THE ENVIRONMENTAL IMPACTS OF IRRIGATION IN THE EUROPEAN UNION

A report to the Environment Directorate of the European Commission

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Executive Summary

Contemporary Irrigation in the EU and Accession States

1. Agriculture is a significant user of water resources in Europe, accounting for around 30 per cent of total water use. The scale and importance of irrigation is significantly greater in the southern Member States but far from negligible in most northern Member States. In the south, irrigation accounts for over 60 per cent of water use in most countries, while in northern Member States it varies from almost zero in a few countries to over 30 per cent in others. In terms of the area irrigated and the amount of water used, water demand for irrigation is relatively insignificant in Ireland and Finland, modest in Sweden, Luxembourg and Denmark, of increasing regional importance in the UK, Belgium, the Netherlands, Germany, Austria and France, and nationally significant in Portugal, Spain, Italy and Greece.

2. Among the accession states, a similar pattern is found. Historically, irrigation accounted for very little water demand in the Baltic states; it had some regional significance in Poland, the Czech republic, Hungary and Slovakia, and it was particularly important in Bulgaria and Romania. However, since the collapse of the command economies in the last decade, the use of water for irrigation declined sharply in most countries and is only now beginning to creep back upwards.

3. Within the EU, many of the crops subject to irrigation consist of fruit, vegetables and other high value produce which do not receive a high level of market support under the Common Agricultural Policy (CAP). Potatoes are one of the main irrigated crops in northern Europe. However, the irrigation of crops receiving support under the CAP market regimes, including maize, rice, tobacco and olives is also significant, particularly in some Member States including Greece, Spain, France, Austria and Italy.

4. Because most irrigation is practised in southern Europe, it is overwhelmingly associated with large numbers of very small farms. Often, the availability of irrigation is critical to the viability of these farm businesses. The socio-economic importance of irrigated agriculture within the EC is therefore considerable.

Types and Trends in Irrigation

5. Traditionally, much of the irrigation practised in Europe has consisted of gravity-fed systems, where water is transported from surface sources via small channels and used to flood or furrow-feed agricultural land (furrow irrigation). In sizeable areas of the southern Member States including Portugal and Spain, this remains the dominant form of irrigation. However, in an increasing number of regions in both north and south, irrigation by sprinklers using pressure, often drawing water from subterranean aquifers, is the most common practice. It is often in these areas where the quantities of water used, and thus the impact on the environment, can be most severe.

6. The area of land irrigated has risen in several Member States in recent years but the pattern is variable. Since 1980, the irrigated area as a proportion of total land area in the EU15 has risen almost consistently year on year, from around 2.9 per cent to over 3.5 per cent today, but this masks significant variation between the countries. In some Member States the most rapid increases were during the 1980s and growth has been slower since then (eg Spain, Portugal,

Italy), while in others the most significant expansion has been over the last decade (eg France, UK).

7. In the past, the substantial expansion of the irrigated area in several Member States including France and Spain, has been influenced by policy measures supporting the provision of irrigation infrastructure and providing subsidies to farmers installing irrigation equipment, as well as guaranteeing low water prices for agriculture. In most CEECs the area of irrigated land has fallen sharply since the late 1980s and there has also been a sharp decline in the new Länder of Germany over the same period.

8. Technical change has resulted in a series of significant transformations in irrigation technology. The most recent drip systems tend to be more efficient in their use of water but they are often far too costly to be within the means of the majority of small irrigators in the south. Thus the adoption of the most efficient water use systems tends to be concentrated in regions where farms are relatively large businesses, crops are high-value and/or water pricing is well established (eg Netherlands, UK, some regions of Spain and Italy).

Agricultural Water Management and Pricing

9. Institutional arrangements for the management of irrigation vary considerably at national and local levels. They range from systems involving unregulated, private abstractions (ground or surface) by large numbers of small producers, to centrally controlled irrigation systems, usually public-funded and owned, where collective management decisions can be made. There are also systems where the rights to abstract may be given or sold by public authorities to private individuals, either for a limited time and quantity of water use, or without specific conditions. In some cases, use rights may be transferable between landholdings, whereas in others they are tied the land. The variation in management arrangements is found as much within individual countries as between them.

10. In many countries but particularly among southern Member States, there is strong public-sector involvement in building water supply infrastructure and managing irrigation systems. In countries such as Spain and Greece with large irrigated areas, the promotion of irrigation has been an important strand of rural development and agricultural policies.

11. Water management in many southern Member States is a highly charged political issue. This study gives one example of how attempts to control water use through regulation may be almost entirely ineffective due to a combination of local resistance to these measures and the high economic value of continued irrigation to agriculture in these areas.

12. Agricultural water pricing does not follow a consistent pattern between Member States but the overall level of prices is relatively low. In the EU as a whole, especially where large, collective irrigation networks are managed by public bodies, the price of water to farmers rarely reflects its full resource and environmental cost.

13. A number of countries are beginning major reforms of water supply policies, including moving toward a greater degree of cost recovery for water supplied to agriculture. In water management, the trend appears to be towards more organised approaches with user rights and charges or the formation of user groups to manage water in the collective interest (which may be broadly or more narrowly defined).

14. In the accession countries, the collapse of the command economies also led to the decline and collapse of irrigation management. Prior to this, water use was collectively organised and funded. Today, some countries are charging increasing amounts for abstraction (eg Hungary) while most others have yet to reach this point.

15. Although the study has not included an analysis of the impact of “full cost recovery” prices it is generally assumed that these would prompt a considerable reduction in the use of irrigation water and a more limited programme of investment in new schemes in future. There is still a long way to go until a systematic approach and the full internalisation of the external costs of water use (including its environmental impacts) are achieved. Indeed, the removal of the proposal for full cost recovery from the draft text of the Water Framework Directive, which is currently proceeding through EU negotiations, suggests that it will be some time before concepts such as this become accepted by the majority of Member States.

16. For these reasons, it is anticipated that irrigation and its environmental impacts will continue to be a concern for the European Union.

Environmental Impacts

17. The environmental impacts of irrigation are variable and not well-documented in many EU Member States. The information presented in this study draws from a mix of expert opinion, case studies and published empirical research, but the latter is much more abundant in some countries (notably, Spain) than in many others.

18. This evidence suggests that some environmental impacts can be very severe, as demonstrated in case-studies from four Member States. In general, the regions with the most severe problems of permanent resource pressure are concentrated in the southern Member States, whereas these pressures are often only severe during drought periods in the northern Member States. Impacts are usually site specific, and they can be profound, even where they may occur only for a relatively short period.

19. Across Europe as a whole, the main types of environmental impact arising from irrigation appear to be:

- water pollution from nutrients and pesticides;
- damage to habitats and aquifer exhaustion by abstraction of irrigation water;
- intensive forms of irrigated agriculture displacing formerly high value semi-natural ecosystems;
- gains to biodiversity and landscape from certain traditional or ‘leaky’ irrigation systems in some localised areas (eg creating artificial aquatic habitats);
- increased erosion of cultivated soils on slopes;
- salinisation, or contamination of water by minerals, of groundwater sources;
- both negative and positive effects of large scale water transfers, associated with irrigation projects.

20. Of these, the most significant problems are indicated in relation to:

- a combination of over-abstraction of groundwater supplies, salinisation and severe pollution by nutrients, pesticides and other farm inputs in signifcant areas of intensive irrigated agriculture. These include the Spanish interior, many parts of the Mediterranean coastline from southern Portugal across to Greece, and some localised areas in northern Europe including parts of the Netherlands – these problems are exemplified in case studies from southern Europe (Daimiel, Dalias and Argolid);

- soil erosion, arising both from intensive irrigation itself, and from the abandonment of formerly hand-irrigated, traditional terrace agriculture in the hills. Erosion is a serious concern in some southern Member States including Spain, Portugal and Greece;

- the dessication of former wetlands and the destruction of former high nature value habitats including dryland arable, low intensity pastures and sensitive aquatic environments by the expansion of irrigated agriculture and its knock-on effects. This was historically a problem in many Member States, and continues to be significant in particular regions of both southern and northern Europe (eg west France, inland Spain, Hungary, southeast England). The case study of Tablas de Daimiel in Spain presents a fairly extreme example of the potentially devastating consequences of such processes, while that of the Beauce in northern France indicates how similar but less extreme issues can occur even in more temperate conditions.

21. There is a clear north-south divide apparent in these impacts. Certain impacts are common among southern Member States and relatively absent in the north (eg salinisation), while others occur in most countries but are generally more severe in the south than the north (eg nutrient pollution, erosion, habitat loss and degradation). However, in the longer term, climate change could increase the severity of drought periods and aggravate resource pressures in many regions of Europe. Particular crises in water availability are predicted for Spain, while in more northern Member States, including France, the UK and Germany, the frequency and severity of periodic drought is expected to increase, potentially driving a greater economic need for irrigation.

22. In central and eastern Europe data on the environmental impacts of irrigation is even more limited. Nonetheless, there are concerns in some countries. If the area of agricultural land under irrigation were to expand substantially, with or without Community assistance, certain pressures could be expected to increase. At the same time, there is clearly scope for improving existing irrigation schemes. More detailed analysis could help to set priorities for investment in irrigation and associated rural infrastructure, in the coming years.

Ameliorating Environmental Impacts

23. A variety of measures is available for mitigating the negative impacts of irrigation and enhancing environmental benefits where these are achievable. Some of these are technical or site specific but many could also involve policy changes and adjustments to the institutional management of water at national and regional levels.

24. Some technical measures can be applied to increase the efficiency of irrigation systems, reducing both abstractions and soil erosion, for example, switching from sprinklers to drip irrigation. However, the environmental gains may be very limited if more efficient techniques do not result in lower net water use, but simply allow an increase in irrigated volume or area.

In practice, major investment in new technology can be extremely costly and may therefore be beyond the reach of many small, private irrigators.

25. Member States can take steps to identify and exploit new sources of water previously not used in irrigation, in order to reduce overexploitation of existing sources. This can include large-scale and long-distance water transfers. However, these kinds of development can themselves cause serious negative environmental impacts if not adequately planned and scrutinised in advance.

26. It is possible to adopt less environmentally damaging or more beneficial agricultural practices associated with irrigated farming. Integrated management systems which reduce the use of fertilisers or pesticides, and mixed cropping practices which preserve greater diversity in habitats and landscapes, can both bring benefits. Farmers can switch to organic or integrated production methods, or take certain, most sensitive areas of land out of irrigated cropping (eg to create buffer zones adjacent to valuable habitats). These kinds of change could be particularly valuable in the most intensively irrigated areas.

27. There is a range of possible measures to reduce the quantity of water used in irrigation in order to mitigate environmental damage. These include economic and regulatory policies such as water metering, charging, licenses and time-limited abstraction permits. Controls over where irrigation can be practised can also avoid damage. Such measures are within the competence of different authorities, including regional and national government, water management institutions and other more local organisations.

28. The incentives available to farmers provide another avenue for encouraging best practice in irrigation. Relevant policies include compensation payments for irrigated crops under the CAP (with appropriate cross-compliance conditions) and agri-environment payments under Regulation 2078/92 and its successor in the rural development Regulation, 1257/1999. Examples of policy options at EU level are summarised in paragraphs 30-40.

29. The full implementation of existing and proposed new EU environmental Regulations in the Member States and accession countries will be an important factor in mitigating the negative environmental impacts of current and future irrigation. In particular, this study has highlighted the nitrates Directive, the habitats Directive, the Environmental Impact Assessment Directive and the forthcoming Water Framework Directive, as key policies.

Policy Recommendations – Member State Policies and Water Management Structures

30. Many of the measures required to reduce negative impacts require action at Member State level. These include the following.

- Appropriate hydrological and land use planning procedures to take a strategic overview of national water supplies, demand and trends in demand and supply.

- The development of stronger institutional structures and legislation to allocate property rights (including user rights) in ways that will support the optimal and environmentally sensitive use of limited water resources, and encourage local ownership of such policies.

- Policy developments could include the adoption of water charging regimes which internalise external costs, policies to establish collective management structures, and more widespread use of metering and independent enforcement in relation to environmental protection.

- The promotion of appropriate technologies through advice and demonstrations of best practice, supported by further research on environmental impact and valuable sites, to identify new technical options to address problems.

- In regions with particularly severe problems, a combined approach involving advice and support to encourage reduced and/or more efficient use of water, with strong enforcement of water charges and appropriate abstraction limits on users.

Policy Recommendations – EU Policy Implementation and Development

Agricultural Policy

31. New or enhanced use by Member States of agri-environment, less-favoured area and rural development measures under EC Regulation 1257/99 could include the following:

- more widespread payments to support organic or extensive rice production, or traditional mountain-terrace agriculture;
- greater support to maintain environmentally valuable dryland farming systems against the threat of abandonment or transformation to irrigated agriculture;
- payments used in combination with appropriate aids for training and investment, to encourage the adoption of more water-conserving strategies and techniques;
- the development of integrated projects under Regulation 1259/1999 to promote longer-term sustainability of environmentally beneficial systems of irrigated agriculture, combining agri-environmental schemes, marketing, processing, eco-tourism and other economic development aids, increasing their ability to compete successfully.

32. The Commission and competent national authorities should ensure thorough scrutiny of plans and projects to ensure that investment and other aid under the new rural development plans does not promote the development of irrigation in ways that will cause environmental damage. This should include scrutiny of ex-ante appraisals, mid-term reviews, and the production of guidance for Member States on how to meet the obligations of environmental protection under the reformed CAP.

33. Cross-compliance options for the Member States could include the following:

- where supported crops are grown using irrigation and water authorities have insufficient control over levels and conditions of use, conditions placed on the receipt of direct payments could require farmers to have licences and water meters as well to observe existing and forthcoming water control legislation;

- conditions could be applied to limit input use on supported, irrigated crops such as maize, rice, olives, cotton and tobacco, or to require the use of drip-irrigation to minimise erosion in ‘erosion vulnerable zones’, alternatively, all irrigated crops receiving support could be subject to nutrient or soil conservation management plans.

Environmental Policies

34. The full implementation of the nitrates Directive in the Member States will be an essential mechanism for addressing and ameliorating the serious pollution problems associated with intensive, irrigated agriculture in many parts of Europe. The forthcoming water framework Directive should also be helpful in reducing over-abstraction and related quality problems, by requiring the prior authorisation of all water abstractions and requiring catchment plans, which include measures to achieve ‘good water status’ for all surface and groundwaters, by the end of 2010.

35. The full implementation of the habitats Directive should also help to address biodiversity issues. Irrigation projects which are likely to cause damage to valuable sites or important species should be prevented or addressed by modifications, before such development is permitted. Achieving favourable conservation status for designated Natura 2000 sites and species will also require any damaging irrigation practices to be addressed.

36. It will also be important to ensure that the EIA Directive is fully implemented, particularly in respect of Annex 2 projects involving agricultural intensification on semi-natural or uncultivated land. EIA should also be undertaken in accordance with consistent quality criteria which ensure that the full environmental impacts of irrigation are assessed and evaluated. Member States must have effective means of prohibiting or modifying proposed irrigation developments where necessary, and ex-post reporting of environmental impacts should be compulsory.

37. The Commission will need to continue to take measures to encourage a swifter and more ambitious implementation of all these Directives at Member State level. A wider promotion of best practice examples could be valuable, as well as a closer linkage between the requirements of the Directives and the implementation of key related EU policies within the Member States, notably agriculture and regional development policies.

Regional Policy and Structural Funds

38. The Commission should encourage the establishment of consistent data on the most sensitive and vulnerable sites in relation to irrigation, from an environmental perspective (eg those most vulnerable to salinity, erosion, pollution, etc), to allow the most potentially damaging new irrigation or irrigation enhancement projects to be identified and avoided. As with rural development policies, EC guidance should make it clear that Member States have an obligation to exercise detailed and thorough environmental scrutiny in their regional and national appraisal systems, to identify potential negative environmental impacts and to take appropriate action.

Accession Policy

39. Similar principles as those which apply to the Rural Development measures under the CAP, and measures under Regional Policy, should also be applied to SAPARD and ISPA plans and projects. Good practice guidance could be valuable for those countries where

irrigation was formerly important and where it is likely to increase in future, as well as ex-ante evaluation of the reinstatement of irrigation, in order that limited resources are targeted using environmental as well as economic criteria.

Research and Information

40. This study has been hampered by the lack of consistent data on irrigation itself, and on related water management structures and procedures. The Commission should consider the adoption of a common classification system of irrigation to be used in gathering data within the Member States. The establishment of a database on irrigation and its impacts could be very valuable in determining future priorities for resources and new initiatives, furthering a greater strategic awareness of environmental risks in relation to irrigation within Europe.

41. More focused research to identify, analyse and promote examples of best practice in minimising or ameliorating environmental impacts of irrigation would also be beneficial. This should be drawn from different areas of Europe and further afield, where similar issues occur (eg California, Australia). Also, climate change research should include specific studies of impacts upon water resources and agricultural water demand, in the EU.

Introduction

i. Objectives of the Study

The environmental impact of irrigation is an issue of increasing importance to European agriculture. Although farm land in some regions has been irrigated for many centuries, the types of irrigation used, the amounts of water involved and the areas of land to which irrigation applies have all changed considerably in recent decades. This has given rise to a number of significant environmental impacts, many of which are expected to become more widespread and/or more pronounced in the future due to continuing technical and economic development in many of the countries concerned. These pressures also need to be considered in the context of other concerns about the aquatic environment, including the potential impact of climate change and growing demand in areas undergoing continued economic development.

The aims of this study have been:

- *to investigate and describe the current extent of irrigation in the EU* and to set this in the context of its recent development and likely future trends, taking account of economic and environmental factors (eg market trends, climate change), including a consideration of the likely availability of freshwater supplies in future;

- *to categorise the principal systems and institutional arrangements* for irrigation in different parts of the EU;

- *to identify the range of environmental impacts* (both positive and negative) of irrigation for agriculture within the EU, and to evaluate their scale, geographical distribution, and quantitative significance where possible;

- *to illustrate this with detailed case-study examples* of the most significant environmental impacts;

- *to make an initial comparison of these findings for the EU with the known situation of irrigation in applicant countries in Central and Eastern Europe*;

- *to generate and briefly evaluate a shortlist of options for improving the environmental impact of irrigation* within the EU and to highlight sources of more detailed information and analysis of these options.

ii. Methodology

The study has involved five stages, as set out below.

- **Survey of Irrigation within the EU:** This included a literature survey of European and some international research work, and circulation of a questionnaire to policy and technical experts in all EU Member States, to ascertain the extent of irrigation within each Member State. The data gathered pertains to the historic development, area covered, crop cover and types of farming and irrigation practices involved; as well as the institutional arrangements for delivery of irrigation, and economic trends, in each country. For the purposes of this survey, a classification of the main types of European irrigation has been developed and used.

- **Assessment of Environmental Problems:** drawing upon information identified in the literature search and gathered from responses to the questionnaire, the main environmental impacts were identified, and assessed in terms of their current and likely future importance for agriculture and the environment. Because much of this information was qualitative in nature (for example, based upon expert opinion or a number of specific cases), the assessment has been a predominantly qualitative one. We do not believe that it is yet possible to make an exhaustive, quantitative assessment of these impacts throughout Europe.

- **Five Case Studies** were selected from different Member States, to give a more detailed and quantitative analysis, where possible, of the environmental impacts of irrigation upon soils, water quantity and quality, microclimate, biodiversity and landscape. The case studies also looked at different strategies for ameliorating the environmental impacts of irrigation.

- **Assessment of Irrigation in Applicant Countries**: this involved a brief survey of Central and Eastern European countries to assess the extent of irrigation and nature of environmental impacts in these countries. The assessment has noted examples where the differences in institutional, economic and political arrangements between these countries and EU Member States have affected both the extent of irrigation and its impacts.

- **Practical and Policy Suggestions for Ameliorating Environmental Impacts**: this section of the report has drawn upon the information gathered for the main survey and for the case studies, and on discussion with key contacts in different Member States. A short list of possible actions has been drawn up for each of the main impacts identified, covering farm-level changes, institutional changes and policy adjustments at regional, national or European level. The suggestions have been subject to a brief evaluation to determine their ease of implementation and identify likely costs and benefits to agriculture and to the environment.

iii. Timing

The research for this project has been undertaken during the period January to December 1999. The final report of the project was completed in March 2000.

iv. Acknowledgements

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Chapter 1. Irrigation in the EU

1.1 Overview of Water Use and Irrigation

There are wide variations between EU Member States with regard to water availability, climate and aridity, leading to a heterogeneous agricultural water demand. The average annual availability of water within the EU is in the region of 1,212 km^3, equivalent to 3,326 m^3 per person per year (Eurostat). Adding the water supplied by neighbouring countries which share a number of catchment areas, the total water availability reaches 1,303 km^3 and 3,740 m^3 per person per year, respectively. However, the total volume available and the degree of reliance on water supplies from neighbouring countries differ considerably between Member States. Hence, despite the adequacy of supplies for the EU as a whole, many EU regions face problems of water scarcity (Strosser et al, 1999), and several rely heavily upon irrigation for their agricultural production.

This Chapter reviews the current pattern of irrigation in the Member States of the EU, as far as can be determined from available statistics and specific 'expert sources'. It covers the purpose and relative importance of irrigation in the EU, its sources of water, trends in its extent and use of water, and descriptions of the main technical types of irrigation found. Finally, there is a section on the main institutional arrangements by which irrigation is organised and a brief discussion of the related issue of water pricing. The intent is to provide the reader with a relatively concise overview of the context for this study, within which our more detailed examination of environmental impacts and potential policy solutions should be set.

It is important to recognise that in compiling the information in this Chapter, it has been necessary to bring together a variety of incomplete data sources and to attempt to fill in the gaps in the data through direct contact with experts and officials in the Member States. There is no single, reliable and comprehensive source of data on irrigation in the EU from which we could draw. As a result, several of the tables that we present contain figures from a number of different sources. Also, the discussion of qualitative elements such as types of irrigation and institutional arrangements has of necessity been kept relatively broad, because of the difficulties of ensuring the equivalence of terminology at a more detailed level. The aim has been to give a clear picture of main characteristics which are relevant to the environmental and policy analyses which follow, rather than to present a thorough and exhaustive catalogue of information. The latter would have required research which was way beyond the scale of resources available for this study.

Purpose of Irrigation

Irrigation can have two main purposes in relation to agricultural production:

- It can enhance the quantity of output;
- It can enhance the quality of output – for example preventing damage by temperature extremes, dessication or related crop disease.

In arid and semi-arid areas of the EU, including much of Spain, Portugal, Italy, Greece and southern France, irrigation allows crop production where water would otherwise be a limiting factor. In more humid and temperate areas including Denmark, the Benelux states, north and central France, Germany, southern Sweden, south-eastern UK and eastern Austria, irrigation provides a way of regulating the local amount and seasonal availability of water to match agricultural needs. It thus reduces the risks to crops which can arise from unexpected climatic events.

Relative Importance in the Member States

In the Mediterranean regions, water has been used for agricultural purposes by successive civilisations for several millennia and, today, irrigation is the principal user of water. Irrigation for agriculture accounts for over 80% of total water abstractions in Greece (Caraveli, 1999), 72% in Spain (Sumpsi and Varela-Ortega, 1999), 60% in Italy (Hamdy and Lacirignola, 1999) and 59% in Portugal (Caldas, 1999). By contrast, in much of Northern Europe agriculture uses relatively little water, while highly intensive water-consuming industries such as cellulose and paper production take the biggest share of total water consumption.

Table 1.1 illustrates these patterns with figures collected mainly by the OECD in 1997 and 1998. Unfortunately, these do not give a complete picture of water use in all the Member States. The European Environment Agency reports that the total use of water by agriculture in the EU is around 73 billion cubic metres per year, which represents approximately 30 per cent of total water abstractions in the Union. Manufacturing industry accounts for 25 billion cubic metres/year (10%), domestic supply for 35 billion cubic metres/year (14%) and cooling for electrical power generation around 78 billion cubic metres/year (32%).

Table 1.1: Freshwater Abstractions by Major Use (percentage)

Member State	Total abstracted in billion m^3/year *	Public Water Supply		Irrigation		Industry, excluding cooling		Electrical cooling	
	1995	**1990**	**1995**	**1990**	**1995**	**1990**	**1995**	**1990**	**1995**
Austria	2.2	33.3	31.0	8.5	8.9	20.7	21.3	37.4	38.7
Belgium	7.0	-	-	-	-	-	-	-	-
Denmark	0.9	40.9	53.0	25.6	15.8	19.2	9.0	-	-
Finland	2.4	18.1	17.2	0.9	-	69.0	66.4	10.6	15.4
France	40.6	15.9	14.6	12.9	12.1	11.1	9.7	60.2	63.5
Germany	46.3	14.1	-	**	-	23.7	-	62.2	-
Greece	5.0	-	-	-	80.0	-	-	-	-
Ireland	1.2	-	40.0	-	15.2	-	21.3	-	-
Italy	56.2	14.1	-	61****	-	-	-	-	-
Luxembourg	0.1	95.0	58.9	0.3	0.4	4.7	24.5	-	-
Netherlands*	7.8	8.0	-	1.0	-	4.0	-	87.0	-
Portugal	7.3	7.9	6***	52.6	59.0	3.3	11***	36.8	24***
Spain	33.3	11.9	12.9	64.2	72.4	-	5.6	12.2	9.0
Sweden	2.7	32.9	35.0	3.2	3.9	37.5	27.7	0.9	2.5
UK	11.8	47.0	52.0	1.3	1.2	6.2	4.3	16.9	2.2

Source: OECD, 1998, *EEA, 1999 from OECD, 1997
** other sources of data estimate this proportion at around 3 per cent, with a lower figure for cooling
*** Caldas, 1999, **** OECD, 1997

Table 1.2 shows the irrigated area in the EU Member States in 1993.

Table 1.2

Member State	**Irrigated area ('000 ha), 1993**	**Irrigated area as a proportion of total agricultural area**
Belgium-Luxembourg	1	0.1
Denmark	435	17.1
Finland	64	2.5
France	1,485	7.6
Germany	475	3.9
Greece	1,314	37.6
Austria	4	0.3
Ireland	<1	Insignificant
Italy	2,710	22.8
Netherlands	560	60.0
Portugal (1997)*	791	21.0
Spain	3,453	17.6
Sweden	115	4.1
UK	108	1.8

Source: FAO, 1995 and OECD, 1996, quoted in EEA, 1999, * Caldas, 1999

Sources of Irrigation Water

Abstraction from surface waters accounts for over 80% of irrigation abstractions in Greece (Caraveli, 1999). Surface waters are also the main source for irrigation in Spain (68%, Sumpsi *et al*, 1999), France (80%, Ifen, 1997), Germany (c.75%, Strosser *et al,* 1999), the UK and Ireland. However, in Denmark, Sweden, the Netherlands, Austria and Portugal abstraction is mainly from groundwater sources (ibid). In several Member States, either ground or surface waters may be the dominant source of irrigation water at regional level – for instance in France, where the Loire-Bretagne, Rhin-Meuse and Seine-Normandie regions are heavily dependent upon groundwater sources for agricultural water supplies (Ifen, 1997). Many coastal Mediterranean regions depend largely on groundwater sources for irrigation. In Italy, the northern regions source their irrigation mainly from groundwater, while in the south the use of surface water is widespread and large-scale surface-water transfers are found (Hamdy and Lacirignola, 1999).

Trends in Irrigated Area and Water Use

Taken together, the published statistics and the results of our questionnaire to officials in the Member States show a clear upward trend in the overall irrigated area in the European Union over the past 40 years. However there is some evidence that this trend has slowed in recent years, particularly in some Member States. Overall, the irrigated area in the EU grew from approximately 6.5 million ha in 1961 to 11.6. million ha in 1996. However, the figures in Table 1.3 indicate that the rate of growth fluctuated considerably over the thirty-two years after 1961, and declined in the 1990s.

Table 1.3 Irrigated Areas in 1,000 ha

	Irri-gated							**Increase in IA**

	Areas (IA)							'93/61, percent
	1961	1970	1975	1980	1985	1990	1993	
Spain	1,950	2,379	2,818	3,029	3,217	3,402	3,453	177
Italy	2,400	2,400	2,400	2,400	2,425	2,711	2,710	113
France*	360	539	661	870	1,050	1,476	1,468	413
Greece	430	730	875	961	1,099	1,195	1,314	306
Portugal	620	622	625	630	630	**871	**791	128
Netherlands	290	380	430	480	530	555	560	193
Germany	321	419	448	460	470	482	475	148
Denmark	40	90	180	391	410	430	435	1,088
Sweden	20	33	45	70	99	114	115	575
UK	108	88	86	140	152	164	108	0
Total for these states	6,539	7,680	8,568	9,431	10,082	11,400	11,429	175
Growth ('000 ha/yr)		127	178	173	130	264	10	

Member States are ranked in decreasing order of irrigated area in 1993. Those with irrigated areas less than 100,000 ha in 1993 are not included.
Source: FAO, * *Ifen*, 1997, **Caldas, 1999 (these figures are for 1989 and 1997)

Table 1.4 indicates how the volume of freshwater abstractions for irrigation has grown in absolute terms in some Member States, but declined in others, over the period since 1980. In most Member States where data is available the proportion of total abstractions allocated for irrigation has increased since 1980.

Table 1.4 Freshwater Abstractions for Irrigation, by Member State

	Trend in volume, 80-95	Abstractions for irrigation (million m^{3}/year)				Irrigation as a percentage of total abstractions			
		1980	1985	1990	1995	1980	1985	1990	1995
Austria	**Increase**	50.4	55.1	200.6	200.2	2.3	2.6	8.5	8.9
Belgium	**Stable**	18.1	-	-	18.1	-	-	-	0.2-4 #
Denmark	**Decline**	-	-	300.3	140.1	-	-	25.6	15.8
Finland	**Increase**	-	20.0	21.1	58.5	-	0.5	0.9	2.4
France	**Increase**	4,388.0	4,466.9	4,939.0	4,917.6	12.5	12.8	12.9	12.1
Germany	**-**	-	-	-	-	-	-	-	3-4 #
Greece*	**Increase**	4,158.0	-	-	5,659.2	82.5	-	-	80.5
Ireland	**Increase**	129.50	-	-	142.3	12.1	-	-	15.2
Italy	**Stable**	32,202.6	-	-	*32,310	57.3	-	-	*71.8
Luxembourg	**Stable**	-	-	0.2	0.2	-	-	0.3	0.4
Netherlands	**-**	-	-	-	-	-	-	-	1-34 #
Portugal	**Increase**	-	2,646*	3,833	-	-	-	52.6	48-79 #
Spain	**Variable**	26,227.4	30,386.0	23,689.8	24,100.5	65.7	65.7	64.2	72.4
Sweden	**Increase**	65.7	95.0	95.0	106.3	1.6	3.2	3.2	3.9
UK	**Increase**	87.0	77.7	185.1	141.0	0.6	0.6	1.3	1.2
EU-15	**Increase**	-	-	-	69109.6	-	-	-	30.1

Source: OECD 1996, Blue Plan (developed within the framework of the Mediterranean Action Plan and convention for the protection of the marine environment and coastal region of the Medierranean sea – Barcelona, 1976) and EEA, 1999, *Caldas, 1999
There are some significant data discrepancies between the different sources used to compile this table, in relation to these particular figures, hence the full range of values is given here

Types of Irrigation Practised – A Technical and Physical Typology

The principal types of irrigation found in the EU can be divided according to four main *technical and physical criteria.* The environmental impacts of particular systems depend greatly on these characteristics, as well as the specific conditions at the location concerned. The four criteria are:

A. technical characteristics
B. water source
C. time-related characteristics
D. crop types

The key technical characteristic of an irrigation system concerns whether the supply depends upon pressure or gravity:

- With pressure systems include sprinklers and drip irrigation systems
- Gravity (without pressure) systems include whole-field/sheet irrigation (flooding of fields) and furrow irrigation (using shallow channels to carry the water into fields).

Water sources for irrigation are usually of three kinds:

- groundwater (eg using wells or boreholes)
- surface water sources on-farm, including abstractions from farm reservoirs or rivers,
- surface water sources off-farm, where water is brought from more distant sources such as rivers and reservoirs, often via large-scale water distribution infrastructure.

Time-related characteristics of irrigation include:

- permanent irrigation (practised all-year and every year to produce crops)
- support irrigation (practised mainly in short periods during the dry/peak growing season, but still used every year)
- temporary irrigation (practised only occasionally, in those years where there is a water shortage)

Crop types – different crops are subject to irrigation at varying levels of intensity. Four main categories can be distinguished:

'Extensive crops' (E): these are generally lower value or permanent crops for which irrigation is used mainly in arid regions to stimulate enhanced growth and productivity, at a fairly low level, eg

- permanent grassland
- permanent crops (including olives, vines and citrus/apple orchards)

'Semi-intensive crops' (S): these are generally lower value crops where irrigation is more widely used to improve growth rates and productivity, either on a seasonal basis at times of peak demand (notably in northern Member States) or for most of the cropping period. Rates of water use are generally higher than for extensive crops, eg

- sown or temporary grassland or alfalfa (less than 5yrs old)
- cereals or oilseeds
- maize (noted separately because it has different growth characteristics to other cereal crops, and is associated with greater environmental risks)

'Intensive crops' (I): these are generally high value crops where irrigation can be critically important to maintain yields and quality and it is therefore more intensively applied to the crop, eg

- root crops (potatoes, sugar beet, swedes)
- industrial crops (cotton and tobacco)
- open air horticulture (salads, green vegetables grown in the open)
- glasshouse production (salads, tomatoes, many other vegetables grown intensively under glass in controlled environments);

'Saturated crops' (R): where water is used to flood fields in order to facilitate the production of crops which require saturation conditions, eg rice.

Note: in this typology, the use of the word 'intensive' is not meant to refer to other input use in addition to water. Depending on the Member States considered, crops which are classified here as extensive or semi-intensive (eg managed grassland and maize) might be classified as intensively managed, if the term were used in relation to the levels of chemical inputs (fertilisers and pesticides).

Table 1.5 indicates the occurrence of these types of irrigation by EU Member State.

Table 1.5 Types of Irrigation by Member State

Country	**Technical**	**Water source**	**Timing**	**Crop types**
Greece	Sprinklers dominant, with and without pressure, drip irrigation increasing slowly esp on tree crops, vines and horticulture	Mainly surface (85% nationally), often mixed, with regional variations	Support irrigation – from late spring to early autumn	E – tree crops, S- maize, I – cotton, beet, horticulture, vines (traditionally: trees and horticulture)
Spain	60% gravity (furrows and flooding) – widespread in many areas, traditional 24% sprinklers, esp in plateau/inland areas 17% drip irrigation, esp in Mediterranean coastal areas	71% surface, 28% aquifers 1% return flows <1% purified <1% desalinised seawater	Generally permanent or support in most regions. Where there is enough rainwater, irrigation is temporary, eg in Cantabria and Asturias	Continental areas – E/S/I: maize, beet, cereals Mediterranean – E/I/R: citrus, horticulture, rice South – all types: maize, tobacco, rice, horticulture, olives, fruit
Portugal – North/central Southern/ coastal	Mainly gravity Increasingly sprinklers and drip systems	Surface Surface and ground	Permanent Permanent	I Intensive S/I/R: Semi, Intensive, and rice
Italy	Sprinklers 33% Flooding 4% Gravity 51% Drip irrigation 10%	Ground 28% surface 72% Groundwater in north, surface in	Mainly permanent in South, support in north	Olives, vines, fruit trees, field crops, horticulture Cereals, maize, rice

		south with some groundwater in coastal areas		
France	Sprinklers 85%(arable) Gravity 10% (rice, arable) Drip 5%(horticulture and tree fruit)	Ground 62% Surface 26% Mixed 12%	Mainly support, some temporary, some permanent in south	Grain maize 45% Forage crops 11% Other arable 18% Sugar beet 2% Potatoes 2% Horticulture 8% Vines 1% Tree fruit 9%
UK	Sprinklers/rainguns	Ground and Surface	Mainly temporary and support	Mainly potatoes, some beet
Germany	Mainly sprinklers, some drip in Rheinland and Hessen	Mainly ground, Surface in Rheinland and some in East	Support irrigation	Intensive cropping (horticulture, mainly) and some semi-intensive
Netherlands	West and north: gravity East, central and south: sprinklers Glasshouses: sprinklers and drip	Surface rivers/lakes Groundwater Mainly surface, some ground, long distance surface	Permanent Support Permanent	Grass and arable, some vegetables Arable, horticulture, grass Glasshouse horticulture, intensive
Belgium	Sprinklers	Ground Surface	Support and temporary	Mainly semi-intensive/intensive, eg Horticulture, maize
Austria	Sprinklers, some drip systems	Mainly ground Some surface	Support and temporary	Beet, horticulture, Vineyards, soft fruit
Denmark	Sprinklers and some drip	Ground 95% Surface 5%	Temporary, some support	Mainly semi-intensive and intensive – maize, horticulture, glasshouses
Luxembourg	Sprinklers	Ground	Temporary, some support	Not specified
Sweden	Sprinklers	Ground 25% Surface – lakes rivers and farm reservoirs 70% Treated waste 5%	Support	Extensive 20% Semi 20% Intensive 60%
Finland	Sprinklers	Surface – lakes and rivers	temporary	Some semi-intensive but mainly horticulture – potatoes, beet and vegetables
Ireland	Sprinklers	Surface – lakes and rivers	temporary	Some early potatoes and vegetables, soft fruit

Sources: Expert/official responses to IEEP questionnaire, 1999

Types of Irrigation: Institutional Arrangements, and Water Pricing

The use of water for agriculture is subject to a variety of controls and institutional conditions within Europe, the nature of which depends on the distribution of property rights as well as the organisation of the irrigation system. An appreciation of these institutional characteristics is important not only in defining the systems and evaluating their environmental impact, but also in considering options for regulating them in future. No authoritative account of this topic at a European level was discovered during the course of the study and it was necessary to rely on disparate sources of information. However, a simple four-fold categorisation was used to assist the analysis, as follows.

- Systems involving unregulated, private abstractions from one water source (ground or surface) by small producers without any external (off-farm) control;
- wholly public controlled and operated irrigation systems, where collective management is possible and off-farm measures to control on-farm water use may be implemented wherever necessary;
- Public administered systems where the rights to abstract water may be given or sold by public authorities to private individuals or businesses, either for a limited time and quantity of use, or without specific conditions to limit either of these parameters. In some cases, water use rights may be transferable between landholdings, whereas in others they are tied to specific areas of land. These systems give some degree of management control to public authorities but many individual decisions about abstraction remain with the users;
- Privately controlled systems where water user groups collectively control and manage individuals' use of irrigation water, without any state intervention.

These institutional conditions commonly vary at sub-national level, so that in some Member States there will be areas of public irrigation, others of public administration of private use rights, and further areas where irrigation remains virtually unregulated. However, the current trend appears to be towards an increasing use of systems whereby water is owned by the public and administered by public regional, provincial or water-basin management authorities, while the rights to abstract water are controlled through permits or licences issued to individual or collective 'private' users. Only in those countries where water use for agricultural irrigation remains very low, is irrigation still likely to be totally unregulated (eg Republic of Ireland).

In the southern Member States in particular, public and collective structures for the provision and management of irrigation infrastructure have been an important influence upon the spread of irrigated agriculture in recent decades. Many such structures have been established or supported with EU funding, often through the Structural Funds for regional development, and the Cohesion Fund.

Under the forthcoming Water Framework Directive, all Member States will be obliged to move towards the planning and management of water resources at a catchment level. This should help to increase the management of irrigation water through a common scale of planning in all the Member States. However, the variety of institutional arrangements for collective management is expected to remain.

Water pricing is an issue which has received much attention from policy makers in recent years. In overview, most Member States already operate charging systems for water abstraction, through the issue of permits or licences to abstract, or through more general user charges to contribute towards the maintenance of the collective irrigation infrastructure. In most cases, neither the cost of permits or licences nor more general charges tend to be set at levels which reflect the real resource cost to the environment of the water used in irrigation.

However, it is generally the case that in systems involving private abstraction, the users fund the full cost of setting up or maintaining irrigation infrastructure, whereas in large scale public irrigation systems these costs are frequently borne, in whole or part, by the public sector.

Chapter 2. Country Profiles

This Chapter gives additional information from our investigations within the Member States in order to paint a picture of the great variety of irrigation across the EU. For each Member State a short profile is given of contemporary irrigation and trends, illustrating regional variations and links with agricultural change. Where available, information is also provided on the institutional arrangements for irrigation and the issue of water pricing.

We have chosen to group Member States broadly following a typology developed by the OECD (1998), which divides countries into three main groups according to the role and potential productivity of irrigated farming:

- A: countries or regions which have arid climates that make irrigated agriculture much more productive than dry-land agriculture. In many cases, therefore, irrigation is a long-established feature of some kinds of agriculture and it is often one of the principal users of water. EU regions where this applies would include most southern and Mediterranean areas, with a few exceptions. Therefore the countries we have included in this group are *Greece, Spain, Portugal and Italy*. However, the characteristics of this group could also apply to southern France and some parts of south-eastern Austria, and there are parts of Spain and Italy, in particular, which do not conform to this particular group definition.

