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Water use in agriculture and in food products industry. A case study for Italy to evaluate pressure on water resources

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DOI: 10.1481/icasVII.2016.d24d

ABSTRACT

The increasing demand of water resources (wr) due to population growth, production and consumption activities of socio-economic systems, combined with Climate Change (CC) effects on hydrology and water use, are exerting a strong pressure on this natural resource. To face the risk of water scarcity, the challenge is to reduce the wr use intensity in agriculture, industry, energy production and civil use. A consistent and detailed knowledge on the amount of water used by each sector is essential to improve wr management, addressing appropriate policies to protect water availability and quality. In Italy the construction of a comprehensive and consolidate system of data collection on wr used by economic sectors is in place, to reach a higher degree of robustness and comparability of the estimations. To this aim, the role of official statistics need to be strengthened to fill data gaps and to enable more reliable analysis. Collecting data on water volumes used by sectors through statistical surveys and administrative archives can allow to highlight differences on wr requirements linked to various types of products, production processes, technologies used and specific features of the Italian productive structure. The aim of this paper is to present methodology and results of a study developed for Italy by Italian National Institute of Statistics (Istat) to estimate for the first time the volumes of wr used in the production of agricultural crops and vegetable food processed products. An estimation procedure based on the integration of data collected from various sources with official statistics provided by current surveys is implemented. The amount of irrigation water for agricultural crops and water used as input by industry to process vegetable food products is estimated. Results, carried out at the national level, provide an estimation of volumes of water used by the vegetable food chain segment to meet its own activities (reference year 2012). From these results, measures of pressure on wr by domestic production activities are provided.

Keywords: Water Resources, Agricultural Crops, Food Products Industry, Pressure Indicators

PAPER

1. Introduction

Interactions between Climate Change (CC), wr and socio-economic systems are complex and region-specific. CC can affects hydrology and wr through several dimensions: changes in the patterns of climatic variables (precipitation, temperatures, heat waves, extreme events), wr availability, impacts on water quality, changes in runoff, river flows, floods and droughts. Changes in the water cycle can deeply affect countries of many areas of the world, due to their negative impacts not only on agricultural production and food security but also on non-agricultural water uses such as industrial and urban uses. In this context, increasing competition for freshwater use in the sectors mentioned (including through population growth) has resulted in unprecedented pressures on wr, with many countries experiencing conditions of water scarcity as well as in ensuring the integrity of ecosystems. Moreover, water quality continues to worsen, further limiting the availability of fresh wr (IPCC 2014, OECD 2014). According to environmental sustainability and from a policy perspective, CC impacts on water cycle and consequences for agricultural, industrial and urban water uses, highlight prioritizing wr conservation and management in a sustainable way. To face the risk of water scarcity, the challenge is to reduce the water use intensity in agricultural and industrial sectors, in energy production processes and civil use. A consistent and detailed knowledge on the amount of water used in each sector is essential to improve wr management and to address an appropriate mix of policies to protect water availability and quality and to achieve a sustainable growth. Lack of integrated wr data is a systematic impediment to informed decision making about the sustainable use of such natural resource. Concerning Italy, data availability on the amount of wr abstracted, supplied, used, discharged and treated for different uses doesn't completely meet the information needs. Water statistics are produced by various agencies and institutions - often with administrative purposes - preventing data homogeneity, standardization and comparability at temporal and local scale. Istat has been working for several years to improve national knowledge on wr statistics, following EU guidelines relating to the Water Framework Directive 2000/60/EC and Eurostat initiatives on Water Statistics and Water Accounts (UNITED NATIONS 2012 - 2013). In this framework, the construction of a comprehensive

[1] Contribution to the ICAS VII: Rough draft on gender and rural women's empowerment in relation to DW/rural employment.

and consolidate system of data collection on wr used by different sectors is in place. Objective is to reach a higher degree of robustness and comparability of these environmental statistics to provide measures (in physical and monetary terms) of the phenomena taking place, also consistent with the system of monetary national accounting, to support policy decision making. Due to the aim complexity, the role of official statistics need to be strengthened to fill existing data gaps and to enable more reliable multidimensional analysis. To reach this objective collecting data on water volumes used by industry through an integration of sources is needed. By integrating current statistical surveys with administrative archives of public institutions and industry associations can allow to underline differences on water requirements linked to various types of products, production processes, technologies used and features of the Italian productive structure.

