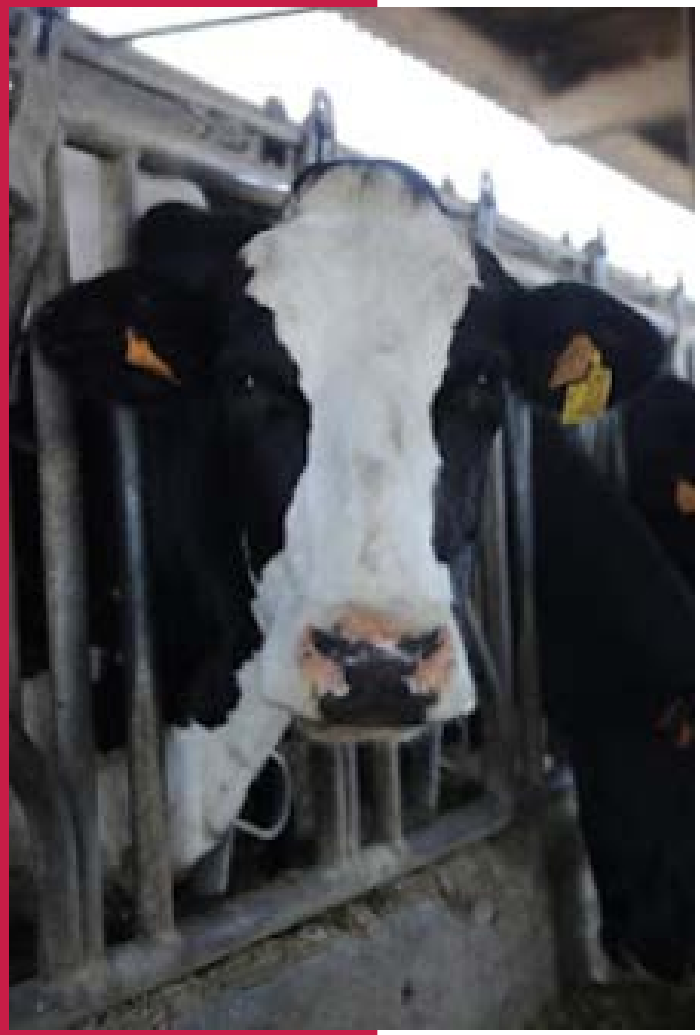


Understanding spatial dynamics in LCA application: regionalization of CF

Marta Ruiz-Colmenero, Ariadna Bàllega, Miquel Andon, Marta Terré, Assumpció Antón, Anna Targa, Maria Devant, Ralph Rosenbaum, Montserrat Núñez

Water use assessment of livestock production systems and supply chains

14-16 December 2022, Potsdam, Germany

OECD Co-operative Research Programme: Sustainable Agricultural and Food Systems

www.oecd.org/agriculture/crp/conferences/
section on 2020 conferences

RAMADERS DEL BAIX EMPORDÀ, SCCL
LLET NOSTRA

Generalitat de Catalunya
Departament d'Acció Climàtica, Alimentació i Agenda Rural

Fons Europeu Agrícola de Desenvolupament Rural:
Europa inverteix en les zones rurals