- B: countries or regions in which irrigation is carried out mainly as a complement to natural rainfall, which is otherwise generally sufficient for productive agriculture. In these countries or regions the areas of irrigated agriculture tend to be increasing, as farmers invest in irrigation equipment primarily in order to reduce risk and increase yields of certain more drought-prone crops such as maize, vegetables and industrial crops. In the EU, areas falling into this group would include northern France, England, many parts of Germany, the Netherlands, Belgium and much of Austria, as well as northern Italy. We have therefore put *the UK, Belgium, Netherlands, Austria, Germany, Denmark and France* into this group.

- C: countries in which irrigated agriculture is negligible, or is generally limited to horticultural production in the summer time. EU countries assigned to this group are *Sweden, Finland, Ireland and Luxembourg.*

Group A

Common features of the countries belonging to this group include:

- strong inter-sectoral competition for water resources;
- wide differences in net agricultural returns, depending on whether or not irrigation takes place;
- long and deep involvement of public agencies in water works and/or irrigation projects;
- increasing difficulties in preserving the environmental quality of waterways without reducing the quantity available to users;
- increasing costs of generating new sources of water supply.

In these countries, irrigation is generally perceived as a vital means of promoting economic development. In many regions, irrigated farming provides the basis of economic and social activity, and water-based agriculture is a significant contributor to local employment and economic prosperity (OECD, 1998). However, the factors listed above also mean that in some areas, the further expansion of irrigation has now been limited in an effort to re-balance priorities for the use of scarce water resources.

Greece (Caraveli, 1999)

Geography
Greece has a combination of mountains and plains, with a relatively high proportion of poor soils. High levels of precipitation deficit result in prolonged periods of drought in many parts of the country. Geomorphology, geological structures, uneven distribution of rainfall in space and time and diminishing precipitation have all resulted in a scarcity of water during the peak period for irrigation.

Farming and irrigation
There is a dominance of small-scale farms, but there have been significant changes in land use and structure of farm production in the past 20 years due to EU and national farm policies and changing market demands. There is an increasing area of industrial and other monoculture crops, subject to highly intensive production methods and a significant use of water for irrigation. This has led to the displacement of traditional variety in cropping, but also an impressive increase in crop yields. Irrigation was initially limited to horticulture and tree crops, but has now expanded to areas occupied by arable crops such as cotton, maize and sugarbeet. Vine cultivation also increasingly takes place on irrigated land.

Agricultural irrigation uses 83% of water supplies in Greece. Surface water accounts for around 85% of the total quantity of water used, of which one-third has its origin outside the country. 1,202,116 ha were irrigated in 1991 (approximately 34% of total cultivated area), using 5,355 million m^3 of water. The average use of water in cubic metres per ha per year for the total irrigated area generally ranges between 5,000 and 8,000 m^3.

Trends
Between 1963 and 1996, irrigated areas increased from 15% to 38% of the total agricultural area – a mean annual increase of 2.5%. The increase was highest in the plains, where irrigated areas grew from 17% in 1963 to 45% in 1996. In semi-mountainous areas, the increase was from 11% to 24%. The area irrigated remained almost constant or decreased in Greece’s mountainous areas.

Types
During 1985-1992, the number of holdings with modern irrigation systems more than doubled. Sprinklers remain the dominant irrigation technology in Greek agriculture, while considerably slower adoption rates have been observed in drip irrigation. Traditional irrigation systems are more important in areas where irrigated land forms a small proportion of cultivated land.

No specific connection between geographic region, irrigation technology and type of crop can be drawn and in most regions of Greece and for most crops, all types of irrigation systems can be found. Both groundwater and surface water sources are used and, in some cases, a small proportion of water is drawn from springs.

For all crop types and regions, the dominant system is support irrigation, lasting from late Spring to early Autumn. However, rice production in saturated systems is also a feature of some areas.

Institutional Arrangements
Law 1739/89 on the "Management of Water Resources" constitutes the current legislative framework for the management of water resources on a national and regional level. Under this law, Greece is divided into 14 water districts. Any legal entity or person must obtain a license for the use of water. This license is given free of charge.

The body responsible for the co-ordination and monitoring of activities related to research, use and protection of water resources is the Ministry of Development, in co-operation with other ministries which are responsible for specific sectors.

Italy (Hamdy and Lacirignola, 1999, Ministry for Agricultural Policy Innovation, 1998)

Geography
A wide diversity of ecosystems and landscapes can be found in Italy, partly due to the range of rainfall and climatic conditions reaching from Mediterranean to Alpine and Continental. Rain is relatively abundant, with an average rainfall of 1000mm per year, but not evenly distributed between seasons and regions. High evapotranspiration during the long, dry summers causes significant losses, estimated to be 140 billion m^3 per year. The differences amongst regions are particularly pronounced, especially between the industrialised, affluent north and the less developed south: two thirds of groundwater resources are in the north.

Irrigated farming
In 1998 about 41% of the land area was used for arable agriculture and permanent crops. 27% of farms in Italy were irrigated over a total of 2.6 million ha, about 18% of the utilised agricultural area. Just under two thirds of the irrigated area is in the northern regions, involving 34.9% of farms with an average area of 6.5 ha. In the centre, only about 17.9% of farms are irrigated, whereas in the south the practice is carried out on 25% of farms with a total area of 758,000 ha, equivalent on average to 2.2 ha per farm. The total national freshwater abstraction per annum is 56 billion m^3, 60% of which is used for irrigation.

Trends
A statistically significant increase in irrigable areas occurred in the period 1980-96 (+25,000 ha/year, overall). However, since 1990 there has been a significant drop in the number of farms involved (-23%), whilst the area irrigated fell slightly over the six years to 1996.

Total water withdrawal is high and has reached the maximum desirable level in places. National water requirements for 2000-2015 are predicted to be 53,5 billion m^3 per annum, a 31% increase compared to the 1980s. Fifteen per cent of this increase is predicted to be in the agricultural sector. About 66% of irrigation water will come from rivers, 6% from reservoirs and 28% from wells, springs and other water points.

Types
Irrigation in Italy takes the form of permanent or support irrigation. The water source is mostly groundwater in the north, and surface water in the south.

Institutional Arrangements
The Ministry of the Environment is responsible for water management. Regional government passes regional water management legislation, monitors water resources and draws up resource inventories. Under the Merli Law it is required to formulate regional water purification plans which set priorities for investments in water supply and wastewater treatment. The role of provincial government is to issue permits for municipal waste-water discharges and to verify compliance by monitoring and keeping records of discharges into natural waters.

There are also some special-purpose bodies active in the field of water resource management and development. Law 183/1989 on the integration of water and soil management defined three classes of river basins and mandated the establishment of river basin authorities for them. There are six national basins, 15 regional basins, and 17 inter-regional basins. The role of the river basin authorities is to co-ordinate land and water use throughout their basin. There are also drainage and irrigation consortia and mountain watershed consortia. These are public bodies under regional control which can submit proposals for works to river basin authorities.

Portugal (Caldas, 1999)

Geography
The Portuguese landscape is characterised by a marked contrast between the mountainous north of the country and the great plains of the southern region, and corresponding differences in climatic conditions. Average annual precipitation is 990mm for the whole of the country, with a maximum of 2000mm in the Noroeste region and less than 300mm in the regions Beira Interior and Alentejo. The frequency of rainfall also varies between these regions, typically 150 and less than 50 days respectively.

Farming and Irrigation
The total irrigable area covers 21% of the total agricultural area, but varies between a maximum of 76% and a minimum of 7% among the different regions. However, not all this area will be irrigated in any one year. Between the late 1930s and mid 1970s, the government built irrigation systems to provide water to irrigate 75,000 hectares of farmland. However, the irrigated area never exceeded 60% of capacity, and these systems now account for only 7% of the total irrigated area in Portugal.

Trends in Use
Between 1989 and 1997, the total actual irrigated area in Portugal has decreased by 9%, while the average area irrigated per project has slightly increased. The annual increase in potentially *irrigable* areas has been limited and remains below 1,000 ha/year (Strosser et al, 1999). Despite this, the trend for irrigation systems and potential irrigation water use in Portugal is increasing, with some major plans to increase the irrigated area.

Types
Sprinklers, drip systems as well as sheet irrigation are applied. In most cases on-farm surface water is used, but also some groundwater. Irrigation is permanent.

Institutional Arrangements
Public bodies or private individuals can own water resources in Portugal. Water is defined as publicly owned if it comes from lakes and lagoons, navigable channels, rivers and streams, or springs on public land. Water from springs on private land is also public property if it flows to public water sources. Private water includes all other water from sources on private land, including groundwater. Traditionally there were no charges for public water use, but there were restrictions – including controls on pollutant discharges, breach of which could lead to fines and other penalties. Private owners of water were free to use and manage it with few controls (Caldas, 1998).

On completion of the major public investments in new irrigation between the 1930s and 1970s, water use was to be subject to charges levied by the state and by collective water management groups. Until the mid-1970s, these charges proved sufficient to cover the operational costs of the system but not to recoup the initial investment costs.

Even today, about 90 per cent of Portuguese irrigated areas are supplied by private irrigation systems, although major public investment in additional irrigation is planned, over the next 7 years, which will supply a further 115,000 ha of farmland by damming the river Guadiana in Alentejo (Strosser, *pers comm*). Among the public irrigation systems, charging is now common but charges are frequently too low to encourage efficiency in irrigation practices (Caldas, *ibid*).

Spain (Sumspi and Varela-Ortega, 1999)

Farming and Irrigation
An important characteristic of irrigated land in Spain is its farm structure. About 86% of irrigated farms have fewer than 10 hectares. In a large part of the traditionally irrigated areas, the average plot has an area of less than half a hectare while most farms have under 2 hectares.

Some irrigated lands are of marginal importance in the agricultural economy but play an important role in the rural world, in leisure and in the landscape. These include family kitchen gardens, where agriculture has nothing to do with commerce, and irrigated mountain pastures which are very important in the heads and high basins of the valleys, to provide winter food for the many cattle that sustain both the landscape and the regional economy and culture.

Contemporary Irrigation
In 1999, the land cultivated by irrigation covered 3.7 million ha, that is 14.5% of useable agricultural land and 55% of total agricultural production. Irrigation today represents 80% of the total water demand in Spain and nearly 90% of actual water consumption.

Types
Most of the water used for irrigation comes from surface water sources (68%). Another important share of water used in agriculture comes from aquifers (28%). Water is transferred to areas of greatest need where the surface and subterranean resources are insufficient. The water is transported from areas where there is an ‘excess of water’ to areas of need, sometimes hundreds of kilometres distant. In coastal areas where rainfall is low, the aquifers are over-exploited, and there is no possibility of water transfer, desalination plants are used.

The desalinisation process is very costly and therefore is only used in high value agriculture in a few localised areas. These include the coastline of Murcia and Almeria, and the Canary Islands, where fresh vegetables, fruits and flowers are grown in irrigated systems both in the open air and under glass, mainly for export.

Most of the irrigated land in Spain, almost 60% of the total, uses irrigation by gravity. The next most common method is sprinklers. Crop types irrigated include a wide variety, from permanent crops (olives, citrus) through annual crops (wheat, maize, rice) to a large number and area of horticultural crops, including a substantial area of glasshouse horticulture in the southern coastal regions. A significant proportion of irrigation is year-round, rather than seasonal.

Three main groups of irrigated land can be distinguished:

- historical or traditional systems set up before 1900, covering about 1.2 million ha. They are located in the most fertile river plains and irrigation is carried out by surface water through gravity;
- state initiative irrigation systems covering 1.1 million ha with complex, government-funded infrastructure;
- private initiative irrigation systems with mostly subterranean water resources with direct elevation, totaling 1.1 million ha.

Trends

The increase in potentially irrigable area in Spain was significant up until 1980 (almost +60,000 ha/year), but has fallen sharply since. The irrigable area rose by only +34,000 ha/year over the period 1980-1996 and there has been no statistically significant trend in the 1990s. Overall, the irrigable area in Spain increased by 80% over the period 1961-1996 (Strosser et al, 1999).

Irrigated agriculture is at present being overhauled as a result of the scarcity of water and the demands caused by the increase in second homes and other tourist development. The profitability of future irrigation development is now doubtful, especially in areas where its agricultural products are relatively low-value. The impact on the environment of both infrastructure and the use of irrigation is another factor which raises doubts about the prospect of any new big irrigation projects.

Institutional Arrangements

Since 1982 the delivery of irrigation has been the responsibility of regional governments. It remains the task of the national government, however, to establish the general criteria for the planning of irrigation. In Spain, the ownership of water is public, so there are no private property rights. In contrast, the use of water is private so that there are rights of use; the River Basin Agency grants user concessions which are based upon estimates of available water in River Basin Hydraulic Plans. The user concessions are temporary - no longer than 75 years - and they must respect a certain order of preference.

The current Water Act of 1985 requires that hydrological planning will be carried out through the River Basin Hydrological Plans and the National Hydrological Plan, which will be drawn up in coordination with the different planning authorities affected by it. The River Basin Hydrological Plans “will include the basic obligatory norms for improvements and transformations into irrigated land, which will ensure the best use of the water resources and lands available".

- The users of water and other beneficiaries from the same outlet or concession form Users' Associations. Where water is used mainly for irrigation these become Irrigators' Associations. The Statutes of these Associations are drawn up and passed by the users themselves. They regulate the organisation of irrigators and establish standards for the distribution and control of the use of irrigation water, as well as penalties. They also regulate the use and maintenance of the hydraulic systems, as well as the corresponding fees and charges. Each Irrigators' Association is responsible for addressing any problems that arise within its irrigation district. There are Irrigation Juries to resolve disputes which, if presented to the Administration, would paralyse the judicial and administrative services of the River Basin Agency (Hydrigraphic Confederations).

Two other elements of water law are also relevant to irrigation: the laws on water transfer and the Spanish-Portuguese agreement on shared water.

Spanish water laws distinguish between water transfers on-basin (within a basin) and off-basin (between different basins). The former do not need any specific legal regulation while the latter are covered by law (Articles 43 and 44 of Spanish Water Law).

In Spain there are several off-basin water transfers: the Tajo-Segura (regulated by Law 21/1971), Tajo-Daimiel to transfer water from the Tajo river to Tablas de Daimiel National Park (Law 13/1987), the Ebro-Nervión (Law 24/1977), Ebro-Besaya (Law 12/1978), Ebro-Tarragona (Law 18/1981) and Guadiaro-Guadalete (Law 17/1995).

The main issues regulated by water transfer laws are:
- management rules on water transfers,
- institutional arrangements to exploit water transfers,
- economic and financial aspects of the transfer arrangements,
- transferred water distribution among users, and
- definition of property rights in relation to transferred water.

The Spanish-Portuguese agreement on shared water was signed in November 1998 ("Convenio sobre cooperación para la protección y el aprovechamiento sostenible de las aguas de las cuencas hidrográficas hispano-portuguesas"). It extends the scope of prior agreements (in 1964 and 1968) which regulated only the hydroelectric use of water in the shared rivers of the two countries. The current agreement extends the co-operation between Spain and Portugal to new fields including the improvement of water quality, preventing the effects of drought and floods and polluting accidents, and providing for information and knowledge exchange concerning the status of water in the rivers.

A *Plan Nacional de Regadios* (National Irrigation Plan) will become law within the next few months. This Plan sets out the need for investment to provide for the improvement and modernisation of already irrigated land. Within each autonomous region it will be the regional government that decides the location of new irrigation lands assigned in the National Plan. Public funding will be provided equally by the Nation's General Budget and by the funds of the respective autonomous region.

Group B

Group B consists of countries in which irrigation is still expanding. However, each country's institutional framework follows somewhat different paths.

France (various sources as cited in references)

Farming and Irrigation

Agriculture and forestry cover 85% of the total land area in France. The sector therefore exerts strong pressures on the quality of natural resources, biodiversity and landscape. At the end of 1995, there were 734,800 farms in France, 66,000 fewer than in 1993. Since 1970, the total area in agricultural use has been declining, by an average of 100,000 ha per year, but the average size of farms has increased. Despite the declining land area used for farming, the volume of production increases each year.

The existing pattern of irrigation reflects three very distinct situations:

- the Mediterranean areas with highly subsidised collective, public irrigation schemes for fruit and vegetable crops which receive little CAP support;
- the Centre, East/Alsace and Poitou-Charentes regions with mainly individual schemes, where investment costs are mainly borne by the farmers but the crops are CAP-subsidised;
- The South-West with combined (individual/collective, public) access to water and relatively well subsidised crops.

Trends

France shows the highest increase in irrigated area of all EU Member States, totalling +25,000 ha/year between 1961 and 1980, +48,000 ha/year between 1980 and 1996 and even reaching a maximum of +59,000 ha/year in the 1990s. The largest increase was in the Poitou-Charentes region, where irrigated areas grew tenfold during the full period 1961-1996 (Strosser et al, 1999).

The rise in irrigated acreage is connected with changes in crop type. In 1975, 41% of irrigated land was used for market gardening, horticulture and orchards. This figure had fallen to 27% by 1995. 43% of irrigated land is now used for growing maize, followed by soya beans and sunflowers (Rainelli & Vermersch, 1997). There is a linkage between these trends and the various EC support regimes, in that France has applied different reference yields to determine the levels of CAP area payment for irrigated and unirrigated crops, thus increasing the incentive to apply irrigation.

Institutional arrangements

Two main laws govern water institutions in France: the Loi of 16 December 1964 and the Loi of 3 janvier 1992. The first of these recognised the unity of water resources and the interdependence of its uses, creating a supreme authority charged with defending the general interest in water, and responsible for delegating water management, within the Ministry of the Environment. The second law established the principle that water is a public good, and gave the state the unique responsibility for regulating water use and management.

These laws created two levels of *Schémas d'Aménagement et de Gestion des Eaux*, which are voluntary contractual mechanisms bringing together water users into collective units for water management and distribution. Five year plans for water use are established through *Schéma*

Directeurs d'Aménagement et de Gestion des Eaux (SDAGE) which operate at the scale of the river basin. SDAGE fix quality and quantity targets for water use and define how these are to be achieved, under the direction of the *Agences de l'Eau* and the *Direction Régionale de l'Environnement* (DIREN). Then at a local/sub-basin level, SAGE are established within the framework of the SDAGE. In addition, the state administration has established *Comités Locaux de l'Eau (*CLE) which are responsible for overseeing the activities of the SAGE.

Any landowner wishing to irrigate farm land must obtain an authorisation to abstract water, which specifies how much water can be taken from which sources. Authorisations can be given to individuals or to collective groups such as *Associations Syndicales Autorisées (ASA)* or companies such as the regionally organised *Sociétés d'Aménagement Rural (SAR).*

Associations or companies who are given authorisations to abstract must meet public interests in water use and management as well as those of their irrigator-members. ASAs are generally responsible for relatively small areas of irrigated land with a few dozen farmer members in each. One of their responsibilities is to administer water abstraction charging of their members. However, these charges frequently fail to cover more than the ongoing costs of the ASAs themselves, and thus provide little incentive to increase the efficiency of irrigation. SARs are a more recent creation than ASAs and they are granted a 75 year concession to operate water management and distribution services for a variety of user members, be they individuals, local collectivities, or industrial users. However, as private companies, their main objective is to cover their own financial costs. There are 3 SARs in France at present, in Provence, Bas Rhone-Languedoc and the Gascogne coast. Again, they influence the use of water in irrigation by means of a variety of charges to users.

For the strategic oversight of water management, France is divided into six 'grands bassins', for each of which there is a Comité de Bassin with responsibility for ensuring that water use balances the interests of different users, the state and the wider environment. The A*gences de l'Eau* are their executive agencies. The Agences have to take into account the non-commercial value of water resources and take action to address problems with water quality and quantity, conflicts of use and division of resources between users. Their funds come from additional charges called 'redevances' which are levied on all water users. A pollution redevance is related to the likely polluting impact of different users, and a resource redevance relates to the likely effect of a particular user's consumption of water upon the quantity and rate of renewal of the natural resource itself. As well as levying these charges, the agencies offer subsidies and loans to encourage more efficient water use, which will be part of the 5 year plans of the SDAGE.

UK (MAFF and EA, *pers comm* and various)

Agriculture

Agriculture uses about 18.4 million ha or approximately 77% of the total land area in the UK. In 1995, the total value of agricultural output was about £9 billion or 1.5% of gross domestic product, of which the value of irrigated crops was £2.6 billion, or around 29% of this total.

Contemporary Irrigation

There are slightly more than 100,000 ha of irrigated land in the UK. Irrigation water is now an essential requirement for competitive crop production systems, particularly on light soils in the drier parts of the country, especially in Eastern England.

Nationally, agriculture accounts for about 1% of all surface and ground water abstractions although there are major regional differences, with East Anglia having the lowest rainfall and largest area of irrigated crops. To produce to the high standards demanded by retailers and consumers, particularly for salad crops, effectively requires farmers to have irrigation water available all year – hence the construction of water storage facilities on farm (MAFF, 1998).

Trends
Irrigation use has changed from supporting lower value output to higher value output. The area of cereal and grass irrigation has reduced and that of field crops such as potatoes and vegetables has increased. Future irrigation water demand is estimated at about 250m m^3 by 2021, a 52% increase on 1995. Over three quarters of the crops receiving irrigation in 1995 were not supported under the CAP (eg vegetable and salad crops, cut flowers, etc) and it is these which are forecast to expand.

Climate change is likely to see a gradual move north and west of the crops currently receiving irrigation. More exotic crops (eg grain maize, sunflowers, soya) could be introduced into southern England in future and many of these will require irrigation, albeit with differing timings and amounts. It is also likely that double cropping will occur which will require a wider irrigation window, with crops needing water earlier and later in the year (MAFF, 1998).

Types
The predominant types of irrigation in the UK are sprinkler systems (rain guns), used outdoors on field vegetables and some other intensive and semi-intensive crop types such as maize and sugar beet. Drip irrigation is mainly confined to glasshouse horticulture systems.

Institutional Arrangements
The main ministerial responsibility for water management in each UK country falls to the Department of the Environment, Transport and the Regions (DETR) in England, and the various devolved assemblies in Wales, Scotland and Northern Ireland. England and Wales the regulator of environmental issues related to water policy is the Environment Agency (EA), while in Scotland there is a separate Scottish Environment Protection Agency (SEPA) and in Northern Ireland these roles are carried out by the central administration. The agencies have a wide remit covering, amongst other issues, water quality, water quantity and the management of surface and ground water. It is therefore responsible for regulating the abstraction of water for irrigation.

The control of abstraction is achieved by issuing licences. Those wishing to abstract must apply to the EA giving details of the volumes required, timing of abstraction, type of crops to be irrigated, crop area etc. The EA will then evaluate the impact the planned abstraction may have on the environment. After consideration, the EA may issue a licence providing resources are not fully committed. The licence will restrict abstractions to particular times of the year, to specified volumes and specified daily abstraction rates, which may also be related to minimum river flow. Abstractors are obliged to record the volumes they abstract and may be subject to a verification inspection. Those who abstract without a licence or do not adhere to the conditions stipulated in their licence are liable to prosecution. The EA have developed catchment plans for most of England and Wales which allow the effects of additional water abstractions to be fully evaluated.

Austria (various sources)

Agriculture
The total agricultural area in Austria is 3.4 million ha, 42% of which is arable land and 58% grassland. Of the arable land, 60% is used for cereal production, the rest is taken up by oilseeds, maize, sugar beet, legumes and potatoes. The amount of agricultural land is increasing.

Agricultural production conditions differ vastly between the different regions. Mean annual precipitation is about 1100mm, but it decreases west to east, from 2500 mm for the western alpine region to 400 mm for the north eastern lowlands. Not surprisingly, the need for irrigation is greater in the east. However, there are also extremely dry areas in the alpine valleys of western Austria with precipitation of only 600-800 mm per annum. A good water balance is found in some regions (Cepuder, 1998)

Contemporary Irrigation
Seventeen per cent of the total agricultural area in Austria (96,210 ha) could potentially be irrigated, but significantly less than this actually is, mainly due to crop rotation factors and climatic conditions (Cepuder, 1998). The irrigated area in Austria in 1994/95 was 45,000 ha. Fifty-three million cubic metres of water were used for irrigation between the end of May 1994 and the beginning of June 1995. About 90% of irrigation abstractions take place in the northeastern lowlands (22% in Burgenland and 68% in Niederoesterreich), 10% in western and southern irrigation regions. Sugar beet, the most water-intensive crop type, takes up more than one third of the irrigation need in Burgenland and Niederoesterreich (Huettler, 1996).

Trends
The trend is generally stable, with the exception of increasing irrigation in the Marchfeld Hochterasse and the Wachau region (Bundesministerium fuer Land- und Forstwirtschaft, pers. comm.) Due to the high productivity of Austrian field crops, the objectives of irrigation have undergone great changes in recent years. The priority is no longer an increase in output but in quality, especially for more specialised crops. In the future, the irrigated area is likely to be extended only for viticulture and fruit farming, so that the total irrigated area is expected to increase only moderately.

Types
Irrigation is primarily applied in the form of supplementary water in field crop farming, for fodder meadows and in viticulture to compensate for a lack of rainfall during the vegetation period. In a few cases frost protection irrigation is used in orchards. Mostly temporary and some support irrigation is used in the north-eastern lowlands, temporary irrigation in western and southern Austria and support irrigation in the Wachau region.

In the north-eastern lowlands as well as western and southern Austria mainly sprinkler irrigation is used to ensure agricultural output and to improve crop quality (Mottl, 1992). The Wachau region relies fully on drip systems (Bundesministerium fuer Land- und Forstwirtschaft, pers. comm.) In the north-eastern lowlands irrigation water is used mostly on root crops and some temporary (less than 5 year old) grass and alfalfa. In western and southern Austria the relevant crops are also mostly root crops, with some permanent grassland as well as temporary (less than 5 years) grass and alfalfa. In the Wachau region, irrigation water is mostly used on permanent grassland.

Institutional Arrangements
Federal Water Law sets the legal framework for irrigation in Austria by regulating water withdrawals from ground or surface water, and water quality. Water authorities at district level are responsible for small and medium sized irrigation projects with ground water withdrawal of up to 300l/s and withdrawals from other sources of up to 1000l/s. Projects using a greater amount of water have to be approved by the provincial authorities.

There are organisational structures for water users' co-operatives or associations that are defined by the Water Law: the "Wassergenossenschaften". They consist of the water users and are controlled by the water authorities. Private water users as well as co-operatives have to apply for approval for their individual water right or claim. The Water Authority has to grant the right if there is no conflict with the public interest or other private claims.

Denmark (Danish Agricultural Advisory Centre, 1999, *pers comm*)

Agriculture
The total cultivated area was 2,679,000 ha in 1998, which was 62.4% of the total land area. Annual rainfall amounts to an average of 664mm, with 34mm in the driest month (March) and 81mm in the wettest month (August) (Agricultural Council of Denmark, 1998).

Contemporary Irrigation
Irrigated farming represents about 35 % of all consumptive use of water (OECD, 1998), with water use for agricultural and irrigation purposes amounting to 400 million m^3 against a total annual water consumption of 1173 million m^3 in 1992 (OECD, 1997). The total irrigated area in 1997 was 476,004 ha, about 17.7% of the total area. The average water use per ha/per year is between 600 and 700 m^3, but there are some regional differences.

Trends
There has been a small increase in the irrigated area and the amount of water used over the past 10-20 years. Today, the trend for irrigation in Denmark is stable.

Types
Sprinklers and drip systems are used and more than 95% of the water used is groundwater-sourced. The water is applied to semi-intensive and intensive crops and irrigation is only used in dry periods.

Institutional Arrangements
The counties are responsible for the administrative aspects of irrigation.

Germany (various sources)

Agriculture
Agriculture in Germany is highly varied, reflecting its diverse topography and climatic conditions. In the north and east there are large expanses of flat land that is well suited to arable cultivation. In the centre and south, there are more hills and mountain ranges and it is here that the main areas of pastoral agriculture are found, as well as more specialised crops such as vines. Water supplies are generally adequate for agriculture in most areas, however, the use of irrigation to boost crop quality and yields has been a common feature in many areas, particularly in arable regions.

Contemporary Irrigation
The irrigated area in 1995 was about 531,000 ha, which is 3.1% of the arable area and it is estimated that it has increased to 550,000 ha in 1999. There are significant differences between the Länder, with 44% of irrigated areas being situated in Lower Saxony, where 8.6% of the agricultural area is irrigated.

Trends
The irrigated area increased continuously from 1976 to 1987 to more than 800,000 ha, and then decreased to 531,000 ha in 1994. The main reason for this significant decrease is the abandonment of many big irrigation facilities in the new Länder.

Types
There are two main types of irrigation in Germany:

- Type 1 uses sprinklers with pressure and is mainly groundwater sourced. It is applied to semi-intensive or intensive crop types in the form of support irrigation (short periods during the season). The trend for this type of irrigation is stable.
- Type 2 also uses sprinklers with pressure but is surface sourced (both in situ and transported over long distances). It is applied to semi-intensive to intensive crop types in the form of support irrigation (short periods during the season). The trend for this type of irrigation is increasing.

Institutional Arrangements
Water management is the responsibility of the Länder, which have established water associations. Since irrigated agriculture is not very extensive, general water policies tend to override more specific policies that pertain exclusively to the agricultural sector. Traditionally, water prices have been based on the costs of extracting water from the natural cycle, and of water treatment and transportation. Until Baden-Wuerttemberg established a "water tax" in 1988, water remained significantly undervalued. Since then, other Länder have followed suit, and water taxation has become more common.

However, these water taxes deviate from the commonly-accepted definition of water charges for two reasons. Firstly, they are generally levied only in cases where a permit or licence is required. Since water metering in the agricultural sector is not common in Germany, some estimates show that the allotted volumes as stated in licences deviate substantially from the actual abstractions carried out by licencees. Secondly, revenues collected through water taxes have often been used to compensate farmers for restrictions on fertiliser use in vulnerable areas. There are also tax rebates for those farmers who can provide evidence of being financially impaired by the tax. However, these rebates are conditional on farmers implementing water-saving strategies, and on using surface instead of ground water sources.

Netherlands (various sources)

Agriculture
The Netherlands is a very flat country with a high population density and an important part of the country is situated below sea level. Agriculture is intensive, with very high production levels per hectare. This has been achieved by the development of technology and the use of fertilisers and pesticides. The pollution rate is accordingly high.

Contemporary Irrigation

Generally, there is excess water entering the country from the east and south from major rivers (eg the Rhein) and from rain. Nevertheless, some areas of polder (reclaimed land) with drained, peat-rich soils are vulnerable to drying-out in periods of low rainfall, exacerbated by groundwater lowering as a result of continuous pumping. The necessary drainage of agricultural land has led farmers who suffer droughts in very dry seasons to invest in irrigation systems which are fed by groundwater. The environmental consequences of such action has led to a prohibition on any major expansion of groundwater extraction by law, in most Provinces.

Trends

The area of land irrigated in the Netherlands has shown a modest but steady increase over the past 20 years.

Types

Three main types of irrigation are practised. In the west and north of the country, polder systems have been established below sea level providing inlets for surface water from the Lake Ijsselmeer, originating from the Rhein. Mainly grassland but also arable land and horticulture are irrigated. In the east, centre and south of the country sandy regions above sea level can be found. Here irrigation is carried out with groundwater sourced sprinklers, mainly on arable land but also for horticulture and grassland. In the whole country rainwater sourced sprinkling and drip systems are used to irrigate intensive crops (glasshouse crops and horticulture). Occasionally, surface water and groundwater is also used. Rainwater is caught in on-farm reservoirs, and surface water is often transported from a long distance.

Sprinklers with pressure are the main means of irrigation. The water source is groundwater, applied to intensive crop types in the form of support irrigation (short periods during the season). The trend for this type of irrigation is increasing.

Institutional Arrangements

The national government is responsible for water management policy at the national level. On a regional scale the foundation of the system is 66 regional Water Control Boards which are in charge of management of water quality and quantity. In some cases, there is a distinction between Water Control Boards for quantitative water management and Water Purification Boards concerned only with water quality. The Boards work in close co-operation with the areas' inhabitants. One of the main purposes of the Boards is to maintain water at a certain level (eg in ditches and dykes), to optimise hydrological conditions for agriculture. They maintain the water level in polder systems in dry seasons by admitting water from surface water sources.

The total costs of each Water Board are covered by levies paid by the inhabitants. The agriculture sector contributes 27% of the cost of levies raised for quantitative water management. The Dutch agricultural sector contributes more revenue to water management than is actually spent on its direct benefit, with a discrepancy of about 5%. Farmers are generally subject to a groundwater extraction tax. If they find the price too high, they can decide to extract groundwater directly themselves. For this, a permit from Central Government is required if the capacity of the pumping facility exceeds $10m^3$ per second.

Any farmer using more than one million cubic metres per year has to pay the abstraction tax, and a smaller provincial tax also has to be paid for facilities exceeding 10 cubic meters per second. Generally, farmers ensure that they do not install pumping facilities that exceed 10 cubic metres per second so they do not pay the abstraction tax.

Belgium
Insufficient information available.

Group C

Group C is characterised by countries where farms generally have easy access to water resources, and where, in aggregate, agricultural water consumption is not very significant relative to total abstractions. Water pricing policies in all of these countries are much less important than other environmental policies which affect irrigated and non-irrigated farming, including general natural resource management policies. However, it is still possible for certain regions within these countries to require significant irrigation and to suffer drought.

Sweden (Swedish Board of Agriculture, *pers comm*)

Agriculture
Most of the productive agriculture in Sweden is found in central and southern areas, with forestry dominating the north. In some localised areas, intensive agricultural production can benefit from the use of irrigation to improve crop yields and quality.

Contemporary Irrigation
Practically all irrigation takes place in Southern Sweden. Total withdrawals for irrigation amount to 100 million m^3 as a round figure for a dry summer season, to cover 100,000 ha. (ie the average application is $1000m^3$/ha). Of the potentially available resources less than 2% is withdrawn for irrigation, municipal water supply and industrial water supply. Of this, irrigation accounts for less than 5%, less than the annual losses of municipal water systems.

Trends
The irrigated area has been decreasing since 1976 (NB this statement is contrary to the figures provided from other sources in tables 1.3 and 1.4). It is estimated that 55,000 ha will be irrigated in 2000 using 32 million m^3 of water under normal conditions, or 90,000 ha using 95 million m^3 of water if it is a dry year.

Types
All irrigation water is applied with sprinklers (rainguns). Water sources are groundwater (25%), surface water from rivers, lakes and reservoirs (65%) and other sources such as saline Baltic water and treated sewage water. Irrigation takes place every year from about the middle of April until the end of September with very small amounts in April and September, but throughout the summer is only supplementary to the rainfall.

About 20% (30%) of irrigation is applied to extensive crops, 20% to semi-intensive and 60% (50%) to intensive crops (numbers in brackets indicate figures for particularly dry years).

Institutional Arrangements

Irrigation withdrawals are governed by the 1999 Environmental Act. Water rights are private in the sense that to be allowed to use the water the abstractor must own the land on or adjacent to the water. For irrigation use, the need to irrigate land that is owned or cultivated under a rental agreement gives the right to withdraw water on somebody else's property. This can be obtained by agreement with the landowner or by a decision of the Environmental Court.

Water withdrawal for irrigation also requires a permit from the Environmental Court. A large number of farmers, however, withdraw water without a permit. This is partly justified by another rule which states that a permit is not required if it is obvious that neither public (environmental) nor private interests are harmed by the impact of the withdrawal. Each farmer has to decide if he needs to apply for a permit. If the controlling authority, the County Board, questions the withdrawal it is up to the farmer to prove that his withdrawal is not harmful.

Ireland (Teagasc, *pers comm*)

Agriculture
Ireland's agriculture is overwhelmingly pastoral in character. With an annual rainfall of 800-1000mm there is little need for irrigation of most outdoor crops in Ireland.

Contemporary Irrigation
Even on light soils where substantial increases in the yields of grass and root crops could be achieved by irrigation, the practice has not become established for a variety of reasons, and the overall demand for irrigation is very light. In the southern, south-east and eastern regions, some growers irrigate early potatoes, as well as some other vegetable crops. Typically they might receive two applications of about 25mm per hectare each, from sprinkler systems. The areas involved are no more than about 500 ha of potatoes and 500 ha of other vegetables. In the same regions there are about 100 ha of strawberries grown in plastic tunnels, which might receive up to 100mm per hectare through a drip system. In the rest of the country, the areas of outdoor crops irrigated are so small as to be insignificant. The only area where irrigation is expanding is on golf courses.

Trends and Types
In the present regime of production quotas and falling prices for most produce, further investment in irrigation for farm crops seems unlikely. The most common source of irrigation water is direct abstraction from local lakes or rivers. The number of on-farm reservoirs is small. Both sprinklers and drip systems with pressure are applied in Ireland. The water source is surface water, which is applied to intensive crops in the form of support irrigation (short periods during the season).

Institutional Arrangements
With such a small amount of irrigation, management is not a serious issue. City and county authorities exercise general management of the waterways, but their main concern is the quality of the water and pollution abatement. They have not generally found it necessary to restrict abstraction for irrigation.

Finland (Field Drainage Centre, *pers comm*)

Contemporary Irrigation
Irrigation practice in Finland is marginal; in dry summers 1-3% of the field area are irrigated, mostly potatoes, sugarbeet and vegetables. The total irrigated area is 20,000-40,000 ha and the average use of water per ha/per year is 200-400 m^3.

Trends and Types
The trend in irrigation is stable. In the south and west of the country sprinklers are used and water is drawn from surface water sources. Irrigation is temporary and applied to semi-intensive and intensive crops.

Insitutional arrangements
No information available.

Luxembourg (Ministry of Agriculture, *pers comm*)

Contemporary Irrigation
Irrigation is not an issue in Luxembourg and is almost non-existent in agriculture.

Types
The small amount of irrigation practised is all with pressure, using sprinklers, and sourced from groundwater.

Institutional Arrangements
A permit system is in operation for the abstraction of water and the majority of permits issued by the Ministry of Agriculture are for small-scale vegetable growers who abstract water from rivers with the help of small pumps available in do-it-yourself stores, to the extent of about 1000 litres/minute. There is a certain amount of abstraction going on without permit, but not to a significant degree.

Chapter 3: The Environmental Impacts of Irrigation

3.1 Overview

The overall environmental sustainability, and precise environmental impact of irrigation depend on local water availability and other water uses, on the historical background of how irrigation systems have developed and on the particular characteristics of the irrigation practices used. There is a wide variety of types of irrigation in use in Europe, which have been practised for very different lengths of time in varying climatic and economic circumstances. Thus it is to be expected that the environmental impacts will also be highly variable by country and by region.

Irrigation can affect the environment through:

- Direct impacts upon water sources – both their quality and quantity, affecting ground and surface waters

- Direct impacts upon soils – both quality (eg through contamination) and quantity (through erosion)

- Direct impacts upon biodiversity and landscapes – by displacing former habitats and creating new ones, by degrading or maintaining existing habitats, and by affecting the diversity and composition of landscapes

- Secondary impacts arising from the intensification of agricultural production permitted by irrigation, such as increased fertiliser use.

These effects may be gradual (eg declines in certain species arising from pollution) or particularly dramatic (eg flooding a valley to create a reservoir for irrigation, or canalising a river and thereby reducing the stability of its flow). In those countries with a long history of irrigation in particular, the environmental impacts of irrigated agriculture may involve a succession of effects including negative impacts, initial remedial actions, further knock-on impacts and further remedial actions, spanning many decades. This process is well illustrated in the two case studies from Spain, in Chapter 4.

3.2 Types and Trends in Environmental Impacts

The main types of environmental impact from irrigation in the EU are generally recognised to include the following.

1. *Pollution of water and aquatic ecosystems from nutrients and pesticides* due to the agricultural intensification that is facilitated by irrigation, sometimes exacerbated by increased use of agro-chemicals when crops are grown in conditions not otherwise well suited to their cultivation.

This is a fairly widespread phenomenon in EU agriculture, particularly where irrigation is used to support relatively high value crops such as horticulture, salads and soft fruits, especially when these are grown year-round under glass. It is also commonly associated with intensively managed industrial and forage crops including cotton, sugar beet, tobacco and maize. Both northern and southern Member States present examples of these problems (eg the Netherlands, southern Spain, Greece, northern France, Italy, Germany and Austria) and in many cases, the trend is for an increase in such cropping. There has been criticism that agricultural policies and increased competition in European markets have encouraged an increase in these production systems, with their associated environmental impacts, in many regions (eg Caraveli, 1999). In the EU as a whole, these problems seem to have increased over the past few decades, as agricultural systems have modernised and production has intensified in many regions.

2. *Damage by Abstraction of Irrigation Water*

When water is withdrawn from groundwater tables or from rivers, lakes or springs for use in irrigation, the reduction in the quantity of water which remains can have detrimental effects upon the physical and chemical characteristics of these sources and upon the biodiversity associated with them. Aquatic and wetland species may suffer as a result of the drying out of wetlands, or lowered flow and increased temperature in rivers, as a result of abstraction for irrigation.

Groundwater abstractions, if they exceed the natural recharge rates of the aquifers concerned, can lower water tables and thereby reduce flows into wetlands and rivers. Surface water abstractions from rivers or springs can reduce the volume and increase the variability of flow rates (ie leading to more marked ‘peaks’ and ‘troughs’ with reduced ability to buffer seasonal changes in water supplies). This can increase flooding risks and threaten wildlife due to drying-out, water temperature rises or reduced dilution of potentially harmful contaminants. The seasonality of irrigation water demand, which is usually highest in the summer months, coincides with the period when water flow in rivers tends also to be lowest. The resulting effects can be to disrupt aquatic and wetland ecosystems and to threaten the survival of rare species.

