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Istituto Superiore per la Protezione
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Programme Interreg IIIB MEDOCC
Pour la cohésion des territoires de l'Europe du Sud
FEDER

RAPPORTI

Metodologie e strumenti per la pianificazione e la gestione sostenibile dell'irrigazione in condizione di siccità

Irrigation Management during Drought Periods in Europe - ISPRA's Activities

MIPAIS






129 / 2010

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Metodologie e strumenti per la pianificazione e la gestione durevole dell’irrigazione in condizioni di siccità

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PRÉFACE: LE PROJET MIPAIS

Méthodologies et Instruments pour la Planification
et la gestion durable de l'Irrigation en condition de Sécheresse

Les sécheresses périodiques et consécutives, en particulier dans les régions du bassin méditerranéen, sont sources de conflits entre les différents usages de l'eau. Dès que les ressources en eau diminuent, la priorité donnée à l'eau potable limite la disponibilité pour l'irrigation alors que les besoins sont maximaux, et ceci pose de sérieux problèmes au secteur agricole.
Cette situation exige que l'on rationalise l'utilisation de l'eau en agriculture.
L'objectif du projet MIPAIS était d'expérimenter, dans des différentes zones représentatives du bassin méditerranéen, des méthodes qui permettent la gestion durable de l'irrigation en condition de sécheresse. Ce projet a débuté au mois d'avril 2005 et s'est terminé au mois d'octobre 2007.
Le groupe de projet est constitué par 7 partenaires plus un observateur, représentant 5 pays différents:

	ITALIE
	CBSM: Consorzio di Bonifica della Sardegna Meridionale (Chef de file) avec l'appui de Hydrocontrol, Centre de recherche dans le domaine de l'eau www.hydrocontrol.com
	ISPRA Ex APAT: Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici, Roma www.isprambiente.it/site/it-IT/
	ARPA-SIM: Agenzia Regionale prevenzione e ambiente Emilia Romagna, Servizio Idro - Meteorologico, Bologna www.arpa.emr.it
	PPZ: Provincia di Potenza www.provincia.potenza.it
	ESPAGNE IAS-CSIC: Instituto de Agricultura Sostenible, Consejo Superior de Investigaciones Científicas, Alameda del Obispo, Cordoba www.csic.es/index.do
	FRANCE CEMAGREF: Centre de Recherche pour l'Ingénierie de l'Agriculture et de l'Environnement, Aix-en-Provence www.cemagref.fr
	PORTUGAL CEER: Instituto Superior de Agronomia – Universidade Técnica de Lisboa www.isa.utl.pt
	TURQUIE ARTC: Turkish Research Group Agrohydrology Research and Training Centre Menemen Research Institute, Izmir (observateur) http://www.thaem.gov.tr/

Le projet s'est articulé selon les phases suivantes:

1) **Etudes et acquisition d'informations et de pratiques optimales** sur la limitation de la demande en eau et la gestion des périodes de sécheresse dans le contexte du bassin méditerranéen ; étude de modèles de bilan hydrique, et collecte de données sur des expériences où l'on applique la technique d'irrigation basée sur le déficit hydrique contrôlé.
2) **Projets pilote**: réalisation sur six zones pilotes dans le bassin méditerranéen, et application des conseils aux agriculteurs sur les volumes d'eau à apporter et sur les périodes les plus appropriées pour l'irrigation des cultures.
3) **Réseau d'échange**: réalisation d'un site web pour la mise en commun des connaissances acquises et des résultats élaborés par les partenaires du projet.
4) **Échange d'expériences**: des séminaires sur les résultats obtenus dans le cadre du projet MIPAIS ont été organisés pendant le déroulement du projet et à la clôture des activités.
5) **Actions de formation et de sensibilisation** organisées pour les agriculteurs et leurs associations.

Le projet a été testé dans 6 zones pilotes différentes :

- ❏ En Sardaigne : dans une zone agricole près du centre rural de Villacidro, à environ 50 km de Cagliari, chef-lieu de la Région
- ❏ En Emilie-Romagne : dans le bassin du Santerno dans le sud-est de la région Romagne, située entre Bologne et Ravenne.
- ❏ En Basilicate : dans la province de Potenza, dans le bassin du Pertusillo.
- ❏ En France: dans le Val de Drôme, qui est une petite région en rive gauche du Rhône, entre Montélimar et Valence.
- ❏ Au Portugal : dans la région de l'Alentejo (dans le sud du Pays).
- ❏ En Espagne: dans la vallée du Guadalquivir, dans la partie ouest de l'Andalousie.

Le projet MIPAIS a été financé par le programme Interreg IIIB 2000-2006 MEDOCC, pour la cohésion des territoires de l'Europe du Sud.

PREMESSA: IL PROGETTO MIPAIS

**Metodologie e strumenti per la pianificazione
e la gestione sostenibile dell'irrigazione in condizioni di siccità.**

La razionalizzazione dell'uso della risorsa idrica in agricoltura è una necessità non più rinviabile, soprattutto nelle regioni del bacino del Mediterraneo, dove il verificarsi periodico di stagioni siccitose consecutive determina una conflittualità tra gli usi principali dell'acqua. La priorità dell'uso idropotabile, in condizioni di siccità, sottrae risorse all'agricoltura proprio nella stagione irrigua, arrecando gravi problemi al settore.
L'accertata riduzione degli apporti meteorici, della diversa distribuzione degli eventi e dell'accrescersi della loro intensità in ambito mediterraneo sollecitano l'applicazione di scelte consapevoli e mirate volte alla valorizzazione e protezione delle risorse idriche con l'adozione di servizi legati all'irrigazione efficienti ed efficaci.
Per la soluzione delle problematiche sopra esposte, i bilanci idrici, nella programmazione a scala territoriale e aziendale, rappresentano una via obbligata alla gestione sostenibile delle attività agricole.
Il progetto MIPAIS, che avuto inizio nel mese di aprile del 2005 e che si è concluso nel mese di ottobre 2007, ha lo scopo di sperimentare, in diverse aree rappresentative del bacino del Mediterraneo, delle metodologie che permettano la gestione duratura dell'irrigazione anche in condizione di siccità. Il progetto è stato condotto da 7 partner più un paese osservatore che rappresentano cinque nazioni diverse:

	ITALIA
	Partner capofila: Consorzio di Bonifica della Sardegna Meridionale – CBSM, con il supporto di Hydrocontrol, Centro di ricerca sulle risorse idriche www.hydrocontrol.com
	ISPRA Ex APAT: Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici, Roma www.isprambiente.it/site/it-IT/
	ARPA-SIM: Agenzia Regionale prevenzione e ambiente Emilia Romagna, Servizio Idro - Meteorologico, Bologna www.arpa.emr.it
	PPZ: Provincia di Potenza www.provincia.potenza.it
	SPAGNA IAS-CSIC: Istituto di Agricoltura Sostenible, Consiglio Superiore di Indagini Scientifiche, Alameda del Obispo, Cordoba www.csic.es/index.do
	FRANCIA CEMAGREF: Centro di ricerca per l'Ingegneria dell'Agricoltura e dell'Ambiente, Aix-en-Provence www.cemagref.fr

	PORTOGALLO CEER: Istituto Superiore de Agronomia – Università Tecnica di Lisbona www.isa.utl.pt
	TURCHIA ARTC: Gruppo di Ricerca Turco di Agro - Idrologia, Centro di ricerca e formazione Menemen, Izmir (partner osservatore) http://www.thaem.gov.tr/

Il progetto è articolato secondo le fasi seguenti:

1) **Studi ed acquisizione di informazioni e di esperienze** sulla limitazione della domanda idrica e la gestione di periodi di siccità nel contesto del bacino del Mediterraneo; studio di modelli di bilancio idrico e la raccolta di dati sulle esperienze di applicazione della tecnica irrigua che si basa sul deficit idrico controllato.
2) **Progetti pilota:** realizzazione ed applicazione sperimentale del consiglio irriguo sui volumi idrici necessari e i momenti più indicati per l'irrigazione delle colture, rivolto agli agricoltori nelle diverse zone pilota dei partner di MIPAIS.
3) **Rete di scambio:** realizzazione di un sito web per la condivisione delle conoscenze acquisite e informazioni elaborate dai partner di progetto.
4) **Scambio di esperienze:** seminari sui risultati raggiunti dal progetto MIPAIS.
5) **Azioni di formazione e d'informazione** rivolte agli agricoltori degli enti dei Consorzi di Bonifica coinvolti.

Il progetto è stato testato in 6 diverse zone pilota:

- ❏ Sardegna: in una zona agricola vicino alla cittadina di Villacidro, a circa 50 km da Cagliari, capoluogo della Regione
- ❏ Emilia-Romagna: nel bacino del Santerno nel sud-est della Regione Emilia Romagna, situata tra Bologna e Ravenna.
- ❏ Basilicata: nella provincia di Potenza, nel bacino del Pertusillo.
- ❏ Francia: nella Val Drôme, che è una piccola regione sulla riva sinistra del Rhône, tra Montélimar e Valence.
- ❏ Portogallo: nella regione dell'Alentejo (nel sud del paese).
- ❏ Spagna: nella valle del Guadalquivir, nella parte occidentale dell'Andalusia

Il progetto MIPAIS è stato finanziato dal programma Interreg IIIB 2000-2006 MEDOCC, per la cooperazione dei paesi dell'Europa del sud.

PREFACE: MIPAIS PROJECT

Methodologies and instruments for the sustainable planning and management of irrigation under drought conditions.

The need of rationalizing water resources use in agriculture cannot be postponed further, particularly in the Mediterranean regions, where the periodical occurence of consecutive droughty seasons causes a conflict among the main usages of water. Under drought conditions the priority of drinking use deducts water resources to agriculture just during the irrigation period, damaging this sector seriously. To solve this situation, water balances and the territorial planning are the fixed route to the sustainable managing of agricultural activities. MIPAIS project, started in April 2005 and completed in October 2007, aimed at testing in different areas of the Mediterranean basin methodologies enabling a durable irrigation management even under drought conditions. The project was carried out by partners plus an observer representing five different countries:

	ITALIE
	CBSM: Reclamation Consortium of South Sardinia (Leadpartner) with the support of Hydrocontrol, water research centre www.hydrocontrol.com
	ISPRA EX APAT: Governmental Agency for environmental protection and technical services, Rome www.isprambiente.it
	ARPA-SIM: Agenzia Regionale prevenzione e ambiente Emilia Romagna, Servizio Idro - Meteorologico, Bologna www.arpa.emr.it
	PPZ: Province of Potenza www.provincia.potenza.it
	SPAIN IAS-CSIC: Instituto de Agricultura Sostenible, Consejo Superior de Investigaciones Científicas, Alameda del Obispo, Cordoba www.csic.es/index.do
	FRANCE CEMAGREF: Centre de Recherche pour l'Ingénierie de l'Agriculture et de l'Environnement, Aix-en-Provence www.cemagref.fr
	PORTUGAL CEER: Instituto Superior de Agronomia – Universidade Técnica de Lisboa www.isa.utl.pt
	TURKEY ARTC: Turkish Research Group Agrohydrology Research and Training Centre Menemen Research Institute, Izmir (observateur) http://www.thaem.gov.tr/

The project included the following phases:

1) **Studies and acquisition of information and experiences** on water demand limit and its managing under droughty conditions in the Mediterranean basin; study of water balances models and data collection on application experiences of the irrigation technique based on controlled water deficit.
2) **Pilote projects:** realisation and experimental application of irrigation advice to farmers of different MIPAIS pilote areas on necessary water volumes and most appropriate times for crops irrigation..
3) **Exchange network:** realisation of a website to share developed knowledge and information among project partners.
4) **Experiences exchange:** workshops on results obtained through MIPAIS project.
5) **Training and information actions** addressed to the farmers of the involved Reclamation Consortia.

The project was tested in 6 different pilote areas:

❑ Sardinia: in a farmlamd near the village of Villacidro, about 50 km from Cagliari, regional capital.

❑ Emilia-Romagna: in the basin of Santerno river in the South-East of Emilia Romagna region, between Bologna and Ravenna.Basilicata: in the province of Potenza, in the Pertusillo basin.

❑ Francia: in the Drôme valley, a small region on the left bank of Rhône, between Montélimar and Valence.

❑ Portugal: in Alentejo region (in the south of the country).

❑ Spain: in the Guadalquivir valley, in the western part ofAndalusia

MIPAIS project has been financedin the frame of Interreg IIIB 2000-2006 MEDOCC Programme, for thecooperation among South-European countries.

ISPRA (ex APAT) activities within the sphere of the project

The present report has the objective of describing the work carried out by ISPRA (ex APAT) for the MIPAIS project.
In particular the most significant activities of ISPRA in the MIPAIS project have focused on the studies concerning the water demand limitations and irrigation management during drought periods in Europe and in particular in the Mediterranean countries, and the analysis of the hydrological cycle.
The first part of this report concerns an overall overview of the situation around Europe, in particular in the Mediterranean countries, regarding the irrigation water uses focused on the drought periods management and on the suitable irrigation technologies.
Moreover, present an overview of irrigation, water scarcity and vulnerability to drought cycles in Italy, as well as the Italian experience in monitoring and managing drought risk, and the protection of water quality and quantity.
The second part illustrates ISPRA's available databases referring to specific and necessary parameters or indexes for drought monitoring. This information concerns various phases of the hydrological cycle and droughts in accordance with the literature. All analyses are developed taking into account the reference frame and the need to place and integrate these results with some more information.

1 PRESSURES ON WATER RESOURCES: AGRICULTURAL WATER USE

1.1 Different Uses Inciting Water Demand

This section in the second chapter examines the different types of water use before focusing on the primary agricultural use of water: irrigation.
The terms *water use* and *water demand* are often used interchangeably. However, these terms have different meanings.
The term "**water use**" is defined as the use of water altering its natural condition for increasing the production of goods and services (International Glossary of Hydrology ; WMO – UNESCO).
The term "**water demand**" is defined as the volume of water requested by users to satisfy their needs. In a simplified way it is often considered equal to water abstraction, although conceptually the two terms do not have the same meaning (EEA *Glossary*).
Different sectors have different demand for water. The main drivers of water use are agriculture (irrigation), urbanisation, population growth, lifestyles, including tourism, and the need for water for industrial processes and cooling at power plants. Virtually all of these human uses require fresh water.

> On average, in **Europe** 37 % of total water use is for *agriculture*, 33 % for *energy* production (including cooling), 18 % for *urban* use, and 12 % for *industry* (excluding cooling). Abstractions for agriculture remained almost unchanged over the period, while those for urban use and energy decreased by 11 % and for industry by 33 %. Irrigation is the most significant use of water in agriculture in southern countries, accounting for 50 to 80 % of water use (EEA, 2005). In central Europe energy production (including cooling water), followed by urban use are generally the main users. In particular, Belgium, Germany and Estonia use more than half of their abstracted water for energy production. Tourism, one of the fastest increasing socio-economic activities in Europe, places severe, often seasonal, pressures on water resources, and the increase in demand is often associated with recreational uses such as swimming pools, golf courses, and aquatic parks as well as by a much increased population during holiday seasons.
>
> *Sources*: EEA 2005

Uses of fresh water can be categorized as consumptive and non-consumptive (sometimes called "renewable"). A use of water is consumptive if that water is not immediately available for another use. Losses for sub-surface seepage and evaporation are considered consumptive, as it is water incorporated into a product (such as farm produce). Water can be treated and returned as surface water, such as sewage, which is generally considered non-consumptive if that water can be put to additional use.
There are many reasons why water resources are coming under pressure: increasing population, economic growth, intensive agriculture, rapid urbanisation, growing tourism and leisure activities, as well as the lack of proper supply and treatment facilities or institutional arrangements for water management.
Not all water uses put equal stress on water resources. To reach the goal of sustainable water management a balance has to be achieved between the abstractive uses of water (e.g. abstraction for public water supply, irrigation and industrial use), in-stream uses (e.g. recreation, ecosystem maintenance), discharges of effluents and the impacts of diffuse sources. This requires that quantity, quality, and ecological effects are all taken into account.
In the **Mediterranean** region, water is a rare, fragile and unevenly distributed resource. Water demands are increasing, with agriculture as the main water-consuming sector. It accounts for 65% of the total demand in the Mediterranean basin (48% in the *North* and approximately 80% in the *South* and *East*). In numerous Mediterranean countries water use is approaching the lim-

it level of available resources. Momentary or structural water shortages have been observed. Water supply in several Mediterranean countries is endangered by the over-exploitation of a part of the renewable underground water (generating salt-water intrusion, which makes the water unusable) and the exploitation of non-renewable resources (including fossil water). In addition to this stress on natural water resources, man-induced degradations and pollution also impact the water regime and its quality, thus further limiting the possibilities of water use (Plan bleu, 2006).

Fig. 1 - Mediterranean countries and their different limits

1.2 Agricultural water use and his impacts

Sustainable development is the management and conservation of the basic natural resource and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and future generations.
Such sustainable development (in the agriculture, forestry and fisheries sectors) preserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO's definition of *sustainable agricultural development*).
Water used for agriculture comes from natural or other alternative sources:
<u>Natural sources</u> includes rainwater and surface water (lakes and rivers). Rain water resources rely on the atmospheric conditions of the area. Surface water is a limited resource and normally requires the construction of dams and reservoirs with a significant environmental impact. These resources must be used in a sustainable way.

Agricultural water use includes water abstracted from surface and groundwater, and return flows (withdrawals) from irrigation for some countries, but excludes precipitation directly onto agricultural land (OECD *glossary*).

Alternative sources of irrigation water are the reuse of municipal wastewater and drainage water.

Recycled water is most commonly used for nonpotable (not for drinking) purposes, such as agriculture, landscape, public parks, and golf course irrigation. Other nonpotable applications include cooling water for power plants and oil refineries, industrial process water for such facilities as paper mills and carpet dyers, toilet flushing, dust control, construction activities, concrete mixing, and artificial lakes.

However the use of recycled water for irrigation may have some adverse impacts on public health and environment. This will depend on recycled water applications, soil characteristics, climate conditions and agronomic practices. Therefore it is important that all these factors are taken into account in the management of recycled water.

Water reuse for irrigation is a normal practice worldwide. The water quality used for irrigation is essential for yields and especially for the quantity of crops, maintenance of soil productivity and for environmental protection. For example, the physical and mechanical properties of the soil, soil structure (stability of aggregates) and permeability, are very sensitive to the type of exchangeable ions being present in irrigation water.

Irrigation water quality can be best determined by chemical laboratory analysis. The most important factors to determine the suitability of water use in agriculture are the following: PH, salinity hazard, sodium hazard (sodium adsorption ration or SAR), carbonate and bicarbonates in relation with the Ca & Mg content, other trace elements, toxic anions, nutrients and free chlorine. From a river-basin perspective, wastewater irrigation is an important form of water and nutrient reuse; however, there are important considerations to be made on water quality, environmental protection, and public health.

Agricultural impacts on water quantity

The amount of water to be withdrawn for irrigation varies annually; it depends mainly on two factors:

- winter precipitation
- weather and soil moisture conditions during the growing season

Temperature, the amount and timing of rainfall, wind, and evaporation all influence the need for supplemental water for optimum plant growth.

Water consumption has increased significantly in Europe and currently agriculture is the main water user in Southern Europe.

The increasing pressure on water resources by agriculture faces competition from other water use sectors and represents a threat to the environment.

Agricultural impacts on water quality

Agriculture is both cause and victim of water pollution. It is a cause through its discharge of pollutants and sediment to surface and/or groundwater, through net loss of soil by poor agricultural practices, and through salinization and waterlogging of irrigated land. It is a victim through use of wastewater and polluted surface and groundwater which contaminate crops and transmit disease to consumers and farm workers.

Tab. 1 - Agricultural impacts on water quality

Agricultural activity	Impacts	
	Surface water	Groundwater
Tillage/ploughing	Sediment/turbidity: sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.	
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth leading to deoxygenation of water and fish kills.	Leaching of nitrate to groundwater; excessive levels are a threat to public health.
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.	Contamination of ground-water, especially by nitrogen
Pesticides	Runoff of pesticides leads to contamination of surface water and biota; dysfunction of ecological system in surface waters by loss of top predators due to growth inhibition and reproductive failure; public health impacts from eating contaminated fish. Pesticides are carried as dust by wind over very long distances and contaminate aquatic systems 1000s of miles away (e.g. tropical/subtropical pesticides found in Arctic mammals).	Some pesticides may leach into groundwater causing human health problems from contaminated wells.
Feedlots/animal corrals	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.	Potential leaching of nitrogen, metals, etc. to groundwater.
Irrigation	**Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.**	**Enrichment of groundwater with salts, nutrients (especially nitrate).**
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.	Disruption of hydrologic regime, often with increased surface runoff and decreased groundwater recharge; affects surface water by decreasing flow in dry periods and concentrating nutrients and contaminants in surface water.
Silviculture	Broad range of effects: pesticide runoff and contamination of surface water and fish; erosion and sedimentation problems.	
Aquaculture	Release of pesticides (e.g. TBT1) and high levels of nutrients to surface water and groundwater through feed and faeces, leading to serious eutrophication.	

1 TBT .= Tributyltin

Source: FAO,1996

1.3 Agricultural water use in the mediterranean countries

Agriculture is the most important land cover type in Europe in terms of proportion of total land area occupied. It covers approximately 55 % of land surface, compared to 37 % for forests and 5 % for urban settlements.
Europe is one of the world's largest and most productive producers of food and fibre. The agricultural sector in Europe contributes 2.6 % to European GDP (gross domestic product) and employs 5 % of all workers.

