WATER USAGE, SOURCE AND SUSTAINABILITY: EXAMPLES FROM THE REGION OF NAVARRA (SPAIN) AND GREECE

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ABOUT THE FLINT PROJECT

FLINT will provide an updated data-infrastructure needed by the agro-food sector and policy makers to provide up to date information on farm level indicators on sustainability and other new relevant issues. Better decision making will be facilitated by taking into account the sustainability performance of farms on a wide range of relevant topics, such as (1) market stabilization; (2) income support; (3) environmental sustainability; (4) climate change adaptation and mitigation; (5) innovation; and (6) resource efficiency. The approach will explicitly consider the heterogeneity of the farming sector in the EU and its member states. Together with the farming and agro-food sector the feasibility of these indicators will be determined.

FLINT will take into account the increasing needs for sustainability information by national and international retail and agro-food sectors. The FLINT approach is supported by the Sustainable Agriculture Initiative Platform and the Sustainability Consortium in which the agro-food sector actively participates. FLINT will establish a pilot network of at least 1000 farms (representative of farm diversity at EU level, including the different administrative environments in the different MS) that is well suited for the gathering of these data.

The lessons learned and recommendations from the empirical research conducted in 9 purposefully chosen MS will be used for estimating and discussing effects in all 28 MS. This will be very useful if the European Commission should decide to upgrade the pilot network to an operational EU-wide system.

PROJECT CONSORTIUM:

1	DLO Foundation (Stichting Dienst Landbouwkundig Onderzoek)	Netherlands
2	AKI - Agrargazdasagi Kutato Intezet	Hungary
3	MTT Agrifood Research Finland	Finland
4	IERiGZ-PIB - Instytut Ekonomiki Rolnictwa i Gospodarki Zywnosciowej-Panstwowy Instytut Badawcy	Poland
5	INTIA - Instituto Navarro De Tecnologias e Infraestructuras Agrolimentarias	Spain
6	ZALF - Leibniz Centre for Agricultural Landscape Research	Germany
7	Teagasc - The Agriculture and Food Development Authority of Irelan	Ireland
8	Demeter - Hellenic Agricultural Organization	Greece
9	INRA - Institut National de la Recherche Agronomique	France
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LIST OF ACRONYMS

AWU	Annual working unit
BAT	Best available techniques
BWF	Business water footprint
CAP	Common Agricultural Policy
CWR	Crop water requirements
EU	European Union
IRBM	Integrated river basin management
UAA	Utilized agricultural area
WF	Water footprint

EXECUTIVE SUMMARY

The sustainability concept is determined by three components: social, economic and environmental. Water has a wide range of uses from basic need to business. Water and agricultural sector, especially in southern European Union (EU) Member States, are linked because agricultural yields without water are very low. Hence, water usage, especially in irrigation, is a limiting factor for agriculture in many regions of the south of the EU. Social and economic consequences of water as a business input are important.

The main objective of this report is to investigate relations between water and sustainability. For that, indicators based from the Farm Accountancy Data Network (FADN) and the data collected in the FLINT project are proposed. Some of them are quantitative, others are qualitative. Some are simple, others composite.

Two kinds of problems are detected in this study:

1.- Problems linked to data collection. In some countries, regions, river basins, water is not a scarce resource and metering consumption is not a priority. In other cases information about water is sensitive.

2.- Problems to analysis of information. Water use has very different consequences depending not only on the country or region but also river basin. Hence, identifying quantitative and synthetic indicators to analyze sustainability is not feasible. An approach must be followed using composite and qualitative indicators for specific types of farming.

For these reasons the approach here has taken into account the problem of data accuracy and has been based on different kinds of indicators applied to Mediterranean regions and irrigation.

1 INTRODUCTION

1.1 Water use and irrigation in agriculture in the European Union

The Water Framework Directive (WFD) is probably the most ambitious European effort for a common integrated management of environmental resources in the European Union (EU). The WFD states that water is not a commercial product like any other, rather it is an heritage which must be protected. Irrigated agriculture is the largest consumer of water in European Mediterranean areas, and an important economic activity in the rest of the European landscape. On the other hand, the Common Agricultural Policy (CAP) influences decisively the use of water in irrigated systems (Berbel, 2004).
Agriculture is a significant user of water resources in Europe, accounting for around 30% of total water use. The scale and importance of irrigation is significantly greater in the southern Member States but far from negligible in most northern Member States. In the south, irrigation accounts for over 60% of water use in most countries, while in northern Member States it varies from almost zero in a few countries to over 30% 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 United Kingdom, Belgium, the Netherlands, Germany, Austria and France, and nationally significant in Portugal, Spain, Italy and Greece (IEEP, 2000).

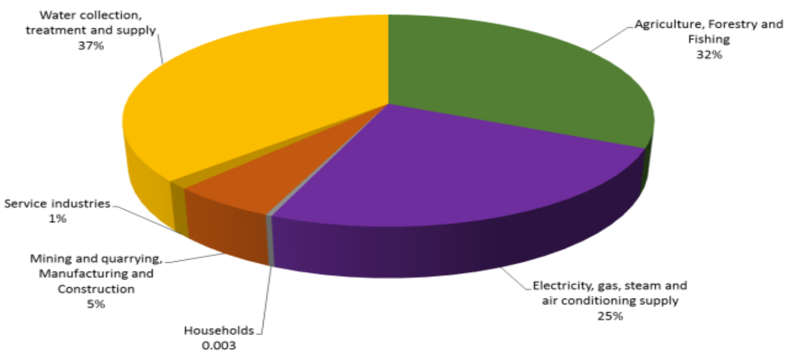


Figure 1: Water use by sectors

Source: European Environment Agency (2015)

In the first approach to information related to water and agriculture in the EU, one consideration must be taken into account, and this is the relevance of irrigation in water consumption and the differences across countries in the level of irrigated areas and the crops cultivated in these areas.

There is no single, reliable and comprehensive source of data on irrigation in the EU from which we could draw (IEEP, 2000).

Table 1: Irrigable and irrigated areas, EU-28 and Norway, 2013

	UAA	Total irrigable area		Area irrigated at least once a year	
	(ha)	(ha)	(% of UAA)	(ha)	(% of UAA)
Greece([1])	3,381,510	1,516,930	44.9	1,164,620	34.4
Malta	10,880	4,200	38.6	3,660	33.6
Italy ([1])	11,813,630	4,004,450	33.9	2,866,330	24.3
Cyprus ([1])	109,040	38,060	34.9	24,670	22.6
Portugal ([1])	3,539,350	551,760	15.6	477,160	13.5
Spain ([1])	21,694,850	6,751,710	31.1	2,898,970	13.4
Denmark	2,619,340	438,980	16.8	241,980	9.2
EU-27	717,730	339,340	11.3	217,380	6.2
EU-28	121,496,470	4,953,330	11.3	2,475,590	6.2
Netherlands	1,847,570	499,400	27.0	101,770	5.5
France ([1])	27,064,300	2,811,440	10.4	1,423,640	5.3
Hungary ([1])	4,589,290	258,960	5.6	141,190	3.1
Bulgaria ([1])	3,794,910	115,520	3.0	98,670	2.6
Germany	16,699,580	691,260	4.1	365,590	2.2
Austria ([1])	2,524,750	119,840	4.7	51,680	2.0
Norway	996,270	88,910	8.9	19,450	2.0
Sweden	3,035,920	155,520	5.1	51,870	1.7
Romania ([1])	11,509,310	230,390	2.0	152,840	1.3
Slovakia	1,901,610	99,640	5.2	24,600	1.3
Croatia ([1])	1,292,310	25,870	2.0	13,430	1.0
Slovenia([1])	462,750	4,270	0.9	2,540	0.5
Czech Republic	3,491,470	34,070	1.0	17,840	0.5
Belgium	1,307,900	19,180	1.5	5,740	0.4
Finland	2,282,400	102,130	4.5	9,510	0.4
Poland	14,409,870	75,810	0.5	45,550	0.3
United Kingdom ([1])	15,900,920	115,380	0.7	49,130	0.3
Lithuania	2,861,250	4,080	0.1	1,600	0.1
Estonia	957,510	430	0.0	310	0.0
Latvia	1,877,720	630	0.0	410	0.0
Ireland([1])	4,536,430	0	0.0	0	0.0

([1]) UAA calculated without common land

Note: UAA stands for utilized agricultural area. Blue color rows for FLINT countries. .

Source: Eurostat (2016)

The representativeness of countries included in the FLINT project (Table 2) is similar in terms of utilized agricultural area (UAA) and in terms of irrigated area to that of the EU (Table 1). However, two countries representing the Mediterranean agriculture (Spain-ES and Greece-GR) with only 15% of total UAA, are responsible for 40% of the irrigated UAA.

