Food and Agriculture Organization of the United Nations

SDG 6.4 MONITORING SUSTAINABLE USE OF WATER RESOURCES PAPERS

Guidelines for calculation of the agriculture water use efficiency for global reporting

The agronomic parameters in the SDG indicator 6.4.1: yield ratio and proportion of rainfed production

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The agronomic parameters in the SDG indicator 6.4.1: yield ratio and proportion of rainfed production

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Abbreviations and acronyms

FAO Food and Agriculture Organization of the United Nations

GVA Gross Value Added

ISIC International Standard Industrial Classification of all Economic Activities

MIMEC Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; constructions activities

SDG Sustainable Development Goals

1. Introduction

The monitoring and reporting mechanism of the SDG framework assigns to countries the responsibility of delivering to the custodian agencies all the data and information needed to compile and report the indicators to the Statistical Division of the United Nations. Whereas the custodian agencies can provide countries with general values of some parameters, to be used as default, it is undoubtable that country ownership is reinforced when country teams are able to produce their own data for the computation of the indicators.

These guidelines are intended to assist countries in understanding the agronomic parameters involved in the computation of the agricultural component of the Sustainable Development Goal (SDG) indicator 6.4.1 on the change in water use efficiency over time. They provide a detailed explanation of the calculation process starting from the base data, so that it can be reproduced by countries willing to generate a more accurate estimation using their national data. Default values for the yield ratio are also provided, based on the FAO perspective study “Agriculture Towards 2030-2050” (FAO, 2012).

Countries that have more comprehensive and accurate agronomic data will be able to make use of that data when compiling the annual FAO AQUASTAT questionnaire on water and agriculture collecting the SDG 6.4.1 and 6.4.2 data and also to add additional details on water use efficiency to their Voluntary National Review. Indeed, the AQUASTAT database, the FAO’s information system on water and irrigation hosts the data for the SDG 6.4.1 and 6.4.2 for which FAO is custodian.

2. Scope of the irrigated agriculture water use efficiency

The SDG indicator 6.4.1 "Change in water use efficiency over time" is computed taking into account the three economic sectors listed below.[1] The sectors are identified based on the codes of the International Standard Industrial Classification of all Economic Activities, revision 4 (ISIC 4), as follows:

a. *Agriculture; forestry; fishing (ISIC A);*

b. *Mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; constructions (ISIC B, C, D and F) or MIMEC;*

c. *All the service sectors (ISIC E and ISIC G-T).*

This paper focuses only on the agricultural sector included in the SDG 6.4.1 indicator, which is restricted to irrigated agriculture, livestock and aquaculture.

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1 Description of the SDG indicator 6.4.1 and its methodology is available at: https://unstats.un.org/sdgs/metadata/ and https://www.fao.org/3/ca8484en/ca8484en.pdf.

Similar to the other sectors the irrigated agriculture, livestock and aquaculture water use efficiency, has its calculation formula corresponding to the ratio between the gross value added (GVA) for irrigated agriculture, livestock and aquaculture and the volume of water used by these agricultural sub-sectors (Equation 1).

$$A_{we} = \frac{GVA_{ai}}{V_a} \qquad \text{Eq.1}$$

Where:

A_{we} = Irrigated agriculture water-use efficiency (including livestock and aquaculture) [USD/m^3]

GVA_{ai} = Gross value added by irrigated agriculture, livestock and aquaculture (excluding river and marine fisheries and forestry) [USD]

V_a = Volume of water used by the agricultural sector (including irrigation, livestock and aquaculture) [m^3]

However, most countries do not have disaggregated data between the GVA originating from irrigated and rainfed agriculture. Hence, a corrective coefficient, called Cr is introduced to distinguish the part of agricultural GVA due to rainfed agriculture from the part produced under irrigated conditions. In other terms, this coefficient allows differentiation of the GVA originating from the irrigated agriculture from the GVA produced under rainfed conditions. Such coefficient is needed in order to focus the indicator on the irrigated production. The resulting irrigated agriculture water use efficiency is calculated as:

$$A_{we} = \frac{GVA_a \text{x} (1 - C_r)}{V_a} \qquad \text{Eq.1a}$$

Where:

A_{we} = Irrigated agriculture water-use efficiency [USD/m^3]

GVA_a = Gross value added by agriculture (excluding river and marine fisheries and forestry) [USD]

C_r = Proportion of agricultural GVA produced by rainfed agriculture [%]

V_a = Volume of water used by the agricultural sector (including irrigation, livestock and aquaculture) [m^3]

In case countries have more disaggregated data for the livestock and aquaculture sectors, the following, more accurate, equation can be used:

$$A_{we} = \frac{GVA_{al} + GVA_{aa} + [GVA_{ac} \times (1 - C_r)]}{V_a} \qquad \text{Eq.1b}$$

Where:

GVA_{al} = Gross value added of the livestock sub-sector [USD]

GVA_{aa} = Gross value added of the aquaculture sub-sector [USD]

GVA_{ac} = Gross value added of the crop cultivations sub-sector [USD]

C_r = Proportion of agricultural GVA produced by rainfed agriculture [%]

V_a = Volume of water used by the agricultural sector (including irrigation, livestock and aquaculture) [m^3]

For the cropping sector, these equations 1a and 1b clearly show that only the irrigated agriculture is included by applying the C_r factor and this is to ensure that only renewable surface water and groundwater (so-called blue water) are considered when computing the volume of water used—and not the soil water used by rainfed agriculture.

