Working Papers
10/2011

Modelling irrigation water consumption at the micro data level in the Survey of Production Methods in Agriculture 2009 (Spain)[1]

Jorge Saralegui Gil
Fernando Celestino Rey

First draft: August 2011
This draft: December 2011

[1] A reduced version of this paper was the subject of an oral presentation by Jorge Saralegui in the 58th Congress of the International Statistical Institute, Dublin, Aug. 2011.

Modelling irrigation water consumption at the micro data level in the Survey of Production Methods in Agriculture 2009 (Spain)

Abstract

Preliminary studies for the second phase of the Agricultural Census 2009 (Survey of Production Methods) recommended not to include in the survey forms the quantity of water consumed (required by the EU regulation) as an specific question, mainly due to the risk of high measurement errors. Therefore it was decided to launch a project of model assisted estimation in several stages, described in the paper:

I) Theoretical water needs. After several treatments, the theoretical water requirements per crop are estimated based on an agroclimatic model.

II) Adjustments for irrigation efficiency. In this stage the irrigation water needs per crop is imputed according to the irrigation techniques used by the holding.

III) Management efficiency. Final estimation of effective consumption is implemented and adjusted to external sources to take into account the management efficiency of irrigation.

Keywords

Water used per crop. Theoretical water needs. Evapotranspiration. Irrigation efficiency.

Authors and Affiliations

Jorge Salaregui Gil

Directorate Environmental and Structural Business Statistics, INE

Fernando Celestino Rey

Directorate Environmental and Structural Business Statistics, INE

Modelling irrigation water consumption at the micro data level in the Survey of Production Methods in Agriculture 2009 (Spain)

1. Introduction

During the first half of 2010, INE (Spain) carried out the second phase of the Agricultural Census 2009, by collecting additional data on production methods through the statistical operation Survey of Agriculture Production Methods (SAPM 2009).

The survey was based on a sample drawn from the census frame. One of the goals of SAPM 2009 is to estimate at the micro data level for each of the sampling units, the volume of irrigation water used for crop year 2009. In addition to the interest of this variable for national users, Ine is to submit these estimates to Eurostat in December 2011, as required by the FSS EU Regulation 116/2008.

Preliminary studies came to the conclusion on the non-feasibility of including in the questionnaires direct questions about amounts of water consumed by the holding, mainly because of the risk of incurring high observation and measurement errors. Consequently a decision was taken to launch a project of model assisted estimation in several stages, combining direct data with additional information available from external sources.

The development of the project took place in the Directorate of Business Structural and Environmental Statistics (INE). SAPM 09 EDP team and INE cartography unit implemented some of the applications. The Ministry of Environment and Rural and Marine Affairs[2] gave and important support in particular steps of the project, providing expert advise and data bases containing specific agro climatic parameters and administrative data related to theoretical water needs, as explained bellow.

The paper first presents the target variables and the primary information available to build the model. Next, the general model and the process of preparing the input data bases are described, to go on with the formulation of the different estimation stages. A summary of final results of the model are presented as well as intermediate data referred to a particular region of the south of Spain, taken as example to show the output of the model (when the data refer to sub regional levels, geographical codes are anonymous).

[2] Directorate of Irrigation Areas. MARM.

2. Statistical information available as input to the model

2.1 Data from the 2009 Census of Agriculture

In the 2009 Agricultural Census information is requested on the irrigated area per crops for each holding, according to a standard classification adapted to the requirements of the EU Regulation. At this point it is important to keep in mind the fact that the census files contain the same elementary identifiers as those used in the SAPM 2009, as the latter is a sample of holdings drawn from the census, considered as sampling frame.

2.2 Complementary information collected in SAPM 2009

Although the SAPM 2009 questionnaire does not provide direct information on water consumption by the holding, important data is collected about certain characteristics of irrigation: a) distribution (%) of the volume of water by source (surface, underground) and b) distribution (%) of the irrigated area per irrigation technique applied (localised, gravity, spray).

This final distribution will be used, as shown below, in the second stage of the model, called 'adjustment according to the efficiency of irrigation techniques'.

