrigation; in fact, a great part of these systems are currently irrigated lands.

A general conclusion on the usefulness of this study can be derived: it is a helpful tool to separate areas clearly unsuitable for irrigation. If the map of Fig. 2 is superimposed on a map where the lands irrigated at the present time are localized, an inventory of the potential irrigable land can be accomplished. Those identified areas lacking sufficient soil information can be mapped by means of more detailed soil surveys, as it is described in the following paragraph.

Reconnaissance surveys for land evaluation

Purposes

Soil surveys for irrigation suitability assessment are carried out previously to feasibility studies in the planning stage of new irrigation projects with two purposes: to delimitate the project area and to supply basic information on crop requirements, suitable irrigation method, drainage requirements and other soil improvement techniques.

In rehabilitation projects of irrigated lands, besides the modernization of the irrigation systems, two main objectives are commonly considered: to improve field irrigation management, by reducing surface run-off and deep percolation, to save water and reduce the negative environmental impacts of irrigation, and to reclaim waterlogged and salt affected soils. In both instances a detailed soil mapping is required. In the first case, field irrigation evaluations must be performed in each relevant soil unit. If land reclamation is the main purpose, those areas affected by waterlogging and salinity must be differentiated from those lands with good drainage conditions and salt free.

Methods

In these land evaluation studies IRYDA applies the FAO guidelines for soil survey investigations for irrigation and for land evaluation for irrigated agriculture (FAO, 1979 and 1985). The procedure consists of three phases: soil survey, soil survey interpretation and land classification by means of the USBR system (USBR, 1953).

The intensity of survey varies from detailed reconnaissance surveys at scale 1:50,000 to semidetailed studies at scale 1:25,000. They can be considered into the framework of land evaluation as a potential land classification.

In the first phase the physiographic approach (Veenenbos, 1972) is applied. This approach starts with a photointerpretation study to delimit the geomorphologic units of the studied area. Field observations are made to describe those soil characteristics which affect land qualities relevant for crop growing, water movement through the soil profile and other qualities related to irrigation, drainage and soil improvement techniques.

This approach has been successfully applied in Spain during the last 20 years because the soil maps obtained are easily understood by irrigation and drainage engineers, who are not generally familiar with genetic and morphometric soil classifications. Besides, with relatively cheap field observations the required intensity of the survey is reached, once the relationship between the landscape units and the soil characteristics is established. This method is particularly suitable in land reclamation projects, since a close relationship exists between geomorphology and drainage conditions.

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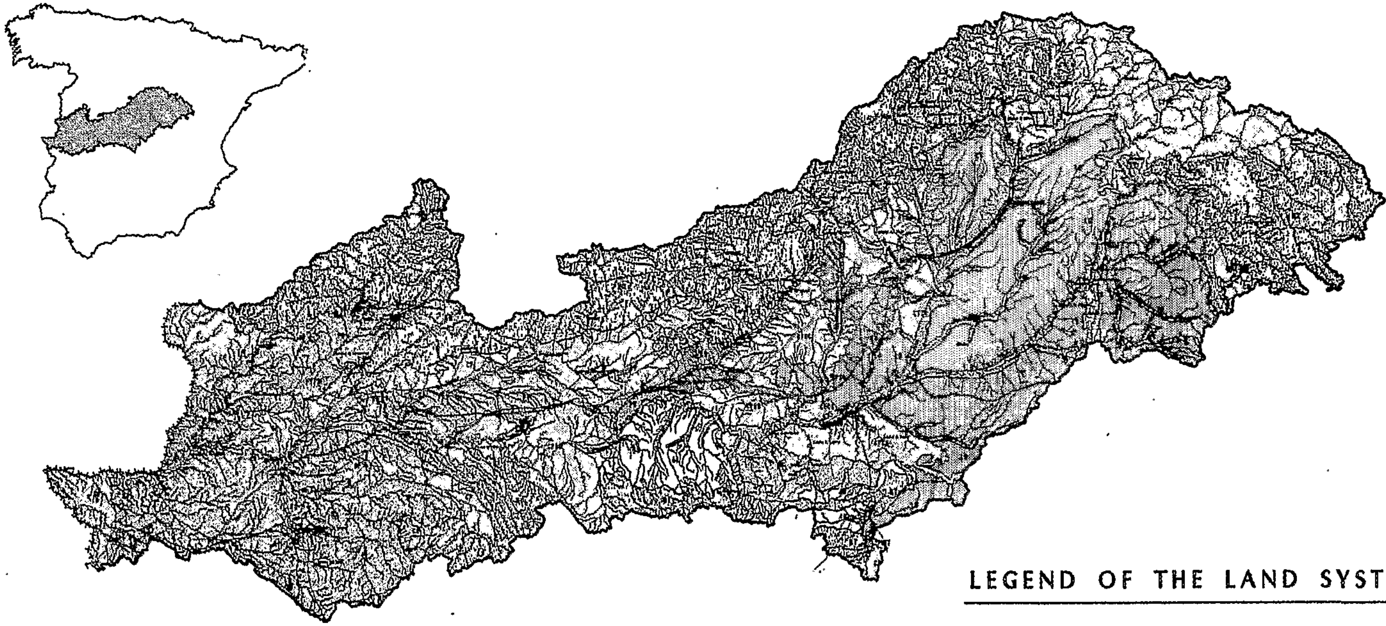