For countries where the data required for equation 1a and 1b is only partially available, the choice of equation and which agricultural subsector to include in equation 1b should be guided by the least approximation. For example, if Va, the volume of water used by the agricultural sector does not include water for aquaculture (example of countries where extraction for inland aquaculture is not monitored), then GVAaa, the gross value added of the aquaculture sub-sector, should also be disregarded; i.e., the same sub-sectors should be in the numerator and the denominator. The purpose of Equation 1b is not to disaggregate the indicator by sub-sector but to eliminate the distortion created by using irrigation factors for livestock and aquaculture.

Computation of the coefficient Cr

The agricultural GVA created by irrigation depends on the proportion of arable land that is irrigated. Moreover, irrigated agriculture is more productive so irrigated crop yields are higher than those from rainfed crops. Yields from agriculture with some type of water management can be twice as high as yields from strictly rainfed agriculture (FAO, 2002).

Hence, in order to get a more accurate estimate of the GVA of irrigated agriculture, the difference in productivity/yield is also considered. In the computation of SDG indicator 6.4.1, the additional agricultural GVA created by irrigation is estimated through the ratio between rainfed and irrigated cultivation yields, called Yri. As a result, the proportion of agricultural GVA produced by rainfed agriculture (Cr) depends on both:

- Ai, the proportion of irrigated land to the total cultivated land
- Yri, the ratio between rainfed and irrigated yields

C_r is calculated with the formula below detailed in Annex 1:

$$C_r = \frac{1}{1 + \frac{A_i}{(1 - A_i) * Y_{ri}}} \qquad \text{Eq.2}$$

Where:

A_i = proportion of irrigated land to the total cultivated land, in decimals

Y_{ri} = ratio between rainfed and irrigated yields

The following section will present in detail these two elements.

3. Proportion of irrigated land to cultivated land (Ai)

The part of GVA originating from rainfed crops is largely dependent on the portion of the cultivated land that is irrigated, also named Ai:

$$Ai = Irrigated\ land \,/\, Cultivated\ land \qquad \text{Eq.3}$$

The cultivated land[2] of a country is the sum of both arable land and land under permanent crops.

Arable land is defined as the land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture and land under temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included. Arable land does not include land that is potentially cultivable but is not normally cultivated.

[2] Cultivated land has been recently renamed "cropland" in FAOSTAT.

Permanent crops are sown or planted once, and then occupy the land for several years and do not need to be replanted after each annual harvest, such as cocoa, coffee and rubber. This category includes flowering shrubs, fruit trees, nut trees and vines, but excludes trees grown for wood or timber, and permanent meadows and pastures.

$$\textit{Cultivated land} = \textit{Arable land} + \textit{Permanent crops} \qquad \text{Eq.4}$$

Data for these variables are usually easily available in most countries, as part of the land use categories. Unfortunately this is not always the case for the first element of Eq. 3, the part of the cultivated land that is irrigated. This stems from the fact that multiple interpretation can be given to “irrigated land” and that cultivated land, as defined above, is a physical area. Physical areas do not account for multiple cropping. However for the SDG 6.4.1. indicator to properly correlate the agricultural output to the agricultural water used, multiple cycles need to be reflected in the irrigated land variable.

In fact, several variables, for example in AQUASTAT, provide indications on the cultivated land that is irrigated, each with a relative accuracy discussed below.

For our purposes, the **total harvested irrigated crop area**[3] is most accurately correlating the water used for irrigation to the actual production from irrigated area. This area refers to those temporary and permanent crops cultivated under full control irrigation and it is not a physical area, meaning that areas under double cropping are counted twice, if both cycles are irrigated. The accuracy stems from fact that the water used for the two cropping seasons produces twice the amount of agricultural output. However, as the cultivated land is a physical area, the proportion between the two may carry some distortion, which will be discussed in Box 1.

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3 The three AQUASTAT variables indicated in this section, ie the total harvested irrigated crop area, the total area equipped for irrigation actually irrigated and the total area equipped for full control irrigation, are all variables collected through the AQUASTAT questionnaire (available here: https://www.fao.org/aquastat/en/overview/methodology).

Data for this variable usually comes from agricultural census or yearly agricultural production survey.

In countries where this data is not immediately available, the second best option to be considered as a proxy is the **total area equipped for irrigation actually irrigated**. This is the portion of the area equipped for full control irrigation[4] — i.e. the area under surface irrigation,[5] sprinkler irrigation and localized irrigation—that is actually irrigated, in a given year. Irrigated land that is cultivated more than once a year is counted only once. As such, it refers to physical areas, contrarily to the previous harvested irrigated crop area. So when using this estimation, the double harvest produced on some fields is not accounted for and the irrigated production can be underestimated compared to the amount of water used, resulting in a lower water use efficiency.

