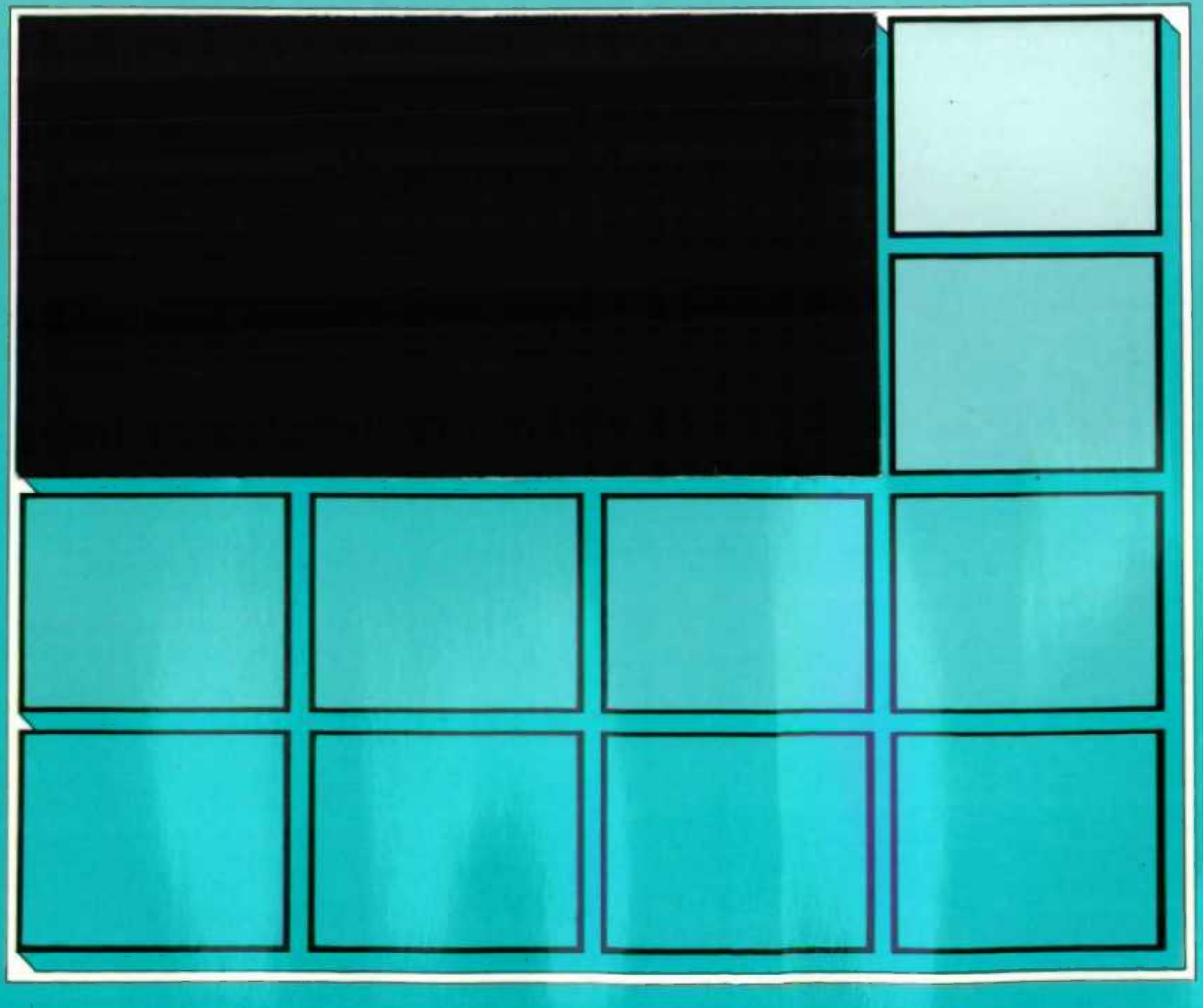
INSTITUTE of HYDROLOGY



1989

IFEDA

A review of proposed sites in South-East Spain and South-West Niger

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Institute of Hydrology report to
World Climate Research Programme of WMO

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IFEDA

ISLSCP Field Experiment in Desertification-threatened Areas

A review of proposed sites in
South-East Spain and South-West Niger

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INTRODUCTION

1.1 Background to IFEDA

The International Satellite Land Surface Climatology Project (ISLSCP) has three major objectives:

- Improvement of the usefulness of satellite data for global climatic studies
- Organization of field experiments to investigate the interaction between land surfaces, atmosphere and vegetation
- Production of data sets at a scale applicable to global climatic modelling.

A key feature is the integration of physical processes observed at a very local scale to establish effective land surface-atmosphere interactions at the scale of general circulation models. The primary approach to these objectives is through the organization of collaborative field experiments which include intensive periods of satellite, airborne and field measurements.

The First ISLSCP Field Experiment (FIFE) is taking place in Kansas. Four Intensive Field Campaigns (IFCs) were held in 1987.

Although not formally related to ISLSCP, the Hydrological Atmospheric Pilot EXperiment (HAPEX) set up in South-West France shares the objective of refining the representation of ground-atmosphere interactions in general circulation models. This experiment started in 1986.

A European/African Task Group (EATAG) was established in 1985 to provide a framework for ISLSCP-related activities in Europe and Africa. At the initiative of the World Meteorological Organization (WMO), a meeting has been called to assess the relevance to the World Climate Research Programme (WCRP) of proposals for IFEDA - an ISLSCP Field Experiment in Desertification-threatened Areas. Two possible venues have been proposed: a site in South-East Spain and a site in South-West Niger.

1.2 Request for hydrological assessment

On behalf of WCRP, Prof. Morel commissioned the UK Institute of Hydrology to prepare a hydrological assessment of the proposed study areas. Dr Reed was subsequently appointed as principal reporter. The scope of, and schedule for, the review were agreed in November 1988.

1.3 Scope of review

The primary objective of the assessment is to ensure that the siting of IFEDA takes due account of the known hydrological characteristics of the regions. A secondary outcome is the provision of summary information and reference lists - for both the South-East Spain and South-West Niger study proposals - within a single document.

The review had to be compiled relatively swiftly and the brief did not permit field inspection of sites within the proposed study areas. With the full cooperation of many organizations, it has nevertheless been possible to assemble much information and to present this in a reasonably systematic fashion. It is hoped that in due course this review will stimulate further, more comprehensive, reporting of the hydrology of the selected IFEDA study area.

1.4 Structure of report

The proposed study areas in South-East Spain and South-West Niger are reviewed separately, through duplicate mini-reports. The final section of the main report (Section 9) reviews the suitability of the study areas and draws attention to some of their contrasting features.

2. PRE-EXISTING PROPOSALS

2.1 Lead organization

The lead organization is the University of Valencia (UV), with Prof. Melia the principal contact. In collaboration with colleagues within the University - and with the Instituto Nacional Meteorologia (INM) - he is preparing a formal proposal to WCRP for IFEDA to be held in South-East Spain.

2.2 Possible sites

Earlier in 1988, it was suggested that a 10km x 10km field experiment might be held in a semi-arid area of South-East Spain. Possible sites were visited in June 1988 by a group of scientists collaborating in European ISLSCP research.

In the weeks preceding our visit, it was suggested to Prof. Melia - principally by Prof. Bolle - that a much larger field experiment was required if the proposal were to be within the terms of reference of WCRP research. The Spanish group were asked to identify a 50km x 50km or, ideally, a 100km x 100km study area that was both desertification-threatened and reasonably homogeneous (so that local irregularities would not add to problems of reconciling experimental results obtained at different scales).

Such an area was identified by Prof. Melia's group on the day of our arrival in Spain. It is a 100km x 100km area in the province of Castilla-la-Mancha, centred approximately 130km southeast of Madrid (see Fig. 5.1, Section 5).

3. ORGANIZATIONS VISITED

3.1 Programme

Dr Reed and Dr Bromley had four working days in Spain. The first day was spent in discussion with Prof. Melia's group, the second in visiting related research organizations in Valencia. The third and fourth days were spent in Madrid, visiting a range of mainly national organizations.

The meetings had three objectives. The first was to introduce the concept of IFEDA, where this was not already known. The second aim was to gain an impression of the nature of research undertaken by the organization and its possible relevance to IFEDA. The third, and most important, objective was to secure the information necessary to an appraisal of the hydrology of the proposed study area.

Appendix 1 lists the organizations visited and people met.

3.2 Univ. of Valencia, Faculty of Physical Sciences

Prof. Melia heads the Thermodynamics Department, which includes both basic research on thermal processes (inc. evaporation)

and a Remote Sensing (or Teledetection) Unit.

The Remote Sensing Unit is using METEOSAT, NOAA, LANDSAT and SPOT data in a range of studies. Ernesto Lopez has used METEOSAT visual channel (qualitative) data to look at surface reflectance (albedo). The minimum reflectance in images gathered over a ten day period showed the proposed study area (see Section 5) to be notably homogeneous in terms of surface albedo. Ampara Gilabert is using LANDSAT data to map crop types: for example, citrus orchards. Another application has successfully distinguished types of rice. Vicente Caselles is a prolific researcher who has published on a range of topics, including the spectral signature (LANDSAT images) of frost-affected citrus crops, frost forecasting, atmospheric correction of LANDSAT images, and estimation of evapotranspiration using satellite temperature and albedo images.

The Unit uses a PERICOLOR 1000 image-processing system with built-in software, and some PCs.

Under Prof. Melia, the Remote Sensing Unit has established close links with many other researchers who use teledetection for a range of applications, principally within the Valencia province. Prof. Melia is also president of a National Remote Sensing Group which publishes proceedings of its annual symposia, the second of which was held in Valencia in December 1987.

3.3 National Meteorological Institute (INM)

We did not meet Alberto Lines (who had attended the Spanish group's planning meeting) but met instead regional representatives, Luis Sanchez and Francisco Andres. INM publishes climate station data in a standard form; there are reasonably long records for several stations in the study area (see Subsection 6.2).

INM is part of the Transport, Communications and Tourism Ministry. The Spanish group suggest that the most intensive experimental periods scheduled for Apr/May and Aug/Sep be postponed from 1992 to 1993. This is because INM will be heavily committed in 1992 in connection with the Olympic Games (Barcelona) and the World Trade Fair (Seville).

3.4 University of Valencia (UV), other faculties

As in many other countries, hydrology in Spain is studied by many different disciplines in a range of institutional settings. The geographers and soil scientists at UV are concentrated on an older campus just east of the city. The work on soil classification and mapping undertaken in the Pharmacy Faculty was particularly impressive. Using aerial photography and detailed sampling of some 20 soil characteristics they have produced a number of thematic maps of the Valencia province, for example showing land capability, erosion risk, as well as maps of lithology and soil types. They would be well able to apply similar techniques to produce an improved soil map for the study area, and expressed an interest in doing so.

3.5 CSIC Unit of Desertification, Valencia

Consejo Superior de Investigaciones Cientificas (CSIC) is the national scientific research council and has many research institutes. The Unit of Desertification has worked very closely with the soil scientists in the Pharmacy Faculty (see Subsection 3.4) in the preparation of the thematic maps for the Valencia province. Much of the physical, chemical and simulated rainfall analyses of soil samples are undertaken in this laboratory. D. Rubio spoke further of the integrated cartographic database being assembled for the Valencia province.

D. Rubio also collaborates in a number of international projects, their focus being improved understanding, mapping and land management with particular regard to erosion. He cited afforestation as an example of land use that was not always working well in Spain.

That much erosion research has been concentrated along the Mediterranean coastal provinces (especially Valencia and Murcia) reflects the particular problems in this zone. While some of this is related to topography (steep slopes) and soil and vegetation types, a key factor is the incidence of intense storms. These arise as warm, moist air arriving from the Mediterranean is forced upwards when it meets the main Iberian plateau.

D. Rubio expressed only moderate interest in joining a project in which erosion was possibly a secondary topic. We were given the impression that a prior approach (Prof. Bolle to CSIC headquarters, Madrid ?) had backfired in some way.

His participation in existing international projects (LICC, LUCDEME and the CEC soil erosion model project) make him well placed to advise on aspects of these soil erosion projects that may be complementary to IFEDA. He is the Spanish representative to a CEC committee (programme DG6 - Science R&D).

3.6 CSIC Institute of Edafology and Vegetal Biology, Madrid

This Institute also works in soil science, with more emphasis on agronomy than on erosion and desertification per se. D. Labrandero and colleagues have experience in applying remote sensing data, partly in collaboration with IGME.

3.7 National Geological Institute (formerly IGME), Madrid

Instituto Tecnologico Geominera de Espana (IGTE) is the national organization concerned with geological survey and research. It publishes a wide range of high quality geological and hydrogeological information, referenced under IGTE's former IGME name (Instituto Geologico y Minero de Espana)

The Institute is using remote sensing techniques in a number of applications. Of particular relevance to IFEDA is their joint work with CSIC (see Subsection 3.6) in detecting irrigated subareas and crop types in La Mancha.

We met Da. Ascuncion Riaza who, with Da. Carmen Anton, has many years experience in remote sensing applications. They collaborate with the CSIC erosion unit in Murcia, the University of Murcia, the French geological research institute BRGM, and others, in studies of soil erosion potential in the Adra valley in Almeria. IGME also have cooperative links with remote sensing scientists in the USA (New Orleans) and the UK (Southampton, Reading and Bristol universities).

IGME have undertaken hydrogeological studies in many parts of Spain. Of particular interest is the work of Vicente Fabregat, who has studied the hydrogeology of Castilla-la-Mancha generally, and the three main aquifers in the study area in particular.