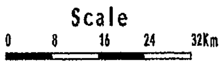

LEGEND OF THE LAND SYSTEMS MAP

SYSTEMS	SUBSYSTEMS	CODE
Mountains	Undifferentiated	M
Hill systems	Piedmont formations Central formations	CP CC
Accumulative systems	Ranas Colluvial	AR AC
Peneplains	Undifferentiated	P
Plains	Undifferentiated	L
Fluvial systems	Valleys and fans	F

Fig. 1. Simplified land system map of the Tajo river basin (reduced and adapted from the 1:400,000 map; IRYDA, 1992).

Table 1. Limitations and land suitability of the units of the land system map (IRYDA, 1992).

Systems	Subsystems	Code	Climatic limitations	Soil limitations	Land suitability
Mountains	Undifferentiated	M	Very high	Very high	Forestry
Hill systems	Piedmont formations	CP	Very variable	High-moderately high	Forestry and grassland
	Central formations	CC	Moderately high	Moderately high-high	Forestry and grassland
Accumulative systems	Rañas	AR	Moderately high	High-medium	Forestry and arable land
	Colluvial	AC	Medium	Medium-low	Arable land
Peneplains	Undifferentiated	P	Low	High	Grassland and forestry
Plains	Undifferentiated	L	Medium-low	Low	Arable land
Fluvial systems	Valleys and fans	F	Medium-very low	Very low	Arable land

However, this approach has some disadvantage as it is the difficulty of comparison of soils of different areas. This drawback can be overcome by the morphometric description of a representative soil profile of each mapping unit.

To obtain the geomorphologic map the ITC classification system is also used (Van Zuidam, 1985-86). On this map the field work is based. Therefore, it is possible to intensify field observations in those units more relevant to the study purpose, decreasing the intensity in those area with less suitability.

After completing field work and laboratory analysis the soil map is designed. The soil map legend is formulated by using the formula of the Soil Conservation Service of California (USDA, 1957). In this formula soil hydrologic qualities related to land drainage have been added (Fig. 3).

In Table 3 the intervals used in the soil mapping of the Muga irrigation project (Fig. 6) are shown.

By means of the soil survey interpretation the draft map of land classes is obtained. IRYDA applies the USBR land classification system since the sixties. In this system six classes are distinguished according to their suitability level. Each class can be subdivided into subclasses because soil, topography and drainage limitations. For each subclass different management units can be defined; in the irrigation development plan these units will have an specific land and water management treatment. In the land classes map each management unit is described by a formula describing its main characteristics (Fig. 4).

To formulate land classification criteria a relationship between soil, topography and drainage characteristics and economic factors must be established, mainly if the purpose is to obtain a quantitative land classification. To determine this relationship irrigated districts with similar soils must be checked. If that is not possible only a qualitative approach can be achieved.

Results and discussion

This procedure has been applied in the rehabilitation project of the river Muga irrigation district. This area is located in the Alto Ampurdán, in northeastern Spain, and was put under irrigation in the seventies. Nowadays about 6,000 ha are irrigated.

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LEGEND OF THE GEOMORPHOLOGIC UNITS MAP

LAND SYSTEM	SUBSYSTEM	GEOMORPHOLOGIC UNITS	CODE
Mountains	Central system Toledo mountains	Mountains and hills Mountains and hills	MC-S4 MT-S4
Hills	Piedmonts	Slopes and hills Slopes	CP-D1-D9 CP-S3
Accumulative systems	Central formations Great fans Accumulative covers	Slopes and hills Inactive alluvial fans Footslopes	CC-D2 AR-F8 AC-D7
Peneplains	Valdecanas formation	Peneplains	PV-D5
Plateaus	Central formations	Plateaus	LC-D6b
Fluvial systems	Undifferentiated	Fluvial terraces	FV-F6

Fig. 2. Geomorphologic units map of part of the Tajo river basin (reduced from the 1:200,000 map; IRYDA, 1992).

Table 2. Main characteristics and land suitability of the geomorphologic units (IRYDA, 1992).