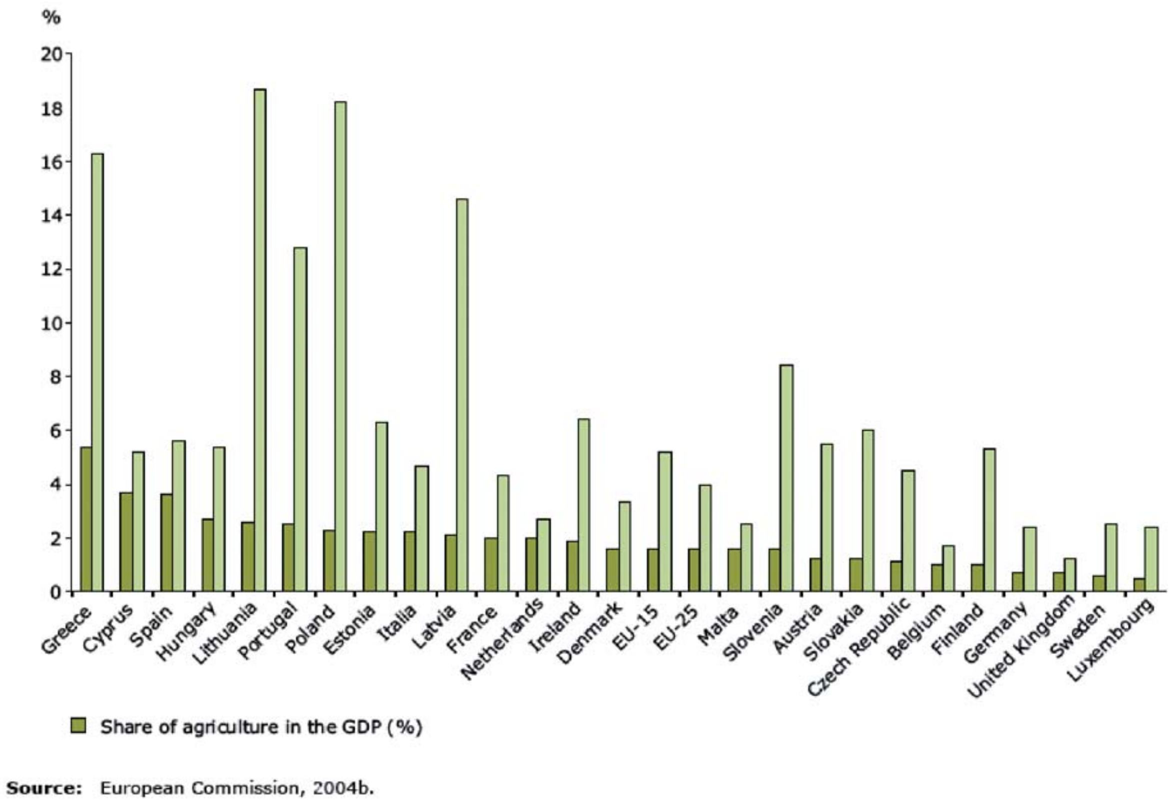

Fig. 2 - Agricultural employment and production in EU Member States

Agricultural water demand is the largest item in water demand, representing 65 per cent of total demand in the Mediterranean basin, 48 per cent in the north (*Spain, France, Italy, Greece, Monaco, Slovenia, Croatia, Bosnia-Herzegovina, Serbia-Montenegro, Albania, Cyprus and Malta*) and 82 per cent in the south (*Turkey, Syria, Lebanon, Israel and the Palestinian Territories, Egypt, Libya, Tunisia, Algeria and Morocco*).
The area under irrigation is becoming more or less constant (reducing in Italy) in the north and is expected to lead to a more or less constant demand for agricultural water, in both absolute and relative terms. On the other hand, forecasts project a large increase in agricultural water demand in the south and especially in the eastern part of the basin.
Water resources in Europe are, in many locations, under threat from a range of human activities, which lead to problems of overexploitation and low quality of inland waters.
Qualitative changes altering the ecological status of water resources being already vulnerable naturally have to be added to the changes in the quantities of water resource regimes.

Tab. 2 - Agricultural water use in the mediterranean countries (ref.: nostrum-dss project)

Country	Population (millions people)	Total Area (ha)	Agricultural area (% total area)
Algeria	31.3	238174	16.8
Croatia	4.4	5654	41.7
Cyprus	0.8	925	23.0
Egypt	70.5	100450	3.4
France	59.6	55150	53.7
Greece	11	13196	65.5
Israel/Palestine	6.6	2171	26.1
Italy	57.5	30134	52.5
Lebanon	3.6	1040	32.2
Morroco	29.9	71085	42.4
Portugal	10.0	9198	45.3
Spain	41	50599	60.5
Syria Arabic Republic	18.2	18518	32.0
Tunisia	9.7	16361	51.8
Turkey	70.3	77482	54.2

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2 AVAILABLE WATER RESOURCES FOR IRRIGATION

European countries meet their freshwater needs from surface water such as rivers, lakes and reservoirs, and from groundwater. The share of each source varies among countries and according to regional characteristics. Countries such as Norway, Spain and the United Kingdom, for example, use more surface water, while Austria, Denmark and Germany use more groundwater.
In southern Europe, there is growing use of desalinated sea water, notably on Mediterranean islands where there is heavy seasonal water demand from tourists. Furthermore, several countries, including Spain, plan to greatly increase their desalination capacity as an alternative to bulk transfer of water between river basins.

2.1 River Run-Off

In a long-term water balance, runoff is the amount of precipitation that does not evaporate, usually expressed as an equivalent depth of water across the area of the catchment. Stream-flow, in general terms, is the water within a river channel, usually expressed as a rate of flow passing a point, typically in $m^3 s^{-1}$. A simple link between the two is that runoff can be regarded as stream-flow divided by catchment area, although in dry areas this does not necessarily hold, because runoff generated in one part of the catchment may infiltrate before reaching a channel and becoming stream-flow. Over short durations, the amount of water leaving a catchment outlet is usually expressed as stream-flow; over durations of a month or more, it is usually expressed as runoff. Renewable water resources include waters replenished yearly in the process of the annual water cycle; they are defined as the total volume of river run-off and groundwater recharge generated annually by precipitation, plus the total volume of actual flow of rivers coming from neighbouring territories. Thus, river runoff represents renewable water resources and constitutes the dynamic component of the total water resource. Climatic and physical properties of the catchment, aggravated by human activities, such as river impoundment and land use changes, may lead to significant variations in seasonal flow regimes. In general, trends in hydrological data are consistent with those identified for precipitation: runoff tends to increase where precipitation has increased and decrease where it has fallen over the past few years. Variations in flow from year to year have been found to be much more strongly related to precipitation changes than to temperature changes (e.g. Krasovskaia, 1995; Risbey and Entekhabi, 1996). There are some more subtle patterns, however. In large parts of Eastern Europe (Westmacott and Burn, 1997), a major—and unprecedented—shift in streamflow from spring to winter has been associated not only with a change in precipitation totals but more particularly with a rise in temperature: precipitation has fallen as rain, rather than snow, and therefore has reached rivers more rapidly than before
There is also a considerable spatial variation in river flow across Europe. The average annual runoff in Europe very closely follows the pattern of average annual rainfall. Annual runoff is larger than 3000 mm in western Norway, and decreases to less than 25 mm in southern and central Spain and is about 100 mm over large part of Western Europe (Europe's water: an indicator based assessment, EEA, 2003).

2.2 Groundwater

Groundwater represents the largest single source of freshwater in the hydrological cycle (about 95 % globally), larger in volume than all water in rivers, lakes and wetlands together. In gen-

eral, groundwater is of good quality because of natural purification processes and very little treatment is needed to make it suitable for human consumption unless in the case of high natural occurrence of toxic substances.
Natural underground reservoirs can have an enormous storage capacity, much greater than the largest man-made reservoirs; they can supply “buffer storage” during periods of drought. In addition, groundwater provides base flow to surface water systems, feeding them all through the year. Thus, groundwater quality has a direct impact on the quality of surface waters as well as on associated aquatic and terrestrial ecosystems.
Groundwater represents the portion of precipitation that infiltrates into the land surface, entering the empty spaces between soil particles or fractured rocks; the larger the soil particles, the larger the empty spaces, and the greater the potential for water infiltration.
Groundwater systems are dynamic. Water is continuously in motion; its velocity is highly variable, ranging from a few meters per year to several meters per day. Many aquifer systems possess a natural capacity to attenuate and thereby mitigate the effects of pollution. The soil purifies the infiltrating water in three different ways. It serves as a physical filter retaining particles like a sieve. Secondly, pollutants undergo chemical conversion through contact with soil minerals. Furthermore, the surface layer of the soil supports intense microbial life; bacteria break down certain undesirable substances, neutralizing them.
Although groundwater is not easily contaminated, once this occurs, it is difficult to remediate. Therefore, it is important to identify which aquifer systems are most vulnerable to degradation. The replacement cost of a failing local aquifer will be high and its loss may stress other water resources serving as substitutes.

Groundwater abstraction
In some regions the extent of groundwater abstraction exceeds the recharge rate, thus leading to over-exploitation. In Europe, the share of groundwater needed at the country level to meet the total demand for freshwater ranges from 9 % up to 100 %. In the majority of countries, however, total annual groundwater abstraction has been decreasing since 1990. The vulnerability of an aquifer to overexploitation depends on its type, the climate, the hydrological conditions, and the uses of water. The rapid expansion in groundwater abstraction over the past 30 to 40 years has supported new agricultural and socio-economic development in regions where alternative surface water resources are insufficient, uncertain or too costly.
Over-abstraction leads to groundwater depletion, with consequences like landscape desertification, deterioration of water quality (e.g. saltwater intrusion), loss of habitats (e.g. wetlands), modification of river/aquifer interactions, and ground subsidence.

Aquifer recharge
Natural aquifer recharge (from rain or surface water infiltration) is vital in order to maintain the groundwater and to replenish the discharges from the aquifer with a good quality water resource, but in many cases is quite impossible to grant a sustainable groundwater level only considering natural recharge. In many areas of the world, aquifers that supply drinking-water are being used faster than they recharge. Not only does this represent a water supply problem, it may also have serious health implications. Moreover, in coastal areas, aquifers containing potable water can become contaminated with saline water if water is withdrawn faster than it can naturally be replaced. The increasing salinity makes the water unfit for drinking and often also renders it unfit for irrigation. To remedy these problems, some authorities have chosen to recharge aquifers artificially with treated wastewater, using either infiltration

or injection. Aquifers may also be passively recharged (intentionally or unintentionally) by septic tanks, wastewater applied to irrigation and other means. Artificial recharge is the planned, human activity of augmenting the amount of groundwater available through works designed to increase the natural replenishment or percolation of surface waters into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction.

2.3 Reservoir Stocks

The use of storage reservoirs helps to overcome the uneven distribution of natural water resources. Runoff in the wet season can be held back and used in the dry season (seasonal regulation), and water available in wet years can be stored and used in dry years (interannual regulation). The beneficial aspects of reservoirs in safeguarding water resources and supplies have to be balanced against the significant impacts that their construction and subsequent operations have on natural landscapes and ecosystems.
The predominant functions of reservoirs in Europe are storage for hydroelectric power production, public water supply, and irrigation. Water is not always available to meet demands. In particular, water for urban use must be guaranteed and irrigation demands often need to be met during the dry season, when river discharges are at their annual lowest level. Water storage by reservoirs helps to overcome this temporal unavailability of freshwater resources. In Europe, approximately 13 % of mean annual runoff is stored by dams. It represents a significant increase in the standing stock of natural river water, with residence times in individual reservoirs of less than one day to several years.
The countries with the highest percentage of stored water volume in relation to their annual renewable freshwater resources (over 20 %) are Turkey, Spain, and Cyprus. These countries also use the highest percentage of their resources for irrigation. This activity demands the largest water volumes in the driest seasons, requiring winter storage. Spain and Cyprus are considered to be water stressed, whilst Turkey has low water stress. In many countries such as Austria, Finland, France, Greece, Ireland, Italy, Norway, Portugal, and Sweden the majority of large reservoirs are used for hydropower production. In particular, the primary purpose of major reservoirs in Sweden and Norway is almost exclusively for hydroelectricity (EEA, 1999).

2.4 Non - Conventional Resources

With increasing pressure on natural freshwater in parts of the world, other sources of water are growing in importance. These non-conventional sources of water represent complementary supply sources that may be substantial in regions affected by extreme scarcity of renewable water resources. Such sources are accounted for separately from natural renewable water resources. They include:
- the production of freshwater by desalinization of brackish or saltwater (mostly for domestic purposes),
- the reuse of urban or industrial wastewaters (with or without treatment), which increases the overall efficiency of use of water (extracted from primary sources), mostly in agriculture but increasingly also in industrial and domestic sectors. This category also includes agricultural drainage water.

Desalinization

Initially sea-water desalinization technologies were based on distillation; hence energy consumption was very high. The development of more efficient technologies (such as inverse osmosis) has reduced the cost of desalinization considerably (below 1 /m^3). However, this technique still tends to be considerably more expensive than supply from conventional sources (surface water and groundwater). Desalinization of sea water or brackish groundwater is therefore mainly applied in places where no other sources are available. Sea-water desalinization in Spain accounts for about 0.22 km^3/year. Although this volume is small in comparison to total renewable water resources in the country (111 km^3/year), it represents a significant share of resources in the areas where this technology is applied (mainly the Canary and Balearic Islands). In Greece, five desalinization plants are in operation, all of them on islands.

Desalinization can produce the degradation of coastal habitats like Posidonia sea-grass if the concentrated salt is not released adequately.

Water reuse

Water reuse is the use of wastewater or reclaimed water from one application such as municipal wastewater treatment for another application such as landscape watering. The reused water must be employed for a beneficial purpose and in accordance with applicable rules (such as local ordinances governing water reuse). Factors that should be considered in an industrial water reuse programme include (Brown and Caldwell, 1990):

- identification of water reuse opportunities,
- determination of the minimum water quality needed for the given use,
- identification of wastewater sources that satisfy the water quality requirements,
- determination of how the water can be transported to the new use.

Tab. 3 - Water recycling and reuse definitions

Definition	
Reclaimed water	Treated wastewater suitable for beneficial purposes such as **irrigation**
Reuse	Utilization of appropriately treated wastewater (reclaimed water) for some further beneficial purpose
Recycling	Reuse of treated wastewater
Potable substitution	Reuse of appropriately treated reclaimed water instead of potable water for non potable applications
Non-potable reuse	Use of reclaimed water for other than drinking water, for example, **irrigation**
Indirect recycling or indirect potable reuse	Use of reclaimed water for potable supplies after a period of storage in surface or a groundwater
Direct potable reuse	conversion of wastewater directly into drinking water without any intermediate storage

In terms of quantitative water resources management, the reuse of wastewater or reclaimed water is beneficial because it reduces the demand for surface and groundwater. The greatest benefit of establishing water reuse programmes might be their contribution in delaying or eliminating the need to increase potable water supply and the capacity of water treatment facilities, and in reducing the costs of long sea outfall pipes to dispose of wastewater.

Main applications of this technique can be found for irrigation in agriculture, parks, recreational areas, golf courses, etc. Usually, simplified water treatment is carried out, in order to guarantee minimum quality standards of the water to be reused. Few studies and data about the reuse of wastewater are available, and further research is needed to assess the long-term effects of irrigation with treated wastewater on soils and agriculture.

In France, wastewater reuse has become a part of regional water resources management policies. It is practised mostly in the southern part of the country and in coastal areas, compensating local water deficiencies. In Portugal, it is estimated that the volume of treated wastewater is around 10 % of the water demand for irrigation in dry years, and that between 35’000 ha and 100’000 ha could be irrigated with treated wastewater. In Spain, the total volume of wastewater reclaimed amounts to 0.23 km^3/year, being used mainly for irrigation in agriculture (89 %), recreational areas and golf courses (6 %), municipal use (2 %), environmental uses (2 %), and industry (1 %).

Water recycling

Reuse of water for the same application for which it was originally used. Recycled water might require treatment before it can be used again.

Rainwater harvesting

For centuries, people have relied on rainwater harvesting to supply water for household, landscape, livestock, and agricultural uses. Before large centralized water supply systems were developed, rainwater was collected from roofs and stored on site in tanks known as cisterns. A renewed interest in this approach has emerged due to the escalating environmental and economic costs of providing water by centralized water systems or by well drilling, and the potential cost and energy savings associated to rainwater collection systems which are a source of water.

The use of reclaimed water is quite different between two regions: in southern Europe, reclaimed wastewater is reused predominantly for agricultural irrigation (44 % of the projects) and for urban or environmental applications (37% of the projects); in nouthern Europe, the uses are mainly for urban or environmental applications (51% of the projects) or industrial (33% of the projects).

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3 IRRIGATION IN THE MEDITERRANEAN REGIONS

The amount of water involved in agriculture is significant and most of it is provided directly by rainfall. Since many regions do not get enough precipitation to grow crops, they depend on 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. The scale and importance of irrigation in Europe 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. Irrigable areas increased from 1990 to 2000, with grain maize as the most important irrigated crop. In parallel, the water allocation rate decreased slightly between 1990 and 2000 (from 6 578 to 5500 m?/ha/year).

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.

Irrigation is also the source of a number of environmental concerns, such as over-abstraction of water from subterranean aquifers, irrigation driven erosion, soil salinisation, alteration of pre-existing semi-natural habitats; and, secondary impacts arising from the intensification of the agricultural production permitted by irrigation.

The environmental impacts of irrigation vary considerably between countries and regions. Irrigation can affect the environment through impacts on water quantity (e.g. lowering the groundwater table and affecting river flow), water quality through increased content of salts and pollutants, and soil, biodiversity and landscapes. Secondary impacts such as increased fertiliser and pesticide use also result from irrigated agriculture.

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.

There is a clear north-south division 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.

3.1 Overview of irrigation among the Mediterranean countries

The scale and importance of irrigation is most significant in the member countries or regions that have arid climates, but far from negligible in most other member countries. In arid countries such as Cyprus, Malta, Greece, parts of Spain, Portugal, Italy and Turkey, irrigation accounts for more than 60 % of water use. In the more humid and temperate member countries irrigation is carried out mainly to complement natural rainfall, and its share of total water use is generally less than 10 %. In the EU-15, 85 % of irrigated land is in the Mediterranean area (France, Spain, Italy, Portugal, and Greece). In the acceding and the new 10 countries, the major part (93 %) is in Romania and Turkey.

Tab. 4 - European countries with large water use for irrigation (2001)

Country	Total water extractions (hm^3)	Irrigated land (1000 ha)	Irrigation water (hm^3)
France	33500	2200	4800
Germany	40400	490	620
Greece	8900	1450	7700
Hungary	5600	210	500
Italy	56200	2700	25850
Poland	11600	100	1030
Portugal	9900	650	8770
Spain	37700	3650	24600
United Kingdom	15900	110	1900
Bulgaria	5800	800	870
Romania	7300	2670	1020
Turkey	39800	4500	31000
Total Europe	291900	21170	109470

Source: EEA (2005), INE (2005), IFEN (2005).

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.
Traditionally, much of the irrigation in Europe has consisted of gravity-fed systems. However, in an increasing number of regions in the north and south, irrigation by sprinklers using pressure, often drawing water from groundwater, is the most common practice. It is often in these areas that the quantities of water used, and thus the impacts on the environment, are the largest (IEEP, 2000).

3.2 Moving from old to modern irrigation technologies

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.

Tab. 5 - Types of Irrigation by MIPAIS partners

Partner	Technical	Water source	Timing	Crop types
Italy	Sprinklers 33% Flooding 4% Gravity 51% Drip irrigation 10%	Ground 28% surface 72% Groundwater in north, surface in south with some groundwater in coastal areas	Mainly permanent in South, support in north	Olives, vines, fruit trees, field crops, horticulture Cereals, maize, rice
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 rain-water, 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	Mainly gravity Increasingly sprinklers and drip systems	Surface Surface and round	Permanent Permanent	I Intensive S/I/R: Semi, Intensive, and rice
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%

Sources: Expert/official responses to IEEP questionnaire, 1999

Traditional **surface irrigation** is the most popular method. Water is pumped or brought to the fields and allowed to flow along the ground among the crops. This method is simple and cheap, and is widely used. The problem is that about one-half of the water used ends up not getting to the crops.
Sprinkler irrigation is a method of applying irrigation water which is similar to natural rainfall. Water is distributed through a system of pipes usually by pumping. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.
Micro irrigation includes all methods of frequent water application, in small flow rates, on or below the soil surface. The terms “drip”, “trickle” and “spray” irrigation, common in many quarters in the last 15 years, have been supplanted by the term “micro irrigation”.
For irrigating fruits and vegetables, drip irrigation is more efficient. Water is sent through plastic pipes with holes that are either laid along the rows of crops or even buried along their rootlines. Evaporation is low, and water is saved when compared to flood irrigation.

<u>Surface irrigation</u>
“Surface irrigation is defined as the method of irrigation in which water is applied to the land by allowing it to flow by simple gravity before infiltrating. It applies various systems depending upon the relative magnitude of the surface flooding phase and infiltration phase after accumulation.” (Source “AQUASTAT Glossary & ICID Water Dictionary”)
“Flood irrigation is defined as the method of surface irrigation in which water is swiftly taken towards one or more storage basins where it is collected before infiltrating into the soil. It includes all types to make use of rising water from flood for inundating areas without major structural works, e.g. flood recession, spate irrigation, and wild flooding.”(Source “AQUASTAT Glossary & ICID Water Dictionary”)
The term flood irrigation is used differently in different geographical regions. In some places, flood irrigation refers to any surface irrigation method, it may also refer specifically to contour-levee irrigation typical of rice paddies, various forms of wild flooding, or level basin irrigation. The use of this term is not recommended since it has such varied interpretations.
Either the entire field is flooded (*basin irrigation*) or the water is fed into small channels (*furrows*) or strips of land (*borders*).
– Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides. Trees can also be grown in basins, where one tree is usually located in the middle of a small basin. In general, the basin method is suitable for crops that are unaffected by standing in water for long periods (e.g. 12-24 hours). Basins are flat areas of land, surrounded by low bunds. The bunds prevent the water from flowing to the adjacent fields.
– Furrows are small channels, which carry water down the land slope between the crop rows. Water infiltrates into the soil as it moves along the slope. The crop is usually grown on the ridges between the furrows. This method is suitable for all row crops and for crops that cannot stand in water for long periods (e.g. 12-24 hours).
– Borders are long, sloping strips of land separated by bunds. They are sometimes called border strips.

<u>Sprinkler irrigation</u>
“Sprinkler irrigation” is defined as the method of irrigation under pressure in which water is sprinkled in the form of artificial rain through lines carrying distribution components: rotary

sprinklers, diffusers with permanent water streams, perforated pipes. (*Source "AQUASTAT Glossary & ICID Water Dictionary"*).
Sprinkler irrigation is similar to natural rainfall. Water is pumped through a pipe system and then sprayed onto the crops through rotating sprinkler heads. It is then sprayed into the air through sprinklers so that it breaks up into small water drops which fall to the ground. The pump supply system, sprinklers and operating conditions must be designed to enable a uniform application of water.
A typical sprinkler irrigation system consists of the following components: pump unit, mainline and sometimes submainlines, laterals, sprinklers. The main objective of a sprinkler system is to apply water as uniformly as possible to fill the root zone of the crop with water.
Some of the most common sprinkler systems are: center-pivot and wheel line

Center-pivot
This self-propelled sprinkler system rotates around the pivot point and has the lowest labor requirements of the systems considered. It is constructed using a span of pipe connected to moveable towers. It will irrigate approximately 130 acres out of a square quarter section. Center pivot systems are either electric, water, or oil-drive and can handle slopes up to 15 percent. Sprinkler packages are available for low to high operating pressures (25 to 80 psi at the pivot point). Sprinklers can be mounted on top of the spans or on drop-tubes which put them closer to the crop. The speed of the rotation controls the water application amount. Center pivots are adaptable for crops of any height and are particularly suited to lighter soils. They are generally not recommended for heavy soils with low infiltration rates.