3.8 Geological Service, Madrid

Servicio Geologico is the hydrogeological arm of MOPU, the Ministry of Public Works and Urbanization. It deals with groundwater resource and supply problems encountered in regions throughout Spain. The organization has published a series of hydrogeological reports dealing with the Llanura-Manchega region of Castilla-la-Mancha. This corresponds with the central and southern parts of the proposed IFEDA study area. Servicio Geologico's consulting role allows little scope for research but their detailed reporting of the hydrogeology of much of the study area is of considerable relevance (see Subsection 6.5).

3.9 University Complutense, Madrid

The Geodynamics Department in the Geological Sciences Faculty undertakes hydrogeological research, in part in the proposed IFEDA study area. Da. Zazo has researched the geomorphology of La Mancha, including a study of Quaternary climatic change. Prof. Llamas is a widely published groundwater authority who also has experience of the La Mancha region. Two recent publications concern the impact of falling groundwater levels on the wetlands close to the south western edge of the study area (the Tablas de Daimiel national park).

3.10 Centre of Hydrological Studies, Madrid

The primary role of this organization appears to be to collate, vet and publish data from river gauging stations in the national network. Annual or biennial reports are produced for individual hydrographic basins; tables give daily flows and some summary statistics (eg. mean annual rainfall and runoff for a 25-year standard period). The reports are produced several years in arrears but we understand that the database held on computer is reasonably up-to-date. Many of the stations do not have limnigraphs; the daily flows in such cases are presumably calculated from one or two water level observations only. The basins relevant to the proposed study area are the Guadiana and the Jucar. In its lower reaches, the Guadiana passes through South-East Portugal.

3.11 Hydrographic Confederation for the Guadiana

Because of language difficulties we were unable to establish the precise role of Spanish hydrographic confederations. Clearly they are responsible for flow gauging. They drew our attention to the Servicio Geologico hydrogeological studies in Castilla-la-Mancha but not to any specific hydrological studies.

3.12 Ministry of Agriculture, Fisheries and Food (MAPA)

We visited the MAPA publications department, obtaining copies of very detailed land use maps (and monographs) for much of the study area. We also obtained copies of recent reports which characterize the provincial agroclimate for Ciudad Real and Toledo. The equivalent reports for Cuenca and Albacete provinces are understood to be in preparation.

3.13 Nature Conservation Council (ICONA)

ICONA is the part of MAPA dealing with nature conservation. This includes national parks and forestry. Manuel Tuero explained the partnership of central and regional governments in dealing with environmental problems that do not readily conform to administrative boundaries. He confirmed that erosion is a high priority topic in Spain; central government now bears more than 50% of the costs of schemes undertaken regionally. He suggested that the proposed IFEDA project be drawn to the attention of the autonomous government of Castilla-la-Mancha. He did not draw our attention to any specific hydrological information but gave us a copy of the recently published report and maps dealing with erosion and erosion risk in the Jucar basin. An equivalent publication for the Guadiana basin is in preparation.

We also obtained detailed maps of forestry potential, and certain other thematic maps, from the ICONA publications department.

4. OTHER RELEVANT ORGANIZATIONS

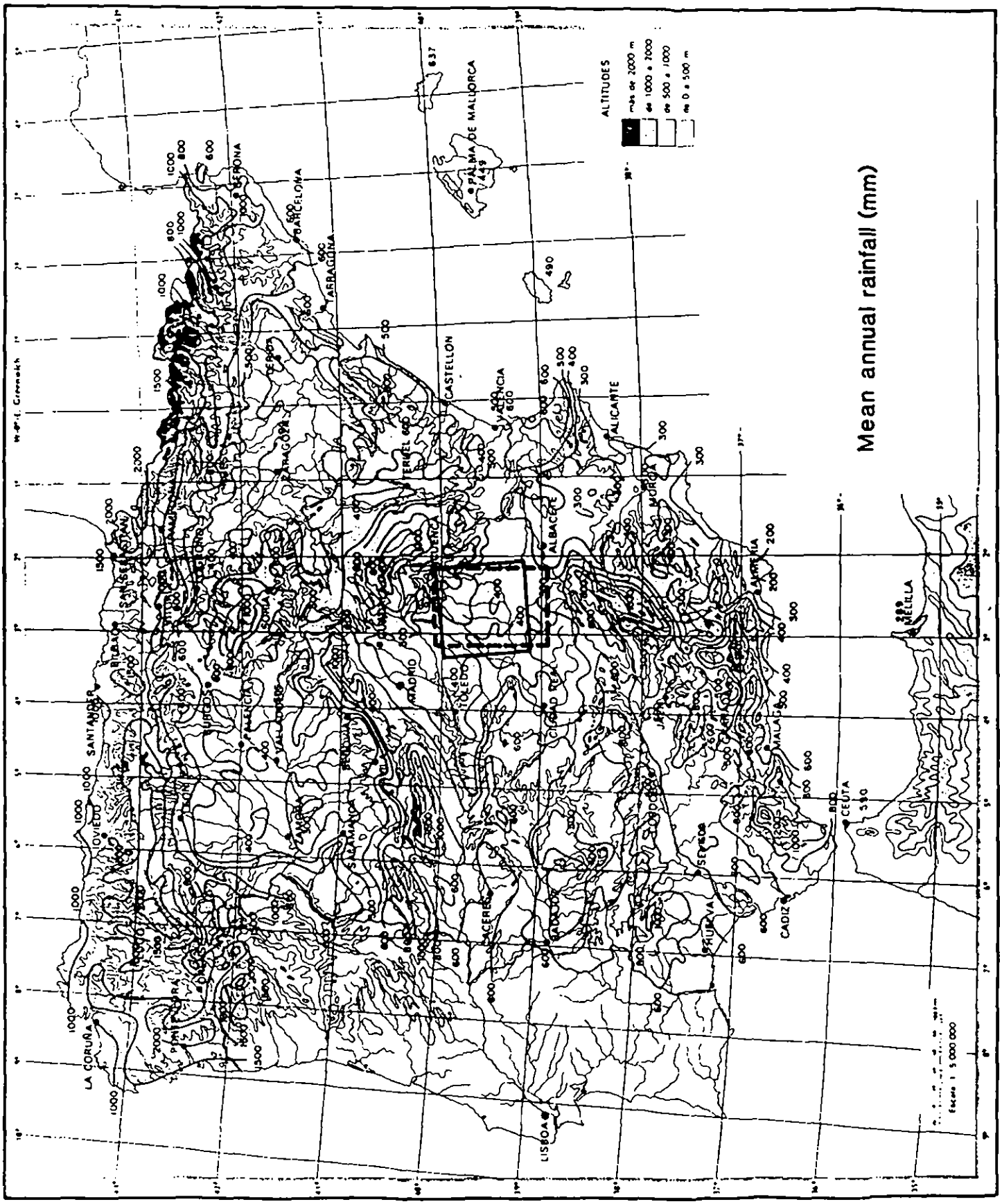
Within a period of only four days it was not practical to contact all organizations in Spain that might have an interest in IFEDA or might be a source of information about the hydrology of the study area. Appendix 2 lists several organizations that we believe may be relevant.

5. DEFINITION OF STUDY AREA

The study site proposed by Prof. Melia's group is a 100km x 100km area in Castilla-la-Mancha, approximately 130km south-east of Madrid (see Fig. 5.1). This choice gave us some difficulty.

Preparatory work for our visit to Spain had assumed that the Spanish proposal would be to site the experiment south-east of Albacete, in the general region visited in June 1988 by the group of European scientists (Section 1). Because of its 200km distance from Valencia, it was impractical to visit Castilla-la-Mancha

Figure 5.1


Mean annual rainfall (mm)
ALTITUDES
más de 2000 m
de 1000 a 2000
de 500 a 1000
de 0 a 500 m
PALMA DE MALLORCA
BARCELONA
CASTELLON
VALENCIA
ALICANTE
MADRID
TOLEDO
ALBACETE
MURCIA
SEVILLA
CADIZ
MALAGA
CEUTA
MELILLA
LISBOA
LA CORUÑA
OVIEDO
SANTANDER
BILBAO
VALLADOLID
SALAMANCA
CACERES
BADAJOZ
CORDOBA
JAEN
GRANADA
ZARAGOZA
HUESCA
LERIDA
TARRAGONA
GERONA

with Prof. Melia. We chose to spend what time we had available in Spain in visiting as many relevant organizations as possible rather than attempting to visit the site independently.

The Spanish group chose the site for the following reasons:

* It is of the general size indicated by WCRP.
  The area is vulnerable to climatic change. It is a region of mainly dryland arable farming, with wheat and sunflowers the major crops. Some irrigation takes place but is not extensive.
  The topography is relatively flat and uniform, averaging 600 to 700m in elevation. The few hills within the area are of low relief and of no significant climatic consequence.
* Precipitation has a strongly seasonal character.
* Mountain chains surround the area at a distance but their influence on weather patterns is thought to be relatively minor. Those to the north-east have a pronounced local effect on the climatology; however,this is not a dominant direction from which weather systems approach Castilla-la-Mancha.
- Communications in the area are generally good.

Our assessment does not differ radically. The characteristics of the study area (detailed in Section 6) appear to be as homogeneous as might reasonably be found in a 100km x 100km region in Spain.

However, it seems sensible to us that the study area be adjusted slightly to conform better to hydrometric boundaries. Thus we recommend the revised study area also shown in Fig. 5.1. In terms of longitude and latitude, the area is that between 2° 11' and 3° 11' W (of Greenwich meridian) and 38° 55' and 40° 5' N.

6. CHARACTERISTICS OF STUDY AREA

6.1 Regional context

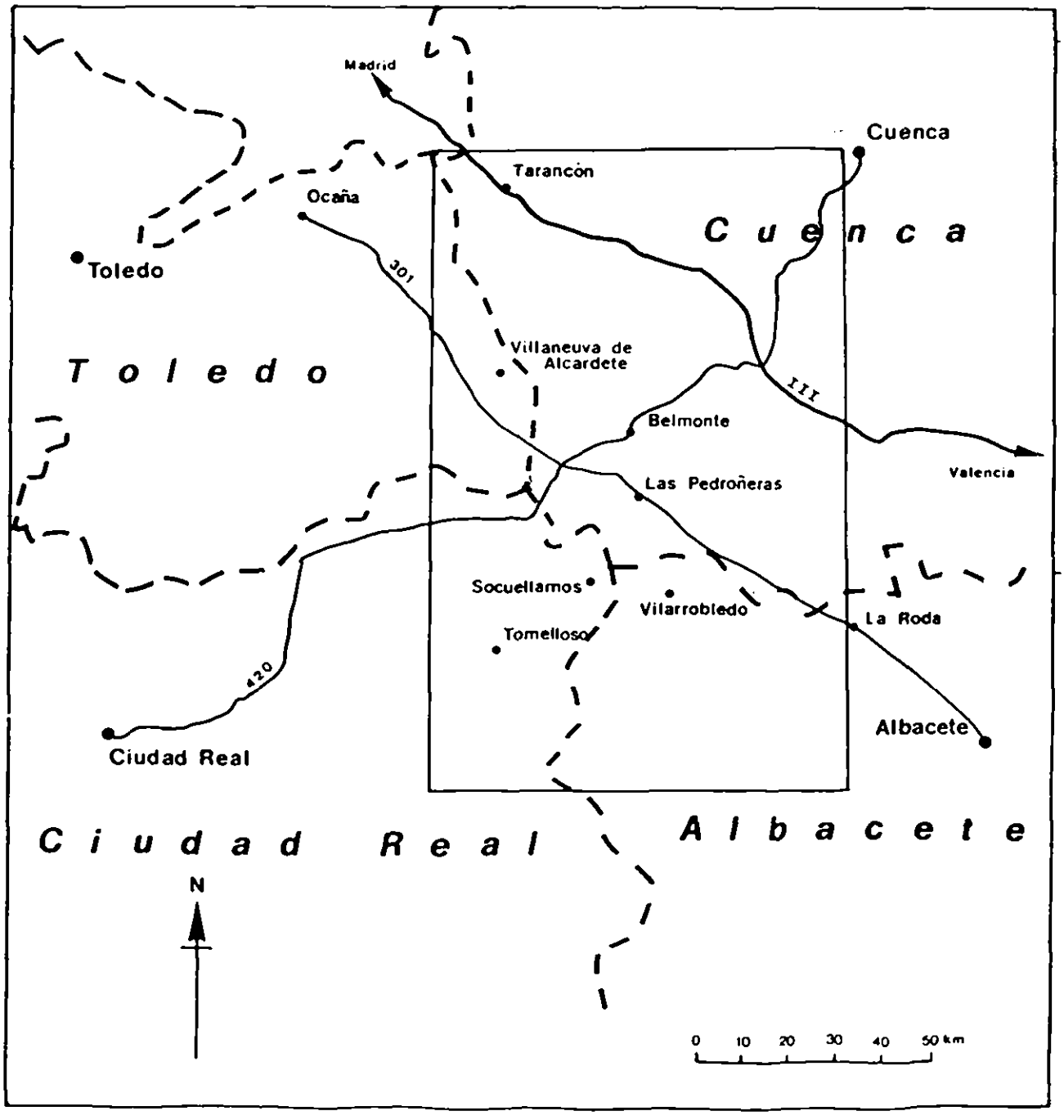
The proposed study area (see Fig. 6.1) is approximately 86km E/W by 130km N/S. It falls entirely within the Communidades del Castilla-la-Mancha. This autonomous region is the third largest in Spain (79,226 sq.km.) and comprises five provinces: Guadalajara, Cuenca, Albacete, Ciudad Real and Toledo. The 11,280 sq.km. study area includes parts of four of these provinces: 55% falling in Cuenca, 20% in Albacete, 17% in Ciudad Real and 8% in Toledo.