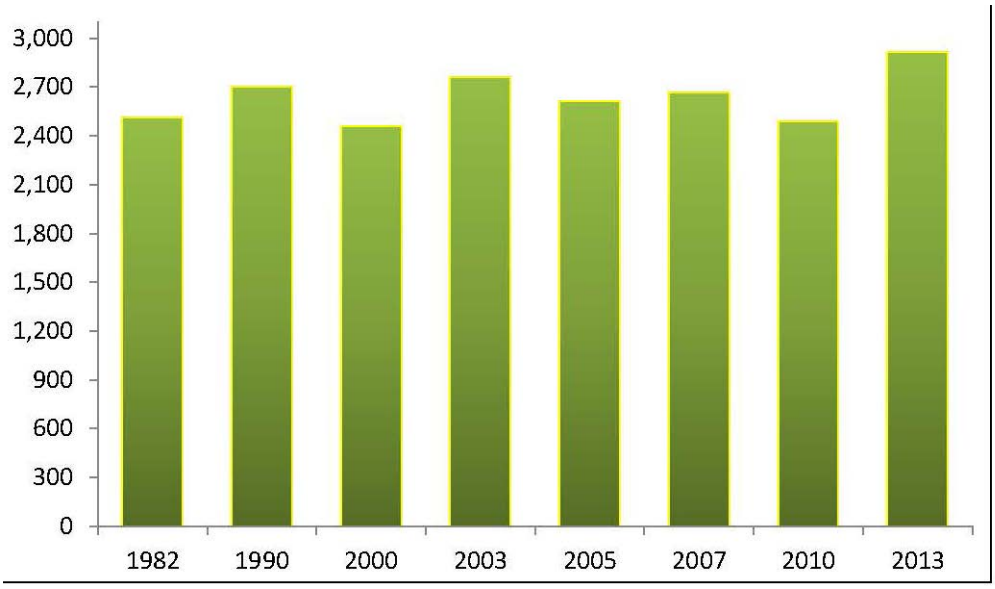
The aim of this work is to present methodology and results of a study developed for Italy to estimate for the first time overall volumes of wr used in agricultural crops production and in food products production whose origins are vegetable. Moreover measures of pressure on wr due to domestic production activities have been calculated. Istat have implemented an estimation procedure based on the integration of data collected from various sources: i) official statistics provided by current Istat surveys as Farm Structure Survey, Industrial Production PRODCOM Survey 2012, VI Italian General Agricultural Census 2010; ii) administrative archives of Italian public institutions; iii) a selection of representative Italian firms; iv) Industry Associations; v) EPD Environmental Product Declaration of firms ISO 14025; vi) international literature (Hosang and Bischof 1998, WS Atkins Ltd & Cranfield University 2002); vii) methodological guidelines for the OECD/Eurostat Joint Questionnaire on Inland Water (Eurostat 2012). The amount of irrigation water by type of crop and of water used as input by manufacturing industry for processing vegetable food products by groups of products have been estimated (Nace Rev. 2 and Ateco 2008 classifications). Produced at the national level, results of our study provide official estimates of the amount of water required by the food chain segment related to the production of fresh and processed vegetable products to meet its own activities. Results also highlight the more waterdemanding crops and the more water-intensive industrial food products. From these estimates, measures of pressure on wr exerted by domestic production activities due to the production of agricultural crops and vegetable food processed products (intended to satisfy final domestic and foreign demand) are provided. The paper is organized as follows. In section 2, data on irrigation water used by agricultural crops are analysed. In section 3, we present main results of the Istat study developed for year 2012 aiming to improve water statistics on industrial activities by producing, for the first time, official estimates on the volume of water used by manufacturing industry by sector.The findings of our research are summarized in the last section, providing measures of pressure on wr exerted by domestic production activities.