Wheel line
It is an irrigation system that moves through a field, from one set position to another, under its own power. The primary element of this system consists of the Lateral Wheel Line, the Power Mover and the Mainline.
The lateral wheel line is composed of 4" or 5" (101.6mm or 125mm) thick-wall aluminum irrigation pipe with large wheels attached so that it may be rolled through the field (above the crop) automatically. Each section of pipe has one wheel attached at its center, and each length may be quickly connected to an adjoining length by a special torque coupler and clamp band. Simply connect as many lengths of pipe as are needed to cross the field (up to 805m). At each torque coupler joint is a rotating impact sprinkler head and a self leveler which automatically keeps the sprinkler head in a steady upright position.
The power mover is located in the center of the rolling lateral wheel line. By means of an air-cooled gasoline engine geared to rotate the pipe (like an axle), the entire lateral wheel line may be moved across the field by a single person.
The mainline transports water from the pump to the field. It is a pipeline perpendicular to the lateral wheel line located either in the center or along one entire edge of the field. Every 50' or 60' (15.24m or 18.29m) along the mainline are outlet valve stubs from which a flexible pipe or hose is used to connect the water source from the mainline to the lateral wheel line.
Once the actual wheel line (lateral & power mower) is placed in the field, a flexible connection is attached between one end of the lateral wheel line and the first mainline outlet valve (valve stub). The water is then turned on with a special Valve Opener and the first section of the field is sprinkled for the required amount of time (determined by the crop and soil). When it is time to move the lateral wheel line to the next station (50' or 0'/15.24m or 18.29m), the operator simply turns off the mainline valve and allows the lateral line to automatically drain

itself of water via pressure activated flapper type drain valves located at each pipe connection. (a wheel line must never be moved with water in the lateral pipe line.) When the flexible water source is disconnected, the operator then starts the power mover and the entire line is driven down the field to the next mainline valve position. At the next valve, the flexible water source is reconnected, the water is turned on, the pressure automatically closes the drain valves, and the sprinkling procedure is repeated.
Once the wheel line reaches the end of the field, it is put into reverse power back to the beginning of the field where the cycle is repeated.

Micro-irrigation

The term "micro-irrigation" describes a family of irrigation systems that apply water through small devices. These devices deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone.
Ideally, the volume of water is applied directly to the root zone in quantities that approach the consumptive use of the plants. Through good management of the micro irrigation systems the root zone moisture content can be maintained near field capacity throughout the season providing a level of water and air balance close to optimum for plant growth. In addition, nutrient levels which are applied with water through the system can be controlled precisely. During the dry season in humid areas, or in arid climates, micro irrigation can have a significant effect on quality and quantity of yield, pest control and harvest timing.
In micro irrigation systems, water is distributed using an extensive hydraulic pipe network that conveys water from its source to the plant. Outflow from the irrigation system occurs through emitters placed along the water delivery (lateral) pipes in the form of droplets, tiny streams or miniature sprays. The emitters can be placed either on or below the soil surface. In general micro irrigation systems are classified by the type of emitter used in the system. These are drip, bubbler, spray jet, and subsurface.
Emitters can vary from sophisticated, constant-flow-rate at variable pressure types of devices (pressure compensating emitters) to very small, simple orifices. A large number of different types of emitters have been developed in attempts to find a perfect one. The main objective is to assure uniformity of water distribution.
Due to the manner in which water is applied by a micro irrigation system, only a portion of the soil surface and root zone of the total field is wetted. Water flowing from the emitter is distributed in the soil by gravity and capillary forces creating the contour lines, often referred to as "onion" patterns. The exact shape of the wetted volume and moisture distribution will depend on the soil texture, initial soil moisture, and to some degree, on the rate of water application.
Irrigation water requirements can be smaller with micro irrigation when compared with other irrigation methods. This is due to irrigation of a smaller portion of the soil volume, decreased evaporation from the soil surface, and the reduction or elimination of the runoff. The losses due to the evaporation from the soil are significantly reduced compared with other irrigation systems since only a small surface area under the plant is wetted and it is usually well shaded by the foliage. Since the micro irrigation system allows for a high level of water control application, water can be applied only when needed and deep percolation can be minimized or avoided.

Micro-spray irrigation

Spray-jets cover greater areas with water (diameters of coverage from 3 to 20 feet). Thus, fewer emission devices may be required to irrigate certain landscaped areas by using spray-jets rather than drippers. Various spray patterns are also available depending on the type of spray-jet used to accommodate the different landscape designs. In addition, flow rates of spray-jets are greater than drippers, 10 to 20 gallons per hour (gph) versus 0.25 to 2.0 gph.

Spray jets can also be easily observed while operating, thus allowing inspection for clogging, misting, proper spray orientation, or some other distortion of the discharge. However, plant branches and foliage can easily distort spray patterns, possibly necessitating placement of the sprayer above the canopy on a stationary or pop-up riser. Micro-sprayers emit water from an orifice onto a deflector plate and creates a fan type of water distribution pattern (fan-jet) with fine water droplets. In general, fan-jets have performed well when used for directional sprays and confined area applications. The addition of shaping vanes (spokes) to the deflection area creates streams of water which are less susceptible to distortion, and result in spoke-shaped application patterns (spoke-jets). These work well as single tree emitters and can be fitted with deflection caps to confine the application to smaller diameter areas (2 to 5 feet) limiting use in the landscape to large trees and shrubs. Applications to sandy soils result in dry areas between "spokes" which could result in poor growth of small plants in those areas. Some manufacturers have added spinner devices to create a sprinkler effect. These "micro-sprinklers" have more uniform water distribution than the fan-jets or spokejets and can provide excellent water coverage. Regular inspection and maintenance are not difficult for the homeowner or landscape manager.

Drip-irrigation

Drip irrigation is the slow, even application of low pressure water to soil and plants using plastic tubing placed directly at the plants root zone. This method is suitable for cultivation of edible (grapes, fruits, and vegetables) and ornamental (nursery stock) plants with high commercial value. This system may be used not only to increase soil moisture but to apply fertilizers and micronutrients as well.

Drip irrigation systems allow the more efficient use of water in agriculture. Water in the system is distributed directly to each cultivated plant and dosed in a controlled manner by drippers. The high efficiency of drip irrigation results from two primary factors. The first is that the water soaks into the soil before it can evaporate or run off. The second is that the water is only applied where it is needed, (at the plant's roots) rather than sprayed everywhere. The method is fully compatible with traditional methods of irrigation used in southern parts of Europe.

The main components of such a system include the sprinkler lateral and its parts; the dripper lines; a pressure compensator; pressure and water quantity metering instruments; water treatment facilities and fertilizer injectors; and, automation systems, if used. The most refined technologies have an integrated multi-system controller, including computerized micro-climate weather monitoring sensors, humidity and temperature sensors, and computerized control of rates of irrigation and fertilization. This technology provides precision irrigation monitoring, accurate irrigation direct to the point of greatest water need, and controlled fertilization.

Depending on the size of the irrigation scheme and complexity of the system design, the principle operating requirements include standard control, repair, and adjustment procedures. System design parameters should be planned on the basis of climatic data, physiographical relief, hydrological data, soil conditions, type of cultivation, crop water demand, and irrigation times. Such data will allow the system to be adequately sized for the particular application.

Advantages: this technology improves the growth rates of high value crops by delivering moisture directly to their root zones. This saves water because only the important part of the plants are irrigated. Weed growth is reduced since only the plant is irrigated, and working between the

plants is easier because of the dry soil. This technology can be used in hilly terrain, and is not labour-intensive as it can be automated. The technology can be adapted to use energy-saving components.
Disadvantages: the technology is not well suited to machine-based cultivation, as the machinery may damage the pipelines. If not properly applied or monitored, these systems can increase the salt concentration of certain soils and result in over-irrigation. The capital costs of the equipment needed to employ this technology may be higher than those for surface or sprinkler irrigation systems. Drip irrigation also suffers from the tendency for the drippers to become stopped up easily.

New techniques

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. Knowledge and technologies that exist to provide for a more efficient use of water in irrigation need that appropriate quality control of equipments and management tools be enforced to support farmers in modernizing the systems

Deficit irrigation

Water stress affects crop growth and productivity in many ways. Most of the responses have a negative effect on production but crops have different and often complex mechanisms to react to shortages of water. Several crops and genotypes have developed different degrees of drought tolerance, drought resistance or compensatory growth to deal with periods of stress. The highest crop productivity is achieved for high-yielding varieties with optimal water supply and high soil fertility levels, but under conditions of limited water supply crops will adapt to water stress and can produce well with less water.
In the context of improving water productivity, there is a growing interest in *deficit irrigation*, an irrigation practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. Under conditions of scarce water supply and drought, deficit irrigation can lead to greater economic gains than maximizing yields per unit of water for a given crop; farmers are more inclined to use water more efficiently, and more water-efficient cash crop selection helps optimize returns. However, this approach requires precise knowledge of crop response to water as drought tolerance varies considerably by species, cultivar and stage of growth.
Some practices for deficit irrigation are briefly described here below:

Regulated Deficit Irrigation (RDI)

RDI is the practice of using irrigation to maintain plant water status within prescribed limits of deficiency with respect to maximum water potential for a prescribed part of a seasonal cycle. The aim is to control vegetative growth and to improve water use efficiency. The rewetting frequency is determined by detection or prediction of a decrease in plant water status (Kriedemann and Goodwin 2003).
With RDI, trees are kept short of water when fruit growth is slow or after harvest but are given ample water during the time of rapid growth of fruit. This reduces the growth of shoots. If RDI is properly managed, there is no reduction in the size of fruit or yield; in fact, both may

increase - such results have been achieved. The reason why the above technique works relates to the growth pattern of shoots and fruit. On most deciduous fruit trees, the shoots grow rapidly early in the season, and their growth slows down as the fruit begins to grow rapidly. In contrast, early in the season the fruit grows slowly. Water stress at this time will reduce the growth of shoots without markedly affecting the growth of fruit.
With RDI, the irrigation season can be divided into four periods. The duration of these periods is determined by both weather and the relationship between vegetative growth and the growth of fruit.

Partial root zone drying (PRD)
Partial rootzone drying (PRD), as the name suggests, is the creation of simultaneous wet and dry (or drying) areas within the root zone. Only part of the root zone is irrigated and kept moist at any one time. PRD is implemented by irrigating one side of the plant row and allowing the other side to dry out. The irrigations are then alternated to the dry side after a set period of time and then back and forth thereafter after the same period of time.

Subsurface drip irrigation (SDI)
Traditional drip irrigation is found above ground, subsurface irrigation allows the precise application of water, nutrients and other agro- chemicals directly to the root zone of plants. This allows the farmer to optimize the growing environment and leads to higher quality and quantity crop yields. The depth and placement of subsurface driplines is determined by the soil composition and the crop needs. An efficient installation has water moving by capillary action at a depth of 4 to 30 inches beneath the surface, forming a continuous wetted area along the plant rows. Frequent irrigation cycles (several times daily) maximize capilllary action and minimize water surfacing.
The goal is to maintain soil moisture content at a level which is optimal for plant growth and root development. Therefore, it is important that irrigation with SDI be scheduled using devices such as evaporation pans soil moisture measuring equipment, or weather stations as opposed to fixed schedules based on something other than crop needs.

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4 DROUGHT AND WATER SCARCITY

"Drought" is a normal, recurrent feature of climate, although often erroneously considered an unexpected and extraordinary event. It occurs in virtually all climatic zones, but its characteristics vary significantly from one region to another. Drought is a temporary aberration within the natural variability and can be considered an insidious hazard of nature; it differs from aridity which is a long-term, average feature of climate.
High air temperatures and evapotranspiration rates may act in combination with lacking rainfall to aggravate the severity and duration of a drought event. High air temperatures in summer, when associated with clear skies and sunshine, increase evapotranspiration to the extent that little or no rainfall is available for groundwater or river recharge.
It is important to differentiate between aridity, which is restricted to low rainfall regions as a long-term average feature, and a drought situation that indicates a deviation from the average situation, but still within the ecosystem's natural variability. It is very important to discern among transitory periods of water deficiency, a cause of exceptional droughts, and long-term imbalances of available water resources and demands, as reflected in figure 3.

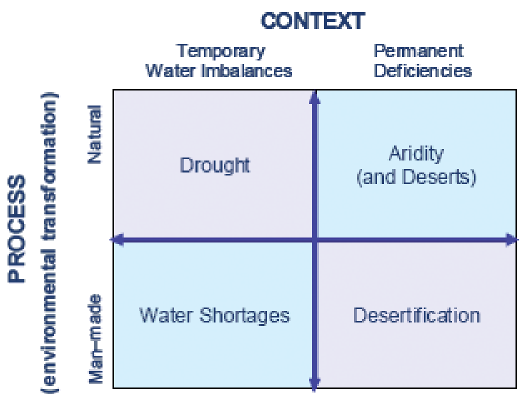

Fig. 3 - Typology of water stress condition (Vlachos, 1982).

The operational definitions of drought are categorized in terms of four basic approaches to identify and describe drought events: *meteorological*, *hydrological*, ***agricultural***, and *socio-economic* droughts. The first three approaches consider a drought as a natural, physical phenomenon. The latter one regards a drought event in relation to anthropogenic supply and demand, thus tracking the effects of water shortfall as it passes through the socio-economic system.
The above indicated stages of drought appear and disappear in sequence as a cycle (fig. 4), and the previous conditions re-establishment in different stages are not immediate.
In this regard, it is likely that the natural system, having evolved in the face of climatic fluctuation and change, will be capable of maintaining its integrity and production potential during and after the next episode of unfavorable climate.
At moment drought is unpredictable and can only be monitored. Weather forecast does not mean drought prediction even in the case of meteorological drought.
ISPRA provide a continous phenomenon monitoring through its Drought Bullettin available on the web site.

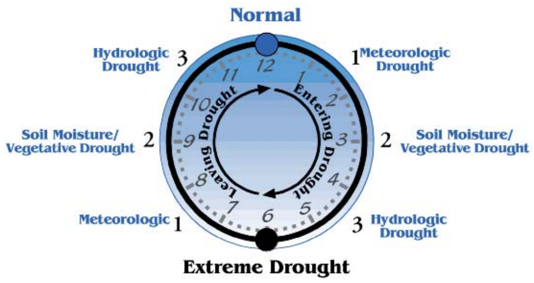	This graphic explains the stages of drought, which typically appear and disappear in sequence. As you see, an end to meteorologic drought does not necessarily translate to an end of soil moisture/vegetative or hydrologic droughts.

Fig. 4 - Stages of drought cycle
Source: TWDB http://www.twdb.state.tx.us/home/index.asp

An imbalance in water supply and demand is a situation where there is insufficient water to satisfy long-term average requirements. Populations with normally high levels of consumption may experience temporary scarcity more severely than other societies who are accustomed to use much less water.
The term "*water scarcity*" has the following specific meanings:
- an imbalance of supply and demand under prevailing institutional arrangements and/or prices,
- an excess of demand over available supply,
- a high rate of utilization compared to available supply, especially if the remaining supply potentials are difficult or costly to tap.

Some causes of water scarcity are natural, others are anthropogenic. The impact of natural processes can be aggravated by human responses. Human behaviour can modify our physical environment in a way that the availability of usable water resources is reduced. The demand for water may be artificially stimulated, so that at a constant rate of supply the resource becomes "scarce".
With respect to water management related to agricultural production there are broadly speaking three agro-climatological zones, being: temperate humid zone, arid and semi-arid zone and humid tropical zone.
In addition, in principle, four types of cultivation practices may be distinguished, being:
? rainfed cultivation, without or with a drainage system;
? irrigated cultivation, without or with a drainage system.
Dependent on the local conditions different types of water management with different levels of service will be appropriate. In drought prone regions agriculture is normally impossible without an irrigation system. Drainage systems may be applied for salinity control and the prevention of waterlogging.
Moreover, there has been a recent large-scale introduction of irrigation in same cultivations that were traditionally not irrigated. In fact, recently irrigation has been recognized as constructive in order a) to increase yields and quality of cultivations traditionally grown under dry soil conditions b) to allow high-density orchards and c) to expand production into regions where there is not enough rainfall to otherwise support the crop.

4.1 Water scarcity and vulnerability to drought cycles in the Mediterranean countries

The Mediterranean basin is 3 800 km long and 400 to 740 km wide. It takes 90 years for the water in this sea to be completely renewed. Hence, it is especially susceptibility to pollution.

The population is between 150 and 250 million.
The Mediterranean region has diverse climatic conditions with generally low and highly variable annual rainfall and high degree of aridity, particularly in south-eastern parts of the basin. The typically prevailing climatic conditions are characterized by extended periods of dry spells and wet periods with a regime of irregular precipitation, with flash flood, associated with low probabilities of occurrence.
Interannual rainfall variability is also high, within the range of 25-50 percent in subhumid and semi-arid parts to 50-100 percent in the arid and hyper-arid zones (UNESCO, 1979). As a result of aridity and rainfall variability, the region is extremely vulnerable to drought.

> Drought is a normal, recurrent feature of climate. Droughts generally result from a combination of natural factors that can be enhanced by anthropogenic influences. The primary cause of any drought is a deficiency in rainfall, and, in particular, the timing, distribution, and intensity of this deficiency in relation to the existing water storage, demand, and use.

In the Mediterranean, drought is a naturally occurring phenomenon and a normal part of climatic variability. The Mediterranean climate is characterised by the rainfall pattern. The maximum rainfall is in the autumn or winter, but rainfall is always low in summer when the heat is greatest. Vegetation is therefore particularly capable of adapting to periods of drought. From the north to the south these periods of drought are increasing. Drought is a recurring event that has strongly influenced the physical, natural and human features of the Mediterranean region over the millennium. The vulnerability to drought in different Mediterranean countries depends on the national aridity and drought management policies. Drought effects may be environmental, social, economical, national, strategic, etc.
When less rain falls than usual, there is less water to maintain normal soil moisture, stream flows, and reservoir levels and to recharge ground water. Falling levels of surface waters create unattractive areas of exposed shoreline and reduce the capacity of surface waters to dilute and carry municipal and industrial wastewater. Water quality often decreases as water quantity decreases, adversely affecting fish and wildlife habitats. In addition, dry conditions make trees more prone to insect damage and disease and increase the potential for grass and forest fires.
Many economic activities, especially in Southern Europe (e.g. tourism), depend on available water. Shortages in water availability directly affect the economic performances. Hence, adaptation measures to address these adverse impacts are important in the Mediterranean region.
Water scarcity can bring about the impoverishment of the land and other natural resources due to erosion, salinisation and loss of fertility caused by human activities and climate variation.
Than mismanagement of the drought inevitably leads to irreversible damage like desertification. This process differs from drought but represents the ultimate consequence of it if no timely adequate measure is taken.
As a natural hazard, drought imposes differential vulnerability on society and the compounded impact of hazard and vulnerability represents the risk associated with the drought event (Wilhite, 2000).
Nothing can be done to reduce the recurrence of the drought events themselves, consequently, drought management should not be regarded as managing a temporary crisis. Rather, it should be seen as a risk management process with emphasis on monitoring and managing emerging stress conditions and other hazards associated with climate variability.
International conventions and Institutions such as the World Bank and the International Water Forum all consider the area in need of special attention due to problems resulting from its vulnerability to drought and its requirements for better water management.

Drought events have regularly occurred in the last thirty years. The duration of each event, the area and population affected have been variable throughout this period.
Information provided by member States made it possible to identify severe events that yearly affected more than 800 000 km? of the EU territory (37%) and 100 million inhabitants (20%) in 1989, 1990, 1991 and more recently in 2003.

> Water scarcity occurs where there are insufficient water resources to satisfy long-term average requirements. It refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system.

The major problem in drought prone areas is of course the problem of the shortage of water. Water scarcity is one of the most challenging issues in the Mediterranean region, particularly in North Africa and Middle East countries, although some Mediterranean countries of Europe, notably Spain and Portugal, may also experience severe water shortages in the event of a drought.
Droughts in the Mediterranean cause water shortages for domestic, agricultural and industrial water use and low flows for hydropower and cooling water. The use of alternative resources and their overexploitation could increase the risk of water quality deterioration.
The EEA (European Environmental Agency) indicate the Water Exploitation Index (the mean annual total abstraction of freshwater divided by the mean annual total renewable freshwater resource at the country level, expressed in percentage terms) as an indication of how the total water demand puts pressure on the water resource and also it identifies those countries that have high demand in relation to their resources and therefore are prone to suffer problems of water stress.
Changes in the WEI help to analyse how changes in abstraction impact on freshwater resources by increasing pressure on them or making them more sustainable.
The WEI is part of the set of water indicators of several international organisations such as UNEP, OECD, EUROSTAT and the Mediterranean Blue Plan. There is an international consensus about the use of this indicator.
There are no specific quantitative targets directly related to this indicator. However, the Water Framework Directive (2000/60/EC) requires countries to promote sustainable use based on long-term protection of available water resources and ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status by 2015.
The warning threshold for the water exploitation index which distinguishes a non-stressed from a stressed region is around 20 %. Severe water stress can occur where the WEI exceeds 40 %, indicating strong competition for water but not necessarily enough extraction to trigger frequent water crises.
Data at the national level cannot reflect water stress situations at the regional or local level. The indicator does not reflect the uneven spatial distribution of resources and may therefore mask regional or local risks of water stress.
Caution should be used when comparing countries, because of different definitions and procedures for estimating water use (e.g. some include cooling water, other do not) and freshwater resources, in particular internal flows. Some sectoral abstractions, such as cooling water included in the industrial abstraction data, do not correspond to the specified uses.
Sectoral use of water does not always reflect the relative importance of the sectors in the economy of one country. It is rather an indicator of on which sectors the environmental measures need to focus in order to enhance the protection of the environment.
Data need to be considered with reservation due to the lack of common European definitions and procedures for calculating water abstraction and freshwater resources.

Although countries in the Mediterranean region are very different from one another, a common solution to all of them would be to improve the use of water in agriculture, which is the most important economic activity in these countries.