From Fig. 6.1 it is seen that there are no major towns in the area, but many smaller communities of which Socuellamos, Tomelloso and Vilarrobledo are the largest. The average population density of the study area is about 15 habitants/sq.km.

The centroid of the study area is between the communities of Belmonte and Las Pedroneras in the south-west corner of Cuenca province. The provincial capitals of Cuenca, Albacete, Ciudad

Figure 6.1

Regional context



Real and Toledo are respectively 80km NE, 90km SE, 120km WSW and 120km WNW. Madrid is 130km NW and Valencia 200km E.

Access to the study area is generally good. The area is transected by the Madrid/Valencia national highway (route III), the parallel Ocana/Albacete highway (route 301), and the roughly perpendicular Cuenca/Ciudad Real highway (route 420). The southern part of the area is served by railway stations at Socuellamos and Villarrobledo. Madrid airport hosts a full range of international flights. Aircraft for IFEDA remote sensing activities might fly from Albacete airport.

6.2 Topography and climate

The study area is part of the central plateau of Spain (the Meseta: typical altitude 500 to 1,000m). The topography reflects the geological history of the study area (Subsection 6.4). It is a relatively flat plain bounded by mountains to the north, east and south. Most of the study area drains west to the Rio Guadiana but a small part drains east to the Rio Jucar (see Fig. 6.2). The lowest point is about 630m, where the Rio Zancara leaves the area. Most of the area is below 900m in altitude but small parts in the south and northeast exceed 1100m.

The study area has a moderately warm, dry Mediterranean climate but with continental characteristics, notably large diurnal and annual temperature ranges. Cloudless conditions prevail for much of the summer leading to high temperatures but the effect of altitude can give rise to very low temperatures in winter, especially with airstreams from eastern Europe. This is exemplified by a very wide temperature range: the difference between January and July long-term mean monthly temperatures is typically about 20 ˚C in La Mancha.

An INM report lists long-term climate data for 12 sites in the study area. The most central are those at Belmonte and Las Pedroneras (Fig. 6.2 and Table 6.1).

TABLE 6.1

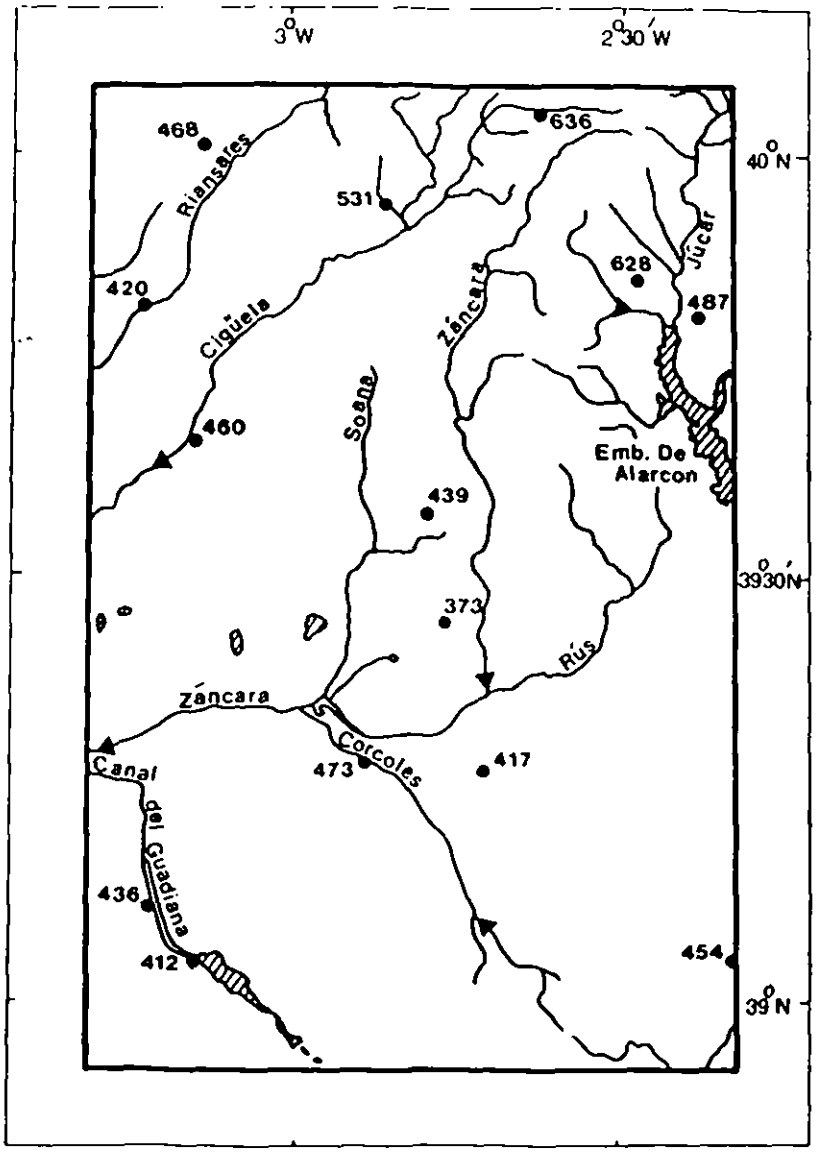
Climatic variable	Mean annual value (1941-70) Belmonte (750 m)	Las Pedroneras (704 m)
Temperature	13.8 ˚C	13.8 ˚C
Potential evaporation	771 mm	759 mm
Precipitation	439 mm	373 mm

Mean annual rainfall is little more than 400 mm in much of the study area, making La Mancha one of the driest regions in Europe. Precipitation is seasonal, with lower depths in Summer (June-August) and high year-to-year variability (see Table 6.2). Thus the periods of highest temperature and lowest rainfall coincide.

The INM report (Almarza, 1984) makes soil moisture calculations assuming a 100mm storage. For the study area, the model indicates that, on average, soil moisture begins to accumulate in late October, reaches saturation in February, begins to deplete in mid-April and is exhausted in late June. Thus late February,

Figure 6.2

River network, long-term flow gauging stations and climate stations



Scale 1:1,000,000

Legend

▲...Gauging station

●439 ..Raingauge with mean annual rainfall(mm)

March and early April is the typical period of moisture excess, while July, August, September and October are the typical months of drought.

The climate is a little less severe in the north-east of the study area, towards Cuenca city. Here the altitude and average rainfall are rather higher and average temperatures a little lower; thus a slightly longer period of moisture excess and a slightly shorter period of drought are typical.

Monthly climate data are included in the hydrometric yearbooks for selected sites. For example, monthly mean, minimum and maximum air temperatures, tank evaporation measurements and daily wet and dry bulb tempeartures are published in the yearbooks for the Jucar basin, for a major reservoir (Embalse de Alarcon) on the ENE fringe of the study area.

More comprehensive summaries of climatic data are presented in recently published agroclimatic reports for Ciudad Real and Toledo provinces (MAPA, 1988). These reports evaluate the agricultural potential and limitations of the various provinces with respect to a wide range of crop types. Similar reports for Cuenca and Albacete are in preparation. Extracts of information follow for two climate stations in the study area.

TABLE 6.2

Climatic variable	Long-term mean value	
	Socuellamos (674 m)	Villaneuva de Alcardete (725 m)
Temperature	14.0 ˚C	14.3 ˚C
Minimum temperature	7.9 ˚C	7.2 ˚C
Maximum temperature	20.2 ˚C	21.5 ˚C
Seasonal temperature		
Winter	5.6 ˚C	6.3 ˚C
Spring	12.0 ˚C	13.0 ˚C
Summer	23.8 ˚C	23.3 ˚C
Autumn	14.6 ˚C	14.7 ˚C
Seasonal min. temp.		
Winter	1.2 ˚C	0.4 ˚C
Spring	5.9 ˚C	5.8 ˚C
Summer	15.8 ˚C	14.9 ˚C
Autumn	8.5 ˚C	7.9 ˚C
ETP (evapotransp. pot.)	779 mm	785 mm
Seasonal ETP		
Winter	34 mm	38 mm
Spring	149 mm	164 mm
Summer	425 mm	413 mm
Autumn	171 mm	170 mm
Precipitation	551 mm	480 mm
Seasonal rainfall		
Winter	164 mm	140 mm
Spring	172 mm	153 mm
Summer	71 mm	61 mm
Autumn	145 mm	127 mm

6.3 Soils and land use

Much work appears to have been done on the classification and mapping of soils in Spain, in addition to the current research by CSIC and the University of Valencia, referred to in Subsections 3.4 to 3.6.

A 1:1,000,000 soil map is available in several forms. It is convenient to refer to that presented as Sheet 5 of the Soil Map of the European Communities (CEC, 1985). The dominant soils in the study area are Calcic Cambisols, with some Gleyic Cambisols in the lower central and western parts. Some Gleyic Solonchaks occur in wetland areas adjacent to the main river system, with smaller tracts of Orthic Luvisols occurring in valley bottoms higher up the drainage system. There are a few areas of Chromo-Calcic Luvisols in the slightly wetter highlands on the southern and eastern margins of the study area. The classification follows that used in the 1:5,000,000 FAO/Unesco Soil Map of the World (FAO/Unesco, 1974).

The source map used in preparation of the CEC map is the 1:1,000,000 soil map of Spain (CSIC, 1966) and is reproduced, for example, as part of the ICONA maps of vegetation (ICONA, 1987). This is shown in Fig. 6.3.

The 1:400,000 maps of natural vegetation produced by ICONA place most of the study area in the Manchegan and Aragonese Meso-Mediterranean series, with roundleaved or perennial oak.

Of greater insight are the very detailed maps of cultivations prepared by MAPA. These 1:50,000 maps are reasonably up-to-date and the accompanying monographs present a comprehensive description of the agriculture of the study area, and related factors.

We have studied monographs for about half of the 24 maps covering the study area; these deal with the central and lower central parts. The monographs indicate the following proportions of land use: 5% irrigated, 40% intensive cultivation, 39% vineyards, 3% forestry, 10% scrub & pasture, and 3% unproductive. Spatial trends in the above are for scrub & pasture to the south, irrigation to the south-west, and forestry to the east.

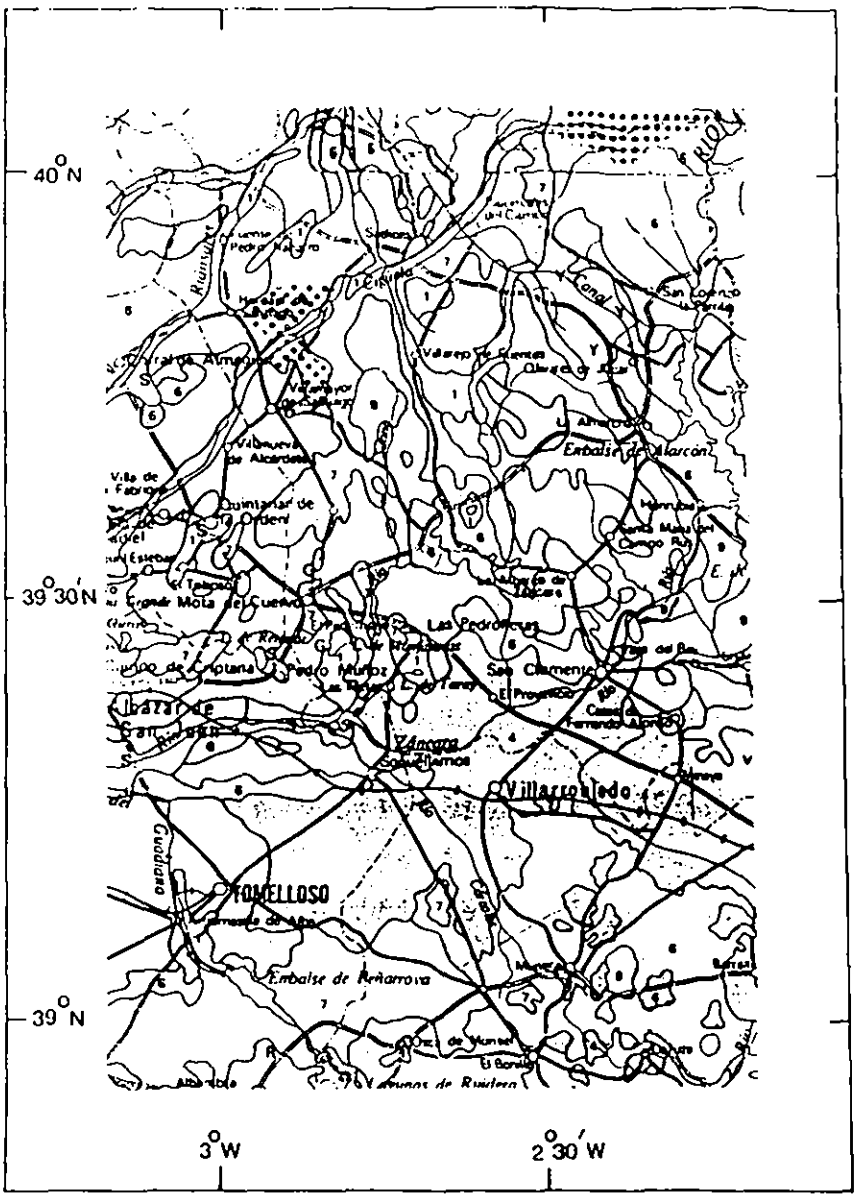
6.4 Geology

Centred in the headwaters of the Guadiana basin, the study area occupies the southeastern part of a sedimentary basin preserving strata of Tertiary and Quaternary age. The basin, roughly circular, covers about 30,000 sq km and is centred on the settlement of Tarancon, on the northern edge of the study area. The basin is encircled by rugged highlands of Mezozoic Dolomites to the east and Palaeozoic intrusives and metamorphics to the west (see Fig. 6.4).