Land system	Subsystem	Geomorphologic units	Code	Physiographic unit	Geology	Land use	Soil unit	Soil characteristics	Climatic factor	Land class
Mountains	Central system	Mountains and hills	MC-S4	Steeply mountains Moderately to severely dissected	Granite, gneiss, quartzite and shale	Forest, shrubs and grazing	Lithosols and brown soils	Total topography limitation	E	6
	Toledo mountains	Mountains and hills	MT-S4	Steeply mountains anticline, valleys and hills	Granite, shale and quartzite	Forest	Lithosols and non calcic brown and reddish soils	Total topography limitation	E	6
Hills	Piedmonts	Slopes and hills	CP-D1	Moderately steeply undulating formations, slightly dissected	Granite, shale limestone, gypsum and mudstone	Forest and grazing; occasionally arable land	Brown soils; sierozem and reddish-brown soils	Shallow soils; undulating topography	C,D	4,6
		Slopes and hills	CP-D9	Very steep scarps severely dissected	Shale and quartzite	Grazing and oak	Lithosols	Shallow soils	C,D	6
		Slopes	CP-S3	Moderately to very steeply slopes, moderately dissected	Shale and granite	Olive-trees, shrubs and arable land	Lithosols, brown soils and non-calcic reddish soils	Shallow and moderately deep soils	C,D	4,6
	Central formations	Slopes and hills	CC-D2	Steep eroded slopes	Detritic formations limestone and mudstone	Grazing and arable land	Sierozem and brown soils	Shallow soils; moderate slope	C,D	6,4
Accumulative systems	Great fans	Inactive alluvial fans	AR-F8	Nearly flat fans, moderately dissected	Shale and quartzite alluvium	Rainfed arable land	Non-calcic reddish soils	Stony shallow and moderately deep soils	C	3,6
	Accumulative covers	Footslopes	AC-D7	Footslope severely dissected	Pliocene formations		Lithosols and brown soils	Shallow and moderately deep soils		4,6
Peneplains	Valdecanas formation	Peneplains	PV-D5	Ondulating peneplain, moderately dissected	Arkoses	Forest, grazing, some irrigated crops	Planosols, regosols and brown soils	Shallow soils, undulating topography, sometimes waterlogged soils	B,C	4,6
Plateaus	Central formations	Plateaus	LC-D6	Flat lands at different levels	Detritic formations: limestones, gypsum mudstone	Rainfed agriculture, grazing	Brown soils	Shallow and moderately deep soils	C,D	2,3,4
Fluvial systems	Undifferentiated	Fluvial terraces	FV-F6	Terraces and flat colluvium	Old alluvium and recent colluvium	Rainfed and irrigated agriculture	Alluvial and colluvial soils	Deep and very deep soils	B,C,D	1,2,3

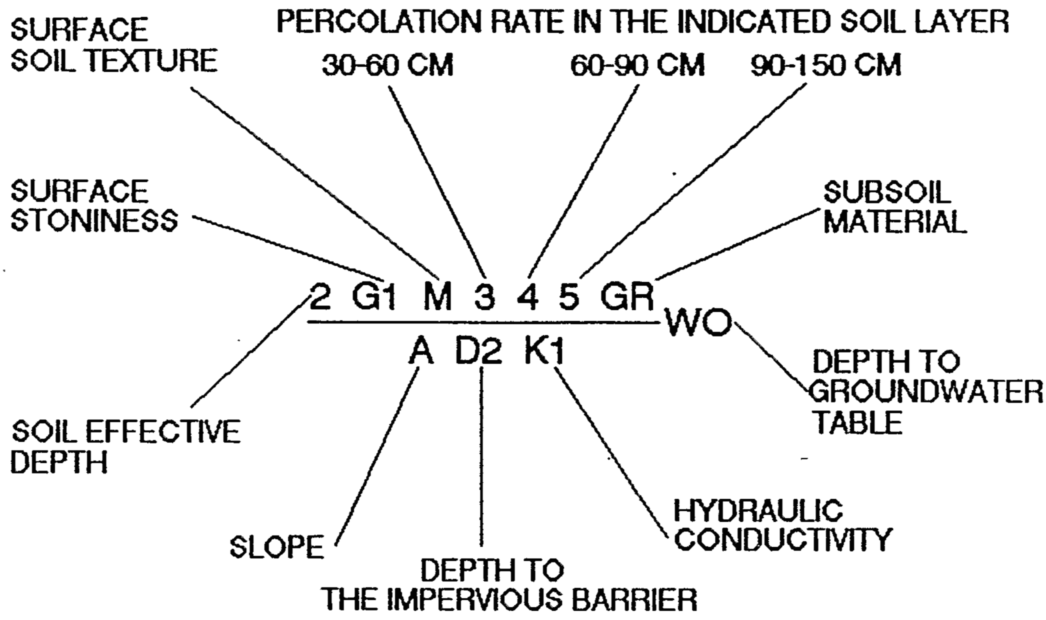


Fig. 3. Modified formula of the SCS used in the legend of the soil units map.

Table 3. Intervals used in the Muga map (Fig. 6).