In the case of peatland fens and bogs, dessication can lead to peat fires which can wipe out large areas of habitat, irreversibly. There are dramatic examples of these problems in southern Europe, where their effects can be both persistent and devastating. However, they have also been observed in northern Member States, particularly during periods of prolonged drought such as was seen in northern France and eastern England from 1988-94. The overall incidence of such problems seems likely to increase with global warming as water supplies are predicted to decrease across many areas of the EU (CEC, 1999).

These impacts of irrigation have been identified, particularly in southern Europe, for many decades. However, their geographical incidence and severity have undoubtedly increased as irrigated agriculture has spread into new areas, particularly in the past few decades.

3. Another potentially significant negative impact is *where irrigation displaces formerly high natural value ecosystems*, such as the dryland steppe agriculture of the central Spanish plateau.

In Mediterranean countries, the conversion of large areas of land from dryland cereal production to irrigated horticulture or other higher-value cropping threatens the survival of rare steppe species, such as the great bustard *(otis tarda)*. This has been a particularly serious phenomenon in some southern Member States in recent years.

Elsewhere in Europe, there have been negative environmental impacts where irrigation has increased the profitability of intensively managed crops such as maize, or potatoes, relative to permanent grassland, leading to the conversion of pasture to irrigated cropland with associated biodiversity losses and landscape impacts. This phenomenon has been particularly marked in France during the 1980s and 1990s, as well as in southern UK.

In these instances, the negative environmental consequences are related to the change in land use patterns rather than the direct impact of irrigation itself, but it is the ability of irrigation to increase the profitability of certain more damaging crop types, that has fuelled such change. Again, this pressure is being maintained or even increased in several regions with growing areas of irrigated land.

4. In some areas, often where irrigation has been practised for some time, there have been *gains to biodiversity and landscapes.* This study has identified three main ways in which environmental benefits can be generated through irrigation practices.

Long-established 'leaky' irrigation systems can create wetland areas which provide new feeding and/or breeding opportunities for wildlife.

Traditional, hand-operated extensive irrigation systems supporting terrace agriculture in mountainous regions of southern Europe, create diverse and intricate landscapes which support a variety of wildlife and have important cultural and historic value. However, economic trends are leading to the marginalisation and decline of these kinds of irrigated agriculture in many parts of the EU because it is relatively labour intensive and produces low-value crops.

The creation and management of rice fields in certain countries has provided important feeding and overwintering opportunities for important bird species. However, there has been a trend of increasing use of fertilisers and pesticides on these fields which may now pose a threat to their wildlife value.

5. Irrigation can increase the rate of *erosion of cultivated soils on slopes*, leading also to a deterioration in water quality downstream, due to siltation. This can lead to the subsequent desertification of some arid areas with light and erosion-prone soils, particularly on steep slopes.

Particularly dramatic examples of this phenomenon can be found in Greece and other Mediterranean regions where irrigation is practised on slopes. This problem is particularly severe where pressure systems of irrigation are used, and it has therefore been a growing concern in recent decades. Alternative methods using extensive gravity-powered, trickle or drip systems can significantly reduce erosion rates. Indeed in some areas of Spain where erosion was a serious problem due to the recent abandonment of traditional terrace agriculture in mountainous areas, the reintroduction of farming using drip irrigation has been able to stabilise soils and decrease the rate of soil loss.

6. Lowering of the groundwater table can lead to *salinisation of water and land or contamination by minerals of groundwater* sources. This can be due either to saltwater intrusion, where irrigated land is near to the coast, or it can be caused from over-

saturation and concentration of salts in the topsoils of irrigated land due to the increased circulation of water through them.

Again, this is a more serious phenomenon in southern Europe, particularly on the relatively fertile coastal strips of flat land around the Mediterranean where peak seasonal demand for water is particularly high, both for agriculture and for tourist use. In some areas, desalinisation plants have been installed to provide clean water supplies for drinking and for irrigation from marine sources, but this is generally recognised to be a highly expensive solution to the problem. The scale of negative impacts seems likely to increase over time, in line with increasing irrigation and increased tourism in these areas.

7. *Negative and positive effects of large scale water infrastructure constructed as part of irrigation projects and schemes.*

Often, the development or enhancement of agricultural irrigation necessitates sizeable infrastructure projects to collect, divert or otherwise move large quantities of water from water-rich areas to water-poor areas, both within and between different regions. Dams may be built on rivers in order to collect water for irrigation and large canals or pipelines may be installed through which water is moved across the landscape.

These can lead to potentially irreversible negative impacts upon landscapes and biodiversity as habitats are submerged under water, or damaged by construction activities. In addition the collection, removal or canalisation of water flowing in rivers can affect the natural flood control properties of watersheds and river catchments, reducing their ability to buffer peaks and troughs in water flow through the catchment.

Such works are often implemented as a means of resolving other irrigation problems in water-poor areas, for example where agricultural water use has exceeded the sustainable capacity of local water sources. The variety and scale of environmental impacts involved in these projects may be similar to those engendered by a wide range of other infrastructure investment projects; including habitat loss and increased flood risks in some areas.

On the other hand, many proponents of these schemes highlight the potential environmental benefits of the redistribution of water resources, such as improved aquifer recharge and habitat conservation in those areas receiving the new water. Environmental impact studies and structural fund policies are particularly relevant since few such projects are undertaken without a degree of public subsidy or a requirement for prior approval from public authorities. There are more such projects being implemented in the EU (eg the Alentejo scheme in Portugal, Marchfeld in Austria) and others may be developed in future, although the likely implementation of the EU Water Framework Directive over the coming few years may reduce Member States' ability to justify new dams.

Future Trends

In the longer term, climate change is predicted to increase the severity of drought periods and aggravate resource pressures in many regions of Europe. Ongoing EC-funded research is examining the implications of climate change on hydrological regimes and water resources in Europe. Although overall annual rainfall is expected to change little, there are likely to be considerable variations in the spatial and seasonal distribution of water supplied by rainfall. Generally, winter rainfall will be increased in many areas and there will be much longer dry spells with decreased discharges in the summer months. Modelling work on aquifers in southern Member States indicates that a doubling of CO_2 will result in further depletion of groundwater aquifers due to increased evapotranspiration. In northern Europe, many rivers will experience decreased low-flow discharges during the drier seasons. For example, models of the Rhein catchment predict that irrigated, intensive horticulture may be affected by a need to restrict abstractions during the summer periods (SEC, 1998).

3.3 Occurrence, Scale and Significance of Impacts Identified

Table 3.1 overleaf gives a broad indication of the countries where each of the impacts has been identified.

As can be seen, many impacts are found in all those Member States where irrigation is a significant phenomenon at either national or regional level – ie those countries in groups A and B, as characterised in Chapter 2.

However, there is a north-south divide also apparent, in that certain impacts are clearly observed mainly in southern Member States while others are more widespread, but are nonetheless judged to be more severe or signficant in the south.

Table 3.1 Environmental Impacts of Irrigation in the EU

Impact	**Water poll-ution**	**Over abstr-action**	**Habitat Displac-ement**	**Biodi-versity benefits**	**Salini-sation**	**Soil erosion**	**New Infras-tructure**	**Comments on Signficance**
Austria	+	+	Historic					Variability between regions, most in arid eastern areas
Belgium	+		Historic					Little data available
Denmark		+						Only in dry years, localised effects
France	+	+	+	+rice, terraces	+	+	+	Severity of impacts varies markedly between regions – a few are relatively unaffected
Finland								No impacts reported
Germany	+		Historic	+				Localised impacts, mainly
Greece	+	+		+ terraces	+	+	+	Widespread impacts
Ireland								No impacts reported
Italy	+	+		+ rice	+	+	+	Variability between regions
Luxembourg								No impacts reported
Netherlands	+	+	+			+		Impacts mainly localised, more significant in dry years
Portugal	+	+	+	+ terraces leaky systems	+	+	+	Widespread impacts but varied between regions
Spain	+	+	+	+ all 3 types	+	+	+	All impacts are found in most regions except Galicia, Asturias, Cantabria, Basque country
Sweden		+						Localised surface water shortages in dry years
UK	+	+			+			Localised issues in dry years

Source: Compiled from questionnaire responses

Each of these main types of impact is discussed below in more detail, to assess its extent and significance in Europe. In gathering the material for this chapter we have been able to trace more information for Spain than for many other countries. This is partly because of the importance of irrigation to Spanish agriculture, making it a subject that has been studied for many decades, and partly due to the importance of Spain's environment in relation to key European legislation (eg the birds Directive 79/409) which means that it has been a particular focus for recent environmental evaluation work.

We have therefore many Spanish examples in the discussion of impacts in section 3.2, in order to explain how impacts have arisen and to illustrate the potential magnitude of these impacts. Data and examples from other countries have been added wherever possible. A more comprehensive overview of impacts in each country is given in section 3.3.

It should be noted that many irrigated lands produce both positive and negative environmental effects at the same time, so that the net environmental impact of irrigation in any particular area will often depend on the importance and weighting of the mix of positive and negative effects that it has. These issues are explored in more depth through the case studies in Chapter 4.

Finally, it should also be noted that because much of the information, which has been gathered for the first time in this study, is qualitative, it is difficult to make robust comparisons of the scale and significance of the different impacts identified. It has therefore not been possible to rank impacts and instead the following sections attempt to illustrate how significant some of them can be, at both national and more local levels.

3.2.1 Pollution

Spread

The contamination of soil and water by high levels of fertiliser and pesticide use does not only occur on irrigated farm land – it can be a more general phenomenon of intensive farming methods in many different situations. However, in many countries in both northern and southern Europe, irrigation is used to facilitate particularly intensive kinds of production so there is often a greater use of inputs on such land, by comparison with dryland farming systems as a whole. The data in Chapter 1 highlights this link between irrigation and intensive cropping; the trend is for such areas to expand, while more extensive irrigated agriculture is commonly in decline.

In many countries including Portugal, Greece, Spain, Italy, France, the Netherlands, UK, Austria and Germany, irrigation in some regions has stimulated or accelerated a change in land use from less productive, less intensively farmed dryland cropping systems to intensive arable or horticultural production using irrigation. In addition, the use of water on the land helps nutrients and the active ingredients in pesticides to penetrate to deeper layers of the soil and it may increase rates of leaching and run-off into watercourses. An example is provided by the Prespa National Park area in Greece. The construction of an irrigation system, beginning in the 1960s, led to a conversion from extensive and diverse farming towards an intensive bean monoculture on irrigated crop land in the 1980s. This was accompanied by increased energy inputs, mechanisation and the greater use of agrochemicals. Today, almost the whole of the irrigable part of the area is intensively cultivated with beans. Nitrates have been overused, and the application of other fertilisers and pesticides has been the subject of severe criticism (Catsadorakis et al, 1997).

Impacts

The use of organic or inorganic fertilizers produces changes in soil ecology. The population of soil organisms can be altered significantly, thereby causing changes in the chemical composition of the soil: its pH, electrical conductivity and capacity for cationic exchange. In some cases the effects produced by an excess of specific nutrients - above all micronutrients like magnesium, iron and boron which may be present in the sources of irrigation water - can cause problems of phytotoxicity.

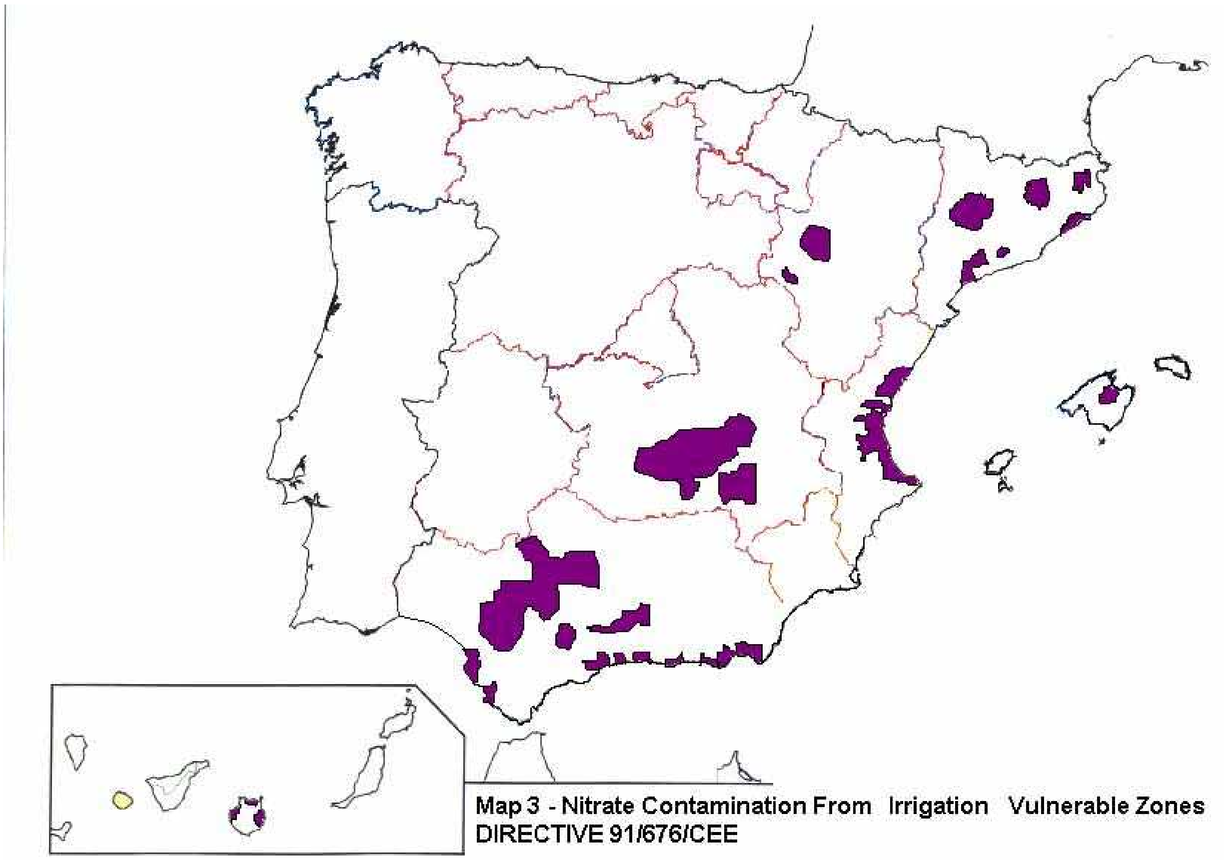
The use of agrochemicals can have serious effects on plant and animal populations in agricultural ecosystems. It can alter biochemical processes in soils, for instance increasing denitrification or slowing down the mineralisation of organic matter. Irrigation can lead to higher levels of use of nitrogen and phosphorous, subsequently these nutrients can be washed through soils by irrigation, potentially leading to water systems saturated by nutrients. This can cause eutrophication and damage to fragile aquatic species and habitats as well as the contamination of drinking water sources.

In Spain, each of the Autonomous Communities had to state the areas where groundwater resources are vulnerable to nitrate contamination *as a result of irrigated agriculture*, under a Spanish law transcribed from EC Directive 91/676. This refers exclusively to areas where contamination arises from the irrigation of crops, not from livestock wastes (Murcia has a problem with contamination by nitrates from animal sources). The maps overleaf show how these areas coincide with areas of nitrate contamination in aquifers. It indicates that nitrate leaching is particularly associated with areas of intensive agriculture where continuous irrigation, high levels of crop fertilisation and sandy soils are predominant.

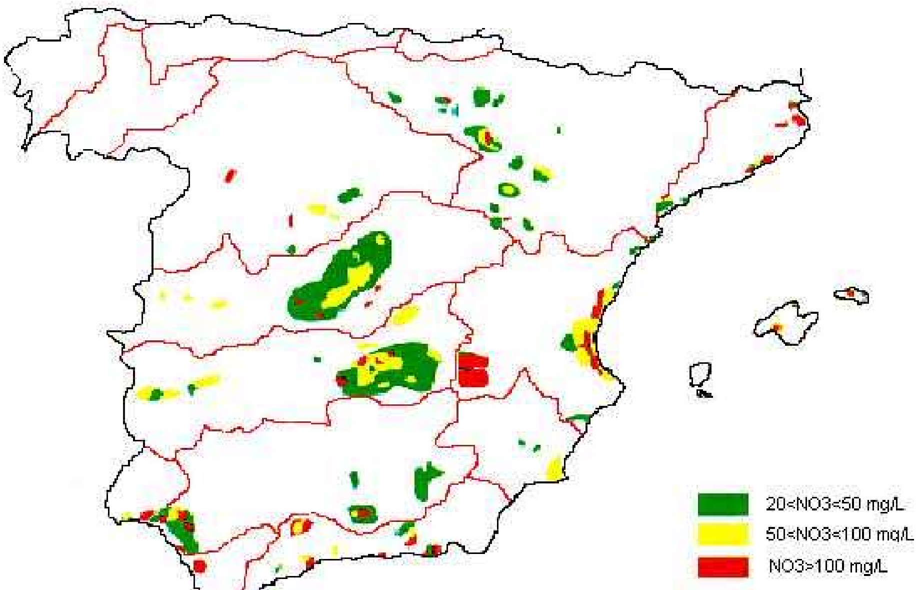
The same phenomenon occurs in Greece, where several of the country's Nitrate Vulnerable Zones coincide with the areas of greatest irrigation, particularly where irrigated agriculture is used to produce intensively cultivated crops (eg Argolid, Kopais Lake, Thessaly plain).

In France, the Water Agencies now levy charges for pollution from various water users, including farms in areas where intensive cultivation has led to problems of nitrate and pesticide contamination of water. The four agency regions in France with the greatest area of irrigated land are Seine-Normandie, Adour-Garonne, Loire-Bretagne and Rhone-Med/Corse, and in all these areas the incidence of water pollution by nitrate and phosphate compounds has been increasing in recent years, although some of this increase is related to livestock issues. In Adour-Garonne, 30 percent of the basin area is considered sensitive with regard to pollution by nitrates and eutrophication of rivers (Seres, 1998). However, it remains very difficult to identify whether irrigation per se has a significant marginal; effect upon nutrient leaching.

Maps Showing Coincidence of Nitrate Vulnerable Zones as Designated Under the EU Nitrates Directive and identified as vulnerable due to irrigation, and Location of N-contaminated aquifers, in Spain Source: Sumpsi and Varela-Ortega, 1999 (both maps)



Map 3 - Nitrate Contamination From Irrigation Vulnerable Zones DIRECTIVE 91/676/CEE



Map 4.- Nitrate contamination in aquifers

The Adour-Garonne Water Agency has instigated projects designed to address some of these problems by, *inter alia*, involving farmers in the planning and maintenance of river flow, supporting the installation of water meters and conducting research to identify husbandry techniques which can reduce leaching from irrigated maize fields (Seres, 1998).

Groundwater contamination by nitrate is also found in several regions of Austria which coincide with the areas of greatest agricultural irrigation. Both the Marchfeld and Pandorfer plateau in the east of the country, and the Welser Heide and Eferdinger Becken areas north-west of Linz, are areas of highly irrigated agriculture where nitrate contamination of groundwaters above 45 mg/litre is found in more than 25 percent of all measurements (Cepuder, 1998).

Pollution of groundwater by nitrogen leached from fertilisers on irrigated soils is related to

- the quantity of nitrifiable nitrogen present,
- the leaching potential, based on soil texture and percent depletion of available water in the root zone, and
- the amount of water entering the soil profile (Guimera et al, 1995).

When analysing the main causes of groundwater pollution by nitrate, economic factors influencing agricultural practices also have to be taken into consideration. Major determinants of the economic return from irrigated land are fertiliser costs and the price of water. The cost of surface water used for irrigation is very low in many southern Member States where water is scarce, including Spain, Greece, France and Italy. Moreover, the price of inorganic fertilisers will generally be in the range of 3-5 percent as a proportion of the annual value of final output, which is insufficient to provide a significant incentive to improve the efficiency of use of these inputs in many cases (Sumpsi et al, 1999).

In many areas where irrigation is practised, soils have a low natural fertility and high fertiliser applications are required to obtain significant yields. Over-fertilisation frequently occurs, with applications of 1,000kg N $ha^{-1}/year^{-1}$ being common for greenhouse crops, such as strawberries. A further characeristic of these soils is that water moves rapidly through them, which provides a great potential for nitrate movement to the groundwater (Guimera et al, 1995). Increased nitrate leaching as a result of increased soil moisture levels has for example been reported for a tomato crop (Cook et al, 1990).

Groundwater contamination also affects drinking water sources in various regions of Spain, Greece and Italy, where levels occasionally exceed the maximum admissible level of 50 mg/L NO_3^-. On the Spanish Mediterranean coast, for example, irrigated horticulture is one of the most intensive agricultural land uses in terms of water and nutrient use. Irrigation is carried out with groundwater, which also serves as drinking water supply. The groundwater use frequently changes the acquifer hydrodynamics. As there is no drainage system, excessive irrigation leaching recharges the acquifer through the vadose zone (1-30m). Groundwater is extracted through partially penetrating wells a few metres below the water table for irrigation, so that recirculation of leachates occurs. This causes serious damage to the groundwater quality and several cases of nitrate concentrations exceeding 300mg l^{-1} have been reported (Custodio, 1982, Guimera, 1992). One of the most polluted areas is the Maresme coastal acquifer in Barcelona (Guimera et al, 1995).

There appears to be less data to illustrate the level of pesticide pollution in aquifers, due to irrigation. National assessments in Spain have identified both Aldrin and Lindane as significant contaminants in some areas.

3.2.2. Over-exploitation of Water Resources

When surface water is scarce, as it is in most of southern Europe and in many parts of the north where irrigation is practised, groundwater is often used. Excessive abstraction can produce a wide variety of negative environmental effects, the most serious resulting from the exhaustion of the resource when abstraction is greater than natural recharge. Reductions in the level or availability of groundwater can cause the drainage of marshes, peat bogs and fens, as well as low or even zero flow in rivers that are normally fed by the groundwater table. Because of the large scale of historic losses of such habitats, many of the remaining areas are now of European and even global importance for their biodiversity. The drop in the water level of these areas can also start fires or lead to serious erosion by wind, because of soils rich in organic matter. The scale of these effects is equaled only by their irreversibility.

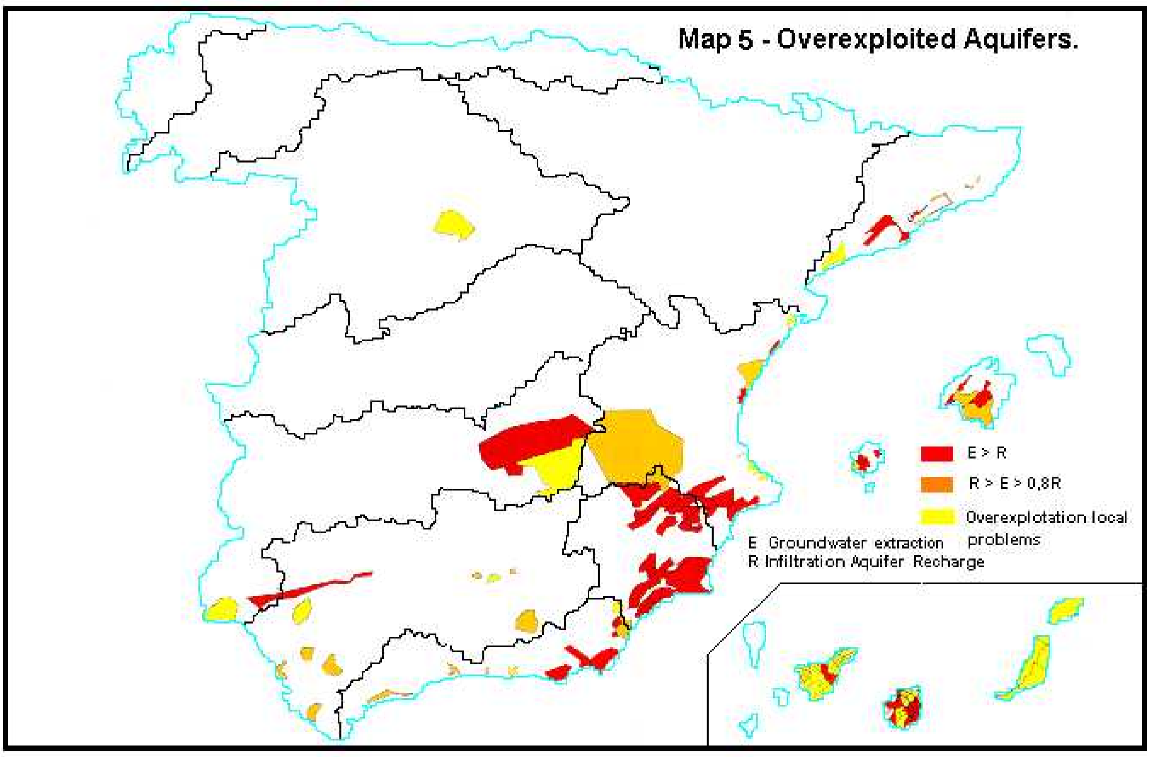
The drop in the level of groundwater due to over-abstraction can either be restricted to the cone of influence of a few wells, or across a wider area due to the juxtaposition of the cones of influence of different wells. It can cause the complete lowering of groundwater level for an entire aquifer, wherever abstractions exceed the aquifer's natural capacity for refilling. The degree of alteration in the aquifer's hydrological cycle and knock-on effects on ecosystems will increase as the fall in the level of the water increases, leading eventually to an exhaustion of resources. The situation can be critical to the survival of important flora and fauna in areas where irrigated farming systems are cheek by jowl with wetland and aquatic ecosystems.

The drop in the water table brings with it the need to carry out pumping at a greater depth, with a consequent increase in energy use and economic cost. The problem can worsen to such an extent that it makes the use of irrigation systems that require large flows impractical.

In Spain, the Hydraulic Public Property Bylaw Article 171.2 defines over-exploitation thus:

> "an aquifer is considered to be over-exploited or at risk when it is endangering the sustainability of its use, as a consequence of suffering annual extractions superior or very close to the average volume of the resources renewable annually, or which produce a serious deterioration in the quality of the water. The existence of the risk of over-exploitation can also be detected when the amount of water extracted in comparison with the renewable resources of the aquifer causes the aquifer to develop in such a way that its long-term exploitation is put in danger."

The existing shortfall between pumping and refilling in Spain is calculated at around 710 cubic hectometres per year. Over a third of this is borne by Western La Mancha in the province of Ciudad Real; almost as much corresponds to various aquifers in the province of Murcia, notably the Guadalentin valley, and the remainder is distributed among the provinces of Alicante and Almeria.



Source: Sumpsi and Varela-Ortega, 1999

In Greece, a number of studies on the impact of irrigation on groundwater in the valleys of Iria and Argolis (Peloponese) show that over exploitation of the groundwater, to meet the increasing demand for irrigation, coupled with prolonged periods of drought, has led to both the exhaustion of groundwaters and the deterioration of their quality. Over-pumping has resulted in the lowering of the water table and reversing of the hydraulic head gradients, allowing sea water intrusion into the aquifers in the area (Aggelides, 1995b). Nitrate concentrations were also found to be significant in both areas.

Groundwater shortage has also been a problem in some areas of the Netherlands, where irrigation is one of the factors contributing to the dessication of valuable nature reserves. In this case, the prior drainage of agricultural land in previous decades has meant that some farms now experience droughts in summer months and have therefore invested in sprinkler irrigation fed by groundwater. When combined with abstractions for industrial and domestic use, this has led to the drying out of nature areas. Over 600,000 hectares of nature area have been affected by dessication due to groundwater shortages. As a result, further significant expansion of groundwater extraction is now prohibited in state legislation (van der Wal, 1998).

Irrigation also influences the quality of water systems outside the limited scheme area. Irrigation return-flows typically carry more salt and minerals than the surface or groundwater sources used, due to evaporation and concentration in the agricultural system. This potentially affects downstream agricultural and natural systems. Irrigation withdrawals can leave downstream systems so depleted in water that riparian systems and fish and wildlife populations are damaged (Matson et al, 1997).

Surface water shortages as a result of excessive abstraction are a problem which has affected a number of northern Member States as well as some regions in the south. These areas include parts of France (see case study 5), the south-east of England, the Netherlands, Austria, Germany and even some localised areas of Sweden, in particularly dry seasons. These shortages are most commonly associated with direct abstraction for irrigation from rivers and springs. However, as in the case of Beauce in France (case study 5), they can also occur via groundwater abstractions which lower the water table to a level below the usual source of a particular river or stream, so it dries up.

In southern England during the period 1988-94, severe drought affected many of the region's aquifers and as a result, summer abstractions of water for irrigation caused significant impacts upon rivers, streams and related wetlands in many areas (see map on the following page). In 1990, the National Rivers Authority identified over 40 cases of over-abstraction which led to inadequate river flows in dry periods. It was estimated that 9 per cent of freshwater wetland Sites of Special Scientific Interest (the UK's protected nature sites) were threatened by abstractions for domestic water supplies and agriculture (English Nature, 1996). These threats resulted from a combination of abstraction from aquifers close to or underlying wetland areas, abstraction from rivers and lakes, and drawdown from agricultural drainage and drought. The impacts of abstractions upon fenland were particularly significant for nature conservation. Fenland vegetation is associated with low-productivity, base-rich, spring-fed sites which generally have a high water table. Many fenland plant communities are highly susceptible to desiccation. For example, in Redgrave and Lopham fen, which is an internationally important RAMSAR site, an average of 35

Rivers in England suffering from low flows (Fojt, 1993)

species was recorded in the spring-fed areas in the 1950s, but by 1992 only 5 species were found (Fojt, 1992).

3.2.3. Displacement of, or damage to high natural value habitats and landscapes

The alterations caused by the introduction of irrigation will often have dramatic effects on habitats, landscapes and biodiversity. Throughout the EU, there are areas where the spread of modern agriculture has displaced valuable semi-natural ecosystems. In the particular case of irrigated agriculture, such displacement has occurred in many parts of southern Europe over a significant period. Today, the trend continues in many regions, particularly in central France and along parts of the Mediterranean coast, as well as in the pseudosteppes area of inland Spain, where irrigated areas are still increasing.

The profound changes produced by the introduction of irrigation will inevitably include the disappearance of pre-existing ecosystems. The changes in the vegetation and the fauna of an area can affect other nearby areas and even distant ones (as happens with migratory species). Such changes can have dramatic effects upon the populations of many of Europe's most vulnerable species.

Wetland areas are particularly affected by intensive agricultural practices supported by irrigation. Two-thirds of the wetland area of Spain, France, Italy and Greece have been drained during the last two generations (Commission of the European Communities, 1995). The losses in other Mediterranean countries are thought to be equally high. A study carried out by Gerakis et al (1998) on Greek Ramsar sites started off by assessing the functions and values of wetland sites and then identified agricultural activities carried out in the watersheds and evaluated their effects on the wetland functions and values. There was also an assessment of the intensity with which each activity is practiced in each watershed. It was found that irrigation, of a total of ten agricultural activities common in the watersheds of Greek Ramsar sites, was the activity with the most profound and long term effects on all functions (nutrient removal/transformation, sediment/toxicant retention, flood flow alteration, groundwater discharge) and values (biodiversity, fishing, hunting, recreation).

Until the mid 1920s, the agroecosystems of Greece were predominantly rainfed (Zalidis et al, 1998). The expansion of irrigation since the mid 1950s enabled the use of more and larger subsidiary energy inputs in terms of fertilisers, pesticides, heavy machinery, improved crop varieties and livestock breeds. Moreover, the mismanagement of irrigation schemes may lead to excessive irrigation return flow which results in increased nutrient, sediment and toxicant inputs into wetlands (Turner et al, 1980).

The transformation of dryland to irrigated land most often implies the adoption of more intensive cultivation practices which can also have negative impacts upon landscape quality and character. Intensive cropping can lead to monotony in the shapes and colours of landscapes, as well as reduced diversity in vegetation types and textures. The most clear examples of this negative impact are in those regions where irrigation has facilitated a large scale expansion of arable or industrial cropping (eg cotton in Greece, maize in France) and where glasshouses have become the dominant form of irrigated agriculture, creating so-called “plastic seas" (see case study 2, Spain).

The creation of artificial barriers as part of the irrigation infrastructure (eg approach roads, ditches, irrigation channels) can also make difficult, or even prevent, the migration of terrestrial species. In the long term, such isolation can lead to a decline in the genetic diversity of plant and animal communities which can render them more vulnerable to future climatic or other external change.

During the development of the irrigation system in the Prespa National Park area in Greece for example, profound landscape changes took place. All small forest tracts and natural hedges in the scheme area were clearcut, large numbers of trees and scrub were felled, embankments were created and natural streams straightened. Ground levelling and the removal of large quantities of soil took place, marshes and wet meadows were drained and roads were opened, redesigned and asphalted (Catsadorakis et al, 1997).

The introduction of irrigation can alter biological processes. In Prespa National Park, the development of the irrigation system from the 1960s led to an increase in reedbeds, to the detriment of wet meadows. After 1990, the water level of Lake Megali Prespa steadily lowered, leading to the exposure of alluvial flats, the formation of temporary marshes and drying out near the coast line (Catsadorakis et al, 1997).

Modifications to food chains by the use of insecticides and pesticides, the elimination of herbivorous species and the creation of monocultures, all common by-products of irrigated agriculture, can have damaging effects upon wildlife. Even where irrigation could have a positive effect in enabling a marked increase in crop diversity, economic subsidies to farm products, market forces and other factors may favour monoculture. An example is provided by Greece, where the semi-arid climate of most of the country makes winter cereal monocultures in rainfed ecosystems inevitable. Even though the irrigated agroecosystems of Greece are more diversified than the rainfed ones, the above effects signficantly reduce the potential positive effect upon biodiversity (Gerakis et al, 1998).

The Prespa National Park is an area of high biodiversity. The dramatic habitat changes in the 1960s described above led to strong declines and the local extinction of several species from the early 1970s (Catsadorakis, 1997). Between 1970 and 1980, six bird species ceased breeding or became completely extinct. Between 1981 and 1994 eight further bird species were affected, as well as a range of plant species. The bean monoculture created with the help of the irrigation system remains without any vegetation cover up to mid-April and offers little cover throughout the season. There was also a decline in the diversity of domestic animals, with livestock farming decreasing significantly and the number of local cattle breeds also declining. Dairy cattle disappeared completely from the area (Catsadorakis et al, 1997).

In Spain, studies of bird populations in the pseudosteppes indicate that the conversion of land by introducing irrigation is the most significant factor affecting declines in certain important species. For instance, a good example of the relationship between steppe birds and traditional dryland management is given by the lesser kestrel. The reproductive success of lesser kestrel has been found to be positively related to the proportion of the area surrounding the nesting colony that is occupied by its selected feeding habitats, i.e. traditional dryland crops, long-term fallow, and pastures. The bustard, by contrast, can feed on irrigated as well as dryland areas, but its ability to hunt effectively can be reduced by the large-scale water management infrastructure that often accompanies modern irrigation.

The presence of Spanish imperial eagle is also affected by irrigation, as has been shown by radio-tracking of young birds in Andalucia. Eagles live in areas with a typically Mediterranean climate providing both nesting habitats (woods) and hunting habitats (Mediterranean scrub with rabbits). They completely avoid areas converted into irrigated land.

3.2.4. Positive impacts upon biodiversity and landscapes

Traditional systems

Traditional irrigation systems may generally be viewed as having a positive effect on the environment, in that they have sustained a small-scale, labour intensive agriculture which has increased the diversity of some historic landscapes, particularly in southern Europe. However, the majority of historically irrigated land is situated in the most productive areas of the Mediterranean littoral and the most fertile valleys and plains in the interior of Spain, Italy and Greece, so there are now strong incentives for producers to change their methods and increase yields. In Spain, the small farms in these areas have now taken as much advantage as possible of available resources to develop intensive irrigated agriculture which, together with an irrigation infrastructure in generally bad condition, usually means that the negative environmental impacts (eg pollution, contamination) outweigh the positive.

The very small units of intensive agriculture that characterise many traditional irrigated lands today have tended to move either into intensive crops under plastic which generate a high yield per unit area; or into tree crops which require less labour-intensive management. In the latter case, many farmers now work only part-time on the holding and they supplement their incomes with other work which is more stable and better paid, even if usually seasonal (eg in tourism, leisure or agro-industry).

Whichever type of cropping is now employed on these small holdings, the incorporation of technology has become essential to their economic survival. In this context, there is a growing use of drip irrigation systems (high frequency and low flow rate).

However in Greece, Spain, Portugal and southern France there also exists irrigated agriculture which promotes soil conservation and the maintenance of areas of valuable cultural landscapes, including terraces bounded by small stone retaining walls (dry stone walls). This form of agriculture is to be found in mountain areas of the Mediterranean hinterland with a favourable microclimate. It is based on the construction of terraces, on a moderate use of water (irrigation by hand, along furrows) and on non-intensive systems of production (often fruit trees, almonds and olives).

Today, many of these landscapes are in serious decline due to the relatively low productivity of such systems and their high labour requirement; irrigated terrace agriculture has been abandoned on a large scale, in some regions, leading to problems of erosion and desertification.

New landscapes in the hills – an example from Spain

Intensive irrigated agriculture already covers a significant area of the land along the Mediterranean littoral in Spain, but its continued expansion is now constrained by both lack of water and land. As a result, new areas of tree crops are now being established on the slopes of the nearby mountains, where the cost of introducing irrigation is lower. They use irrigation from wells instead of expensive hydraulic infrastructure, and earthworks are not necessary because the irrigation is by drip systems instead of by hand.

In comparison with the prosperous and extensive market gardens of the Mediterranean littoral, the hinterland's agrarian economy has been based on unirrigated crops grown on the extensive piedmonts and glacis that shape the valleys of the Castilian plateau. However, with its high labour use and low yields, this traditional agriculture has become economically marginal and has therefore been abandoned in many areas. Over the last three decades the abandonment of large areas of vineyards, almonds, cereals and olives on mountain terraces has occurred.

More recently, new groundwater sources have been identified in these areas, opening up the possibility of a new kind of irrigated farming, to produce tree crops. There can be environmental benefits from the application of drip irrigation in these areas, as follows:

- Less land is abandoned and the amount of vegetation on the slopes increases. This diminishes the risks of desertification and erosion.

- Less work is needed to farm these areas. The irrigation water includes all the nutrients needed as well as being more efficient in its application. Drip irrigation together with the fact that little cultivation is required for the crops on the slopes (olives, almonds, tree fruit) mean that the soil is preserved, although it also increases the use of herbicides.

However, these irrigated systems are not free from negative consequences, among which the following stand out:

- The use of fertilisers and pesticides increases, being conveyed in the irrigation water, which may lead to the contamination of subterranean aquifers and the soil.

- There is greater potential for over-exploitation of local surface and groundwater resources due to the increase in pumping. When the pumping goes beyond certain limits the decline in water quality is so rapid that it becomes unsuitable for irrigation; salinisation may also occur.

- The agrarian landscape becomes scattered with small and medium-sized, private and communal, plastic or metal reservoirs, due to the need to store water.

Creation of wetland areas of high potential biodiversity
Some irrigated agriculture has created new habitats for certain species of fauna. This is especially true in the rice-producing regions of southern Europe, including Spain, Italy and the Camargue in France. In Spain the growing of rice began in the Ebro Delta, the Albufera (Valencia) and the Guadalquivir Marshes as a consequence of the Islamic invasion in the eighth century. During the reproductive season the rice fields of Southern Europe are used by many aquatic birds for breeding and feeding.

The positive impact of irrigation has been studied in some detail for the Ebro Delta. Yellow-footed gulls and Audouin gulls use the rice fields of the Delta as a source of food alternative when their sources of sea fish diminish. During the periods when they are not migrating the percentage of captures obtained in the rice fields increases from 13 percent to 17 percent for yellow-footed gulls and from 0 percent to 20 percent for Audouin gulls, which take leeches, crustaceans and eels from the rice plots. The importance of the rice fields in providing this food is such that the Ebro Delta has become essential for the survival of the young Audouin gulls during migration.

Rice fields may also become good habitats for ducks, water rails, egrets, gulls and waders. As many as 40 species of small waders live in the Ebro Delta during the winter, a population of between 12,000 and 20,000 birds, depending on the extent of the area that is under water. Moorhens and water rails also live in the Ebro Delta during the autumn and winter. White-headed and yellow-footed gulls, the most numerous species in the Delta during the winter, feed by following the machines working in the rice fields; while herons usually accompany them.

The plots in the Ebro Delta are used in a different way by each farmer, creating a mosaic of fields with different levels of flooding. While there is no quantitative data on heron feeding after the breeding period, the rice fields are where the herons - including small flocks of grey herons - choose to spend the winter in Spain. The birds are especially numerous when the rice fields are under water, from October to December.

However, the positive impact on bird species in the rice fields coexists with negative impacts, which are a consequence of the farming practices used in the growing of rice. Irrigation is achieved by means of a network of channels which carry the water from the rivers to the plots. The variation in the water levels while the rice is growing causes stress in the plots due to reduced oxygenation and poor conditions for the aquatic fauna developing there. The different kinds of pesticides used to control algae, broadleaved weeds, crustaceans and insects in the rice fields obviously also affect the aquatic birds, both directly and indirectly. Interesting studies are now taking place to evaluate the impact of converting some plots to organic rice production and allowing virtual abandonment to take place on others. Environmental benefits have been detected in both cases by the Spanish Ornithological Society, SEO.