Tertiary beds crop out in much of the study area although older strata are exposed in places, principally in the south where the Jurassic dolomites appear but also within many small scattered

Figure 6.3

Soils



Escala 1:1,000,000

1 Suelos aluviales, coluviales y transformados por el riego

Rendzoformes sobre margas calizas

Rendzoformes sobre margas yesíferas y yesos

Rendzoformes sobre margas abigarradas del Trías

4 Suelos pardos sobre depósitos aluviales pedregosos

5 Con horizonte de Mull forestal muy desarrollado sobre materiales calizos, con lavado de carbonatos. Tierra parda caliza

Con horizonte de Mull forestal muy desarrollado sobre materiales calizos, sin lavado de carbonatos. Suelo pardo caliza forestal

6 Con horizonte de humus muy poco desarrollado sobre materiales calizos. Suelo pardo caliza sobre material no consolidado

7 Con horizonte de humus muy poco desarrollado sobre materiales calizos. Suelo pardo caliza sobre material consolidado

Con horizonte de humus muy poco desarrollado sobre materiales calizos. Suelo pardo o pardo-rojizo caliza con horizonte de costra caliza

AREA DE

S Suelos salinos

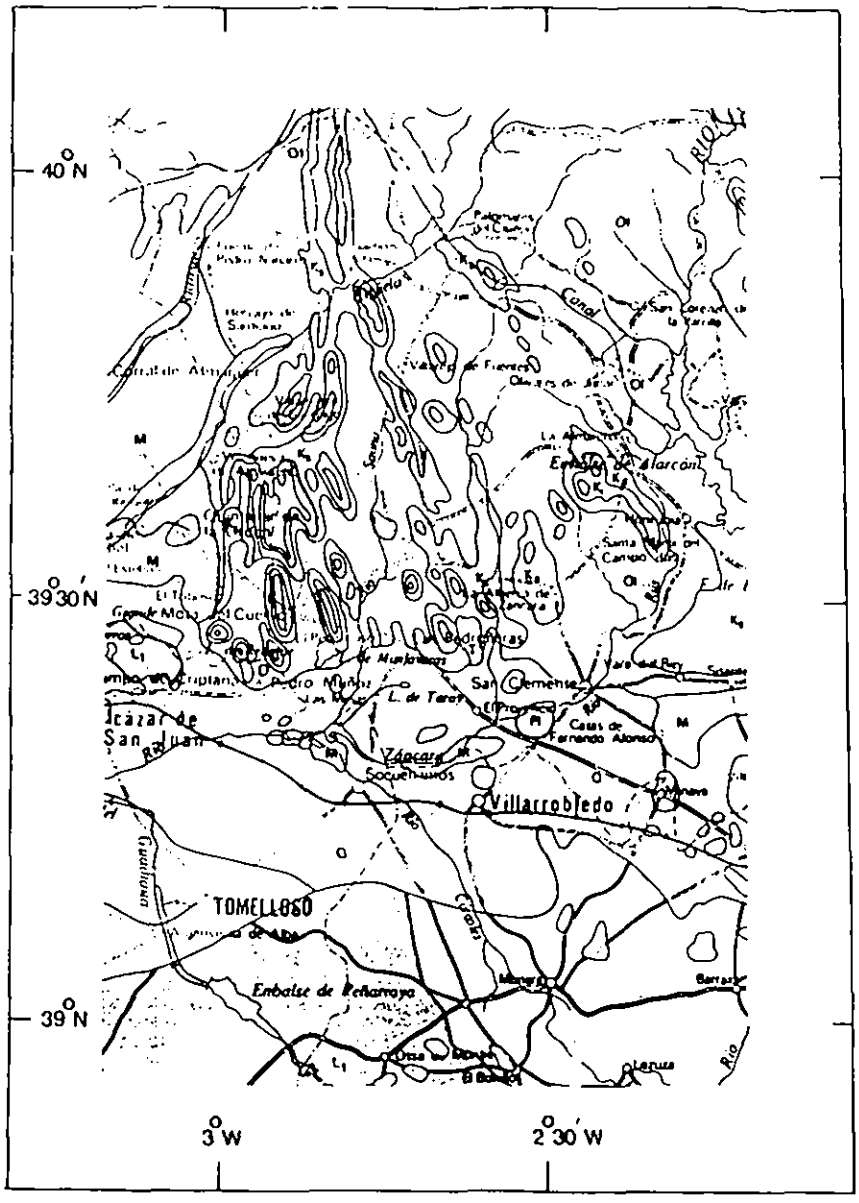
G Suelos de gley etc.

Y Suelos asociados con yesos

Asociaciones con zonas pedregosas

Figure 6.4

Geology



inliers which expose dolomites and sandstones of Jurassic and Cretaceous age.

The dolomite outcrop in the south is karstic. The remaining Jurassic and Cretaceous outcrops are mainly a series of narrow inliers driven up along a number of north-south oriented thrust planes in the northwestern and eastern parts of the study area.

Most of the study area is underlain by flat-lying Tertiary sediment of Palaeocene to Pliocene age. Younger Pliocene and Miocene beds are concentrated in the west and south of the area, whilst older Oligocene and Palaeocene formations are restricted to the north and west.

Lithology is complex but overwhelmingly calcareous in nature. Generally the Palaeocene and Oligocene tend to be the more argillaceous, with gypsum, clays and marls dominating. These formations are classed as semi-permeable.

In contrast, the Miocene and Pliocene successions are dominated by limestones and sands, with marls and clays subordinate. Commonly the limestones are karstic. These two formations provide the most important aquifers in the study area.

6.5 Hydrogeology

The study area incorporates five recognized aquifers (Fig. 6.5 and Table 6.3).

TABLE 6.3 Aquifer systems

Unit	Location	Composition
19	Altomeira	Cretaceous and Jurassic dolomites & limestones
20	N. la Mancha	Miocene and Pliocene limestones, marly limestones & sands
23	W. la Mancha	Miocene limestones, marly limestones, marls, Pliocene limestones, piedmont deposits, soils & volcanics
24	Campo del Montiel	Jurassic and Cretaceous dolomites & limestones
18	E. la Mancha	Similar succession to no. 23, but drains east to Jucar basin

Unassigned parts of the study area are considered to be largely impermeable with no significant aquifer present.

Detailed descriptions of the aquifer systems are provided in Servicio Geologico and IGME reports and maps. The central system, aquifer no. 23, is especially well researched.

Known as the western La Mancha aquifer, this system coincides with about a third of the study area. Permeable formations are the Upper Miocene limestones and the overlying Pliocene-Quartenary succession of sands, gravels and piedmont deposits. These form an unconfined aquifer which crops out over the entire

LEYENDA

I. FORMACIONES PERMEABLES GENERALMENTE NO CONSOLIDADAS

CUATERNARIO — Aluviales: Gravas, arenas y limos

TERCIARIO Y PLIOCUATERNARIO — Arcillas, arenas, arenas arcillosas, areniscas

II. FORMACIONES PERMEABLES POR FISURACIÓN Y KARSTIFICACIÓN

TERCIARIO — Calizas, margocalizas, intercalaciones detríticas

CRETACICO SUPERIOR — Calizas y dolomías

CRETACICO INFERIOR — Calizas con niveles de margas y areniscas

JURASICO SUPERIOR — Calizas y dolomías

JURÁSICO MEDIO — Dolomías, calizas y calcarenitas

JURÁSICO INFERIOR — Dolomías, carniolas y calizas

III. FORMACIONES IMPERMEABLES O CON ACUÍFEROS AISLADOS

TERCIARIO Y CUATERNARIO — Arcillas, gravas, arenas, margas, localmente niveles de yesos. Intercalaciones de lapillis, cenizas y coladas volcánicas

CRETÁCICO. FACIES UTRILLAS Y WEALD — Margas, arcillas, arenas y calizas margosas

CRETACICO-JURÁSICO — J-C — Margas y calizas margosas

JURÁSICO — J — Margas, arcillas, intercalaciones calizas

TRIÁSICO — T — Conglomerados, areniscas, dolomías, arcillas, margas y arcillas yesíferas

PALEOZÓICO — Pizarras, grauvacas y cuarcitas

COMPLEJO ÍGNEO METAMÓRFICO — Granitos, granodiontas y gneises

IV. SÍMBOLOS GEOLÓGICOS

Contacto entre formaciones

Cabalgamiento, falla

Estructura horizontal, inclinada o plegada

Estructura intensamente plegada y fracturada

V. CAPTACIONES Y OBRAS

Sondeo representativo. A: Abastecimiento a población C. Red de control de calidad P: Red de control piezométrico

Acueducto del trasvase Tajo-Segura y canal del Taibilla. A trazos tunel del Talave

Canal

A / B / C — Estación de aforo. A: Caudal medio en hm³/año. B: Periodo de medicion C: Área abarcada en km²

VI. HIDROLOGÍA SUBTERRÁNEA

650 — Línea isopiezométrica con indicación de la cota sobre el nivel del mar (Primavera, 198

Dirección del flujo subterráneo

Zona con artesianismo (1983)

Divisoria de aguas subterráneas

VIII. HIDROLOGÍA SUPERFICIAL

65 — Capacidad de embalse en hm³

Manantial. A: Abastecimiento a poblacion. C: Red de control de calidad

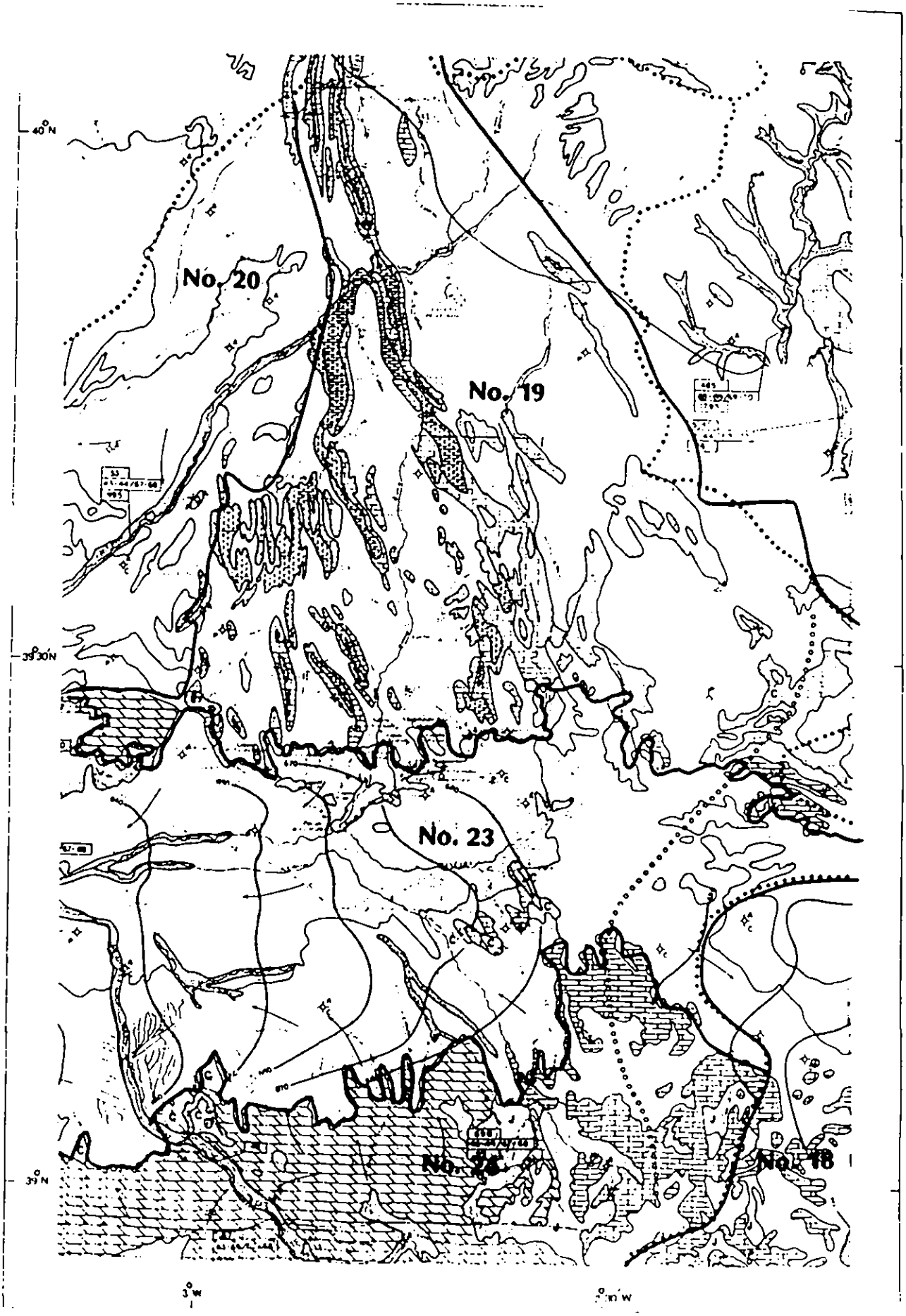
Zona húmeda

Divisoria de grandes cuencas hidrográficas

Figure 6.5

Hydrogeology

showing boundaries of aquifer systems



ESCALA 1 400.000

aquifer system area.