2.3 Agro-climatic data

The Ministry of Environment and Rural and Marine Affairs (MARM) manages a network of 419 agro-climatic stations geo-referenced (through UTM coordinates) that register the weather-related and other parameters that condition the local growth of crops (rain, wind, sun, soil moisture). In particular, each agro-climatic station provides average evapo-transpiration data (ETO) which corresponds to that occurring on the surface of a standard plot completely covered with (common) grass.

It should be noted that a municipality and therefore the irrigated area of holdings included within them, are assigned to one, and only one, agro-climatic station.

2.4 Irrigation Areas and crop coefficients

The MARM, as part of its preparatory technical studies for the elaboration of the National Hydrological Plan 2008 (NHP) conducted a subdivision of Spain in 811 irrigation areas, with its limits defined by UTM coordinates, defined on the basis of agronomic characteristics and water environment conditions (shared river basins, common water supply for the area, type of crops, among others). Within the irrigation area, each crop is assigned a crop coefficient Kc, a-dimensional, which is the correction factor to be applied to the standard evapo-transpiration ETO as defined above. The Kc for each crop within an irrigation area is identical, regardless of the situation of the crop. However, Kc coefficients of the same crop may vary from one irrigation area to another. MARM databases also allow to determine, for every crop present in the irrigation area, an associated ***q*** coefficient representing the weight of the crop acreage in respect of the total of the irrigation area. These coefficients are essential to calculate weighted means of coefficients K, when several crops, following the MARM classification, coexist within an irrigation area and correspond to the same crop as classified in SAPM 09.

3. Target variables

The main target variable, which must be calculated at the microdata level is the total volume of water used for irrigation in each of SAPM 2009 holdings (about 60,000 units, of which 35,000 are expected to declare irrigated crops).

The information to be produced by the model is the 'theoretical water needs' of each crop grown in a given municipality. The municipality is the basic geographical unit in the context of the survey to which every holding (and its crops) can be assigned. In addition to its official code, the municipalities perimeter is also geo-referenced (UTM coordinates).

The water needs of each crop within a municipality is thus applied to the irrigated surface of the crop declared by the holding. For a given it month can be formulated as:

$$H = (Kc \cdot ETO) - Pe$$

Where:

- *H* is the theoretical crop water need for the month (m3 /Ha).
- *Kc* is the crop coefficient, within each irrigation area (without dimension).
- *ETO* is the standard evapo_transpiration. ETP units are in mm, which are converted to m3/ha for introduction in the model.
- *Pe* is effective precipitation for the month, mm, which are converted to m3/ha for introduction in the model.

The theoretical crop water needs in a year (in this case, 2009) are given by the sum of the theoretical water needs calculated for each month.

4. Preparatory work of the auxiliary information input for the model

4.1 Assigning agro-climatic stations to municipalities

In this stage, the correspondence between municipalities (about 8,000 in Spain) and agro-climatic stations is defined. At this end, the cartography unit within INE, by using UTM coordinates, assigned the appropriate station to each municipality of the SAPM 2009 frame, based on the geographical proximity to its centroid.

4.2 Crops correspondence

The crop coefficients Kc to be introduced in the model, are available for 300 categories of crops that do not correspond with the 50 categories used in the agricultural census.

Crop categories used in the technical studies for the NHP (MARM) are aimed at classifying crops based on their water requirements and, particularly, to reflect its seasonality, while crop categories in the Agricultural Census follow an harmonized list, according to EU regulation on the Farm Structure Survey. It is therefore necessary to built a correspondence between crop categories used in the NHP 2008 (MARM crops from now on) and crop categories used in the Agricultural Census 2009 (INE crops in the following).

4.3 Delimitation of polygons intersection municipality-irrigation area

When it comes to the spatial integration of the information, it may occur or not intersections between the polygons that form the municipalities and the polygons that form the irrigated areas, which poses further methodological problems. The following table summarizes the distribution of the number of polygons generated by the intersection of municipalities and irrigation areas:

Table 4.1. Number of polygons resulting from the intersection Municipality–irrigation area

Number of irrigation areas intersected	**Number of municipalities**	**Number of intersecting polygons**
1	3,017	3,017
2	2,63	5,926
3	1,293	3,879
4	538	2,152
5	185	925
6	89	534
7	33	231
8	30	240
9	13	117
10	8	80
11	4	44
12	3	36
13	2	26
15	1	15
30	1	30
Total	**8,180**	**17,252**

It can be seen that there may be up to 30 polygons within one municipality, giving a total of 17,352 polygons, although 80% of municipalities present less than four intersections. In addition to coefficient q referred to above, representing crop area weights within an irrigation area, we also need to define w values representing the weight in respect of the total area of the municipality of the polygon intersection with each irrigation area. The general idea is to assign weighted means of water needs for all MARM crops corresponding to the same INE crop, and among all irrigation areas intersecting the municipality.