A third option, **the total area equipped for full control irrigation** is not desirable for the estimation of the irrigated land for the calculation of the Cr corrective coefficient. In fact, this area cumulates both the inaccuracy related to the physical areas, already discussed above, and to the yearly variability of the areas irrigated. Indeed not all the areas equipped for irrigation are actually irrigated every year due to a number of issue: lack of water, infrastructures repair, pump broken, etc.

Table 1 displays an example of the significant differences existing between these "irrigated areas" for Thailand, and the corresponding impacts on the agricultural GVA used for the calculation of the SDG 6.4.1. In countries, such as Thailand, where multiple crop cycles occur at large scale, the area equipped for full control irrigation actually irrigated and the area equipped for full control irrigation, do not accurately reflect the increased agricultural

[4] Full control irrigation is opposed to partial control irrigation, which corresponds to equipped lowland areas, and areas equipped for spate irrigation. A last category include other forms of agricultural water management, such as non-equipped flood recession cropping area and non-equipped cultivated wetlands and inland valley bottoms. The degree of water control in each of these categories is decreasing.Supplementary irrigation is considered full control irrigation, that is water applied to make up to rainfall deficit, to stabilise or increase yields.

[5] Manual irrigation using buckets or watering cans are included in surface irrigation. Surface irrigation does not refer to the method of transporting the water from the source up to the field, which may be done by gravity or by pumping.

output allowed by the multiple cycles and thus propose a reduced irrigated agriculture GVA, compared to the harvested irrigated crop area. In countries where multiple cropping cycle is less frequent, differences obtained for each variable are less significant.

Table 1.
Example of calculation of the proportion of the cultivated land that is irrigated, the Ai component for **Thailand** using the various AQUASTAT irrigated areas:

	1st option Harvested irrigated crop area	2nd option Area equipped for full control irrigation	3rd option Area equipped for full control irrigation actually irrigated
AQUASTAT data for Thailand for 2007 (in ha)	7 387 000	6 415 000	5 060 000
Cultivated area (in ha)	19 000 000	19 000 000	19 000 000
Ai using each option (in %)	0. 389	0.338	0. 266
Cr	0.425	0.480	0.565
Irrigated agriculture GVA in percentage of the GVAa	58%	52%	43%

Finally, a particular case of Ai is for arid countries, where all crop production is considered irrigated. In those cases, Ai is set at 100 percent, and the agricultural GVA is considered to originate entirely from irrigated agriculture. At the time of writing, the countries where the whole agricultural production is considered irrigated are: Djibouti, Egypt, Kuwait, Oman, Qatar, Saudi Arabia, Turkmenistan, United Arab Emirates.

It has to be noted however that all cases where Ai=100% represent a singularity in equation 2—as we get a division by zero and a null value; in those cases, Cr is set = 0.

BOX 1
PARTICULAR CASE WHERE TOTAL HARVESTED IRRIGATED CROP AREA IS LARGER THAN CULTIVATED AREA

The harvested irrigated crop area because it is also measured on the time dimension, can include the cultivated area multiple times over the cropping season. Hence theoretically Ai could even be above 100 percent. However, irrigation cannot be practiced over more land than the cultivated area, and subsequently GVA cannot be produced over more land than the cultivated area. In these cases, in practice Ai is capped at 100 percent. This is coherent with the fact that for the SDG 6.4.1 calculation purpose, the GVA from irrigated agriculture cannot be larger than the total agricultural GVA. However, this limitation can overestimate the irrigated part of GVA by disregarding its rainfed component.

In the very uncommon case of a country being in this situation, the following calculation for the GVA from irrigated agriculture is recommended as it recalculates the fraction of irrigated agricultural GVA per hectare in case Ai is over 100 percent and some of the harvested production is cultivated in rainfed conditions:

$$GVA_{ai} = \frac{GVAa}{(AHi + AHr * Yri)} * AHi \qquad \text{Eq.5}$$

Which will result in the irrigated agriculture water use efficiency formula:

$$A_{we} = \frac{\frac{GVAa}{(AHi + AHr * Yri)} * AHi}{V_a} \qquad \text{Eq.6}$$

Where:

A_{we} = Irrigated agriculture water-use efficiency [USD/m^3]
GVA_a = Gross value added by agriculture (excluding river and marine fisheries and forestry) [USD]
GVA_{ai} = Gross value added by irrigated agriculture, livestock and aquaculture (excluding river and marine fisheries and forestry) [USD]
V_a = Volume of water used by the agricultural sector (including irrigation, livestock and aquaculture) [m^3]
AHi = Total harvested irrigated crop area
AHr = Total harvested rainfed crop area
Yri = ratio between rainfed and irrigated yields

BOX 1 (CONTINUED)

The above calculation is only possible when both the area equipped for full control irrigation actually irrigated and the total harvested irrigated crop area are available.

However, as mention at the top of this box, this situation is very uncommon: only two countries currently have their total harvested irrigated crop area larger than their cultivated land in the AQUASTAT database—Egypt and Turkmenistan. These two countries also happen to have their Ai already capped at 100 percent as considered fully irrigated due to their very arid climate.