Table 2: Relevance of FLINT countries in total UAA and irrigated area

	UAA		IRRIGATED AREA	
	Number of ha	As a share in EU-28 area	Number of ha	As a share in EU-28 area
TOTAL EU-28	166,512,640	100%	10,254,750	100%
FLINT COUNTRIES	96,505,800	58%	6,150,840	60%
ES+GR	25,076,360	15%	4,063,590	40%
	Number of ha	As a share in FLINT countries	Number of ha	As a share in FLINT countries
ES+GR		26%		66%

Source: Eurostat (2016) and the authors based on FLINT

In the report "The environmental impacts of irrigation in the European Union" (IEEP, 2000) there is a classification of countries depending on the irrigation relevance. The report classifies countries in three groups:

A: countries or regions which have arid climates that make irrigated agriculture much more productive than dry-land agriculture. In many cases, therefore, irrigation is a long established feature of some kinds of agriculture and agriculture is often one of the principal user of water. EU regions where this applies would include most southern and Mediterranean areas, with a few exceptions. Therefore the countries we have included in this group are Greece, Spain, Portugal and Italy. However, the characteristics of this group could also apply to southern France and some parts of south-eastern

Austria, and there are parts of Spain and Italy, in particular, which do not conform to this particular group definition.

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

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

On the other hand, not only irrigated area is more important but also water volume used in irrigation is much more important in countries of group A. As can be seen in Table 3, Mediterranean countries have more consumption per hectare than northern countries.

Table 3: Volume of water used for irrigation, EU-28 and Norway, 2010

	Total area irrigated at least once a year (³) (hectares)	Volume of water used for irrigation per year (1,000 m³)	Average volume of water used for irrigation (m³ per ha)
EU-28	9,984,330	39,863,943	3,993
Malta	2,830	28,176	9,956
Portugal	466,330	3,437,366	7,371
Spain	3,044,710	16,658,538	5,471
Italy	2,408,350	11,570,290	4,804
Bulgaria	90,400	355,610	3,934
Greece	1,025,210	3,896,683	3,801
Cyprus	28,290	91,510	3,235
Slovenia	1,260	2,644	2,098
Croatia	14,480	30,281	2,091
Sweden	63,250	111,053	1,756
France	1,583,610	2,711,481	1,712
Romania	133,460	203,667	1,526
United Kingdom	66,350	86,647	1,306
Lithuania	1,530	1,215	794
Germany	372,750	293,374	787
Austria	26,480	18,316	692
Denmark	320,180	219,246	685
Czech Republic	19,200	11,147	581
Netherlands	137,310	64,857	472
Hungary	114,550	48,907	427
Slovakia	14,840	5,579	376
Finland	12,610	4,369	346
Poland	45,530	12,855	282
Estonia	330	60	182
Latvia	710	73	103
Belgium (²)	4,260	:	:
Ireland(¹)	0	0	0
Luxembourg (²)	:	:	:
Norway	40,370	25,262	626

(¹) Data considered not existing or non-significant

(²) Data not available

(³) Excluding kitchen gardens and area under glass

Note: Blue color rows for FLINT countries.

Source: Eurostat (2016)

"Different crops are subject to irrigation at varying levels of intensity. Four main categories can be distinguished:

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

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

(2) 'Semi-intensive crops' (S): these are generally lower value crops where irrigation is more widely used to improve growth rates and productivity, either on a seasonal basis at times of peak demand (notably in northern Member States) or for most of the cropping period. Rates of water use are generally higher than for extensive crops, e.g.:
- sown or temporary grassland or alfalfa (less than 5 years old)
- cereals or oilseeds
- maize (noted separately because it has different growth characteristics to other cereal crops, and is associated with greater environmental risks);

(3) 'Intensive crops' (I): these are generally high value crops where irrigation can be critically important to maintain yields and quality and it is therefore more intensively applied to the crop, e.g.:
- root crops (potatoes, sugar beet, swedes)
- industrial crops (cotton and tobacco)
- open air horticulture (salads, green vegetables grown in the open)
- glasshouse production (salads, tomatoes, many other vegetables grown intensively under glass in controlled environments);

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

Note that in this typology, the use of the word 'intensive' is not meant to refer to other input use in addition to water. Depending on the Member States considered, crops which are classified here as extensive or semi-intensive (e.g. managed grassland and maize) might be classified as intensively managed, if the term were used in relation to the levels of chemical inputs (fertilisers and pesticides)" (IEEP, 2000).

One of the most important reasons to have more water consumption per hectare is that some crops produced in dry lands in most of European countries, must be irrigated in Mediterranean countries. This is the case of maize and sugar beet and with a lower difference in potatoes (Tables 4 and 5).

In other crops (cereals excluding maize), although the biggest share of cultivated area is in dry lands, the number of hectares is important in countries like Spain (630,350 ha).

Table 4: Cereals and maize area and irrigation share in the EU countries, Norway and Switzerland, 2010

	Cereals (excl. maize and rice)			Maize (grain and green)		
	Total area	Are irrigated at least once a year	Share of area irrigated once a year	Total area	Area irrigated at least once a year	Share of area irrigated once a year
	(ha)		(%)	(ha)		(%)
Greece	832,100	66,530	8,0%	163,800	157,080	95.9%
Spain	5,603,500	630,350	11,2%	411,200	313,830	76.3%
Portugal	184,600	14,190	7,7%	182,800	138,160	75.6%
Italy	3,131,100	109,780	3,5%	1,209,700	511,540	42.3%
France	7,610,800	252,860	3,3%	3,006,500	749,510	24.9%
Denmark	1,474,900	153,730	10,4%	183,200	29,590	16.2%
Sweden	948,800	28,530	3,0%	16,300	1,390	8.5%
Bulgary	1,430,900	1,220	0,1%	347,800	17,240	5.0%
Netherlands	196,200	5,640	2,9%	252,900	11,870	4.7%
Hungary	1,514,100	13,740	0,9%	1,163,500	39,560	3.4%
Germany	6,128,800	100,260	1,6%	2,295,500	49,230	2.1%
Austria	610,700	860	0,1%	282,300	5,510	2.0%
Slovakia	516,700	550	0,1%	243,100	4,280	1.8%
Romania	2,813,000	33,810	1,2%	2,314,100	28,980	1.3%
Norway	301,000	15,470	5,1%	0	0	
Switzerland	134,600	1,960	1,5%	63,700	2,030	3.2%

Note: Blue color rows for FLINT countries.

Source: Eurostat (2016)

Table 5: Potatoes and sugar beet area and irrigation share in the EU countries, Norway and Switzerland, 2010

	Potatoes			Sugar beet		
	Total area	Area irrigated at least once a year	Share of area irrigated once a year	Total area	Area irrigated at least once a year	Share of area irrigated once a year
	(ha)		(%)	(ha)		(%)
Cyprus	4,170	4,570	100.0%	0	0	
Greece	20,630	20,050	97.2%	18,700	17,710	94.7%
Malta (¹)	700	630	90.0%	0	0	
Italy	27,110	20,700	76.4%	58,650	24,530	41.8%
Denmark	38,140	27,570	72.3%	39,070	60	0.2%
Portugal (¹)	17,720	12,330	69.6%	140	0	0.0%
Spain	61,890	38,290	61.9%	48,580	42,260	87.0%
France	161,150	62,670	38.9%	383,590	40,970	10.7%
Sweden	27,200	10,560	38.8%	37,950	4,450	11.7%
Bulgary	13,550	5,210	38.5%	40	10	25.0%
Hungary	16,740	5,630	33.6%	15,510	860	5.5%
Germany	254,370	81,900	32.2%	364,120	34,830	9.6%
United Kingdom	138,020	39,160	28.4%	118,600	5,840	4.9%
Slovakia	8,770	2,470	28.2%	17,920	1,480	8.3%
Finland	25,150	3,990	15.9%	14,620	320	2.2%
Austria	22,170	3,220	14.5%	44,760	4,750	10.6%
Netherlands	158,270	22,390	14.1%	70,580	5,470	7.8%
Czech Republic	25,410	3,320	13.1%	56,370	1,090	1.9%
Croatia	11,420	1,340	11.7%	24,660	240	1.0%
Romania	118,290	6,140	5.2%	25,310	220	0.9%
Belgium	81,760	2,680	3.3%	59,300	170	0.3%
Poland	374,760	7,390	2.0%	206,220	610	0.3%
Lithuania	33,200	640	1.9%	15,390	0	0.0%
Slovenia	4,120	60	1.5%	0	0	
Latvia	24,590	180	0.7%	0	0	
Estonia	6,110	30	0.5%	0	0	
Ireland	12,200	0	0.0%	820	0	0.0%
Luxembourg(²)	620	:		0	:	
Norway	13,240	5,510	41.6%	0	0	
Switzerland	10,870	3,650	33.6%	17,840	680	3.8%

(¹) Data for sugar beet were not available; not existing or non-significant

(²) Data for potatoes and sugar beet were not available

Note: Blue color rows for FLINT countries.

Source: Eurostat (2016)

1.2 Irrigation and sustainability

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

"Irrigation can affect the environment through:

- Direct impacts upon water sources – both their quality and quantity, affecting ground and surface waters
- Direct impacts upon soils – both quality (e.g. through contamination) and quantity (through erosion)
- Direct impacts upon biodiversity and landscapes – by displacing former habitats and creating new ones, by degrading or maintaining existing habitats, and by affecting the diversity and composition of landscapes

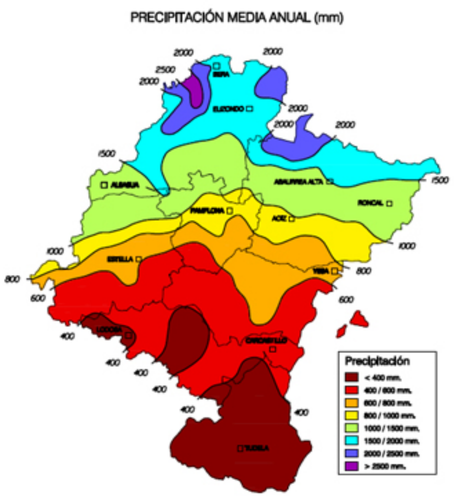
- Secondary impacts arising from the intensification of agricultural production permitted by irrigation, such as increased fertilizer use" (IEEP, 2000: pp29).