2. Water use for irrigation

Irrigation represents in Italy one of the most relevant pressures on natural environment in terms of wr use as in other Mediterranean countries, where increasing hot and dry seasons create conditions for additional water requirements to ensure the optimal growth for several crops (Istat 2016). Irrigable and irrigated areas represent two basic indicators to assess irrigation needs trend and their share in the total utilized agricultural area (UAA).

Irrigable and irrigated areas greatly vary among countries mainly because of regional climate and type of crop production. Based on official statistics provided by Istat Farm Structure Survey of agrarian year 2012-2013 (Istat 2015) the irrigable areas of Italian farms were equal to 4,074,750 hectares by 783,647 farms (Figure 1).

Figure 1 – Irrigated areas. Italy, agrarian years 1982-2013, thousands of hectares

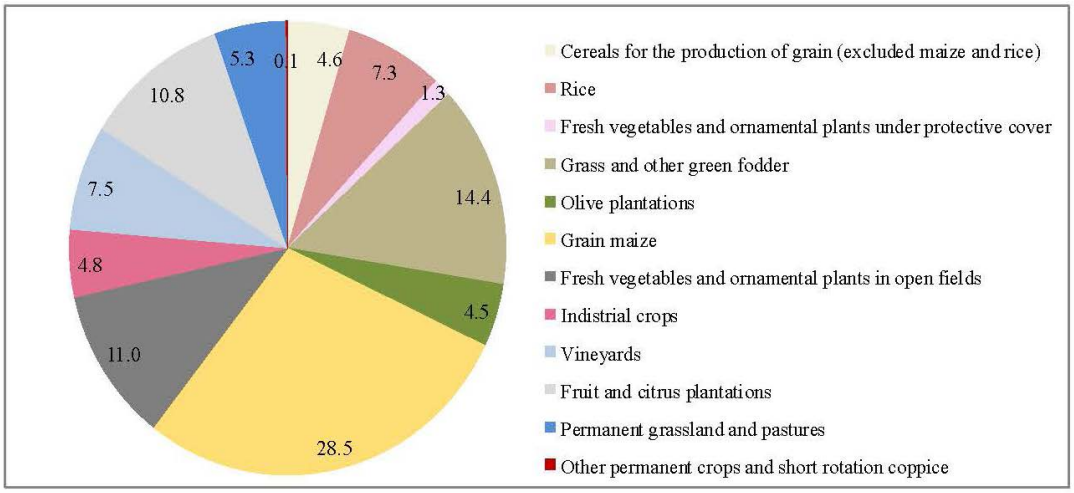


Source: Istat - Farm Structure Survey and General Agricultural Census

Compared to the agrarian year 1981-1982, irrigable areas have increased by about 3%. In agrarian year 2012-2013 irrigation was carried out by 720,335 farms (49% of farms) on 2,917,649 hectares of irrigated area + 16.2% with respect to 1982.

While for some types of crops full irrigation of the entire cultivated area is a distinctive feature, for other crops irrigation is supplementary and generally used to improve production especially in dry periods. Considering the overall irrigated areas by crops, 28.5% of the irrigated areas are planted with grain maize followed by grasslands and other green fodder reaching 14.4% (Figure 2). Fresh vegetables and ornamental plants in open fields represent 11.0% and fruit and citrus plantations almost 10.8%.