4. Initial and FAO's estimations of yield ratio

All other parameters being equal, irrigation enables an increase in yield compared to rainfed conditions for the same crop and same variety. The yield ratio measures the difference in yield between these rainfed and irrigated conditions and in particular the additional yield that can be attributed to irrigation. For the purpose of the calculation of the SDG 6.4.1 indicator on water use efficiency, this yield ratio enables one to more accurately attribute the part of the agricultural production, and thus GVA, which comes from irrigated agriculture for which water is used.

The yield ratio is equal to the yield of a rainfed crop divided by the yield of the same irrigated crop and the following formula is:

$$Yri = \frac{Yr}{Yi} \qquad \text{Eq.7}$$

Where:

Yri = ratio between rainfed and irrigated yields

Yr = Mean yield in rainfed conditions

Yi = Mean yield in irrigated conditions

The above formula for the yield ratio component, Yri, can also be used for very arid countries where the whole agricultural production originates from irrigated agriculture. In such countries where there is no rainfed production, Yri is null because Yr is also null. The practical implication for agricultural GVA is that no portion of rainfed agriculture is discounted, and the whole agricultural GVA is included for the sectoral water use efficiency of agriculture.

This section describes the method for estimating this essential parameter, which also provides a brief history on the evolution of the estimation procedure since the indicator was first presented in 2016.

a. First version of the metadata of indicator 6.4.1

The first version of SDG indicator 6.4.1 took into consideration a very coarse approximation of the ratio between rainfed and irrigated yields. That was based on the rough estimate, which became a common assumption, that 20 percent of the cropped areas in the world were irrigated but produced 40 percent of the world crop production, while rainfed areas represented 80 percent of the surface but yielded only 60 percent of the total produce (FAO, 2007). According to these estimations, the yield ratio was initially calculated at 0.375.

This value of the ratio between rainfed and irrigated yields was used in the initial preparation of the methodology of the indicator. However, that estimation was very coarse and did not reflect the diversity of countries, in terms of irrigation, considering for example that the benefits of irrigation differ widely between humid and arid areas. Country-specific estimations were needed to provide a more accurate parameter Yri for the disaggregation of the rainfed and the irrigated part of the agricultural GVA.

b. Refined estimation based on country data

The FAO perspective study "Agriculture towards 2030-2050" portrays a forward-looking scenario for food and agriculture from 2007 to 2050 (FAO, 2012). Supply and demand of the main agricultural commodities, natural resource and fertilizer use, are projected under moderate economic growth assumptions and population dynamics. These scenarios are based on 2006 yields and areas under both irrigated and rainfed conditions by country and by crop.

Using the same 2006 baseline data, the yield ratio, ie the difference between rainfed and irrigated situations, is calculated for each crop with available data in each country. This means that the yield ratio cannot be calculated when:

- A crop is not cultivated in both conditions, ie irrigated AND rainfed within the country, or
- When at least one of the four required variables (area and production under rainfed conditions and area and production under irrigated conditions, blue shaded column in Table 2) is not available

In general, the yield ratio was calculated for 5 to 10 crops by countries. Once the yield ratio was calculated for a country for all crops, for which the four variables were available, an average value was calculated at national level, weighted by the area of each crop (in order to give more importance to the main crops). The corresponding calculation can be formalized in the equation below:

$$Yri = \frac{\sum_{crop} R^{*}A}{\sum_{crop} A} \qquad \text{Eq.8}$$

Where:

Yri = ratio between rainfed and irrigated yields at national level

A = area of each crop, ie total of the irrigated and rainfed areas for a specific crop

R = ratio between rainfed and irrigated yields at crop level

Country yield ratios have been calculated for 95 countries following the methodology described above (see Annex 2 – Table of country yield ratio) and detailed in Table 2 for Philippines. For the remaining countries, a new default value was estimated as an average of the 95 national country yield ratios, which is equal to 0.5625.

The yield ratio for the Cr calculation is considered a stable variable over time. However, when more accurate data become available, it could be also updated regularly to reflect changes to the ratio yields. The methodology for such an update is described in the section 5.

Table 2.

Example of calculation of the yield ratio for **Philippines** using the data from AT 2030/2050

Crop	Rainfed area	Rainfed production	Rainfed yield	Irrigated area	Irrigated production	Irrigated yield	Crop area	Crop yield ratio	Weighting
Formula	A_{rain}	P_{rain}	$Yr=P_{rain}/A_{rain}$	A_{irri}	P_{irri}	$Yi=P_{irri}/A_{irri}$	$A=A_{rain}+A_{irri}$	R= Yr/Yi	=R*A
Unit	**ha**	**1000kg**	**kg/ha**	**ha**	**1000 kg**	**kg/ha**	**ha**		
Rice	2382	8191	3439	1785	7199	4033	4167	0.853	3554
Maize	2457	5724	2330	97	300	3106	2554	0.750	1916
Sugarcane	316	23622	74660	65	8195	126075	381	0.592	226
Vegetables	565	4520	7998	38	600	15849	603	0.505	305
Banana	414	6558	15858	14	300	21145	428	0.75	321
Citrus	35	251	7098	2	19	9464	37	0.75	28
Groundnut	15	14	927	12	15	1235	27	0.75	20
Tobacco	3	3	1022	24	33	1363	27	0.75	20
			-			-	8225	-	6390
Yield Ratio	$[\Sigma_{crop} (R * A)] / \Sigma_{crop} A = 0.777$								