The base of the aquifer is defined by Lower and Middle Miocene beds, a semi-permeable sequence of clays, marls and gypsum. The composite Quaternary-Tertiary succession averages 100m in thickness.

Recharge to the system is from river infiltration, rainfall and groundwater flow from the adjacent Jurassic and Cretaceous aquifers lying to the south. In places the limestones are karstic, with sink holes carrying rivers and streams underground. In some signicant instances, notably on the Guadiana close to Tomelloso, some modification has been attempted through channelization works.

Groundwater elevations range from 690m at the Zangara-Rus confluence to about 630m at the western limit of the study area. Borehole data for the period 1974 to 1987 demonstrate a serious progressive decline in groundwater levels throughout the system. A long-term rate of depletion of 1.1 m/year is typical, with some parts having experienced a fall of more than 20m in 14 years. This serious situation has resulted from over-abstraction of groundwater resources for crop irrigation.

Until recent decades, La Mancha was predominantly a dryland farming area. However, exploitation of groundwater resources for irrigation has increased greatly and some 20% of the area of aquifer system no. 23 has been given over to intensive; irrigated agriculture. The resultant long-term depletion in groundwater levels highlights the criticality of water resources in much of the study area.

Neighbouring aquifer systems have experienced less dramatic declines in groundwater levels and these may in part be attributable to climatic effects rather than over-abstraction. There is little doubt that the region would be acutely vulnerable to a shift in climate towards higher mean temperatures and/or lower mean rainfalls.

6.6 River flows

The study area is principally drained by tributaries of the Rio Guadiana, notably the Ciguela, Zancara and Corcoles. Small parts of the eastern fringe of the area drain to the Jucar basin. As indicated in Fig. 6.3, the area includes several river gauging stations belonging to the national network. Summary information for five of these is given in Table 6.4.

TABLE 6.4 Gauged catchments

River	Gauging station	Basin area sq.km.	1st year	Mean annual r'fall mm	Mean annual runoff mm	Mean daily flow m3s-1	Max. daily flow m3s-1	Date of max.
Guadiana basin								
Ciguela	Quintanar	995	1921	507	33	1.05	39.7	4/3/78
Zancara	El Provencio	906	1923	507	37	1.08	29.7	21/3/72
Corcoles	Castellones	92	1923	456	71	0.19	11.3	6/1/70
Zancara	Cervera	5506	1953	484	12	2.47	42.2	17/2/79
Jucar basin								
Marimota	Belmontejo	187	1978				9.4	31/5/79

Some of the gauging stations record river level continuously but other data appear to be based on daily observation. The semi-arid nature of much of the study area is confirmed by the very low percentage of runoff in the upper Guadiana basin. Even main rivers such as the Zancara dry up in some summers. The Corcoles has negligible flows for much of most years, periods of significant runoff occurring relatively infrequently. The low runoff characteristics reflect both the strong influence of the hydrogeology of the area (permeable soils and underlying strata), as well as the climatic regime.

These data indicate that over-exploitation of groundwater in western La Mancha in recent decades has not had a pronounced effect on main river flows. Flow records for the Ciguela and Zancara indicate some long-term fluctuations over the last 70 years, with 1943 to 1959 very much drier than other periods. Presumably these fluctuations are of climatic origin.

The north-eastern corner of the study area is notably less arid. The Marimota catchment thus provides something of a contrast to typical La Mancha conditions. Draining to the Embalse de Alarcon - one of the ten largest reservoirs in Spain - it may be of interest in studies of water resource implications of land use and/or climatic change. Compared to the Manchegan catchments, the Marimota has a relatively swift response to heavy rainfall, with peak instantaneous flows many times greater than peak daily flows. In the time available, we were unable to verify either the quality of flow records or the availability of flood analyses.

Given the range of organizations interested in water resource and agricultural problems in La Mancha, it would seem likely that some experimental (ie. research) catchments already exist in the study area. However, we have no specific details.

6.7 Water quality

Servicio Geologico and IGME reports document several water quality parameters for the main aquifer systems in the study area. It is interesting to note that, throughout much of aquifer system no. 23, Nitrate (NO3) levels exceed 20 mg/l and, in places, 50 mg/l.

7. PRE-EXISTING RESEARCH INITIATIVES

Some existing research initiatives in Spain and Europe may have relevance to the IFEDA project. Several of these concern erosion, specifically erosion by water and its consequences for land use capability.

Lucha contra la desertificacion en el Mediterraneo (LUCDEME) fight against desertification in the Mediterranean - is a national and international project with the objectives of studying desertification processes and developing policies and techniques to fight the problem. ICONA is the arm of Spanish government under which the project resides although CSIC appear to contribute much of the scientific initiatives.

The LICC project involves biologists and soil scientists from the Netherlands; it is concerned with soil erosion and the impact of climatic change.

The CEC funds an international research project seeking to develop a European model for soil erosion prediction. CSIC collaborate with soil scientists from the University of Leuven (Belgium) and Silsoe College (UK).

LEARN is a European network of scientific and technical cooperation concerned with water management in the alluvial valleys of large rivers. One of its themes is the study of interactions between river channel and wetland systems.

BRE is a network of European researchers concerned with the collection and analysis of data from representative basins.

Some coordination of national research on remote sensing applications is achieved through a working group (el Grupo de Trabajo en Teledeteccion - GTT) with members drawn from universities and national research organizations. The group arranges symposia; the December 1987 meeting was held at the University of Valencia while that in October 1989 will be hosted by the Instituto Tecnologico Geominero de Espana in Madrid. CSIC and the Instituto Nacional de Tecnica Aeroespacial also participate.

8. DISCUSSION & RECOMMENDATIONS

8.1 Choice of study area

The choice of a study area in Castilla-la-Mancha has much merit. The region has serious water resource problems. Agriculture is no more than marginal; the low, and highly seasonal, rainfall severely limits land use and, in many years, agricultural production. Where irrigation is possible it is highly effective. However, the long-term effect of increased abstractions for crop irrigation has been to lower groundwater levels dangerously, leading to quantity, quality and environmental problems in natural wetlands. One example is the Lagunas de Ruidera National Park in the southwest corner of the study area. That remote

sensing techniques have been used to detect areas of illegal irrigation is a symbol of the critical state, and importance, of water resource management in La Mancha.

The study area is remote from the southeastern coastal strip and, as such, does not experience the most serious erosion and desertification problems that are found, for example, in Almeria. However, this is not seen as a disadvantage. Locating IFEDA in La Mancha will meet the requirement for a relatively large, climatologically homogeneous, area - and will complement existing research initiatives, which are largely concentrated in the coastal strip.

The Spanish group led by Prof. Melia suggested a 100km x 100km study area. We recommend that this be modified to the 86km x 130km area shown in Fig. 6.1. The latter choice conforms better to hydrometric catchment boundaries.

While communications to this study area appear generally good, the logic of coordinating the project from Valencia is less clear. Several groups of researchers in Valencia, notably those concerned with thermodynamics, remote sensing, soil mapping and desertification studies have much to contribute to IFEDA. However, the remoteness of Valencia from the study area is less than ideal. Had the present study area been selected at the outset, it seems likely that the project would have been coordinated from a national organization based in Madrid, through a regional organization in Castilla-la-Mancha, or by the University of Valencia establishing an outpost in the region (perhaps in the offices of a collaborating organization).

8.2 Preparatory studies

The need for some preparatory studies prior to the main IFEDA observational periods was recognized in WCRP's conception of IFEDA. Further items of preparatory work have been proposed by the Spanish group led by Prof. Melia. Rather than review these suggestions, we merely add a few additional ones.

Although soil mapping in Spain appears to be generally well advanced, we believe that work undertaken by CSIC in collaboration with the University of Valencia is producing very much better information for the Valencia province. We recommend that consideration be given to similarly detailed soil mapping of the study area.

A comprehensive hydrological survey of the study area does not exist in a single document. There is ample information available in perhaps a dozen Spanish reports but, prior to an international project, it would be valuable to pull this together in a more complete form than has been possible in our report, ideally producing versions in Spanish and English. The survey would identify key data series in the study area and might usefully include some additional standard analyses to quantify the regional water balance and flow regime.

Such a survey, perhaps by a national organization such as CSIC, might also serve to integrate hydrological research in Castilla-la-Mancha prior to the main field experiment phase of IFEDA. The survey would include site visits to the study area and might usefully assist in planning the deployment of instrumentation, both for the main field experiments and for further preparatory studies.

8.3 Acknowledgement

Finally, we record that the organizations visited demonstrated a high degree of technical competence and, in many cases, showed considerable enthusiasm for the national and international collaboration that IFEDA is generating.

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13: Madrid
18: Ciudad Real
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Instituto Nacional para la Conservacion de la Naturaleza (ICONA)
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Hydrology of wetlands in semiarid and arid regions
Proc. IAH/IAHS Intl. Symp., Seville, May 1988.

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Aprovechamiento conjunto de recursos hidraulicos superficiales y subterraneos
Servicio Geologico de MOPU, publicas no. 48, Madrid, 1988.

Ministerio de Agricultura, Pesca y Alimentacion (MAPA)
Mapa de cultivos y aprovechamientos, 1:50,000
(eg. 763: Sotuelamos)
MAPA, Madrid, various dates (eg. 1977).
Ministerio de Agricultura, Pesca y Alimentacion (MAPA)
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and
Caracterizacion agroclimatica de la provincia de Toledo
Direccion General de la Produccion Agraria, MAPA, Madrid, 1988.

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Sheet 5
Office for official publications of the European communities,
Luxembourg, 1984.

APPENDIX 1: ORGANIZATIONS VISITED

Universidad de Valencia:

Unidad de Investigacion de Teledeteccion, Dpt. Termologia, Facultat de Ciencias Fisicas

Prof. Joaquin Melia (Miralles)
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D. Vicente Caselles (Miralles)
Ma. Ampara Gilabert (Navarro)

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Soils Unit, Dept. of Vegetal Biology, Faculty of Pharmacy

Prof. Juan Sanchez (Diaz)
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Univ. Valencia
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Ministerio de Transportes, Turismo y Comunicaciones

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D. Alberto Lines (Escardo) - DID NOT MEET

Suddirector General de
Climatologia y Aplicaciones
Ministerio de Transportes, Turismo y Comunicaciones
Instituto Nacional de Meteorologia
Apartado 285
Madrid

Also

D. Luis V Sanchez (Muniosguren)
Jefe del Centro
Meteorologico Zonal de Murcia
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30107 Guadalupe
6-8834404

Also

D. Francisco Andres (Pons)
Insituto Nacional de Meteorologia
Explanada de Espana, 14
Alicante
6-5208652

Consejo Superior de Investigaciones Cientificas (CSIC)
Instituto de Agroquimica y Tecnologia de Alimentos
Valencia Unidad de Desertificacion
D. Jose Luis Rubio (Delgado)
Jefe de Unidad de Estudios sobre Desertizacion
Jaime Roig, 11
46010 Valencia
6-3690800

Instituto de Edafologia y Biologia Vegetal
D. Jose Luis Labrandero (Sanz)
CSIC
Serrano, 115 (or 155?)
28006 Madrid
1-2625020 x229

Instituto Tecnologico Geominero de Espana (ITGE)
[formerly Instituto Geologia y Minero de Espana (IGME)]
Da. Carmen Anton (Pacheco) - DID NOT MEET
Da. Asuncion Riaza
D. Vicente Fabregat - DID NOT MEET
Instituto Tecnologico Geominero de Espana
Rios Rosas, 23
28003 Madrid
1-4416500 (AR is x251 or x211)

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Da. C Zazo - DID NOT MEET
D. Javier de Pedraza
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Facultad de Ciencias Geologicas
Universidad Complutense de Madrid
28040 Madrid
1-4490060

Ministerio de Obras Publicas y Urbanismo (MOPU)

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Jefe del Sector de Hidrologie
Centro de Estudios Hidrologicos
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Servicio Geologico
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D. Fernando Anguita (Bartolome)
Servicio Geologico
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Madrid
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Also

D. Domingo Rubio (Caja) - DID NOT MEET
Comisario de Aguas
Confederacion Hidrografica del Guadiana
Edificio de Servicios Multiples
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APPENDIX 2 : OTHER POSSIBLY RELEVANT ORGANIZATIONS

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Plaza del Conde, 2
45002 Toledo

2. PRE-EXISTING PROPOSALS

2.1 Lead organization

The lead organization is ORSTOM, the French Scientific Research Institute for Development in Cooperation. ORSTOM have very wide experience in agricultural and hydrological studies in tropical countries, not least in French-speaking West Africa. Dr Hoepffner is preparing a formal proposal to WCRP for IFEDA to be located in South-West Niger.

2.2 Possible sites

In cooperation with the Niger Meteorological Service, ORSTOM have initiated EPSAT: a project aimed at developing improved estimates of precipitation by combining raingauge, satellite and radar observations. The site of the experiment is a 100 km x 100 km area just east of Niamey (see Fig. 5.1). Some sixty rain recorders commenced operation in 1988, with a further 20 stations planned for installation in 1989. The network of recorders has been designed to yield rainfall information at a range of spatial and temporal scales.