Effective depth (m)	Soil texture	Stoniness (%)
1: > 0.9 2: 0.6 - 0.9	H: Clay - silty clay h: Sandy clay - silty clay loam M: Sandy clay loam - loam l: Sandy loam - fine loamy sand L: Coarse loamy sand	G0: < 5 G1: 5 - 20 G2: > 20
Percolation rate	**Subsoil material**	**Slope (%)**
1: Very slow 2: Slow 3: Moderate 4: Moderately high 5: High 6: Very high - : Undetermined	GR: Gravel AR: Sand AC: Clay - : Undifferentiated	A: < 2 B: 2 - 6
Groundwater table depth (m)	**Depth to the impervious barrier (m)**	**Hydraulic conductivity (m/d)**
W0: > 2.0 W1: 1.5 - 2.0 W2: 1.0 - 1.5 W3: 0.5 - 1.0 W4: < 0.5	D0: > 2.5 D1: 2.0 - 2.5 D2: 1.5 - 2.0 D3: 1.0 - 1.5 D4: 0.5 - 1.0 - : Undetermined	K1: 2 - 3 K2: 3 - 5 K3: 5 - 7 - : Undetermined

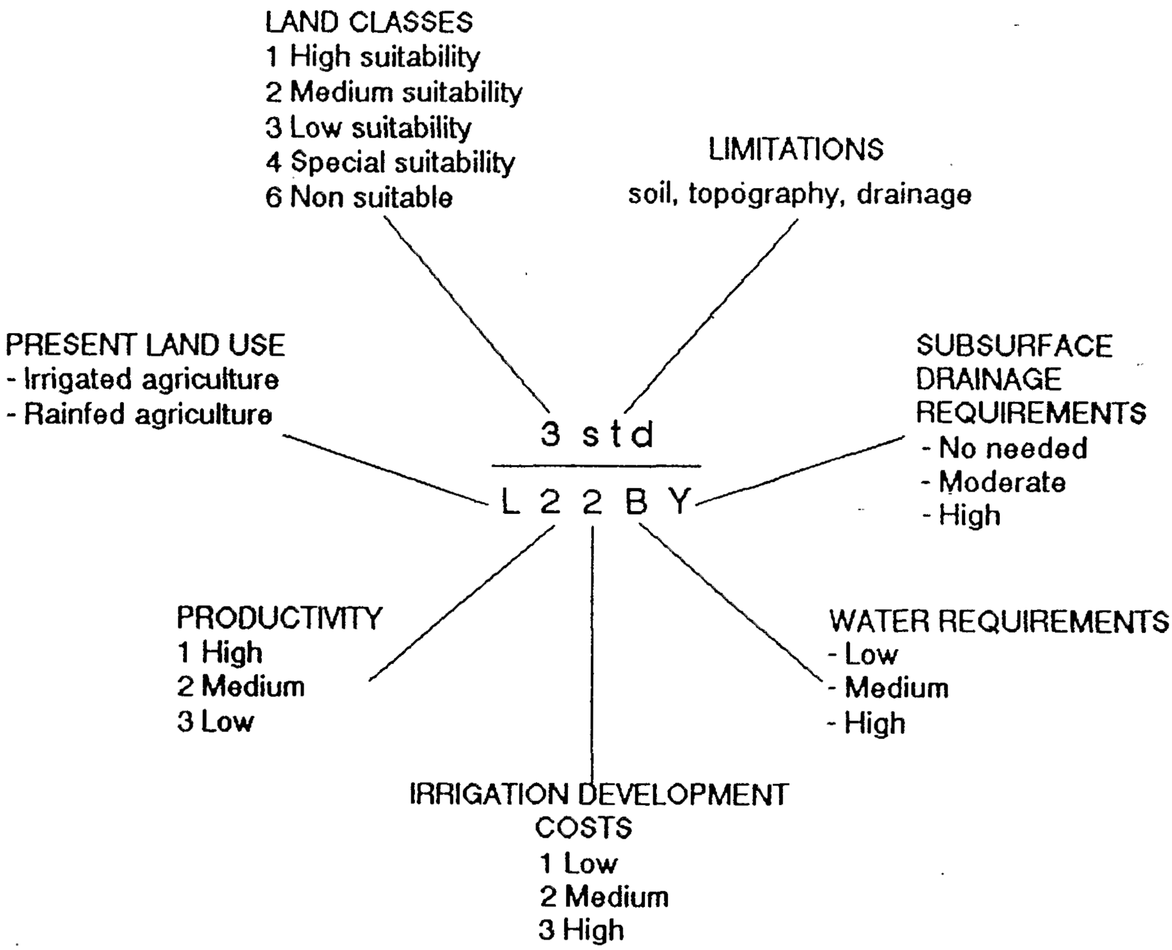


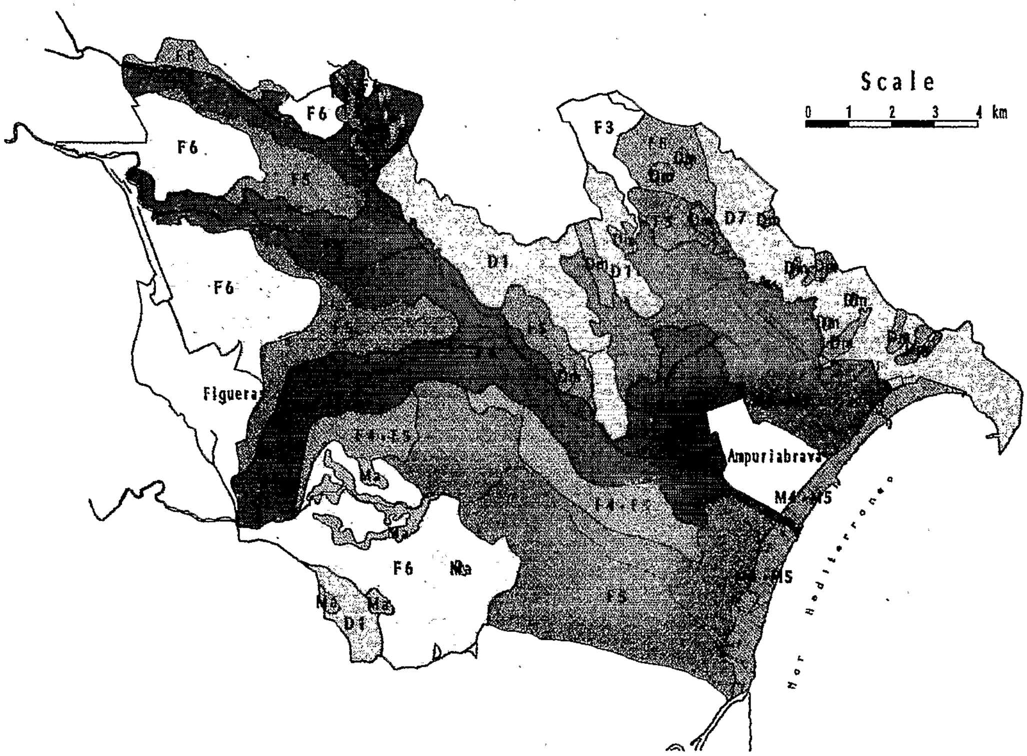
Fig. 4. Formula used in the land classes map (USBR system).