BOX 2
STEPWISE CALCULATION OF CR – EXAMPLE OF PHILIPPINES

$$C_r = \frac{1}{1 + \frac{A_i}{(1 - A_i) * Yri}} \qquad \text{Eq.2}$$

Equation 2 is applied for Philippines using the following variables:

- Yri = 0.777 as calculated in Table 2
- Ai = 0.300 calculated from AQUASTAT figures for Philippines for 2018:
  - Cultivated land: 10 940 000 ha
  - Irrigated land: 3 286 000 ha

Replacing these 2 variables, Equation 2 is then calculated step-by step as detailed below:

$$C_r = \frac{1}{1 + \frac{0.3}{(1 - 0.3) * 0.777}} = 0.644$$

$(1 - 0.3) * 0.777$ → 0.554

$\frac{0.3}{(1 - 0.3) * 0.777}$ → 0.552

$1 + \frac{0.3}{(1 - 0.3) * 0.777}$ → 1.552

5. Recommended methodology for refined yield ratio at country level

The yield ratio estimation from the FAO Study Agriculture Towards 2030-2050 detailed in the previous section provides country-specific yield ratio for 95 countries, and a more accurate global average for the remaining countries.

While those values can be used to calculate the indicator for the purpose of SDG reporting, FAO supports the efforts of countries to nationalize the indicator by using national data. In doing so, countries ensure that the data are always up-to-date, at the same time reinforcing their internal mechanisms of data collection and quality assurance.

FAO encourages those countries who wish to embark in the calculation of a yield ratio using national data, to follow the methodology presented in this section, so that the resulting ratios and therefore the SDG 6.4.1 indicators can be globally comparable.

a. Data requirement

As presented in Equation 7 of section 4, the data required for the calculation of a national yield ratio is area and production both in rainfed and irrigated cultivation by crop at national level. For accuracy, the calculation should include the most important crops, in terms of cultivation area, when they exist under the two types of cultivations. For the purpose of this indicator, importance is measured in terms of cultivation area, which is also the agronomic parameters defined in irrigation planning.

The two main potential sources which usually include this type of detailed data at national level are: agricultural censuses and annual agricultural production survey. Other documents such as the irrigation master plan, government budget, or water policies might also contain data of interest, although probably not systematically or comprehensively for the whole country or all existing crops. The most complete dataset should be selected, with crop area and production all referring to the same year to avoid any distortion from annual variability.

Although agricultural data of area and production, are often available, the distinction between the rainfed and irrigated conditions and between different varieties of a same crop is less commonly available.

b. Proposed tool

A simple Excel tool to ease the calculation of the country yield ratio from national data is available and can be downloaded here.[6] Table 3 reproduces this tool for easier reference and to detail the recommended methodology:

1. Select a crop in the drop down menu (in Excel) or indicate the crop (in Table 3)

[6] https://storage.googleapis.com/fao-aquastat.appspot.com/SDG641/Cr_Calculation_Sheet.xlsx.

2. Fill in the 4 variables in the blue shaded cells, ie area and production in both rainfed and irrigated conditions.

3. Calculations

   a. In Excel all the calculations will be made automatically

   b. In Table 3, the following calculations are needed:

      i. Rainfed and irrigated yields calculated by dividing the corresponding production by its area.

      ii. Crop Area (A) calculated as equal to the sum of the harvested rainfed and irrigated areas for each crop; a total harvested rainfed and irrigated area could also be used but the following steps should be disregarded and it would introduce further approximation.

      iii. The crop yield ratio (R) is equal to the rainfed yield divided by the irrigated yield for each crop.

      iv. Weighting: the last column is the multiplication of the results obtained in i and ii for each crop.

      v. The sum of the weighting column is divided by the sum of the total Crop area (A) and the result is the national yield ratio.

The recommended units for areas and productions are ha and kg respectively. If other units are used, they should be the same for both rainfed and irrigated conditions for the ratio to be independent of unit.

The table, once completed, and the raw data used for the calculations will need to be shared with FAO, for comparison and validation, if countries wish FAO to officially use the nationally-calculated ratio in the calculation of the SDG 6.4.1. indicator.

The following sections discusses the existing limitations of this methodology and potential refinements.

Table 3.
Template table to use for the calculation of country yield ratio from national data

Crop	Rainfed area	Rainfed production	Rainfed yield	Irrigated area	Irrigated production	Irrigated yield	Crop area	Crop yield ratio	Weighting
Formula	A_{rain}	P_{rain}	$Yr=P_{rain}/A_{rain}$	A_{irri}	P_{irri}	$Yi=P_{irri}/A_{irri}$	$A=A_{rain}+A_{irri}$	$R= Yr/Yi$	$=R*A$
Crop 1									
Crop 2									
Crop 3									
Crop 4									
Crop 5									
Crop 6									
Crop 7									
Crop 8									
Yield Ratio	$\Sigma_{crop}(R * A) / \Sigma_{crop} A = Y$								


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6. Limitations and discussions

a. Biophysical parameters vs. economic efficiency

The SDG 6.4.1 indicator is above all an economic indicator as it estimates the economic efficiency (in USD) of the water used by each sector of the economy in m^3 (FAO, 2019).