"Since the term sustainability was coined back in the 1970s it has always been associated with the simultaneous and long-term fulfillment of environmental, economic and social aspirations. Later on, multiple criteria sustainability assessment frameworks were proposed that considered a number of relevant system properties simultaneously" (Tittonell, 2013: pp8). Water, as a limited resource, is one of the subjects included in this multidisciplinary approach; and irrigation, as the most important consumer of water in agriculture, is the most relevant aspect to analyze.

"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" (IEEP, 2000: pp3).

Socio-economic sustainability has been the reason to justify the large investments that have been made for new irrigation infrastructures. A lot of researches and reports have been made to identify the relevance of water in agriculture in the Mediterranean countries. One recent example is the case of Navarra. The infrastructure called Itoiz-Canal de Navarra is a project to irrigate more than 50,000 new hectares in the south of the region building a big reservoir in the north (100 kilometers). An investment like that requires a cost-benefit analysis and for that it is necessary to foresee the profitability of crops in the new scenario. Water gives in some arid regions two important possibilities: assured yields and option to alternative crops. In the case of Navarra region, annual rainfall in the south is less than 600 mm and with an unequal distribution along the year (Figure 1). So in these areas, crop alternatives without water are very limited.

Figure 2: Annual rainfall in Navarra

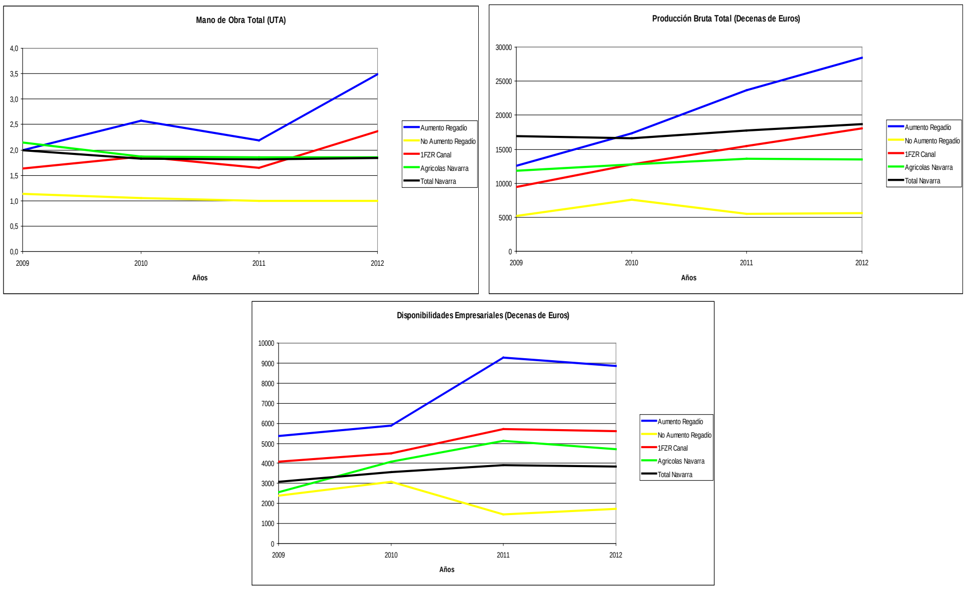


Source: Government of Navarra (Gobierno de Navarra)

Some reports assure that "the irrigation area of Canal de Navarra will generate 2,097 annual working units (AWUs) more and this employment will be better paid (150%) than in dry-lands offering a more options to maintain rural population. On the other hand, the hydroelectric power station built in the reservoir will save 33,342 t oil per year" (Riegos de Navarra, 2003:pp25).

Other reports based on the regional Farm Accountancy Data Network (FADN) of Navarra show how much productive, profitable and generator of employment are areas where irrigation is increasing compared with others without irrigation (Figure 3).

Figure 3: AWU, total output and family farm income for areas where irrigation is increasing compared with non-irrigated areas in Spain 2009-2012



Note: The top left panel shows the number of AWUs, the top right panel shows total output in 10 Euros, and the bottom panel shows family farm income in 10 Euros. Blue line shows areas where irrigation increased and yellow line areas where irrigation did not increase.

Source: Government of Navarra (Gobierno de Navarra, 2013)

On the other hand, water usage can be an environmental problem at least is some cases and regions. Negative externalities linked to water are usually mentioned: ”salinity and water logging (45 million ha worldwide), changes in the level of water table, loss of soil fertility, erosion and water pollution” (Tittonell, 2013: pp7).

One of the most important challenges to analyze sustainability and water management is that the consumption of the same cubic meter is not the same problem if it occurs in Finland or in the south of Spain, it is not the same problem if water is stored on farm from rainfall or is groundwater abstraction, and it is not the same if irrigation is on level lands or in slopes. In some cases also positive externalities linked to irrigation have been found. Water impacts depend a lot on geographical location and water scarcity of the region or river basin district.

“In overview, the impacts of irrigated agriculture in **Spain** vary at regional level. Negative impacts upon biodiversity are found in regions with wetlands: Andalucía, Aragon, Castilla La Mancha, Castilla y León, Cataluña and Murcia; and in regions where irrigated farms are adjacent to wetlands. The most common impact is where the irrigation of former dry land areas threatens valuable dry land species. In the case of Castilla y León and Aragón there are significant negative effects upon pseudo steppe bird life. The trends are increasing or stable in each affected region, but mainly increasing overall. Impacts of irrigation upon water pollution, groundwater exhaustion, salinization and erosion principally affect Andalucía, Murcia, the Balearic islands, Valencia and the Canaries. The most common impacts here are eutrophication of water by nutrients, lowered groundwater tables, salinization by marine intrusion and reduced water flow in rivers. These trends are also increasing. However, in the regions of Asturias, Cantabria, Galicia and País Vasco there are no important negative impacts because of the relative insignificance of irrigation here. Positive impacts are most marked in relation to a few localized mountain and delta areas” (IEEP, 2000: pp51).

“In **Greece** the agricultural intensification process in the lowlands, associated with irrigated production of industrial crops such as sugar beet and cotton, has been a principal source of environmental degradation. The increase in irrigation here, in particular, has been a major cause of the over-exploitation of aquifers and the exhaustion of water resources. The expansion of mass tourism in coastal areas has aggravated the problem through its impact on land-use patterns and the allocation of water resources - over-abstraction of water for both drinking and irrigation is found in these areas. A deterioration of the quality of affected water courses and lakes has also been observed, where nitrates,

phosphates and ammonia emissions have exceeded accepted values in recent years in many cases. Overall, the most severe environmental problems related to irrigation in Greece are significantly lowered groundwater tables, salinization of ground water from the sea and from dissolved salts in soil strata, contamination of land by salts and related desertification, and desertification as a result of significant soil erosion on irrigated slopes" (IEEP, 2000: pp52).

"As would be expected, the environmental impact of irrigation in other Member States, including Sweden, Finland, Luxembourg and Ireland is minimal and appears unlikely to become any more significant in future. The only one of these countries reporting any environmental impacts has been Sweden, where it is noted that irrigation can reduce nitrate contamination of water by diluting agricultural leachate, and that in dry summer months, abstraction of surface waters from small streams for irrigation can cause localized problems for the ecology of these rather sensitive habitats" (IEEP, 2000: pp53).

Table 6: Environmental impact of irrigation

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

Source: IEEP, 2000: pp34

"Groundwater contamination also affects drinking water sources in various regions of Spain, Greece and Italy, where levels occasionally exceed the maximum admissible level of 50 mg/l NO3 (Table 6).
On the Spanish Mediterranean coast, for example, irrigated horticulture is one of the most intensive agricultural land uses in terms of water and nutrient use. Irrigation is carried out with groundwater, which also serves as drinking water supply. The groundwater use frequently changes the aquifer hydrodynamics. As there is no drainage system, excessive irrigation leaching recharges the aquifer through the vadose zone (1-30m). Groundwater is extracted through partially penetrating wells a few metres below the water table for irrigation, so that recirculation of leachates occurs. This causes serious damage to the groundwater quality and several cases of nitrate concentrations exceeding 300mg l-1 have been reported. One of the most polluted areas is the Maresme coastal aquifer in Barcelona.
There appears to be less data to illustrate the level of pesticide pollution in aquifers, due to irrigation. National assessments in Spain have identified both Aldrin and Lindane as significant contaminants in some areas" (IEEP, 2000: pp38).

In the case of Navarra, one of the most important reasons to transport water from the mountains to the south of the region is not so much the necessity of water for irrigation but the bad quality of the tap water in this area. In four of the six water supply systems of this area, quality of water is considered bad because of the presence of pesticides, nitrates and phosphates (Gobierno de Navarra, 2016).

The conclusions that can be drawn from some studies (Berbel, 2004) lead us to hypothesize that there is a contradiction between two policies: on the one hand, the CAP reforms attempt to favor free trade and the competitiveness of EU agriculture (even if this goal is not fully achieved by policy-makers), while on the other hand, the WFD may impose additional costs on irrigated farming, negatively affecting its competitiveness.