The project area is situated in the lower Muga valley close to the Mediterranean coast. In the geomorphologic map (Fig. 5) it can be observed the flood plain of the Muga river -with its fluvial levees, backswamps and transition- fluvial terraces, and other minor units of fluvial origin, plus the tidal flat and other units of denudational origin.

Soil mapping (Fig. 6) was mainly focused to assess land drainability and soil moisture availability, which depends of soil effective depth and soil texture. Therefore, these characteristics have been remarked in the soil map legend. As far as the first land quality is concerned soils requiring artificial land drainage have been mapped apart from soils with good natural drainage. Taking into account soil moisture availability, crops and irrigation methods the sites for field irrigation evaluations were located.

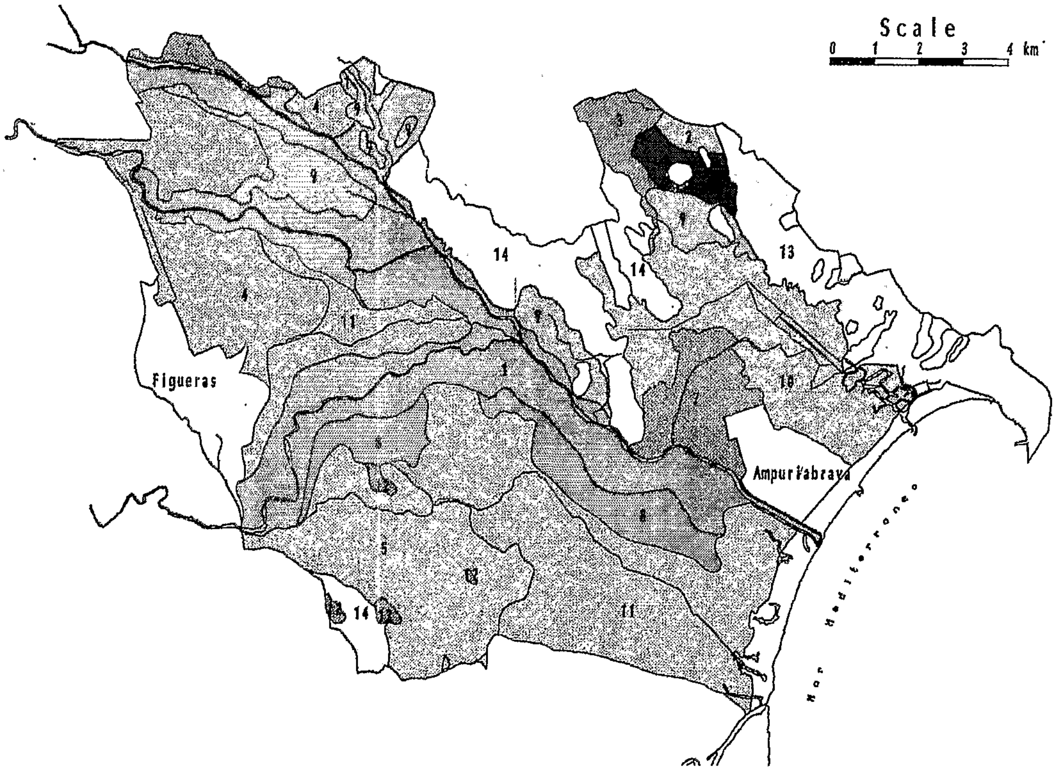
The soil units map shows that only the soils of backswamps and transitions of the flood plain, the soils of the tidal flat and small swamps have restricted drainage.