The most accurate way to assess the agricultural GVA originating from irrigated agriculture, as opposed to rainfed agriculture, would be to record production from rainfed and irrigated conditions, and their respective value, in different accounts nationwide. However such distinction is very seldom done in the countries' economic accounts. Due to this limitation in data availability, the estimation of the GVA originating from irrigated agriculture is calculated by assessing the extent of the area on which irrigation is practiced and considering the difference in yield between the irrigated and the rainfed areas, based on agronomic or biophysical parameters.

However, the distinction of the agricultural GVA originating from irrigated and rainfed agriculture based on biophysical parameters—area and production—disregards the value of the crops themselves; the unit value of an irrigated crop is assumed to be equal to that of the same rainfed crop. Nonetheless in practice, irrigation allows reaching a preferred state (larger fruits, optimum quality, etc.) and timing, and subsequently irrigated crops are paid a higher price.

In addition, the respective value of each crop can differ widely—staple crops are widely recognized to have a lower economic value than vegetables or fruits for example. Further, for the same crop, there may be also different values between one variety and another—durum wheat is usually more expensive than common wheat (European Union, 2021). However the level of disaggregated data required to account for such differences, is not available at country level, thus it is not possible to account for differences in value between irrigated and rainfed crops due to the differences in quality, timing and value of different crops or variety.

b. Monitoring ladder: accuracy adaptation

The methodology for SDG indicator 6.4.1 – recognizing that countries have different levels of capacity to monitor water–use efficiency – allows countries to start their monitoring efforts according to the level of their national capacity and available resources, and from there advance progressively. Similarly, this methodology, to assess the portion of the agricultural GVA originating from the irrigated agriculture, Cr, can also be adapted by the reporting countries depending on the availability of their data.

1. Where the data is not available, Cr can be calculated using the FAO country-specific estimation or global average of Yri, the yield ratio. Annex 2 provides these values for every country.

2. Where data is only available for one time period, Cr can be estimated based on a yield ratio Yri calculated from nationally produced data following the methodology proposed in the previous section of this guideline.

3. Where data is available more frequently, regular updates of the yield ratio Yri can be calculated from nationally produced data when they become available.

This guideline indeed stated in section 4, that the yield ratio Yri may be considered stable over time, while the Ai ratio enables a more contextualized overview and reflects the continuous changes to the irrigated area of the country.

However, a crop yield can change over time, either in the long term due to large increases in yield at national level, resulting from the wide take up of innovations, or due to specific conditions in a cropping cycle, such as drought, flood, pests, etc. A dry year will undeniably strongly affect the yield of rainfed agriculture and subsquently the yield ratio Yri.

Table 4 shows a qualitative indication of the possible combinations of using the different options of the Cr components, Ai and Yri.

Table 4.
Qualitative description of the variables options for the Cr calculation from red to green, worst to best

Ai/Yri	Estimation (Annex 2)	Calculated from national data	Regularly calculated from national data
Area equipped for irrigation			
Actually irrigated area			
Harvested irrigated crop area			

c. Notation in AQUASTAT

The SDG 6.4.1 metadata and the previous sections of this guidelines use the rainfed perspective, ie Cr – the proportion of agricultural GVA produced by rainfed agriculture-, and Yri – the Ratio between rainfed and irrigated yields. However, this perspective is not the one used in AQUASTAT.

As AQUASTAT focuses on water and irrigation, it shows the proportion of agricultural GVA produced by irrigated agriculture, Ci. This Ci is displayed in the "Geography and population" section under the "Economy, development and food security" sub-section of the database. It can easily be calculated from Cr:

$$Cr = 1 - Ci \qquad \text{Eq.9}$$

Where

C_r = Proportion of agricultural GVA produced by rainfed agriculture

C_i = Proportion of agricultural GVA produced by irrigated agriculture

Similarly, the Yir, the ratio between irrigated and rainfed yields, highlighting the beneficial impact of irrigation is available in AQUASTAT in the "Irrigation and Drainage development" section under the "Irrigated crop yield" sub-section of the database, with:

$$Yri = \frac{1}{Yir} \qquad \text{Eq.10}$$

Where

Yri = Ratio between rainfed and irrigated yields

Yir= Ratio between irrigated and rainfed yields

d. Geographical disaggregation

Like for all SDG indicators, geographical disaggregation is recommended for more accurate information at subnational level, following the administrative areas when the following primary data are available:

- For the calculation of Ai:

  - Cultivated area.
  - Harvested irrigated crop area.
- For the calculation of Yri:
  - Rainfed and irrigated crop area.
  - Rainfed and irrigated crop production.

All variables for the SDG 6.4.1 calculation, including the GVA and volume of water used, should refer to the same geographical disaggregation unit.