4.4 Data Bases with the parameters input to the model.

Preparatory works described in 4.1, 4.2 and 4.3, allow the generation of databases to be used in subsequent phases of the project, containing ETO, Kc and Pe values per crop within every polygon of the intercession, as well as the weights (q) and (w) defined above.

Table 4.2. refers to region C taken here as an example to illustrate the results of the model. We can observe the profile of the input parameters Kc, ETP y Pe for three important crops in the region, along the 12 months of the year 2009.

ETP data are extremely variable, and greater than zero in every month of the year. For region C, ETO values rang from 404 to 1,517 m3 / ha, the lowest in spring-autumn and the highest in the summer months, when Pe (rainfall) values are minimal. For seasonal crops, Kc values only take nonzero values for the months with the presence of the crop, while in perennial crops (i.e. citrus) they have a very stable value along the twelve months of the year. For region C, the Kc for citrus vary from 0.500 to 0.650.

Table 4.2. Crop coefficients and agroclimatic data

Month	3007 wheat and Spelt			3506 Citrus			3590 Wine grape quality wine		
	Kc	ETP	Pe	Kc	ETP	Pe	Kc	ETP	Pe
JAN	0	523.21	115.81	0.500	480.58	437.24	0.000	519.96	74.590
FEB	0	558.62	27.95	0.500	570.72	3.440	0.000	584.52	0.000
MAR	1.10000	903.21	564.76	0.550	929.90	457.31	0.000	922.51	643.65
APR	1.10000	1,128.18	93.65	0.550	1,167.9	159.69	0.450	1,173.9	182.63
MAY	0.69999	1,517.61	3.45	0.550	1,524.8	0.000	0.550	1,600.8	59.260
JUN	0	1,797.49	0	0.670	1,848.7	0.000	0.650	1,869.7	0.000
JUL	0	1,888.77	0	0.670	1,955.8	0.000	0.600	2,018.5	0.000
AUG	0	1,656.72	5.22	0.670	1,736.7	0.000	0.500	1,626.0	0.000
SEP	0	1,061.78	681.52	0.670	1,215.7	952.70	0.250	1,123.4	312.21
OCT	0.30000	795.02	152.13	0.550	832.88	73.610	0.000	881.40	0.000
NOV	0.2	609.75	0	0.500	573.51	73.020	0.000	636.04	0.000
DEC	0	404.42	298.77	0.500	451.28	700.56	0.000	470.62	393.16

5. First Step: Formulation of the theoretical water needs

Date bases described above made it possible to run the model algorithm to calculate the theoretical water needs, (in cubic meters per Ha) for each and every crop found in a municipality corresponding to at least one holding included in the EMP sample. Thus every irrigated crop within a sample holding will be assigned a theoretical amount of water need, to be understood as the water handed for irrigation in optimal conditions of availability, and in the absence of any losses in transport, deposit, or others.

Let be

M: Municipality;

a: irrigation area intersecting with municipality M;

n: INE crop;

j: MARM crop;

i: irrigation month ;

H: theoretical water needs;

K_{aijn}: coefficient of irrigation in the area (a) of MARM crop (j) corresponding to INE crop (n), in month (i) ;

Let q be the relative weights:

$$\sum_{j \in a} q_{aj} = 1$$

corresponding to fraction of the acreage covered by each crop MARM (j) in respect of the total irrigated area (a).