It has been suggested that a HAPEX or ISLSCP experiment might be colocated with EPSAT. The region has a severe climate, with low and unreliable rainfall, marginal land use, and a high risk of desertification. It would therefore appear to be a natural candidate for IFEDA.

3. ORGANIZATIONS VISITED

3.1 Programme

The schedule for the hydrological assessment did not permit a visit to Niger. Dr Reed had four working days at the ORSTOM laboratory in Montpellier, gathering information about the hydrological characteristics of the study area and discussing EPSAT. Certain references, notably Dubreuil (1986) and Brunet-Moret et al (1986), have helped to piece together a description of the study area; however, the hydrological assessment is inevitably rather basic.

3.2 ORSTOM

ORSTOM is a French national scientific and technical research institute, sponsored by the Ministry of Research and the Ministry responsible for Cooperation and Development. The Institute specializes in research in tropical environments, with teams active in more than 40 countries.

Hydrology within ORSTOM is centred at the Montpellier Laboratory under the direction of Dr Pouyard and Dr Jaccon. Fields of activity include the design, installation and management of remote measuring networks (eg. rainfall, climate, water level and water quality), the acquisition, management, and publication of hydroclimatological data, and the development and application of

deterministic and stochastic hydrological models. Some contact information is given in Appendix 1.

The main theme of the existing EPSAT project is the measurement and analysis of rainfall. In addition to the project leader (M. Hoepffner), the team includes an experienced analyst (T. Lebel), and a fieldwork coordinator in Niamey (M. le Barbe). Three postgraduate researchers have recently been appointed to the EPSAT project: V. Thauvin (analysing raingauge data), Y. Arnaud (analysing satellite data) and C. Roux (to study raingauge and radar data). The project also draws on ORSTOM's more general experience of hydrological investigations in West African countries, including: fieldwork, database development, statistical analysis and satellite telemetry systems.

ORSTOM's considerable experience in applying remote sensing techniques in the region is summarized by Poncet (1986) and further illustrated in the hydrological study of la Mare d'Oursi (Chevallier et al, 1988).

4. OTHER RELEVANT ORGANIZATIONS

ORSTOM works closely with the Niger meteorological service. The latter produce climatological summaries, published by the Comite Interafricain d'Etudes Hydrauliques (CIEH). There are, of course, other relevant national organizations, for example the Institut National de Recherches Agronomiques du Niger (INRAN).

ORSTOM collaborates with a range of French research organizations who also work in West Africa. Of particular relevance are those specializing in hydrogeology, agronomy and remote sensing. Hydrogeology is studied by the Bureau de Recherches Geologiques et Minieres (BRGM). Organizations carrying out agricultural research in Niger include the centre for Cooperation Internationale en Recherche Agronomique pour le Developpement (CIRAD), the Institute de Recherches Agronomiques Tropicales (IRAT) and the Institute National de la Recherche Agronomique (INRA). All these organizations make use of remote sensing techniques, often in collaboration with the Centre National d'Etudes Spatiales (CNES). Some contact information is given in Appendix 2.

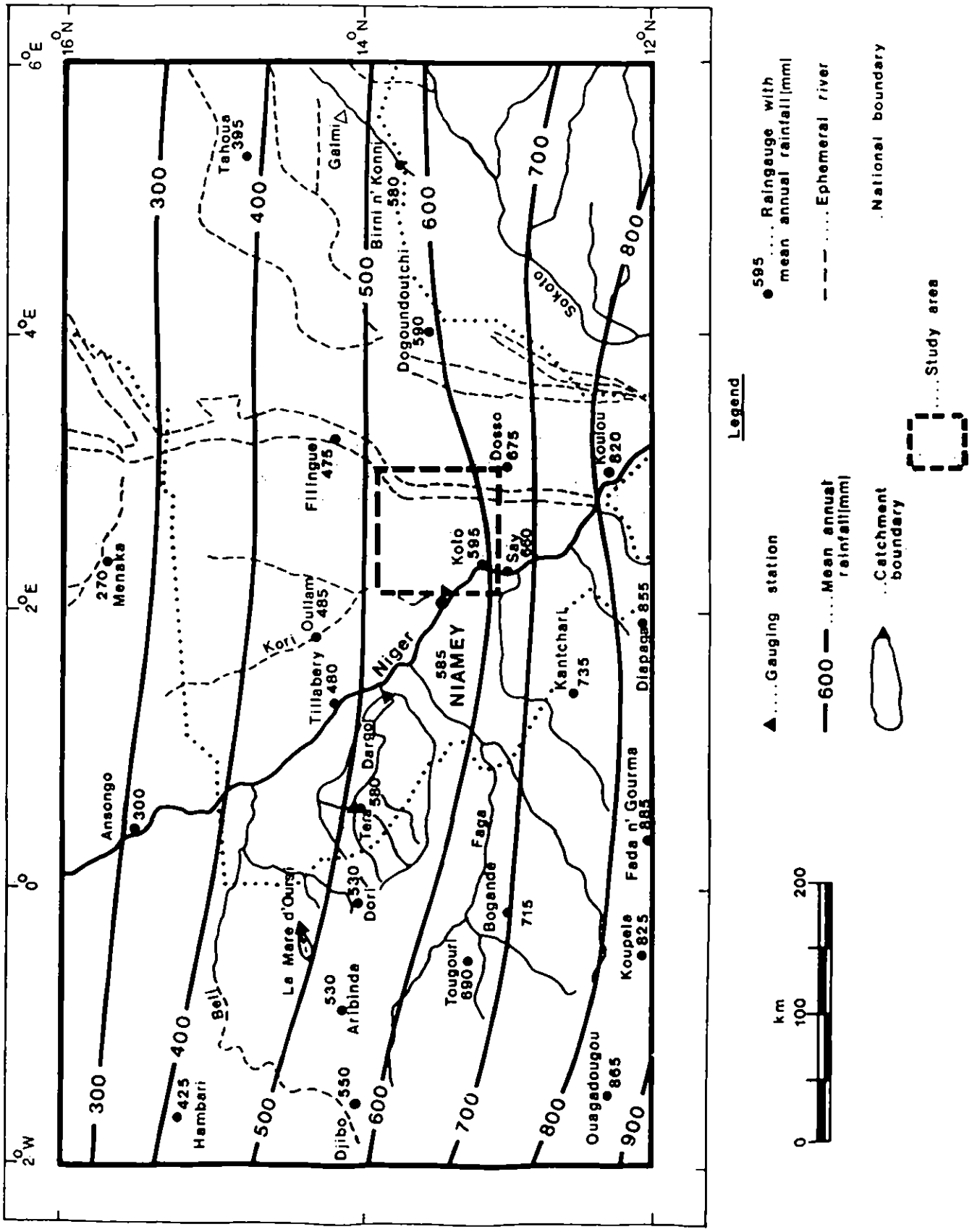
A number of major international projects are already based in, or near, Niamey (see Section 7).

5. DEFINITION OF STUDY AREA

The EPSAT study area is defined by the network of raingauges (Fig. 6.1). Some of these gauges lie along the boundary of the study area and it might therefore be said to represent an area slightly bigger than the 100km x 100km square shown on Fig. 5.1.

ORSTOM has installed additional raingauges just west of the study area to provide further integration with existing international research projects (see Section 7). It might therefore be possible

Figure 5.1


16°N
14°N
12°N
6°E
4°E
2°E
0°
2°W
300
400
500
600
700
800
900
Tahoua 395
Galmi
Birni n' Konni 580
Dogoundoutchi 580
Sokoto
Dosso 675
Kolo 595
Say 660
Koulou 820
Filingue 475
Menaka 270
Oullam 485
Kori
Tillabery 480
Niger
585 NIAMEY
Kantchari 735
Diapaga 855
Fada n' Gourma 885
Ansongo 300
Dargol
Tera 580
Dori 530
Faga
Boganda 715
Koupela 825
Tougouri 890
Arbinda 530
Djibo 550
Hambari 425
Bell
Le Mare d'Oursi
Ouagadougou 865
Legend
595 ....Raingauge with mean annual rainfall(mm)
.....Ephemeral river
.....National boundary
▲....Gauging station
600 .....Mean annual rainfall(mm)
..Catchment boundary
.....Study area
km
0
100
200

for some IFEDA experiments to be carried out in the subsidiary area, permitting continuity and coordination with existing projects. However, the assessment that follows refers primarily to the characteristics of the EPSAT study area.

6. CHARACTERISTICS OF STUDY AREA

6.1 Regional context

The study area is situated in South-West Niger, just east of the capital, Niamey. The communities of Hamdallaye, Dantiandou, Kolo, Baleyara and Dosso are in or adjacent to the study area. The most intensively monitored site is about 60km due east of Niamey (see Fig. 6.1). Closeness to Niamey makes for relatively easy access to the study area, with flights from Niamey airport. The Niamey/Dosso highway (Route National 1) crosses the south-west part of the study area.

6.2 Topography and climate

The study area lies mainly to the north-east of the River Niger and to the west of the Dallol Bosso ephemeral river system (see Fig. 6.1). The area is relatively flat with only minor undulations. The altitude range is between about 200 and 300m, although the topography is only poorly defined by the 40m contours shown on the Institut Geographique National (IGN) 1:200,000 map series. The study area lies on the Niamey ND-31-IX sheet. According to Poncet (1986), aerial photography in 1963 provides images of much of the study area at 1:60,000 scale, with limited portions close to the Dallol Bosso photographed in more detail in 1973.

The study area has a Sahelian climate. Precise definitions vary; a simple one is those semi-arid regions of West Africa which experience a mean annual rainfall of between 300 and 800mm. The isohyets in Fig. 5.1, redrawn from ORSTOM's Hydrological Monograph of the River Niger (Brunet-Moret et al, 1986), indicate that the study area has a mean annual rainfall of 500mm in the north to 650mm in the south.

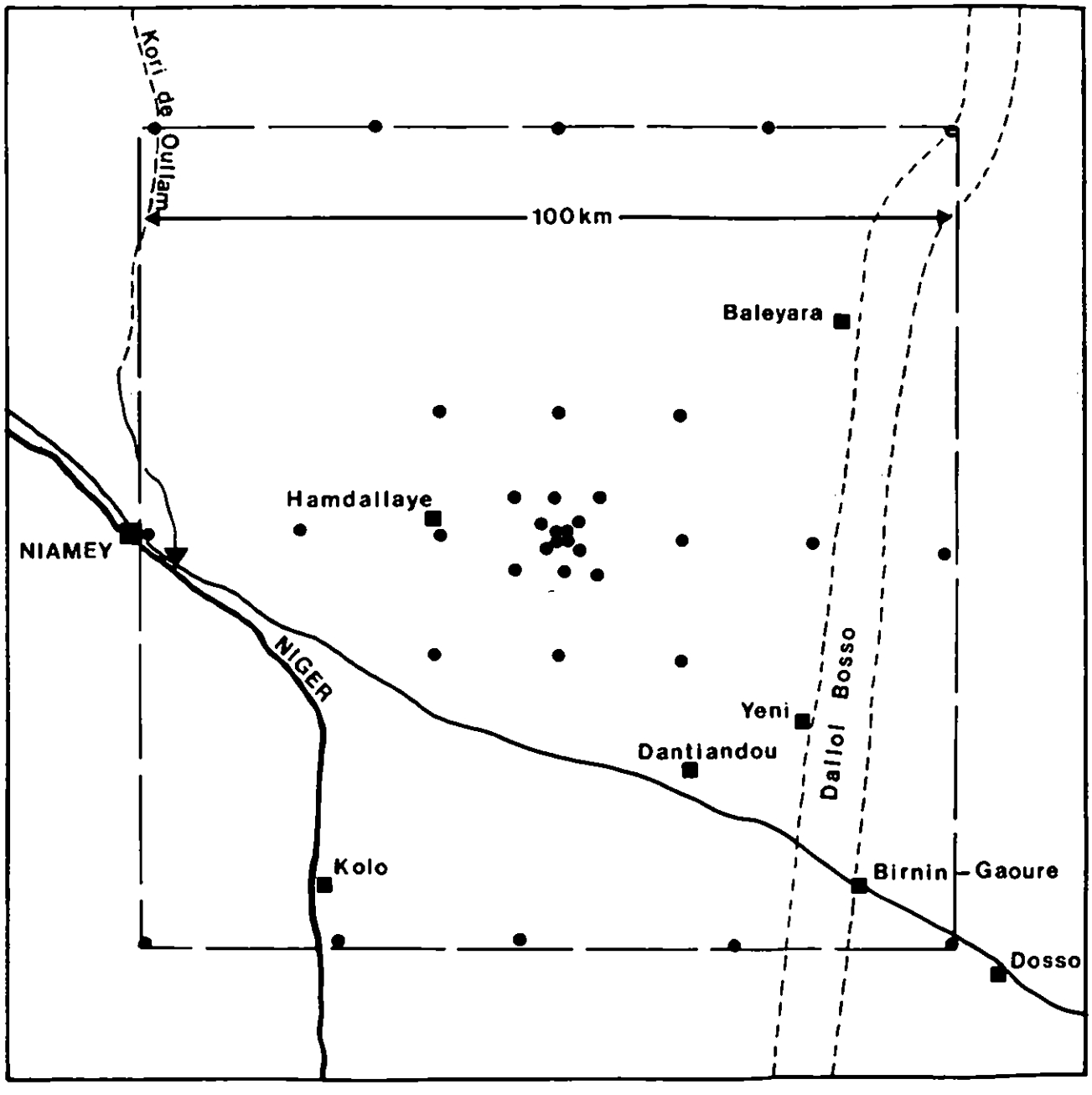
The East/West alignment of isohyets exemplifies the dominant link between climate and latitude. While the climate (and water balance, land use and vegetation) of the study area differ radically to those of the sub-desertic regions to the north and the tropical regions to the south, a corollary is that an east-west transfer of information is possible. Thus, studies of catchments such as the Dargol at Kakassi, la Mare d'Oursi and the Galmi are of interest, although only the Galmi 1 catchment appears to have comparable soils and geology.