> *Agricultural drought*
> Agricultural drought occurs when there is not enough soil moisture to meet the needs of a particular crop at a particular time. Typically, agricultural drought happens after meteorological drought but before hydrological drought. Non-irrigated agriculture is usually the first economic sector to be affected by drought.

Agricultural drought links the various characteristics of meteorological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, and soil moisture deficits. Agricultural drought is largely the result of a deficit of soil moisture and is most commonly applied to non-irrigated agricultural regions. A plant's demand for water is dependent on prevailing weather conditions, biological characteristics of the specific plant and its stage of growth, as well as the physical and biological properties of the soil.

Water deficiency for agricultural production can lead to increases in irrigated cultivation or increased harvest failures (Martinez et al., 2003).

It is important to mention that the effects of droughts are different in irrigated and non-irrigated agriculture. In regions which rely on irrigation, the impacts of short lived agricultural droughts are usually lower than in regions where crops are not irrigated. Irrigated agriculture relies on stocks of water so if it doesn't rain, these crops still get the water they need (until the resevoirs run dry).

However, in non-irrigated agriculture crops depend directly on the rain as their water source. If it doesn't rain, the crops don't get the water they need to survive.

The rapid development of irrigation in several drought prone areas, especially when groundwater is being extracted by tubewells, has already in several instances resulted in the exhaustion of the resource and the requirement to stop with agricultural exploitation.

Aside of the problems of water shortages and the mining of groundwater and surface water resources there is also the problem of salinization, especially in irrigated areas.

Sustainable agricultural exploitation in the arid and semi-arid zone will require a careful water and salt management in a river basin context. Water saving techniques may result in larger cultivable areas, while water in these regions is the major constraint to sustainable agricultural exploitation.

4.2 Competition in the water sector and impacts of irrigation under drought conditions

Conflicts arise when waters are perceived as scarce resources, both in absolute terms, as physical shortages, or in relative terms, compatible with the development expectations by a State, by a community or a water users group. Conflicts can also arise when resources are not scarce but some uses are penalised or some stakeholders have difficult access with respect to their consuption needs.

The major sectors of human water use are: (a) domestic consumption; (b) industrial production; (c) agricultural production (including livestock); and (d) recreational uses.

Although domestic and industrial uses are usually associated with urban demand (and agriculture with rural demand), a closer look indicates that all of these uses cut across rural, peri-urban, and urban divisions and although agriculture is a predominantly rural activity, urban agriculture is also significant.

Most societies and national policies accord highest priority to water for direct human consumption, including drinking, cooking, bathing, and cleaning. Lack of access to sufficient water for drinking and bathing increases the spread of many water-borne and water-washed diseases, especially diarrheal and skin diseases. Furthermore, domestic water should be of good quality. Both bacterial and chemical contamination can also cause disease.

Defining basic human needs for water is difficult. However, domestic water demand is not simply a multiple of the population size. Per capita demand increases with urbanization and rising incomes.

Beyond domestic water needs, water is an input into the economic development process. Industrial production requires water, although the exact amount varies depending on the industry and the technology used. Because of the clustering of factories in cities, industrial demand forms a significant amount of urban water demand. However, a growing number of factories in rural areas also demand water. Industries not only require water for the manufacturing process itself but also for cooling or cleaning. This allows the possibility of recycling water in factories.

Since the chief aim of hydrological management has been to speed up economic development, water management plans are often not based on a comprehensive assessment of the full economic, social and cultural costs and benefits of alternative allocation strategies. Often, the resulting allocation is inadequately planned, inefficient, unsustainable and inequitable, discriminating against the urban and rural poor.

Agriculture is the largest water-consumption sector worldwide, especially in developing countries. Irrigation has been and will continue to be critical to achieving food security.

The increased food production needed to supply the growing urban and rural populations of the future will likely require even more irrigation: the International Water Management Institute (IWMI) estimates that 17 percent more water will be needed for irrigation by 2025 to meet food demand (IWMI, 2000).

Within the agricultural sector, crop production receives the greatest attention, but fish and livestock also require water. Animals (including fish) consume a relatively small volume of water in comparison to crop consumption and can produce a very high value of output (Bakker et al., 1999). Moreover, as worldwide demand for animal products increases the importance of supplying water for aquaculture and livestock is also likely to increase.

In terms of water quality, agricultural production does not require its water supplies to be as clean as those for domestic use but the sector is often a user of bulk volumes of high quality groundwater, resulting in intense competition with other users, usually to the detriment of domestic users but also of certain industrial sectors requiring relatively high quality water.

However, crop production is very sensitive to salinity levels and to some industrial pollutants. Treated sewage can actually provide nutrients to crops, but the danger from contamination depends on how and where the crops are used in the food chain (e.g., vegetables that are eaten fresh are most susceptible, followed by grain and tree crops; danger of contamination is least for fiber or fuel crops). Furthermore, continuous use of recycled sewage can lead to deposits of salt making the soil unproductive.

Agriculture is also a diffuse source of pollutants, from the extensive use of pesticides and fertilisers, and from turbidity and sedimentation from soil erosion through land clearance and tillage.

Providing water for utilitarian purposes (production and domestic consumption) alone is not enough; people also demand water for recreational and aesthetic purposes. Ornamental gardens, lawns, swimming pools, and golf courses may not be considered “essential” water uses, but demand for such uses rises with income levels. They thus need to be included in long-term plans for water supplies or managing water demand.

Furthermore ecosystems are increasingly being seen as a user of water resources in competition with other users, yet they are important providers and regulators of water resources, both in terms of availability and quality. Over-abstraction of water resources and pollution are having dramatic impacts on ecosystems. However, because of the paucity of data on the ecological and economic consequences of these impacts, the effects on ecosystem and riparian agriculture are often overlooked in water resource allocation decisions.

In sum, stereotypical images of "thirsty cities" that equate (a) urban demand with "drinking water" or factories, and (b) rural water supply with irrigation do not adequately portray the water uses in each area. Rural areas also need domestic water supply; and with rural industrialization, factories are increasingly drawing water (and discharging wastes) in rural areas. Nor should the water uses of urban agriculture and landscaping be overlooked.

When water scarcity arises, governments generally allocate water resources among sectors by assigning priorities and setting quantitative limits for each user.

Rather, social and political factors exert a major influence on these decisions. Because water supply is so vital to life as well as to livelihoods, its provision is critical for social stability and political legitimacy of governments. Thus, intersectoral competition for water cannot be understood without looking more closely at (a) the users and other stakeholders, (b) their power relations, and (c) the strategies they employ to secure their water demands.

Of all potential sectors forging the water demand, the irrigation sector is the most important one, while lower proportions go to industrial and municipal uses. Ecological demand is residual and the interest for manteinance of a minimum vital level for the river ecosystem is not often expressed; this is the reason why the wetland areas have decreased dramatically.

In the Mediterranean region the competition is caused by a scarcity and seasonality of water resources, and by an increased consuption rate, with highest peaks during the driest seasons, to respond to agricultural and tourist needs.

Competition for scarce water resources will increase in the Mediterranean basin in the coming decades and will seriously aggravate the existing shortage of water, according to a new study published today by the International Programme for Technology and Research in Irrigation and Drainage (IPTRID).

When agricultural drought comes on, in order to maintain the best equilibrium among the water sectors, the irrigation practices management become important. When water becomes scarce, farmers have two options: find new sources of irrigation water or find ways of minimizing irrigation demand.

Irrigation represents an alteration of the natural conditions of the landscape by extracting water from an available source, adding water to fields where there was none or little before, and introducing man-made structures and features to extract, transfer and dispose of water.

Irrigated agriculture depends on supplies from surface or ground water. The environmental impact of irrigation systems depends on the nature of the water source, the quality of water, and how water is delivered to the irrigated land.

Environmental impacts from irrigation can be of different types: aquifer exhaustion from over abstraction, salinization of groundwater, increased erosion of cultivated soils on slopes and water pollution by nutrients and pesticides. These impacts are not well documented in many EU member states but different case studies show that over-abstraction and salinization of aquifers occur in many parts of the Mediterranean coastline (Portugal, Spain, Italy and Greece) and some localized areas in northern Europe (the Netherlands) (Digital Atlas of Global Water Quality, UN GEMS/Water Programme). Soil erosion is particularly severe in Spain, Portugal and Greece. The desiccation of former wetlands and the destruction of former high nature value habitats are

significant in different regions of both southern and northern Europe (west France, inland Spain, Hungary and south-east England).
Managing irrigation scheduling in water scarcity condition is important but, poor irrigation scheduling will result in under - or over-watering. Over-watering has a direct impact on water resources at a time when they are at their lowest. Overwatering will also result in increased drainage during the growing season, which increase nitrate leaching to groundwater. Under-irrigation may conserve water resources, but by reducing nitrogen uptake by the growing plant, may increase the risk of winter nitrate leaching.
A good irrigation plan will set trigger deficits as high as possible and irrigation applications should leave sufficient storage capacity in the soil to allow for rainfall.
The major need for development of irrigation in areas of water scarcity is to minimise water use. Effort is needed to find attractive economic crops needing minimal water, to find and use application methods that minimise loss of water by evaporation from the soil or percolation of water beyond the depth of the root zone and to minimise losses of water from storage and delivery systems.

4.3 Irrigation management during periods of drought

Droughts, which often occur in the dry regions, amplify water management problems and require long-term measures to reduce the vulnerability of water systems and short-term measures to mitigate impacts of the drought. Water-resources management in arid and semi-arid regions is a complex, multifaceted task, because of the need to integrate many hydrological, environmental, economic, social, and managerial factors. The holistic approach is appropriate to providing all users of diverse sectors sufficient supplies of adequate water while ensuring environmental protection.
Successful water management aims to prevent water shortages in times of drought so that agricultural production does not suffer. Drought conditions require special attention to the timing and rate of irrigation, as well as the quality of the water being used. In fact, water shortage is man induced and is associated to problems such as soil erosion, land degradation, mainly through salinisation, over exploitation of soil and water resources, and water quality degradation.
Combating water shortage includes:

• Re-establishing the environmental balance in the use of natural resources
• Restoring the soil quality
• Minimising water wastes
• Combating soil and water salinisation
• Controlling water withdrawals
• Managing the water quality
(Pereira, 2003)

Coping with water scarcity requires measures and policies of water management that may be grouped into two main areas: **demand** and **supply management**.
Agricultural water-demand management relies on more efficient use of water, changes in agricultural production practices, and reduction of waste.
Adequate water-demand management in the agriculture sector requires structural incentives, regulations, and restrictions to help, guide, influence, and coordinate farmers' efforts in making

efficient use of water and encourage their adoption of innovative water-saving technologies. Agricultural water-demand management should have the achievement of the following as its guiding principles:

- Interaction of the quantitative, qualitative, and biological aspects of both ground- and surface water;
- Sustainability of irrigation and drainage schemes;
- Better water savings and reduced irrigation losses;
- Environmental sustainability;
- Improved economic return on irrigation;
- Institutional and human-resources capacity-building for the execution of management tasks; and
- Certain aspects of implementation, such as financing, monitoring, and control; farmer's participation; consideration of social and cultural issues; and technical facets of water use.
- To achieve efficiency and equity, a program of agricultural water-demand management would require development particularly in the following aspects:
- Economic incentives; and
- Irrigation efficiencies and water conservation.

Modeling irrigation management under drought conditions, aiming to select, improve, and/or develop the models to be used for determining appropriate irrigation scheduling at different levels of information availability with reference to different management objectives.
Demand management objectives for irrigation under water scarcity concern a reduction of irrigation requirements, the adoption of practices leading to water savings in irrigation, both reducing the demand for water at the farm, and an increase in yields and income per unit of water used. In fact, yield expressed in terms of production per unit of land has been the traditional measure of productivity in agriculture. But as water is a limited resource, production per unit of water has emerged as an important concept. For a farmer with a scarce supply, strategies to increase the productivity of water may lead to more income and better nutrition (Labhsetwar, 2003). The challenge is to produce more with less water (Oweis et al., 1999).
Issues for irrigation demand management refer to **irrigation scheduling** and **irrigation methods**, than a conjunctive approach is required (Pereira, 1996;1999). Irrigation scheduling is the farmers decision process relative to "when" to irrigate and "how much" water to apply to a crop (Martin et al., 1990). The irrigation method concern "how" that desired water depht is applied to the field. The crop growth phase, its sensitivity to water stress, the climatic demand by the atmosphere, and the water availability in the soil determine when to apply an irrigation. The frequency of irrigations depends upon the irrigation method. Both the irrigation method and the irrigation scheduling are inter-related (Smith et al., 1996).
To improve irrigation method requires the consideration of the factors influencing the hydraulic processes, the water infiltration and the uniformity of water application to the entire field.
Irrigation scheduling requires: monitoring moisture availability (crop stage of growth and vigour, air temperature and wind speed, rainfall or irrigation water applied and soil moisture) and calculations of daily crop water use or evapo-transpiration and soil water balances and water available to plants.

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5 THE EU POLICY CONTEXT

5.1 The Common Agricultural Policy

Born 50 years ago when the EU founder members had just come out from a decade of food shortages, the Common Agricultural Policy (CAP) began by subsidising production of basic foodstuffs in the interests of self-sufficiency and food security. Now the focus is on the role of agriculture in the preservation and management of our natural resources.

As the most fully integrated of EU policies, the CAP takes a large share of the EU budget. Nevertheless, this has dropped from a peak of nearly 70% of the EU budget in the 1970s to 34.9% of the budget for the 2007-2013 period, reflecting cost savings from reforms, a shift of some agricultural spending into rural development, which will take 9.7% of the budget over the same period, and expansion of the EU's other responsibilities.

The creation of a common agricultural policy was proposed in 1960 by the European Commission. It followed the signing of the Treaty of Rome in 1957, which established the Common Market.

By 1962, three major principles had been established to guide the CAP: market unity, community preference and financial solidarity. Since then, the CAP has been a central element in the European institutional system.

The initial objectives were set out in Article 33 of the Treaty of Rome:

- to increase productivity, by promoting technical progress and ensuring the optimum use of the factors of production, in particular labour;
- to ensure a fair standard of living for the agricultural Community;
- to stabilise markets;
- to secure availability of supplies;
- to provide consumers with food at reasonable prices.

In 1992, the MacSharry reforms (named after the European Commissioner for Agriculture, Ray MacSharry) were adopted to limit rising production, while at the same time to adjust it to the trend toward a more free agricultural market.

On 26 June 2003, EU farm ministers adopted a fundamental reform of the CAP, based on almost entirely "decoupling" subsidies from a particular crop. The new "single farm payments" are linked to respect for environment, food safety and animal welfare standards. The aim is to make more money available for environmental protection, quality or animal welfare programmes by reducing direct payments for bigger farms.

The most recent reform, in June 2003, constituted a major development in the CAP. It brought the following innovations:

- a single payment per holding for EU farmers, independent of production ("***decoupling***" of support);
- linking of these payments to compliance with standards relating to the environment, food safety, animal and plant health and animal welfare ("***cross-compliance***");
- a reinforced rural development policy, with reduction of direct payments to large farms in order to fund the new policy ("***modulation***");
- a financial discipline mechanism (placing a ceiling on market support expenditure and direct aid between 2007 and 2013).

The reform also includes a revamp of the policy of common organisation of markets under the CAP. Several sectors have already been reformed: tobacco, hops, cotton, olive oil and sugar.

5.2 EU Policy instruments for irrigation under drought conditions

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.

CAP offers a variety of instruments which can be used to counterbalance adverse climate effects although the CAP is primarily designed to support farmers' income or structural change in the agriculture sector and the broader rural economy.

Rural development policy in particular offers a number of measures related directly or indirectly to water issues, such as support to irrigation plans, infrastructure modernisation and incentives for water savings, or preventive measures and restoration after natural disasters. While climate change is not their primary driver, these measures could help to reduce vulnerability and facilitate adaptation to climate change.

In addition, the regulation underpinning future EU rural development policy in 2007–2013 already contains explicit references to the EU water policy and targets for climate change mitigation, as well as the need to anticipate the likely effects of climate change on agriculture production and policy.

According to the subsidiarity principle, in their rural development programmes Member States and regions can include the combination of measures most appropriate to their objectives, thus leading to a great diversity of strategies and levels of intervention. Mediterranean countries have usually devoted substantial investments and support to irrigation systems. Irrigation infrastructure may occasionally help to offset seasonal droughts, but it is mostly intended to solve the uneven distribution of rains across time and territories, with a view to ensure regularity in supply and higher added value for agriculture production.

The impacts of climate change on the agricultural sector will vary across Europe, and the adaptation efforts required will be different.

The challenges will be most pronounced for farmers in southern and parts of central Europe. Here, the projected reductions in water availability will seriously impact on crop yields. Reducing the dependence of farming systems on irrigation water will thus be a key issue for effective adaptation strategies. By contrast, regions at higher latitudes might also benefit from rising temperatures.

Funding through the CAP rural development policy has been applied in a number of ways to help address drought and water scarcity issues. The following national examples are focussed on maintaining and improving security of supply (including enhancing efficiency) and, more specifically, reducing pressures on water supplies.

In terms of improving efficiency, actions in Cyprus concerning the establishment of improved irrigation systems (sprinklers, drip irrigation, etc.) are eligible for co-financing.

In Finland, some projects have included elements to improve insufficient or insecure water supply to crops, and similar support seems possible in the next programming period. There is concern, however, that if agriculture moves away from grain and towards special crops, the need for irrigation will increase and there may be pressure to increase funding for drought-related measures in that sector.

In Slovenia, rural development measures include irrigation schemes (including water reservoirs), but possible gaps include the need to include adaptation measures such as new crops and prac-

tices to reduce pressure and dependency and thus help address water scarcity issues.
In Italy, maintaining the quantities and improving the quality of water resources is identified as a main objective to be tackled at the regional scale. and the National Strategic Plan includes specific measures for protection of supplies especially under Axis 1 (Improvement of agricultural sector and forestry competitiveness) and Axis 2 (Environmental and rural areas improvement).
Under the 2000–2006 programming period France's included 175 agro-environmental measures classified into 30 types. Only one type, 'reduction of withdrawals at farm scale', was directly related to measures addressing water scarcity and droughts; this included two measures:
• reduction of irrigated crop areas;
• reduction of the level of irrigation per hectare.
France identified that the 2000–2006 rural development programme only contributed weakly to reducing vulnerability to droughts and water scarcity. In the next programme period (2007–2013), funds specifically aimed at water scarcity and droughts will remain limited, with only the 'reduction of the farm irrigated area' measure planned.
Traditionally, irrigation policy has been of major importance in Spain, as part of the rural development policy. For the next programming period, Spain also identifies that there will be a number of examples of actions eligible in the context of water scarcity and drought.
A number of Member States (including Cyprus and Portugal) note that, while rural development measures are valuable, they can not solve all problems. These funds are not focused on water scarcity and droughts. Member States themselves have numerous priorities and do not address water demand management measures first. In addition, payments are often under the second (optional) funding pillar of CAP and are dependent on uptake by farmers and other stakeholders (eea_technical_report_2_2007).
There is no doubt that the adaptation measures in agriculture will strongly interact with measures in other sectors. Synergies with other policy areas, such as the Water Framework Directive, the future Soil Framework Directive, and the Flood Risk Management Directive should be promoted.

5.3 CAP and WFD

In the EU agricultural and environmental policies are seeking to converge progressively toward mutually compatible objectives and, in this context, the recently reformed Common Agricultural Policy (CAP) and the EU Water Framework Directive constitute the policy framework in which irrigated agriculture and hence water use will evolve. The link between agriculture and WFD has been identified as one of the highest priorities in the 2005-2006 work programme in the Common Implementation Strategy (CIS) for the Water Framework Directive.
The **WFD** has the following main objectives:
■ Achievement of "good status" for all waters by
■ 2015 (quality and quantity)
■ Protect related aquatic ecosystems
■ Prevent further deterioration
■ Reduce discharges of certain priority substances
The agricultural sector is, besides residential and industrial needs, one of the major reasons for water degradation and often impedes the achievement of the primary goal of the WFD, which is to achieve "good status" of all waters. On the other hand, agricultural production depends strongly on the availability of sufficient qualitative water.

To reach the WFD objectives is not only a problem linked to agriculture itself but demands multidirectional activities and close co-operation between different sectors. Accordingly, there is a need to further strengthen the dialog with all sectors, and especially the exchange between the agricultural and water sectors.

The **CAP** contains several tools, under both the 1st and 2nd pillar, which can contribute to the WFD objectives. Further tools have been introduced through the 2003 CAP reform, that makes an important step towards the integration of environmental concerns by including, inter alia, the following elements: (i) decoupling direct payments for EU farmers from the production, which is expected to further reduce incentives for intensive production and also make land-use change easier, (ii) making the full payment of the direct payments conditional on the respect of statutory environmental requirements and minimum standards of good agricultural and environmental condition (cross-compliance), (iii) introducing an obligatory modulation, with the progressive reduction of direct payments for all producers in receipt of more than 5000 annually and the corresponding funding made available for financing rural development measures, and (vi) strengthening the rural development policy with new measures to promote the environment, and in particular with the new "meeting standard" measure.
The rural development policy of EU has evolved as part of the historical development of the CAP. It is a response to the various characteristics of Europe's rural areas, which differ both in geographical and landscape features, as well as in the challenges they face.
This approach may offer a more efficient way of raising environmental standards and increasing compliance with legislative requirements. Potentially this offers an opportunity for CAP to play a more important role in water protection programmes. Similarly, with the new approach of the WFD shifting from a patchwork regulation to a holistic river basin management approach, the future water policy will affect agriculture more strongly than before.
The current programming period (2000-2006) has shown that Rural Development measures can have positive impacts on water resources. The experiences gathered should be transferred to the design of the upcoming RD programmes (2007-2013).