In Fig. 7 the land classes map is shown, whose legend describes the different land subclasses and management units. Only 2d and 3sd subclasses need subsurface drainage to control a shallow groundwater table, which is the origin of waterlogging and salinization.



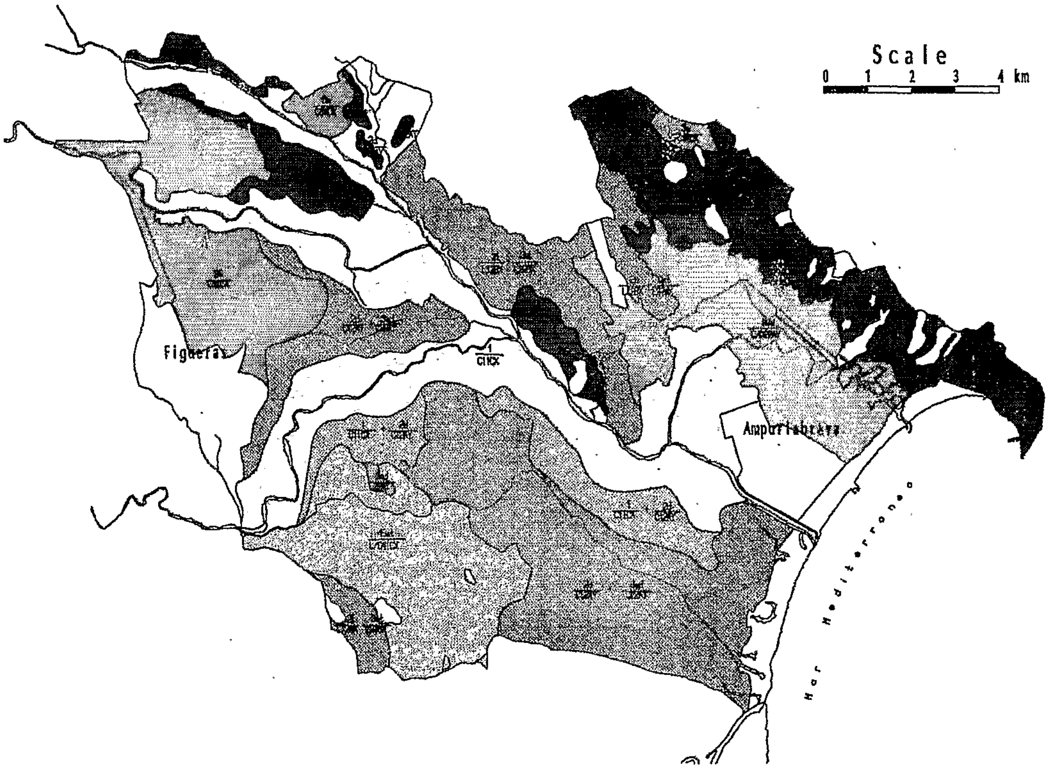
MAPPING UNIT	SLOPE %	RELATIVE RELIEF	PROFILE	CODE
Denudational hills and gentle slopes	2-6	High	Convex and right	D1
Denudational hills and steep slopes	> 6	High	Convex	[illegible]
Fluvial terraces	< 2	Medium	Flat	F6
Old flood plain	< 2	Low	Flat	F3
Present flood plain: fluvial levees	< 2	High	Slightly convex	[illegible]
Present flood plain: transition	< 2	Medium	Flat	[illegible]
Present flood plain: backswamps	< 2	Low	Slightly concave	F5
Tidal flat	< 2	Very low	Flat	[illegible]
Beach ridges and swales	variable	High and low	Concave and convex	[illegible]
Colluvial footslopes	< 2	Medium	Right and concave	D7
Alluvial fan	< 2	High and medium	Right and convex	[illegible]
Narrow valleys and small backswamps	variable	Low and very low	Variable	[illegible]

Fig. 5. Geomorphologic units map of the Muga irrigation project (IRYDA, 1989 b).