Let be the adjusted weights of the MARM crops (j) corresponding to the same INE crop (n) such as:

$$\sum_{j \in a,n} \overline{q}_{ajn} = 1; \text{ where } \overline{q}_{ajn} = \frac{q_{ajn}}{\sum_{j \in a,i,n} q_{ajn}}$$

Let ETO_i^M and P_i^M be respectively the evapo-transpiration and monthly rainfall for the month i in the municipality M (agro-climatic station assigned by the criterion of proximity UTM to its centroid).

Then, the annual water needs, H, for an INE crop (n) in the irrigation area (a) that intersects with the municipality are given by the expression:

$$H_{an}^{M} = \sum_{j \in a,n} \overline{q}_{ajn} \sum_{i}^{12} \; (K_{aijn}.ETO_{i}^{M} - P_{i}^{M}) \, ;$$

with $H_{aijn}^{M} = 0$ if $K_{aijn} \cdot ETO_{i}^{M} - P_{i}^{M} \leq 0$, where $H_{aijn}^{M} = K_{aijn} \cdot ETO_{i}^{M} - P_{i}^{M}$

Let w be the weights:

$\sum_{a \in M} w_{a}^{M} = 1$; corresponding to the intersection of each irrigation area with a municipality M, adjusted as

And

$\overline{w}_{an}^{M} = \dfrac{w_{a}^{M}\delta_{an}}{\sum w_{a}^{M}\delta_{an}}$; wtih $\delta_{an} =$ 0 if and only if $\sum_{j \in n} q_{ajn} = 0$; $\delta_{an} = 1$ if not;

Then: $H_{n}^{M} = \sum_{a \in M} \overline{w}_{an}^{M} H_{an}^{M}$

(annual theoretical water needs for an INE crop n in a municipality M).

In the following table 5.1., for the same crops selected above for region C, it can be seen real data derived from the model of theoretical water needs for all the municipalities in the region (whose geo codes have been made anonymous) . The table shows for region C sample averages and standard deviation among municipalities together with a comparison with an external source, the *"Irrigation recommendations of the National Hydrological Plan (NHP) 2008"* for the same crops and region. These recommendations are linked to objectives of official policies on saving water resources, especially in the Spanish regions most exposed to negative rainfalls trends.

Model estimates fall systematically near the top of NHP data. Given that they are sample data, referred to a different year (the annual cycles of rainfall are showing a great variability during the last decade in Spain), and that region C is one with scarce water resources (thus water use savings are officially strongly recommended in NHP), it is considered that estimates of the theoretical water needs in the region used as example here behave as expected. Generally speaking, the same behaviour of the estimated theoretical water needs was observed in all other regions as the model was run to each target crop.

Table 5.1 Theoretical water needs region C (m^3/Ha)

3506 CITRUS	3590 GRAPES QUALITY WINES	3339 VEGETABLES UNDER COVER	3066 CORN	Municipality
5,968.29		5,376.53		57001
7,047.08				57002
7,335.51				57003
7,335.51	4,911.66			57004
6,495.91	4,374.23			57005
5,693.47		5,016.58		57006
6,113.28	4,351.89			57007
6,436.94	4,724.94			57008
6,358.21	4,568.76	5,754.68		57009
7,335.51	4,911.66			57010
6,236.27		5,689.71		57011
6,495.91	4,451.60			57012
			6.660.09	57013
6,242.22	4,481.03			57014
6,814.04	4,718.75	6,096.83		57015
7,335.51				57016
6,436.94				57017
6,699.72	4,406.28	6,070.22		57018
7,335.51				57019
5,380.67		4,808.74		57020
5,380.67		4,808.74		57021
7,196.41		6,459.45		57022
6,242.22	4,481.03			57023
6,236.27	4,429.57	5,689.71		57024
7,602.88	5,284.44			57025
5,968.29		5,376.53		57026
7,335.51				57027
	4,402.83		6.343.57	57028
6,433.56	4,392.51			57029

Table 5.1 Theoretical water needs region C (m^3/Ha) (cont.)