Figure 2 – Irrigated areas by crops typology. Italy, agrarian year 2012-2013, percentage values (%)



Source: Istat - Istat – Farm Structure Survey

Two indicators can be calculated to synthetize data on the irrigation needs. The first indicator is Propensity to Irrigation (PI), estimated by total irrigated areas on cultivated areas. The second is Tendency to the Use of Irrigation Potentiality (TUIP) measured by the percentage ratio between irrigated areas and irrigable areas. From official statistics on the agrarian year 2012-2013, PI is equal to 23.5% and TUIP to 71.6%.

Italian crop production system faces and will cope deep changes of weather conditions and wr availability, intensifying problems of water scarcity and irrigation requirements especially in the South, increasing drought risk and heat stress (Gismondi et al. 2016).

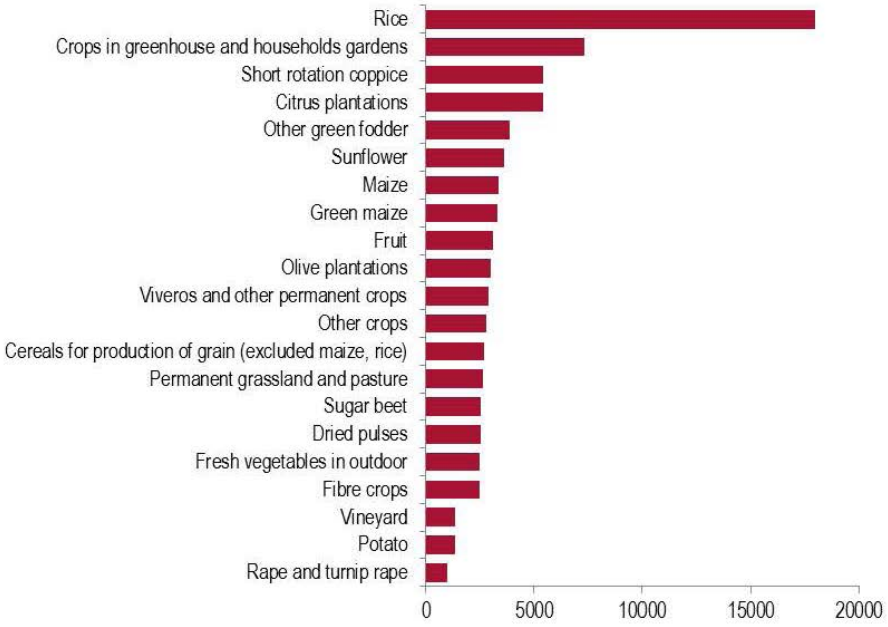
Data on irrigable and irrigated areas alone doesn't give a complete indication of water use intensity, which also depends on the type of equipment used (surface irrigation, sprinkler irrigation, drop irrigation). The type of irrigation system and the size of the agricultural holding may often be linked (Dono et al. 2011).

Being water the most critical resource for sustainable agricultural development, measures in physical units are needed. Volume of water used seems a meaningful indicator to evaluate the pressure on wr exerted by agricultural crops, taking into account several factors (such as CC, current weather conditions, crop type, harvested production, yields, soil characteristics, cultivation practices and irrigation techniques). Volume of water used for irrigation was provided for Italy once in 2010, in occasion of Istat VI General Agricultural Census and it's estimated about 11.6 billion of m3 of irrigation water 2,489,915 hectares of crops by 708,449 farms in agrarian year 2009-2010 (Istat 2014). The average volume of water used to irrigate one hectare of land was equal to 4.7 thousands of m3, with a certain degree of variability based on the type of crop (Figure 3). Rice, representing 10% of the irrigated area, required the highest water volume, almost equal to 18,000 m3 of water per one hectare of irrigated area. Greenhouse and households gardens - despite the low incidence of this crops on irrigated area (2.9%) - required 7,300 m3 per hectare. The less water-demanding crops are rape and turnip rape (beneath 1,000 m3 per hectare) and potatoes (1,300 m3 per hectare), overall represeningt only the 1% of the total irrigated areas.