3.2.5. Soil Erosion

Spread

Due to soil and hydraulic properties (Koluvek et al, 1993), both the occurrence and the risk of erosion due to irrigation are greatest in Spain, Greece, Italy and Portugal, but it is also a problem in some regions of France, Austria and Germany.

Impact

There are two kinds of erosive phenomena in irrigated areas: natural erosion by the action of rain or wind, and erosion produced by irrigation water. Lighter, more drought-prone sand, silt or chalk soils are generally more easily eroded than heavy clays. Whenever land is cultivated excessively and its organic matter is not replenished erosion will be accentuated. The slope, both length and gradient, is an important factor in determining the degree of erosion by water, while the size of fields and absence of field boundaries can be a factor determining erosivity by wind.

Erosion by irrigation water can include: the impact of drops of water on the soil surface (eg from pressurised sprinkler systems), laminar erosion from flooding (eg in gravity systems), and erosion in furrows and ditches, in any system where water flows across the land. Each irrigation system may cause one or more of these effects, depending on its characteristics. It is considered that most erosion caused by surface irrigation occurs with channelised flows in furrows (Koluvek et al, 1993).

- Drip irrigation is the best system for minimising erosive processes, given that it produces neither washout nor direct impacts on soil particles. Because of low application rates, runoff and erosion do not normally occur (Trout et al, 1993).Irrigation with sprinklers can cause erosion due to drops beating on the soil when the application rate exceeds the soil infiltration rate, which frequently occurs near the outer end of center pivot systems (Trout and Neibling, 1993). The degree of erosion will depend on two main factors:
  - the size of the drops;
  - the speed at which the drops fall.

  Irrigation which uses large sprinklers or water cannons will produce a greater erosive effect than microsprinkling systems

- The degree of erosion caused by irrigation by hand depends to a large extent on the knowledge and awareness of the farmers using these practices.

Soil erosion from irrigated agriculture has been a particular issue in those parts of France which have seen a rapid expansion in the area of irrigated maize grown in recent years. The erosion is exacerbated by irrigation water and also by the fact that maize farmers have removed many field boundary features in order to enlarge fields and thereby reduce the cost of crop husbandry. Maize is a particularly poor soil conserver since the stems of the crop are widely spaced and the soil surface is therefore left exposed for a large part of the year. Furthermore, the regions where irrigated maize has spread include those which are commonly affected by serious storms during the spring and summer, when significant erosion events will occur. In the area of Rennes in Brittany, the spread of irrigated maize on slopes around the town has led farmers to concentrate their cattle at the base of the hills, where a drain system supplies water for local domestic use. The combination of eroded and enriched soil sediments from the maize fields, plus localised poaching and pollution from the cattle, has seriously contaminated these water supplies (Pujot et Dron, 1998).

3.2.6. Salinisation

Spread

Salinisation of water and soils as a result of irrigation is a major issue in Greece. About 25 percent of existing irrigated lands in Greece face severe problems of salinity and many more thousand hectares of land are expected to be affected by salts in future, due to the use of poor quality irrigation water, improper irrigation practices and bad soil management. The phenomenon is also widespread in many areas of Spain and some parts of Portugal, as well as south-west France.

Impact

The factors which determine the risk of salinisation are the drainage systems available on irrigated land, the amount of water used, and the quality of water used in irrigation. Where land drains are deficient or blocked it can cause not only waterlogging of soils but also an increase in the salinity of the soil, particularly if this already has an excess of salts or if it is irrigated with saline water. An excess of water in a system due to irrigation will make the phenomenon of swamping more acute and, as a consequence, increase salinisation of the water (Guimera et al, 1995).

Salinisation of water by marine intrusion arises where water abstractions from aquifers exceed natural recharging rates, and the level of the water table drops. This occurs in most coastal irrigated areas in Spain, and many parts of Greece, as well as some regions of Portugal and Italy.

In Spain, 82 aquifers in the coastal areas of the Iberian Peninsula and the Balearic Islands have been degraded by marine intrusion through over-exploitation of groundwater for irrigation and other uses. In some cases the intrusion is local and limited to specific areas, but there are also areas where most of the aquifer is affected by these problems.

Map 2 shows the occurrence of marine intrusion in Greece. Regions with salinisation problems can be found all over Greece, but mainly in the coastal regions of the provinces of Pieria and Kavala (in Macedonia), as well as those of the Eastern and Southern Peloponese and the islands of the East Aegean and Crete

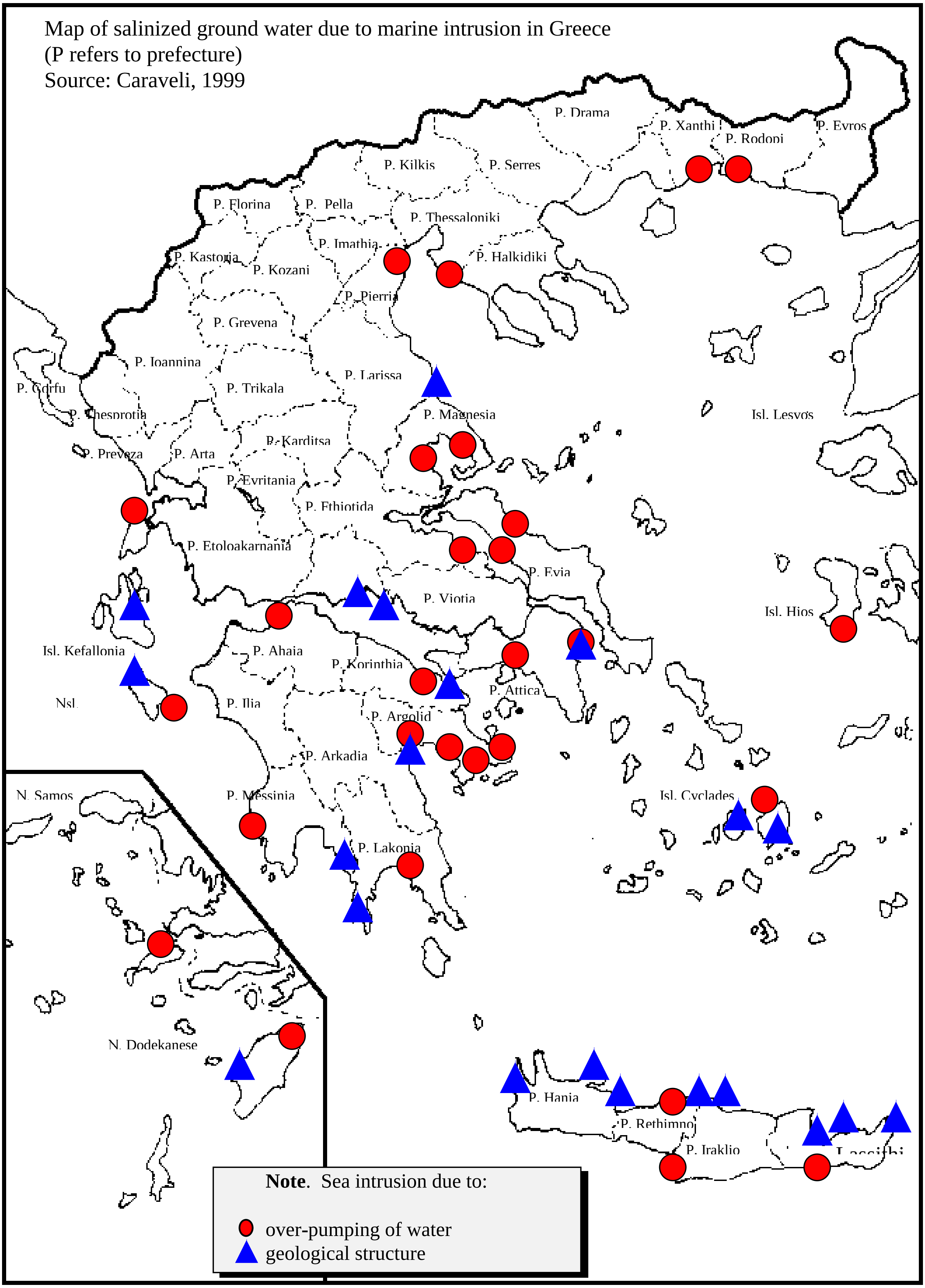
An excessive or imprecise use of fertilisers in irrigated systems can also contaminate the soil solution and modify the concentrations of ions in it, thereby producing salinisation.

In Greek and other mediterranean soils, there is often potential for the accumulation of soluble salts. As the warmer and drier climate which is expected to prevail in future will increase aridity and drought hazard, the expansion of irrigation over larger areas will be increasingly necessary if agricultural production is to continue. According to expert assessments in Greece, about 25 percent of existing irrigated lands in the country face severe problems of salinity or alkalinity and many more thousands of hectares are expected to be affected in future. The problem will be aggravated through diminishing groundwater recharge due to reduced rainfall and the intrusion of brackish water into aquifers (Kosmas, 1999).

Studies in the Peloponese show that the salinity status of the soil is correlated with that of the groundwater used in irrigation; most of the salt is found to be leached through the soil profile and to move towards the groundwater; and sea water intrusion in conjunction with the leaching process tends to establish a vicious circle of soil and groundwater degradation, leading to desertification, if untreated (Poulovassilis et al, 1996). Other studies in Greece have indicated that salinisation due to irrigation with brackish water is higher for tree crops (citrus) than for annual horticultural crops, because the former use water for a much longer season (May to October).

The process of salinisation has increased over time in the Guadalentin Basin in Murcia in Spain because of the high salt content of water in areas that have been exploited for a long time. This is caused by the increase of free carbon dioxide (CO_2) liberated by falling water-tables. An increase in water temperature and in the content of bicarbonate and sulphate ions also occurs. The contamination of agricultural soils by these salts causes the development of a dark crust that obstructs root aeration. Moreover, chemical reactions between the soil salts and the bicarbonates in the irrigation water generate compounds (e.g. sodium carbonate) that are highly toxic to plants, leading to reduced productivity.

MAP 2



Map of salinized ground water due to marine intrusion in Greece
(P refers to prefecture)
Source: Caraveli, 1999
P. Drama
P. Xanthi
P. Rodopi
P. Evros
P. Kilkis
P. Serres
P. Florina
P. Pella
P. Thessaloniki
P. Imathia
P. Halkidiki
P. Kastoria
P. Kozani
P. Pierria
P. Grevena
P. Ioannina
P. Larissa
P. Corfu
P. Trikala
P. Thesprotia
P. Magnesia
Isl. Lesvos
P. Preveza
P. Arta
P. Karditsa
P. Evritania
P. Fthiotida
P. Etoloakarnania
P. Evia
P. Viotia
Isl. Hios
Isl. Kefallonia
P. Ahaia
P. Korinthia
P. Attica
Nsl.
P. Ilia
P. Argolid
P. Arkadia
N. Samos
P. Messinia
Isl. Cyclades
P. Lakonia
N. Dodekanese
P. Hania
P. Rethimno
P. Iraklio
Note. Sea intrusion due to:
over-pumping of water
geological structure

3.2.7. Major infrastructure impacts

The construction of large dams to create enhanced water sources for irrigation (and other purposes) can have dramatic effects on landscapes and biodiversity. In Portugal and Spain there have been several cases where new dams have flooded historic landscapes and displaced traditional communities, as well as submerging valuable natural and semi-natural habitats of some importance for rare species of wildlife. For example, Spanish dams such as Melonares (in Sevilla), Breña II (Córdoba), Irueña (Salamanca) and Andévalo (Huelva) will destroy *Lynx pardina* habitats, which is a priority species in Appendices II and IV of the habitats Directive.

Bringing very large quantities of water from distant areas by means of integral irrigation plans, reservoirs or canalisation of rivers can lead to an unnatural increase in groundwater level in some regions. The dangers of this are the swamping of the soil, a decrease in its aeration and parallel chemical processes, with important repercussions on soil microfauna and vegetation. Both agricultural and wild plants may suffer significantly retarded growth rates.

In some regions of France, the recharging of rivers in dry periods with irrigation water which has been transported from mountainous areas can have significant impacts upon local flora and fauna. This has been particularly noted in the south-west and Poitou-Charentes. Cold and clear water released into the area causes a thermal shock to wildlife and can be highly erosive. Another phenomenon in these areas has been the effect of canalisation of rivers as part of irrigation infrastructure projects, which has been damaging to local aquatic biodiversity (Pujot et Dron, 1998).

3.3 Environmental Impacts of Irrigation by Member State

This section briefly summarises experts' views about the occurrence and severity of impacts in the Member States, grouped according to the classification presented in Chapter 2.

Group A Member States

In overview, the impacts of irrigated agriculture in *Spain* vary at regional level. Negative impacts upon biodiversity are found in regions with wetlands: Andalucía, Aragon, Castilla La Mancha, Castilla y León, Cataluña and Murcia; and in regions where irrigated farms are adjacent to wetlands. The most common impact is where the irrigation of former dryland areas threatens valuable dryland species. In the case of Castilla y León and Aragón there are significant negative effects upon pseudosteppe bird life. The trends are increasing or stable in each affected region, but mainly increasing overall. Impacts of irrigation upon water pollution, groundwater exhaustion, salinisation and erosion principally affect Andalucía, Murcia, the Balearic islands, Valenciana and the Canaries. The most common impacts here are eutrophication of water by nutrients, lowered groundwater tables, salinisation by marine intrusion and reduced water flow in rivers. These trends are also increasing. However, in the regions of Asturias, Cantabria, Galicia and País Vasco there are no important negative impacts because of the relative insignificance of irrigation here. Positive impacts are most marked in relation to a few localised mountain and delta areas, as discussed under section 3.2.4.

In *Greece,* the agricultural intensification process in the lowlands, associated with irrigated production of industrial crops such as sugar beet and cotton, has been a principal source of environmental degradation. The increase in irrigation here, in particular, has been a major cause of the over-exploitation of aquifers and the exhaustion of water resources. The expansion of mass tourism in coastal areas has aggravated the problem through its impact on land-use patterns and the allocation of water resources - over-abstraction of water for both drinking and irrigation is found in these areas. A deterioration of the quality of affected water courses and lakes has also been observed, where nitrates, phosphates and ammonia emissions have exceeded accepted values in recent years in many cases. Overall, the most severe environmental problems related to irrigation in Greece are significantly lowered groundwater tables, salinisation of ground water from the sea and from dissolved salts in soil strata, contamination of land by salts and related desertification, and desertification as a result of significant soil erosion on irrigated slopes (Caraveli, 1999).

In *Italy,* over-abstraction of groundwater is a serious issue in some areas of the Po valley, and in many parts of the country water sources are polluted by a combination of agricultural inputs and domestic and industrial contamination. Coastal pollution of seawater is also a problem in some areas. In both these cases, irrigated intensive agriculture makes some contribution to the overall impact. In southern Italy, a marked regional disparity in water availability has led to the construction of large surface water transfer facilities from Basilicata to Apulia, with some negative impacts upon landscapes and habitats (Hamdy, Lacirignola, 1999).

In *Portugal,* irrigation leads to a mix of positive and negative impacts depending on the regions considered. In the regions of Entre Douro e Minho, Beira Litoral and Beira Interior, where irrigation is generally in decline, the traditional systems here make a positive contribution to the maintenance of landscape character and biodiversity. In Tras os Montes also, beneficial extensive systems of irrigation persist. However in Lisbon and Vale do Tejo, irrigation is associated with modern intensive cultivation methods which give rise to problems of pollution, drinking water contamination and habitat and species decline. The irrigation practices in the Algarve have led to serious pollution of drinking water sources, and the problem also occurs in relation to the production of vines, horticultural crops, rice and maize around Lisbon and Vale do Tejo. Salinisation is also a problem in coastal areas of Alentejo, Algarve, Beira Litoral and the coast north of Lisbon. Investigation of this problem in the Algarve has shown it to be caused by seawater intrusion (Caldas, 1999).

Group B

In *Austria*, existing irrigation practice in the east of the country has led to contamination of ground water with pesticides and nutrients (especially nitrate). Significantly lowered groundwater tables are a problem only in some regions (e.g. Marchfeld). Elsewhere, insufficient water sources for irrigation may locally restrict the development of agriculture. Agricultural use and irrigation of former dryland areas still threatens valuable dryland species in some regions. However, irrespective of the development of irrigation, the agricultural use of former meadows (dryland and wetland) has already destroyed habitats and valuable species in some lowland areas of Austria (Mottl, pers. comm.).

In *the UK,* the picture is similar to Denmark. Serious drought in the period 1988-94 led to some dramatic incidents of streams drying up and low flow in larger rivers in much of the south-east of England. Groundwater tables were also significantly lowered during this period. However, since then a succession of wetter years has largely restored water balance. In the long term, the UK authorities see an increasing need to control and to improve the efficiency of agricultural water use in south-east England since this area is expected to suffer more frequent water shortages as a result of global warming (MAFF, EA, personal communication 1999).

In *the Netherlands,* the dessication of former wetland areas due to over-abstraction of groundwater is a serious phenomenon affecting 560,000 hectares of semi-natural and natural habitats. Between 1950 and 1985 the water table in the Netherlands fell by an average of 25cm. The problem is a combined result of abstraction by industry, domestic supplies and agricultural and horticultural irrigation, mainly by sprinklers. In addition, the use of poor quality surface water from the Rhine for irrigation purposes has led to localised problems of soil and water contamination, and the pollution of polder waters by nutrients, due to increased run off from irrigated land, is also recognised in some areas (Bleumink and Buys, 1996).

In France, the principal environmental impacts of irrigation vary markedly between the main irrigated regions. In the mediterranean and south-west areas, where most irrigation is via collective systems and is used for horticulture, the most notable impacts of irrigation have been the result of major engineering works to supply water from rivers to arid regions, including canals, dams and reservoirs. Here, there has been significant damage to semi-natural habitats and to aquatic ecosystems as a result of these changes. In addition, the lowering of groundwater tables is also an issue. In the more northerly regions problems of pollution and soil erosion, particularly from irrigated maize, predominate, although as the case study shows, lowered groundwater tables have also been a problem in some areas, particularly during periods of prolonged drought (Ifen, others, 1997).

In *Germany*, the most common environmental impact of irrigation today is the localised contamination of water supplies due to nitrate leaching from irrigated fields. In a few rare cases, soil erosion due to irrigation on slopes has also been a problem. However, in the past it is likely that the introduction of groundwater irrigation led to the dessication of former wetland areas in several regions (Sourell, pers. comm.).

In *Denmark*, the environmental impacts of irrigation are not nationally significant. However, surface water irrigation causes some low-flow or drying out of rivers with damage to aquatic flora and fauna in some regions, particularly in years of drought (Hvid, pers. comm.).

In *Belgium*, ground and surface water contamination by pesticide and fertiliser run-off from irrigated land has been observed in some areas, but the extent of the problem is not fully known at this stage (OECD, 1998).

Group C

As would be expected, the environmental impact of irrigation in these Member States, including *Sweden, Finland, Luxembourg* and *Ireland* is minimal and appears unlikely to become any more significant in future. The only one of these countries reporting any environmental impacts has been Sweden, where it is noted that irrigation can reduce nitrate contamination of water by diluting agricultural leachate, and that in dry summer months, abstraction of surface waters from small streams for irrigation can cause localised problems for the ecology of these rather sensitive habitats.(de Mare, pers comm).

Chapter 4. Five Case Studies of the Environmental Impact of Irrigation

This chapter includes a selection of case studies which have been chosen to illustrate in more detail some of the environmental impacts of irrigation in the EU. The selection has been designed to include areas from both the south and north of the Union, and to cover a broad spread of irrigation types and environmental impacts.

The five areas selected are:

- Daimiel (Cuidad Real) in Castilla La Mancha (central-southern plateau), Spain;
- Campo de Dalias (Almeria coastline) in Andalucia (south), Spain;
- Argolis area in the North-East Pelopponese, Greece;
- Marchfeld, in eastern Austria;
- Beauce, northern France.

The principal characteristics of irrigation in each area are shown in table 4.0.1 below.

Table 4.0.1 Overview of Case Study Characteristics

Area	North or south EU	Type of irrigation	Crop production systems	Institutional arrangements	Environmental impacts
Daimiel, Spain	South	Groundwater with pressure (sprinklers), permanent or support	Arable Vineyard	Water rights with users, public regulation and control on water extractions, and agri-environmental incentives (2078/92)	Deterioration and dramatic desiccation of valuable wetlands with negative effects on biodiversity
Dalias, Spain	South	Groundwater with pressure (drip), permanent	Glasshouse horticulture	Water rights with users, public regulation and control on water extractions	Salinisation (marine intrusion) and pollution from high levels of chemical inputs, but some wildlife benefits from artificial lagoon
Argolis, Greece	South	Surface and Groundwater with pressure (sprinklers) continuous	Intensive (tree crops and horticulture)	Complex system – 50% of abstractions private and under-regulated, 50% collective.	Marine intrusion – salinisation of soils and groundwater, erosion and desertification
Marchfeld, Austria	North	Groundwater and Surface waters	Arable and other crops	Formerly unregulated, now controlled through a project instigated by the state, with charges to farmers	Biodiversity losses due to lowered groundwater table, pollution of rivers by agricultural inputs
Beauce, France	North	Groundwater with pressure (sprinklers), periodic	Arable, outdoor horticulture	Private use rights but with quotas and water metering; inter-basin working group (local government, water authorities, environment and industry)	Aquifer lowering causing low/no flow in rivers with likely negative impact on aquatic ecology as well as economic impacts on non-irrigated cropland

Each of these is presented here in turn.

4.1 CASE STUDY 1: TABLAS DE DAIMIEL

4.1.1 Introduction

The *Tablas de Daimiel*, in the province of Ciudad Real, are one of the most peculiar geographical accidents in the landscape of La Mancha, in southern Spain. The geomorphological and hydrological conditions that come together in the High Basin of the River Guadiana give rise to a network of small lakes and areas flooded by the overflowing of the Rivers Guadiana, Gigüela, Riansares and Záncara. The resulting wetland area is included in Category A - exceptional interest - in the Catalogue of important wetland areas in Europe, as a habitat for the conservation of European and North African aquatic birds.

Until recently the River Gigüela, which flows from the north-east (in the province of Cuenca) to the south-west (province of Ciudad Real), overflowed naturally at various points downstream from the area of Puerto Lápice. These floodings are known locally as *tablas*; the two main ones in La Mancha are the *Tablas de Villarta* and the *Tablas de Daimiel*. The River Guadiana, which also floods, rises in Los Ojos de Guadiana and joins the River Gigüela in the area of the *Tablas de Daimiel*.

The considerable ecological productivity and biodiversity of the wetlands in La Mancha give them a high environmental value and unique geochemical and limnological character. They provide good conditions for many species and large populations of nesting and overwintering waterfowl. The area has attracted special national and international recognition for its conservation value. It is designated as a UNESCO Biosphere Reserve, RAMSAR site, Special Protection Area (SPA) under the birds Directive 79/409, and has been proposed as a Natura 2000 site under the habitats Directive 92/43. A number of other international and local designations also apply to the area.

Origins of irrigation
The plains of Castile La Mancha are an area of scarce and often irregular rainfall, between 300 and 400 mm/per year. This, and the fact that the drainage of the soil is deficient due to the multitude of depressions and small lakes with high evapotranspiration, makes them among the most arid parts of the Iberian Peninsula.

Dry farming on these plains is limited to some winter cereals, vineyards and olive groves. The irregularity of rainfall means land is often fallowed for long periods. On the whole, such farming is not very profitable. However the area has been transformed by irrigation.

In the early 1980s there was a rapid increase in the cultivation of maize at the expense of winter cereals. This produced yields higher than the Spanish average, leading to talk of a ‘maize revolution’. In 1991 81,000 hectares were under cultivation; this went down to 60.000 hectares in 1992 and fell further to 38.000 in 1993, since when maize has almost disappeared. Large areas in the region have also been devoted to sugar beet and alfafa.

Table 4.1.1 shows annual extractions from the Western La Mancha aquifer and the areas irrigated:

Table 4.1.1

Year	volume extracted	area irrigated	water delivered

	(hm^3)	(ha)	m^3/ha
1974	152	28,666	5,302.4
1976	221	48,750	4,533.3
1978	265	66,250	4,000.0
1980	320	78,125	4,095.0
1982	387	91,254	4,240.9
1984	415	96,585	4,296.7
1986	525	117,200	4,479.5
1988	568	121,276	4,683.5
1990	522	117,212	4,453.4
1992	410	89,280	4,592.2
1994	236	73,505	3,210.5
1995	217	73,582	2,949.0

Initiatives

The expansion of irrigated land on the plains of La Mancha was made possible by the use of groundwater and the building of wells and infrastructure by farmers, on an individual basis. The use of water from the Western La Mancha Aquifer 'nº 23', with an area of 5,000 km^2 in the centre of La Mancha, was particularly significant. Until the middle of the 1970s the aquifer could be regarded as being in surplus. Between 1980 and 1987 the rhythm of drillings and extractions accelerated, influenced by several factors:

- the good returns from irrigated land compared to dry land increased the number of farms switching to irrigated cropping;
- public subsidies were available for irrigation machinery and infrastructure;
- a new Water Act had been proposed (eventually passed in 1985) which would limit the number of wells in the area;
- there was a view locally that the water should be exploited before supplies dried up.

The Rhythm of Change

The 30,000 hectares irrigated by the Aquifer in 1974 had become nearly 130,000 hectares ten years later. However, at the end of the 1970s the drop in level of the Aquifer's water table indicated an excess of demand over supply, putting extreme pressure on the resource. The Aquifer's natural outlets, responsible for the course of the Guadiana (los Ojos de Guadiana), ceased to flow, which led to a progressive reduction in the extent of the La Mancha wetlands. The *Tablas de Daimiel* National Park, the heart of these wetlands, began to deteriorate as the incidence of flooding seriously diminished.

The text box below presents a chronology of irrigation in the area, illustrating the long sequence of cumulative damage to the aquifer and the National Park due to the gradual expansion of irrigation.

Chronology of irrigation in the Daimiel region: - 1945-84

1945 The *Obra Sindical de Colonización* (Union Colonization Department) excavated a large well to extract water and irrigate the area of Gil Pérez, near the town. A huge tank with a capacity of around 6,000 cubic metres was built; however the irrigation channels were never built.

1948 Valencian businessmen started growing rice in the Guadiana; the maximum area used was 30,000 hectares. This lasted about 10 years but ceased due to the gradual disappearance of the water.

1950 In the decade 1940 to 1950 a total of 6 wells were legalized; they are listed with the Communities of Farmers with a Right to Irrigate.

1950s Some farmers formed a consortium and contacted the State Forest Patrimony to get subsidies for planting poplars in wetland areas. The lack of adequate title deeds in some cases, however, and negligence in others meant that only 10 hectares were reforested.

1954 Ricardo Ibáñez Gerez suggested the creation of the Vallehermoso Reservoir and the transformation of the area of the Vega del Azuer into irrigated land.

1956 The Act which regulated the activity of the National Institute of Colonisation (*Institúto Nacional de Colonización*) and the Ministry of Public Works so that they could begin drainage of the banks of the Guadiana and its tributaries; it was estimated that 30,000 hectares of La Mancha wetlands needed to be drained. The Act also enabled the Ministry of Public Works to subsidise the building of an irrigation channel, the 'New Guadiana River'. This became the collector of a network of axial drainage channels.

1957 **A** Forestry Company planted 10 hectares of poplars in easily flooded areas to produce paper pulp. The venture failed when both the water table and the river dried up. In the town of Daimiel there were 1890 hectares of irrigated orchards and 300 hectares of rice fields beside the river Guadiana.

1959 The Ministry banned duck shooting in the *Tablas* indefinitely.

1960 In the decade 1950 to 1960, 411 wells were legalised and listed in the Irrigators' Associations.

1965 Union groups were set up to drain the Daimiel wetlands. Priority was given to the draining entrusted to the Institute of Colonisation and the Ministry of Public Works in July 1956.
The first list of the 200 most important global wetlands appeared. 4 out of 10 in Spain were in Category A: Las Marismas del Guadalquivir (the Coto de Doñana) - the Guadalquivier river marshes (Analusia); the Ebro Delta (Catalonia); La Albufera (Marine marshes in Valencia); Las Lagunas de Castilla La Nueva (Castile-La Mancha lagoons) (no longer in existence).

1966 Act setting up the Las Tablas National Hunting Reserve.

1967 The work necessary to canalise the rivers of La Mancha was speeded up.An alarming drop in the level of water in the *Tablas* began to be noticed.

1970 In the decade 1960 to 1970, 78 wells were legalised and listed with the Irrigators' Associations.

1971 The RAMSAR Agreement caused controversy because of its adverse effect on the Tablas de Daimiel: the Government ordered the cessation of drainage work and sets up an inter-ministerial committee. For the first time the *Tablas* was completely drained.

1973 'Tablas de Daimiel' National Park was set up, with an area of 1,875 hectares.

1974 24 wells in Daimiel were legalised during the year. The level of water in the wells fell 70 centimetres. According to the Ministry of Public Works 5,723 hectares were under irrigation in the *Tablas* area, a consumption of 28 hectometres per year. The Guadiana Water Commissariat calculated the existence of around 31,000 hectares irrigated from Aquifer 23.

1975 RAMSAR Convention came into force. 70 wells legalised in the *Tablas*. The water level fell 1m.

1976 38 wells legalised in the *Tablas*. The water level fell by a further metre.

1977 According to the Ministry of Public Works, 9,469 hectares of the *Tablas* were irrigated, with a consumption of 51 Hm^3 per year. 118 wells were legalised: the water level fell by another metre.

1978 325 wells were legalised; the water level fell another metre.

1979 251 wells were legalised; the water level fell another metre.

1980 The area Los Ojos del Guadiana dried up; natural auto-combustion of peat began. The uncontrolled extraction of peat for sale as fertiliser began.135 wells were legalised; the water level fell 1 metre.

1981 The Guadiana Water Commissariat calculated that some 83,000 hectares had been irrigated from Aquifer 23.

1982. 72 wells were legalised during the year; the water level fell by another metre.

1984 The Ojos del Guadiana flowed for the last time. The Guadiana Water Commissariat calculated that 101,000 hectares had been irrigated from Aquifer 23.78 wells were legalised.

Chronology continued: 1985-95

1985 The Water Act was passed, making all groundwater public property. The Puente Navarro dam was completed in an attempt to recuperate 425 hectares of the area of Las Cañas. The new dam was useless, however, as no water was provided by the rivers. The Guadiana Water Commissariat calculated that 109,000 hectares had been irrigated from Aquifer 23.82 wells were legalised; the water level fell by 1.6 metres.

1986. The National Park dried up. On September 5th a third of the National Park was burnt; the subterranean combustion of the peat would continue for a further 8 years. A 'Viability Study of a Plan for the Hydric Regeneration of the Tablas de Daimiel National Park' was carried out by the consulting firm EPTISA. The Guadiana Water Commissariat calculated that 120,000 hectares had been irrigated from Aquifer 23. During the year 293 wells were legalised; the water level did not fall as it was a wet year.

1987. The La Mancha plains' Aquifer was provisionally declared to be over-exploited. Water was brought to the National Park from the High Basin of the River Tagus by means of the Tagus-Segura Aqueduct. 60 Hm^3 were authorised over three years, and the water could not be used for any other purposes than environmental ones. The Guadiana Water Commissariat calculated that 127,000 hectares had been irrigated from Aquifer 23. 153 wells were legalised this year; the water level fell by 1.5 metres.

1988 The Guadiana Water Commissariat calculated that 127,500 hectares had been irrigated from Aquifer 23. 3 wells were legalised; the water level fell by 1.3 metres.

1989 A device was built to control the level of water inside the National Park. This device would only work when there was water, which there had not been for the last few years. The neighbouring villages' sewage outlets were stopped. The green filters of Daimiel, Villarubia de los Ojos and other municipalities filter part of their sewage but do not prevent the contamination of the Aquifer.

1990 During the decade 1980 to 1990, 782 wells were legalised in Daimiel. ICONA carried out 7 deep drillings, from which water was extracted to fill the ponds beside where the visitors walk to avoid the danger of fire. These were super-wells from which up to10 Hm^3 of water could be extracted in a year. The Guadiana Water Commissariat calculated that 123,000 hectares had been irrigated from Aquifer 23. The water was at a depth of 25.2 metres. The Tagus-Segura Transfer to the National Park was extended for another three years.

1991 The Guadiana Water Commissariat calculated that 120,000 hectares had been irrigated from Aquifer 23. The water was at a depth of 29.5 metres.

1992 Income Compensation Programme was launched. The Guadiana Water Commissariat calculated that 117,000 hectares had been irrigated from Aquifer 23.

1993 The water was at a depth of 30.9 metres. A Royal Decree-Law extended the water transfer to the National Park for another 3 years. The Guadiana Water Commissariat calculated that 111,000 hectares had been irrigated from Aquifer 23.
Results of the first year of the Income Compensation Programme: No. of beneficiaries: 1,335, Total payments in pesetas: 1,978,718,818, 56 cases sanctioned.

1994 The water was at a depth of 37.1 metres
The number of legalised wells about which the Daimiel Community of Farmers with a Right to Irrigate had information was: Legal wells: 2,315, In the process of being legalised: 485, those refused legalisation: 279, those built after 1986 and with no possibility of being legalised: 300. Total: 3,379. Various observers calculate that between 25% and 40% of these wells, which come within the provisions of the Water Saving Plan, were dry, without water.

1995 Western La Mancha's Aquifer 23 was declared over-exploited. A European Commissioner visited Las Tablas de Daimiel. After the visit the Commissioner said that Spain would not receive any aid from the European Union to palliate the drought.

As a result of inaction by the authorities, the drought has led to salinisation of the subterranean water and contamination and eutrophication of the surface water. Also, there has been a reduction in nesting areas due to changes in vegetation, including peat fires, and a generalised subsidence of land with a concomitant impact on the landscape and the loss of traditional enterprises (eg crayfish gathering). Moreover, the drying up of the aquifer, the level of which has fallen by 40 metres, together with long periods of drought, has led to the breaking up of riverbeds and their contamination by polluting agents, fertilisers and pesticides. All these effects are together responsible for a major wetland crisis. Since the end of the 1970s all this has not only had a devastating effect on the flora and fauna but it has also jeopardised irrigated farming itself because of a drop in profitability due to the decreasing availability of water in wells.

4.1.2 Agricultural Structure

Crops

The terrain of the *Tablas* is gently undulating. Traditionally it sustained vines, cereals and some olive groves. Today this has been replaced by large areas of intensive crops irrigated by pipes or gigantic pivots that extract water from the Aquifer. In order of significance, the different land cover in the area is shown in Table 4.1.2.

Table 4.1.2

Crop	area (ha)	percentage
Dry land cereals	9,302.50	21.41
Irrigated cereals	20,684.09	47.60
Vineyards	8,267.63	19.03
Olive groves	895.20	2.05
Olive groves/vineyards	894.36	2.05
Almond trees	71.37	0.16
Oak groves	121.96	0.28
River bank trees	51.62	0.11
Unproductive land	2,712.68	6.25
Uncultivated land	461.16	1.06
TOTAL	**43,462.67**	**100.00**

The cultivable land used for cereals makes up 69% of the municipal district. Next in importance is the area dedicated to vineyards, followed by olive groves, olive groves/vineyards and almond trees which make Daimiel one of the most agricultural districts in Spain.

Farm Size

The average size of an irrigated holding – 11.42 hectares – is misleading. Almost half the holdings account for only 10% of the total surface area, with an average size of 2.37 hectares each; these are part-time holdings. There are also a large number of holdings between 10 and 25 hectares, which is a suitable size for full-time irrigated farms. In addition, there are 61 large irrigated farms of between 50 to 100 hectares each, which account for 31% of the total land.

4.1.3 Irrigation Structure

Table 4.1.4 shows the characteristics of the irrigated farms that obtain water from Aquifer 23.

Table 4.1.4 Irrigation on Farms in Daimiel

Area	Nº of farms	Wells	Ha	m^3 /year	ha/well	m^3/ha/yr	Consum-ption

							m^3/ha
>3 ha	3,067	3,082	4,936.49	18,840.252	1.60	6.113	3,817
3 – 5 ha	1,924	1,957	7,398.82	24,536.058	3.78	12.538	3,316
5 – 10 ha	2,714	2,759	18,938.74	57,806.641	6.86	20.952	3,052
10-20 ha	2,031	2,116	27,401.81	127,553.481	12.94	60.281	4,655
20-30 ha	750	818	17,572.20	80,335.713	21.48	98.210	4,572
30-50 ha	520	624	19,283.20	93,243.379	30.90	149.428	4,835
<50 ha	391	835	39,482.52	179,836.493	47.28	215.569	4,559
TOTAL	**11,397**	**12,191**	**135,013.78**	**582,152.017**	**11.07**	**47.752**	**4,090**

An analysis of the social structure of irrigated land and water consumption highlights the following aspects:

- The owners of 64% of the wells own 23% of the land and extract 17% of the water;
- The farms of between 10 and 50 hectares own 30% of the wells and 48% of the land and extract 52% of the water;
- The farms of more than 50 hectares are those which consume disproportionately more water. 6.5% of the wells in the whole of La Mancha own 29% of the irrigated land in La Mancha and extract 31% of the water from the Aquifer. almost 200 Hm^3 a year.

Types of Irrigation
Flood irrigation is barely used in La Mancha – 0.22% - except for some small areas of vineyards and vegetables. Sometimes the efficiency of this system is no more than 50%. due to the problems of deep filtration and percolation. The main irrigation system used is sprinkling – 77.36% of the area's surface. This is more efficient than flooding but it is still insufficient to ensure the uniform distribution of the water and it is wasteful of both water and energy. For crops with a concentrated root system. drip irrigation is increasingly used, covering 22.42%of the cropped area. This system is potentially the most efficient since it requires only basic technical training for farmers to make the most of all of its potential in the use of water and fertilisers. In Western La Mancha it is used for 99.5% of all melon groves and 35.3% of vineyards.

4.1.4 Sources of Water

Las Tablas de Daimiel is supplied by the following water sources:

- 90 Hm^3 per year by infiltration of surface run off, now lost as a result of the regulation of the head of the Rivers Záncara and Cigüela;
- 180 Hm^3 per year from rain water infiltration;
- 50 Hm^3 per year from subterranean water from Aquifer 24 in the nearby area of Campo de Montiel.

The Ministry of Public Works data (1987) states that Aquifer 23 had a water supply of 335 Hm^3 per year while net extractions were carried out at the rate of 595 Hm^3 per year. This meant that Aquifer 23, the reservoir at the core of the La Mancha region, was being emptied at the rate of 260 Hm^3 per year. By the year 2005 if the present rate of exploitation continues, it will be exhausted.

The reduction of these renewable resources due to the effects of the drought and the very big increase in the number of subterranean water pumping stations, meant an average extraction from the reserves of 300 Hm^3 per year. This made the water table fall by between 20 metres and 40 metres in different locations across the aquifer. The reserves used up between 1974 and 1997 are reckoned to amount to 4000 Hm^3 which is between 40% and 80% of the estimated storage capacity of Aquifer 23. Tables 4.1.5 and 4.1.6 indicate the hydric balances for Aquifer 23 in an average year, for the periods specified:

Table 4.1.5: Water Balance 1974 - 1981

inflow	**Hm^3**	**outflow**	**Hm^3**
River infiltration	56	Draining of Aquifer (Rivers & Tablas)	125
Rain infiltration	195	Pumping	290
Subterranean	50	Evapotranspiration	10
Return of surface water	20		
TOTAL	321	TOTAL	425
Extracted from reserves	104		
TOTAL	425		

Table 4.1.6: Water Balance 1982 - 1995

inflow	**Hm^3**	**outflow**	**Hm^3**
River infiltration	1	Draining of Aquifer (Rivers & Tablas)	18
	100	Pumping	450
Subterranean	50	Evapotranspiration	10
Return of surface water	-		
TOTAL	151	TOTAL	478
Extracted from reserves	327		
TOTAL	478		

Contrasting the inflow and the outflow produces a negative average balance – ie a loss of the Aquifer's reserves – which has increased from 104 Hm^3 in the period 1974 to 1981 to 327 Hm^3 between 1982 and 1995.

4.1.5 Policies to Ameliorate the Environmental Impacts of Irrigation

A number of policies have been implemented in an effort to improve the sustainable management of the aquifer: each is described briefly below.

1. Las Tablas de Daimiel Hydric Regeneration Plan

Of several proposals put forward in this Plan, the only effective one was the Water Transfer of 1988 to 1996, enabled by a Central Government decree-law for Water Transfer from the Tagus-Segura to Las Tablas. This permitted a flow of 60 Hm^3 over the full period. with a ceiling of 30 Hm^3 per year which was put in force for three years until the summer of 1990, and subsequently extended to 1996.