3506 CITRUS	3590 GRAPES QUALITY WINES	3339 VEGETABLES UNDER COVER	3066 CORN	Municipality
5,968.29		5,376.53		57030
5,949.69	4,294.16			57031
7,602.88	5,284.44			57032
6,836.90	4,360.35	6,104.88		57033
6,242.22				57034
6,242.22	4,481.03			57035
6,236.27	4,429.57			57036
6,242.22				57037
6,436.94	4,724.94	5,684.23		57038
7,335.51	4,911.66			57039
6,433.56				57040
7,602.88	5,284.44			57041
				57042
			6,632.55	57043
6,242.22				57044
			6,171.37	57045
6,571.60	4,637.47	5,593.81	6,451.89	Mean
609.16	317.40	500.04	235.52	Standard Dev.
4,950-6,100	2,850-3,800	2,750-5,500	4,300-6,250	NHP Recommend. m^3/Ha

6. Second Step: Adjustments of theoretical water needs according to the efficiency of irrigation techniques.

At this stage of the model the theoretical water needs are adjusted to take into account the impact of the efficiency of the irrigation methods. There exist an extensive literature dealing with the efficiency corrections to apply to the amount of irrigation water needs, which take into account losses due to evaporation, storing and transport or others, along the whole path of water flows from its capture in Nature up to the irrigation plot. But we will not take into account these type of adjustments in our model, given that we consider them already included in the amount of the theoretical needs calculated here, as it has been defined by expert services in MARM.

On the contrary, the adjustments to be considered in this step refer to the increases in the theoretical water needs due to the losses incurred by the irrigation technique employed. A correction to the water needs H is applied based on coefficients provided by MARM agricultural expert services, related to the irrigation technique in use within a municipality to which the holding belongs.

These coefficients, in view of its definition, are lower than one. Currently they vary at the national level in the following ranges:

Gravity (g): 0.63 to 0.70; Spray (a): 0.70 to 0.90; Located (l): 0.90 to 0.95. En Region C taken as an example to illustrate the real profile of the data, gravity efficiency varies from 0.63 to 0.68, while spray and located are practically constant, being 0.82 and 0.95 respectively..

SAPM 2009 questionnaire collects in an ad hoc module the distribution of % of irrigated area under each irrigation technique within the holding. During the last decade a sustained and intensive increase of non-gravity irrigation techniques has been taking place in Spain.

Thus, the effective water needs of a crop (n) for a particular holding (i) in a municipality M becomes:

$$\overline{H}_{in}^{M} = H_{n}^{M} \cdot \frac{1}{(k^{M}(g)p_{i}(g) + k^{M}(a)p_{i}(a) + k^{M}(l)p_{i}(l)}$$

Where the theoretical water need is adjusted by the inverse of the mean of efficiency coefficients K of every irrigation technique (g, a, l), weighted by the % (p) declared in the SPM 2009 questionnaire of the holding (i) for each applied technique. The percentages p are associated to each holding while coefficients k are constant in a municipality M. Consequently, the water requirements adjusted for irrigation techniques efficiency vary also with the holding and are not constant in municipality as the theoretical water needs are.

7. Third step: Adjustment of management efficiency

The water requirements, corrected of efficiency of irrigation techniques, need to be adjusted too by the management efficiency coefficient which represent the saving of water use which can be accomplished by appropriate management practices of the irrigation of the plots taking into account water availability, market prices, product demand, experience in agricultural practices by the holder and other factors. These type of corrections ideally are based on specific survey on a sub sample of holdings in order to test the effective use of water in contrast with the imputations calculated through the models as developed here, and then extrapolating the results to the whole sample. Alternatively, when external sources of a proven quality are available, contrast of model estimations with such exogenous data allow for the construction of the set of final corrections to be applied to the model outputs, in order to estimate the final effective consumption to be imputed to the holding.

Prior to the assignment of this last set of coefficients, sample weights have to be made available. It has to be taken into account that the development of the different stages of the project took place in parallel with EMP sample data editing, thus sample weights were made ready to use only at the final phase of the modelling processes (November 2011).

8. SAPM Sample Weights

The Survey of Agriculture Production Methods (SAPM) 2009, which has been the statistical vehicle to implement the model of assignment of the effective use of irrigation water by the agricultural holdings in the national census year, followed an stratified random sampling design. Frame characteristics used as stratification variables were the NUT II (region), two digit Type of Farming (TF, a census variable) plus five size groups. Size determinants were Usable Arable land (UAL) (arable land + kitchen gardens + permanent crops) and the number of Livestock Units (lu).