2 METHODOLOGY AND DATA

2.1 Methodology

Here we investigate the use of water by farms in the EU, and the link with sustainability. An important obstacle in doing this analysis has up to now been the lack of data. The analysis here will rely on the data collected via the FLINT project. These are farm-level data for a sample of farmers of the FADN in several EU countries (The Netherlands, Hungary, Finland, Poland, Spain, Ireland, Greece, France and Germany). The data include accountancy data from FADN (here after: 'FADN data'), as well as additional data on economic, environmental and social sustainability of farms. These additional data, the 'FLINT data', were collected via face-to-face survey or merging of existing data, depending on the country. The FADN and FLINT data relate to accountancy year 2015, except for France and Germany for which it is 2014.

To analyze the link between water and sustainability at farm level, there exist some information available in the FADN and this information is completed here with specific data collected in the FLINT project.

1. Information coming from FADN

- Location of the farm in a Water Directive Area
- Irrigation system
  This informs on irrigation governance and efficiency because some irrigation systems are linked to more efficient use of water.
- Cost of water
  This information is useful but difficult to analyze. The main reason is that all kinds of water are included in only one variable. The main consumer of water with a low price (irrigation) is mixed with low-level consumptions with high price (tap water), and consumptions without price (own storage or local water suppliers).
- UAA of irrigated area per crop
  The new organization of FADN data collection gives information about the area irrigated per crop, but does not specify which part of the production comes from irrigated lands or from dry lands. So there is a very important lack of information at least for extensive crops in Mediterranean countries: it is not possible to assess the differences in productivity between crops irrigated and not irrigated.

2. Information coming from FLINT

- Water consumption and metering per source: rainfall storage, watercourse, ground water, mains supply.
- Water consumption and metering per usage: livestock, irrigation, others.
- Irrigation: network organization, energy dependence, water payment system.

2.1.1 Availability and reliability of collected information

One of the strengths of FADN is that the information is not theoretical but real, collected every year for a large number of farms. Thus, if data is not based on real invoices and must be estimated by farmers or accountancy offices, obtained results do not offer anything new compared with theoretical studies.

When measuring water, one of the problem could be that real information is not always available. Hence, one of the first outputs is the knowledge of the percentage of farms measuring water consumption. For that reason, in the FLINT questionnaire, for each source or usage of water the

accuracy of data was asked to know if the information about water quantities is based on water meter or on estimations (Tables 7 and 8).

Table 7: Questions asked in FLINT on water source and storage

Rainfall storage		
	Water meter	m^3
	Estimation	m^3
Natural surface water courses		
	Water meter	m^3
	Estimation	m^3
Artificial surface water courses		
	Water meter	m^3
	Estimation	m^3
Ground water		
	Water meter	m^3
	Estimation	m^3
Main water supply		
	Water meter	m^3
	Estimation	m^3
Other		
	Water meter	m^3
	Estimation	m^3

Source: the authors based on FLINT

Table 8: Questions asked in FLINT on water usage

Livestock		
	Water meter	m^3
	Consumption estimation	m^3
Irrigation		
	Water meter	m^3
	Consumption estimation	m^3
Other		
	Water meter	m^3
	Consumption estimation	m^3

Source: the authors based on FLINT

The hypothesis about availability and reliability of data was confirmed by stakeholders when they were asked during the FLINT project (Table 9) and with final data.

Table 9: First remarks of stakeholders within the FLINT project regarding water usage and storage

•	**Collection difficult: no water meters**
•	Farmers know volume used: estimations available
•	Not relevant for some contexts or crops
•	Difficult to separate farm and household
•	Reluctance of farmers to reveal usage

Source: the authors based on FLINT

Probably this is the most important information of this report. While the strength of FADN is working with real data, water consumption is a real challenge.

The second group of questions included in the FLINT survey was relative to irrigation. The hypothesis was that if quantitative information was not good enough (as we have seen above), qualitative information about irrigation as responsible of the major consumption, could be an important help in our analysis.

So questions relative to energy dependence, water payment or network organization where asked (Table 10).

Table 10: Questions asked in FLINT on irrigation

Water distribution network		
	Energy dependence	yes- no- no answer
	Network organization	yes- no- no answer
Water price		
	Water payment	yes- no- no answer
	Proportional fee	yes- no- no answer

Source: the authors based on FLINT

2.1.2 Sample of farms and general indicators

A first approach to water indicators will be using data from FADN (irrigation system, cost of water, share of irrigated area per crop, total income) and FLINT (water consumption, source, usage, and irrigation governance) to build some general indicators useful for different types of farming and regions.

Table 11 describes the FLINT sample at EU level and the FLINT sample in Spain (Navarra) and Greece.

Table 11: FLINT sample: number of farms

	Netherlands	Germany	Finland	Poland	Hungary	Greece	Ireland	Spain	Total
Arable (Specialist cereal-oilseeds-proteinseeds, specialist other fieldcrops, mixed crops)	40	11	1	33	38	25		53	201
Horticulture (Specialist horticulture)	33							3	36
Permanent crops (Permanent crops combined, specialist orchards, fruits)		1				38		1	66
Wine (Specialist wine)		5						2	7
Olive (Specialist olives)						31			31
Dairy (Specialist milk)	53	13	26	25	4		35	28	184
Beef (Specialist cattle)		4	19	1	4		24	15	67
Sheep (Specialist sheep and goats)		3			1	30	3	25	62
Pigs (Specialist granivores)	27	6		22	22				77
Mixed farms (Mixed livestock, Mixed crops and livestock)	2	9	3	39	33		1	1	88

Source: the authors based on FLINT

2.1.3 Water footprint

A tool that calculates freshwater consumption is the concept of the water footprint (WF). This tool has been developed further by Hoekstra et al. (2011). These authors define the water footprint as the total annual volume of freshwater used to produce the goods and services.

The water footprint of a business (BWF) is defined as the total volume of freshwater that is used directly or indirectly to run and support a business. The water footprint of a business consists of two components: the operational water use (direct water use) and the water use in the supply chain (indirect water use).

The water footprint consists of three different components: the green, blue and grey component (Hoekstra et al., 2011).

• **The "green"** component of the water footprint refers to the volume of rainwater that is evaporated during the production process. This is mainly relevant for agricultural products (e.g. crops or trees), where it refers to the total rainwater evapotranspiration during crop growth (from fields and plants).

• **The "blue"** component of the water footprint refers to the volume of surface and groundwater evaporated as a result of the production of the product or service. For example, for crop production, the "blue" component is defined as the sum of the evaporation of irrigation water from the field and the evaporation of water from irrigation canals and artificial storage reservoirs. For industrial production or services, the "blue" component is defined as the amount of water withdrawn from ground- or surface water that does not return to the system from which it came.

• **The "grey"** component of the water footprint is the volume of polluted water that associates with the production of goods and services. It is quantified as the volume of water that is required to dilute pollutants to such an extent that the quality of the ambient water remains above agreed water quality standards.

But green and grey water footprints always had detractors (Garrido, 2015).

"As regard functional units, the water footprint of a business is the sum of the water footprints of the final products that the business produces. The water footprint of a product is always expressed as water volume per product unit. Examples:

– water volume per unit of mass (for products where weight is a good indicator of quantity)
– **water volume per unit of money (for products where value tells more than weight)**
– water volume per piece (for products that are counted per piece rather than weight)
– **water volume per unit of energy (per kcal for food products, or per joule for electricity or fuels**).

In assessing the blue water footprint of a process it may be relevant (depending on the scope of the study) to **distinguish between different sorts of blue water sources.** The most relevant division is **between surface water, flowing (renewable) groundwater and fossil groundwater**. One can make the

distinction by speaking respectively of the blue surface water footprint, the blue renewable groundwater footprint and the blue fossil groundwater footprint (or the **light-blue, dark-blue and black water footprint** if one really likes the use of the colors). In practice, it is often very difficult to make the distinction because of insufficient data, which is the reason the distinction is often not made. It is possible, however, if data allow, specifying the blue water footprint by source" (Hoekstra et al., 2011: pp26).

"When specifying the total blue water footprint by source, one may also like to explicitly distinguish the consumptive use of **harvested rainwater**. Rainwater harvesting is a bit of a particular case, since one may argue whether harvested rainwater is green or blue water. Mostly, rainwater harvesting refers to the collection of rain that otherwise would become run-off. Since consumptive use of harvested rainwater will subtract from run-off, we recommend considering such water use as a blue water footprint" (Hoekstra et al., 2011: pp26).

In this study we will only consider direct blue water footprint using this indicator to compare geographical areas (Mediterranean countries) and similar types of farming: type of farming #151 (specialized cereal farming (other than rice) and oilseed and protein crops) and type of farming #166 (farms with combinations of several large crops). Thus, we are not taking into account rainwater (green footprint) or volume of polluted water associated to production process. On the other hand, the volume of water is that used at farm level, without taking into account the history of inputs used. In conclusion, the water footprint used in this report means the efficiency of water in the irrigation.

2.2 Data

The case of water is a rather an exceptional case. In order to elaborate any type of analysis regarding the use of this resource and its environmental connotations, it is necessary to know both the origin, the destination, the amount of resource used, and the governance mode of this resource. This is why FLINT proposed the following variables to collect: water consumption (m^3), source of water, usage, irrigation governance, energy dependence.