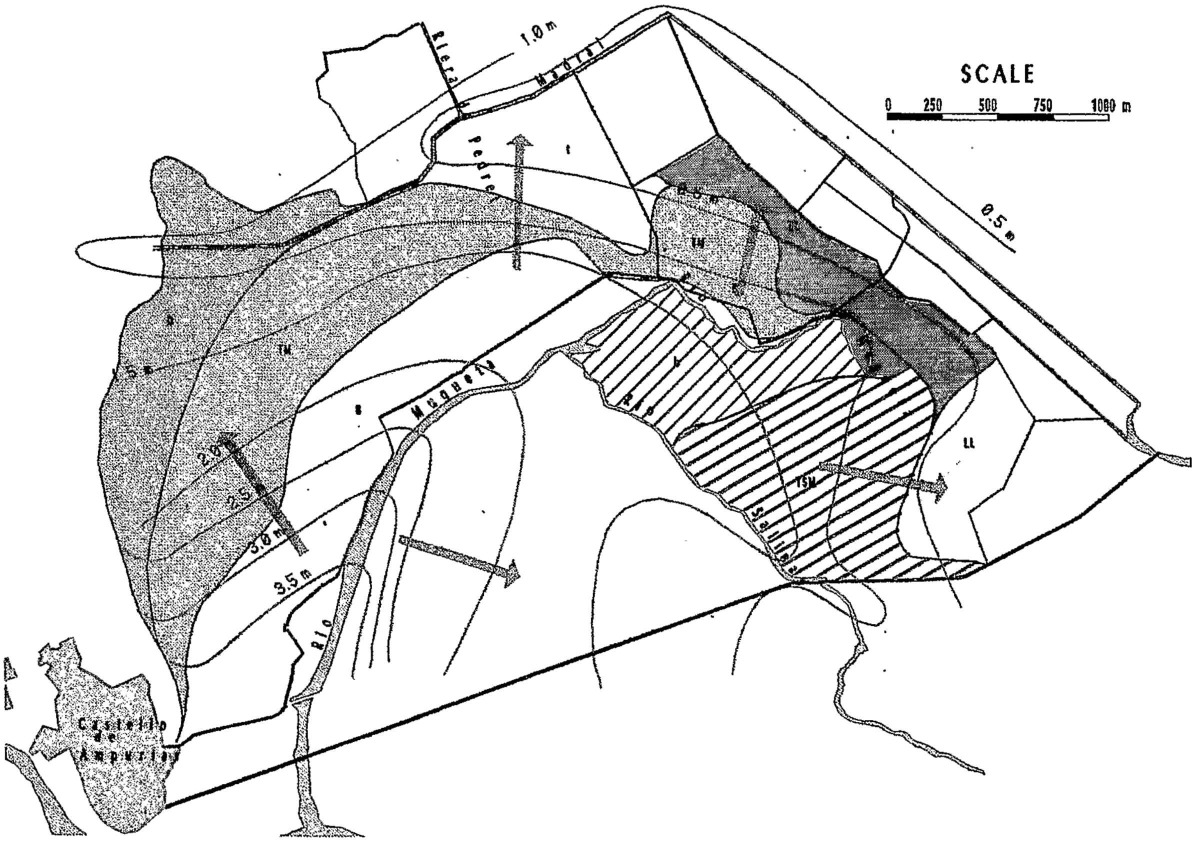
GEOMORPHOLOGIC UNIT	MAPPING UNIT	SOIL CHARACTERISTICS	FORMULA	CODE
Fluvial levee	Well drained alluvial soils	Deep and light textured soils	1 G0 I 3 4 4 AR / A D0 K3 (W0/W2)	1
Upper alluvial fan		Moderately deep light textured soils	2 G1 I 4 4 - - / A D0 - W0	2
Old flood plain		Moderately deep medium textured soils	2 G1 M 3 3 - - / A - - W0	3
Fluvial terrace		Moderately deep light textured soils with gravel subsoil	2 (G0/G1) I 4 5 5 GR / A D0 - W0	4
Fluvial terrace		Moderately deep light textured soils with sandy subsoil	2 G2 I 4 5 5 GR / (A/B) D0 - W0	5
Low alluvial fan	Moderately well drained alluvial soils	Deep and medium textured soils	1 G0 M 3 2 - AC / A (D1/D3) - W2	6
Mugueta levee		Deep and light textured soils	1 G0 (I/M) 3 3 4 AR / A D1 K1 W2	7
Flood plain transition	Poorly drained alluvial soils	Deep soils with variable textures	1 G0 (I/h) 3 3 3 AC / A (D0/D3) K3 W3	8
Backswamps		Deep medium textured soils	1 G0 M 3 3 3 AC / A D3 K2 W3	9
Tidal flat		Deep silty soils	1 G0 h 2 2 2 AC / A D1 K2 (W3/W4)	10
Backswamp		Deep clay soils	1 G0 (H/h) 2 3 2 AC / A D1 K1 W3	11
Small backswamps	Poorly drained colluvial soils	Moderately deep clay soils	2 G0 h 2 2 - AC / A D0 - W3	12
Colluvial footslope	Well drained denudational soils	Deep medium textured soils	1 G0 M 3 4 4 - / B - - W0	13
Hills and gentle slopes		Medium textured soils with variable deep	(1/2) G1 M 3 3 3 - / B D0 - W0	14

Fig. 6. Soil mapping units of the Muga irrigation project (IRYDA, 1989 b).