2. National Wetlands Conservation Plan

The Las Tablas de Daimiel Hydric Regeneration Plan has enabled the recuperation of the ecosystem and the administration of the hydraulic resources by importing water from outside the system. This is surprising, given that the National Park lies above a reservoir of subterranean water of unknown proportions. The proposal. made in 1985 by José Enrique Azcarate, Director of the Geological and Mining Institute of Spain (*Institúto Geológico y Minero de España*), involved using water from the catchment of Aquifer 23, 3 kilometres away from the *Tablas* in places where depressions did not affect natural replenishing. This would have been introduced into the River Cigüela and the *Tablas* would have flooded.

3. Irrigation Policy

In 1987 the over-exploited Aquifers 23 and 24 with a hydric deficit calculated at 4000 Hm^3 received help from the Central Government. The recuperation of the ecosystem with special contributions from the Tagus-Segura Transfer has allowed the Regional Government to use the aquifers for irrigation and the promotion of tourism.

Lack of control was evident in the earlier expansion of irrigation because it did not take into account the resources available which were only sufficient to supply a maximum of 50,000 hectares. This is now causing economic and social tension with the 'victims' of restraint demanding state aid to palliate the low productivity of their dessicated land. Efforts have been made through Aquifer Water Extraction Plans to balance the water extracted by replenishment. Some recovery has been made possible in the last two years due to abundant rainfall.

4. The Farm Income Compensation Plan

In April 1992 the Spanish government, at the request of the Ministers of Agriculture and Public Works and the regional government of Castile-La Mancha, asked the EU to declare Aquifers 23 and 24 (Ciudad Real and Albacete) an Environmentally Sensitive Area (ESA). This was so that the incomes of the La Mancha farmers could be compensated with EU funds. The Spanish government calculated that in the two aquifers there were around 8,400 irrigated farms with an area of between 105 and 135 thousand hectares.

Under Objective 1 Structural Funds the region of Castile La Mancha developed a programme to reduce irrigation levels by compensatory payments, using FEOGA funds (75%); with 25% match-funding from the Regional Government Department of Agriculture and the Central Government Ministry of Agriculture. This Plan reduced the area irrigated and affected more than 200,000 ha in the two Aquifers 23 and 24. Subsidies were paid to farmers amounting to over 10,000 million pesetas by 1996.

Given that the situation of over-exploitation of the Aquifers affected the protected natural areas, the regional government proposed compensation in the form of an agri-environment programme for the area (Income Compensation Programme or Wetlands Plan) under the EU Agri-Environmental Regulation 2078/92. The Spanish government presented the Income Compensation Programme as part of a wider plan: the 'Coordinated Action in Western La Mancha and Campo de Montiel' Plan.

The Programme offers farmers the possibility of contracting to reduce the volume of water used for their irrigated land over five years, in exchange for a payment. Taking the average water consumption in the irrigated areas as 4,920 m^3/ha per year, the reduction agreed can be at three levels - 100%, 70% or 50%. For this the farmers have to present an annual crops plan for an irrigated area consistent with the level of reduction chosen according to a scale of the theoretical consumption for each crop. The reduction in water consumption in any of its forms carries an obligation not to exceed specific limits in the use of fertilisers and pesticides.

Table 4.1.7: Limits on Water Quality

OPTION	WATER (m^3/ha/year)	NITRATE FERTILIZERS Active units/ha/year	PESTICIDES (active ingredient) litres/ha/year
50%	2,460	90	2.00
70%	1,525	70	1.50
100%	0	40	1.00

The farms with a right to benefit from this scheme are those irrigated lands delimited by the Guadiana River Basin (excluding vineyards). The farmer has to accept the plan for the whole of his irrigated land. The Plan has facilitated compensation for the drop in income produced by the reduction in water extraction and hence the necessary cropping change; it has also made it legitimate and socially acceptable. The programme thereby provides a much-needed answer to a social and environmental problem, which explains why it has been so widely adopted.

On the other hand, the reduction in the consumption of water by the farmers has meant an extensification of their agricultural activity. This reduction in activity has obviously had a negative effect on the wider economy of the area. The Plan is a programme with a high economic cost; its environmental benefit is something that will only become evident in the long run. But there are still many farmers who see the Plan as providing provisional economic compensation only until more transfers of water have conveniently replenished the Aquifers and they can go back to irrigating without any restrictions.

The present situation can be summarised in the following points.

- The strong economic boost experienced by the region was closely linked to the over-exploitation that is now being questioned and reduced because of its disastrous effect on its main driver – water.
- The existence of water use rights allowed a large number of individual water entitlements to develop that collectively involved huge volumes of water. These increased water consumption beyond what was reasonably obtainable from the Aquifers.

- Obligatory limitations on extractions imposed by the Water Authorities - enforcing the provisions of the Water Act - started in 1991. These will have to be maintained for as long as the situation of over-exploitation continues.

- There remain doubts among irrigators about the future of the current agri-environmental support which compensates them for the economic loss produced by the reduction in extractions.

- In practice it is very difficult to decide when a viable crop is being abandoned or when a subsidy is being paid for land which could no longer be irrigated anyway. It seems likely that the current system favours the big farmers to the detriment of the small ones.

5. Water Policy - Supply. Drainage and Sewage

The regional government of Castile-La Mancha is providing around 77.000 million pesetas to put two plans into practice:

- improving the water supply;
- drainage and sewerage so that by the year 2005 untreated water will be a thing of the past.

A more detailed knowledge of the water resources in 'System 23' as well as the other subterranean waters in Castile La Mancha could potentially lead to a saving in infrastructure. It should enable the authorities to take better advantage of the endogenous hydric resources, plan water flows and provide alternatives for the conservation of natural resources; this is essential given the ecological importance of the area.

In overview, the policies put into practice have sometimes been contradictory and have failed to achieve a proper balance between economic development and conservation. The result has been a long series of environmental impacts, detailed below. Compensation payments under the ESA scheme have, however, played an important part in reducing excessive use.

3.1.6 Environmental Impacts

Negative Impacts

The over-exploitation of the Aquifer has endangered ecosystems in the 'Tablas de Daimiel' National Park dependent on water from La Mancha. The law that established this Park explicitly states the influence of Aquifer 23 on the area.

The problem of the over-exploitation of the Aquifer affects the National Park directly because it is interconnected with it and because its initial equilibrium had already been affected by the draining that took place in the 1960s. This wet ecosystem owes its origin historically to the discontinuous supply from the rivers Záncara - Cigüela system and to the more continuous supply from the natural outlets of the Western La Mancha Aquifer. In this sense the *Tablas* are an indicator of the state of the Aquifer. As a consequence of the over-exploitation of the Aquifer and the subsequent drop in its levels, the natural outlets of the Guadiana through its famous *Ojos* (Eyes) have been temporarily stopped.

Also included in the group of environmental side effects is the drop in the water table levels consequent on the lack of rain; in some cases this has been due to human actions (embanking. artificial lakes and abusive uses. some independent and some associated with other causes). This has meant that the rivers Guadiana. Azuer. Záncara and Cigüela. as well as their main tributaries, have for the time being lost their natural function as physical support for the surface water. This has had a negative effect on the wetlands. Equally. the riverbank vegetation has been almost totally eradicated.

In 1996 heavy rains came, causing yet another problem. This was the subsidence of land mainly near the Rivers Azuer and Guadiana. with the formation of depressions. These formations stem from karstic processes occurring as a result of decalcification. The rains in the winter of 1995/1996 had, with the weight of water, overloaded the surface layers of the soil. This led to the collapse of the structure of underlying limestone rocks, a phenomenon also due to the fall in the level of the water table in the limestone caused by the over-exploitation of the Aquifer.

The closing of the outlets of the *Ojos del Guadiana* and the subsequent draining of the publicly owned land situated downstream led to this land being occupied; it was ploughed, crops were sown and it was irrigated from nearby wells. As a complement to this, areas with a lot of peat have frequently ignited, producing serious risks to people and to this very unusual natural resource.

The quality of the water depends on the contributions made by the different sources; water from the river Gigüela is brackish with salinity above 2g/1, while that from the River Guadiana is sweeter - its salt content around 0.5 g/l. The salinity of the groundwater is therefore midway between the two. However some years have passed since the waters of the rivers Gigüela and those of Las Tablas de Daimiel were 'crystal clear'. The contamination by industry, urban sewage, purifiers and green filters, not to mention the use of fertilisers and pesticides in the agricultural areas, have affected its quality dramatically. The little water still left in the area has become full of toxic and noxious products. High temperatures and an excessive concentration of birds in the few pools means that summer epidemics and botulism have caused very serious damage to the birds and other fauna.

Positive Developments

Fortunately the rainfall in the last few years has alleviated the severe drought. During the season 1996/97 there was a record rainfall: 560 $1/m^2$, when the average in the past has been approximately 400. Las Tablas de Daimiel National Park has therefore had some chance to recover after catastrophic periods of contamination. In another nearby protected area, Las Lagunas de Ruidera, groundwater has appeared again. Unfortunately it does not look as if this will be the case with Las Tablas de Daimiel. The neighbouring Campo de Montiel Aquifer is smaller and so it empties and refills quickly. However the Aquifer that sustains Las Tablas, which has an estimated capacity of 12,500 Hm^3 and an area of 5,200 Km^2 is much more sluggish and its replenishing capacity is not fully known. The Aquifer's water table levels have only risen by some five metres; in some places the water is to be found at a depth of nearly 90 metres while the average is over 28.

On the other hand, the contribution of the River Cigüela has been so large that it has filled the National Park and produced a rare phenomenon – 'the remounting Guadiana' - a phrase used to describe a river that begins to flow backwards. The volume of water from the Cigüela retained by the National Park's hydraulic devices produced a current which flowed up the dry riverbed of the Guadiana in search of its origins. As a result during 1997 the *Tablas* were completely full. with a rising flow upstream in the Guadiana and another natural Guadiana downstream in the direction of the Vicario reservoir. This has meant the return of the traditional colonies of herons and other birds.

New Measures to Address Environmental Impacts

Positive factors for the future include:

- the fact that regulations have now been in existence for some time. known. accepted and observed by a large number of users;
- there has been a reduction in the number of extractions;
- the emergence and progressive organisation of water Users' Associations that have promoted training and been increasingly willing to collaborate and participate in water management and administration;
- the growing demand for - and the carrying out of - modernisation and improvements in the more efficient use of water;

- the greater presence of different collective organisations interested in the positive development of the situation.

The Guadiana River Basin plan of action has now been developed. It involves:

- Increasing hydrogeological knowledge of the area;
- drawing up a Specific Recovery Plan for the environment connected with the wetlands and the specific areas of the Aquifers, including the recovery of the Hydraulic Public Property despoiled in the area of the Aquifers;
- drawing up a Specific Protection Plan for the quality of the water in the area related to the National Sewage Plan, and for the eradication of the diffuse pollution;
- drawing up a Joint Exploitation Plan for the surface and subterranean hydric resources that takes into account a maximum volume of extractions not in excess of 200 Hm^3 per year from the Western La Mancha Aquifer;
- preparation of a Document defining the basic norms, specifically those referring to the area of the Aquifers. This is to find a way out of the situation caused by the Water Act’s Provisional Orders, to allow the individualised administration of the subterranean waters to be replaced by communal management;
- drawing up a Territorial Rearrangement Plan for the areas where water is used and for the crops in the area of the Aquifers. The objective of this Plan is the accomplishment of the sustainable development of the area that will be compatible with the use of hydric resources, the respect of the environment and the recovery of the La Mancha wetlands;
- The design of programmes aimed to increase the users’ participation in administration and management tasks though their organisations;
- drawing up a Plan to establish Extension Services to address the existing problems in the High Basin and propose possible solutions that will engage the whole population of the area.

It is to be hoped that the much more comprehensive range of new measures described here will prove more decisive than past policies, in addressing the environmental problems highlighted in this case study. However it seems likely that for the foreseeable future, a mix of enhanced regulatory and planning controls as well as financial support through the agri-environment scheme, will remain important.

4.2 CASE STUDY 2: GREENHOUSE IRRIGATION IN 'CAMPO DE DALÍAS' (Eastern Almeria Region, Andalucia)

4.2.1 Introduction

Almería is an arid province. Average rainfall varies between 600 mm in the high areas to the south-east of the Sierra Nevada and 200 mm in the southern Levante. Rainfall is usually of short duration but can reach 100 mm in less than an hour. The spatial and temporal variability of rainfall and the peculiar geomorphology of both the seasonal and ephemeral water courses and the aquifer system mean that both surface and subterranean hydrological resources are very scarce. The notable exceptions to this are the aquifers of Western Almería, where Campo de Dalías is found.

This area saw the beginning of the agricultural "miracle" in Spain. It extends from the south-eastern coastal limit of the provinces of Granada and Almeria to the town of Aguadulce in the east, bounded to the south by the Mediterranean and to the north by the Sierra de Gádor. It covers approximately 30.000 square kilometres (see map).

4.2.2 History of Irrigation

The Ministry of Agriculture. through the National Institute for Colonisation (*Institúto Nacional de Colonización* or *INC*). was responsible for the introduction of the irrigation system which has transformed Campo de Dalías. The area was divided into six sectors according to contour lines. Water pumped from the aquifers would be distributed by means of gravity systems from irrigation channels and utilised in the agricultural plots with surface or flood irrigation. In 1941 the National Institute for Colonisation had already declared Sectors I, II and III to be "Areas of National Interest". This was the beginning of the process that would transform it into irrigated land, although until the 1950s only crops with little need of water were grown there. In 1950 the first relatively important well, 35 to 40 metres in depth, was dug by hand and the water was pumped to a concrete irrigation channel for distribution to nearby fields.

Investment in irrigation built up progressively in a series of four geographical sectors, beginning in 1953 with the "General Plan for the Colonisation of the Irrigation Sector at Aguadulce", affecting 1,556 ha, 750 ha of which were suitable for irrigation. Initially, production was concentrated upon traditional crops such as sugar beet, lucerne, cotton and barley, but from the mid 1950s vegetables, especially tomatoes, became more important.

It was not until the 1970s that the expansion of greenhouses began in earnest. New sectors V and VI, following in the steps of sectors I – IV, were declared to be of National Interest. In 1973 the General Plan for the Transformation of Sector VI was passed; this involved the irrigation of 2,100 ha by groundwater. However a drop in the water table of the wells was noticed due to the over-exploitation of the aquifers (it is not known exactly when this had started). There was also a deterioration in the quality of the water. These problems would modify the original project that had planned to use only water from wells. Instead the supply of surface water from the Benínar reservoir was considered. In 1977 the “General Plan for the Transformation of Sector V” using regulated water from this reservoir, was passed

The introduction of drip irrigation with pressure systems took place in the second half of the 1970s. Its uninterrupted expansion since then has been possible because it displaced the traditional surface irrigation systems and thereby saved water through a more efficient system, and because it harnessed new resources.

In 1980 the Spanish Geological and Mining Institute (*Institúto Geológico y Minero de España*. or *IGME*). now the Technological and Geomining Institute (*Institúto Tecnológico y Geominero*. or *ITGE*) resumed a series of studies intended to identify possible marine intrusion. In 1984, with evidence of the over-exploitation of the aquifers and marine intrusion, the first legal restrictions on the expansion of the irrigated area was introduced. Decree 117/1984 (May 2) of the *Junta de Andalucia* (Autonomous Government of Andalusia) regulates access to new resources; while Law 15/1984 (May 24), applicable throughout Spain, limits “the use of scarce hydraulic resources as a result of prolonged drought”. These restrictions meant the freezing of the project to irrigate Sectors IV and V. Nevertheless these decrees have not achieved the desired objective of controlling extractions from the aquifers. Private initiative has drip irrigated land in Sectors IV and V using groundwater, while the water from the river Benínar was used to irrigate Sector VI.

With the Water Law of 1985 in force and under the terms of Article 56, the Royal Decree 2618/1986 (December 24) declared the Campo de Dalías aquifer to be overexploited. It also laid down conditions for the carrying out of any work and specified that authorisation would be needed for any increase in irrigated area. However this has had little or no effect either on the use of overexploited aquifers or on limiting the area irrigated - both continue to increase.

Farmers, on being questioned about this, answer: “if it is forbidden, then it should apply to everyone. Once they report you and you pay the fine, the greenhouse is legal. The water problem couldn’t be solved even if you charged it at 1 million pesetas/ha: people will either build a greenhouse or they won’t.” This suggests that both the enforcement and the economic impact of any enforcement have been insufficient to act as a deterrent to unsustainable practices.

At the same time as the National Institute for Colonisation was improving Sectors I, II and III, private initiative was exploiting the deep aquifers to irrigate land in Sectors IV and V - as well as others not included in the original irrigation parameters. Land in Sector VI which was already irrigated by the Canal de San Fernando had its irrigated area increased as new wells were made by private initiative. In 1986 the network and the regulating tanks for Sector VI were built by the Andalusian Institute for Agrarian Reform (*Institúto Andaluz de Reforma Agraria, IARA*).

In 1990 all aspects of agrarian reform in the West Region of Almeria were declared to be of General Interest by the Autonomous Government of Andalusia. On April 17th 1991 the River Basin Confederation of the South (*Confederación Hidrográfica del Sur*) passed the Statutes of the Central Board of the Users of the West Almeria Aquifer (*Junta Central de Usuarios del Acuífero del Poniente Almeriense*). This Board consists of individual users and irrigators. They decided to organise themselves voluntarily not only to protect their rights and interests from third parties but also to supervise their coordinated use of the water.

In 1992 the first phase of the Transformation Plan for the West Region of Almeria was passed as an urgent measure. This Plan provides. among other things. for the improvement of the irrigation channel in Sector IV. In January 1994 the Almeria City Council stopped boring in Sector III. Its water supply now comes from wells in the Bernal rambla which provide a flow of some 400 litres per second.

4.2.3 Development of Modern Irrigated Agriculture

The gradual transformation of Campo de Dalías and the rest of the Almerian littoral was based on investment in irrigation, starting with infrastructure built by the old *Institúto Nacional de Colonización* in 1953. This work has been continued since 1984 by the *Institúto Andaluz de Reforma Agraria* (in 1984 responsibility for agriculture was transferred to the Autonomous Government of Andalucia). The development of intensive farming under plastic in Almeria has been enhanced by the following factors:

- physical - the climate and the existence of water from the Sierra de Gador aquifers;
- socio-economic and financial - farmers' social homogeneity (equally distributed land ownership) and public and private provision of financial support;
- technological - the continuing development of crops and new production techniques;
- commercial - the growth of the agri-food sector and the progressive consolidation of markets and increasing access to new ones.

Table 4.2.1 shows the development of the area occupied. in hectares by greenhouses in the Netherlands (generally regarded as a pioneer country in this field) compared to all of Spain and to Almería alone. It should be borne in mind that over 90% of the greenhouses in Almería are in Campo de Dalías.

It was soon realised that greenhouses were an essential technological and productive base, allowing a much earlier ripening (and therefore better prices for out of season crops) and an increase in production. Several harvests annually raise profits per hectare. The use of plastic materials contributed to lower investment costs than more traditional structures.

Table 4.2.1 - Greenhouse Area Development (in hectares)

year	Netherlands	Spain	Almería
1904	30	-	-
1927	2.025	-	-
1946	3.254	-	-
1968	6.946	546	30
1970	7.236	1.220	920
1975	7.906	4.400	2.975
1980	8.760	11.270	7.150
1985	8.973	18.680	11.850
1986	9.088	20.260	12.300
1987	9.210	26.160	13.200
1988	9.322	26.564	14.300
1990	9.769	28.100	16.500
1994	10.800	42.426	25.000

Source: Salinas, 1999c

Almeria has first place in horticultural production and fifth place in agricultural production in Spain. About 80 per cent of the greenhouse-covered area is in the west of the Province and 20% in the eastern Levante. There has also been a steady increase both in the area devoted to horticulture and the yields obtained. Between 1988 and 1996 the area under cultivation increased from 29,000 to 40,000 ha, while yield per ha rose from an average of 38.86 million tons/ha to 54.2 million tons/ha.

In the last few years. production and marketing have been concentrated on the following crops, which represent 97% of total production: tomatoes; beans; peppers; cucumbers; aubergines; squash – melons and watermelons; Chinese cabbage and lettuce. Among these, lettuce, watermelons, melons and peppers have experienced a notable increase, while cut flowers have declined.

In Campo de Dalías 57,939 ha are devoted to producing vegetables, which is 31% of the area of Andalucia devoted to horticulture (187,357 ha). Some crops – squash and cucumbers - are grown nowhere else in Andalucia; while others are never grown elsewhere in winter. The coast is devoted almost exclusively to intensive irrigated crops, the inland areas to fruit trees and olive plantations.

Table 4.2.2: Cropping in Dalias: Percentage Cover by Area

	greenhouse	open air vegetables	fruit & citrus	olive groves	other
Campo de Dalías	81.6	11.7	4.7	1.5	0.5

Source: *Encuesta sobre los regadíos en Andalucia (Consejería de Agricultura y Pesca.* 1997)

Farm Size

The area of farms devoted to greenhouses corresponds with the structure of the land ownership in the coastal areas, where small properties are predominant. Typically they are around 1.2 hectares in size and farmed by part- or full-time family farmers. Net family earnings can be up to 10 million pesetas. The average gross earnings from one ha are between 4 and 8 million pesetas and labour requirements per ha are 2 to 3 workers. This explains the migration of population to the greenhouse areas; many people who would once have been day labourers (seasonal workers) are now smallholders.

Types of Irrigation

Greenhouse development has in no way been impeded by the government's restrictions intended to protect the aquifers. At present 26,000 irrigated hectares are occupied by greenhouses, particularly concentrated in the west region. Elsewhere in Almeria, in Bajo Andarax and lower Campo de Dalías, greenhouses were introduced later but have expanded considerably over the last few years partly because of restrictions on new greenhouses in the western region and the hope of new and better water resources in these two areas.

The system has been changed to drip irrigation in almost all the greenhouses, and in much of the irrigation of vegetables and fruit trees in the open air, as can be seen in Table 4.2.3.

Table 4.2.3: Types of Irrigation

	Drip irrigation (%)	**Gravity (%)**
Western Region Campo de Dalías	89	11
Bajo Andarax	41	59
Campo de Nijar	99	1
Bajo Almanzora y Pulpi	55	44
TOTAL/COAST	**78**	**22**
HINTERLAND	**15**	**85**
ALMERIA	**57**	**43**

Source: *Encuesta sobre los regadíos en Andalucia (Consejería de Agricultura y Pesca,* 1997)

The water is pumped from boreholes directly into a network of pipes running from the Sector IV channel to the reservoirs. The length of these pipes is about 500 km of which approximately 100 km belong to the main and secondary network. For the most part they are rectangular irrigation channels made of concrete or stonework with metal sluices at outlets and sectioning points. The average gradient of the main piping is 2m per thousand m. The volume of flow that is carried is variable but it does not exceed 1,200 cubic litres - the figure reached in Sector IV at maximum capacity.

The relative efficiency of the two main irrigation systems in Campo de Dalías can be appreciated in Table 4.2.4.

Table 4.2.4

Water delivery method	**Gravity**	**Drip**	**All systems**
Quantity needed (m^3/ha)	5,397	5,875	5,732
Actual quantity (m^3/ha)	9,242	6,126	6,460
Irrigation efficiency in the plot (%)	58	96	89

Water Sources

The scarcity of surface water has meant resorting to ground water sources, including springs, which represent 78% of all water resources in Almeria but 92% in Campo de Dalías. This allowed the continuation of irrigation during the serious drought in the early 1990s but consequently inflicted serious damage on most of the coastal aquifers.

Given the relative importance of open-air channels, which are mostly made of earth and therefore produce considerable water losses, the networks need renewal. Even on the coast, more than a third of the irrigation network still has water in open channels.

Table 4.2.5: Percentages of Each Type of Distribution Network

	Piping	Lined channel	Earth channel
West Region, Campo de Dalías	59	29	12

Source: *Encuesta sobre los regadíos en Andalucia (ibid,* 1997)

The state of the networks is closely linked to the age and type of distribution system.

Table 4.2.6: Age of Systems

	age (years)			
Area	< 10	> 10 &< 20	> 20 & < 30	>30
West Region, Campo de Dalías	14%	39%	16%	31%

Source: *Encuesta sobre los regadíos en Andalucía (ibid,* 1997).

Institutional Setting

In general the irrigators are organised into Irrigators Associations or within Water Districts which control water distribution over 80 per cent of the irrigated land.

Table 4.2.7 Organisation of Water Supply

area	water districts		Private	
	No.	Ha.	No.	Ha.
Campo de Dalías	90	18.170	1,422	2,613

Source: (*ibid,* 1997).

The most important losses occur in the plots themselves, essentially in those irrigated by gravity; next in importance are those caused by seepage or leakage in irrigation channels and by evaporation in ponds (Table 4.2.8).

Table 4.2.8 Water Losses

Location of water loss	hm^3/ year	% of total loss
Ponds (Evaporation in 6,217 ponds)	3.23	17.1
Channels	5.33	28.1
Pipes	3.31	17.5
Irrigation network	0.28	1.5
Plot	6.79	35.9
TOTAL	18.94	100.0

Source: (*ibid*,1997)

Water Prices

As mainly ground water is used for irrigation and as most of this water remains private, farmers bear the entire cost of water extraction and distribution. The price of this water is relatively high, especially when compared with the usual prices paid in areas where surface water is predominant.

Given the great productivity of the coastal irrigated land, water prices are higher in this zone than in the inland areas. However water prices do not serve to regulate water demand. The high marginal productivity obtained by the utilisation of water in greenhouse farming - sometimes as much as 1,300 pta/m^3 - means the farmer can afford to pay a relatively high price for the water used. The average price of water on the coast is 18 pta/m^3, although in some irrigation districts it can reach 35 pta/m^3. The possible increase in the price of water due to the considerable investment necessary to ensure its availability is unlikely to discourage farmers because the cost of water only represents between 1.5% and 3% of the value of the final product for this type of farming. In fact the price of water is comparatively lower in the Western region than in most other regions of the province of Almeria (Table 4.2.9).

Table 4.2.9: Water Prices

AREA	**PRICE: Pts/ m^3**
Western	16
Bajo Andarax	14
Campo de Nijar	20
Bajo Almanzora y Pulpi	23
COAST	18
INLAND	9
ALMERIA	15

Source*: (ibid, 1997*)

4.2.4 Environmental Impacts

Negative Impacts

The negative impacts caused by greenhouse farming and intensive irrigation can be divided into a number of different categories, as follows.

- *Land Use and Landscape* – in principle, territorial planning as part of overall municipal planning should integrate the aesthetic aspects of the landscape and also those that have a negative effect on resources such as their contamination or exhaustion. In practice, this has been difficult to achieve and over exploitation of the aquifer is a clear result.

- *Soil* – The production system in use requires large quantities of sand. This has led to uncontrolled extractions of "red earth" which has raised the aquifer to surface level and led to the formation of an artificial lagoon called 'Cañada de las Norias'. The waters of this lagoon and the lixiviated waters from the greenhouses constitute a highly polluted habitat. The electricity and telegraph poles that supply the village show that in some places the excavations have reached a depth of 6 m. The lagoon is wholly surrounded by greenhouses; there is no buffer area to protect it and the species that live there. It is the same at Albufera de Adra, a Nature Reserve of 65 ha with a 'buffer zone' of 152 ha that is completely covered with greenhouses.

Panoramic view of Natural Reserve of "Albuferas de Adra"

- *Water* - At the end of the 1970s concerns were raised about the over-exploitation of the aquifers the West Region of Almeria, especially in Campo de Dalías. Although awareness of the problem has grown slowly, further increases in water extraction are expected as a response to the expansion in the greenhouse area and the water quality is declining, as salinity increases. The Hydrological Plans for the Southern Basin (*Cuenca Sur*) and the Segura Basin (*Cuenca del Segura*) estimate a deficit of 270 Hm^3 for the whole of Almeria and specify that this should be reduced to 170 and 80 Hm^3 over the next ten and twenty years respectively. To achieve this objective, the plans state that water demand should be kept constant by improving the use of water resources. This can be achieved by recycling purified sewage and desalinating the salty water. They also recommend that external resources should be transferred, from the river Guadalfeo for the western part and from the river Negratín and the Tagus-Segura water for the eastern part, by means of a canal system interconnecting all Almeria's resources. The loss of water produced during irrigation occurs mainly in the plots, especially in those irrigated by gravity; there is also leakage in channels and evaporation in ponds. Off-farm, water losses occur along the irrigation canals since these channels are in the open air. The plans propose that this situation should be rectified by piping, but of course this will not address the wider issues examined here.

- *Pesticides* - the worst problems in this area are caused by organochlorates and carbamates. The pesticide residues accumulated in the water have caused serious damage in Campo de Dalías; the products of hydrolysis or the action of micro-organisms are sometimes more toxic than the original products.

- *Fertilisers* - the poorly controlled use of fertilisers causes soil contamination and water pollution by nitrogen and phosphorus. This is one of the main causes of serious eutrophication in the area's modest wetlands.

- *Plastics and other waste* - plastic waste is produced by the replacement of the greenhouse covers every two years. This waste is piled up on farms, since no institution accepts responsibility for it. It remains on farms in the fierce sun and the heat reduces its volume. Regularly, farmers set fire to these residues, an illegal but common practice in the Campo de Dalías. The large number of hectares covered in plastic has earned Campo de Dalías the name “Plastic Sea”, indicating its impact on the landscape.

- *Impact on wetlands* – this includes the Nature Reserve of La Albufera de Adra, in the delta of the River Adra. The agricultural use of land in the delta has resulted in the former wetlands becoming reduced to two main lagoons surrounded by narrow strips of marsh that act as a buffer between the farming area and the protected space. At some points it is even possible to touch the covers of the greenhouses from the observation towers. The wetlands arose out of a primitive bay closed by marine deposits formed by the debris accumulated from the bed of the gullies of ‘Las Ramblas de las Adelfas’ and ‘Las Ramblas de la Estanquera’, and from the building of the fishing port of Adra. The same processes are still occurring with the birth of the small lagoon ‘Albufera Nueva’ between the ‘Albufera Grande’ and the beach.

  Before it was declared a protected area, farmers had been reclaiming land from the lagoon, in the process reducing the area for aquatic plants. Even so, it has some notable species such as *Najas marina* and *Potamogeton pectinatus*. These waters also house valuable fish including the *Fartet,* Aphanius *iberus,* endemic in the Iberian Peninsula and an endangered species (Royal Decree 439/1990). The *Fartet* travels by means of the irrigation channels to the private irrigation pools which have the best ecological conditions for it. It feeds on the algae which grow in the ponds and irrigation channels, and its presence is recommended to farmers to control algae. The farmers, on the other hand, prefer to clean the vegetation from the ponds with copper sulphate. Meanwhile the irrigation channels are being changed to pipes to avoid water loss through evaporation. This process will be completed in about a year.

  The main problems the *Fartet* faces for its development in the lagoons are: the disappearance of the surface water course of the River Adra; contamination of the river bed by uncontrolled dumping; drying up of the irrigation channel and ponds; removal of algae from the tanks by toxic copper sulphate (or covering the tanks); eutrophication and contamination of the lagoons; and the introduction of exotic species into the pools (Red Crab, *Gambusia*) which compete with or predate upon the *Fartet.*

- The lack of a buffer zone between the greenhouses and the lagoons makes them an easy place for dumping wastes – plastic, cans, water from washing the tanks, organic residues, debris. This adds to pressures on ecologically vulnerable sites. While the penalties for dumping and other ecological offences are relatively low, this threat will not decrease unless market conditions, such as demand for higher quality products such as organic crops, were to cause a radical shift in farmers' attitudes. Penalties (fines) are frequently levied but even when they are paid, they do not represent 3% of the farmer's annual profits.

Positive Impacts
What is striking in the area is the formation of the artificial lagoon 'Cañada de las Norias', where successive extractions have made the aquifer come to the surface, leading to the formation of an artificial lake. This attracts a large number of aquatic birds of considerable ecological value, such as *Focha Común, Anade Real* and *Malvasía Cabeciblanca*. The lake area is about to be declared a Protected Space.

The *Malvasía Cabeciblanca,* a globally endangered species, at present uses the Albuferas de Adra as its main European area for wintering and breeding. These lagoons and, more recently, the Cañada de Las Norias are where the *Malvasías* take refuge when they are subject to human pressure in other parts of Spain. In 1977 there were fewer than 20 examples at the Laguna de Zoñar (Cordoba), their original habitat, and the species was thought to be almost extinct. Some pairs emigrated and nested in the Albuferas de Adra, the first examples being sighted in 1984. The suitability of the lagoon has led to an increase in the population with up to 2,000 recorded on the census in the summer of 1998.

The secret of this growth is the eutrophication of the waters by the pollution caused by agricultural practices. This is why lagoons in the area are almost anoxic and why mosquitoes of the *Quironomios* family take advantage of the algae to deposit their larvae. This mosquito is an important part of the *Malvasías* food. However, this situation is not ecologically stable because pollution from irrigated lands will create considerable environmental problems in the future.

Measures Adopted to Ameliorate Environmental Impact
The main measures agreed for the conservation of these outstanding areas have been:

- A LIFE Project, the objective of which is the control of wastes from farms, by providing farmers with a collection service for empty containers and other waste, to prevent them being left near the lagoons;

- A civic awareness campaign to encourage farmers not to damage the ecosystem. It is hoped to be able to perpetuate the life of the *Fartet* by advising farmers not to cover their storage pools or use products like copper sulphate;

- Maintained or possibly increased penalties for building new greenhouses. At present the amount of the fine is simply internalised by farmers in their greenhouse construction budgets, because the profitability of greenhouse farming outweighs any possible deterrent effect.

It is clear from the current situation that the mix of current and previously adopted measures has proved insufficient and unsuccessful in conserving the still very valuable area which surrounds Campo de Dalías. Further measures are needed, and some are under consideration, including the longer term possibility of buying the land around the lagoons, to create a true buffer zone. However, it is notable that none of the measures so far implemented is really addressing the irrigation systems which are so integral to the problems documented here. In this context, some of the measures described for case study 1 (Tablas de Daimiel) might also prove to be of some value if applied here.

4.3. CASE STUDY 3: THE VALLEY OF ARGOLID IN NORTH-EASTERN PELOPONESE (SOUTHERN GREECE)

4.3.1 Introduction

In Greece, sea water intrusion into the aquifers due to over-pumping is occurring with varying intensity in almost all the valleys neighbouring the sea of both the mainland and the islands where irrigated agriculture based on groundwater has been introduced. However, the phenomenon has been studied rather systematically only in the case of Argolid in the north-eastern part of the Peloponese (Poulovassilis, 1998). The study which has been conducted covers the main Argolid plain, the valley of Assini-Drepanon, located eastwards of the main plain, and the Iria valley, located further eastwards (see map 1 of the report and Poulovassilis, 1998). Here we will focus on the main Argolid valley.

4.3.2 Main Characteristics of the Region and Sources of Water for Irrigation

The Argolid plain occupies the northern part of a geological depression formed between the Arachneo mountain to the east and the Arcadic mountain ridge to the west, both being limestone formations. The southern part of this depression is occupied by the sea, thus forming the Argolid bay. Several ephemeral (winter only) streams enter the plain and, with the exception of the Xerias and Inachos, they end at the outskirts of the plain, where the water they transport is absorbed by the rather coarse sediments to recharge the underground water-bearing formations.

The total area enclosed by the watersheds of the Argolid is about 1100 km^2, while the plain covers an area of 42,000 hectares of which 29,500 are cultivated. Only 26,000 hectares of cultivated land are considered suitable for irrigation (Poulovassilis, 1998, p.175). A significant expansion of irrigation has been taking place in the region from the 1950s onward, following an intensification of production, with intensive cultivation of tree crops (mostly orange trees) and horticultural crops characterising the plain. Monocultivation of orange trees has gradually replaced the variety of arable crops that were previously grown in the area (eg dry land cotton production and horticulture). As a result, the average use of fertilizers per hectare has risen to 15 kg/ha (in previous decades 1/3 of this quantity was used). On more sloping land olive trees are grown using increasingly more modern methods with irrigation. The average size of holding in the area is about 2 ha[1].

From stratigraphical studies conducted in the region, it has been found that the thickness of the sediments of the plain is variable and that its centre exceeds 600m. It has also been found that at the central-southern part of the plain, the sediments include three to five aquifers, sandwiched between clay layers. These aquifers at their outskirts are encircled by unconfined aquifers, the latter being mainly responsible for the recharge of the confined aquifers (Ibid). The groundwater retained in this region has been the main source for supplying the needs of the area. The region is endowed with a number of springs discharging water of very good quality, the most important of which are the Lerni and Kefalari springs, located at the south-western edge of the plain (Ibid, p. 176).

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[1] Information drawn from discussions with experts from the Argolid Local Administrative Authorities, Spring 1999.

4.3.3 The Expansion of Irrigated Agriculture in Argolid and Environmental Degradation

Warmer and drier conditions prevail in this zone, as compared to Western and Northern Greece, so irrigation is applied from March to October. The basic irrigation technology in the region is sprinklers and drip systems, i.e. pressure systems. In particular, 65% of the systems based on pressure are sprinklers and 35% are drip. There is a tendency to substitute drip for sprinklers, but this is taking place rather slowly due to the high costs involved in setting up new drip irrigation systems. Around 10-20% of irrigation needs in the area are covered by traditional irrigation systems (ie systems without pressure)[2].

Irrigation in the Argolid plain has been mostly based on groundwater abstraction, as was previously mentioned. Only 10-20% of water is drawn directly from the 3 springs that exist in the region.

Estimates of the expansion of the irrigated area and the increase in the volume of water used for irrigation, as well as of the contribution of various water sources, are given in Table 4.3.1.

TABLE 4.3.1 Expansion of Irrigated Area and Increase in Volume of Irrigation Water

Year	Irrigated area (ha)	Irrigation water applied m^3x10^6/year	Contribution of various water sources		
			Direct abstraction from Groundwater	Kefalari-Lerni springs	Kiveri springs
1940	4,600	37	26	11	0
1965	12,500	100	80	20	0
1985	17,000	135	100	20	15
1995	21,000	150	115	20	15

Source: Poulovassilis, 1998

The irrigated area today has reached 25,000 hectares. The expansion has resulted in sea water intrusion into the aquifers. This was first recorded in the early 1960s, when groundwater, pumped from certain wells, showed an increase in the concentration of chlorides, while signs of chloride toxicity - such as leaf burns and defoliation, particularly in citrus trees - were observed. The Ministry of Agriculture was alerted and decided that a comprehensive research programme to investigate the condition of the Argolid natural resources should be initiated. The aim of the programme was not only to address sea water intrusion and pollution problems, but also to secure the continuation of irrigated agricultural production in the area.

Specific research programmes were established on:

(a) the spring water resources of the region (in particular the hydrological regime, water quality and their potential use for irrigation and artificial recharge, etc.);
(b) the hydrological characteristics of the ephemeral streams (in particular those of Inachos and Xerias streams, in an effort to retain their run-off); and
(c) the groundwater resources.

[2] Information drawn from discussions with experts at Agricultural University of Athens and the Argolid Local Administrative Authorities, Spring 1999.

The research programme started in 1963 (Poulovassilis, 1998). Estimates of the evolution in groundwater levels (heads) and the values of chloride concentration (parts per million - ppm) in the region, between 1964 and 1992, are given in Table 4.3.2 and presented graphically in figure 4.3.1.

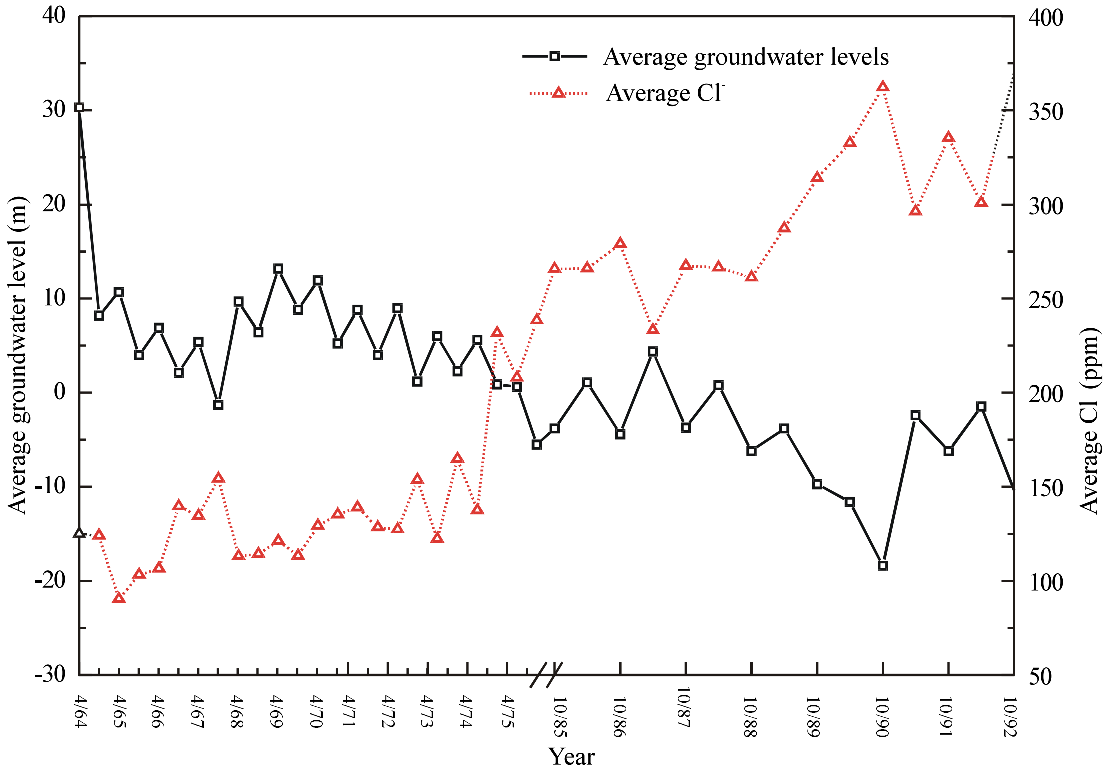
Table 4.3.2 Average Groundwater Levels and Chloride Concentrations

Date	Average gw. Level (m)	Average chloride concentr. (*ppm)	Date	Average gw. level (m)	Average chloride concentr. (*ppm)
Jan-64	30.3	124.8	Apr-74	5.6	137.4
Oct-64	8.2	124	Oct-74	0.9	231.5
Apr-65	10.7	90.2	Apr-75	0.6	208
Oct-65	4	103.2	Oct-75	-5.5	238.3
Apr-66	6.9	106.5	Oct-85	-3.8	265.7
Oct-66	2.1	139.5	Apr-86	1.1	266
Apr-67	5.4	134.6	Oct-86	-4.4	278.8
Oct-67	-1.3	154.2	Apr-87	4.4	233.2
Apr-68	9.7	113.1	Oct-87	-3.7	267.3
Oct-68	6.4	114.2	Apr-88	0.8	266.5
Apr-69	13.2	121.2	Oct-88	-6.2	261.1
Oct-69	8.8	113.3	Apr-89	-3.8	287.1
Apr-70	11.9	129.2	Oct-89	-9.7	314
Oct-70	5.2	135.2	Apr-90	-11.6	332.5
Apr-71	8.8	139	Oct-90	-18.4	362
Oct-71	4	128.4	Apr-91	-2.4	296.1
Apr-72	9	127.4	Oct-91	-6.2	335.1
Oct-72	1.2	153.5	Apr-92	-1.5	300.7
Apr-73	6	122.2	Oct-92	-10.4	370.1
Oct-73	2.3	164.7			

Source: Giannoulopoulos, 1999.