In this approach sought to collect information on the above aspects, we assumed that the quantification of consumption with accurate data would be complicated and that this knowledge was fundamental. For this reason, in each section of origin and use of the water, information was requested on whether the data came from a water meter or an estimate.

As mentioned, for this case study we used data from FADN (irrigation system, cost of water, share of irrigated area per crop, total income) and FLINT (water consumption, source, usage, and irrigation governance) to build some general indicators useful for different types of farming and regions.

In the final sample of 822 farms, in 215 farms (26%) information about water consumption has not been collected. In all the countries there is a lack of information but there are two countries (Finland and Ireland) where data was almost fully not available. In Finland, it appears that this information is irrelevant (no farm provides this information) and in Ireland very little relevant (14% of farms provide this information).

But also where data about water was collected, only in 33% of farms water meter was available, and in only 18% of farms all consumption was measured with water meter (Table 12).

Table 12: Number of farms in the FLINT sample and measurement with water meter

	NUMBER OF FARMS WITH WATER CONSUMPTION DECLARED >0	% of farms in each country	NUMBER OF FARMS WITH WATER METER	% of farms in each country	NUMBER OF FARMS WITH TOTAL WATER CONSUMPTION METERED	% of farms in each country
Poland	138	95%	41	28%	34	23%
Finland	0	0%	0	0%	0	0%
Germany	41	80%	25	49%	17	33%
Spain	89	70%	34	27%	18	14%
Greece	92	74%	2	2%	1	1%
Hungary	89	87%	36	35%	26	25%
Ireland	9	14%	5	8%	4	6%
Netherlands	149	96%	126	81%	49	32%
TOTAL	**607**	**74%**	**269**	**33%**	**149**	**18%**

Source: the authors based on FLINT

However, the volume of water measured with water meter is much more important (44% of total water) (Table 13). The reason is that the main consumption of water is linked to irrigation (94% of total water) (Table 14) and farms measuring with water meter are bigger than average. Spain is the country that consumes the most irrigated water in the sample, with an important percentage of farms with irrigation that measure 100% of water (23% of farms).

Table 13: Water measurement in the FLINT sample

	WATER VOLUME m^3	%
WATER METER	9,436,841	44%
ESTIMATION	12,100,510	56%
TOTAL	21,537,351	100%

Source: the authors based on FLINT

Table 14: Usage of water in the FLINT sample

	WATER VOLUME m^3	%
LIVESTOCK	999,597	5%
IRRIGATION	20,255,136	94%
OTHERS	282,617	1%
TOTAL	**21,537,350**	100%

Source: the authors based on FLINT

Tables 15 and 16 show the number of farms per country with irrigation system, UAA in irrigation, water consumption and share of water measuring.

Table 15: Irrigation in the FLINT sample: number of farms, UAA and water consumption

	NUMBER OF FARMS		UAA (ha)		WATER CONSUMPTION m^3	
COUNTRY	**TOTAL**	**WITH IRRIGATION**	**TOTAL**	**WITH IRRIGATION**	**TOTAL**	**WITH IRRIGATION**
Poland	146	7 (5%)	5,368.01	60.2 (1%)	124,743	34,375 (28%)
Finland	49	0	4,762.05	0.00	0	0
Germany	51	0	8,195.32	0.00	53,665	0
Spain	128	43 (34%)	10,489.90	1,917.6 (18%)	13,784,816	13,686,995 (99%)
Greece	125	61 (49%)	3,393.39	787.2 (23%)	3,788,816	3,759,543 (99%)
Hungary	102	9 (9%)	42,451.24	2,186.4 (5%)	2,305,103	1,743,806 (76%)
Ireland	63	0	3,323.11	0.00	7,018	0
Netherlands	155	20 (13%)	8,291.14	794.1 (10%)	1,473,189	378,397 (26%)
TOTAL	**819**	**140**	**86,274**	**5,746**	**21,537,351**	**19,603,116**

Source: the authors based on FLINT

Table 16: Irrigation and water meter in the FLINT sample: number of farms

IRRIGATION	NUMBER OF FARMS WITH WATER METER	% of farms in each country	NUMBER OF FARMS WITH TOTAL WATER MEASURED WITH WATER METER	% of farms in each country
Poland	1	14%	0	0%
Spain	24	56%	10	23%
Greece	1	2%	0	0%
Hungary	4	44%	2	22%
Netherlands	18	90%	0	0%
TOTAL	48	34%	12	9%

Source: the authors based on FLINT

In summary, the main problem of incorporating the analysis of water consumption into the FADN is the lack of accuracy of the data. The strength of FADN is the use of real data coming from accountancy. In the case of water, data about consumption is estimated in most of cases.

3 RESULTS

3.1 Irrigation in the sample

Using exclusively FADN data it is possible to know the main irrigation system on the farm. In some cases this information is relevant to assess whether an irrigation system could be improved and could be more efficient by substitution of land irrigation by sprinkler. In other cases, it is linked to the kind of crop (drip irrigation is adequate to permanent crops but no for extensive production).

Table 17: Main irrigation system in the FLINT sample (number of farms)

COUNTRY	SURFACE IRRIGATION	SPRINKLER IRRIGATION	DRIP IRRIGATION	OTHER IRRIGATION	TOTAL
Spain	27	10	18	0	**55**
Greece	24	12	47	7	**90**
Hungary	2	6	1	0	**9**
Netherlands	9	1	0	15	**25**
Poland	0	0	8	1	**9**
TOTAL	62	29	74	23	188

Source: the authors based on FADN

Table 17 shows that for some countries considered, the surface irrigation system represented 33% of total number of farms in the FLINT sample, while the respective figure for sprinkler was 15.5%, for drip system 39.5%, and for other systems 12%.

Other important information that could be obtained from FADN relates to the crops irrigated (Table 18).

Table 18: Total and irrigated crops in the FLINT sample

CROPS	TOTAL AREA (ha)	IRRIGATION AREA (ha)	% OF IRRIGATION AREA
Cereals (excluding corn and rice)	2,686.99	88.21	3%
corn	1,152.00	158.79	14%
rice	39.19	39.19	100%
protein crops	75.77	1.41	2%
potatoes	247.05	68.72	28%
sugar beet	66.42	7.20	11%
industrial crops	16.44	14.34	87%
oil seed crops	1,179.21	51.37	4%
fiber plants	0.30	0.00	0%
vegetables	265.00	132.97	50%
temporary grass, green maize	796.24	40.50	5%
pasture, meadows, rough grazing	1,729.63	8.72	1%
fruits (excluding citrus fruits)	76.17	11.26	15%
citrus fruits	15.13	14.32	95%
berries and nuts	20.95	1.97	9%
olives	57.06	21.33	37%
grapes and wine	44.78	2.14	5%
other	200.74	8.77	4%
TOTAL	**8,669.07**	**671.21**	**8%**

Source: the authors based on FADN

Using FLINT data it is possible to know the source of water, which is an interesting piece of information from an environmental point of view. Usage of rainfall stored water is environmentally friendlier than groundwater or tap water usage.

In the FLINT sample 3% of water are from rainfall storage, 12% from natural surface courses, 70% from artificial surface water courses, 11% from groundwater, 2% from tap water and 2% from others.

Table 19 reports the observed percentage of water meter or water estimation per source of water. The highest sources for water meter are artificial source of water and tap water.

Table 19: Water measurement according to origin of water in the FLINT sample

SOURCE OF WATER	% MEASURED WITH WATER METER	% ESTIMATION
Rainfall storage	20%	80%
Natural surface courses	0%	100%
Artificial surface water courses	58%	42%
Groundwater	8%	92%
Tap water	82%	18%
Others	60%	40%

Source: the authors based on FLINT

"Abstraction from surface waters accounts for over 80% of irrigation abstractions in Greece (Caraveli, 1999). Surface waters are also the main source for irrigation in Spain (68%, Sumpsi *et al*, 1999), France (80%, Ifen, 1997), Germany (75%, Strosser *et al*, 1999), the UK and Ireland. However, in Denmark, Sweden, the Netherlands, Austria and Portugal abstraction is mainly from groundwater sources (ibid). In several Member States, either ground or surface waters may be the dominant source of irrigation water at regional level – for instance in France, where the Loire-Bretagne, Rhin-Meuse and Seine-Normandie regions are heavily dependent upon groundwater sources for agricultural water supplies (Ifen, 1997). Many coastal Mediterranean regions depend largely on groundwater sources for irrigation. In Italy, the northern regions source their irrigation mainly from groundwater, while in the south the use of surface water is widespread and large-scale surface-water transfers are found (Hamdy and Lacirignola, 1999)" (IEEP, 2000: pp5).

Using FLINT data it is also possible to know the water consumption (m^3) with a data reliability of 44%, because 44% of water consumption is measured with water meter (Table 13).

In Table 17 we can observe that Spain and Greece consumed 17,573,632 m^3 of water, which is 81% of total water consumption on total FLINT farms, and 99% of this water is to irrigation.