To measure pressures on wr, the indicator volume of water used for irrigation calculated by area and typology of crop can give more detailed information suitable for analysis on the sensitivity of water demand by crops to CC phenomena and on efficiency in wr use if placed in relation to harvested production, irrigation systems as well as meteo-climatic conditions and soil characteristic.

Strengthening the production of official statistics on volumes of water used in agriculture on regularly basis is needed by integrating different data sources. Expanding temporal and spatial scale and disaggregation level at which data are provided allows to carry out medium and long-term reliable analyses.

Figure 3 – Volumes of irrigation water by crop typology. Agrarian year 2009-2010, thousands of m3 per hectare of irrigated area



Source: Istat – VI General Agriculture Census

3. Water used by food products industry

In Italy there is a lack of uniform estimates on the amount of water abstracted, supplied, used, discharged and treated for industrial uses. Available data are often difficult to be collected, as information is produced by various agencies and institutions with administrative and economic purposes, according to different levels of efficiency in archiving procedures.

For this reason, wr statistics on Italian industrial activities suffer from a large fragmentation of information, data heterogeneity and lack of standardization. Concerning statistics on water used by industry, an official survey useful to improve the knowledge on the matter doesn't exist in Italy (Tagliacozzo, Vignani et al. 2015).

Thus an Istat-Eurostat study was developed since 2013 to improve water statistics and accounts on industrial activities by producing for the first time official estimates at national level on the volume of wr used by manufacturing industry and mining and quarrying industry Nace Rev. 2, sectors 07-08 and 10-33 (Vignani, Tagliacozzo et al. 2016). As industrial water needs are strictly connected with the type of industry and product and largely dependent on technological features of the single plant, different types of industrial processes and technologies used have been taken into account.

An indirect estimation method has been developed and applied. The innovative element of the methodology is represented by:

i) using official statistics coming from the current Istat Survey on industrial production PRODCOM 2012, based on data by units of product of different typology and by value of output (instead of data by number of employees as applied in other studies);

ii) applying specific technical processing coefficients - calculated for unit of product in physical terms - to the amount of units of product, grouped by typology within each manufacturing sector.

The method allows to obtain estimates on overall volumes of water used as input in the production of manufacturing industry by unit of product and by sector. Additionally, an estimation of the water self-abstracted by industries have been developed, under the assumption that small firms (industries with 5 or less employees) are supplied by public water supply network. Published technical studies suggest methods to estimate wr use that are not directly suitable for analysis at a large scale, because they need to be calibrated to fit features of the country-specific industrial structure/ production.

Results show the total amount of water used as input in the production of manufacturing industry is equal to 5,509,128 thousands of m3 in 2012, while the volume of water self-abstracted by industries is 5,314,866 thousands of m3 (Table 1). The difference of 194,262 thousands of m3 represents the volume of water provided to small industries by public water network. This information is important to calculate a water balance of wr uses by all domains (civil, agricultural, energy production, industrial).

A sectorial breakdown allow to identify the volume of wr used by each sector and the share of wr used

by the food products sector. Results represent the use of water as a whole in each sector, calculated from the volume of water used by unit and type of product.

The sectors with the higher demand of wr, together using one third of the total amount of water, are: "Chemicals and chemical products" (12.4%), "Rubber and plastic products" (11.7%), "Basic metals" (10.0%). Food products sector is placed in a group of sectors with a medium level of water required as input (6%) equal to 333,182 thousands of m^3.

The analysis have been deepened on the categories of vegetable food processed products to provide an overall estimation of volumes of water used by the food chain segment of vegetable products to meet its own activities. As Nace 10 classification food products includes also products whose origin isn't vegetable (i.e. production and manufacturing of meat, fish, dairy products, milk) a selection of food processed products (VFP) has been made. Wr required as input for their production represent almost 60.7% of the whole water used by food products sector and correspond almost to 184,564,828 thousands of m^3.