In experiments of artificial recharge of the aquifers, which started in 1964, good quality water from Kefalari spring was transported to the eastern part of Argolid. It was injected into existing wells in irrigated areas close to Nafplion city and in the Assini-Drepano valley, where the most severe symptoms of chloride toxicity were observed. The experiments continued until 1967 and involved the injection of about 1 million cubic metres of water per recharge period (winter and early spring). These experimental recharge efforts resulted in a substantial improvement of groundwater locally, accompanied by the improvement of the affected citrus plantations.

Figure 4.3.1 Evolution of Average Groundwater Levels and Chloride Concentrations of the Alluvial Aquifer in the Plain of Argolid



Source: Giannoulopoulos, 1999

Based on the results of these experiments, the Ministry of Agriculture decided that artificial recharge ought to be applied on a large scale using the winter and early spring discharges so that sea water intrusion could be controlled and the natural recharge of the aquifers supplemented. The research programme ended in 1967, but research efforts re-started in 1985 in the framework of a new research project financed by the Ministry of Agriculture and later by the EU. It was conducted under the supervision of the staff of the Laboratory of Agricultural Hydraulics of the Agricultural University of Athens in collaboration with the staff of the local unit of the Ministry of Agriculture. Within the framework of these projects, artificial recharge re-started in the 1990s (Poulovassilis, 1998, p. 177).

In Argolid the over-pumping of water increased over time, accompanied by an increase in salinization. Farmers had to abandon their affected wells and to open new ones further away from the coast or buy water from their northern neighbours. In this way, the pumping fields moved gradually inland towards the central and northern part of the plain. This inland movement somewhat moderated the salinisation process, but did not prevent the lowering of the piezometric surfaces and water tables in this part of the plain. This fall obliged farmers to deepen their boreholes or drill new ones penetrating even deeper layers, so that in many cases they had to pump water from a depth of 200 metres.

An increase in salinisation was observed in the 1963-1990 period and a further dramatic fall in the piezometric surfaces, so that many boreholes dried up. The serious shortage of water observed in the late 1980s led to the application of artificial recharge and the use of the Kiveri water for irrigation. For the recharge, water from the Kefalari spring was used, which was transported to the southern part of the plain. After the construction of the Kiveri canal in 1994, water from this spring could be transported into the central part of the plain by free flow and the recharging front moved northwards. The volume of water injected in the 1990-1996 period is shown in table 4.3.3.

TABLE 4.3.3 Water Volume Applied for Artificial Recharge from 1990-1996

Year	‘0000 m^3
1990	3.09
1991	6.92
1992	5.68
1993	3.89
1994	14.00
1995	13.59
1996	7.22
TOTAL	**54.39**

Source: Poulovassilis, 1998.

As a result, a substantial reduction in salinity was observed in the 1990-96 period, in combination with a substantial upward movement of piezometric surfaces, particularly in the central and northern parts of the plain.

Salt balances in the soil profile were also examined and the conclusion was that the salts are washed out of the upper soil layers under the combined action of rainfall and irrigation water.

Moreover, *irrigation return flows* were monitored and it was concluded that they have led to an increase of various contaminants in groundwater – eg nitrates (the result of agricultural activity). In particular, nitrate concentrations were found to be over 50ppm (which is the drinking water standard) in nearly over two thirds of the aquifer in the area. In the eastern part of the plain *nitrate concentrations* range from 100 to 350ppm. Even though no measurement of pesticide concentrations in water has taken place, the high concentration of nitrates would suggest that pollution from pesticides is also high. The fact that ‘unconfined aquifers’ prevail in the area means that hydrological conditions favour such pollution[3].

4.3.4. Institutional Framework and Strategies for Meeting Irrigation Demand

In Argolis water from the three springs (surface water) is transferred by the ΓΟΕΒ (Land Improvement General Boards) through the canal and distributed by the TOEB (Land Improvement Local Boards) to its members (producers or farm holdings) according to a plan that establishes how each producer will water his crops. The TOEB also collects the relevant sum of money (service fees) from its members. From the 25,000 hectares irrigated in the valley, less than half use this type of collective irrigation measures. while the rest use private irrigation works (with the water drawn through drilling)[4].

As irrigated cultivation is expected to expand further, water requirements will continue to increase. To meet the increased demand for water, two strategies have been adopted.

[3] Information drawn from discussions with P. Giannoulopoulos, Sept., 1999.

[4] Information given by experts from the Argolid local administrative authorities, Spring, 1999.

The first strategy considers the discharges from the Kiveri springs as the basic source of water for irrigation. A pumping station has been installed close to the springs to pump water from the Kiveri canal. Moreover, a number of pumping stations will be installed along this canal to transport water to higher elevations into excavated ponds. Finally, the water retained in these ponds will be pumped into an underground irrigation network consisting of pipes and covering the whole plain.

Apart from the enormous costs involved in this kind of irrigation water delivery system, fears are expressed that the rather high chloride concentrations of the Kiveri water may have detrimental effects on the productivity of the plantations, particularly those consisting of citrus trees. Also, the indiscriminate use of the Kiveri water may cause severe deterioration in the quality of both soils and groundwater, especially in those areas where unconfined aquifers - which constitute 2/3 of the whole plain - are developed.

It has been estimated that for a given quantity of water per year, 150 million m^3/year, 3,000 kg/ha/year of salt will be deposited on the irrigated soils. If this water load were to remain in the soils the latter will be salinised in some years' time (Poulovassilis, 1998).

The second strategy considers groundwater as the main source for irrigation water after supplementing its natural recharge by an artificial one. For the implementation of this strategy, winter and early spring discharges of local springs can be used, mainly those of the Kefalari, which can be transported to the plain by free flow. It is estimated that groundwater could provide sufficient water for the irrigation needs of the region if artificial recharge is properly applied (ibid).

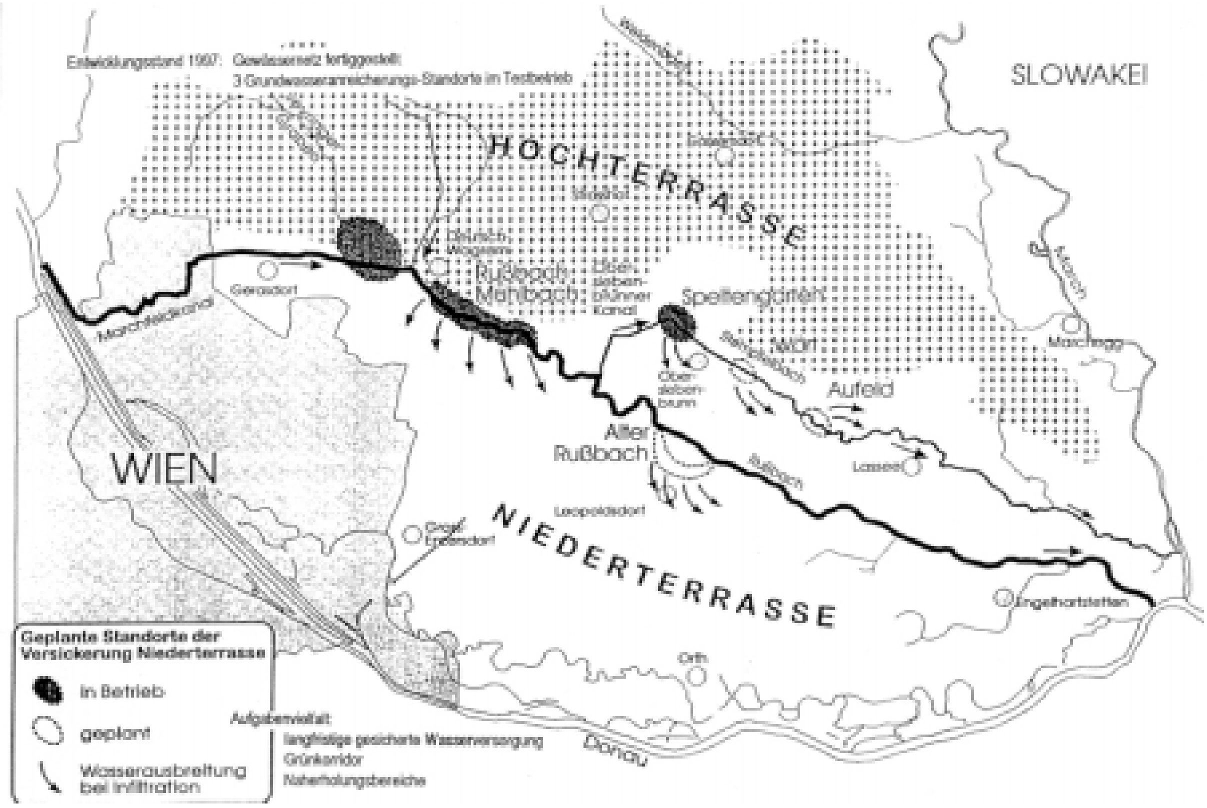
The general conclusion of experts who have conducted research in the region is therefore that ground water from the Argolid plain could continue being the main source for irrigation, provided that an artificial recharge from the Kefalari and Lerni springs (which contain good quality water, without salinity) takes place. This strategy would, they believe, entail little or no negative environmental impact.

These experts claim that the Greek authorities responsible for taking decisions on such matters are considering the two strategies described above, but so far they have not adopted and implemented the second one, which is favoured by the experts. It is to be hoped that such a strategy will be agreed and taken forward in the near future, if further environmental problems are to be minimised.

4.4. CASE STUDY 4: THE 'MARCHFELDKANAL'-SYSTEM, AUSTRIA

4.4.1. Main Characteristics of the Region

The Marchfeld region is situated in eastern Austria, east of Vienna and bounded to the south by the river Danube. The region is known for its special geological and climatic conditions, including water shortage (Ernegger et al, 1998). It is the greatest plain in Lower Austria, covering about 1,000 km^2, 67,000 ha of which are situated on the 'Niederterasse' and 33,000 ha on the 'Hochterasse'. About 70,000 ha are used for intensive agriculture. In total, 190 km^2 of the Marchfeld is within the Donau-Auen National Park which was designated in 1996. The following map shows the area and the Marchfeldkanal.



Source: Grubinger, 1998

The Danube, which has the flow characteristics of a mountain river, was regulated as early as the Middle Ages because the river occasionally flooded and extended far into the Marchfeld. However, the first major regulation took place between 1870 and 1875 and the river was gradually regulated further, leading to a complicated system of water use and flood protection today (Ernegger et al. 1998).

Between 1900 and 1950, the Marchfeld became one of Austria's main corn growing areas with wheat, oats and barley the main crops. This development, together with the expansion of Vienna into the Marchfeld, led to a loss of wetland areas; the landscape was 'improved' to become agricultural steppe. However, the precipitation levels in the Region are mostly too low and the distribution of precipitation too diverse to ensure optimal harvests. Mean annual precipitation amounts to approximately 580 mm, ie 390 mm during the vegetation period with precipitation peaks in spring and autumn (Mottl, 1992), which is one of the lowest figures in Austria. Irrigation therefore began to be introduced, especially after 1950, to increase productivity and secure harvests in dry years. These developments were in line with national agricultural policy guidelines after 1945 (Ernegger et al, 1998).

Today, the total irrigated area is approximately 45,000 ha. About 42,000 ha of these are irrigated with groundwater, while surface water from on-farm rivers and from distant reservoirs is used for about 2,000 ha. Overhead irrigation by means of small-sized sprinkler arms or sprinkling machines is the exclusive form of irrigation. Most water is abstracted from individual wells with the help of diesel operated pumps (tractor pumps), a minor part of overhead irrigation is accomplished by means of electrically operated central pumping stations with buried water distribution systems. Surface water overhead irrigation is also accomplished by means of central pumping stations (Mottl, 1992).

The area in intensive agricultural use has however decreased over the last two decades, together with a fall in the number of agricultural holdings and an increase in the average size of holdings. The following tables show the development of cropped areas in the Marchfeld region between 1979 and 1995.

Table 4.4.1: Area of Crops in 1979, 1990, 1995 in the Marchfeld Region (ha)

Crop	1979	1990	1995
Sugar beet	6,518	7,255	7,181
Sunflower	74	1,660	1,896
Early potatoes	1,489	1,052	1,352
Late potatoes	768	1,605	2,710
Cereals	52,747	40,841	32,948
Vegetables	2,537	2,888	4,023
Winter rape		1,477	365
Soya beans	25	1,305	1,845
Legumes	109	5,556	2,015
Subsidised fallow land		273	6,355
Other	1,537	1,311	1,564
Total area	**65,840**	**65,223**	**62,254**

Source: Land- und forstwirtschaftliche Betriebszählung/Bodennutzung 1979, 1990, 1995, ÖSTAT

Table 4.4.2: Percentage Area of Crops 1979, 1990, 1995 in the Marchfeld Region

Crop	1979	1990	1995
Sugar beet	10	11	12
Sunflower	-	3	3
Early potatoes	2	2	2
Late potatoes	1	2	4
Cereals	80	63	53
Vegetables	4	4	6
Winter rape	-	2	1
Soya beans	-	2	3
Legumes	-	9	3
Subsidised fallow land	-	0	10
Other	3	2	3
Total area	100	100	100

Source: Land-und forstwirtschaftliche Betriebszählung/Bodennutzung, ÖSTAT

4.4.2. Environmental Problems

The Marchfeld hosts one of the most important groundwater deposits in Austria of about 1.4 bn m^3 of water. Intensive agricultural use and drainage have however led to severe lowering of the groundwater table of 5-10 cm per annum and up to 50 cm per annum in particularly dry areas. Between 1945 and 1995 groundwater levels fell by 2.5 metres (Ernegger et al, 1998). This has led to the loss of 80% of all wetlands in the Marchfeld region and a significant decrease in biological diversity. Further problems in the area occur in the form of over-fertilisation and pesticide pollution.

The groundwater table has been falling for more than 30 years, albeit with annual fluctuations depending on the weather. Studies have confirmed that a restoration of the water supply and distribution will only be possible by means of drastically restricting groundwater abstractions.

Reasons for the lowering of the groundwater table include the regulation of the Danube in the last century, leading to accelerated river flow and therefore a decrease in groundwater recharge and the constantly increasing groundwater abstractions for agriculture, industry and households during the last decades. Since 1945 abstractions in the part of the Marchfeld belonging to Lower Austria have increased from:

- 1.5 million m^3 to 5 million m^3 per annum for drinking water;
- 2 million m^3 to 19 million m^3 per annum for industrial use;
- 10 million m^3 to 32 million m^3 for agricultural irrigation.

Additionally, 20-30 million m^3 are abstracted per annum in the part of the region belonging to Vienna. Overall, excessive water abstraction has amounted to about 350 million m^3 during the last decade.

As far as agriculture is concerned, soil compaction, increased evaporation due to increased maize production and intensive grassland management have led to decreased seepage of precipitation water and more rapid drainage. Increased abstractions for irrigation have led to the depletion of existing supplies. In addition, there are water quality problems due to nitrate and phosphate leaching as well as residues from pesticides. Water quality is also affected by deposits from former gravel mining sites and insufficient wastewater treatment. These problems also affect rivers in the region which, over big stretches, have seen a substantial decline in water quality.

4.4.3. Strategies for Meeting Irrigation Demand and Solving Environmental Problems

Several measures have been put in place to counteract these negative environmental effects. Payments under the Austrian agri-environment programme influence the extent of groundwater pollution and pay for set-aside and green cover measures.

The need for large scale water transfer projects to enable the optimal agricultural use of the 'granary' of Austria was recognised as early as 1850 and the use of water from the Danube was one of the first options considered. The earliest outlines for the creation of canals off the Danube appeared in 1953. The geographical situation of the Marchfeld made it possible to construct a descending channel from the Danube to supply the plains with water. Various studies between 1954 and 1974 showed that this was technically possible (Korf, 1958, 1962, Grubinger, 1958), and several project proposals were presented, but were rejected at the time because of the difficulties and high costs associated with land purchase.

In 1974, Lower Austria's regional government reconsidered the proposals due to an increasing need for groundwater table enrichment. The Austrian Raumordnungskonferenz was asked to evaluate the proposal for the Marchfeldkanal and decided to go ahead with the project. In 1983 the Planungsgesellschaft Marchfeldkanal was established and the building of the Marchfeldkanal was decided in 1985. Building work began in 1987 and the canal was first flooded in 1992. The Marchfeldkanal is an artificial channel resembling a natural river. Unlike other water transfer projects in other regions of Europe, its novel design aims to create a range of semi-natural features and habitats along its course.

The costs of the project were divided between the national government (45%), the Environment and Water Fund (30%), the catastrophe fund (15%) and regional government (10%). The local population was involved in the planning stage of the project through information evenings and the opportunity to air criticism and suggestions. Its aims were to:

- enable direct infiltration into the groundwater to secure the water supply;
- improve water quality of rivers;
- create semi-natural wetlands and habitats for flora and fauna;
- renovate leaking dams and regulate drainage to ensure adequate flood protection.

The Marchfeld canal project provided for the construction of an inlet structure on the Danube; an 18 km long, open canal with a maximum normal flow of 15 m^3 of water per second, and a seepage plant for water recharge. The main canal conveys surface water from the Danube into the project area. In the lower section of the channel, part of the water is diverted to a groundwater recharge plant, where it is filtered and seeps continuously into the aquifer. Through this, the groundwater level is gradually raised over a large area by about 2 metres. There is also a groundwater infiltration plant and pressure pipelines to supply the higher parts of the project area. The infiltration plant provides for infiltration of up to 300 litres of water per second, which amounts to 10 m^3 per annum. It is aimed at the long-term balancing of the groundwater level and the direct supply of irrigation water for agriculture. The infiltration plant's operation has been delayed due to contamination from former gravel mines nearby, which have severely affected groundwater quality.

4.4.4 Results To Date

The project essentially aims at replenishing groundwater and providing sufficient amounts of water for different users, especially for irrigation. Renaturalisation of the Marchfeld landscape and the creation of ecological networks of the remaining biotopes were further aims of the project. Its implementation improved low-flow problems in the main tributaries in the Marchfeld. Artificial wetlands of value for flora and fauna were created (BMLF). According to officials from the Donau-Auen National Park there are no adverse effects, and the project has arrested further groundwater depletion, which is regarded as very positive.

A cost-benefit-analysis by the canal's construction company came to the conclusion that without construction of the canal, a stop to groundwater abstractions for agricultural use would have been unavoidable. This would have led to significant changes in the crop structure and would therefore have changed the character and appearance of the whole region.

There would also have been effects on biodiversity because more monocultures would have developed since cereals use the smallest amount of water. The following benefits are ascribed to the project:

- improvement and long-term security of the water supply for agriculture and industry;
- quantitative security of drinking water supply and qualitative improvement in some areas;
- improvement of water quality and better waste water treatment;
- improved flood protection;
- improved ecological and landscape aspects and creation of recreation areas.

These benefits do not occur to the same degree and strength in all parts of the Marchfeld region but depend on the local circumstances.

In 1984, an independent environmental impact assessment was carried out for the project by the Austrian ministry for health and the environment. The assessment came to the conclusion that the project would:

- through its design, create a variety of new habitats and ecological networks;
- lead to an improvement in water quality;
- not lead to soil contamination through long term accumulation of harmful substance through irrigation;
- lead to the creation of recreational areas.

The major area for future development of irrigation plans in Austria is the Marchfeld-Hochterasse, Public discussion of the pros and cons of this led to the elaboration of a study, which identifies appropriate measures to improve the environmental impacts of irrigation in this region (Bundesministerium für Ernaehrung, Landwirtschaft und Forsten, pers.comm).

4.5. CASE STUDY 5: THE BEAUCE, FRANCE

4.5.1 Introduction

The nappe de Beauce is a very important aquifèr system extending for 9000 km^2 between the rivers Loire in the south, Orge and Seine in the north and Loing in the east, in northern-central France. The aquifer straddles six French Departements and two Regions and it feeds two main river basins. The aquifer is held in a reservoir made up of various geological layers including chalks and sands, but the water table itself is supported by an impermeable layer of clay and silex which separates it from the chalk underneath.

The thickness of the water table varies across its length from almost nothing in the extreme west to over 150 metres at the centre. The water resource in the system is estimated to be 20 billion cubic metres, derived exclusively from heavy winter rainfall, estimated at 100mm, which corresponds to an average supply of 900 million cubic metres of water per year. However, the precise behaviour of the aquifer is complex and remains relatively poorly understood (Rieu, *pers comm*)

The map below shows the location of the Beauce region in France.

The Beauce aquifer represents the almost exclusive source of water for certain rivers which only drain from the upper levels of the aquifer and are therefore very sensitive to any lowering of the water table. These rivers include the Conie, Aigre, Essonne and Oeuf. The Beauce aquifer also makes a substantial contribution to the water in the Loire, equivalent to that of a large reservoir, via a number of smaller tributaries.

4.5.2 Agriculture and Irrigation in the Beauce

The Beauce region is a predominantly arable area, devoted to the production of wheat, maize, barley, sugar beet and field vegetables. Oilseeds and sunflowers have also been important crops in the area, as well as legumes such as field peas. The average size per holding is around 100 hectares, which is significantly larger than the national average for France. There has also been a significant trend towards farm enlargement in recent years, as the agriculture of the area has become more specialised. It is therefore an area of particularly modern, mechanised and intensive arable production of relatively high profitability, and the farmers tend to operate at a relatively high level of technical skills and competence (Rieu, *pers comm*).

Table 4.5.1 Cropping in the Beauce (ha)

Crop type	1994	1995	1996	Increase 94-6
Maize	41,440	48,650	57,400	38%
Irrigated maize	32,500	39,640	48,820	50%
Barley	62,370	69,650	85,110	36%
Irrigated barley	4,840	16,520	21,400	442%
Peas	52,620	47,100	42,380	- 20%
Irrigated peas	27,930	23,510	19,950	- 29%
Wheat	279,740	277,850	288,330	3%
Irrigated wheat	167,844	166,710	172,998	3%
Irrigated beet	30,000	30,000	30,000	0 (quota)

Source: Davy, pers.comm.

Irrigation in this region is complementary irrigation applied to the most productive and economically valuable crops including wheat, barley, maize, sugar beet, peas and vegetables. In some of these cases, irrigation water significantly increases the yields per hectare, while in other cases quality attributes may be just as important in providing the incentive to irrigate.

According to official water agency statistics, the average quantity of water used varies from 500 to 2,500 cubic metres per hectare per year, depending upon the crops and the weather conditions. However, it is widely suspected that these figures underestimate real water use because farmers have an incentive to under-declare abstractions in order to minimise water charges (see the discussion in Chapter 6 on cross-compliance). On some farms, water use has been found to exceed 3500 cubic metres per hectare per year, on occasion. It is thought that such a high level of use is probably not efficient and involves a degree of waste which could be reduced by better husbandry and water management techniques.

Irrigation is almost exclusively by sprinkler systems. Individual farmers have sourced irrigation water from the aquifer because it has proved cheaper to sink a well than to attempt to finance surface water irrigation systems using either on-farm reservoirs or transport of water from rivers, which would require some kind of collective infrastructure.

Since 1976, abstractions for irrigation have increased considerably as a result of the introduction of new forage crops, as well as increased numbers of irrigating farms and an expansion of the irrigation season due to its introduction on spring crops.

The total area of land registered for irrigation with the water agency grew from around 50,000 hectares in 1977 to over 300,000 hectares by 1991 (Dubois de la Sablonniere, 1998). Agricultural statistics show that this area increased by a further 260,000 ha between 1991 and 1993 (Davy, 1999). The result of this growth has been a gradual lowering of the water resource in the Beauce aquifer since around 1980.

4.5.3 Environmental and Economic Impacts of Irrigation

When the winter rainfall is insufficient to restock the aquifer to balance the levels of abstraction for irrigation, this can strongly disrupt the functioning of the catchment area by lowering the level of the water table and restricting the supply of water to its rivers. Thus, although the stock of water in the aquifer may still be substantial, its level becomes too low to allow it to supply these outlets.

An approximate balance-sheet for the aquifer is shown in table 4.5.2

Table 4.5.2 Beauce Aquifer Balance Sheet (million cubic metres)

Outputs		**Inputs**	
Supply of drinking water and water to industry	100	Heavy winter rainfall	900
Irrigation	250		
Seine-Normandy waterways	250		
Loire-Brittany waterways	300		
Total	**900**		**900**

Source: Dubois de la Sablonniere, 1998

In the central region of the aquifer, it has been estimated that the quantity of abstractions by 1991 had reached 60% of the level of average rainfall, which thus led to the progressive and increasingly rapid lowering of the water table. A continuing decrease was noted every year between 1988 and 1994.

In five years (including four years of drought from 1989 to 1992 and one normal year in 1993) the level of the aquifer fell below the lowest level previously recorded in 1906. Some of the smaller rivers ceased to flow during this period. The river Conie dried up for 6 weeks in 1991 and then for more than a year and a half in 1992-4. The level of the Loire was also lowered and the watercress beds of the Essonne river dried up (*Perspectives Agricoles,* 1996).

Difficulties were also suffered by the agricultural sector in respect of forage crops situated in the périphéral zones of the aquifer where marked reductions in productivity and a significant increase in the drawing down of the water table was seen. Where irrigation had been sourced from relatively shallow boreholes, many of these became unable to access the aquifer.

There is currently little data available to indicate the ecological effects of the lowering of the Beauce water table and in particular, the low flow and temporary drying up of the rivers that drain from it. However, some work in the United Kingdom has indicated the kinds of effect that are likely to be associated with this process (Fojt, 1993):

- the importance of water within aquatic systems is not simply related to the quantity of water but also to the chemical, nutritional and flow characteristics of the system. Whether the water flow in a river is sluggish or rapid, its water chemistry and nutrient status have a fundamental influence upon associated plants and invertebrates;

- in calcareous streams typical of some of those found around the Beauce aquifer, the aquatic ecology is dependent upon the maintenance of fast flow and low nutrient status, as well as a steady flow regime due to the regular groundwater outflow. The disruption of the supply of groundwater to this river type will undoubtedly have significant ecological consequences;

- in the upper reaches of the stream, grasses and herbs will colonise the dry channel floor. Downstream, lower flow will increase the water's nutrient status, particularly if enriched rainwater is continuing to drain into the river from nearby cropped land. and there is a risk that plant growth in the summer months will clog up the stream flow even further and silts will become deposited. Algal blooms may develop, deoxygenating the water and causing fish kills.

- silt deposition on the river bed may also change the channel gradient, thus increasing the tendency for more siltation in future.

CEMAGREF, a research institute in Montpelier, is currently completing a detailed study of the Beauce aquifer and the impacts of its lowering (Rieu, *pers comm*), which is due to be published some time after March 2000. Unfortunately, it has not proved possible to obtain any early results from this study for the purposes of this report.

4.5.4 Actions to Ameliorate the Impacts of Irrigation

In 1995, a year of heavy winter rainfall followed by a relatively low level of irrigation and other demand during the summer did much to restore the aquifer. However, the water agencies saw a need to take preventative action in future, to ensure that similar problems as had occurred in the early 1990s should not reoccur at a later date.

This led to the development of a series of concerted efforts to address the more effective and sustainable management of the aquifer. Today, the annual lowering of the water table by irrigation, from a similar starting level, has been much less pronounced during the dry season than in previous dry seasons. The improvement stems from the fact that the farm sector and the administration have taken steps to control the level of abstractions in relation to the volume of water that is actually available in the aquifer.

Incentives for Improvement

The two water agencies of Loire Brittany and Seine-Normandy gave permission for the creation of an inter-basin working team involving representatives from Regional councils, local communities, central government, farming organisations, industrial users and environmental protection agencies.

The working team was given the following roles:

- to monitor the state of the aquifer;
- to identify joint goals for the sustainable management of the aquifer to allow its use while still protecting the natural environment;
- to develop action plans to help in the pursuit of these goals;
- to develop a shared commitment to, and ownership of, these action plans among the key stakeholders in the area.

The team has supported a programme to develop a mathematical model which can measure the state of the aquifer after the winter rains and use this to determine the availability of water in each season. The model is being developed by the water agencies and supported by the French Ministries of agriculture and environment, as well as the regional councils. It should be completed by the year 2000.

In addition, there have been further initiatives:

- to increase the use of water meters at all pumping points for the aquifer, the Loire-Brittany water agency has grant-aided water metering up to 80% of the costs of installation;
- technical support has been offered to local farmers to help them draw up water management plans, to monitor soil water status, to assess crop needs accurately and to reduce wastage of water;
- research is underway to develop rules for sharing water supplies and minimising the economic impact of a water quota (see below) on individual farms.

Controls on Water Use
Each year, the average level of the aquifer is calculated crudely by reference to the observed levels in 9 different locations across its area. This is used to set thresholds of increasing restriction on water abstractions. A quota for water use per hectare is then set in each county, for agricultural irrigation.

The water agencies also levy a charge on abstracted water, which increases when the aquifer is in a state of imbalance and abstractions exceed supplies. Individual farmers can have the level of this charge reduced if they can show through water metering that they are using a relatively low level of water. The maximum reduction in the charge (of 33%) applies to those using less than 900 cubic metres per hectare, while those using between 900 and 1900 cubic metres get a smaller reduction and those using more than 1900 cubic metres get no reduction.

It is certainly too early to say whether these measures will prove sufficient to protect the Beauce aquifer and the rivers that it supplies, in the medium to long term, particularly if global warming reduces rainfall and increases the incentive to irrigate, as has been indicated in some studies (CEC, 1999). However, these steps do represent the start of a concerted and co-operative approach to the more effective management of the resource.

Chapter 5. The Situation and Impacts of Irrigation in the Applicant Countries of Central and Eastern Europe

5.1 Introduction

The impact of agricultural irrigation on the environment in Central and Eastern Europe varies considerably from country to country. Irrigation played an important part in the large scale collectivised agriculture which was promoted under the Soviet regime, but most so in the regions and countries covering parts of the Pannonian and Danubian Plains. Thus, during the 1980s about 25 per cent of the agricultural area of Bulgaria was under irrigation, whereas **irrigated** land covered less than 1 per cent of the agricultural area in the Baltic States.

Consequently, the environmental impact of irrigation is significant in countries such as Romania and Bulgaria but negligible in the Baltic States. Due to its high costs, the outright destruction or at least neglect of collective structures and the fragmentation of land ownership, the total extent of irrigated land has declined strongly during the last ten years, in some countries by up to 90 per cent. Given the relatively small extent of the irrigated area and moderate use of fertilisers and pesticides in CEE, agricultural irrigation is currently not judged an important threat to natural resources or biodiversity by most respondents from the applicant countries who were consulted for this study. Historically, however, irrigation infrastructure (reservoirs, canals etc) and the high use of agricultural inputs on irrigated fields had large negative impacts on natural resources and wildlife habitats.

5.2 Historical Extent and Environmental Consequences of Irrigation

Wetland drainage, river regulation and irrigation have been key policies for raising agricultural productivity for centuries, particularly so in the Pannonian and Danubian Plains. Soviet agricultural planners continued these policies enthusiastically with a strong belief in the progress of mankind through technological manipulation of nature. Given the strong productivity increase achievable through irrigation in areas with hot, dry continental summers the expansion of the irrigated area was one of their key activities. Thus, in Bulgaria the percentage of irrigated land increased from 14 per cent in 1960 to 27 per cent in 1989.

Apart from the negative effects of the intensive agriculture that has been facilitated by irrigation, irrigation on this scale required a very large investment in related infrastructure such as river dams, storage reservoirs, transportation channels, river regulation, pumping stations and field based distribution systems. This had a strongly negative impact on river ecosystems and other habitats. Irrigation also enabled the planting of new crops such as rice which are heavily dependent on generous water provision. In 1989 rice fields covered 49,000 ha in Romania, while rice was grown on several thousand hectares in Hungary during the 1950s and 1960s. Most of these rice paddies will have been established on previous wetland areas, due to their need for flood irrigation.

Many reports on the relationship between agriculture and biological diversity in CEE state that a strong negative impact arose from agricultural collectivisation, mechanisation, intensification, drainage and water regulation, affecting habitats and wildlife in various CEE countries (e.g. IUCN, 1992, 1993, 1995). However, irrigation is rarely singled out as a separate factor for habitat destruction or other negative environmental impacts. This may be due to the fact that it is one of a number of stresses on water supply and management including water regulation, wetland drainage and industrial water consumption. Furthermore, irrigation is often only the second step in agricultural intensification after river regulation or drainage, which may greatly reduce a large part of the original natural values of an area.

Nevertheless, the following examples from individual countries show that agricultural irrigation has had a negative environmental impact in CEE countries in the past, the effects of which persist at present in some cases:

Hungary: Agriculture was responsible for 13 per cent of total water use in the late 1980s. Agricultural water consumption and the installation of irrigation to fields is one important factor behind the serious loss of wetlands in Hungary since the 1950s. High levels of water consumption by agriculture were identified as a particular threat for remaining marshy areas and connected lakes in the Hungarian lowlands. Reservoirs for water storage on rivers are blamed for the destruction of riverine forests. The rice paddies mentioned above had been abandoned by 1990 and were considered 'uncultivated wastelands' (all from IUCN, 1992). However, since 1990 the negative impacts of irrigated agriculture have declined. Due to lack of capital and lower crop prices the irrigated area has declined strongly and is mainly targeted at high value crops (fruit and vegetables, some sugar beet). Increasing water prices support a trend towards drip irrigation.

Romania: There are no overviews of the impact of irrigation on the environment in Romania in spite of the importance of irrigated agriculture (3.19 million ha is irrigable, about 21 per cent of total agricultural land). However, the 1998 DG VI report on the agricultural situation and prospects in Romania voices concern about the past use of heavily polluted water from rivers for irrigation purposes. About 200,000 ha of irrigated land are known to have been irrigated with water from unsuitable sources. Nitrate pollution of groundwater (reaching 1,500 mg/l in one extreme case) is particularly serious in irrigated areas along the Danube river and in Botosani Judet. Soil salinisation had occurred on 0.6 million ha of land by 1995, while oil pollution and salt water intrusion were detected on 0.05 million ha (CEC, 1998).

Negative impacts of irrigation on habitats or protected areas are reported for individual cases only, although such damage is likely to be a regular occurrence in the Danubian Plain (in combination with water regulation and drainage). Grimmett and Jones (1989) report damage to brackish lakes along the Black Sea coast (Lacul Istria and Lacul Tasaul) due to inflow of sweet irrigation water that decreases their salinity content. A forest reserve not far from the coast (Hagieni Forest) is also threatened by unspecified effects of irrigation on surrounding land (Grimmett and Jones, 1989).

The quality and use of irrigation infrastructure in Romania decreased sharply during the 1990s. The use of irrigation currently only amounts to 10 per cent of irrigation capacity available at the end of the 1980s. Due to the land privatisation process, the high costs of input and equipment maintenance and a lack of management structures the irrigated area continues to decline. Given the poor economic situation of the country, farmers are using agrochemical inputs very sparingly and the environmental impact of current irrigation practices is thought to be small. Environmental management and sustainable water use need to become an integral part of the anticipated re-building of Romania's irrigation system.

5.3 Current Extent and Type of Irrigation in CEE

The table below shows the considerable importance of irrigation for agricultural production in countries and regions located in the Carpathian basin. Irrigated areas in both the Czech and Slovak Republic are mainly located in southern areas connected to the Pannonian Plain. In the Baltic States and Poland irrigation is generally not very important for agricultural production, although its total area is quite large in Poland. During the Communist period irrigation in these countries was mainly used on grassland for dairy production. In many countries the total irrigated area declined substantially between the mid 1980s and the mid to late 1990s, falling to less than half its previous level in Hungary and Poland for example.

Country	Area of irrigated land / % of agricultural land	Type of irrigation or crops irrigated
Bulgaria	1995: 690,000 ha (~ 11 %) 1997: only 50,000 ha are actually irrigated by farmers	1989: 50 % long furrow irrigation 49 % sprinkler irrigation 1 % trickle irrigation
Czech republic	1995: 141,249 ha (3.3 %) 1999: only 7-14,000 ha are actually irrigated by farmers	1999: 99 % sprinkler irrigation 0.5 % trickle irrigation 0.5 % other systems of irrigation
Estonia	1996: 4,886 ha (~0.3 %) 1999: only ~ 600 ha are actually irrigated by farmers	1996: 100 % sprinkler irrigation (traditionally mainly used on grassland)
Hungary	1980s: 250,000 ha (4 %) 1998: ~ 100,00 ha are actually irrigated by farmers	1999: mostly sprinkler irrigation drip irrigation is increasing sheet irrigation is declining strongly
Latvia	very small (a few hundred ha?)	n.a.
Lithuania	very small (a few hundred ha?)	n.a.
Poland	1997: 138,772 ha (~0.75 %)	1998: 96.6 % furrow or sheet irrigation 3.4 % sprinkler irrigation (90 - 95 % of irrigation is targeted at grasslands)
Romania	1990: 3.19 million ha (21 %) 1999: only ~ 10 % of this is actually irrigated by farmers	1990: 87.7 % sprinkler irrigation 10.2 % furrow irrigation 2.1 % saturated (rice production)
Slovak republic	~ 1990: 350,000 ha (14.3 %) 1998: 323,00 ha are actually irrigated by farmers	1999: all sprinkler irrigation (water use per ha declined by 70 % from 1986-1990 to 1991-1995, then was 309 m^3 /ha/year)
Slovenia	1999: 4,995 ha (0.64 %) stable or increasing in all regions	1999: mainly sprinkler irrigation drip irrigation in fruit plantations

n.a.: data not available

5.4 Current Environmental Impact of Irrigation

Given the relatively small extent of the irrigated area and moderate use of fertilisers and pesticides in CEE, agricultural irrigation is currently not judged to be an important threat to natural resources or remaining wildlife habitats by a number of respondents approached from the applicant countries (see Annex 1). The table below shows information supplied by them or found in publications from the early 1990s. Unfortunately, the available information is quite patchy and ideally, should be addressed by more comprehensive surveys.

Country	Soil and water resources	Landscapes and biodiversity
Bulgaria (past and present effects)	Significant lowering of groundwater tables; salinisation of groundwater and soils; contamination of water by pesticides and nutrients; Reduction of water flow in rivers; Disruption of natural regulation of water flow by flood plains; soil erosion on irrigated slopes	Dryland habitats were destroyed in the past; drying out of valuable wetlands; reservoir creation and diverting water from rivers destroys valuable habitats; leaky irrigation systems are creating artificial wetlands of value for flora and fauna
Czech Republic	No significant problems, sourcing of water is well regulated	Currently no significant problems
Estonia	Negligible	negligible
Hungary	Significant lowering of groundwater tables was a problem in the past, currently not considered a problem by Ministry of Agriculture	Drying out of valuable wetlands; reservoir creation and diverting water from rivers destroyed valuable habitats; leaky irrigation systems are creating artificial wetlands of value for flora and fauna
Latvia	Negligible (?)	Negligible (?)
Lithuania	Negligible	No significant impact
Poland	Significant raising of groundwater tables; contamination of water by pesticides and nutrients; reduction of water flow in rivers.	Drying out of valuable wetlands; reservoir creation and diverting water from rivers destroys valuable habitats; leaky irrigation systems are creating artificial wetlands of value for flora and fauna
Romania	Limited contamination of water by pesticides and nutrients (as inputs are expensive); salinisation effects – localised on groundwater but more extensive on soils.	Dryland habitats were negatively affected in the past.
Slovak republic	n.a.	Reservoirs and dams in upstream catchment areas have negative impact on river ecosystems; no negative impacts reported in irrigated areas
Slovenia	Irrigation is well regulated and does not use very large resources of water compared to river flow	Reservoir creation destroys valuable habitats, no other significant effects; new irrigation projects need to undergo EIA

n.a.: data not available

5.5 Conclusions and Perspectives

Because of the importance of irrigation in regions with summer drought, in particular for high value crops, there is considerable interest, especially in Bulgaria and Romania, in restoring irrigation systems. Given the large potential increase in production, agricultural irrigation is likely to be extended to larger areas in south-eastern candidate countries over the medium term as economic conditions improve. Although the irrigated area is not likely to reach past proportions, irrigation could become a significant negative environmental factor again, particularly if poor management prevails.