Table 20: Irrigation and Mediterranean countries in the FLINT sample

	SHARE IN TOTAL NUMBER OF FARMS IN FLINT SAMPLE	SHARE IN TOTAL UAA OF FLINT SAMPLE	SHARE IN TOTAL WATER CONSUMPTION OF FLINT SAMPLE
MEDITERRANEAN COUNTRIES: SPAIN + GREECE	13%	3%	81%

Source: the authors based on FLINT

Thus, these data show the interest to focus the study on the irrigated farms of the Mediterranean countries, since, although only 13% of farms operate only 3% of the UAA, they consume 81% of the total water of the total sample, although they represent 23% of the standard production (Table 20).

In order to investigate this further, the crops that are irrigated in these Mediterranean countries (Tables 21 and 22).

Table 21: Crop distribution in total UAA and irrigated in the Mediterranean countries (Greece and Spain) of FLINT sample

CROPS	TOTAL AREA (ha)	IRRIGATION AREA (ha)	SHARE OF IRRIGATION AREA
cereals (excluding corn and rice)	435.41	57.76	13%
corn	91.63	91.15	99%
rice	2.95	2.95	100%
protein crops	24.58	3.08	13%
potatoes	0.46	0.43	93%
sugar beet	1.74	1.74	100%
industrial crops	16.03	14.34	89%
oil seed crops	33.27	12.38	37%
fiber plants	0.00	0.00	
vegetables	70.10	69.66	99%
temporary grass, green maize	57.04	28.96	51%
pasture, meadows, rough grazing	388.69	5.22	1%
fruits (excluding citrus fruits)	3.14	3.04	97%
citrus fruits	15.13	14.32	95%
berries and nuts	4.01	0.00	0%
olives	57.06	21.33	37%
grapes and wine	38.11	2.14	6%
other	98.17	2.19	2%
TOTAL	1,337.50	330.70	25%

Source: the authors based on FLINT

As was seen in Tables 4 and 5, some crops only exceptionally irrigated in northern countries are irrigated in Mediterranean countries. In FLINT the results are the same, for crops like corn, potatoes, sugar beet or fruits, irrigation is needed in Mediterranean countries but not always necessary in northern countries (Table 22).

Other crops very important in extension like cereals, oil seeds and grass, usually dry land crops, are irrigated in more than one third of the surface in Mediterranean countries.

In a third group of crops, specifically Mediterranean (olives, grapes, citrus fruits) irrigation is needed.

Table 22: Irrigated crops in the FLINT sample

GENERAL IRRIGATION IN MEDITERRANEAN COUNTRIES		
CROPS	**SPAIN + GREECE**	**OTHER COUNTRIES**
corn	99%	6%
potatoes	93%	28%
sugar beet	100%	8%
fruits	97%	11%
vegetables	99%	32%
% UAA	**12%**	
IRRIGATION RELEVANT IN MEDITERRANEAN COUNTRIES		
CROPS	**SPAIN + GREECE**	**OTHER COUNTRIES**
cereals (excluding corn and rice)	13%	1%
oil seed crops	37%	3%
temporary grass, green maize	51%	2%
% UAA	**39%**	
SPECIFIC CROPS IN MEDITERRANEAN COUNTRIES		
CROPS	**% in Mediterranean countries**	**% with irrigation**
industrial crops	98%	89%
citrus fruits	100%	95%
olives	100%	37%
grapes and wine	85%	6%
% UAA	**9%**	

Source: the authors

With this information we considered important to analyze the sustainability of water use on the two important and representative farm types in the FLINT sample: type of farming #151 (Specialized cereal farming other than rice) and oilseed and protein crops) and type of farming #166 (Farms with combinations of several large crops).

3.2 Water indicators

Irrigation is one of the most important causes of water consumption and its efficiency depends on the irrigation practices. The most intensive irrigated agriculture can be an important contribution to groundwater pollution (fertilizers, pesticides) and eutrophication of surface waters. Sustainable management of resources related to the water governance in irrigation indicates that the farmer is able to manage the hydric resources according to indicators of efficiency and quality.

Water footprint could be an objective indicator to measure water usage efficiency. But there are some problems:

1.- Different water sources

2.- Water consumption is estimated (and not measured) in many cases

3.- Different types of farming.

Water governance is one of the most critical areas through which it is possible to improve the sustainable development of water resources and services. How societies choose to govern their water resources and services has profound impacts on people's livelihood and the sustainability of water resources. Water governance refers to the political, social, economic and administrative systems in place that influence water's use and management.

In our case we take into account source of water, water metering, water fees, irrigation system and its energy dependence.

WATER FOOTPRINT

Water use sustainability is measured through various indicators and its relation with the use of pesticides and fertilizers.

In Table 23 some water indicators and FADN data, namely cost of fertilizers/ha, cost of pesticides/ha, kg of N-P-K(nitrogen-phosphorus-potassium)/ha are shown for farms with irrigation in Spain and Greece.

Table 18: Water indicators for farms with irrigation in Greece and Spain in the FLINT sample

	SPAIN		GREECE	
	Mean	Std. Dev.	Mean	Std. Dev.
Direct blue water footprint (kg) = Water consumption l/kg of product.	484.35	559.34	470.86	452.97
Direct blue water footprint (€) = Water consumption l/€ of product.	2246. 21	2675.1	1629.34	1950.2
Cost of fertilizers /ha (€)	252.71	166.95	200.49	121.01
Cost of pesticides /ha (€)	117.89	77.89	105.17	96.67
Water consumption (m^3/ha)	6039.10	5430.42	6683.02	12453.79
kg mineral N/ha	155.73	149.04	98.50	94.90
kg P_2O_5/ha	74.25	76.15	31.80	28.91
kg K_2O/ha	65.47	79.11	43.19	85.56
Number of farms	**42**		**59**	

Source: the authors based on FLINT and FADN

Direct blue water footprint is similar in both countries when this indicator is expressed by kg of product recollected, but if it is expressed by euros of product the difference is important between both countries. In this direction the consumption of water per ha is quite similar, around 6,500 m^3 but what is significant is the difference in the amount of fertilizers quantities per ha (kg of N, P_2O_5 and K_2O). This consideration is related with the risk of lixiviation of fertilizers to courses of water.

Different types of farming produce different kinds of products. Water volume per unit of product is therefore useful for specialized types of farming. With regard to the type of farming, the results are presented for Mediterranean (Greece and Spain) irrigation farms versus Mediterranean dry-land farms in both types of farming: #151 (Table 24) and #166 (Table 25).

Table 19: Type of farming 151 for Greece and Spain in the FLINT sample: water indicators for irrigation farms versus dry-land farms

Type of Farming 151	IRRIGATION		DRY-LAND	
	Mean	Std. Dev.	Mean	Std. Dev.
Direct blue water footprint (kg) = Water consumption l/kg of product.	427.42	612.14	0.4923	0.57
Direct blue water footprint (€) = Water consumption l/€ of product.	2045.98	2777.44	3.89	6.273
Cost of fertilizers /ha (€)	215.89	116.25	163.1972	91.89
Cost of pesticides /ha (€)	108.43	61.93	78.3843	43.52
kg mineral N/ha	164.97	133.41	115.6446	74.06
kg P_2O_5/ha	68.02	96.84	38.5351	35.43
kg K_2O/ha	63.08	108.89	38.1032	45.90
Number of farms	**19**		**56**	

Source: the authors based on FLINT

In specialized cereal farming (other than rice) and oilseed and protein crops (Table 24), direct blue water footprint is higher in irrigation farms vs. dry-land farms such as expected. Also, the cost in fertilizers and pesticides and the kg of fertilizers are higher in irrigation farms. It is related to a bigger production but it involved a higher risk of water contamination (grey water footprint).

In farms with combinations of several large crops (Table 25), also direct blue water footprint is higher in irrigation farms vs. dry-land farms, but there are not important differences between the kg of fertilizers and the cost of pesticides.

Table 20: Type of Farming 166 for Greece and Spain in the FLINT sample: water indicators for irrigation farms versus dry-land farms

Type of Farming 166	IRRIGATION		DRY-LAND	
	Mean	Std. Dev.	Mean	Std. Dev.
Direct blue water footprint (kg) = Water consumption l/kg of product.	368.94	420.31	1.72	2.78
Direct blue water footprint (€) = Water consumptionl/€ of product.	1984.82	2294.07	19.31	5.98
Cost of fertilizers /ha (€)	241.04	120.47	156.71	95.66
Cost of pesticides /ha (€)	195.78	171.18	160.75	152.45
kg mineral N/ha	124.61	70.16	102.63	78.97
kg P_2O_5/ha	39.04	37.84	30.56	35.34
kg K_2O/ha	52.64	46.10	50.73	50.08
Number of farms	**33**		**26**	

Source: the authors based on FLINT and FADN

SOURCE OF WATER

The source of water is an important indicator from an environmental point of view. For example, the use of rain water is better than the use of ground water.