Very large countries in particular could calculate a subnational Cr component for each subnational administrative areas.

7. Conclusions

This guideline provides an entry into understanding and assessing the agronomic parameters involved in the calculation of the SDG 6.4.1 indicator on water use efficiency. It introduces how to use the various available irrigation-related variables in AQUASTAT and yield ratio proposed by FAO as a first stage estimation for a country of the part of the agricultural GVA, which can be attributed to irrigated agriculture. For those countries with little capacity, this data as provided by FAO can be accepted and used for inclusion in the 6.4.1 calculation. However, where it is known that this data is not of sufficient accuracy to reflect the situation in a country, countries are free to make use of more accurate national data in the FAO AQUASTAT questionnaire[7] but also in more detail during presentation of their Voluntary National Review.

7 The yield ratio is a pre-filled variable as of December 2021, but raw national data can be provided to FAO in the questionnaire's comments as explained in section 6b.

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Annex 1
Cr formula

$$Cr = \frac{Pr}{Pt} = \frac{Pr}{Pr + Pi} = \frac{1}{1 + \frac{Pi}{Pr}}$$

With $P = A * Y$ so $\frac{Pi}{Pr} = \frac{Ai*Yi}{Ar*Yr}$ and $Yri = \frac{Yr}{Yi}$

Thus $\frac{Pi}{Pr} = \frac{Ai}{Ar\frac{Yr}{Yi}} = \frac{Ai}{Ar*Yri} = \frac{Ai}{(1-Ai)*Yri}$

Therefore $Cr = \frac{1}{1+\frac{Ai}{(1-Ai)*Yri}}$

Annex 2
Yield ratio estimated by country

Table A1.
Rainfed and irrigated yield field ratio by country

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Afghanistan	0.4720	2.1189
Albania	0.5625	1.7777
Algeria	0.4530	2.2074
Andorra	0.5625	1.7777
Angola	0.6866	1.4565
Antigua and Barbuda	0.5625	1.7777
Argentina	0.5917	1.6902
Armenia	0.5625	1.7777
Australia	0.4607	2.1707
Austria	0.5625	1.7777
Azerbaijan	0.5625	1.7777
Bahamas	0.5625	1.7777
Bahrain	0.5625	1.7777
Bangladesh	0.6328	1.5803
Barbados	0.5625	1.7777
Belarus	0.5625	1.7777
Belgium	0.5625	1.7777
Belize	0.5625	1.7777
Benin	0.7178	1.3932
Bhutan	0.5625	1.7777
Bolivia (Plurinational State of)	0.4993	2.0029

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Bosnia and Herzegovina	0.5625	1.7777
Botswana	0.7479	1.3370
Brazil	0.5432	1.8410
Brunei Darussalam	0.5625	1.7777
Bulgaria	0.5625	1.7777
Burkina Faso	0.7331	1.3641
Burundi	0.4294	2.3290
Cabo Verde	0.5625	1.7777
Cambodia	0.6188	1.6160
Cameroon	0.6581	1.5195
Canada	0.4843	2.0650
Central African Republic	0.5625	1.7777
Chad	0.7236	1.3820
Chile	0.5690	1.7576
China	0.6500	1.5384
Colombia	0.6237	1.6033
Comoros	0.5625	1.7777
Congo	0.6927	1.4436
Costa Rica	0.7419	1.3479
Côte d'Ivoire	0.3776	2.6482
Croatia	0.5625	1.7777
Cuba	0.4476	2.2339
Cyprus	0.5625	1.7777
Czechia	0.5625	1.7777
Democratic People's Republic of Korea	0.5665	1.7653
Democratic Republic of the Congo	0.3270	3.0578
Denmark	0.5625	1.7777

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Djibouti	-	-
Dominica	0.5625	1.7777
Dominican Republic	0.6212	1.6098
Ecuador	0.5650	1.7700
Egypt	-	-
El Salvador	0.7057	1.4171
Equatorial Guinea	-	-
Eritrea	0.4133	2.4197
Estonia	0.5625	1.7777
Eswatini	0.7101	1.4082
Ethiopia	0.7277	1.3742
Fiji	0.5625	1.7777
Finland	0.5625	1.7777
France	0.5625	1.7777
French Guiana	0.5625	1.7777
French Polynesia	0.5625	1.7777
Gabon	0.7309	1.3682
Gambia	0.5890	1.6977
Georgia	0.5625	1.7777
Germany	0.5625	1.7777
Ghana	0.6429	1.5554
Greece	0.5625	1.7777
Grenada	0.5625	1.7777
Guadeloupe	0.5625	1.7777
Guam	0.5625	1.7777
Guatemala	0.4950	2.0202
Guinea	0.5195	1.9249