Water user organisations and management structures for irrigation systems need to be re-established or re-organised in a number of applicant countries. The World Bank and other donors are already supporting such efforts, for example in Romania. It is important that environmental considerations are taken into account during such projects, and that water users and management organisations are given environmental information and training. Foreign donors should strive to promote environmentally sustainable irrigation management systems and involve the environmental administration as well as relevant experts in project planning and management.

Potential technical mitigation measures have been described for Poland, as listed in Box 5.1. These might usefully be applied in other regions where irrigation is an important factor in agricultural production.

Box 5.1 Options for technical mitigation of the environmental impact of irrigation

1. Development of irrigation systems within an integrated water management system in a catchment area
2. Development and use of groundwater irrigation technologies to protect wetlands and organic soils using regulated run-off
3. Improving the operation of irrigation systems through automation and mechanisation
4. Development of appropriate irrigation systems and practices, under different soil, plant and climatic conditions, in order to achieve optimum yields with high water use efficiency
5. Improving the quantity and quality of yields through improved agricultural techniques and the introduction of new crop varieties
6. Conserving water and fertilisers through the scheduling and monitoring of irrigation and fertilisation
7. Adaptation of pesticide and nutrient use to the natural climatic, agronomic and environmental conditions of the area and water supply
8. Fertigation (supply of nutrients with the irrigation water)
9. Constructing small reservoirs for irrigation water supply in areas with no valuable habitats

Source: *pers comm*, Dr Leszek Labedzki, 1999

The mitigation measures described in Box 5.1, however, would only have a positive effect in areas where irrigation is already an established factor. They could in no way compensate for the destruction of dryland or wetland habitats or of river ecosystems caused by the expansion of existing irrigation systems or the establishment of new irrigated areas. Given the often very negative impact of past water regulation, drainage and irrigation schemes on such habitats in CEE, any substantial new projects would generally be undesirable from an environmental point of view. It would instead be advisable to devote present and future resources primarily to the improvement and optimisation of present irrigation infrastructures and systems in CEE.

Chapter 6. Potential Ways of Ameliorating the Environmental Impacts of Irrigation

As has been shown in chapters 3 and 4, in particular, the environmental impacts of irrigation stem from a variety of direct and indirect effects that relate to the process of irrigation itself, as well as the farming practices enabled by it. Each of these impacts may be amenable to certain measures to ameliorate their negative and enhance their positive effects on the environment.

Several kinds of measure can be considered, in this respect. At the farm level, changes can be made to agricultural practices (eg cultivation techniques), to farming systems (eg switching from sprinkler to drip irrigation) or to land use (eg from crops to grass), to ameliorate impacts. These *on-farm* changes will commonly need to be encouraged or ensured through a mix of *policy* instruments which may include regulations, advice (supported by research), and economic instruments, including charges or financial supports. In order to facilitate the effective operation of policies to ameliorate environmental impacts associated with irrigation, there may also be a need for *institutional* changes or new developments in the management of water at national or more local levels, including major modifications to water supplies.

Potential On-farm Changes

- Technical measures can be applied to increase the efficiency of irrigation systems and thereby reduce abstractions and their adverse environmental impact on water quantity, as well as reducing soil erosion. An example would be a switch from spray irrigation to drip irrigation, which involves lower water losses and reduced impact upon soil surfaces. However, there may be no environmental gains if more efficient use does not result in lower overall water use, but simply allows an increase in irrigated area.

- The adoption of different, less damaging or more beneficial agricultural practices associated with irrigated farming – for example to reduce the use of fertilisers or pesticides which may contaminate soils and water, thus encouraging enhanced water quality, or to avoid large areas of monoculture thus preserving greater diversity in habitats and landscapes. This may involve farmers switching to organic or integrated production methods, or taking certain sensitive areas of land out of irrigated cropping (eg to create buffer zones adjacent to valuable habitats). Finally, in some cases it may be possible to grow more drought-resistant crop varieties in order to reduce irrigation water demand.

Potential Policy Instruments

- Measures to reduce the quantity of water used in irrigation in order to mitigate environmental damage due to excessive use for irrigation. These mainly include economic and regulatory policies such as water metering and charging, licenses and time-limited abstraction permits.

- Measures which control where irrigation can be practised – for example, prohibiting its application in particularly sensitive areas or surrounding ‘buffer zones’.

- Measures which alter the incentives available to farmers under national or EU policies and thereby encourage improved practice in relation to irrigation. Relevant policies would include compensation payments for irrigated crops under the CAP (including the attachment of cross-compliance conditions), agri-environment payments under Regulation 2078/92 and its successor in the rural development Regulation 1259/1999. They could also include environmental conditions in relation to other sources of CAP finance, including direct aids for supported crops and aid to producer organisations (of which the aid offered under the Fruit and Vegetable regime is particularly relevant to this study).

New Developments and Institutional Measures

- Measures which identify and exploit new sources of water previously not used in irrigation (usually adopted in an attempt to reduce the level of overexploitation of existing sources). This can include large-scale and long-distance water transfers as well as coastal facilities to desalinise sea water so that it can be made available for irrigation.

- Measures which improve the institutional management of water resources, for example collectivisation of formerly private and unregulated water use rights in particular regions, thereby facilitating the setting of agreed limits to abstractions.

Different combinations of these approaches will be more relevant to particular kinds of irrigation and specific sites, and to particular types of environmental impact than to others. Briefly, therefore, each impact is considered in turn using the same order as in Chapter 3, so as to address the type and possible mix of measures which might be applied to reduce negative and enhance positive environmental effects. Following this, we develop suggestions in relation to particular aspects of EC policies, including agricultural policy (eg through cross-compliance and agri-environment or rural development spending), environmental policy (mainly through legislation, taxes and charges), regional policy, enlargement policy, and research and development policy.

There can be a large number of actors involved in the planning, financing, construction, management and operation of irrigation systems and the agricultural production which results. This is an important factor in considering the most effective means of managing environmental impacts. The focus here is particularly on measures which can be taken at EU level.

6.1 Pollution of Water and Soils by Agrochemicals and Nutrients from Irrigated Crops

These impacts can be addressed to some extent by the adoption of less intensive production technologies, including integrated crop management and biological pest control. In glasshouse production there may be scope for improved nutrient recycling through the establishment of more closed systems. However at present, economic conditions do not always favour such developments and therefore it may be necessary to use economic incentives (potentially including cross-compliance conditions or agri-environmental incentives) or input charges, in order to shift the balance towards such technologies.

Pollution taxes, although an efficient solution in theory, are rarely feasible in practice since it is usually extremely difficult to make a direct link between particular practices and specific environmental impacts – the relationship is commonly diffuse, time-lagged and often somewhat unpredictable. Thus it is rarely possible to tax the act of water pollution itself, except in cases of extreme, point source pollution. This has been the experience in Spain, where the 1985 Water Law introduced a ‘spillage levy’ to charge farmers for pollution from agricultural inputs. The returns from the levy have been very low in the case of point source pollution, and non-applicable in cases of diffuse spillage, such as is most common in irrigated areas (Sumpsi et al, 1999). However, taxes on potentially polluting inputs such as pesticides are in place in several Member States and are being considered by others (Brouwer et al, in press). These would have an impact on both irrigated and non-irrigated systems.

In irrigated areas which are affected by nitrate pollution from agricultural practices, the full implementation of the Nitrate Directive should help to address this problem. Under the Directive, Member States should establish measures to combat nitrate pollution in water, including establishing and implementing action programmes in all nitrate vulnerable zones, or throughout their territories, by 1995. Implementation of the Directive is, however, significantly behind schedule in many Member States and relatively few had even designated zones by 1997 (CEC, 1997). Most Member States have established Codes of good agricultural practice, which was also required under the Directive. However, many of these contain only guidance on how to avoid pollution, and this alone may be insufficient to ensure the necessary changes in farm practice. The action programmes require mandatory restrictions on farmers’ activities, including reduced use of nitrogen inputs in order to balance crop requirements and soil N-supplies. However, few Member States have yet established these programmes – in the context of this study, the lack of such programmes in Spain, Italy, Portugal and Greece is a particular concern.

Under the Agenda 2000 provisions, cross compliance could be used to address these problems by requiring those receiving direct CAP aids to adopt input use or nitrogen balance plans, or to comply with input limits. Conditions or new regulations could also apply as well to pesticide pollution caused by irrigated agriculture, perhaps in particularly sensitive areas (eg around Natura 2000 sites) or areas where contamination of water supplies is already a significant problem. However, some of the main sectors responsible for heavy pesticide use do not receive direct payments and are therefore not within the scope of the common rules Regulation.

Agri-environmental programmes could also be used to compensate, by means of a hectarage payment, those farmers who voluntarily agree to fulfil strict environmental conditions going beyond good farming practice. For example, they can be used to promote the adoption of organic or integrated farming in sensitive areas, which would require a significant reduction in the use of chemical inputs in intensive irrigation. In some cases these schemes could also pay farmers to cease irrigated, intensive agriculture and possibly take land out of arable production and put it into pasture or woodland. However, such long-term land diversion may pose significant economic problems in areas where irrigated production is particularly important to local business, as is the case in many southern regions.

Environmental regulation or stricter land use planning policies may be necessary to prevent water quality deterioration by chemical pollution and also the accumulation of plastics and other wastes in areas of intensive, irrigated greenhouse production, which also has negative impacts on the landscape (eg the Campo de Dalías case study). The very high profitability of this kind of intensive irrigation, and the fact that it is not subject to direct support under the CAP, means that cross-compliance under the common rules Regulation cannot be applied, and voluntary agri-environmental programmes could be very expensive. However, as the case study has shown, even regulation may be ineffective unless it is backed up by a combination of stiff penalties, strong enforcement and some commitment by local public authorities to develop an alternative, more environmentally sustainable economic future for the area.

The common market organisation for fruit and vegetables, which was reformed in 1996 by Regulation 2200/96, established a new system of subsidies via operative programmes run by producer organisations. Support under the programmes is intended to adapt production better to meet the needs of the market, improve quality, handling, marketing and value and to encourage environmentally sound practice and waste management techniques. In Spain, there are some interesting examples of operative programmes which have had a positive environmental effect in areas of intensive irrigation devoted to fruit and vegetable production, including the Mediterranean coast.

In summary, helpful measures could include the following.

- Stricter implementation of the Nitrates Directive at Member State and local level.

- Improved and targeted incentives for converting to organic or low-input production in the irrigated areas where these problems are particularly evident;

- The application of cross-compliance for crops eligible for direct payments under the CAP. Possible conditions might include specific limits on the use of fertilisers, manure and agrochemicals on irrigated crops, mandatory management plans or nutrient/pesticides bookkeeping requirements and special training requirements.

- In addition, it may be desirable to review the practice of allowing differential payments for irrigated crops. If it is to be retained, a payment differential could be made subject to specific conditions which decrease the incentive to expand irrigation in inappropriate circumstances.

- For areas of intensive irrigated horticulture, stronger regulatory mechanisms coupled with strategies for alternative development, including organic or low-input production methods and a greater promotion of environmentally sustainable operative programmes among producer groups. The latter could be strengthened by specific EC guidance.

- More support for the marketing of organic products from irrigated farm systems.

6.2 Excessive Abstraction Leading to Damage to Valuable Ecosystems

On important nature conservation sites, the full application of the provisions of the EC habitats and birds Directives as well as national and regional legislation could make a major contribution. Under the Directives, valuable habitats of European importance should be designated by the Member States to form the Natura 2000 network of protected areas throughout the EU. Measures should then be taken at national or more local levels to ensure that these sites are maintained or brought up to ‘favourable conservation status’ in order to protect their assets under the habitats Directive. These targets are to be achieved by 2004 at the latest. As with the nitrates Directive, however, the implementation of these Directives has been significantly delayed in most Member States, such that the network of protected sites has yet to be established and protective measures have not all been introduced. Furthermore, some valuable ecosystems will not be formally identified and protected under EC legislation, and these will require additional measures at national or sub-national levels.

In some cases, full implementation of the Directives will have implications for pre-existing irrigation systems, as for example where these are damaging adjacent sites by excessive abstraction (as in the case of Daimiel). Implementation should also affect the design and planning of future irrigated areas through the provisions under Article 6 of the habitats Directive. This requires *ex-ante* evaluations of projects affecting Natura 2000 sites to ensure that there are no negative effects. If it is anticipated that the environmental impacts of a new project on a protected site will be significant and negative and alternatives exist, Member States are obliged to refuse permission for it to proceed, in order to meet the requirements of the Directive. Only in exceptional circumstances are projects with negative impacts allowed, and in such cases compensatory measures have to be taken to ensure that the overall coherence of Natura 2000 is protected.

In southern Member States where the problems of aquifer exhaustion can be particularly severe, adequate protection of some sites may require the cessation or significant reduction of irrigated agriculture in adjacent areas where these are needed as buffers to maintain water supplies to the site. Alternatively, water may be imported from other sources in order to reduce the level of abstraction from the local aquifers. The economic costs of such action can, however, be considerable for farmers in some of the affected areas.

Possible Measures to Achieve Change

In areas where irrigation does not produce high value crops and where most of these crops are supported under the CAP (eg Tablas de Daimiel case study), regulation, cross-compliance and/or agri-environmental payments may be used, either singly or in combination, to reduce the level of abstractions. Higher water charges related to abstraction licenses or water use itself (via water meters) would also seem potentially effective.

In coastal areas of the Mediterranean, the high value of irrigated cropping to produce largely unsupported fruit and vegetables may render cross-compliance measures relatively ineffective and agri-environmental payments extremely costly. Yet it is in these areas that the greatest overuse of water resources occurs, with consequent exhaustion of aquifers, salinisation and pollution. Typically, water demand curves in these areas are also largely price-inelastic (Sumpsi et al, 1999), meaning that water pricing strategies may be limited in their achievements. There has been a tendency for excessive abstraction problems to be addressed by ambitious projects for water transfer from other regions with more ample supplies (eg in Spain, Italy and Austria and some Eastern European countries). However, the potentially negative environmental impacts of such transfers must also be recognised.

A key problem in seeking to tackle excessive abstraction is that in many parts of Europe water rights remain unregulated or poorly enforced. Even where abstraction is authorised by a permit or licensing system, permits may not be time-limited and may not specify the maximum quantities or particular conditions for abstractions that are permitted. Consequently each licence holder may abstract as much as they deem necessary and alter this in accordance with changing agricultural practices.

Today, some governments are taking national action to change this situation. In Spain, a national water use plan has been agreed which seeks to regulate all water use, including that in agriculture, in order to achieve a better balance between supply and demand and to protect the environment. Under a 1985 Water Law, Spanish water authorities have powers to declare that an aquifer is over-exploited. This means that farmers in the area have to organise an irrigation community to ensure collective as opposed to individual exploitation, and to agree a reduction in abstractions and a prohibition on sinking any new wells.

However, although this regulatory approach to over-exploitation of aquifers appears to be a useful measure, the two Spanish case-studies in this report show how in practice, it can remain relatively ineffective on its own. In Campo de Dalias, farmers have not complied with the limits on abstractions and prohibitions on new wells, enforcement is difficult and costly, and the measure is extremely unpopular at local level, due to its potential economic consequences. Where fines are imposed, farmers tend to view these as a normal part of their running costs and no changes are made to the irrigation systems themselves.

In Tablas de Daimiel, a similar pattern of behaviour was observed until the introduction of an agri-environmental scheme, which was viable in this area due to the lower value of the crops produced by irrigation, compared to Dalias. Only once this scheme was in place did farmers begin to comply with the Water Law.

In northern Member States, environmental issues arising from the drought of the early 1990s have led to proposals for the revision of national policies on water use rights and water charging. For example in the UK, the Government has consulted on proposals to end farmers' unlimited permits to abstract water for irrigation and to replace these with time-limited, maximum quantity licences with associated conditions designed to ensure that water is not taken during the most sensitive periods (eg to ensure the maintenance of minimum levels of flow during the summer). This change would follow a sustained campaign by the Environment Agency – the public water regulator for England and Wales - to raise farmers' awareness of the need to plan for the most efficient use of irrigation water. There has also been encouragement for farms to construct their own on-farm water storage reservoirs so that they can take water from rivers during the winter months when rainfall is heaviest and save this for summer irrigation use.

A similar campaign to increase water storage capacities as a means of reducing peak river water demand during the dry season has been promoted in many regions of France, in recent years. From 1982 to 1994, the area of reservoirs, ponds and other water storage structures for agricultural use in France increased from 28,000 ha to 45,000 ha. Some of these structures will be assisted by public finance, while others may result from investment by groups of farmers themselves. However, these developments may not always be beneficial to the environment since they may have direct negative impacts upon local habitats and landscapes if inappropriately designed or sited.

In summary, amelioration measures could include the following.

- Improved progress in implementing the habitats and birds Directives within all Member States, to ensure that future projects for irrigation will not damage these sites and to speed the adoption of new regulatory or other mechanisms to address current threats to sites from established irrigation systems.

- In tandem, the full implementation of the Environmental Impact Assessment Directive in relation to projects involving agricultural intensification or new irrigation infrastructure. Where EIA predicts major negative impacts upon valuable ecosystems, projects should be prohibited or modified in order to reduce significantly these impacts.

- The wider adoption of a system of time-limited, specific permits for water abstraction, including conditions on the seasonality of abstraction where necessary. This is primarily a matter for the Member States but the Commission could encourage a debate on this topic and help to identify good practice.

- The initiation of a wider debate on the adoption of cost recovery and charging systems, once the proposed Water Framework Directive has been adopted. This could include a survey of best practice, and lead to a wider use of charging systems to discourage excessive abstraction, especially in sensitive areas.

- Conditions requiring abstraction permits and water meters from farmers claiming compensatory payments for irrigated crops under Article 3 of the Common Rules Regulation (1259/1999) of the Common Agricultural Policy.

- A requirement by the EC that Member States should supply more evidence about sustainable water abstraction and irrigation in their Objective 1 Programmes and Rural Development Plans, within guidance on planning and implementation.

- EC guidance for accession countries considering further investment in irrigation and careful scrutiny of SAPARD plans to exclude proposals which appear likely to promote unsustainable irrigation projects in areas valuable for wildlife.

- Time-limited incentive schemes for reducing abstraction rates, in some locations.

6.3 Displacement of Valuable Dryland Habitats by Irrigated Agriculture

Again, proper implementation of the habitats, birds and EIA Directives should ensure that inappropriate developments are prevented in Natura 2000 sites, in future. National and regional legislation should also offer protection to other important sites, although its impact is rather variable at present.

The proper application of the Environmental Impact Assessment Directive should ensure that no substantial new irrigation projects can be put in place without a prior assessment of their potential environmental impacts. Such assessments are particularly needed where irrigation projects could have an impact on proposed Natura 2000 sites. The application of EIA to Annex II category projects involving agricultural intensification on uncultivated or semi-natural land, could help to identify and ameliorate damage where irrigation is displacing former dryland habitats.

However, the need to provide an EIA does not in itself ensure that any damaging development will be refused. It is likely that the Commission will continue to have to play a role in ensuring that Member States live up to their obligations under the EIA, habitats and birds Directives, in this respect.

The economic implications of limiting further increases in irrigation, particularly in the southern Member States, could be highly significant. Thus more priority should be given to compensatory measures or alternative economic development strategies (eg ecotourism or adding value to dryland agricultural outputs), to be introduced in parallel with any new limits. Expansion of agri-environment schemes in areas of high nature value dryland farming could also provide a stronger incentive to maintain traditional systems. Such schemes are applied on a very limited scale in some regions or Member States at present – Greece being an example.

In the longer run it is particularly important to recognise that some dryland habitats under agricultural management will not be viable without an element of public support. Such systems are unevenly distributed within the EU and this factor needs to be then taken into account when the distribution of relevant Community funds is being considered. It is legitimate for those Member States that have retained dryland habitats of Community significance to expect some contribution from Community funds for their longer term management, especially when there are heavy opportunity costs involved.

A survey of high nature value farming systems which could be affected by greater investment in irrigation in accession countries would be helpful. This could provide guidance in assessing applications for investment projects under SAPARD.

In sum, possible measures include:

- improved progress in implementing the habitats and birds Directives within all Member States, to ensure that future projects for irrigation will not be permitted to encroach on these sites;

- in tandem, the full implementation of the Environmental Impact Assessment Directive in relation to projects involving agricultural intensification or major new irrigation infrastructure. Where EIA predicts major negative impacts upon valuable ecosystems, projects should be prohibited or modified in order to reduce significantly these impacts;

- compensatory measures (eg agri-environmental payments) or alternative economic development strategies (eg ecotourism or adding value to dryland agricultural outputs) to increase the viability of surviving dryland farming systems;

- further survey and research to ensure that the Commission is aware of the incidence and vulnerability of remaining dryland sites of high nature value across Europe, including in the accession countries.

6.4 Benefits from Leaky Irrigation Systems, Traditional Mountain Irrigation in Terraces, and Rice Cultivation

As noted in chapter 3, inefficient irrigation systems can, in certain circumstances, be associated with environmental benefits. However, rarely will it be desirable to introduce measures to prevent the adoption of new technologies which increase irrigation efficiency, given the increasing demand for water within Europe. Alternatively, wherever irrigators wish to adopt more efficient systems and a clear environmental cost can be demonstrated, they could be required to divert a proportion of water to enhance the supply for nature conservation purposes. The mechanisms for achieving such modifications could include cross-compliance conditions on crop subsidies or voluntary agri-environmental incentives. Cross-compliance will not apply in the CEECs because direct payments are not expected to be made. However, environmental conditions could be attached to investment aid in these, and other, circumstances.

Rice production is a special case. Suitable measures for encouraging environmental benefits and discouraging the costs associated with rice production need to be developed, mainly at Member State level. For example, there is already one Spanish agri-environmental scheme which supports environmentally-sensitive methods of rice production in an area which is important for bird life (the Ebro delta). Incentives for organic rice production could be better targeted, for example in the vicinity of important wetlands.

In relation to mountain terraces where irrigation was traditionally practised, the decline of these systems is a consequence of much broader economic changes. These include high labour costs and increased competition within the EC for agricultural products, coupled with wider socio-economic trends which have encouraged people to move away from isolated hill communities and towards ‘growth poles’ along the coastal belts.

The Common Agricultural Policy offers particular support for less favoured areas (LFA), including mountainous regions, which is designed to contribute to the maintenance of agriculture in areas where the natural and/or social conditions are working against it. To date, aids in some mountainous regions (eg in Spain) have been paid only on livestock headage, which has therefore excluded or only partially reflected areas of traditional irrigated terrace production of permanent and annual crops, despite the fact that the Regulation permits hectarage aid for crops as well. As a result of the Agenda 2000 agreement all future LFA aid must be offered as an area payment and it is therefore possible to envisage the measure having more of an impact upon the survival of traditional terrace systems in southern countries such as Spain. However, since these aids are co-financed by the EC at between 25 and 50 per cent, the payment rates in some Member States may remain insufficient to arrest decline in these areas where working and living conditions are hard. For example, in Spain at present, the average LFA payment is only 40,000 ptas, or around Euro 300, per farm.

In the face of such strong pressures for change, even an amended LFA support scheme would need to be coupled to agri-environmental programmes in most areas to promote positive environmental management and restoration of terraces, to reduce soil erosion and benefit biodiversity and landscapes. There may be some areas in southern Member States where such schemes could be effective, particularly if coupled to new rural development strategies promoting high-quality environmentally-friendly product marketing, ecotourism and other similar activities.

Elsewhere, the development of alternative land uses that can offer some benefits to the environment and prevent desertification, appears to be a possible alternative strategy to ameliorate environmental impacts. Such uses could include the kinds of drip-irrigation discussed in the case of Spain, in chapter 3. Alternatively, certain kinds of sustainable forestry or nature management could be an option in some areas. Again, these may require promotion via agri-environmental incentives, or programmes offering investment, advice and training under the new CAP Rural Development Regulation.

In sum, therefore, the most useful measures here appear to include:

- requirements on those who are investing in more efficient irrigation in areas where leaky systems have generated benefits to wildlife, to divert a proportion of water to enhance the supply for nature conservation purposes – through cross-compliance conditions on direct aids, or conditions on investment aids which support this change (including in guidelines on state aids);

- agri-environmental schemes and other more integrated local business development strategies which encourage the benefits of extensive rice and mountain-terrace irrigated agriculture while discouraging forms of production which can be damaging to the environment – these could be targeted at the most sensitive or valuable remaining areas and include support for training, adding value and marketing local produce;

- imaginative reform of the Less Favoured Area support schemes at Member State level so that they provide additional support to environmentally-beneficial traditional irrigation systems, on condition that these benefits are maintained;

- the targeted support of other environmentally-sensitive farming or non-farming land use practices in areas where traditional systems have been lost and desertification is a serious concern(eg appropriate forestry, nature management, drip irrigation systems). Suitable EU funds for these purposes might include Structural Funds, LIFE-nature, and rural development measures under Regulation 1259/1999.

6.5 Soil Erosion

There is clearly scope for applying appropriate forms of irrigation technology to reduce the incidence and the severity of soil erosion in some regions. As explained in chapter 3, drip systems are less eroding than sprinkler systems or some kinds of irrigation by hand, and there is scope to introduce this technology more widely in many parts of southern and northern Europe.

However, such systems are very costly and frequently beyond the means of the majority of small farms with irrigated plots in the Southern Member States. The collectivisation of water management can improve the potential for installing new technologies, as can the imposition of user charges that can then be used to fund infrastructure improvements of this kind. However, the most important first step in such situations will often be simply to get the myriad of small farmers to recognise that there is a significant problem, which can only be solved if they all agree to take action together.

There are a growing number of local examples of successful joint management schemes which are promoting improvements in the efficiency and environmental impacts of irrigated agriculture in some Member States. France, Austria and Spain all provide useful models which could be applicable in other countries. Some of these schemes are promoted through national legislation and/or voluntary initiatives, while others involve Community assistance.

Agri-environment incentive schemes and other measures under the Rural Development Regulation, including technical assistance, could play a larger part in promoting appropriate joint management schemes in future. There may also be a role for attaching cross-compliance conditions to certain irrigated crops to reduce erosion, deriving such conditions from the codes of practice for soil conservation that already exist in a number of Member States. For example, requiring all farms to have erosion management plans, such as those adopted in the USA under the soil conservation program, could be a first step.

- Promotion of soil conservation plans and soil conserving practices at farm level through investment aids (with appropriate environmental safeguards to prevent over-exploitation of aquifers due to expansion of irrigated areas), advice and possibly agri-environmental incentives;

- Application of cross-compliance conditions on supported crops, or conditions on aid to producer groups, in areas where soil erosion is a serious issue, to require the adoption of soil conserving practices;

- Encouragement of collective water and soil management either through regulation to oblige the formation of collective user groups to manage their water supplies for public as well as private benefit, or advice and/or financial aid to encourage their formation.

6.6 Salinisation

The problem of salinisation is not easily remedied by technical means. It can often be an indicator of over-abstraction of water supplies (eg in mediterranean coastal areas) which can ultimately only be properly addressed by reducing water use, as discussed under section 6.2.

In areas where high-earning agriculture or tourism are partly the cause of over-abstraction and resulting salinisation, it may be cost-effective to finance seawater desalinisation for use in both drinking water and agricultural supplies for irrigation. However there will be many cases where this is not economically viable, and here it seems that the only solutions will be those that introduce alternative production systems which are less dependent upon continuous supplies of irrigation water.

In glasshouse systems, achieving reduced water use through more efficient recycling of water and nutrients will be possible for some producers. For field crops, the use of more drought-tolerant and salt–tolerant varieties may be possible but there may also be situations where, once the full environmental costs of salinisation and aquifer exhaustion are taken into account, irrigated agriculture is no longer a viable proposition. The significant economic consequences of its cessation would suggest that these areas may require a programme of new investment to develop and support sustainable rural development strategies.

A database of areas where salinisation is becoming a severe threat or is likely to become a threat in future would help to give early warning and to guide appropriate investment in alternative agricultural developments, especially for projects relying on Community funding. The feasibility and cost of such a database could be discussed with the EEA. Inappropriate investment in areas with salinisation problems should be avoided.

In sum:

- Adopt similar measures to those recommended under 6.2 above;

- Promote investment in nutrient and salt recycling systems in intensive glasshouse production, the use of salt-tolerant cultivars in some areas and the consideration of desalinisation plants where this is adjudged to be cost-effective;

- In areas already seriously damaged by salinity, support the development of alternative economic and environmental management strategies to replace irrigated agriculture, (eg using Structural Funds, rural development Regulation aids);

- Develop a database of areas in Europe (including accession countries) where salinisation is a serious threat, to guide future project developments in these areas.

6.7 Major Infrastructure Impacts

As with the displacement of valuable, low input agricultural habitats by irrigated lands, irrigation projects which threaten important habitats and species through the development of major infrastructure should be controlled through proper application of the habitats and birds Directives and the appropriate use of EIA procedures. These have been discussed under 6.2 and 6.3 above.

However, the weight given to economic benefit, inadequate enforcement of legislation and a lack of political will, may be the major obstacles to effective use of these measures, in many existing Member States and in the accession countries. The environmental safeguards in the new Structural Fund regulations, including ISPA, will need to be fully utilised in order to ensure that EC legislation is respected, beyond 2000.

In sum:

- Ensure proper implementation of the habitats and birds Directives to protect important sites from damage due to major infrastructure developments for irrigation and produce guidance on best practice in the implementation of Article 6 of the Habitats Directive, in particular;

- Ensure proper implementation of the environmental impact assessment Directive and promote the adoption of the strategic environmental assessment Directive so that projects and programmes of potentially significant negative environmental impacts can be identified and either prohibited or modified in order to reduce these impacts, in future;

- Give guidance to accession countries to ensure that their accession funds are not used to support projects or programmes involving major infrastructure with negative impacts upn the environment;

- Require ex-post monitoring of any approved projects or programmes to check whether they succeed in minimising negative environmental impacts;

- Produce further guidance to Member States and accession countries on how to ensure effective implementation of the Directives, drawing upon the findings of ex-post as well as ex-ante appraisals.

6.8 Suggestions for EC Policy and Member State Implementation of EC Policy

6.8.1 Agriculture Policy

Agri-environment and Rural Development Measures
These are areas where EU policies already provide potential tools for the Member States to apply as they see fit. Some options are presented below:

- Where environmentally sensitive, extensive farming practices associated with irrigation are currently under threat from competition by intensive production methods with more negative environmental impacts, Member States can be encouraged to make use of agri-environmental payments to support the retention of the former. So, for example, payments to support organic or extensive rice production, or traditional mountain-terrace agriculture may be feasible. In the latter cases, there could be scope for channelling more support through the policy for less-favoured areas and areas with environmental restrictions (Articles 13-21 of Regulation 1257/99). This could help to promote the retention of terrace agricultural systems in some regions of southern Europe.

* Similarly, it may be desirable for Member States to offer agri-environmental support under Articles 22-24 of the Regulation, to maintain dryland farming systems against the threat of abandonment or transformation to irrigated agriculture, in those regions where such farming is valuable for maintaining biodiversity and landscapes, as well as conserving scarce water supplies.

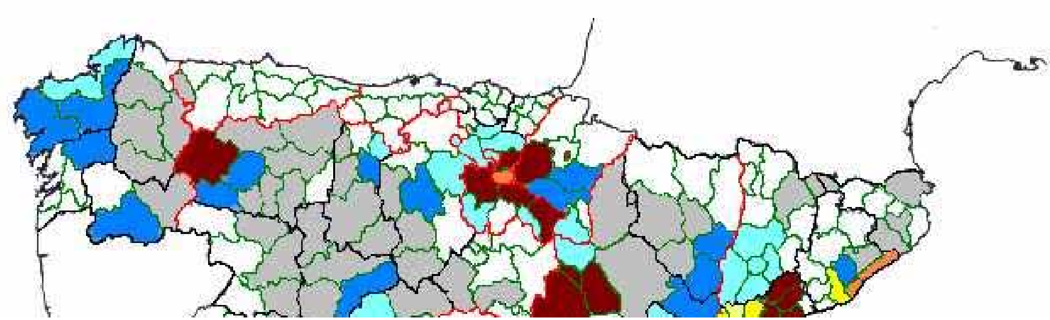
* Agri-environmental payments could also be used in combination with appropriate aids for training and investment, to encourage the adoption of more water-conserving strategies and techniques on a variety of farm types in both southern and northern Member States. For example, the adoption of drip-irrigation systems, the implementation of soil conserving measures and/or conversion to organic or integrated crop management systems could all be valuable in particular areas.

The new rural development plans to be introduced under the Agenda 2000 CAP reforms should also provide an opportunity to develop integrated projects at local level to promote the longer-term sustainability of environmentally beneficial systems of irrigated agriculture. These would allow the use of agri-environmental schemes, to maintain beneficial but economically marginal farming systems, to be linked to marketing, processing, eco-tourism and other economic development aids for the same areas, designed to improve the long-term viability of such production systems by increasing their ability to compete successfully.

Another important aspect of these plans is the requirement for measures to be compatible and consistent with one another. This condition should be used to ensure that investment and other aid under the new plans does not promote the development of irrigation in ways that will cause environmental damage, because these measures would then conflict with agri-environmental measures, which are a compulsory part of all rural development plans. This should be an issue for particular scrutiny in the ex ante appraisal of plans.

Cross-compliance

It is clear from the analysis in chapter 3, and the case studies in chapter 4, that irrigated agriculture involves a mixture of supported and unsupported crops, under the CAP regimes. However, there are particular instances where supported crops appear to have been an important factor in exacerbating the negative environmental impacts of irrigated farming practices. Most notable among these are cotton in the south, and maize in both north and south, but other crops such as starch potatoes, tobacco and non *appelation controlee* wine may also be relevant in some localities (rules for AC wines commonly prohibit the use of irrigation). The map below (Sumpsi et al, 1999) indicates the extent of irrigated crops which are CAP-supported in Spain, showing that with the exception of the intensive horticultural irrigation of the Mediterranean coastline, a clear majority of crops receive CAP support, although not all in the form of direct payments to producers.



In Greece, 95 per cent of cotton production is irrigated, and this is a crop which receives relatively high levels of EC subsidy. The area devoted to cotton production continues to expand and Greece and Spain are now seeking an increase in the Maximum Guaranteed Quantity under the support regime, to reflect this increase. Other subsidised crops which are significant in terms of irrigated agriculture in Greece include maize (100% irrigated), tobacco (45-50% irrigated), vines (27 % irrigated) and a currently very small but growing proportion of olives. Tomatoes produced for processing are also an important irrigated crop in Greece, and these receive support indirectly through the aid granted to processors. However, many of these aids are not covered by Article 3 of the common rules Regulation which establishes the principal cross-compliance mechanism, since the support is not given in the form of direct compensation payments to any of these commodities other than maize, tobacco and olive oil. However, the Commission's proposed new cotton regime would appear to offer scope for cross-compliance in this particular context.

Under the EC's arable aid regime, Member States fix reference yields at national or regional level, which represent the average yields of specific crops. These are used to translate the arable premium payments, which are set in Euro/tonne at EC level, into area payments (Euro/ha) at national or regional level. Under the Regulations, regionalisation plans can provide for different yields for irrigated and non-irrigated land, meaning that the area payments for irrigated crops can be significantly higher than those for non-irrigated crops grown in the same regions. This option has been maintained under the Agenda 2000 reforms, in Article 3(3) of the new arable aid Regulation no.1251/1999.

Also under the arable aid regime, compulsory set-aside requirements apply to supported crops. For most regions, the Member States must set aside a fixed minimum proportion of the arable area in each region. However under special arrangements for Spain, the set-aside area can be wholly allocated to dryland arable areas (‘seccano’), rather than split between these areas and the traditionally irrigated areas (‘regadio’).

It is therefore possible to envisage the application of cross-compliance conditions to ameliorate some of the most signficant environmental impacts of irrigation applied to supported crops. Some options are discussed below.

- The example of cross-compliance to be applied in France from 2000 might have wider applications elsewhere in Europe. In France, the fact that irrigated maize commonly has a much higher yield than unirrigated maize has led the government to adopt two separate reference yields for maize under the CAP arable aid regime. Thus, those producing irrigated maize receive a higher subsidy per hectare than those producing unirrigated maize. This has provided an additional incentive, on top of the yield differential, for producers to ensure that as much of their maize as possible qualifies for aid under the irrigated category. A similar situation exists in Spain for the main supported crops, with differential payments for irrigated and non-irrigated areas.

  The French government noticed that there was a discrepancy between the irrigated maize area as recorded in arable aid claims by producers, and the total area authorised for irrigation, as recorded by the French water authorities. Under the French Water Law of 1992, all irrigating farms have to be registered with the water authority and all must have water meters installed. It therefore appeared that either:

  - Farmers were over-claiming irrigated maize areas when applying for aids from the Ministry of Agriculture – ie making false claims for aid; or
  - Some proportion of irrigated farms were not registered with the water authority and subject to water meters, and were thereby in breach of the 1992 Water Law.

  The cross-compliance condition to be introduced in France in 2000 therefore makes a direct link between allowing claims for aid and demonstrating that farms have complied with the 1992 Law. To receive payments in future, farmers will have to show that they have registered with the authority and have installed a water meter. This should help to ensure that the quantity of water abstracted for irrigation is fully notified to the authorities and can be controlled by them. Similar conditions might be applicable in other areas, such as parts of Spain, where supported crops are grown using irrigation and water authorities have insufficient control over levels and conditions of use.

- It would be possible to use cross–compliance conditions to limit input use on supported, irrigated crops such as maize, cereals, rice, olives and tobacco in order to reduce water pollution risks, or to require the use of drip-irrigation to minimise erosion risks on land growing some of these crops. It would probably be most cost-effective to devise the conditions in such a way that they relate only to farmers in particularly sensitive areas. For example, conditions could place limits on N, P or pesticide usage on land within or close to a designated Nitrate Vulnerable Zone or a protected area under the habitats or birds Directives. Alternatively they could require the adoption of drip irrigation techniques on any land of certain slope and soil types (akin to identifying 'erosion vulnerable zones' at local level). A third option might be to require all irrigated crops receiving support to be subject to nutrient or soil conservation management plans, perhaps similar to those which have been applied under cross-compliance in the USA.

- Finally, it might be possible to link the absolute extent of irrigated agriculture to cross-compliance conditions, aiming to render it uneconomic to produce certain intensive crops in particularly sensitive areas. For example, in order to receive support payments for certain crops grown using irrigation, the areas concerned might need to be approved as 'not highly vulnerable to salinisation' by the local water authority.

In a recent study of the Tablas de Daimiel area in Spain, it has been concluded that the implementation of a cross-compliance scheme could be more effective in reducing water consumption in the area than the current agri-environmental programme (Sumpsi, Varela-Ortega and Blanco, 1999). The cross-compliance system would involve making aid payments to farmers conditional on adherence to new laws to reduce water use in the area, drawn up under the existing Spanish Aquifer Exploitation Regulation and Over-Exploitation Decree.

6.8.2. Environmental policy

Nitrates Directive
Over time, the full application of the Nitrates Directive (91/676) should help to reduce the incidence of nitrate contamination of waters associated with intensive, irrigated agriculture in many parts of northern and southern Europe. However, as discussed in section 6.1 above, implementation of the Directive is considerably behind schedule. Within Europe as a whole, the main areas where there is agricultural contamination by nitrates are those with a high concentration of intensive livestock rearing, but also arable or horticultural areas with heavy use of nitrogen fertilisers which, particularly in southern Europe, will generally coincide with irrigated areas.

In Spain, the process of declaration of vulnerable areas, the key element in the Directive, started in 1998. It has still not been finished, as some regions with serious problems of nitrate pollution from agricultural practices (eg Murcia) have still not designated any vulnerable areas (see table below). Most regional authorities have passed Codes of Good Agricultural Practice (CGAP), which are currently voluntary but which would become compulsory within Vulnerable Zones once corresponding Action Programmes have been agreed. However practically no region has yet passed Action Programmes for these areas.