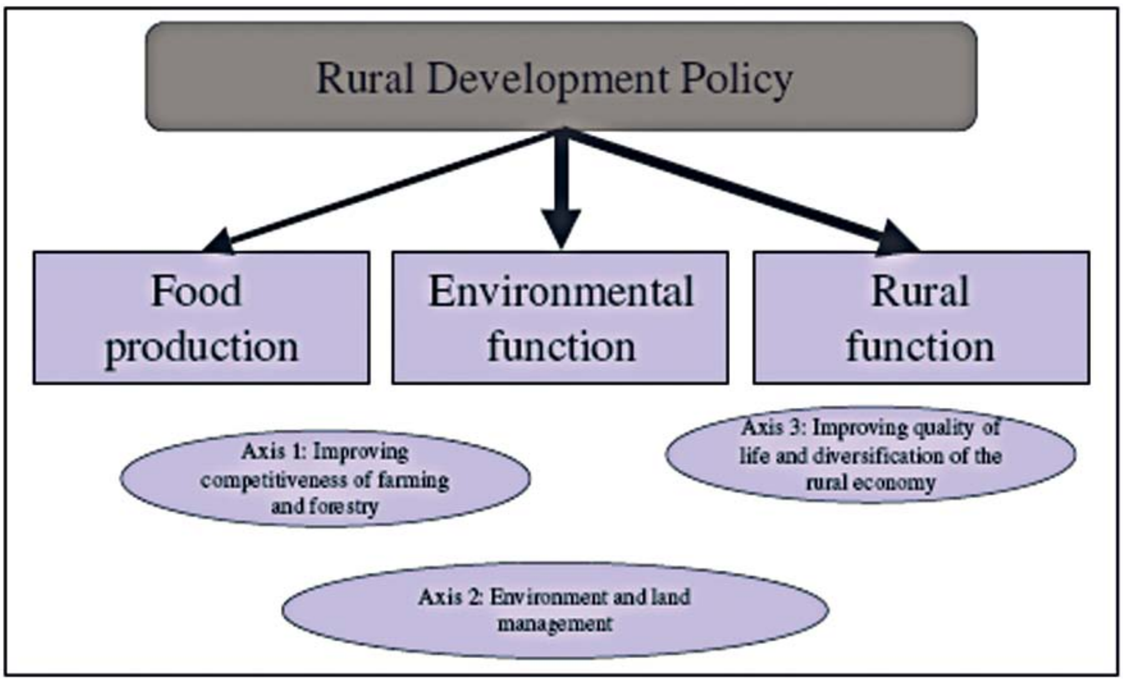

Fig. 5 - Impacts of Rural Developments Policy on water resources (Dworak, 2005)

Of the three categories identified in the RD programme, Environment and land management Axis 2) offers the most obvious opportunities for a direct contribution to the delivery of WFD objectives most specifically in relation to payments linked to the WFD (Art. 38). However RD programmes should not just involve directly targeted measures but should also consider how other measures might be tailored so as to give added value by contributing to the WFD delivery. Improving competitiveness of farming and forestry (Axis 1) and improving quality of life and diversification (Axis 3) offer opportunities to contribute indirectly to WFD delivery. Care needs to be taken to ensure that the best use is made of the opportunities available and that there are no unintended negative influences.

CAP and rural development programmes

2000-2006 programmes
Member State answers and available evaluations on agro-environmental measures set-up in the 2000-2006 period, reveal that these last programmes have partially and sometimes not at all contributed to addressing water scarcity and drought issues. Only very few Member States have adopted some agro-environmental measures aimed at addressing quantitative issues in the 2000-2006 programme. But Member States which adopted one or two of such measures only covered a limited part of the area identified as priority one (2% in Greece, 10% in France). In most cases, priority was mainly given to measures aiming at mitigating qualitative issues such as diffuse pollutions, to the detriment of quantitative issues.
Moreover, some investment supports have tended to encourage the development of new farming supplies like irrigation networks and reservoirs. In these cases, the environmental impacts of the infrastructures have not been systematically assessed and the recovery of the costs has usually not been ensured. The side effects of these measures may be exacerbated by the keeping up of some coupling supports in the framework of the first CAP pillar (France and Spain have kept a partial coupling of direct aids up to 25% of direct payments for arable crops).
2007-2013 programmes
Preliminary analyses carried out by DG Environment on the national strategy plans (required by the regulation on rural development) led to identify some weak points in the drafting.
- Draft of plans (Hungary, Portugal, Spain) suggest an intention to support the development of irrigation or use of desalinated waters, but without making clear that WFD provisions on groundwater (balance between abstractions and natural recharge) and surface water (WFD article 4.7 on new modifications) need to be respected. In addition, no information is given on how the principle of the recovery of costs of water prices will be applied to farmers (WFD article 9) and how environmental costs are integrated.
- Some plans (Greece) intend to improve the efficiency of irrigation systems but do not provide any funding figures, making the statement not easily credible.
- Some plans (Greece) foresee the maintenance of highly water consuming crops, like beetroots, converted to energy crops. The sustainability of such plans is to be questioned.
- Some plans (Spain) do not clearly include agro-environmental measures related to WFD (whereas contribution to achieving WFD objectives is one of the EU priorities in framework of rural development).
- Some plans do not clearly intend to support water saving measures in agriculture.
- Some plans (France) plan a low level of payment for agro-environment (no more than 17,5% in France) and do not well address water quantity issues – in particular problems of overabstractions near wetlands.

(*Water Scarcity and Droughts - Second Interim report)*

The timetables for the development of the 2007 – 2013 RD programmes and for WFD implementation allow an opportunity to make the best use of the funds available.
The CAP and the WFD policies follow specific time tables that are currently not linked to each other. Table 6 shows a comparison of the timetables of the CAP modifications and the WFD implementation.

Tab. 6 - Timetables of the CAP and the WFD (Dworak, 2005)

Year	Common Agricultural Policy	Water Framework Directive
2000	Approval of Rural Development Programmes under Agenda 2000	Adoption and coming into force of the WFD
2003	CAP-Reform (incl. decoupling, cross-compliance, modulation, strengthened rural development policy)	
2004		Analysis of the characteristics, pressures and impacts in river basins (according to Art. 5)
2005	Cross-compliance becomes compulsory	
2006	End of 2000 – 2006 Rural Development programming period Final approval of EU strategic guidelines Drawing up and submission to Commission of national strategies and RD measures	Monitoring network must be established (according to Art. 8) Public consultation of timetable and working programme for the production of a river basin management plans (according to Art. 14)
2007	Start of new Rural Development Programmes	Interim report of significant water management issues (according to Art. 14)
2008	Review of 2003 CAP Reforms	Public consultation on the river basin management plans (according to Art. 14)
2009		River basin management plans (according to Art. 13)
2013	End of 2007 – 2013 Rural Development programming period	
2015		Achievement of good status (according to Art. 4)

Specific actions are under implementation for the Mediterranean components of the EU Water Initiative (MED EUWI) and its Joint process with the Water Framework Directive. Other synergies are on-going with processes such "Horizon 2020", MEDA-Water Programme, EMWIS, Mediterranean Strategy for Sustainable Development, EU Marine Strategy, GEF Strategy Partnership, African Water Facility.

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6 THE ITALIAN CASE

6.1 Overview of irrigation in Italy

Irrigation in Italy is the first use of water, as it absorbs 48% of all abstractions in comparison with the percentage of 19% for respectively civil and industrial usage, and 14% for energy production. More considerable water abstractions take place in the North, where they amount to 66,9% of the national total; they are quite moderated in the Central Italy (4,8%) and equivalent to 28,3% of the total in the South and on the islands. The relevant differentiation among North and South as for water use for irrigation purposes is caused by environmental, hystorical factors, and of production structure.
The irrigated surface at national level represents a slightly lower share than a fifth of the totally utilized surface for agriculture (SAU) in the country; in fact, it is equivalent to 19% of all SAU.
In the Northern regions of Italy, on the whole, the irrigated area being 32,5% with respect to SAU, amounts to a higher percentage than national average. The central regions present at national level the lowest ratio between irrigated surface and SAU (about 7%).
The survey of irrigation in the national farming context on the basis of the Census data reports a total area irrigated in Italy equivalent to almost 2.500.000 hectares and abouts 731.000 farms involved.
In the Northern regions 64% of the national surface is irrigated, South and Isles reach almost 28% of the national irrigated surface, while the lowest number of irrigated hectares is counted in the Central regions of Italy (less than 8% of national total).

Tab. 7 - Irrigated area (hectares) in Italy, number of farms and percentage ratio

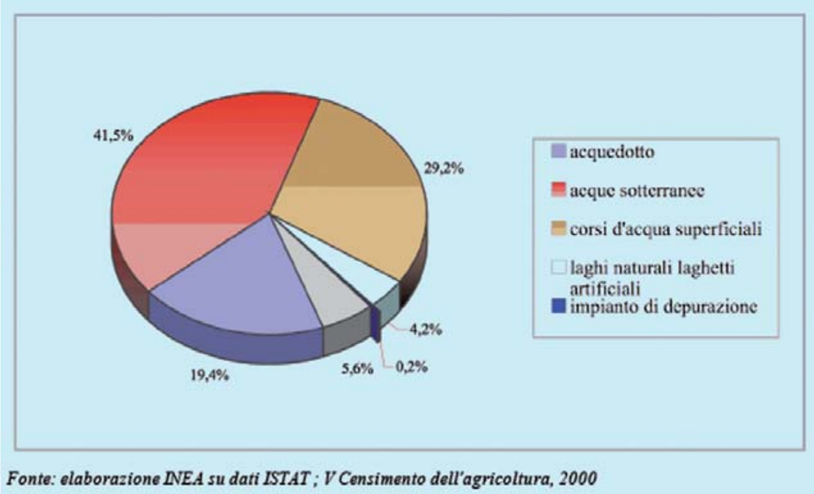
Area geografica	Superficie irrigata (1)		Aziende irrigue (2)		Superficie media irrigata per azienda (1)/(2)
	ha	%	n.	%	%
Nord	1.583.022	64,1	231.490	31,7	6,8
Centro	208.650	8,4	107.728	14,7	1,9
Sud	456.349	18,5	257.124	35,2	1,8
Isole	223.359	9,0	134.540	18,4	1,7
Italia	**2.471.380**	**100**	**730.882**	**100**	**3,4**

Fonte: elaborazioni INEA su dati ISTAT V Censimento anno 2000

With reference to all chief sources of water supply, ISTAT data show only the number of farms using a given typology of source; for this reason, figures related to farms number present the possibility that the same farm may use different sources of water supply. The principal typologies of sources analyzed are:
- aqueduct;
- groundwater;
- surface streams;
- natural lakes, artificial small lakes;
- sewage plant;
- rain water collection.

At national level the main source of water supply for irrigation to which farms ressort is groundwater with 41,5% (figure 6).

Fig. 6 - Sources for water abstractions for farming – total for Italy (in percentage)

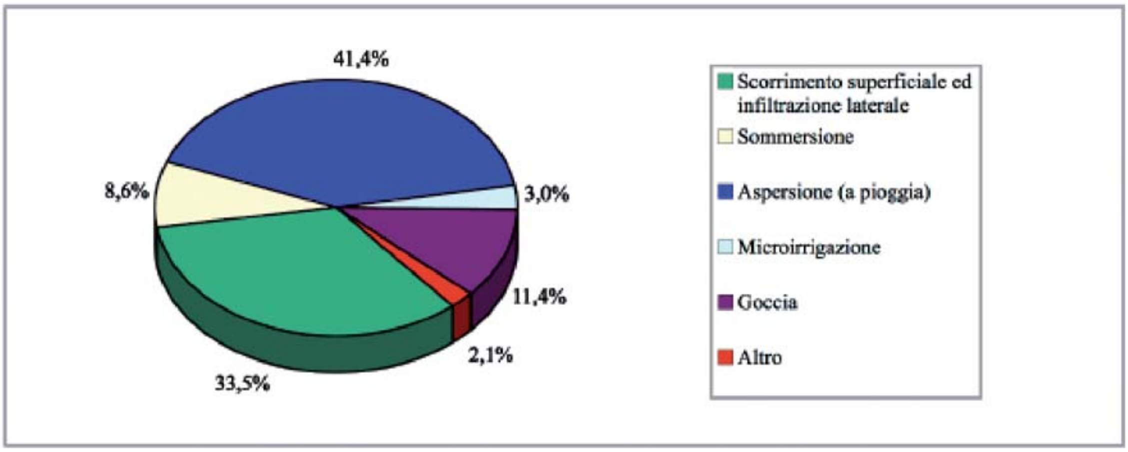


Among the main irrigated crops in Italy there is corn (25,2% of the irrigated area), followed by fodder (10,8%), vegetables potatoes included (8,8%), fruits and vine. Citruses are cultivated almost exclusively in Southern regions and isles. The irrigated area for sugar beet cultivation is considerable and also that for soya bean, which represent about 6,5 % of the total irrigated surface in Italy. The datum of the class “other cultivations” (24,4 % of the irrigated area) is to be underlined, as it includes ornamental plants, flowers, oil seeds plants, rice, dry legumes, kitchen gardens, poplar groves, sowing seedlings. Finally, about 99.000 hectares are planted with wheat. Briefly as aforementioned, 64% of the total national irrigated area is situated in the North of Italy. This is due to the fact that it is possible to irrigate larger surfaces in the Northern regions thanks to the land configuration and its extent, besides of course the greater availability of water. Actually water resources mainly originated from snow melting of Alpine glaciers, are abundant and distributed in a large and well structured network. On the contrary, it is known that Southern regions and islands have always been affected by problems of water sypply as their water availability is uneven and insufficient periodically. This water scarcity often forces the recourse to groundwater which has a better quality and therefore would be more suitable for human consumption.

With reference to the chief irrigation systems and on the basis of ISTAT data surveyed at national level, the most used in farms is sprinkler irrigation with 1.051.000 hectares, equivalent to about 41% of total irrigated surface. This method especially used in Lombardia, Veneto and Emilia-Romagna, adapts well to irrigation of full field crops like corn, lucerne, sugar beet, multi-species meadows, soya beens, which are prevalent cultivations in these regions.
The flowing and lateral infiltration method is on the second rank (850.000 hectares) being practised mainly in the North-West area of the country. This is a gravitational method demanding availability of big amounts of water (for this reason is less used in South and on isles).
Lombardia with more than 300.000 hectares is the region having the most flow irrigated surface, followed by Piedmont, Veneto and Emilia-Romagna.
The method of inundation is practised almost exclusively in rice-fields and concerns about

220.000 hectares of SAU in Italy, whose 50% in Piedmont, the major rice producer.
Lombardia and among the North–East regions Veneto and Emilia-Romagna come after. It is also to be noticed that this method concerns, even if in a quite reduced manner, some areas of Sardinia cultivated with rice (in particular Oristano province) for about 2.200 hectares. Finally, as for drop and microirrigation methods, they are mostly diffused in the Southern regions of Italy (Apulia and Sicily in particular).

Fig. 7 - Irrigation systems used in Italy (in percentage)



The SIGRIA project

In 1998 the Ministry of Agricultural and Forestry Policies and the Ministry of Public Works asked the National Institute of Agrarian Economics (INEA) to conduct a study on the use of water resources for irrigation. The study, which ended in December 2001, made it possible to identify all irrigated areas and the crops produced, as well as the water requirement by crop, by region, and by irrigation cooperative.
The most relevant result of this work has been the implementation of a comprehensive information system, named **SIGRIA (acronym for Sistema Integrato per la Gestione delle Risorse Idriche in Agricoltura - Integrated System for Water Management in Agriculture)** that contains a complete set of databases and tools on land use, irrigation networks and economic data at local level.
According to the project plan each Region was to realize the Regional SIGRIA under the coordination of INEA.
The work carried out by INEA since 1997, and the area for which SIGRIA has been developed consists of the eight regions of Southern Italy (Abruzzo, Molise, Puglia, Campania, Basilicata, Calabria, Sicilia, Sardegna). The total area is about 12 millions square kilometres, of which about 1.6 million are irrigated areas. Water is provided by 300 different sources (including 58 dams) and the total length of the irrigation network (primary and secondary level) is almost 9.000 kilometres. Data were collected and organised at "Consorzi di Bonifica" (Italian administrative structures responsible of irrigation water management) and regional (NUTS II) level. In Southern Italy 65 reclamation consortia manage an area of 8.358.165 hectares. To detect all the irrigated surfaces (about 1.600.000 hectares, inside and outside administrative boundaries of reclamation consortia), a land use map (Irrigation Study Areas Map CASI 3: scale 1:50.000) has been

realised, using remote sensing technology on three different Landsat TM images (thematic accuracy: 1:50.000 scale), referred to three different years and three different season (autumn, spring and summer), and digital orthophotos (greyscale with pixel of 1 m – geometric and geographic base of the whole system) for geometric accuracy (1:25.000 scale). The study area (about 6.500.000 hectares) was previously mapped, thanks to the superposition of different cartographic layers (DTM, CORINE Land Cover, irrigated areas).

SIGRIA has been developed mainly as a tool to support the decision-making process in infrastructures for irrigation. The main infrastructures (including dam and irrigation networks carrying water from the source to the farm gate) are normally financed by public funds (national, in case of projects that have an inter-regional relevance, or regional funds, in case of local infrastructures). Local irrigation consortia prepare feasibility studies and engineering projects, and apply for funds in accordance to basic criteria defined at national or regional level.

National and regional administrations require tools that can provide data for the analysis of projects, in order to ensure that new investments are made in areas susceptible to irrigation, with adequate conditions in terms of local agricultural management and with demand of water compatible with availability and competitive uses.

SIGRIA has been chosen at national and regional level to provide this support.

Due to the nature of SIGRIA, the main intended users are national and regional decision-makers (both at political and technical level). However, the information system has proved being extremely useful to local irrigation consortia, since in most cases they did not have a complete and well-stractured database, both for the alphanumeric and GIS components. By providing them, as a final result of the project, a verified database with the full data they initially provided, has therefore been a key element to obtain their interest and support. In fact, the information flow is always bi-directional (from the local irrigation consortia to the centralised system and vice-versa).

Apart from these direct users of SIGRIA, there have been in the past a number of indirect or ‘ad hoc’ users, who had access to separate sections of the overall database, in order to fulfil specific requirements.

The most relevant situations have been:

– analysis of the effects of drought, with reference to the calculation of the possible economic damage due to a temporary stop in irrigation because of the unavailability of water resources;
– analysis of the impact on the utilisation of treated wastewater in certain areas, by checking the availability of irrigation networks and the suitability to irrigation of existing crops;
– long term forecast of water demand for irrigation, on the basis of scenarios built in accordance with existing irrigated areas, current crop water requirements and trends in crop diversification and improvements in irrigation technologies;
– preparation of feasibility studies by single irrigation consortia, using SIGRIA databases and GIS layers.

SIGRIA presents therefore a wide range of users, both within public organisations and in the private sectore.

Implementing and updating SIGRIA is a complex and resource-consuming process. The main difficulty is due to the fragmentation of information. Most of the data requested are available at local level, and consequently have to be collected and input by local irrigation consortia. Some information are of regional relevance (i.e. wastewater treatment plants); some others are available at regional or national level (i.e. list of financed projects, expected expiration, payments). SIGRIA requires therefore a localised and controlled input.

The situation is made more complex by the need of protecting some databases (that cannot be

disclosed to the general public) and of keeping its costs at a reasonable level.
Taking into accounts these needs and limitations, the following basic decisions have been taken:
- databases are centralised, giving the possibility to external users (according to their user profile) to selectively view and/or update basic information;
- all interactions are made through a simple Internet connection and a browser . This does not require any additional cost, both in terms of telematic connection and of hardware/software purchases. The Internet user interface to SIGRIA is called SIGRIAweb;
- every actor involved in SIGRIA can, at any moment, download its data, in order to import them into other applications, if necessary. Having a centralised database maintains consistency of data, but is not a limitation to using those data at local level;
- whenever possible, open-source tools are used. In this way there is a concrete reduction in costs, while keeping the requested functionalities;
- data are stored with an indication of their year of relevance. In this way it is possible to create time series and to identify trends in irrigation;
- data must be linked, whenever possible, to their geographic attributes. This is necessary to ensure that SIGRIA becomes a complete and comprehensive GIS;
- user profiles, with different levels of access to the system, have been identified.

Given the features requested, available resources, a number of technical implementations have been carried out. The first step consisted of creating the main database. Given the various open-source platforms currently available, PostgreSQL running under Red Hat Linux was chosen. The database consists of 114 tables that can be aggregated as follows:
- economic data on water tariffs;
- economic data on yearly budget of irrigation consortia;
- land use
- organisation of irrigation consortia;
- irrigation networks;
- water sources (including wells and dams);
- crops;
- irrigated area, disaggregated by district, internal basin and consortium;
- system and lookup tables.

The centralised databases is kept in INEA headquarters at Rome, where it is regularly maintained and backed up.
Users in charge of maintaining and updating data have access to a web-based application, that provides full access to the database, by means of a complex hierarchy of menus and forms. Any alphanumeric element of the database can therefore be remotely viewed, added or updated. Any new information is immediately added to the centralised database; log files keep track of any change made and of the user who was responsible for it.
Whenever geographic data have to be added, the situation is a little more complex. Tools currently available do not allow direct on-line updates. Many local irrigation consortia have low-speed Internet connections, that are adequate for simple data input of alphanumeric data, but provide insufficient bandwidth in case of heavy interaction as requested by a GIS application. Each local partner (whether it is an irrigation consortium or a regional government) gas received as a part of the investment for SIGRIA a workstation equipped with a complete GIS software. By using the web interface, it is possible to download all data, export them into the local system and upload them into the centralised database.
SIGRIA contains also two separate models, that are not currently integrated neither in the data-

base nor in the web interface. These models support irrigation consortia in defining crop water requirements and in simulating the effect of different scenarios on diversification of crops, aggregate water demand and profitability of single crops.
The main interface of SIGRIAweb consists of a windows with a map of Italy on the left side and a form containing alphanumeric data on the right side.
The interaction with the map is fairly intuitive and comparable to what is available in a normal GIS software: zoom in and out, pan, center. This GIS component is built on Java code, and is therefore independent on the operating system used. Only the requested bits information of information are transferred, which minimises Internet traffic and allows low-speed connections. The map component of SIGRIAweb is freely available (i.e. any Internet user can fully and at ease browse the map).
By clicking on a specific object on the map (i.e. portion of network, water source, river, etc) the right portion of the screen displays the alphanumeric information. If allowed by the user profile, it is then possible to edit data or to add new data.
SIGRIAweb is based on hierarchical menus, that connect to the single containers of the database. Each container can have itself associated either information or other containers, with more detailed data. Every single element of information has associated two fields:
– date, useful to associate a year-mark and to associate time series; ;
– memo, to input full text. In this way users can input complete documents and SIGRIA becomes a complete system for the storage of text, alphanumeric and geographic data.