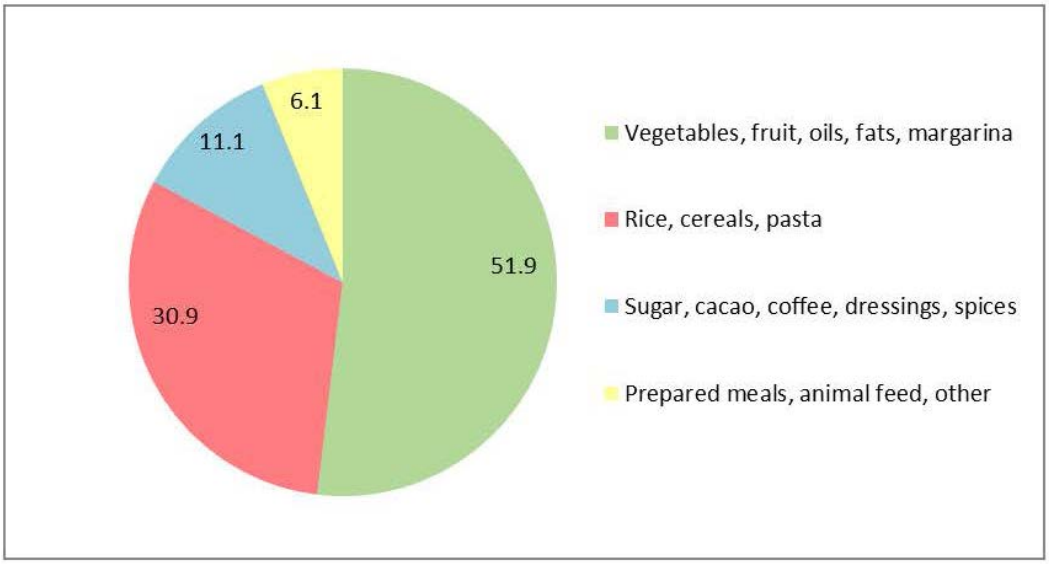
Table 1: *Water used by sector. Year 2012, thousands of m^3 and percentage values* (%)

Nace Division	Water use		Water use (>5 employees)	
	m^3	%	m^3	%
7-8 Mining and quarrying minerals	260,685	4.7	231,528	4.4
10 Food products	333,182	6.0	303,814	5.7
11 Beverages	92,525	1.7	90,883	1.7
12 Tobacco products	2,545	0.0	2,545	0.0
13 Textiles	348,496	6.3	326,351	6.1
14 Wearing apparel	147,585	2.7	129,163	2.4
15 Leather and related products	43,844	0.8	40,985	0.8
16 Wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	120,420	2.2	113,233	2.1
17 Paper and paper products	354,686	6.4	350,408	6.6
18 Printing and reproduction of recorded media	12	0.0	11	0.0
19 Coke and refined petroleum products	2,386	0.0	2,386	0.0
20 Chemicals and chemical products	680,836	12.4	677,278	12.7
21 Basic pharmaceutical products and preparations	40,217	0.7	40,214	0.8
22 Rubber and plastic products	645,486	11.7	628,400	11.8
23 Other non-metallic mineral products	419,030	7.6	409,408	7.7
24 Basic metals	552,148	10.0	551,016	10.4
25 Fabricated metal products, except machinery/equipment	283,844	5.2	274,882	5.2
26 Computer, electronic and optical products	57,793	1.0	56,387	1.1
27 Electrical equipment	202,582	3.7	199,008	3.7
28 Machinery and equipment	224,288	4.1	220,123	4.1
29 Motor vehicles, trailers and semi-trailers	121,864	2.2	121,151	2.3
30 Other transport equipment	163,822	3.0	158,785	3.0
31 Furniture	116,154	2.1	113,241	2.1
32 Other manufacturing	115,625	2.1	113,552	2.1
33 Repair and installation of machinery and equipment	179,071	3.3	160,116	3.0
TOTAL	**5,509,128**	**100.0**	**5,314,866**	**100.0**

VFP products has been classified in four category of homogeneous products (Figure 4). The category including Vegetables, fruit, oils, fats, margarina uses 51.9%of the overall water used in the production of VFP, followed by Rice, cereals, pasta, that use about 30.9% of the total. The third group is represented by Sugar, cacao, coffee, dressings, spices (11.1 %) and the last one by Prepared meals, animal feed, other (6.1%).