Sample size under optimal allocation (controlled by sampling precision and geographical coverage requirements) was increased to cope with the expected levels of non response, originating a total theoretical sample of 66,371 units selected from a sampling frame of 1,400,000 holdings aprox.

In order to control for the impact of the asymmetries in the distribution of the main frame variables, take all strata included the 0.5% of biggest units (following the already mentioned measures of size) within each NUT II. Holdings with 20 or more equivalent annual working units (awu) and/or more than 20 employees and/or part of an enterprise with more than 5 holdings, were also included in the sample with probability equal to one.

Within the effective sample, 38,020 holdings declared irrigated land, thus covering the 24% of total irrigated land in the Census, as can be seen in the tables bellow, which describe the Frame and effective SAPM sample distribution of holdings and irrigated land per NUT II.

Table 8.1 Effective Sample Distribution NUTS II Survey of Agricultural Production methods ID SAPM (SAPM) 2009

	Ner Census Holdings with irrigated land	EMP Holdings with irrigated land	%
Andalucía	102,924	3,854	3.7
Aragón	32,233	2,387	7.4
Asturias, Principado de	11,373	908	8.0
Balears, Illes	5,721	922	16.1
Canarias	10,732	1,339	12.5
Cantabria	3,039	419	13.8
Castilla y León	39,714	2,362	5.9
Castilla - La Mancha	32,470	1,970	6.1
Cataluña	35,603	1,974	5.5
Comunitat Valenciana	94,163	2,386	2.5
Extremadura	18,352	907	4.9
Galicia	55,869	3,481	6.2
Madrid, Comunidad de	2,157	369	17.1
Murcia, Región de	22,686	1,338	5.9
Navarra, Comun. Foral de	9,083	1,089	12.0
País Vasco	11,673	11,673	100
Rioja, La	5,969	642	10.8
Total	**493,761**	**38,020**	**7.7**

Table 8.2 Sample Distribution SAPM 2009 of Irrigated Arable Land (*Ha*)

	CENSUS	SAPM 2009	%
Andalucía	792,633	225,671	28.5
Aragón	368,369	79,746	21.6
Asturias, Principado de	1,615	1,118	69.2
Balears, Illes	12,668	4,443	35.1
Canarias	18,899	5,586	29.6
Cantabria	433	306	70.7
Castilla y León	403,091	63,244	15.7
Castilla - La Mancha	401,610	110,353	27.5
Cataluña	230,959	39,362	17.0
Comunitat Valenciana	266,656	44,528	16.7
Extremadura	190,750	47,027	24.7
Galicia	13,108	7,096	54.1
Madrid, Comunidad de	19,281	8,124	42.1
Murcia, Región de	143,639	53,283	37.1
Navarra, Comunidad Foral de	69,868	21,530	30.8
País Vasco	7,266	7,273	100
Rioja, La	26,771	6,856	25.6
Total	**2,967,616**	**725,546**	**24.4**

Sample design weights, corrected for non response, were finally calibrated to Census margins within NUT II (usable arable land, several livestock variables, irrigation area). The latter calibration variable is obviously of the utmost interest for improving the efficiency of the estimation of water consumption by the agricultural holdings, which is the target variable of the modelling project dealt with here.

9. Imputation of Effective Water Consumption by the holding

Once the EMP 2009 weights were made available, it was possible to estimate the aggregated theoretical water consumption, corrected by the efficiency of irrigation methods, for particular crop aggregates for which external sources on water consumption are regionally available. As stated above, at this stage, an external source of a proven quality was used as a reference to adjust water consumption to exogenous totals at particular aggregation levels.

The external source chosen was the Survey of Water Use in the Agricultural Sector (SWUA) carried out by INE every year. The survey frame for this survey consists of lists of Irrigation Entities (IE) within a river basin. IE are professional associations of long

tradition in Spain, which provide data of water supply to its associated holdings for a set of aggregates. Declared data on water supplied by IE included in the sample (which follows a cut-off sampling scheme, with an extensive coverage of more than 60% of total irrigation area served by IE in Spain) are expanded to total irrigated land estimated by MARM through its annual crop area survey. , In addition, and small part of irrigation water area consumption is self supplied by the associated holdings (most of it from authorised wells within the holding). The SWUA estimation procedure takes those facts into account and introduce a correction of the IE declared data with a water self supplied coefficient based on complementary information from other agriculture surveys, in particular the survey on waste generation in agriculture which includes an specific module with water use/origin questions.
SWUA aggregates at NUT II level are disseminated yearly through the INE web site.