Table 6.1: Regional implementation of Nitrates Directive 91/676 in Spain

AUTONMOUS COMMUNITY	EXISTENCE OF VULNERABLE AREAS	OFFICIAL PUBLICATION DESIGNATION VULNERABLE AREAS *	GOOD AGRICULTURAL PRACTICE CODES *	PROGRAMMES OF ACTION	EUTROPHICATION OF COASTAL WATERS AND ESTUARIES
	Date Commission informed				

				DRAWN UP Date	CARRIED OUT Date	
ANDALUSIA	YES 6/97	12/01/99	YES			NO
ARAGON	YES 5/97	11/06/97	YES 11/06/97			No coast
ASTURIAS	NO 6/97		YES 31/07/97			NO
BALEARIC ISLANDS	YES 6/97		YES			
CANARY ISLANDS	YES 6/97		YES			
CANTABRIA	NO 6/97		YES 2/04/97			
CASTILE-LA MANCHA	YES 6/97	21/08/98	YES			No coast
CASTILE & LEON	YES 6/97	16/06/98	YES 16/06/98			No coast
CATALONIA	YES 10/97	6/11/98	YES 9/11/98			NO
ESTREMADURA	NO 7/97		YES 10/12/98			No coast
GALICIA	NO 6/97		YES			NO
LA RIOJA	NO 9/97	13/02/99	YES			No coast
MADRID	NO 6/97	3/6/98	YES 18/02/99			No coast
MURCIA	NO 6/97	11/05/98	YES 15/04/98			
NAVARRE	NO 6/97	1/06/98	YES not pub.			No coast
VALENCIA	YES 6/97		YES	4/09/98		NO
BASQUE COUNTRY	YES 7/98	27/01/99	YES 27/01/99			

DATE 26/3/99. * = Date of publication in BOLETIN OFICIAL DEL ESTADO.

An examination of the different CGAP passed by Autonomous Communities in Spain shows that the format and specifications they have established are quite similar. The specifications can be divided into three sections:

1. those addressing fertiliser practices, such as the periods when fertilisers should not be used; the ways fertilisers should be used depending on soil type and the location of the plot; the types of fertiliser recommended according to soil type and crops; the application of fertiliser plans for each farm and the setting up of fertiliser plan registers;
2. those laying down the recommended crop rotation and other aspects linked to soil use, and the minimum period when the soil should be covered by vegetation;
3. those concerning irrigation techniques. These establish a classification of irrigated land according to nitrate pollution risk, which depends on the kind of soil, slope, agricultural practices, method of irrigation, use of irrigation water and quantity of water used. For each level of risk there is also a series of specifications with recommendations to increase efficiency: the choice of irrigation technique to use depending on the soil, the availability of water, the type of crop and climate and the way to apply 'ferti-gation' (combined application of fertilisers and water).

However, the CGAP are general recommendations of best practice; they do not establish quantitative limits on the use of nitrogen fertilisers, manures and/or irrigation water. Further measures will therefore be needed in order for Spain to meet its obligations under the Directive.

In Greece, codes of good agricultural practice devised under the nitrates Directive apply to the whole country, and include general guidance on the most suitable irrigation method for each soil type and advice on how to plan irrigation so as to minimise leaching.

However, none of this information has yet been produced in a readily accessible form, for farmers themselves (Greek Ministry of Agriculture, *pers comm*).

Water Framework Directive

Certain environmental impacts of irrigation should come within the scope of the proposed Water Framework Directive which is anticipated to be adopted in 2000.

The new Directive will require Member States to adopt catchment management planning for the protection of water reserves and water quality. This practice is already established in some Member States such as France, Austria and the UK. Perhaps most importantly in relation to irrigation, the Directive will for the first time address the quantitative aspects of water management, requiring a system of prior authorisation of all water abstractions. Catchment plans will also need to include measures to achieve 'good water status' for all surface and groundwaters by the end of 2010. Good water status is defined as when 'the water has a rich, balanced and sustainable ecosystem and…. the established environmental quality standards for pollution are respected.'

In another section of the Directive, a specific reference is made to the issue of water charging, although this has proved highly controversial during the debate on the draft text. The Commission's original proposal would have required Member States to ensure that water charges covered the full costs of water provision by sector. However, this has been rejected by Council and Parliament in subsequent stages of negotiation and the text that is adopted later this year is likely only to make a general statement promoting the concept of cost recovery without obliging Member States to follow this through in any particular context. Thus there seems little scope for the Directive to further the application of environmental cost recovery, in relation to irrigation practices.

Notwithstanding the particular issue of charging, it appears that this Directive could have a profound and beneficial effect in ameliorating the environmental impacts of irrigation throughout the EU. However, the Directive is not yet agreed. Assuming agreement is reached during 2000, there must be a risk that its implementation in the Member States will follow a similar piecemeal and delayed pattern as that already seen in relation to the nitrates and habitats and birds Directives. Indications from some Member States suggest that to date, the proposed framework Directive has not significantly influenced policy developments or debates at the national level (pers comm by Ministry officials in Greece and Spain).

Habitats and Birds Directives

The full implementation of these Directives by the Member States should have two important influences upon the environmental impacts of irrigation. Firstly, under Article 6 of the habitats Directive, new irrigation projects likely to cause damage to existing valuable sites or important species (whether these be dryland or wetland areas) should be prevented or their negative impacts ameliorated by modifications to the plans, before such development is permitted. Secondly, through the pursuit of favourable conservation status for designated Natura 2000 sites and for important species throughout the wider countryside, existing irrigation practices should be modified so as to minimise their detrimental impacts upon biodiversity.

However, as the earlier discussions in sections 6.2, 6.3 and 6.6 have shown, there is currently little evidence that these aims are yet being achieved. Due to the delayed implementation of the Directives in many Member States, it is probably too early to say whether existing or proposed designations are being effective in preventing the expansion of irrigation in sensitive areas, although some positive signs are reported in Spain, for example. The requirement to achieve favourable conservation status could potentially have a far more substantial influence upon irrigation practices in many parts of Europe, but while designation remains incomplete, few Member States have yet given much consideration to this part of the Directive and how it might be achieved, particularly in the longer term and outside Natura 2000 sites.

The Directive itself does not specify or provide any positive funding mechanisms for achieving this target and it has generally been assumed that Member States should use a variety of EC Funds and national measures as available. Since the achievement of these goals will often entail a significant shift in farming practices, it seems very likely that agri-environmental and other rural development aids under the CAP, as well as new funding under EC Structural Funds, will be required.

Under these circumstances, the Commission will need to continue to take measures to encourage a swifter and more ambitious implementation of the Directives at Member State level. The provision of best practice examples and of further guidance on the management of semi-natural and artificial biotopes would be one important aspect of this. Another important step would be to ensure a closer linkage between the requirements of the Directives and the implementation of key related EU policies within the Member States, notably agriculture and regional development policies. In that respect, recent indications by the Commission that regional plans may not be approved until environmental Directives are complied with are particularly welcome, and a similar approach could potentially be applied to rural development plans under the CAP.

Environmental Impact Assessment

Although it has not been a major focus of this study, information gathered from most Member States indicates the historic importance of large-scale agricultural water management projects with adverse impacts upon the environment. Some damaging schemes have involved the expansion of irrigation into new areas where it has displaced valuable dryland systems or led to the dessication of former wetlands, while others have supported large-scale water transfers with associated engineering and infrastructure development which has itself damaged ecosystems and degraded landscapes.

Under the Environmental Impact Assessment Directive 85/337, all such projects should be subject to prior environmental assessment within a broader process which enables authorities to modify or refuse proposals on environmental grounds, once the assessments have been completed. However, the Directive itself does not provide the broader framework for such action; it merely requires that the assessment itself is undertaken. In addition, there is no requirement under the Directive for ex post evaluation of the impact of projects once they are approved.

In addition, EIA only applies to one-off, large scale projects, whereas many environmental impacts of irrigation may result from a series of smaller scale changes over a period of time. The implementation of the proposed Strategic Environmental Assessment Directive could, once agreed, bring an important new discipline to bear upon Member State policies and programmes of a more cumulative and strategic nature.

It is therefore important to ensure that:

- the EIA Directive is fully implemented, particularly in respect of Annex 2 projects involving agricultural intensification on semi-natural or uncultivated land;
- EIA should be undertaken in accordance with consistent quality criteria which ensure that the environmental impacts of irrigation, as discussed in this report, will be assessed and evaluated;
- Member States must have in place the necessary means of prohibiting or requiring significant modifications to proposed irrigation developments where EIA indicates significant and detrimental environmental impacts;
- When permission to proceed is given for any project following EIA, there is a requirement for ex-post reporting of environmental impacts;
- Member States' strategic water management programmes are themselves subject to EA under the proposed new Directive on SEA.

6.8.3 Regional Policy

Structural Funds (ERDF, ESF, EAGGF) and Cohesion Funds

The new Structural Funds regulations incorporate measures intended to ensure that they are used in ways that promote sustainable development. However, these conditions do not apply to the new Cohesion Fund regulation. It is therefore very important that all expenditure under any of these funds should be scrutinised at both Member State and EU levels to ensure that:

- programmes do not include measures which conflict with the overall objectives of environmental sustainability;
- irrigation projects will not damage habitats nor exhaust water supplies;
- any expansion of irrigation should go hand in hand with introduction of adequate controls on abstraction, water charging and collective management strategies to ensure that it will remain strictly within the environmental carrying capacities of the regions concerned;
- funds can be used to promote the conversion of irrigated areas back to dryland culture where appropriate for nature conservation, as well as to promote the more efficient use of water in existing systems, coupled to conditions which would require an overall diminution in total abstractions as a result of adopting new water saving measures.

It will often be difficult for anything more than a general, strategic assessment to be applied at EC level because regional plans do not contain great detail of the proposed measures and kinds of project that these will support. It is therefore important that EC guidance should make it clear to Member States that they have an obligation under the

Funds to exercise a more detailed and thorough degree of environmental scrutiny in their programme monitoring committees and other regional and national appraisal systems.

6.8.4 Accession Policy

Similar principles as those relating to the Rural Development measures under the CAP, and the Cohesion Fund under Regional Policy, should also be applied to SAPARD and ISPA plans and projects under the accession funds.

A survey of high nature value farming systems which could be affected by greater investment in irrigation in accession countries would be helpful. This could provide guidance in assessing applications for investment projects under SAPARD.

Good practice guidance on ways of ameliorating or preventing negative environmental impacts from irrigation could also be valuable, particularly for those countries where irrigation was formerly important and where it is likely to increase in future.

Finally, it would be valuable to undertake an evaluation of the potential reinstatement of irrigation infrastructure in those countries where this is most likely to occur. It is necessary to balance the merits of renewal against any potential environmental disbenefits and thereby to target the limited resources for renewal to those areas where the environmental and economic impacts will be most positive.

6.8.5 Research and Information Policies

It is evident from this study that there are currently no authoritative or comprehensive and consistent sources of data on the irrigated or irrigable areas in all the Member State and the trends in these areas over recent decades. These data are crucial to any overview of irrigation in the EU and assessment of likely future demand. Currently, where data is available, figures are frequently difficult to reconcile (eg OECD versus published national sources), sometimes because different Ministries within a Member State obtain their data from a variety of sources and using different methods (eg water licenses versus CAP claims for irrigated cropland, in France).

It is even more apparent that data on the environmental impacts of irrigation is available for a few areas in some detail (eg Daimiel case study), but that across the Union as a whole, no comprehensive information is collected on this issue. Our findings have therefore been based largely upon expert assessments, supplemented by details from a handful of specific case studies in localised areas. The data for Spain is certainly more abundant than for most other countries but, even here, empirical work on environmental impacts is largely confined to a small number of case studies.

New strategic work on future trends in water use and water supplies is now underway in Europe, particularly in relation to climate change and other long-term trends. There is also a growing international and European focus on water charging policies and strategies, and the economics of institutional water management. However, much of the international research is general and theoretical, and relatively little touches directly on environmental issues and how they can be addressed.

We therefore suggest the following.

- The Commission considers the adoption of a common classification system and glossary of different types of irrigation that could be used in gathering data on irrigation within the Member States;

- The Commission should also consider financing the establishment of a data base on irrigation and its impacts, with the co-operation of the Member States;

- Research funding could also be used to develop a more strategic awareness of environmental risks in relation to irrigation within Europe. For example, areas subject to severe salinisation or under threat of salinisation could be identified and recorded on an EU database. This would provide information to guide investment and signal the need for sensitive future development in these areas.

- More effort should be devoted to identifying, analysing and promoting examples of best practice in minimising or ameliorating environmental impacts of irrigation, drawn from different areas of Europe and potentially from further afield where similar issues may be encountered (eg California, Australia).

- Further, more detailed work should be undertaken to allow EU Member States to prepare for the likely consequences of global warming upon their water supplies and the level of water demand from agriculture and other sectors.

References (Includes References Used in Compiling the National Reports)

Agence de l'eau Artois-Picardie. *Présentation*. In: http://www.eau-artois-picardie.fr/afer2tous/contenu.htm.

Agence de l'eau Adour-Garonne: *Présentation de l'Agence.* In: http://www.eau-adour-garonne.fr/presentation_agag_c.html.

Aggelakis, A. N. and Kotselidou, O. N. (1996) *The Management of Water Resources in Greece.* Paper presented in the International Conference Water Resources Management, Larisa, Greece 13-16 December, 1996 (in Greek).

Aggelides, S. (1995a) *Cadmium concentration in ground waters in the valley of Iria - Peloponese.* Paper presented at the 1st International Congress for the Environment. Geotechnical Chamber of Greece, Athens.

Aggelides, S. (1995b) *Sea-water intrusion in the coastal aquifers of Iria-Peloponese due to over-pumping.* Paper presented at the 1st International Congress for the Environment. Geotechnical Chamber of Greece, Athens.

Aggelides, S. (1995c) *Nitrate concentration in the ground waters of Iria and Argolis.* Paper presented at the 1st International Congress for the Environment. Geotechnical Chamber of Greece, Athens.

Aggelides, S. (1995d) *Soil salt accumulation in the valley of Iria-Peloponese due to irrigation with brackish ground waters.* Paper presented at the 1st International Congress for the Environment. Geotechnical Chamber of Greece, Athens.

Agra Europe, 1999 Portugal to invest heavily in irrigation. Agra Europe, July 23, 1999.

Agricultura y medio ambiente (1994) Nº 131. Servicios de Estudios BBV, 1994.

Agricultural Council of Denmark (1999) *Facts and Figures. Agriculture in Denmark 1998*. Copenhagen.

Agricultural University of Athens (Spring 1999). Personal Communication with experts.

Agriculture et environnement: les indicateurs. In: http://www.environnement.gouv.fr/actua/cominfos/docdir/indicat.htm.

Aides et redevances des agences de l'eau. In: http://www.eaudd.com/contributions/atriob/contributions/talecfr.htm.

Allain, S. (1994) *Construction de règles locales de gestion collective de l'eau en France: Analyse de cas concrêts et nouveaux axes de recherche*. INRA-DADP. In: Approche économique de la gestion de la ressource en eau pour l'irrigation. Thèse. B. Michalland, Toulouse.

Analyse des différents coûts de l'irrigation. In: B.Michalland. Ouvrage cité.

Argolid Local Administrative Authorities (Spring 1999). Personal communication with experts. Peloponese, Greece

Azevedo, A.S., Kanwar, R.S., Pereira, L.S. (1998) *Assessing Atrazine in irrigated soil profiles.* In: Pereira, L.S., Gowing, J. (eds) Water and Environment, E & FN Spon, London, pp 12-19.

Bailey, R.J. (1993) *Irrigation and the Environment. The Case for Irrigation.* Irrigation News, Autumn 1993, No. 22, pp. 29-36.

Beopoulos N. (1995) *The state of environment in Greece. The impact of agricultural activities*. In: The Environment in Greece, 1991-95. WWF, Athens, Greece, pp. 63-83 (in Greek).

Bleumink, J.A., Buys, J.C. (1996) *Farming with Water. Reducing Parching on Farms.* Centre for Agriculture and Environment, Utrecht.

Blue Plan (1976) - developed within the framework of the Mediterranean Action Plan and Convention for the Protection of the Marine Environment and Coastal Region of the Mediterranean Sea. Barcelona.

Boland, D., van Zeijts, H., Buijze, S.T. (1997) *Farming with good quality groundwater II. Setting objectives for nitrogen and pesticide use*. Centre for Agriculture and Enviroment, Utrecht.

Brouwer, Baldock and Dwyer (in press) *A Comparison of Environmental and Health Standards affecting Agriculture in the EU and its Major Competitors*. LEI, the Hague.

Bubenicek, B. (1997) *Quantifizierung der Ausgaben der oeffentlichen Hand zum Schutz der natuerlichen Ressourcen von Wasser und Boden als dominante Produktionsfaktoren im Marchfeld*. Dissertation, Wirtschafsuniversitaet Vienna (unpublished).

Bundesministerium fuer Ernaehrung, Landwirtschaft und Forsten (1985) *Wasserverbrauch und Bewaesserung*. BML, Bonn.

Caja Rural de Almería (1999) *Gestión del Regadío en el Campo de Dalías: las comunidades de regantes Sol y Arena y Sol-Poniente.*

Caldas, J.C., Sousa, P.L., Pereira, L.S. (1997) *Need for new approaches in valuing water: Learning from a successful case.* In: Kay, M., Smith, L. (eds) Water: Economics, Management and Demand, E & FN Spon, London, pp 137-144.

Caldas, J.C. (1999) A Irrigação em Portugal. Unpublished report prepared for this study. Lisbon.

Caraveli, H. (1998a) *Environmental Implications of Various Regimes: The Case of Greek Agriculture*. In: Tracy, M. (ed) CAP Reform: The Southern Products. APS Publications, Belgium, pp.164-174.

Caraveli, H. (1998b) *Greece*. In: Brouwer, F., Lowe, P. (eds) CAP and the Rural Environment in Transition - A panorama of national perspectives. Wageningen Pers, pp. 267-282.

Caraveli, H (1999) Irrigation in Greece. Unpublished report prepared for this study. Athens.

Castro Caldas, J. (1999) *A Irrigacao em Portugal*. Departamento de Economia Agraria e Sociologia Rural, Instituto Superior de Agronomia/Universidade Tecnica de Lisboa.

Catsadorakis, G. (1997) *The importance of Prespa National Park for breeding and wintering birds*. Hydrobiologia, Vol, 351, pp 157-174.

Catsadorakis, G., Malakou, M. (1997) *Conservation and management issues of Prespa National Park.* Hydrobiologia, Vol. 351, pp 175-196.

CEC (1998) *Agricultural Situation and Prospects in the Central and Eastern European Countries - Romania*. Office for Official Publications of the European Communities, Luxembourg.

Cepuder, P. (1998) *Beregnung und Umwelt am Beispiel Nitrathaushalt*. Paper given at the conference on Bewaesserungslandwirtschaft im Jahr 2000, Vienna. Unpublished.

Commission of the European Communities (1995) *Wise use and conservation of wetlands*. Communication from the Commission to the Council and the European Parliament. Document COM (95) final. Office for Official Publications of the EC, Luxembourg.

Convenio de Berna, Conservación de la Vida Silvestre y el Medio Natural en Europa.

Cook, W.P., Sanders, D.C. (1990) *Fertiliser placement effects on soil nitrogen and use by drip-irrigated and plastic-mulched tomatoes*. Horticultural Science, Vol. 25, No. 7, pp 767-769.

Corominas-Masip, J. (1998) *La Infraestructura Hidráulica de Regadío en Almería.* Consejería de Agricultura y Pesca, Junta de Andalucía.

Custodio, E. (1982) *Nitrate build-up in Catalonia coastal acquifers*. International Symposium. AIH, Prague, pp 171-181.

Dennis, A. (1993) *Agriculture and wildlife: ecological implications of subsurface irrigation drainage.* U.S. Forest Service.

Department of the Environment, Transport and the Regions (1999) *Taking Water Responsibly. Government decisions following consultation on changes to the water abstraction licensing system in England and Wales.* DETR, London.

Destandau, F., Point, P. (1998) *La régulation de la pollution des eaux par une redevance différenciée spatialement. Une étude des pratiques de discrimination des Agences de l'eau*. In: L'irrigation et la Gestion. Montpellier.

Directiva 79/409/CE, Conservación de las Aves Silvestres, ampliada por la Directiva 91/294/CE.

Dochev, G., Neshkova, M., Rafailov, R., Krasteva, V. (1993) *Soil erosion under irrigation in Bulgaria.* International Symposium Farmland Erosion in temperate Plains Environment and Hills. Elsevier, Paris.

Dubois de la Sabloniere, F. (undated) *An intensive policy for sustainable managment of irrigation water in the Loire-Britany Basin.* Document de travail RIOB. In: http://www.eaudd.com/contributions/atriob/contribution/lba.htm.

El Acuífero 23: Pasado, Presente y Futuro. Aguas de Alcázar, 1999.

El Problema Hidráulico de la Cuenca Alta del Guadiana. Confederación Hidrográfica del Guadiana, MOPTMA.

English Nature (1996) *Impact of water abstraction on wetland SSSIs.* English Nature Freshwater Series, No.4. Peterborough.

Environment Agency (1996) *Prospects for Spray Irrigation. Making every drop count*. Brochure. EA, Peterborough.

Ernegger, T., Grubinger, H., Vitek, E., Csekits, C., Eitzinger, J., Gaviria, S., Kotek, D., Krisa, H., Nachtnebel, H.P., Pritz, B., Sabbas, T., Schmutz, S., Schreiner, P., Stephan, U., Unfer, G., Wychera, U., Neudorfer, W. (1998) *A natural stream created by human engineering: Investigations on the succession of the Marchfeld Canal in Austria*. Regulated Rivers: Research & Management, Vol. 14, pp 119-139.

Errichtungsgesellschaft Marchfeldkanal (1998) *Das Marchfeldkanalsystem. Ein modernes wasserwirtschaftliches Sanierungsprojekt*. Vienna.

European Environment Agency (1999) *Sustainable water use in Europe. Part 1: Sectoral use of water.* Environmental Assessment Report No 1. EEA, Copenhagen.

Euro-Waternet, a water resources monitoring information and reporting network for Europe. In:http://www.eaudd.com/contributions/at1/contribution/eea.htm.

Fasola, M., Ruiz, X. (1997) *Farming and birds in Europe.*

Fasola, M., Ruiz, X. (1997) *Rice farming and waterbirds: integrated management in an artificial landscape.* Farming and Birds in Europe.

Fojt, W. (1993) *Irrigation and the Environment. Water Abstraction and Conservation in East Anglia*. Irrigation News, Autumn 1993, No. 22, pp. 45-53.

Follett, R.F. (ed.) (1989) *Nitrogen management and groundwater protection*. Developments in Agricultural and Managed-Forest Ecologies, 21, pp 396. Elsevier.

Forum sur l'eau (1997) *Résumé des interventions*. AGPM, Montpellier, 17 Septembre 1997. NOVARTIS, dont: "L'eau et l'irrigation: les chiffres".

Gerakis, A., Kalburtji, K. (1998) *Agricultural activities affecting the functions and values of Ramsar wetland sites in Greece*. Agriculture Ecosystems and Environment, Vol. 70, Issue 2-3, pp 119-128.

Giannoulopoulos, P. (1999). *Groundwater flow and mathematical modelling in the plain of Argolid.* Unpublished Ph.D. thesis. Agricultural University of Athens, Department of Water Resources Management - Laboratory of Agricultural Hydraulics.

Grimmet,R.F.A., Jones, T.A. (1989) *Important Bird Areas in Europe*. ICBP Technical Publication No. 9, Cambridge, UK.

Grubinger, H. (1998) *Marchfeldkanal – eine oekologische Evaluation nach 15 Betriebsjahren*. Vermessung, Photogrammetrie, Kulturtechnik Vol. 11/98, pp. 603-604.

Guimera, J. (1992) *Analisis experimental del flujo y comportamiento el ion nitrato en la zona no saturada y su influencia en el agua subterranea*. Ph.D. Dissertation, Dep. Ingenieria del Terreno, Univ. Politecnica de Catalunya.

Guimera, J., Marfa, O., Candela, L., Serrano, L. (1995) *Nitrate leaching and strawberry production under drip irrigation management.* Agriculture Ecosystems and Environment, Vol. 56, No. 2, pp 121-135.

Hamdy, A., Lacirignola, C. (1999) *Mediterranean Water Resources: Major challenges towards the 21st century*. Centre International de Hautes Etudes Agronomiques Mediterraneennes. Mediterranean Agronomic Institute of Bari.

Huettler, W. (1996) *Regionalisierte Wassernutzungsbilanz Oesterreich 1994 (Water Balance for the Austrian Provinces)*. Oesterreichische Wasser- und Abfallwirtschaft, Issue 11/12, pp. 301-310.

Huinink, J., Janssen, J., Hotsma, P. (1998) *Waterpricing in the Netherlands. Current costs and benefits*. National Reference Centre for Agriculture, Ede.

Institut Francais de l’environnement (1997) *Agriculture et environnement: Les indicateurs.* Edition 1997-1998. Ifen.

Institut Français de l'environnement (undated) *Rapport de synthèse sur l'importance des retenues d'eau: usage, conditions environnementales, tendances.*

Instituto Nacional de Estatistica (1979) *Recenseamento Agricola do Continente.*

Instituto Nacional de Estatistica (1989) *Recenseamento Geral da Agricultura.*

Instituto Nacional de Estatistica (1997) *Inquerito a Estrutura das Exploracoes Agricolas.*

Irrigation et environnement; les relations peuvent s'améliorer. Perspectives Agricoles. N° 214, Juin 1996.

Irri-Mieux: tous les utilisateurs s'impliquent. L'Information Agricole. N° 703. Septembre 1997.

IRYDA (1997) *Estudio análisis ambiental de los regadíos actuales y potenciales su integración en el Plan Nacional de Regadíos en una estrategia nacional de desarrollo rural.*

IUCN (1992) *Interactions between Agriculture and Environment in Hungary.* IUCN East European Programme; Cambridge, UK.

IUCN (1993) *The Wetlands of Central and Eastern Europe.* IUCN East European Programme; Cambridge, UK.

IUCN (1995) *Interactions between Agriculture and Nature Conservation in the Czech and Slovak Republics.* IUCN East European Programme; Cambridge, UK.

Janin, J.L. (1996) *L'irrigation en France depuis 1988*. ICGREF,IFEN-DIREN. La Houille Blanche.

Koluvek, P.K., Tanji, K.K., Trout, T.J. (1993) *Overview of Soil Erosion from Irrigation*. Journal of Irrigation and Drainage Research, Vol. 119, No. 6, pp 929.

Kosmas, C. (1999) *The Impacts of Agriculture on Desertification.* Discussion Paper. Agricultural University of Athens, Laboratory of Soils and Agricultural Chemistry.

Kotsovinou-Andreakou, D. (1998) *Legislative framework for the management of water resources with reference to ground-water.* Paper presented at the one-day Conference on Salinisation of groundwater, organized by the Technical Chamber of Greece. December, 10, Athens (in Greek).

La gestión del agua subterránea en la Cuenca Alta del Río Guadiana: de la economía convencional a la economía ecológica. Tesis Doctoral, UCLM, 1996.

La nappe de Beauce bat tous les records. Perspectives Agricoles, N°214. Juin 1996.

La tarification de l'eau pour l'irrigation (résultats d'une enquête). Source non identifiée, document fourni par S.Morardet, CEMAGREF, Montpellier.

La tecnificación del regadío valenciano: análisis territorial de la difusión del sistema de riego localizado. Tesis Doctoral E.T.S.I.A. Madrid.

Le prix de l'eau: on s'achemine vers plus de transparence. In: L'Information Agricole, N° 703, septembre 1997.

Les Agences de l'eau et le VII ième programme. In: http://www.environnement.gouv.fr/...cominfos/dosdir/DIREAU/ag-o-7.htm.

Les techniques d'irrigation et leur coût. RIEUL. CEMAGREF. Option Méditerranéennes. N° 31. 1997.

L'irrigation en France. Les charges d'irrigation des principales cultures et des exploitation. La tarification de l'eau. Source non identifiée. Document fourni par S. Morardet (Cemagref, Montpellier).

Lopez-Bermudez, F. (1998) *The Guadalentín Basin*, Murcia, Spain.

Lopez-Galvarez, J., Losada, A. (1997) *Uso del Agua de Riego en Almería*. Fundación Argentaria.

Lopez-Galvarez, J. (1998) *Avances técnicos y productividad ecocompatible en agricultura*. Instituto de Estudios Almerienses.

MAFF (1996) *Good Irrigation Practice*. Brochure. MAFF, London.

MAFF (1996) *Winter Storage Reservoirs*. Brochure. MAFF, London.

MAFF (1996) *Irrigation Scheduling. Uses and techniques*. Brochure. MAFF, London.

MAFF (1997) *Survey of Irrigation of Outdoor Crops in 1995, England*. MAFF, London.

MAFF (1998) *Development of a Set of Indicators for sustainable Agriculture in the United Kingdom. A Consultation Document*. MAFF, London.

MAFF (1999) *Irrigation Water Assessment and Management Plan. Efficient use of irrigation water*. Brochure. MAFF, London.

Martinez, J., Quilez, D. (1998) *Technical visit to the Bardenas irrigation scheme: the impacts of the irrigated agriculture on the quality of the drainage water*. FAO, 1998.

Matson, P.A., Parton, W.J., Power, A.G., Swift, M.J. (1997) *Agricultural intensification and ecosystem properties.* Science, Issue 5325, pp 504-508.

Ministerio da Agricultura (1999) *Perimetros de rega em exploracao*. Instituto de Hidraulica, Engenharia Rural e Ambiente, Lisboa.

Ministerio de Industria y Energía y Ministerio de Obras Públicas, Transportes y Medio Ambiente (1994) *Libro blanco de las aguas subterráneas*.

Ministerio de Medio Ambiente (1998) *Libro blanco de las aguas.*

Ministry for Agricultural Policies Italy (1998) *Italian agriculture in figures 1998*. Istituto Nazionale Di Economia Agraria, Rome.

Ministry of Agriculture (Spring 1999) Personal Communication with experts. Athens, Greece.

Ministry of Environment, Spatial Planning and Public Works (1995) *Greece, Ecological and Cultural Heritage. Activities and Programmes for the Protection of the Environment* (in Greek). Athens.

Modèles de fiches de données de l'Institut Français de Environnement (IFEN). In: http://ifen.fr/cacade/fiche.html?fic=2186.

Morardet, S., Mailhol, J.C., Vidal, A., Garin, G., Gleyses, G. (undated) *Sécheresse et demande en eau d'irrigation: éléments de réflexion*. CEMAGREF, division irrigation.

Mottl, W. (1992) *Irrigation and Drainage in Austria*. Paper given at a ICID Conference, Budapest.

National Rivers Authority (1994) *Demand for Irrigation Water*. Report by Silsoe College. HMSO, London.

National Rivers Authority (1994) *Water Resources in Anglia. A sustainable strategy for secure water supplies and a better water environment*. NRA, Peterborough.

Naveso, M.A. (1993) *Respuestas de las comunidades nidificantes de aves a la intensificación agrícola en cultivos cerealistas de la Meseta Norte (Valladolid-Palencia, España).* Aegypius.

Naveso, M.A. (1997) *Extensive grazing and raptors in Spain*. Farming and Birds in Europe.

Naveso, M.A. (1997) *Farming in the drylands of Spain: birds of the pseudosteppes*. Farming and Birds in Europe.

OECD (1997) *Water Subsidies and the Environment.* OECD, Paris.

OECD (1998) *Sustainable Management of Water in Agriculture: Issues and Policies. The Athens Workshop*. OECD, Paris.

Oficina de la Convención Ramsar (1996) *Lista de Humedales de importancia internacional*.

Papanagiotou, E. (1995) *Agriculture and Environment*. Paper presented at the GEOTEE Conference: Agricultural Economics and Politics- new views and perspectives. Athens, 10-12 December.

Pereira, L.S., Paulo, V.C. (1986) *Agricultura e gestao da agua I – Avaliacao de necessidades de agua para rega em Portugal Continental.* Anais do Instituto Superior de Agronomia, Vol. XLII, pp 133-165.

Pergaliotis, P. and Papadakou, S. (1998) *Salted ground waters of Greece and their underlying causes.* Paper presented at the one-day Conference on Salinisation of groundwater, organized by the Technical Chamber of Greece. December, 10, Athens (in Greek).

Plaidoyer pour l'irrigation et Les enjeux de l'irrigation. AGPM, Congrès du Maïs, septembre 1998, Lille.

Plantey, J., Tardiau, H., Mesny, M., Nicol, J.P., Rieu, T., Verdier, J. (1999) *Gestion de l'eau pour l'agriculture en France: durabilité socio-économique et implication des usagers*. In: http://wwwoieau.fr/euromed/france/ate_1/tardieu.htm26/05/99.

Poncet, J.F. (undated) *Le financement des Agences de l'eau en France. Agence de l'eau Adour-Garonne*. In: http://wwweaudd.com/contributios/at3/contribution/poncet.htm.

Poulovassilis, A., Mimides, T., Giannoulopoulos, P., Psyhoyou, M. & Alexandris, S. (1994). *Understanding the natural and athropogenic causes of soil degradation and desertification in the Mediterranean basin*. Archaeomedes project Argolid. Agricultural University of Athens, Department of Water Resources Management - Laboratory of Agricultural Hydraulics.

Poulovassilis, A., Kerkides, P., Aggelides, S., Mimides, T., Psyhoyou, M., Alexandris, S., Kargas, G., Skoumbopoulou, A. (1996) *Assessment of impacts or irrigated agriculture: A case study*. In: Pereira, L.S. (ed) Sustainability of Irrigated Agriculture. Kluwer Academic Publishers, the Netherlands, pp. 601-613.

Poulovassilis, A. & Giannoulopoulos, P. (1996) *Use of water for the Kiveri spring in Argolid valley for irrigation. Monitoring of saline intrusion of the aquifer of the Argolid valley. Remedial measures*. Report for the Ministry of Agriculture.

Poulovassilis, A. (1993) *Methods of Water Application on the Farm*. Class Lectures. Agricultural University of Athens.

Poulovassilis, A. (1998) *Water Resource Management for Sustainable Agriculture in Coastal Areas.* In: OECD (ed) Sustainable Management of Water in Agriculture. Issues and Policies. The Athens Workshop.

Pujot, J.L., Dron, D. (1998) *Agriculture, monde rural et environnement: qualité oblige.* Raport à la ministre de l'Aménagement du territoire et de l'environnement. La documentation française. Résumé sur http:/www.zenvironnement.gouv.fr/.../cominfos/dosdir/agridron9903.htm.

Rainelli, P., Vermersch, D. (1997) *Irrigation in France: Current situation and reasons for its development.*

Ramon-Llamas, M. (undated) *El desarrollo sostenible de la Cuenca Alta del Río Guadiana: aspectos socioeconómicos y ecológicos.*

Real Decreto 439/90, Catálogo Nacional de Especies Amenazadas.

Rieu, T. (1999) *L'eau agricole en France: Etat des lieux et perspectives.Division irrigation*. In: Bulletin du Conseil général du GREF, N° 53. Avril 1999, CEMAGREF, Montpellier.

Rodrigo, I., Santos, J.M.L. (1999) *Agricultura e ambiente no Ribatejo e Oeste*. Instituto Superior de Agronomia, Lisboa.

Roth, D., Eggers, Th., Seesselberg, F., Albrecht, M. (1995) *Analyse des Bundesfachverbandes Feldberegnung zum Stand der Beregnung in Deutschland (Status of Sprinkler Irrigation in Germany – an analysis of the Federal Sprinkler Irrigation Association)*. Zeitschrift fuer Bewaesserungswirtschaft, 30. Jg., Heft 2/1995, pp. 113-120.

Salinas, J.A. (1999a) *Mesa redonda sobre los Recursos Hídricos de Almería*.

Salinas, J.A., Lopez-Galvez, J. (1999b) *Efectos Ambientales y Tecnología en el Sistema de Cultivo Forzado*. U.A.

Salinas-Andujar, J.A. (1999c) *Perspectivas de la horticultura de Almería ante el siglo XXI.*

Santos, D.V., Sousa, P.L., Pereira, L.S. (1998) *Nitrate movement in level basins: Reduced versus conventional soil tillage*. In: Pereira, L.S., Gowing, J. (eds) Water and Environment. E & FN Spon, London , pp 43-51.

Selianites, P. (1998) *Greece: Sustainable Management of Water in Agriculture. Issues and Policies. Report prepared for the OECD Athens Workshop. Ministry of Agriculture.*

SEO-Birdlife (1998) *Áreas Importantes para las Aves en España*.

Seres, C. (1998) *Protection des eaux contre les pollutions agricoles: cadre comptable des dépenses pour la région Aquitaine*. In: L'irrigation et la gestion collective de la ressource en eau en France et dans le Monde. Montpellier.

Sitton, M. (1992) *Water for Irrigation*. Irrigation News Autumn 1992, No. 21, pp. 39-44.

Sourell, H. (1998) *Welche Beregnungstechnik werden wir im 21. Jahrhundert einsetzen ? (Irrigation Techniques in the 21st century).* Zeitschrift fuer Bewaesserungswirtschaft, 33. Jg., Heft 2/1998, pp. 249-260.

Sourell, H. (1999) *Rationalisierungskuratorium fuer Landwirtschaft. Feldberegnung III.* Rendsburg-Osterroenfeld.

Strosser, P., Pau Vall, M., Ploetscher, E. (1999) *Water and agriculture: Contribution to an Analysis of a critical but difficult Relationship*. In: European Commission: Agriculture, Environment, Rural Development. Facts and Figures. A challenge for agriculture. Luxembourg.

Stupples, L. (1992) *Water Resources: An Environmentalist's Perspective*. Irrigation News, Autumn 1992, No. 21, pp. 58-62.

Suarez, F., Alvarez, P. (1997) *Problemática de conservación de los agrosistemas esteparios.* SEO-Birdlife.

Sumpsi, J. (1998) *Agro-environmental Indicators in Extensive Land Use Systems in the Iberian Peninsula: some theoretical and practical problems*. UPM.

Sumpsi, J.M., Varela-Ortega, C. (1999) *Environmental Impacts of Irrigation in Spain.* Unpublished report for this study. Departamento de Economia Agraria, Universidad Politecnica, Madrid.

Sumpsi, J.M., Varela-Ortega, C., Blanco, M.(undated) *La influencia de los distintos escenarios de la política agraria comunitaria en el consumo de agua en la zona regable de Daimiel.* Working Paper. Departamento de Economía y Ciencias Sociales Agrarias. Universidad Politécnica de Madrid.

Tableau des "Superficies irriguées au moins une fois au cours de la campagne". AGRESTE N° idem, pages 106-107.

Teixeira, F.J.B., Basch, G. (1998*) Effects of the traditional and no-tillage systems upon runoff and herbicide transport*. In: Pereira, L.S., Gowing, J. (eds) Water and Environment. E & FN Spon, London, pp 27-34.

Theoharopoulos, S. P., Karagianni, M., Gatzogiani, P., Afentaki, A. & Aggelides, S. (1993) *Nitrogen leaching from soils in the Kopais area of Greece*. Soil Use and Management, Vol. 9, No. 2, June, pp. 76-84.

Thomas, C. (1993) *Irrigation and the Environment. Water Resources*. Irrigation News, Autumn 1993, No. 22, pp. 37-44.

Trout, T.J., Neibling, W.H. (1993) *Erosion and Sedimentation Processes on Irrigated Fields*. Journal of Irrigation and Drainage Research, Vol. 119, No. 6, pp 947.

Turner, F.T., Brown, K.W., Deuel, L.E. (1980) *Nutrients and associated concentrations in irrigation return flow from flooded ricefields*. Journal of Environmental Quality, 9, pp 256-260.

Turpin, N., Vernier, F., Joncour, F. (1997) *Amélioration de l'aspersion et économie d'eau.* Ingéneries - EAT. N° 11 septembre 97.

Une politique (de l'eau) décentralisée, déconcentrée et interministérielle. Rapport du sénat. In: http://www.senat.fr/198-066305/198-0663059.html.

Utilisation du Sol. Tableaux des "Cultures irriguées au moins une fois dans l'année. 1990,1993, 1995 " AGRESTE, données chiffrée agriculture, N° 97.

van der Wal, R.J. (1998) *Netherlands: Sustainable Drinking Water Supply and Dairy Production.* In: OECD (1998) Sustainable Management of Water in Agriculture. The Athens Workshop. Case Studies. OECD, Paris.

Varela, M., Candela, L. (1998) *Groundwater Pollution from mineral fertilizers and pesticides in Spain.* Dirección General de Obras Hidráulicas y Calidad de las Aguas, MIMAM.

Varela-Ortega, C., Sumpsi, J.M. (1995) *The CAP and the enviroment in Spain*. Universidad Politécnica de Madrid.

Varela-Ortega, C., Sumpsi, J.M. (1999) *Assessment of cost-effectiveness of policy instruments for sustainable development in environmentally sensitive irrigation areas*. Paper presented at the IXth Congress of the European Association of Agricultural Economists (EAAE). Warsaw, Poland (August 24-28, 1999).

Villadomiu, L., Rosell, J. (1999) *El programa de compensación de rentas por disminución de regadíos de Castilla La Mancha.*

WWF (1996) *Agua en La Mancha. Humedales manchegos en peligro por la gestión del agua en la Cuenca Alta del Guadiana.* Adena.

WWF (1998) *The Wetland Plan in Las Tablas de Daimiel, Spain.*

WWF (1999) *Environmental Policy. Natura 2000, opportunities and obstacles*.

Zalidis, G.C., Gerakis, A., Misopolinos, N., Apostolakis, A., Prodromou, K. (1998) *The impact of soil and water resources management on salt accumulation in Greece.* Mediterranean Magazine, Science, Training and Technology.

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