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Guinea-Bissau	0.5625	1.7777
Guyana	0.5625	1.7777
Haiti	0.4717	2.1202
Honduras	0.5961	1.6776
Hungary	0.5625	1.7777
Iceland	0.5625	1.7777
India	0.4597	2.1754
Indonesia	0.6196	1.6140
Iran (Islamic Republic of)	0.3982	2.5110
Iraq	0.4544	2.2008
Ireland	0.5625	1.7777
Israel	0.5220	1.9156
Italy	0.5625	1.7777
Jamaica	0.6580	1.5197
Japan	0.6473	1.5449
Jordan	0.5630	1.7763
Kazakhstan	0.5625	1.7777
Kenya	0.7372	1.3564
Kuwait	-	-
Kyrgyzstan	0.5625	1.7777
Lao People's Democratic Republic	0.7230	1.3832
Latvia	0.5625	1.7777
Lebanon	0.5378	1.8594
Lesotho	0.3472	2.8800
Liberia	0.5798	1.7247
Libya	0.3743	2.6720
Lithuania	0.5625	1.7777

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Luxembourg	0.5625	1.7777
Madagascar	0.5004	1.9985
Malawi	0.7359	1.3589
Malaysia	0.6385	1.5662
Mali	0.8240	1.2136
Malta	0.5625	1.7777
Martinique	0.5625	1.7777
Mauritania	0.2802	3.5689
Mauritius	0.5940	1.6835
Mexico	0.5256	1.9027
Mongolia	0.5625	1.7777
Montenegro	0.5625	1.7777
Morocco	0.5569	1.7956
Mozambique	0.7060	1.4164
Myanmar	0.6518	1.5342
Namibia	0.5625	1.7777
Nepal	0.3925	2.5480
Netherlands	0.5625	1.7777
New Zealand	0.7760	1.2886
Nicaragua	0.6365	1.5711
Niger	0.4533	2.2060
Nigeria	0.4692	2.1312
North Macedonia	0.5625	1.7777
Northern Mariana Islands	0.5625	1.7777
Norway	0.5625	1.7777
Occupied Palestinian Territory	0.5625	1.7777
Oman	-	-

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Pakistan	0.4178	2.3935
Panama	0.6040	1.6556
Papua New Guinea	-	-
Paraguay	0.3775	2.6490
Peru	0.5018	1.9927
Philippines	0.7768	1.2874
Poland	0.5625	1.7777
Portugal	0.5625	1.7777
Puerto Rico	0.5625	1.7777
Qatar	-	-
Republic of Korea	0.6675	1.4981
Republic of Moldova	0.5625	1.7777
Reunion	0.5625	1.7777
Romania	0.5625	1.7777
Russian Federation	0.5077	1.9697
Rwanda	0.7155	1.3977
Saint Kitts and Nevis	0.5625	1.7777
Saint Lucia	0.5625	1.7777
Sao Tome and Principe	0.5625	1.7777
Saudi Arabia	-	-
Senegal	0.5584	1.7909
Serbia	0.5625	1.7777
Seychelles	0.5625	1.7777
Sierra Leone	0.3008	3.3240
Singapore	-	-
Slovakia	0.5625	1.7777
Slovenia	0.5625	1.7777

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Solomon Islands	0.5625	1.7777
Somalia	0.3120	3.2053
South Africa	0.4715	2.1210
South Sudan	0.5625	1.7777
Spain	0.5625	1.7777
Sri Lanka	0.6058	1.6508
Sudan	0.2850	3.5088
Suriname	0.5625	1.7777
Sweden	0.5625	1.7777
Switzerland	0.5625	1.7777
Syrian Arab Republic	0.4818	2.0755
Tajikistan	0.5625	1.7777
Thailand	0.4709	2.1235
Timor-Leste	0.5625	1.7777
Togo	0.6394	1.5639
Trinidad and Tobago	0.5625	1.7777
Tunisia	0.4660	2.1459
Turkey	0.6224	1.6066
Turkmenistan	-	-
Uganda	0.8897	1.1240
Ukraine	0.5625	1.7777
United Arab Emirates	-	-
United Kingdom of Great Britain and Northern Ireland	0.5625	1.7777
United Republic of Tanzania	0.3829	2.6119
United States of America	0.6333	1.5789
Uruguay	0.6155	1.6247
Uzbekistan	0.5625	1.7777

Country	Rainfed yield ratio (Yri)	Irrigated yield ratio (Yir) as in AQUASTAT
Venezuela (Bolivarian Republic of)	0.6493	1.5400
Viet Nam	0.4924	2.0310
Yemen	0.4271	2.3416

Notes:

- Figures in grey are using the average/default yield ratio
- Countries without a ratio in the table are either very arid and all their agricultural production is considered irrigated (Djibouti, Egypt, Kuwait, Oman, Qatar, Saudi Arabia, Turkmenistan, United Arab Emirates) or do not have any known irrigated area (Equatorial Guinea, Papua New Guinea and Singapore).

These guidelines are intended to assist countries in understanding the agronomic parameters involved in the computation of the agricultural component of the Sustainable Development Goal (SDG) indicator 6.4.1 on the change in water use efficiency over time. They provide a detailed explanation of the calculation process for calculation by countries willing to generate a more accurate estimation using their national data. The guidelines provide the minimum standard method using an estimated or default value proposed by FAO, as well as the available methodologies to progressively improve the accuracy through a monitoring ladder for countries that have more comprehensive and accurate data on their main crops areas and productions.

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