Daily rainfall records of 40 years or more are available for Niamey (two sites), Kolo, Say, and Dosso. Somewhat shorter records are available for Yeni and Birni-Gaoure in the south-east.

Rainfall is highly seasonal. Records for Kolo indicate that the

Figure 6.1

EPSAT raingauge network



5-month period November to March is invariably rainless, with October and April generally very dry also. The rainy season extends for 2 to 4 months, with the biggest falls typically in July or August.

An analysis of 35 years of record for Kolo (1940 to 1978, omitting incomplete records for 1941-3 and 1976) yields a mean annual rainfall of 582mm and a coefficient of variation of 0.29. With regard to storm rainfall, the mean annual maximum 1-day rainfall for Kolo is 63mm, with a coefficient of variation of 0.33. Neither the annual totals nor the maximum 1-day rainfalls show a long-term trend over the period 1940 to 1978, although some year-to-year persistence is evident. However, other evidence indicates that there has been a shift in climate in the Sahelian region, with lower rainfall totals in the last twenty years leading to drought conditions (Hubert and Carbonnel, 1987).

In comparison to North-West Europe, climatic conditions in Niger are relatively favourable for rainfall observation by radar, with few "bright-band" and anomalous propagation problems. A 5cm C-band radar at Niamey provides such measurements and, from 1989, data archiving will be possible. Preliminary results from the EPSAT project confirm that rainfall occurs principally from intense storm cells passing over the area. These tend to be arranged in squall lines with considerable variability between cells. Squall velocities of 50 km/hr have been observed. Research by ORSTOM and others (eg. University of Reading, UK) has met with some success in relating rainfall depths to duration of satellite-sensed cold cloud-top cover. A typical storm duration (at a point) is 1 or 2 hours, with much of the rain concentrated in a 5 to 20 minute period when intensities often exceed 100 mm/h. Bouvier presents depth duration freuency curves for point rainfall estimation at Niamey.

Long-term climatic data are available for Niamey. Brunet-Moret et al (1986) quote a mean temperature of 28.9 ˚C from data for 1944-1954. However, climatic data for Niamey may not be fully representative of the study area because of the proximity to the River Niger.

More detailed information is given in Chevallier et al (1985) for a site in the Oursi experimental catchment in neighbouring Burkino Faso. La Mare d'Oursi is a lake fed by runoff from a closed catchment area. The mean temperature from data for 1977-1983 is 29.3 ˚C, only a little higher than at Niamey. Mean daily minimum temperature at Oursi is 21.8 ˚C, with a seasonal minimum of 15.1 ˚C in January. Mean daily maximum temperature is 35.9 ˚C, with a seasonal maximum of 40.8 ˚C in May; there is a second maximum of 38.6 ˚C in October. The lowest and highest temperatures recorded in the seven years of record are 7.6 ˚C on 26 December 1977 and 45.7 ˚C on 8 May 1983.

Chevallier et al quote a mean daily relative humidity of 34%, with a seasonal range from 17.5% in March to 62.5% in August. Mean wind speeds are highest in June and July (4.1 m/s), with the dominant direction in these months being from the south-west. Mean wind speeds are lower outside the rainy season, the dominant

direction in October to April being from the east. Mean potential evapotranspiration calculated by the Penman formula is 7.87 mm/day (for an albedo of 0.15), with a seasonal range from 6.17 mm/day in December to 9.42 mm/day in May. Chevallier et al also report monthly mean actual evaporation rates from the lake; these are generally somewhat lower than the Penman estimates.

6.3 Soils and land use

The study area has red-brown soils, classed as "ferruginous tropical soils, unleached or slightly leached" (see Fig. 6.2). A subclassification quoted by Gavaud (1977) distinguishes red soils and armoured soils within the study area but Brunet-Moret et al (1986) indicate that, away from the valley bottoms, the soils are heavily armoured and of low permeability. Collinet (1988) presents tables of physical and chemical properties of ferruginous tropical soils, by reference to the Galmi 1 experimental catchment.

Under the FAO/Unesco 1:5,000,000 soil map of the world classification, the soils are Luvic Arenosols (ie. showing lamellae of clay accumulations) with associated Eutric Regosols.

Land cover in the study area comprises savannah, "tiger bush", and some cultivated areas. The "tiger bush" is so-called because of the stripey appearance from the air. It consists of regular alternating bands of dense bush and bare, almost white, soils. Typically the bush width is about 40m, with a 60 to 80m gap between the stripes; thus it can be detected by LANDSAT or SPOT imagery. The tiger bush lands are too degraded for cultivation, being used as permanent pasture for grazing and exploited for firewood. As in the savannah, overgrazing and low rainfall can lead to further degradation and, ultimately, desertification. Bush fires present a hazard.

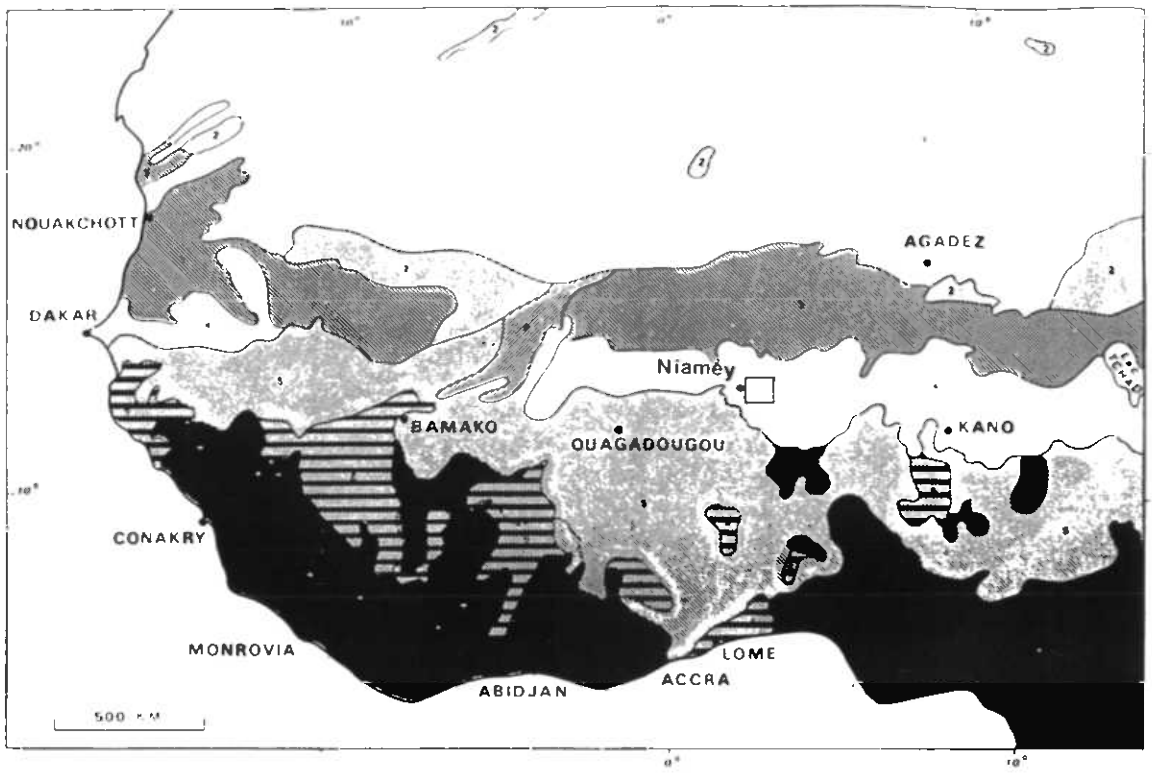
Parts of the study area support some agriculture, a typical crop being millet. The crops are often planted in the troughs of the undulating landscape, thus benefitting from such runoff as occurs. Some irrigated crops are grown immediately adjacent to the River Niger and in the lower reaches of the Dallol Bosso.

Away from the Dallols (see Subsection 6.5), trees occur only sporadically, the acacia and baobab being typical. These can tolerate long periods of drought and survive even where the groundwater level is as much as 35m below the surface. There is a substantial area of managed woodland in the south-west corner of the study area, close to the River Niger.

6.4 Geology

The study area is part of a sedimentary basin with tertiary sandstones of continental origin (see Fig. 6.3). They are of Oligocene-Miocene age. It seems that the region has been mapped only at 1:500,000 scale; however, it is thought to be relatively homogeneous.

Figure 6.2 Soils



LEGENDE

1 Sols minéraux bruts des déserts

2 Sols peu évolués subdésertiques

3 Sols isohumiques (sols bruns subarides ; sols brun-rouge subarides)

4 Sols ferrugineux tropicaux non ou peu lessivés

5 Sols ferrugineux tropicaux lessivés

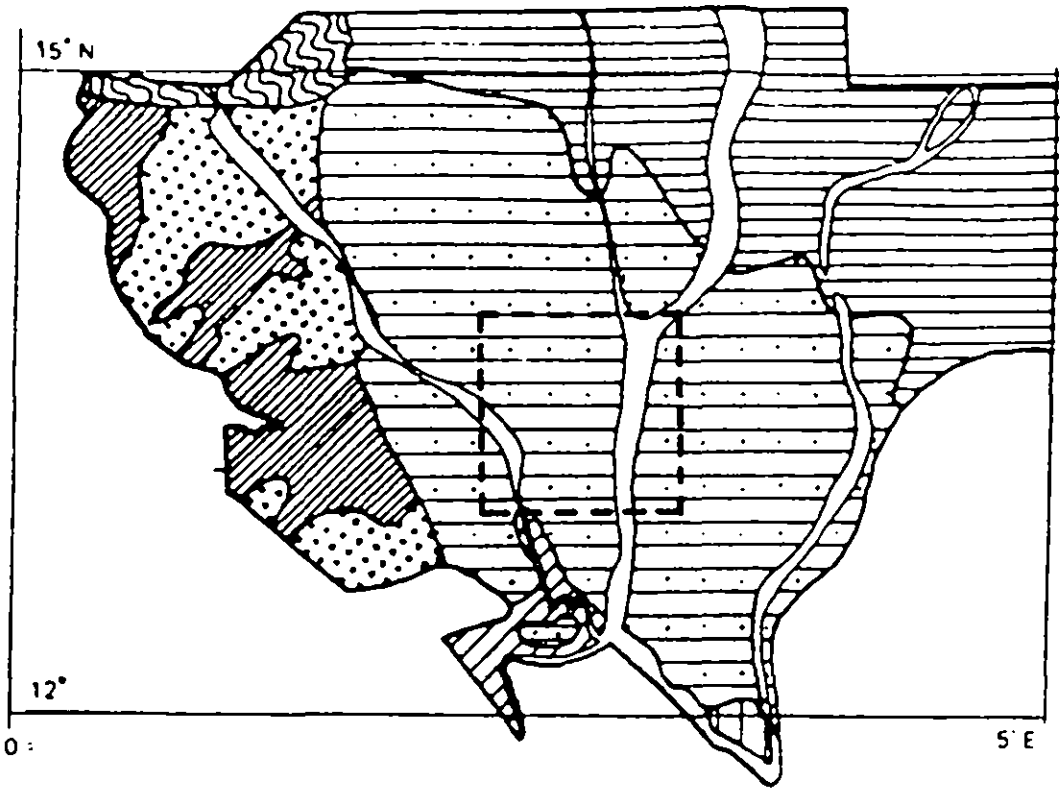
6 Association de sols ferrugineux tropicaux lessivés et de sols ferrallitiques

7 Sols ferrallitiques faiblement et moyennement désaturés

8 Sols ferrallitiques fortement désaturés

9 Sols hydromorphes

Figure 6.3 Geology



BIRRIMIEN

schistes métam.

granites

NIGERIEN

snales

VOLTAIEN

grès-quartites

CRETACE

contiental, grès

CONTINENTAL TERMINAL

Sidérolithique, Ct 1

argilites, Ct.2

grès Ct 3

QUATERNAIRE

cailloutis

The relative uniformity of the soils is attributable to the mineralogical homogeneity and the strong evolution of the material. The topographic landscape is rather more variable, because of the different degrees of mechanical resistance according to surface slope.

6.5 Hydrogeology

The hydrogeology of the study area does not appear to have been mapped in detail but further reference to the Bureau de Recherches Geologiques et Minieres (BRGM) is required to confirm this. According to Dubreuil (1986), a "planning map of water resources" is available at 1:1,000,000 scale. An adjacent area to the south-west (just south-west of the River Niger) was investigated by Barrat and Puyoo (1984) in connection with the siting of village boreholes. Their report indicates a groundwater level typically 15m below the surface in the Liptako area. But the succession of soils and geology is different, with laterites occurring frequently.

It appears that within the study area the groundwater level is typically about 30m below the surface. It is an important aquifer much used for watering cattle; however, its recharge is thought to be of purely local origin. According to Brunet-Moret et al (1986), the mode of recharge is as follows. Seasonal runoff occurs in heavy storms, travels over or close to the surface and reaches the main drainage paths. There the soils are less armoured, and the tertiary sandstones more exposed, leading to rapid infiltration of much of the flood runoff.