The following containers have been implemented:
– irrigation consortia,
– irrigation basins
– districts
– duration of the irrigation period
– typology of irrigation
– crops grown per district
– networks
– weather stations
– wastewater treatment plants
– satellite images
– land use
– suitability to irrigation
– crop water requirements
Although not incorporated in SIGRIA datasets, two separate models have been developed with the purpose of being used as operational tools for irrigation consortia.
The first model supports in determining water requirements per irrigation district is based on GIS technology. It incorporates algorithms to take into account crops, soils and weather, and determines global and localized water needs for different types of irrigation. This software is particularly useful:
– to identify water demand in new irrigated areas;
– to simulate changes in water demand with different sets of crops and irrigation technologies.
The software allows a complete user interaction to simulate different scenarios.
The second model is based on linear programming; it incorporates technical processes per crop, costs, revenues, water requirements and fees. It provides simulations on the reaction of the components to the model to changes in the current equilibrium situation. Ir allows a wide range of simulations, like:

– changes in crop diversification as a reaction to an increase in water cost;
– effects of the adoption by farmers of new irrigation techniques;
– enlargement of the irrigated district.

Infrastructures for irrigation require enormous investments and can have a relevant impact on agriculture evolution and on environment. The definition of priorities requires therefore a complete, updated, homogeneous and representative set of information, that must be incorporated into investment plans and in the decision-making process.
The main problem is collecting and validating data in a heterogeneous institutional context. For this purpose SIGRIA has proven to be a successful way of creating a stable system and of feeding it with the data requested.
It should be noticed that although SIGRIA has been mainly started as a tool for central and regional governments, it has acted as a local capacity building mechanism, since it involves training, provision of computers and collection of data that can be further utilized by local irrigation consortia.
By itself the system is not self-sustainable, since it requires investments at central and local level. However the idea of data collected jointly with local irrigation consortia has proven successful.
Furthermore the basic data structure of SIGRIA could be easily replicated in other areas of Italy or in other countries. In this view, an on-going project is in charge of extending SIGRIA tools and database structure to include Central and Northern Italian regions.

6.2 Water scarcity and vulnerability to drought cycles in Italy

Drought events in the last thirty years

Italy has experienced many drought events both in the northern regions, characterized by humid climate and sufficient water resources, and southern regions where the more changeable hydro-meteorological variables and the reduced amount of water compared with its increasing demands cuse more frequent conditions of water deficit.

Tab. 8 - Major damaging droughts in Italy

Date (year)	**1977-1983**	**1989-1991**	**2001-2002**	**2003**	**1995-2004**	**1995-2004**	**2006**
Duration (days)	Prolonged drought	Prolonged drought	From autumn 2001 to winter 2002	summer	Prolonged drought	Prolonged drought	Summer
Population	20.130.644	56.679.549	57.158.407	57.888.245	5.004.670-5.003.262	1.651.101-1.643.096	729.838
Area affected in km_	Southern Italy and islands 123.103,23	Italy 301.333	Central, Southern Italy and islands 181.441	Italy and particularly in Northern Italy 301.333	Sicily 25.710	Sardinia 24.090	Norther n Italy 119892

The most droughty episodes are characterized by prolonged drought causing different impacts to the affected area.

It seems appropriate a distinction between meteorological drought, referred to a specific region, which is usually an expression of negative departure from normal precipitation conditions over some periods of time, and hydrological drought referred to deficiencies in surface and subsurface water supplies.
Drought, recently (2003/2006) affecting also the alpine area, is seen in the significant reduction of rivers flow. This aspect is a direct consequence of meteorological drought (precipitation reduction as in terms of rain as in terms of snow) in wintertime.
This phenomenon is being observed since 2000.

Irrigation water emergencies due to drought events

Only a reactive response to drought has been experienced in Italy. In particular, two main tools have been applied: Emergency actions of the Department of Civil Protection; and subsidies to farmers for covering agricultural damages due to drought, under the provisions of national acts on national disasters.
Water availability during droughty periods are strongly conditioned by the water quantity contained in natural water bodies and in artificial reservoirs. In the central and southern regions of Italy the water stockpiling for facing drought periods is made mostly by artificial reservoirs; in the North big lakes have supplied water during the last crisis.
Neverthless, besides drought reducing water availability from its supply sources, it is also to be considered the condition of the adduction and distribution network from the sources to the districts served. Many reservoirs have structural problems or are filled with earth and need restoration for the full reutilization of their storage capacity. In other cases, even if there are reservoirs, adduction sytems and/or connection ways among water sources are missing.
In conclusion water emergency, even though made worse by drought, should be faced in a risolutive manner, taking into account also the network features and its management.
Lately, the attention of administrators, researchers and public opinion towards water resources has increased also owing to the occurence of frequent and severe drought events. While in the southern regions the economic sectors affected by drought impacts are agriculture, with difficulties mainly for the most valuable fruit and vegetable produce, and tourism, as for more severe water scarsity occurs in summertime, recent events affecting Northern regions have pointed out the vulnerability of the whole national system for power production to drought.
Of six sustained droughts in Italy in the last 60 years four have occurred since 1990.
The 1988–90 drought produced very severe impacts on domestic and agricultural water supplies mainly because the management policies of water systems did not take into account the occurrence of a three-year drought.
The analysis of the effects of drought on irrigation water availability in central and southern Italy shows that the irrigated land in 1989 and 1990 decreased by 50% as a direct consequence of water shortage. In some areas of southern Italy, water was released to irrigate tree groves only, mainly to sustain trees until the following rainy season rather than to save production; farmers were severely discouraged from planting summer crops.
Lack of surface water for both domestic and irrigation use caused overexploitation of ground water supplies. Many temporary wells were dug; their numbers and locations, as well as the volumes of water drawn, are mostly unknown; thus it is impossible to accurately assess the contribution, certainly essential, of ground waters in mitigating drought. To a very small extent,

waste waters and brackish waters were also used. In the most affected areas, drought effects on water resources persisted long after termination of the event.
With the passage of national law no. 225 in 1992 establishing guidelines on natural disasters defense strategies and organization of civil protection, local plans were developed for prevention of water emergencies due to drought and for reducing the vulnerability of water systems (Rossi, 1995).
In summer 2003 a severe drought in northern Italy has caused so much damage and concern that several regions have asked for special aid from the national government, which is considering declaring a state of emergency. Months of dry weather coupled with intense heat have devastated the Po, Italy's longest river, whose catchment basin interest the territory of seven regions, and one of its most crucial for agriculture. Its water levels have dropped to nearly 25 feet below average, one of its lowest marks in almost a century.
Italy has experienced an unusually dry winter with rain and snowfall in December 2006 down 86% from the same month in 2005.
Regulations and competences in water sector are under deep evolution also for the need of implementing the Water Frame Directive EC 2000/60. A lively discussion in the Italian Parliament has concerned the amendments to the third part of Legislative Decree 152/2006 on soil defence, water resources conservation and management. These amendments refer to the final description of water districts and responsibilities charged to the district authorities, among which the functions concerning the drought management and the planning of mitigation interventions in relation to the scenario and the thresholds considered.

6.3 Protection of Quality and Quantity: Italian experience

6.3.1 The Italian Legislative Framework

Italian policy in the water sector has been much modified in the last decade by a number of legislative acts. Since the early '90s the higher degree of complexity and decentralisation achieved has been leading to some conflicting attempts to integrate the water policy regimes.
Tentative efforts to integrate occur at two separate and conflicting levels: at the water basins level, through the creation of the Water Basin Authorities (AdBs), responsible for water planning in the water basins under their authority, and at the local level, through the creation of the Optimal Management Areas (ATOs), responsible for setting up locally the integrated water services.
The individual River Basin Authorities are required to set up specific rules for rivers under their responsibility. The slow and difficult process of institutional reform of the State has influenced the evolution of water policies, being partly responsible for the contradictions that we observe in the tentative process of integration of water policies.
We will briefly illustrate the main features of the water laws which did contribute to the recent evolution of water policies:
- Law **183/89** on water and soil conservation is aimed at adopting an integrated approach to water and land conservation problems. Both planning and management of water and land conservation must be conceived within a single vision for the whole territory of each hydrographic basin. It introduced the River Basin Plan concept, which was established as the main tool to collect relevant information and to identify the actions necessary for hydraulic defence and soil conservation, utilization of water resources, and pollution control of water bodies.
The law established that River Basin Authorities be entrusted with the coordination of all the planning, construction and control activities in water fields within the river basin.

Furthermore, it has reformed the National Technical Services, transferred under Prime Ministerial jurisdiction, assigning also the task of organising and managing the Information System on hydrometeorological data. Later on, three Technical Services were transferred to various Ministries (e.g. Hydrographic Service to the Environment Ministry, Dams Service to the Infrastructure Ministry)
- With Law **225** dated 24th February 1992, Italy has organised the civil defence as a National "Service", coordinated by the Prime Minister's Office and composed, as stated in the first article of the law, by State administrations, central and peripheral, by the regions, by the provinces, by the local councils, by the national and territorial public authorities and by every other institution and organisation, public and private, existing on national territory.
The Department of Civil Defence intervenes, jointly with the competent Ministries and with those Regions involved, in events that, due to intensity and extension, must be faced with exceptional means and powers. It prepares, jointly with the Regions and local institutions, water emergency plans and gives guidance to Commission delegates for the destination of the available resources. Lastly, with the D.P.C.M. n.59 of 27/02/2004, the authorities are identified with whom rests the decision and responsibility of alerting the civil defence system at various levels. The institutional bodies and the territorial units involved in the activity of risk forecast and prevention and emergency management are defined. The tools and modalities with which the information relative to the manifestation and evolution of hydrogeological and hydraulic risk, associated with the manifestation of particularly intense meteohydrological events have to be recorded, analysed and made available to the authorities.
- Law **36/94** has removed the exceptions to the general principle that all surface and groundwater resources must be considered public, and has introduced important innovations asserting that water resource use must achieve the criterias of efficiency and of effectiveness, also taking into account the criteria of solidarity and of environmental protection. Besides, the law confirms that the management of the infrastructures pertaining to water (water mains, sewers, treatment plants) must be traced to single management at the ATO level and the land reclamation consortia are responsible for the construction and management of water networks for irrigation purposes, for the reuse of treated wastewater, and for rural water mains. Law 36/94 has been followed by decree 47/96, that issued some guidelines for the identification of the areas under risk of water crisis, unfortunately not yet accomplished.
- Legislative Decree **152/99** (amended by Legislative Decree 258/2000) has been established in order to adopt into Italian legislation the European Directives 91/271 on Urban Wastewater Treatment and 91/676 on the Protection of Water from Agricultural Pollution. It also rearranged all previous Italian legislative framework on pollution control, replacing fundamental law n.319/86 (Merli act).
Finally, it has defined the stages for achieving environmental quality objectives, including the analysis of present conditions and classification of environmental status, the identification of restoration objectives and the implementation of the necessary actions in water bodies.
The Decree involves directly agriculture, in terms of pollutants release and exploitation for irrigation and livestock production.
In particular, agriculture is included in: directive 91/676/CEE, relative to water protection from nitrate pollution produced by agriculture; directives 76/464/CEE and 80/68/CEE concerning protection from pollution generated by dangerous substances.
Another important points are contained in Decree 152/99 is the obligation to apply a "code of best agricultural practice" in the areas designated like vulnerable to nitrates from agricultural sources; the definition of Action Programs for agronomic use of livestock production waste-

water and of olive oil production wastewater; the norms for urban wastewater reuse for irrigation.
- The **Decree 12 July 2003 n. 185**, (Technical tools for the Urban Wastewater Reuse)
- The **Decree 28 July 2004**, (Guide Lines for the computation of the Water Balance At River Basin Scale and criteria for the survey of the existing uses) , (Guide Lines for the assessment of the Minimum Vital Flow)
- The **Environmental Code**

6.3.2 The Minimum Vital Flow in the legislative context

The definition of the quantitative state of water bodies is one of the pillars of integrated qualitative and quantitative water body protection and is a fundamental survey element for the water protection plans organisation.
Law n.183/89 gives that "rational surface water and ground water use" shall be set among the planning objectives "in order to ensure that the abstractions will not compromise the minimum vital flow in the downstream catchments".
The "Galli Act" (Law n. 36/94) develops this concept and gives that the River Basin Authorities shall set out a "water balance". The water balance is a strategical river basin planning tool which is introduced in order to assure both the satisfaction of human needs and a water flow capable of protecting water body hydromorphology, water quality and the typical biocenosis of the natural local conditions.
The Article 3.3 deals with this matter and establishes that "in the catchments subject to huge water abstraction or water transfer [...], the abstractions shall be regulated in order to assure the flow level needed to support life in the downstream river beds so that water resources, environmental livability, agriculture, aquatic fauna and flora, geomorphological processes and hydrological equilibrium are protected".
The Galli Act definitions are also included in Legislative Decree n.152/99, which gives indications for the definition of the minimum vital flow which shall be defined by the Regions (in the Water Protection Plan) on the basis of the "water balance" as determined by the River Basin Authority. These three legal acts constitute the framework of the Ministerial Decree 2004 July 28th which, as established in the Legislative Decree n.152/99, defines the guide lines for the arrangement of the water balance, including the criteria for the uses census and for the definition of the minimum vital flow.
This Decree takes into account the previous legal acts on water planning and management and gives accurate indications for the water balance definition; in particular it specifies: the spatial and temporal scale, the basic data, the information flow management and the activities required for the evaluation of natural water resources. Furthermore the water balance equilibrium condition is defined through the following:

$$R_u - \Sigma F_i + R_{reu} + V_{rest} > 0$$

R_u = useful surface and ground water resources in the river basin
ΣF_i = human needs as a whole (potable, agricultural, industrial, hydroelectric, etc...)
R_{reu} = water resources re-used in the river basin
V_{rest} = water volumes restored from activities placed inside the river basin

Also, the Ministerial Decree establishes that the useful water resources shall be calculated taking into account the M.V.F.; R_u shall be equal to the Potential Water Resources (which are the

natural resources rectified with the abstracted water and with the water derived from other catchments) less the M.V.F..
The M.V.F. is defined as the instant flow - calculated in every homogeneous section of the water course - which ensures the preservation of its natural evolutionary trend (morphological and hydrological), of the water quality status (according with the quality objectives defined in Legislative Decree n.152/99) and of the biological communities typical of the considered area.
Finally the Ministerial Decree gives accurate indications for the data collection and for the selection of the method for computing the M.V.F. value.

6.3.3 The Environmental Code

This Legislative Decree approves the Code on the Environment, which sets out the legislative framework applicable to all matters concerning environmental protection.
The Code is composed of six Parts.
Part I (arts. 1-3) defines the application scope and lays down general provisions applicable to all areas covered by the Code.
Part II (arts. 4-52) defines and regulates the procedures related to the Strategic Environmental Assessment (VAS), Environmental Impact Assessment (VIA) and Integrated Environmental Authorization (IPPC).
Part III (arts. 53-176) is devoted to **soil protection** (particular regard is given to the need to combat **desertification**), **protection of waters against pollution** and **management of water resources**. As regards water policy and management, the national territory is divided into hydrographical districts upon which basin plans shall be implemented.
Part IV (arts. 177-266) deals with waste management and rehabilitation of polluted sites. It provides for the arrangement of the Integrated Waste Management Service.
Part V (arts. 267-298) deals with air quality and aims at reducing emissions into the atmosphere.
Part VI (arts. 299-318) implements the precautionary principle and lays down the liability regime.

The methods adopted and the contents of this legislative text were strongly contested by representatives of the Italian regions and the river basins authorities.
For this reasons, the government has decided that the decree 152/06 will be radically corrected before the end of 2006, taking into account the observations of the main actors involved in the water sector.
The transposition of the Water Framework Directive in the Italian legislation was formally approved with a government decree (152/2006).But regions, environmentalists, unions, and part of the water sector have criticized the decree because technically not sound and elaborated without consultation.
The government has given to the Ministry for Environment the task of elaborating the necessary amendments to completely adopt the Water Frame Directive and the “Daughters” Directives issued meanwhile and to be approved by the Ministers Council by the end of April 2008.
The articles concerning agricultural issues are:
ART. **96** (modification Royal Decree n. 1775 of 11 december 1933), that
ART. **146** (water saving)
ART. **167** (Agricultural use of water).

6.4 Some Italian Experiences in monitoring and managing drought risk

In recent years Italy has experienced several severe droughts affecting large areas of the country or the entire territory. After the extended drought between 1988 and 1992, with socio-economic effects to 1995 and beyond, the need to implement monitoring tools as first step towards deeper knowledge of the phenomenon was recognized, being the knowledge premise of the development of proper strategies for the mitigation of its effects and the planning of interventions and measures to take during the drought management phases and for preventing water shortages. As a result, a National as well as several regional Drought Bulletins were implemented.
ISPRA, in the framework of the activities of PIC INTERREG II C "Territorial planning and coping with the effects of drought", with the scientific support of various Universities, developed a Drought Bulletin, in principle as a prototype and now operating for several years and extended to cover, from the meteorological point of view, the entire Mediterranean basin. The analysis of the climatic condition in Italy is available from the first days of each month and it can be consulted on the ISPRA web site at the address www.isprambiente.it where it is possible to also obtain the full text of the publication from which the major part of the information about the national and regional approach to the drought was taken (Monacelli G., Galluccio M.C., Ferramosca E. (2006) –Linee guida per l'individuazione delle aree soggette a fenomeni di siccità (Rome, Italy). Manuali e linee guida ISPRA 42/2006).
The drought conditions are documented by some significant indexes, among which the Standard Precipitation Index and the Palmer Drought Severity Index.

ISPRA Drought Bulletin- 09/2007

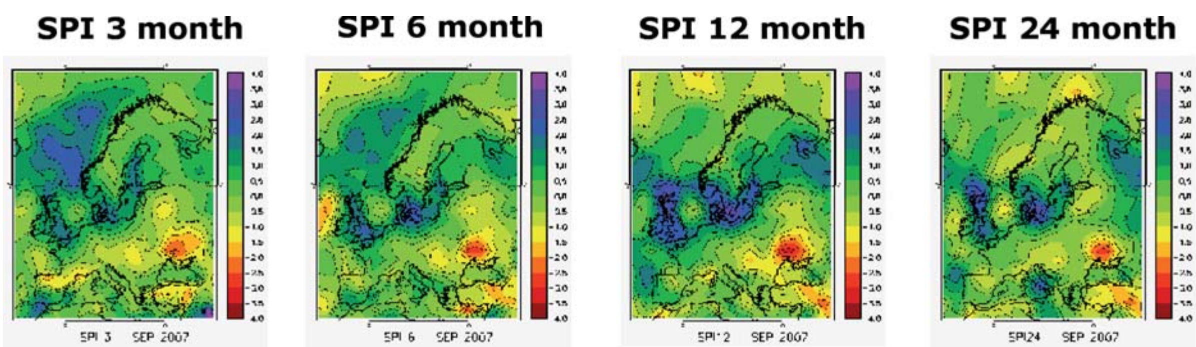
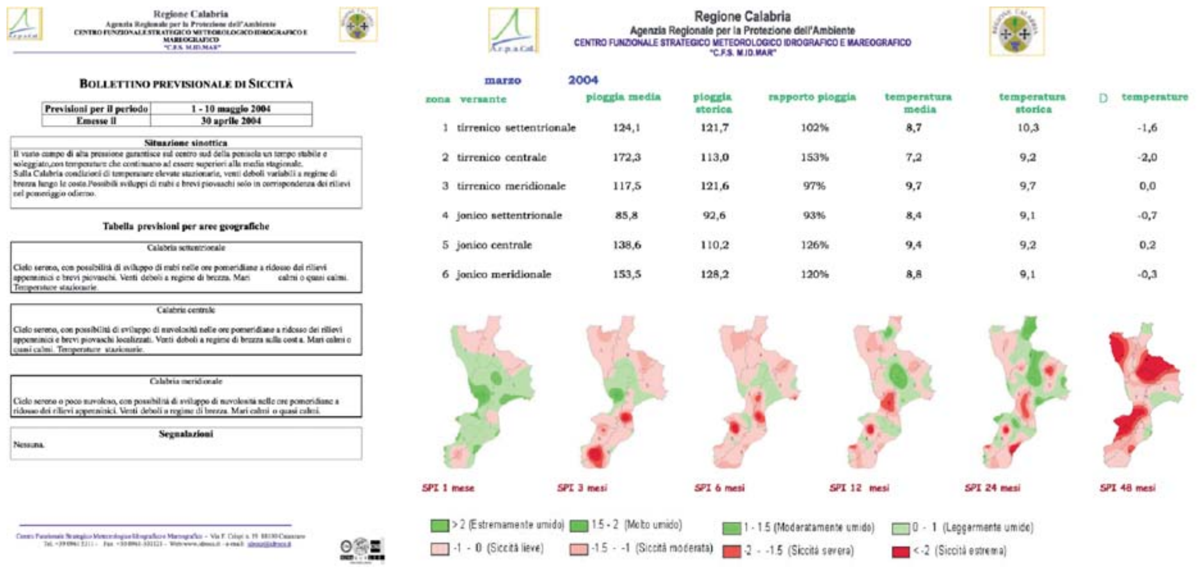


Fig. 8 - ISPRA Drought bullettin - SPI thematic maps concerning Europe

While the analyses present on ISPRA National Drought Bulletin are based on the data of NCEP/NCAR global scale reanalysis, the regional analyses are mainly based on the observed data from the local hydro-meteorological networks. The regional drought bulletins give information on the principal meteo-climatic parameters and on the state of drought in the region, permitting the identification of the affected areas.
The Calabria Region bulletin, managed by the Functional Centre for Civil Protection CFS-MIDMAR and visible on the site http://www.protezionecivilecalabria.it// , integrate on daily scale the data transmitted by the telemetering hydro-meteorological networks present on the regional territory. The ad hoc data base for the drought monitoring is organised in order to contain data grouped in decades (precipitation, temperature and SPI): such DB is automatically updated every ten days. The BD drought data together with the geographical information are elaborated for the produc-

tion of maps showing the spatial distribution of the principal climatic variables on the web. Every ten days the maps of the total precipitation, maximum, medium and minimum temperatures and the SPI values at 1,3,6,12,24,48 months are elaborated. Every month the monthly maps of precipitation, temperature, radiation and wind speed are elaborated and the comparisons between the obtained values of the above mentioned variables and those of the historical average in the month of the year under examination are considered. All the elaborations are printed on a bulletin which every ten days gives information o the temperature, precipitation and meteo forecast at global scale whereas every month it gives information on the state of drought of the interested month for the six zones in which Calabria Region is subdivided.



zona	versante	pioggia media	pioggia storica	rapporto pioggia	temperatura media	temperatura storica	D temperature
1	tirrenico settentrionale	124,1	121,7	102%	8,7	10,3	-1,6
2	tirrenico centrale	172,3	113,0	153%	7,2	9,2	-2,0
3	tirrenico meridionale	117,5	121,6	97%	9,7	9,7	0,0
4	jonico settentrionale	85,8	92,6	93%	8,4	9,1	-0,7
5	jonico centrale	138,6	110,2	126%	9,4	9,2	0,2
6	jonico meridionale	153,5	128,2	120%	8,8	9,1	-0,3

Fig. 9 - Calabria Region Drought Bulletin

The prototype bulletin for the drought monitoring in Sicilian Region has been developed by ICA Dept. of Catania University on behalf of the Regional Water Agency – Hydrographic Observatory and it is visible on the web site of the Office at the address http://www.uirsicilia.it//. The information that constitutes the core of the bulletin has been divided into three groups, each constitutes by one or more sub pages. The first group concerns the basic information used for the realization of the bulletin and in particular the map with the location of the selected thermo-pluviometric stations and the observed historical series in the same stations used for the long period statistical calculations (the meteo-hydrologic DB contains historical series for the period 1921-2006). The second group, to which belong the "Precipitation " and "Temperature" sub pages, gathers the information regarding the hydro-meteorological variables, object of particular analysis for the purpose of drought monitoring, transmitted by the telemetering stations of the regional networks. More precisely, information on the spatial distribution of monthly precipitation and temperature are shown, also expressed in function of the long period "normal" values, through a representation using isolines and with scales of colours. Finally, to the third group the sub pages named "Precipitation Deficit", "S P Index", "Palmer Index" and "Storage volumes in Reservoirs" and Freatimeters" belong. Such sub pages contain information on the spatial drought distribution both on the basis of indicators of anomalies in the trends of the meteorological parameters under control (e.g. the map of the difference in precipitation of the current month respect to the long period average) and of indexes (maps of the Palmer and SPI) and on information on the state of the water resources, in particular with indication on the storage volumes of water in the main reservoirs of run off regulation and on the observed levels of aquifers.