The FLINT indicator **E_16_5: Source of water** is given by the maximum value of water use (from water meter (WM) + consumption estimated (CE)) among the following sources:

a) Z10_WU_1000_WM_1 + Z10_WU_1000_CE_1 Rain water
b) Z10_WU_1000_WM_2 + Z10_WU_1000_CE_2 Natural surface water course
c) Z10_WU_1000_WM_3 + Z10_WU_1000_CE_3 Artificial surface water course
d) Z10_WU_1000_WM_4 + Z10_WU_1000_CE_4 Ground water
e) Z10_WU_1000_WM_5 + Z10_WU_1000_CE_5 Tap water and other

The following values are assigned to the indicator:

If max = a), then E_16_5 = 4

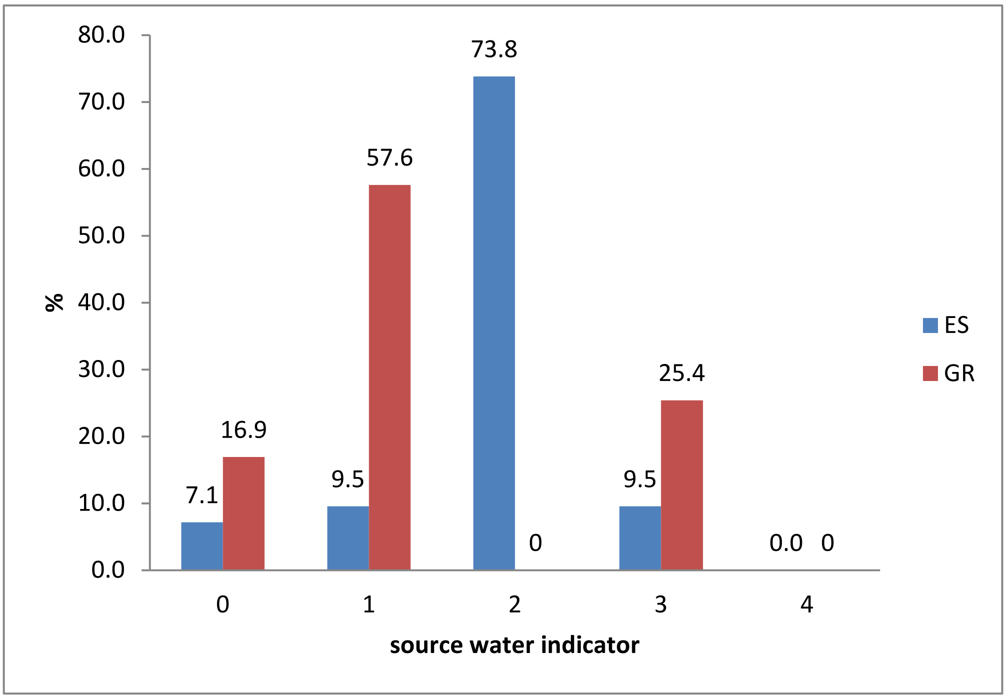
If max = b), then E_16_5 = 3

If max = c), then E_16_5 = 2

If max = d), then E_16_5 = 1

If max = e), then E_16_5 = 0

Figure 4: Distribution of score for source water indicator E_16_5 for Spain (ES) and Greece (GR) in the FLNT sample



Source: the authors based on FLINT

Considering that the best score for source water indicator is 4 (rain water) and the worst 0 (tap water) from an environmental point of view, in Figure 4 it can be observed that in Greece (GR) around 75% of

the water comes from environmentally incorrect sources while in Spain only 17% of water have this problem. The main source water in Spain is artificial water course (73.8%).

These results are in line with the literature. Abstraction from surface waters accounts for over 80% of irrigation abstractions in Greece (Caraveli, 1999). Surface waters are also the main source for irrigation in Spain (68%, Sumpsi et al. 1999).

WATER GOVERNANCE

Water governance is a composite indicator. Pricing with proportional fees, metering and network organization improve water governance.

a) Water distribution network (NO) managed by an organization. Value of 1 if yes, 0 if not. We consider that collective management of water implies more control of water usage.
b) Water payment (WP). Value of 1 if water consumption is paid, 0 if not. Price is the most important tool to influence consumers to an efficient use of the resource. In some irrigation systems water is paid per cubic meter but in other systems payments are linked to surface so water consumption is not penalized.
c) We consider that if prices of water are proportional to consumption (PF), there are reasons to use water more efficiently. For that reason if this class of water payment system is used (yes), the value is 1, and 0 if not.

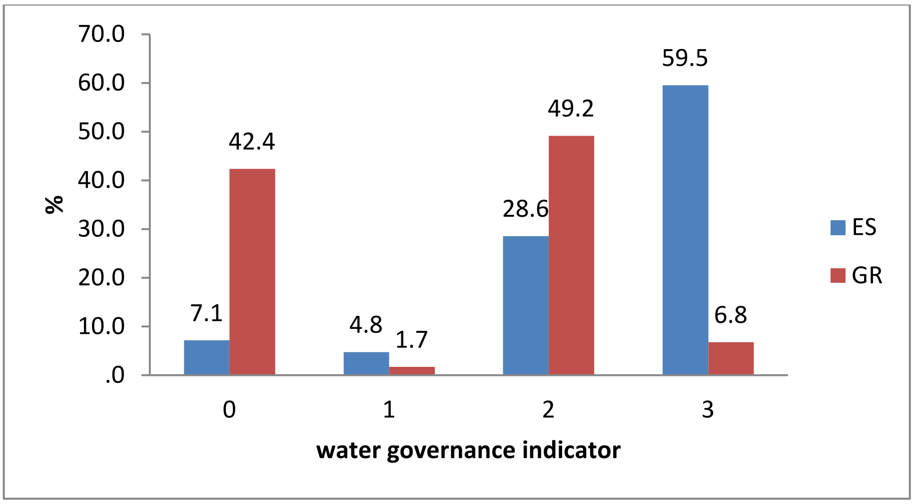
The FLINT indicator **E_17_1: Water governance** is calculated as follows:

a) If Z10_IR_3000_NO = "Yes" (Value = 1) then a) = 1
b) If Z10_IR_4000_WP = "Yes" (Value = 1) then b) = 1
c) If Z10_IR_4000_PF = "Yes" (Value = 1) then c) = 1

E_17_1 = a) + b) + c).

The best value for this indicator is three because it means that water is managed collectively, and price is used as an important tool to dissuade excessive usage of water.

Figure 5: Distribution of score for water governance indicator E_17_1 for Spain (ES) and Greece (GR) in the FLINT sample



Source: the authors based in FLINT

In Figure 5 it can be observed that in Spain (ES) there is a better governance than in Greece (GR) because around 60% of farms obtained a score of 3 for this indicator while in Greece 42.4% of farms had a score of 0.

WATER IRRIGATION SYSTEM

From an environmental point of view the use of more efficient irrigation system is very important when the source of water is limited. Most of the irrigated land in Spain, more precisely almost 60% of the total irrigated land, uses irrigation by gravity (surface). The next most common method is sprinklers.

The FLINT indicator **E_17_4: Water irrigation system** is calculated as follows: FADN collect information about the irrigation system in each farm (A_OT_210_C). The objective of this information is to know how efficient is irrigation taking into account that drop saves more water than sprinkler and the latter is more efficient than surface. With these references the indicator is built, with a maximum value of three (no irrigation at all) an a minimum of 0 (surface irrigation)

If A_OT_210_C = “not applicable (when no irrigation on the farm)” (Value = 0) then E_17_4 = 3

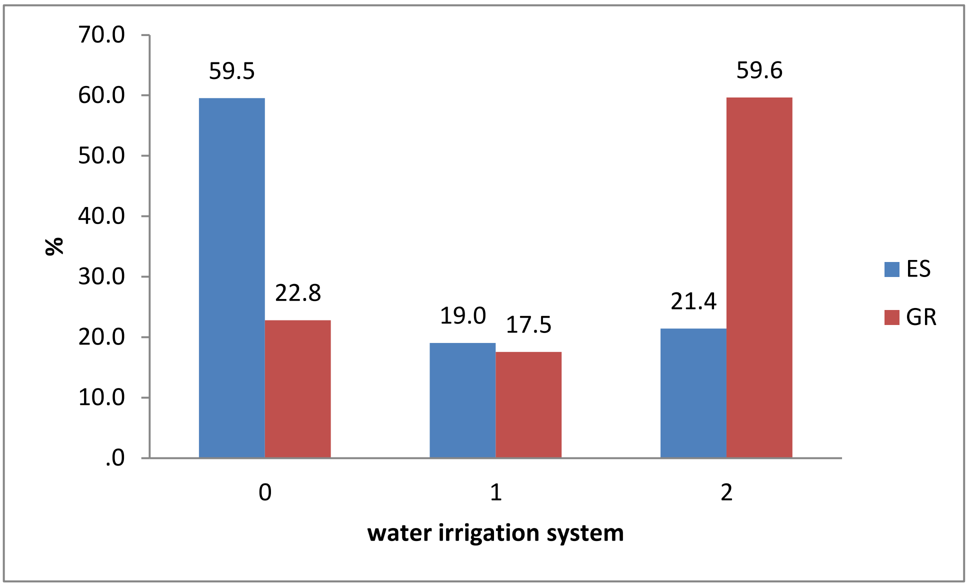
If A_OT_210_C = “drip” (Value = 3) then E_17_4 = 2

If A_OT_210_C = “sprinkler” (Value = 2) then E_17_4 = 1

If A_OT_210_C = “surface” (Value = 1) then E_17_4 = 0

For A_OT_210_C = “other” (Value = 4)) not applicable, no data.

Figure 6: Distribution of score for water irrigation system indicator E_17_4 for Spain (ES) and Greece (GR) in the FLINT sample



Source: the authors based on FLINT

In Figure 6 it can be observed that in Spain (ES) 60% of farms use an irrigation system that is unfriendly to the environment (surface) whereas in Greece (GR) 60% of farms use more efficient systems (drip) so have a better score for this indicator.