LAND CLASS	LAND SUBCLASS	MANAGEMENT UNIT: LAND USE	IRRIGATION METHOD	DRAINAGE REQUIREMENTS	ACREAGE: ha	%
1	1/C11CX	Good suitability arable crops	Either surface or sprinkler irrigation	No needed	3858	21.2
1+2	1/C11CX + 2d/C12AY	Moderate and good suitability arable crops		Subsurface drainage	768	4.2
2	2s/C21BX	Moderate suitability for arable crops		No needed	2496	13.7
	2d/C12AY			Subsurface drainage		
	2t/L12BX			No needed		
2+3	2d/C12AY + 3sd/C22AY	Moderate and limited suitability for arable crops		Subsurface drainage	4405	24.2
	2t/L12BX + 3st/L22BX			No needed		
3	3s/L/C31CX	Good suitability for fruit trees		No needed	3288	18.0
	3sd/L/C/D22AY	Limited suitability for arable crops		Surface and subsurface drainage		
4	4Sst/L/C41CX	Good suitability for fruit trees	Sprinkler	No needed	1565	8.6
6		No suitability			1853	10.2
					18233	100.0

Fig. 7. Land classes map of the Muga irrigation project (IRYDA, 1989 a).



CODE	MAPPING UNIT	SURFACE SOIL TEXTURE	SUBSOIL TEXTURE	SUBSOIL K (m/d)	IMPERVIOUS BARRIER DEPTH(cm)	IMPERVIOUS BARRIER TEXTURE	GR.W.T. DEPTH (m)	DRAINAGE REQUIREMENTS L(m)/P(m)
B	Mugueta levee	Loam-Sandy loam	Loamy sand	2.0	3.0	Clay	1.5	-
TM	Mugueta transition	Silty loam	Sand-loamy sand	2.0	2.6	Silty clay (gley)	0.9	50/1.3
D	Backswamp	Silty clay	Silty clay (Pseudgley)	2.0	2.0	Silty clay (gley)	0.5	30/1.3
t	Pedret-tidal flat transition	Silty clay	Silty-clay	1.6	3.0	Silty clay (gley)	1.1	30/1.3
LL	Upper tidal flat	Clay loam	Coarse sand shells	8.7	2.1	Silt	1.0	
ll	Low tidal flat	Silty clay	Coarse sand shells	8.7	1.2	Silt	0.8	Wet land
b	Salins-Mugueta levee	Silty loam	Loamy sand with loamy clay layers	3.9	2.8	Silt	1.4	-
TSM	Salins-Mugueta transition	Silt-silty loam	Sand with silty clay layers	2.7	1.7	Silt	0.9	30/1.3
———	Isohypses							
⇨	Groundwater flow							

Fig. 8. Detailed soil map with groundwater flow lines of the Sector IV, Muga irrigated area (reduced from the 1:5,000 map; IRYDA, 1989 a).

Detailed surveys for design of irrigation and drainage systems

Purposes

At detail level soil mapping has two purposes: to delineate more accurately the soil units mapped in previous surveys and to measure hydrologic soil qualities relevant for the design of the irrigation and drainage systems, namely moisture availability, infiltration rate, the thickness of the pervious soil profile up to the impervious barrier, and the hydraulic conductivity and drainable pore space of the different layers of the soil profile.

Following on with the Muga case study, once the problem areas were identified in the map (Fig. 7), the waterlogged and salt affected soils were mapped in detail, as a source information to design the drainage system.

Methods

The physiographic approach (Veenenbos, 1972) is also applied in the soil survey phase. Therefore, after completing the geomorphology map and field work a soil map comprehending soil data relevant for drainage design is obtained.

For drainage design purposes besides a detailed soil survey a hydrologic study is needed, to determine the groundwater flow in the project and surrounding areas. The mapping scale varies from 1:10,000 to 1:5,000 according to the extent of the project area. The groundwater map is designed once hydraulic head data from the aquifer have been obtained by means of piezometer recording.

Results and discussion

In the land classes map of the Muga project management units in need of subsurface drainage were identified. One of these problem areas is Sector IV of the irrigation district.

The detailed soil map of Sector IV is shown in Fig. 8, where it can be observed that drainage conditions and land qualities are different in each mapping unit. In the soil map legend different intervals of depth to the groundwater table, average hydraulic conductivity and depth to the impervious barrier are described.

In addition the groundwater flow map has been superimposed. It can be observed that the soils of the river levee are better drained and transmit water, through the transition unit, towards the soils of the backswamp, which have the poorest drainage conditions.

With this soil and water information the design parameters of the drainage system -drain depth and spacing- can be computed for each mapping unit, by applying to drainage equations the mean hydrologic constants and drainage design criteria, formulated according to the specific land use and irrigation water management. In this way the layout of the drainage system can be easily achieved.

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