In Piedmont Region the Drought Bulletin has been developed by the Regional Environmental Agency (http://www.arpa.piemonte.it/upload/dl/Bollettini/bollidromensile.pdf) and it is issued monthly, but updated more frequently in case of severe crisis in water availability. It is organized in three sections in which indication on the current state of water resources and the forecast of the phenomenon using the SPI. In the first section the precipitation of the current month for each sub basin of the region and 3, 6, 12 months SPI are shown.

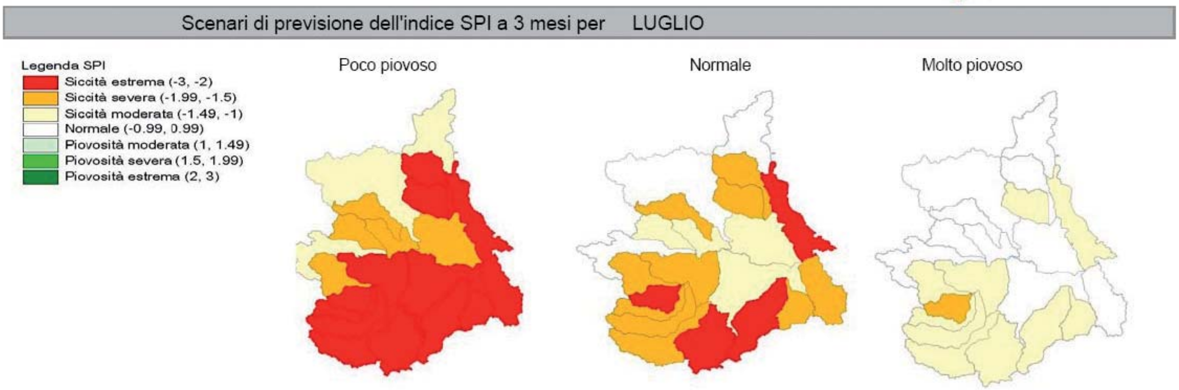


Fig. 10 - SPI Index 3 month - Piedmont Region drought bulletin

In the bulletin three maps showing the 3 months SPI estimated for the next month (an attempt of forecasting) for the three different scenarios corresponding to low precipitation, normal precipitation and high precipitation conditions. The second part of the bulletin gives information on the status of snow as water resource in terms of equivalent volume of water in each regional sub basin.

Neve

Bacino	Volume d'acqua equivalente SWE [Mm3]	Altezza di precipitazione equivalente [mm]
Ticino svizzero	1.9	0.4
Toce	4.9	2.7
Sesia	2.7	2.4
Cervo	0.0	0.0
Dora Baltea	22.1	5.6
Orco	Non significativo	-
Stura Lanzo	Non significativo	-
Dora Riparia	Non significativo	-
Pellice	Non significativo	-
Alto Po	Non significativo	-
Varaita	Non significativo	-
Maira	0.0	0.0
Stura Demonte	0.0	0.0
Tanaro	0.0	0.0

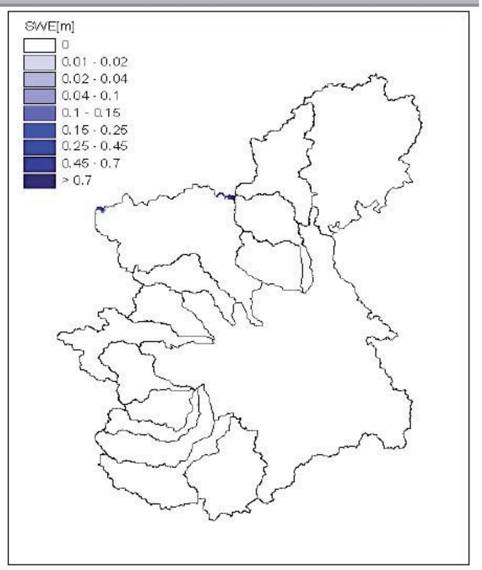


Fig. 11 - Status of snow - Piedmont Region drought bulletin

Finally, in the last part of the bulletin the conditions of the available resources are shown using a graph representing the level of Lake Maggiore (the most important natural water reserve in Piedmont) and a table with the stored volumes in the artificial reservoirs. The use of the Surface Water Supply Index as indicator of the hydrological state at sub basin scale is under development.

Also in Veneto Region the monitoring of the drought and water resources status is operated by the regional environmental agency ARPAV
(http://www.arpa.veneto.it/bollettini/htm/risorsa_idrica.asp).
The information reported regards : a synthesis of the regional situation, monthly rainfall (mm) and hydro-climatic balance (P-ETP), average monthly rainfall for each hydrographic basin (confined to the part of the basin inside the regional boundaries) and for the entire region, estimate of the monthly water fallen on the regional territory (Mm3), 1, 3 , 6 and 12 months Standardized Precipitation Index calculated on the base of the rainfall data for the period 1994-2006 referred to the entire regional territory and the seven early warning zones in which the regional territory is subdivided, monthly rainfall data referred to the seven early warning zones in which the regional territory is subdivided, snow fall condition in the Dolomites and Venetian Alps, water equivalent of the snow cover in Piave River basin, Garda Lake situation (levels), water volumes in the main Venetian reservoirs, groundwater situation or aquifers levels for selected monitoring stations, water courses situation or graphs showing average daily discharges

Fig. 12 - SPI Index 3 month: August 2007

The Emilia Romagna Region is the only one, till now, that used the drought monitoring tools in order to identify the vulnerable areas. In fact, the Italian Legislation (Decree n. 152/99) assigns to the Regions and the Basin Authorities the check on the presence of areas subject to or threatened by drought and the adoption of specific protection measures in the framework of the basin planning and its implementation, according to the criteria foreseen in the National Action Plan for Combating Drought and Desertification approved on 22 December 1998. The vulnerable areas are indicated in the Water Protection Plan, that is the planning instrument at hydro-graphic basin scale envisaged as the proper plan for reaching the water quality objectives and the rational use of the water resources. In the case of Emilia Romagna Region all the available data at the different scales were gathered, starting from the consolidated consideration that the entire Region is subject to drought events. In order to calculate the climatologic indexes, in particular the 3, 6, 12 and 24 months SPI, the quite complete historical series of monthly precipitation available for the period 1952-2000 for 19 stations were used.

Fig. 13 - Distribution of the used stations to calculate the SPI index

The distribution of the used stations gives a quantitative information on the spatial variability of the precipitation and related anomalies. The SPI was used for its ability to quantify the precipitation deficit for different time scales, each one of which reflects the impact of drought on the availability of the different water resources. While the soil humidity gives responses also at short term scales, the groundwater and the water in rivers and reservoirs undergo variations on longer time scale, so all these parameters are monitored for an overall control of the territory.

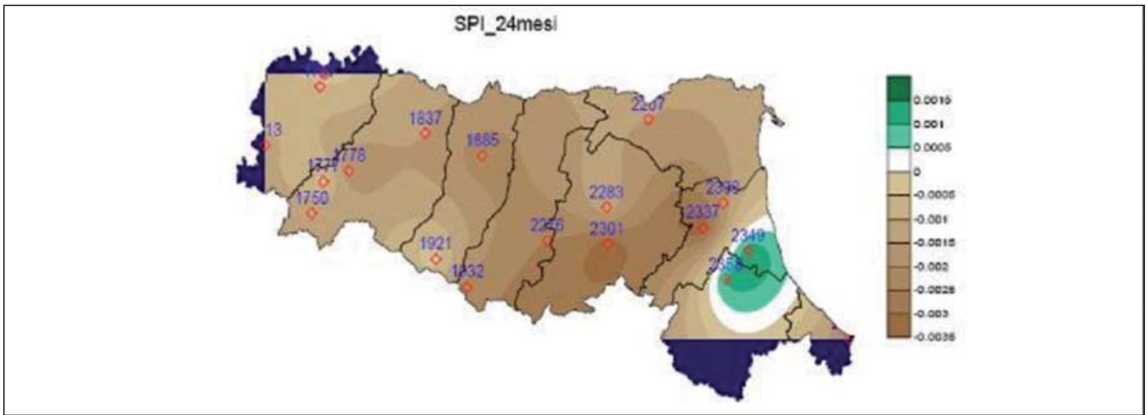
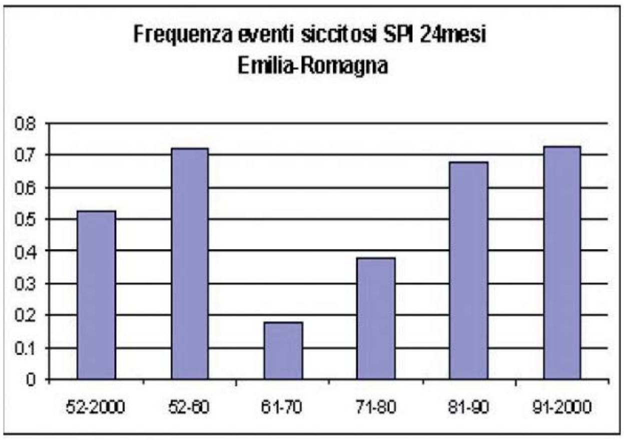


Fig. 14 - SPI and drought events frequency_24 month

http://www.arpa.emr.it



Hereinafter two case studies are reported regarding the application of restriction measures on part of Water Basin Authorities in case of drought condition (hydrologic drought).

Case study 1
The Adige River Water Authority, North-East Italy, on the base of a now 8 year experiment, manages a 30,8 mc/s multiple use water abstraction (mainly irrigation) which serves 5 Irrigation Districts. As regulated by the Regional offices, the abstraction must be decreased on the base of 2 monitoring points in the river where the level is continuously recorded. The abstraction must be reduced when at the upstream point the flow falls below 140 mc/s, and must be stopped when at the downstream point the flow falls below 80 mc/s. In the ranges of flow between the two extreme cases, abstractions are regulated gradually under the Adige River Water Authority indications. A written agreement between the 5 Irrigation Districts specifies the percentages of water to be used at each flow regime.

Case study 2
The Alto Adriatico Water Authority, North-East Italy, adopted new measures in 2004 to address Water Scarcity and Drought. In case of Drought the Authority declares an emergency status and identifies procedures and interested subjects (in the energy and agriculture sectors specifically). The regulation of abstractions will follow, from that moment, a set scheme of progressive reduction of abstractions according to "gravity" of drought and "period of the year". The criteria is a combination of return time (20, 10, and 5 years respectively for severe, medium, and light drought) and period (April to May, June 1st to 15th, June 16th to August 15th, August 16th to August 31st, September). Specifically in case of severe drought, percentages of reduction are 40, 30, 20, 30, and 40% respectively; in case of medium drought, percentages are 30, 20, 10, 20, and 30% respectively; in case of light drought percentages are 20, 10, 5, 10, and 20% respectively. Minimum flow rates are set in correspondence of a set point of the river (3, 5, and 7 mc/s respectively for severe, medium, and light drought), and flow rates "to define case by case" at other points. Finally, the body managing the hydropower reservoirs must always release enough water to assure irrigation needs as set in the previous description, however respecting a minimum volume corresponding to 20% of the maximum capacity.
More in general, measures to save water resourses are identified and supported (network sealing, flow meters at inlet and outlet of abstractions, adoption of technologies able to save water, utilization of aqueduct networks) and indications to regulation bodies are given for what water permits are concerned (limit permit to a maximum of 3 years duration).
An interesting third case study regards the Drought Management Plan adopted by the Drainage and Irrigation District Romagna Occidentale both on meteorological and hydrological indicators.

Case study 3
The Drainage and Irrigation District Romagna Occidentale, North-East Italy, adopted in 2007 a Drought Management Plan. The Plan will be set by each Drainage and Irrigation District and Public Water Agency by the end of 2007, as set by the Regional Drought Management Program.
A number of scenarios and measures are set at different levels of meteorological and hydrological droughts (rainfall, lake water level, snow level, Po river level thresholds and/or distribution network emergencies). At District level 4 scenarios (alert, pre-alarm, alarm, serious drought) and a large number of measures to be implemented gradually are set, as a combination of sce-

narios and measures set at Regional and second degree Irrigation District level. Measures include also nomination of a drought representative, constitution of a Drought Panel able to negotiate and impose measures at technical and political level, and a complete communication and advisory system.

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7 ISPRA DATA BASES

7.1 Climatic “reforecast” database

ISPRA contributes to the MIPAIS databases by generating and providing a 10-year climatic dataset of predicted gridded surface meteorological fields (10-km grid step over the whole Mediterranean basin) generated using an improved version of the QBOLAM atmospheric limited-area model, operational at ISPRA since year 2000.

Recent advances in forecasting research (Hamill *et al.* 2004, 2006) suggest to build–up such “reforecast” (i.e., long-term series of retrospective forecasts produced with a fixed, up-to date model version) databases for different uses including, for instance, model verification, model bias correction and predictability studies. In the MIPAIS framework, the availability of a consistent and continuous time series of high-resolution, wide-coverage, atmospheric gridded fields can provide a useful basis for quantitative studies on drought conditions, hydrological cycle, and so on (provided it is clearly kept in mind that one is dealing with *model forecast* data, rather than observations). Other major advantages are the full spatial coverage (including sea areas) and the inclusion of quantities which are impossible to be directly observed with the desired time-space resolution and coverage (*in primis*, evapo-transpiration).

Note also that the most comparable observation-based products, namely *global reanalyses* (as the NCEP reanalysis and the ECMWF ERA-40) suffer a serious disadvantage: low horizontal resolution (typically, 1-2 degrees). Indeed, it seems quite difficult to perform hydro-meteorological climatic studies on Mediterranean countries, especially when aimed to agro-meteorological issues, employing, for instance, a 1° dataset, since the scale of the phenomena object of such studies is by far smaller. With this respect, a 10-km grid step seems to be at least fairly adequate.

The model employed to generate the “meteo-climatic” database is an improved version of QBOLAM, the atmospheric LAM operating at ISPRA as a part of the Sistema Idro-Meteo-Mare operating chain (Speranza *et al.* 2004). QBOLAM (Quadrics BOlogna Limited Area Model) is a hydrostatic, primitive-equation, finite-difference LAM, daily running at ISPRA on a massively-parallel platform (QUADRICS APE-100) with a 10-km grid step over a domain covering all the Mediterranean sea. ECMWF analysis and forecast provide the initial and boundary conditions, respectively. The SIMM chain includes also a 10-km wave model (WAM) over the Mediterranean Sea, a shallow-water version of the Princeton Ocean Model (POM) for sea elevation over the Adriatic Sea and a finite element model (VL-FEM) for sea elevation in the Venice Lagoon.

The model version employed to build the “meteo-climatic” database differs from the operational one due to the improvement of cumulus convection and the porting over a new parallel platform: an 8-processor SGI ALTIX machine. The resulting increase in computational power made it possible to carry on a massive program of retrospective forecasting. This involves firstly the reproduction, with the new implementation, of all the past forecasts since the start of QBOLAM production (October 2000); then, the backward extension of the “reforecast” series, up to 10 years at least. In order to store the huge amount of model output data, 12 1-TB (exactly, 932 GB) portable dedicated hard disks have been purchased. Stored products include the initial data; the full model output (in the BOLAM’s native format, MHF); and the post-processed surface fields selected to be used into the MIPAIS framework. Post-processing involves the horizontal bilinear interpolation on a 0.1° longitude-latitude grid; however, since it is proven that such grid-to-grid transformations can affect statistical properties of the model output (Accadia

et al., 2003), fields on the native, “rotated”, model grid are conserved, as well.
Database includes daily run output, from 1 January 1997 to 1 January 2007, for seven atmospheric surface fields:

– mean sea-level pressure;
– 2m temperature;
– 10 m wind (u and v components);
– total precipitation;
– convective precipitation;
– surface latent heat flux.

As in the SIMM operational chain, each daily run is initialised with the 1200UTC ECMWF analysis; outputs are saved hourly from 0000UTC of the following day, for the subsequent 48 hours of forecast (the first 12 hours are discarded as spin-up). So, any day is represented in the database by two subsequent daily forecasts.
Possible use of data includes statistical studies of drought and hydrological cycle, on scales ranging from tenth of kilometres to the whole Mediterranean basin. Latent heat surface flux value provides indeed an estimate of evapo-transpiration and thus, joined to rainfall forecast, allows evaluating the water balance. Furthermore, precipitation, together with surface temperature and wind speed forecasts, are suitable for studies on the occurrence of drought conditions. Mean sea-level pressure can be checked against analysis in order to assess the forecast quality and then to evaluate the reliability of studies carried on using forecast quantities.
Data format is binary unformatted (suitable for use in GRADS environment). As already seen, full model output is also stored, but data extraction requires the use of a specific post-processing code, developed to be used under UNIX or LINUX environment.

7.2 SPI Database

In the frame of its activity of monitoring drought in the Mediterranean area, ISPRA has implemented a monthly drought bulletin based on the Standardized Precipitation Index also referred as SPI.
This bulletin was initially set up by collaboration between the former DSTN (now ISPRA) and the MEDEA (*MEteorologia Dinamica Elaborazione e Analisi*) group of Prof. Alfonso Sutera of the Physics Dept., University of Rome “La Sapienza”. In fact, the previous version was developed, in the frame of the Drought project - INTERREG IIC programme, in order to produce a prototype to monitor current states of drought in Italy on a monthly basis.
For this bulletin, it was decided to use as drought index the SPI index (McKee et al., 1993). The purpose of SPI, based only on rainfall probability, is to assign a single numeric value to the precipitation that can be compared across regions with markedly different climates. More in detail, SPI was designed to show that it is possible to simultaneously experience wet conditions on one or more time scales, and dry conditions at other time scales. Consequently, a separate SPI value is calculated for a selection of time scales. These time scales reflect the impact of a drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, streamflow, and reservoir storage reflect the longer-term precipitation anomalies.
Mathematically, the SPI calculation for any location is based on a long-term precipitation record for a desired period. For this reason, it was decided to use the daily NCEP/NCAR precipitation rate (kg m^{-2} s^{-1}) reanalysis which are available online from 1948 up to now over the entire ter-

restrial globe. Reanalysis data have been stored for the entire domain, but for our purpose, only data over Europe and the Mediterranean basin have been considered for the SPI calculation (see Fig. 15).

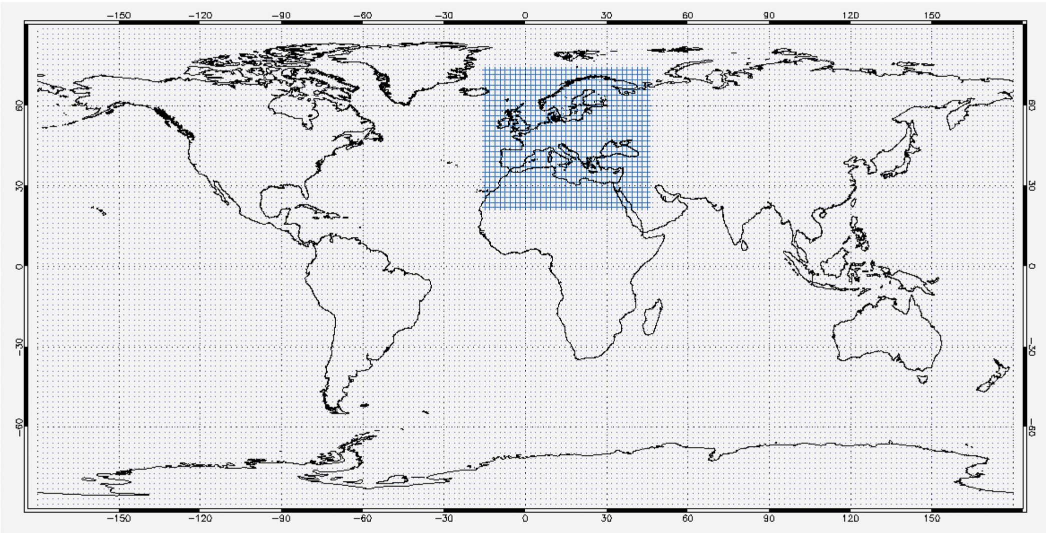


Fig. 15 - NCEO/NCAR reanalysis data grid indicating the data domain considered for calculating ISPRA's bulletin (blue grid)

For each grid point, the long-term record is fitted to a probability distribution. Thom (1966) found that the gamma distribution fits well this climatological precipitation time series.
Given *X* the precipitation time series, for each $x > 0$ the gamma distribution is defined as:

$$g(x) = \frac{1}{\hat{a}^{\acute{a}}\,\Gamma(\acute{a})} x^{\acute{a}-1} e^{-x/\hat{a}}$$

where α (>0) is a shape parameter, ? (>0) is a scale parameter and ?(?) is the gamma function. The fitting is performed by optimally estimating the alpha and beta parameters by means of the maximum likelihood method:

$$\hat{a} = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right)$$

$$\hat{\hat{a}} = \frac{\bar{x}}{\hat{a}}$$

where:

$$A = \ln(\bar{x}) - \frac{\sum \ln(x)}{n}$$

and *n* is the total number of precipitation observations. Thus, the longer the period used to calculate the distribution parameters, the more likely you are to get better results. For this reason the NCEP/NCAR precipitation reanalysis data, which is available since 1948 (about 60 years), seem to be an optimal choice to perform the drought monitoring at European scale. Therefore, this long time period (1948-2007) is useful to calculate the parameters of the gamma distribution. The cumulative probability is then given by:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\hat{\hat{a}}^{\hat{a}}\,\Gamma(\hat{a})}\int_0^x x^{\hat{a}-1} e^{-x/\hat{\hat{a}}}\, dx$$

.