Following the contrast of SWUA data with the estimated aggregates output of the model, the effective water consumption of the holding can be formulated as:

$$VOLTE_{iC} = \sum_{K} \sum_{j \in K} SUP_{ijK} \bar{\bar{H}}_{ijKC};$$

$$with:$$

$$\bar{\bar{H}}_{ijKC} = \bar{H}_{ijKC} \frac{VOL(SWUA)_{KC}}{\sum_{i \in C} \sum_{j \in K} \bar{H}_{ijK} SUP_{ijK} w_i}$$

where the holding total water consumption is calculated through aggregation of water effective requirements of every crop declared by it in SAPM 09 ,

being:
i: SAPM 2009 sample holding
j: crop within the holding;
K: group of crops as in the Survey Of water use in Agriculture (SWUA 2009) to which j belongs;
C: NUT II;

$\bar{H}_{ijKC}$ (crop theoretical requirement, corrected by efficiency of irrigation techniques cubic meters per ha.)

$\bar{\bar{H}}_{ijKC}$:effective water requirement per Ha

VOLT: aggregated water volumes SWUA
VOLTE: SAPM water volumes effectively consumed by the holding (target variable);
SUP: area (ha);

w: design weights SAPM 09 , corrected of non response and calibrated to Agric. Census 2009;

Taking into account expert contributions and NHP recommendations, the correction formulated above, corresponding to the so called management efficiency, has been bounded to the interval 0,7-1, imputing the closest extreme value when the original value fell out of the interval.

Table 9.1 SAPM 09 water volumes estimated in the three main steps of the modelling process.

Group of Crops (K)	Theoretical volume needs (1,000 m^3)	Volumes adjusted for irrigation techniques Efficiency (1,000 m^3)	Effective water used (1,000 m^3)	SAPM 09 Irrigated Area under crops (Ha)
Grass crops	3,761,446	5,141,849	4,662,840	909,196
Rice	806,685	1,175,769	978,101	83,196
Corn	1,838,927	2,576,968	2,323,327	288,118
Fruit trees	3,016,684	3,567,067	3,108,136	536,884
Potatoes and vegetables	1,094,679	1,323,179	1,321,608	252,841
Olive trees	1,574,180	1,788,429	1,430,789	497,515
Vineyard	820,498	943,978	691,829	213,804
Industrial crops	1,009,389	1,294,770	1,019,489	179,798
Others	819,178	1,131,526	1,120,665	132,103
TOTAL	14,741,672	18,943,538	16,656,784	3,093,455

10. Results

In order to give an overview of the final profile of the estimations, Table 9.1 bellow shows, for the group of crops K, at the national level, aggregated results corresponding to the three main steps of the modelling process: theoretical requirements, volumes adjusted for irrigation techniques efficiency; and effective consumption, corrected for management efficiency. Results have been found acceptable and consistent with expert knowledge, official recommendations and external sources fed with direct observations.

Not to forget that the implementation of the model presented here has an extraordinary value added. It has generated an statistical tool with a great potential to improve significantly the quality of the estimations produced by current statistical INE operations on eater issues which provide aggregates and indicators of great relevance for international and national users, particularly in countries as Spain where this sector accounts for around 70% of all water used in a year.

REFERENCES

Regulation (EC) Nº 1,166/2008 of the European Parliament and of the Council of 19 November 2008 on farm structure and the survey on agricultural production methods.

Carcelén, Vicente. (1999) "Estimations of the water demand in the irrigation planning". In: XVII National Congress of Irrigation. Murcia (Spain).

Spanish National Plan of Irrigation. Royal Decree 329/2002, April 5th.

INE (2010) "Survey on Water Use in Agriculture " http://www.ine.es/

INE (2010). "Censo de Agricultura 2009" http://www.ine.es/