To measure the pressure of water demand by products at net of production levels a Water Use Intensity

Figure 4 – Volumes of water used by categories of vegetable food products. Year 2012, percentage values (%)



(WUI) indicator have been calculated by the ratio between volumes of water used an sold production, by sector. Considering, in fact, unit of production vary within and between sectors among several type of measurement (weights, volumes, m2, number of pieces, monetary units), a normalization method into monetary terms allows to compare the demand of water, net to the sector's production levels and type.

The WUI indicator represents the volume of wr necessary to produce one euro of production sold. Calculated as average value among all sectors, it is equal almost to 8.8 litre/euro. The food products sector records a WUI equal to 3.9 litre/euro.

Our work represents a first attempt to estimate volume of wr used by industrial activities through and indirect methodology applying technical coefficients to unit of products. Although the method can be replicated for each year considered, the estimations - mainly due to PRODCOM sample features- have statistical significance at national level. Regional as well as sectorial breakdown decreases the estimation robustness. Goal to achieve is to strengthen the production on regularly basis of official statistics on volumes of water used by national manufacturing industry through collected data with the aim to expand temporal and spatial scale and disaggregation level at which data are provided.

4. Conclusions

In the context of CC, increasing competition for freshwater use in different sectors has resulted in high pressures on wr, with many countries facing the risk of water scarcity. To improve wr management and to address appropriate policies to protect water availability and quality, a consistent and detailed knowledge on the amount of water used by each sector is essential. In this context, the role of official statistics need to be strengthened to fill data gaps and to enable more reliable analysis on the pressure on wr. In Italy, Istat have been worked for the construction of a comprehensive and consolidate system of data collection on wr used by economic sectors and by population. Being water the most critical resource for a sustainable agricultural development, measures in physical units are needed. Volume of water used seems a meaningful indicator to evaluate wr pressure exerted by agricultural crops and food industry. This paper presents methodology and results of a study recently developed by Istat. For the first time volumes of wr used in national agricultural crops production and in vegetable food processed products production have been estimated. The amount of irrigation water by type of crop and of water used as input by manufacturing industry for processing vegetable food products by groups of products have been provided for one year, limited by data availability. The statistical procedure is based on the integration of data collected from various sources with official statistics provided by current surveys. Concerning national agricultural crops, water used for irrigation was estimated about 11.6 billion m3 in 2010, as provided once by VI Italian General Agricultural Census. Concerning vegetable food products industrial sector, the volume of water used as input corresponds almost to 184.564.828 thousands of m3 in 2012, as provided by the Istat study. The innovative element of the methodology applied is represented by: i) using official statistics coming from the current Istat Survey on industrial production PRODCOM, data by units of product of different typology and by value of output; ii) applying specific technical processing coefficients,- calculated for unit of product in physical terms, to the amount of units of product grouped by typology within each manufacturing sector. The indicator volume of water used calculated in physical units can give more detailed information suitable for conducting analysis on pressures on wr , sensitivity of water demand by crops/products to several factors (CC effects, irrigation systems, technology used) and efficiency in wr use. This work permits to fill some gaps on water pressure analysis so as to encourage strengthening the production of statistical information necessary for a comprehensive and multidimensional analysis. As underlined, several data sources

can satisfy partially information demand on wr use and macro-aggregates at national scale only can be calculated in many cases. At date, in the Italian statistical system data on wr are collected with different purposes and integration is limited.

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