However, since the gamma distribution is not defined for *x* equal to zero and the precipitation distribution may contain zeros, the cumulative distribution is redefined as follows:

$$H(x) = q + (1 - q)G(x)$$

where *q* is the probability of a zero precipitation that can be estimated as the ratio between the number of zeros in the precipitation time series (*m*) and the total number of precipitation observations: *m*/*n*.
The cumulative distribution *H*(*x*) is then transformed into a normal distribution (Panofsky and Brier, 1958) so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). The transformation allows maintaining the probability of being less than a given value of the variate from the gamma distribution the same of the probability of being less than the corresponding value of the transformed normally distributed variate.
Conceptually, SPI represents the number of standard deviations above or below that an event is from the mean. Thus, the unit of the SPI can be considered to be "standard deviations". Standard deviation is often described as the value along a standard normal distribution at which the cumulative probability of an event occurring is 0.1587. In a like manner, the cumulative probability of any SPI value can be found, and this will be equal to the cumulative probability of the corresponding rainfall event.
SPI can effectively represent the precipitation amount over a given time scale, with the advantage that it provides not only information on the amount of rainfall, but that it also gives an indication of what this amount is in relation to the normal, thus leading to the definition of whether a monitored grid point is experiencing drought or not. Positive SPI values indicate greater than median precipitation, and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way, and wet periods can also be monitored using the SPI. A schematic description of the correspondence between the SPI value and the drought regime is reported in Table 9.

Tab. 9 - SPI classification used to define drought intensity regime.

SPI Values	**Class**
≥ 2.0	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-0.99 to 0.99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
≤ -2.0	extremely dry

Further details on SPI, in particular on the mathematics used in the calculation, may be found, for instance, in the chapter 3 of Dan Edwards' Master Thesis available online at the Colorado Climatic Center website (http://ccc.atmos.colostate.edu/pub/spi.pdf).

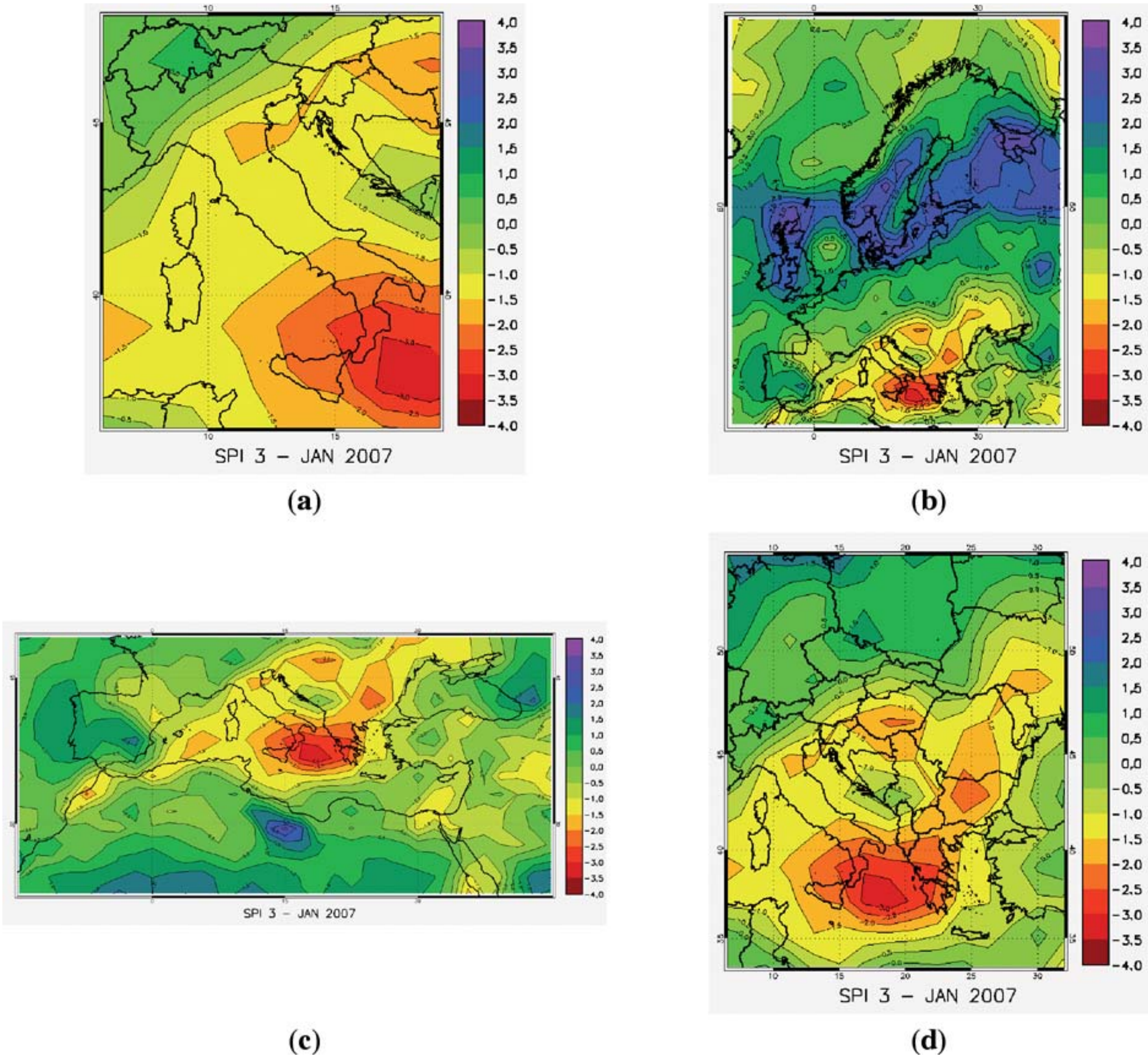


Fig. 16 - SPI thematic maps concerning: a) Italy; b) Europe; c) the Mediterranean basin; d) the CADSES area

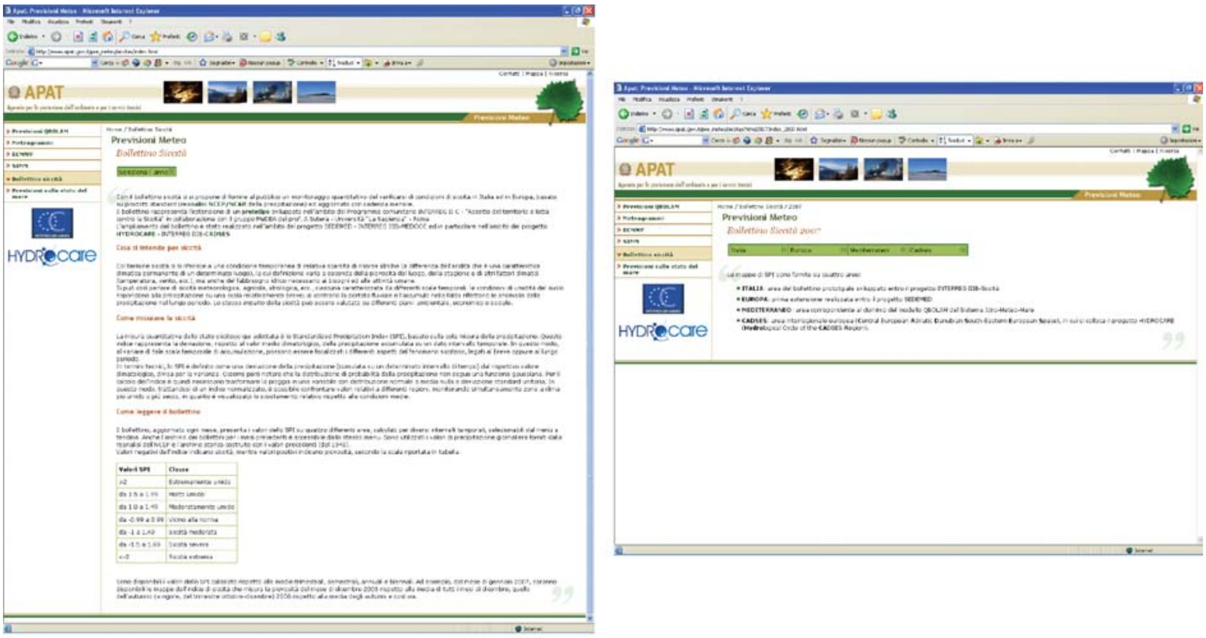
McKee et al. (1993) originally calculated SPI for 3, 6, 12, 24, and 48 month time scales. For our purposes, the SPI calculation is performed only for 3, 6, 12 and 24 month time scales. Besides the fact that NCEP/NCAR reanalysis data have been initially used to compute SPI only for Italy, their time-space resolution has been judged sufficient to compute the drought indexes for the large-scale analysis, such as the Mediterranean area.

Thus, it was decided to extend the bulletin target over three areas:

- an area covering Europe;
- an area covering the Mediterranean Basin, and coincident with the domain of the ISPRA operational meteorological model QBOLAM (belonging to the Hydro-Meteo-Marine forecasting system);
- and an area covering the CADSES (**C**entral European **A**driatic **D**anubian **S**outh-Eastern **E**uropean **S**pace) region, since the bulletin project is partially funded by the HYDROCARE project of the INTERREG III B CADSES programme.

An automatic system has been then implemented for the monthly production of the drought bulletin. The system includes the download of the precipitation reanalyses data from the

NCEP/NCAR ftp site; the calculation of the SPI values – using a FORTRAN code – for the four areas (Italy, Europe, Mediterranean Basin, and CADSES area) and the four time scales above reported; the plotting of the SPI thematic maps using an IDL code; and finally the update of the website available online at the ISPRA web page:
http://www.isprambiente.it/pre_meteo/siccitas/index.html.
At the moment, the thematic maps present on the web page cover the period from December 1989 to January 2007 (last update). The SPI thematic maps for January 2007 are presented, as an example, in Fig. 16.; whereas in Fig. 17 is reported two snapshots of the ISPRA website of the drought bulletin.



(a) (b)

Fig. 17 - Two snapshots of the drought bulletin in ISPRA's website: a) description of SPI and selected year; b) short description of the monitored areas and periods

The reanalysis precipitation data for the entire globe, the SPI time series for each grid point considered (see blue grid in Fig. 15) and the SPI thematic maps have been then stored in a ISPRA archive in order to create a sort of "climatic" database.
For each monitored grid point in Europe and in the Mediterranean Basin, it is possible, this way, to plot the SPI time series along the whole period (or a part of it) in order to have a local indication of the drought occurrence and trend. At the same time, it is possible to make a relationship with the NCEP/NCAR reanalysis time series of the corresponding grid point.

7.3 The Hydrogeological map

In the frame of the operational programme INTERREG IIC "**Territorial Planning and coping with the effects of drought**" realized in the Italian regions of Objective I (Molise, Campania, Puglia, Basilicata and Calabria), the European Commission enstrusted the Department for the National Technical Services (D.S.T.N.) with the task of coordinating the project activities.

In charge of the section "**Hydrological cycle analysis in the region of Objective 1**" the DSTN proposed the project: "Evaluation of groundwater in South Italy and optimization of the monitoring network in the Naples Office of the National Hydrografical and Marigraphic Service for measuring groundwater tables". This study was given to the Department of Geophisics and Volcanology in the Naples University "Federico II" through an agreement.
The study was organized in different objectives related to different analyses scales and directed to give full details of the hydrological knowledge of the continental part of Southern Italy, in order to define its particolar features on territory, which are essential for the organization and the management of a regional monitoring network. In particular, the first of these objectives concerned the "definition of a synthetic frame in groundwater knowledge and groundwate use in South Italy", based on the analysis of the bibliographic hydrogeological information collected for the objective I regions.
The study for the recostruction of this synthetic frame on the groundwater knowledge in continental part of Southern Italy was realized through the acquisition of the most scientific publications concerning hydrology in the Objective I regions. It was also carried out on the basis of hydrogeological researches already published and new studies supported by local istitutions, regional bodies, reclamation consortia, irrigation consortia.
Through the above mentioned sources of hydrogeological literature, the bibliographic research was bolstered thanks to the results of unpublished studies carried out in Italian universities and national research centres as doctoral thesis, degreee thesis, internal reports.
This bibliographic research also allowed the collection of 479 studies for all abovementioned regions. The typology of such studies, to be defined on the basis of the subject mainly discussed, covers different fields of hydrology and waterground management ranging from the recostruction of the groundwater ciculation schemes to the evaluation of the water potentiality in the hydrogeological structures, from the study of the physical and chemical features of groundwater to the analysis of questions related to the construction of abstraction works, to studies for the evaluation of the inherent vulnerability of aquifers to pollution.
In order to homogenize the bibliographic information and make it accessible rapidly, infomation recording was standardized in a relational database designed to get an high number of hydrological information levels. This operation allowed the different typologies of data collected from the quoted studies to be analysed in the following tables: a) study identification; b) administrative localization; c) physiographic localization; d) geological and hydrogeological characterization; e) contents and results; f) sources; g) groundwater levels; h) wells and equipped drillings; i) water streams; l) hydrogeochemical analyses; m) pluviometric data; n) thermometric data. The information levels named fields in the databases terminology were distribuited in 123 fields in the abovementioned tables on the basis of their hydrogeological topic. The relational structure among the different tables was realized linking them in an unbinding manner, then with bijective links between each table and all the others in order to allow a free information query.
A particular approach was adopted for the collection of information concerning springs which can be named differently in different bibliographies. In many cases in fact, the identification of the same spring could not be univoque, since different names originated by the local toponymy given to the same source.
Besides, the information collection concerning springs was made taking into account the need of considering and representing cartographically not only the main sources with a flow higher than 0.05 m3/s, but also those less important with flows higher than 0.001 m3/s, providing however relevant indications on the groundwater circulation schemes of minor hydrological struc-

tures. Therefore, information gathered for each spring was validated through a cross check among the bibliographic sources. This control was also extended to the cartographic location, making reference to I.G.M. 1:25.000 cartography. The bibliographic data concerning springs flow measures pointed out unfortunately that this information is incomplete for time blanks due to the lack of systematic sources measurement. Actually, for many chief springs there is at most a flow evaluation with low and high water; for those less relevant sources there are only the data reported in the "Sources book" as they were surveyed by the Hydrographic Service in the years '30.
The main analysis provided by this study is the hydrological map on a scale of 1:250.000, on which all aquifers being relevant in the regional geological context were represented. This operation required the choice of a classification methodology for aquifers which proved to be appropriate to the details of the representation scale, which also required the differentiation of the less permeable units.
The hydrogeological interpretation of the lithostratigraphic and tectonic units known in the geological literature concerning the Southern Appenines regions, allowed the individuation of 39 hydrogeological complexes for which the main hydrogeological features were detailed (kind of permeability, degree of permeability and C.I.P. potential infiltration coefficient estimated): a) complexes of quaternarian coverings; b) complexes of volcanic plio-quaternarian deposits; c) complexes of marine plio-quaternarian deposits; d) complexes of molassic late-orogenic deposits; e) complexes of flyscho sinorogenic successions; f) complexes of carbonatic paleogenic successions; g) complexes of mesozoic successions of carbonatic platform; h) complexes of external basin units; i) complexes of internal basin units; l) complexes of hercynian units of Calabria.
The geometric information concerning the surfacing areas of these hydrogeological complexes was digitalized in vector format and implemented in a geographical information system (G.I.S.), supplied with geographic references in the international U.T.M system. Furthermore, the graphic representation of the hydrogeological information database produced in addition to the above mentioned hydrogeological map, other derived maps on type and degree of relative permeability, and on estimated potential infiltration coefficient (C.I.P.).
The operation of recording and homogenizing bibliographic information into the hydrogeological map of southern continental Italy produced a basic instrument which is essential for the study of questions related to water supply from an interregional point of view. It also allowed to detect through hydrological balances water resources integrating the already used quantity in the acqueduct networks. In particular, for the almost total utilisation of springs coming from highly permeable aquifers, mainly calcareous and calcareous-dolomitic, the eventual additional water resources could be detected, first in a deductive manner through hydrological balances and then through specific hydrogeological studies, in the hydrogeological complexes with a medium degree of permeability, which are represented by porous plio-quaternarian aquifers, especially where they are fed through groundwater transfers coming from carbonatic hydrostructures. In fact, as the data related to the areal distribution of these hydrogeological complexes have shown, they occupy relevant parts of each regional territory, and present in the whole area of southern continental Italy an extension of almost 28.000 km2, corresponding to about 45% of the total extension.
The possibility of extending the hydrological map to Lazio and Sardina has been considered in MIPAIS project in addition to a closer examination to be carried out in the Viterbo area, which is chiefly bent on farming, as pilote zone for the analysis of groundwater contribution to agriculture.

7.4 Eddy Covariance Station measures

ISPRA partecipated in the Community Initiative Programme INTERREG III B MEDOCC with the project SEDEMED "*Sécheresse et desertification dans le Bassin Méditerranéen*" whose aims are the definition of proper studies and mitigation strategies and the organization of an integrated information system supporting water resources planning in order to combat drought and desertification in the frame of an international collaboration.
In order to determine specific and necessaire parameters or indexes for drought knowledge, SEDEMED project has also foreseen the development of hydrometric station networks in some areas of Southern Italy and the promotion of innovative actions even from the point of view of new instrumental techniques. Infact, the most difficult parameter to be evaluated in the water budget calculation is the evapotranspiration which has required the utilization of a portable instrument able to produce very good results in research activities and give expectations of functionalities on active service.
The first results relative to mass and energy flux measurements recorded by two complete eddy covariance stations, installed in a plane of high agricultural interest in southern Italy, are now available.
The ground ET measurements obtained from eddy covariance systems at two different sites in southern Italy, analyses the performance given by the surface Energy Balance Algorithm for Land (SEBAL) model using both National Oceanic Atmospheric Administration-Advanced Very High Resolution Radiometer (NOAA-AVHRR) images and Moderate Resolution Imaging Spectroradiometer (MODIS) on the EOS-1 Terra satellite.
The results obtained during a three-day summer-period pointed out good ET predictions for both satellites in the eddy covariance sites, whilst evident differences were observed in some highly vegetated mountain zones, extending the procedure to the regional scale.
The technique of eddy correlations is represented by the use of sophisticate sensors able to measure the real evapotranspiration of a given surface whose extension has a variable radius between 200-300 meters to 1 km. This technique is considered the most reliable in the measurement of the atmospheric flows.
The eddy correlation system is a modular structure because it is composed by many instruments. In this case, it is formed by a supply system, a datalogger, an anemometer, a rapid acquisition hygrometer and a thermocouple, a sharp radiometer, a tester for temperature and heat flows at ground level and by a traditional instrumentation for the measurement of wind direction and speed , air temperature and humidity.
The measurements analysed have been carried out in two *eddy covariance* stations.
Instrumentation of the first station, managed by the Department of Soil Conservation, University of Calabria, is located (2004 and 2005) near the Demonstrative Experimental Center of the Calabria Region ARSSA Institute (Agenzia Regionale per lo Sviluppo e per i Servizi in Agricoltura), located in Sibari (39° 44' 23.9'' N, 16° 26' 52.8'' E, 7 m s.l.m.), and later (2006) near a redtop field (*alfalfa*) near Paglialonga di Bisognano (CS).
The instrumentation in Sibari is at the centre of a rectangular field whose dimensions are about 250?150 m2 and at a distance of about 4 km from the sea.
The field is generally cultivated with various kinds of vegetables and wheat, but it is laid fallow in the analysed period (August-December 2004), therefore the concerned area is characterised by sparse vegetation. The field, where the instrumentation is located, is surrounded on three of the four sides by high but not very dense rows of cypresses that in some way influence the definition of the fetch. The pedological characterization led to a clayloamy soil, instead from

a geological point of view the Sibari plain is a sedimentary basin, emerging from a geological structure segmented by numerous fault systems.
The analysed site is bio-climatically characterised by a climate varying from sub-humid to semi-arid (IOVINO 2003). The meteorological station of Villapiana managed by the Centro Funzionale Meteo-Idrologico Regionale (CFS-MIDMAR), near the eddy covariance station, recorded a mean annual temperature of 21.5 °C and a mean annual precipitation of about 500 mm. Close the eddy station another meteorological station is available since about ten years, managed by the Ufficio Centrale di Ecologia Agraria (UCEA). The mean monthly temperature values recorded by this station during the analysed period vary from 25.8 °C (August) to 10.5 °C (December), while mean monthly precipitation values vary from 3.8 mm (August) to 88.8 mm (December). The prevailing winds, both in terms of frequency and intensity, derive from E and NE, that is from the sea.
The second station was sited in a mountain forest, in the territory of the town of Longobucco-CS.
The eddy covariance stations provide continuous measurements of the main components of the energy balance averaged every 30 minutes, besides measuring other micrometeorological variables (such as wind speed and direction, air humidity, surface, air and soil temperature, soil water content, and also the content of CO_2 in the atmosphere). The recorded data of R_n, G, λE, H and cumulated daily ET have been used to analyze the performance given by SEBAL.
A first comparison was carried out using both the measurements recorded by the Sibari and Longobucco stations during the period August 18-20, 2004. The differences in measured and estimated λE and H values are shown in figures 10(a) and 10(b). Even though the analyzed period is very short, some general aspects can be pointed out. Specifically, it can be observed a more reliable estimate in the agricultural area (Sibari) than that obtained in the mountain area (Longobucco). The difference is mainly due to the correct definition of the aerodynamic resistance, which for tall forests becomes very difficult to determine. In this case sudden changes in vegetation height and density strongly affects the satellite estimate, based on a representative mean value. Therefore, in addition to the detailed knowledge of the actual density and phenologic characteristics, also a suitable spatial resolution of satellite images is required to capture the heterogeneity of vegetation. With the aim of increasing the spatial information content of a satellite image, a downscaling procedure can be applied through a multi-sensors approach. This procedure has been tested only for the area interested by the Sibari station, because just for it were available, for a same period, images recorded by diverse sensors typified by different spatial resolutions.

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