ENERGY DEPENDENCE

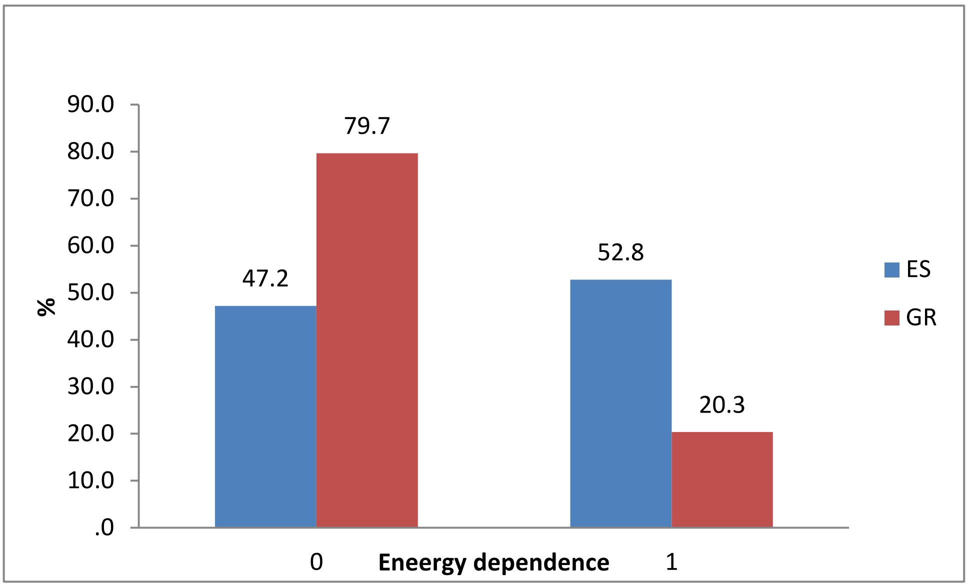
Energy dependence adds pollution and risk to irrigation system. Some irrigation systems are energy dependent and other not. This dependency is environmentally worst, and economically has a bigger risk because of the increasing of prices of energy. For this reason we ask farmers about their irrigation system and energy dependency (Z10_IR_3000_ED) and give the value of 1 to systems that are not dependent and the value of 0 to dependent systems.

The FLINT indicator **E_17_5: Energy dependence** is calculated as follows:

If Z10_IR_3000_ED = "Yes" (Value = 1) then E_17_5 = 0

If Z10_IR_3000_ED = "No" (Value = 2) then E_17_5 = 1

Figure 7: Distribution of score for energy dependence indicator E_17_5 for Spain (ES) and Greece (GR) in the FLINT sample



Source: the authors based on FLINT data

In Figure 7 it can be observed that the Spanish farms (ES) are equally distributed across both scores of energy dependence, while in Greece (GR) 79.7% of farms have a low score (0) for this indicator because they are dependent of energy to use water and this dependence is a risk to the environment.

PRICE OF WATER

Water pricing is an issue which has received much attention from policy makers in recent years. In overview, most Member States already operate charging systems for water abstraction, through the issue of permits or licenses to abstract, or through more general user charges to contribute towards the maintenance of the collective irrigation infrastructure. In most cases, neither the cost of permits or licenses nor more general charges tend to be set at levels which reflect the real resource cost to the environment of the water used in irrigation.
However, it is generally the case that in systems involving private abstraction, the users fund the full cost of setting up or maintaining irrigation infrastructure, whereas in large scale public irrigation systems these costs are frequently borne, in whole or part, by the public sector.

To calculate the price of water, taking into account the different prices depending on sources and usage, we only consider water for irrigation. There are only five countries with irrigated crops, and the mean price ranges from 0.026 €/m^3 in Hungary to 0.592 €/m^3 in Poland. In any case, taking into account the three countries with more farms with irrigation (Greece, Spain and the Netherlands) the mean price of water ranges from 0.06 to 0.085 €/m^3 (Table 26).

Table 21: Price of water in the FLINT sample (euros/m^3)

	N	Minimum	Maximum	Mean	Std. deviation
SPAIN	43	0	0.827	0.085	0.176
GREECE	61	0	1.572	0.060	0.225
HUNGARY	9	0	0.057	0.026	0.022
NETHERLANDS	20	0	0.572	0.083	0.134
POLAND	7	0	2.627	0.592	1.12

Source: the authors based on FLINT and FADN

The average price in most of the countries is around 0.07 euros per m^3.

4 DISCUSSION AND CONCLUSION

The main objective of this study was to analyze the sustainability of water use in European agriculture. The origin of data for this analysis is, first, the FADN where economic information of more than 80,000 European farms is collected every year. But economic information is not enough to analyze social and environmental sustainability. For this reason, new information has been asked in the FLINT questionnaire, specially linked to quantity of water consumed, origin and destiny.

The first problem that has been detected is linked to the lack of information in some countries and low level of data accuracy. The reason is because in some regions water is not a scarce resource, so consumption is not metered. In others, such information is sensitive. As a result, 26% of farms have no information about water consumption in cubic meters and only 18% of farms are metering 100% of the consumed water. In any case, irrigation is the main factor of water consumption (94%) and is metered more usually (44% of water consumption is metered). For this reason, this study focused on irrigation and Mediterranean regions.

The second challenge to obtain some conclusions about water and sustainability is to build indicators useful for different types of farming and regions. One of the indicators used for this objective is the water footprint. This indicator evaluates the volume of water consumed by unit of product obtained. This indicator is quantitative and synthetic but its interpretation is not always easy, because of different origins of water and issues of each river basin. "To think that the water footprint is a sustainability indicator similar to the carbon footprint is a mistake. In the case of carbon footprint a molecule released to produce a product is equivalent, doesn't mind the origin, process or geographical situation. It's accumulated in the atmosphere and contributes to global warming. On the contrary, water is a renewable resource, is not used up, it flows. The problem of water concerns to the river basin. This is the reason that water analysis has to be referred to the specific geographical point or region" (Garrido, 2015).

We have calculated the water footprint but only direct blue, without taking into account green or grey and indirect, for similar regions (Mediterranean countries) and types of farming (#151 and #166). Some conclusions obtained are:

- The average water footprint for farms with irrigation in Spain (Region of Navarra) and Greece is 477 liters per kilogram of product.
- For type of farming #151 (specialized cereal farming (other than rice) and oilseed and protein crops), direct blue water footprint for farms with irrigation is 427 liters per kilogram of product while in dry land systems it is only 0.5. For type of farming #166 (combinations of several large crops), for irrigation it is 369 liters per kilogram and in dry lands 1.72.
- But not only water consumption is different in dry lands and irrigated farms. In type of farming #151, mineral N per hectare is 42% higher for irrigated farms and P_2O_5 and K_2O are 66% higher. This shows the higher level of intensification for irrigated crops. In type of farming #166, differences are lower, around 25%.

Considering the difficulties to use water footprint as general indicator, some other indicators are built to analyze sustainability.

- Source of water: Surface water gives to Spanish farms a higher level of sustainability comparing with Greece where the most important source is groundwater.
- Water governance: The irrigation system in the region of Navarra (Spain) is based in water networks and water is at least partially paid depending on consumption. That gives to Spanish farms a higher score for this indicator compared with Greek farms.
- Water irrigation system: In this indicator, Greek farms have a higher score because drop irrigation system is more important than in Spanish farms, mainly because of the type of farming. Olives, grape production and citrus (in the Greek sample) use drop, while cereals, oilseed and horticulture use sprinkler and surface.
- Energy dependence: Linked to the source of water, groundwater abstraction is more dependent on energy than surface water irrigation system.

- Price of water: Pricing water is one important tool to encourage water efficient use. But if price is too high, irrigation crops are not profitable, and hence improving socioeconomic sustainability is more difficult. In any case, prices of water for irrigation are not very different in different countries.

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5 REFERENCES

Berbel, J., Gutierrez, C. (2004) Sustainability of European Irrigated Agriculture under Water Framework Directive and Agenda 2000. European Communities, Luxembourg.

Hoekstra, A., Chapagain, A., Aldaya, M., Mekonnen, M. (2011) The water footprint assessment manual. Setting the global standard. Earthscan, London, United Kingdom.

Garrido, A. (2015) El valor de evaluar la huella de agua: el camino hacia una aplicación masiva de este indicador está ya marcado. Presentation of i-agua magazine.

Gobierno de Navarra (2016) Abastecimiento de agua para uso urbano e industrial en la Ribera de Navarra. Diagnóstico de la situación actual y alternativas de mejora.

Gobierno de Navarra (2013). Indicadores de la zona regable del canal de Navarra a partir de la Red de Información Contable Agraria de Navarra.

European Environment Agency (2015). Pan European water assets accounts and regionalized water exploitation index WEI+.

Eurostat (2016) Statistics available on http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_irrigation

IEEP (2000) The environmental impacts of irrigation in the European Union. Institute for European Environmental Policy, London, United Kingdom.

Riegos de Navarra S.A. (2003). Gestión del agua, economía y territorio en Navarra: Una valoración de los aspectos socioeconómicos del canal de Navarra.

Tittonell, P. (2013) Farming Systems Ecology. Towards ecological intensification of world agriculture. Inaugural lecture upon taking up the position of Chair in Farming Systems Ecology at Wageningen University, The Netherlands, on 16 May 2013.