6.5 River flows

The area is bounded by "Dallols" to the west and east. Dallols are ancient left-bank tributaries of the Niger, which drained large parts of the Sahara in milder climatic periods. Nowadays the Dallols are large, wide valleys with much siltation. That to the east is the Dallol Bosso which, theoretically, has an immense catchment, connecting with the Azaouak and stretching north into the Sahara. In practice the Dallols flow only seasonally, receiving runoff from only a fraction of their theoretical catchment. There is no regular baseflow, despite the dominance of sandstones; the region receives too little rainfall. Nevertheless, floods occur and can have a significant impact, destroying crops and disrupting communications.

River flows in the study area occur only in the rainy season and are short-lived. Many parts of the study area consist of closed hollows, which receive runoff from a relatively small zone. In these cases the runoff never reaches a major watercourse but either infiltrates or is ponded and evaporates.

Potential drainage routes are difficult to determine from the 1:200,000 scale map available for the study area. However, there are significant catchment outlets towards the south-east corner of the study area (to the Dallol Bosso) and along the western edge of the area (to the Kori de Ouallam).

The Kori de Ouallam has recently been gauged close to the Route National 1 crossing (see Fig. 6.1). The theoretical catchment extends as far north as the Mali border but, in practice, the effective catchment is much smaller. A number of small catchments, some partly urbanized, have been gauged previously in Niamey, and have been analysed, particularly with respect to floods (Bouvier).

Over the years, ORSTOM have set up a network of representative basins in West Africa, some of which have been catalogued by Dubreuil (1972). A detailed hydrological analysis of the Oursi experimental catchments (see Fig. 5.1) is presented by Chevallier et al (1988). While the climate is similar to that of the study area, the soils are not. This also appears to be the case for the larger Tera and Dalgol gauged catchments also shown on Fig. 5.1.

The experimental catchment having soils and geology most analogous to the study area is possibly Galmi 1, approximately 350 km to the east. This is one of a number of sites for which Collinet reports very detailed studies of soil properties and infiltration. He studied percentage runoff rates using a rainfall simulator, obtaining values of about 80% runoff for a small plot. Rodier (1982) reports an analysis of mean annual rainfall and runoff for the catchment, quoting percentage annual runoff values of 22 to 41% for four years of record. It appears that this refers to an area of 29.2 sq.km.

Galmi 1 is at the head of the 45 sq.km. Galmi 4 catchment. Rainfall-runoff analysis of flood events drawn from eight years of record indicates a very flashy response to rainfall.

6.7 Water quality

From the little information seen, it appears that groundwater quality is generally good within about 30km of the River Niger; at greater distances, the degree of mineralization increases.

It is known that minor drainage paths within the study area are frequently modified by soil erosion in heavy storms. When significant runoff occurs, the watercourses presumably experience high sediment loads.

7. PRE-EXISTING RESEARCH INITIATIVES

ICRISAT is the International Crops Research Institute for the Semi-Arid Tropics. A number of major investigations are sited at the ICRISAT Sahelian Centre (ISC). This is situated just south-west of the River Niger, close to Say. The ISC serves as an African regional centre for the improvement of crops. For example, there are major programmes concerned with pearl millet breeding, sorghum improvement and groundnut improvement. A further ISC objective is to identify the constraints on agricultural development in the Sahelian zone and to evaluate means of alleviating them.

A small project based at the ISC - and of particular relevance to

IFEDA objectives - is the Sahelian Energy Balance EXperiment. SEBEX is obtaining direct measurements of available energy, evaporation and sensible heat flux from three contrasting Sahelian land uses. These are: well managed savannah, savannah denuded of much of its vegetation (due to over-grazing and/or low rainfall) and agricultural land used for growing millet. The objective of SEBEX is to determine the sensitivity of the energy balance to changes in vegetation. Clearly the vegetation types being studied bear some similarity to those found in parts of the proposed IFEDA study area.

The AGRHYMET programme is concerned with the acquisition of meteorological and other data throughout North Africa, and is also based in Niamey.

HYDRONIGER is concerned with the forecasting of flows and water quality throughout thr River Niger. French research organizations play a major role in the project. ORSTOM are responsible for the development and operation of the telemetry system, which is satellite based. SOGREAH Consulting Engineers have developed models for flow and water quality modelling. The HYDRONIGER International Forecasting Centre is sited at Niamey.

8. DISCUSSION & RECOMMENDATIONS

8.1 Choice of study area

It seems logical that the area already being investigated in the EPSAT rainfall project could realistically be adopted as a suitable study area for IFEDA. The area appears to be reasonably homogeneous in terms of climate, topography, soils, geology, and land use. The extreme south-west of the study probably experiences slightly different conditions due to the presence of the River Niger.

The proximity of the study area to Niamey, and to existing international projects (eg. ICRISAT, AGRHYMET and HYDRONIGER), should be favourable to further international collaboration. The soils and geology of the study area are, however, thought to be somewhat different to those at the ICRISAT Sahelian Centre.

8.2 Preparatory studies

It is clearly advantageous that much of the existing information about the hydrology of the region is held by a single organization, ORSTOM. The need for some preparatory studies prior to the main IFEDA observational periods will presumably be recognized in the proposal put to WCRP by Dr. Hoepffner.

While much is known about the general climatology of the region, the level of specific information about the study area is fairly limited. It would be helpful if more comprehensive mapping coud be undertaken, of the topography, soils, geology, natural vegetation and land use. Thematic maps at 1:200,000 scale would be most useful; a topographic survey to 1:50,000 scale is also desirable.

It is understood that ORSTOM propose to establish a number of experimental catchments in the study area, to complement the impressive raingauge (and climate station) network installed in EPSAT. Catchment studies are a particular theme of HAPEX-type energy balance experiments.

ORSTOM already make available a number of reports about their catchment experiments in South-West Niger and some of these are undoubtedly of relevance to an understanding of the hydrology of the study area. However, it might be helpful if this experience and data could be gathered in a single document - possibly with French and English versions - to make it readily accessible to researchers collaborating in IFEDA.

Clearly the paucity of long-term river flow data in the study area is a weakness. Given the severe and unreliable character of the Sahelian climate, it will be important to interpret IFEDA results with reference to long-term climatic conditions. This historical perspective will presumably be provided by an analysis of rainfall and temperature data. However, a long-term flow or groundwater level record in or close to the study area would be a valuable adjunct, if such a record can be found.

8.3 Acknowledgement

We acknowledge with gratitude the cooperation and courtesy extended by ORSTOM in making information and reports readily available at short notice.

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Dr. Jacques Claude	- director of Montpellier centre
Dr. Gilbert Jaccon	- research director
Dr. Bernard Pouyard	- director of continental water dept.
Dr. Frederic Moniod	- vice-president of scientific commission on hydrology and soils
Dr. Michel Hoepffner	- EPSAT project coordinator
Dr. Thierry Lebel	- rainfall, flood and spatial analyst
Dr. P. Ribstein	- flood analyst, process studies
Valerie Thauvin, Yves Arnaud, Christian Roux	research students working on EPSAT
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REVIEW

9.1 Suitability

The proposals to establish IFEDA in South-East Spain and South-West Niger have much to commend them. Both areas are at risk of desertification; neither has previously been studied intensively. However, there are notable differences between the study areas and proposals: some hydrological, some organizational.

9.2 Contrasts

a) The climate in South-West Niger is severe and restricts development.

b) The La Mancha region of Spain has a worsening water resource problem, aggravated by over-abstraction.

c) The Niger study area is typical of a wider region.

d) There are many long-term climate stations, and several long-term river flow gauges, in La Mancha.

e) The Niger study area has a newly installed and highly sophisticated raingauge network, with some climate stations.

f) The proposed study area in South-East Spain conforms well to river basins.

g) An operational radar can provide estimates of rainfall for the Niger study area.

h) Detailed mapping of topography, geology, hydrogeology, soils and vegetation is available for the study area in South-East Spain.

i) Niamey hosts many international research projects, several concerned with agronomy and meteorology.

j) La Mancha has a rich scientific and cultural heritage.

k) Niger is a developing country.

l) Spain is a member country of the CEC.

m) A single organization has much expertise in hydrological studies in Niger, and can move quickly to develop a HAPEX/ISLSCP project there.

n) The planning group in Spain wishes to postpone the Intensive Field Campaigns until 1993.

9.3 Recommendation

There is no over-riding hydrological factor that makes one or other of the proposed study areas clearly preferable. Either site would be suitable, though both would require preparatory work. For the Niger study area, there is need of more detailed mapping of topography, geology, hydrogeology, soils and vegetation. The primary need with respect to the study area in South-East Spain is to coordinate the existing hydrological data which, although extensive and detailed, are widely dispersed.

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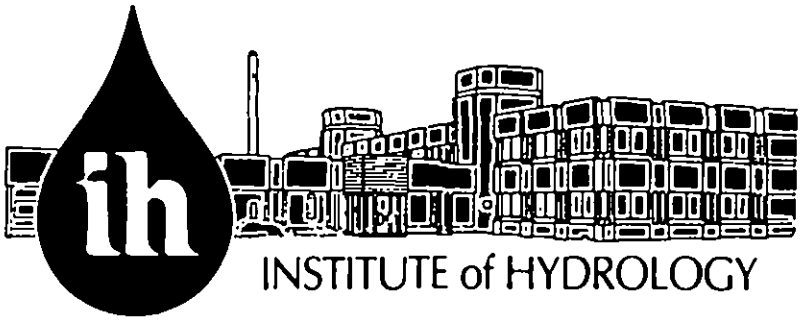

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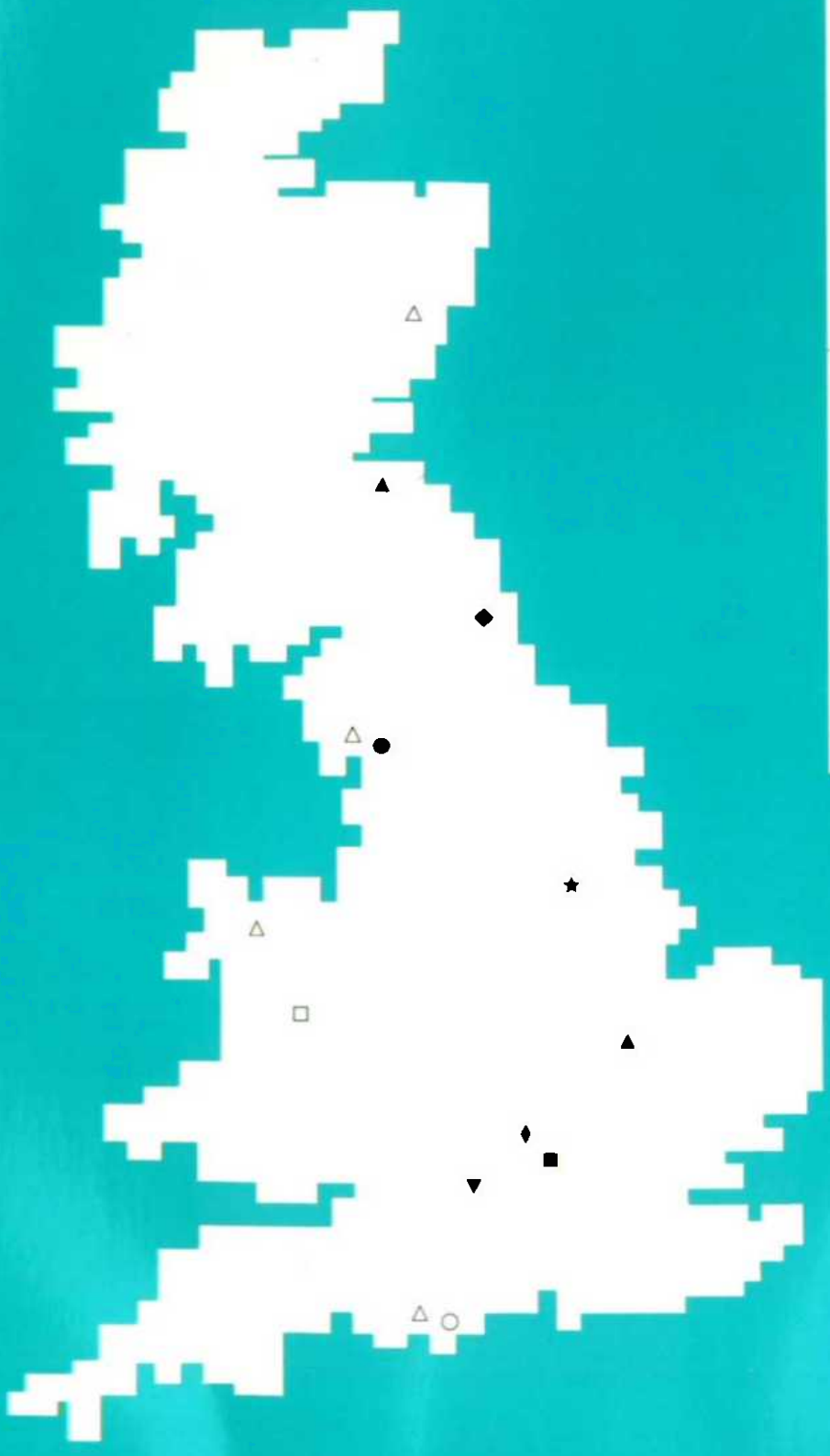

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