INDEX

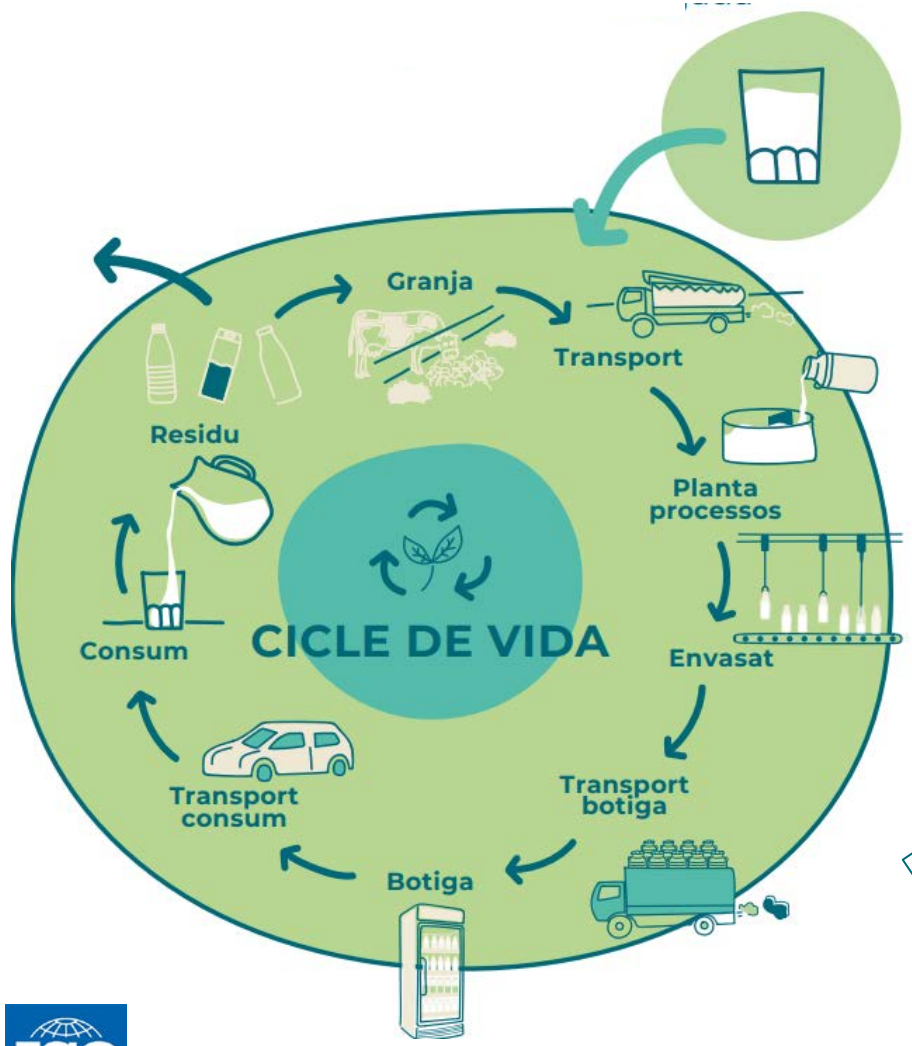
Context

- to assess the environmental impact of the dairy value chain in Catalonia, north-eastern Spain, from cradle to distribution,

- to test the suitability of the PEF and dairy-specific PEF Category Rules (PEFCRs) guidelines to our production systems.

PEFCR, Product Environmental Footprint Category Rules for ***Dairy Products*** *(EC, 2018)*

Methodology: Life cycle assessment



ISO 14040 and ISO 14044 (2006, 2016)

PEF: Product Environmental Footprint (EC, 2013; 2019)

Impact category	Impact category Indicator (unit of measure)	Description
Climate change, total	Radiative forcing as global warming potential – GWP100 (kg CO_2 eq)	Increase i… tempe… gas… …enhouse
Ozone depletion	Ozone Depletion Potential – … (kg CFC-11 eq)	
Human toxicity, cancer	Comparative … humans …	…man health caused by … substances through the air, … and soil. Direct effects of …ducts on humans are not measured
Human toxicity, non-cancer		
	…lth (disease	Impact on human health caused by particulate matter emissions and its precursors (e.g. sulfur and nitrogen oxides)
	…man exposure efficiency relative to U-235 (kBq U-235 eq)	Impact of exposure to ionising radiations on human health
	…emical … formation, …man health	Tropospheric ozone concentration increase (kg NMVOC eq)	Potential of harmful tropospheric ozone formation ("summer smog") from air emissions
Acidification	Accumulated Exceedance – AE (mol H^+ eq)	Acidification from air, water, and soil emissions (primarily sulfur compounds) mainly due to combustion processes in electricity generation, heating, and transport
Eutrophication, terrestrial	Accumulated Exceedance – AE (mol N eq)	
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (kg P eq)	Eutrophication and potential impact on ecosystems caused by nitrogen and phosphorous emissions mainly due to fertilizers, combustion, sewage systems
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (kg N eq)	
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	Impact of toxic substances on freshwater ecosystems
Land use	Soil quality index, representing the aggregated impact of land use on: Biotic production; Erosion resistance; Mechanical filtration; Groundwater replenishment	Transformation and use of land for agriculture, roads, housing, mining or other purposes. The impact can include loss of species, organic matter, soil, filtration capacity, permeability
Water use	Weighted user deprivation potential (m^3 world eq)	Depletion of available water depending on local water scarcity and water needs for human activities and ecosystem integrity
Resource use, minerals and metals	Abiotic resource depletion – ADP ultimate reserves (kg Sb eq)	Depletion of non-renewable resources and deprivation for future generations
Resource use, fossils	Abiotic resource depletion, fossil fuels – ADP-fossil (MJ)	

Water use
Weighted user deprivation potential (m^3 world eq)
Depletion of available water depending on local water scarcity and water needs for human activities and ecosystem integrity

Methodology: AWARE

AWARE: indicator recommended by EC (EF) and UNEP (LC-Initiative)

Consensus-based method development to assess water use in LCA:

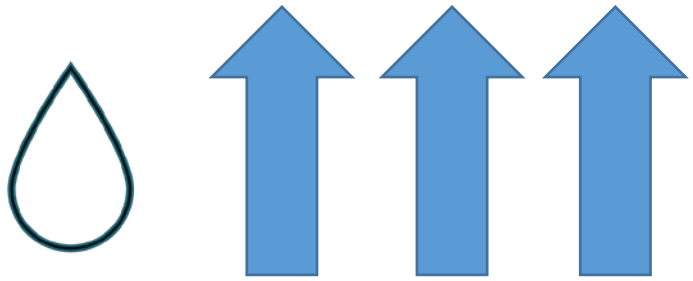
"midpoint indicator representing the relative **Available WAter REmaining** per area in a watershed, after the demand of humans and aquatic ecosystems has been met."

https://wulca-waterlca.org/aware/download-aware-factors/

(Excel & Google Earth)

Results

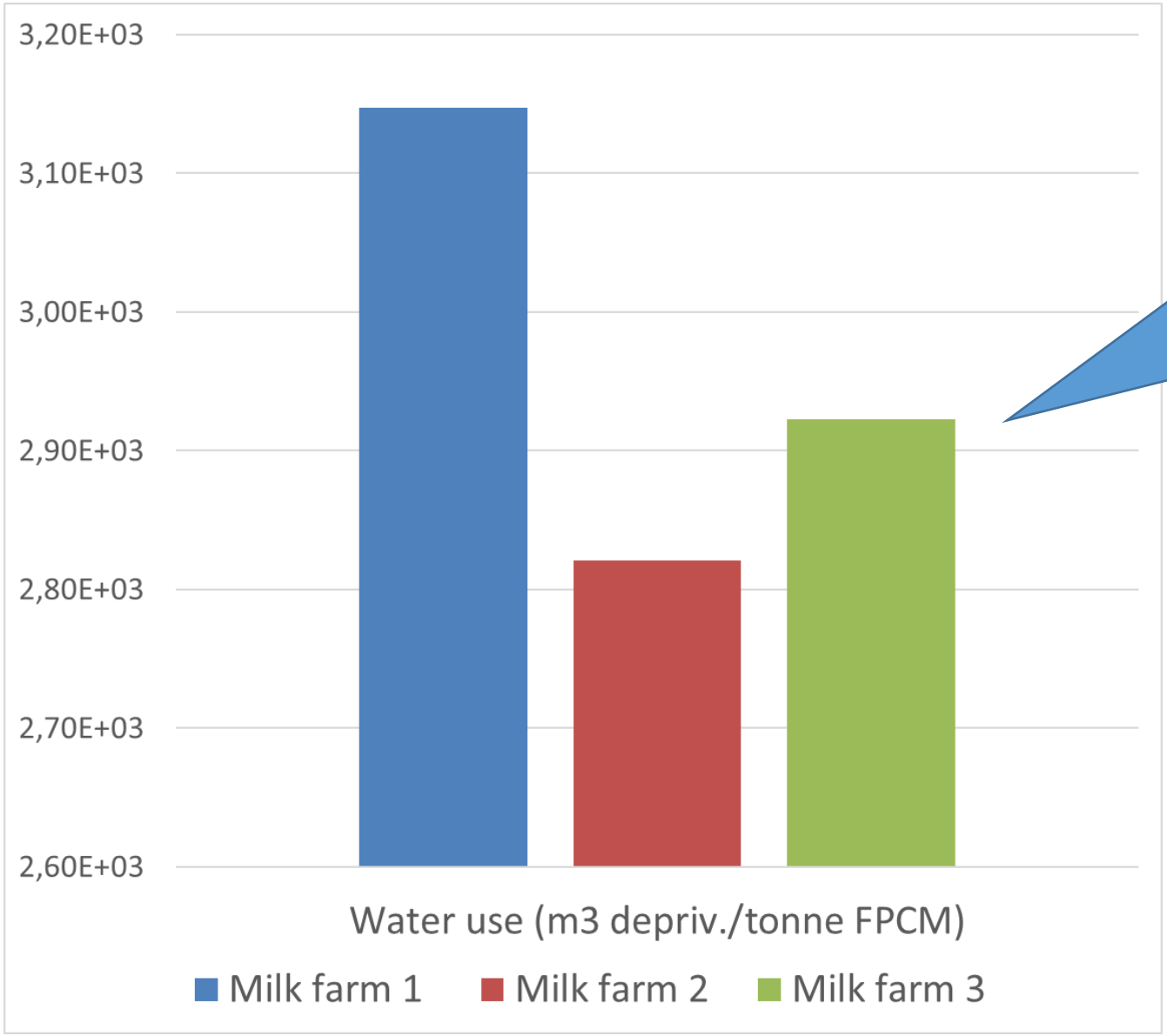
Dairy farms	Farm 1	Farm 2	Farm 3
National CF (Spain)		77.7	
m^3 depriv. $tonne^{-1}$ FPCM milk	3.23E+03	2.94E+03	3.09E+03



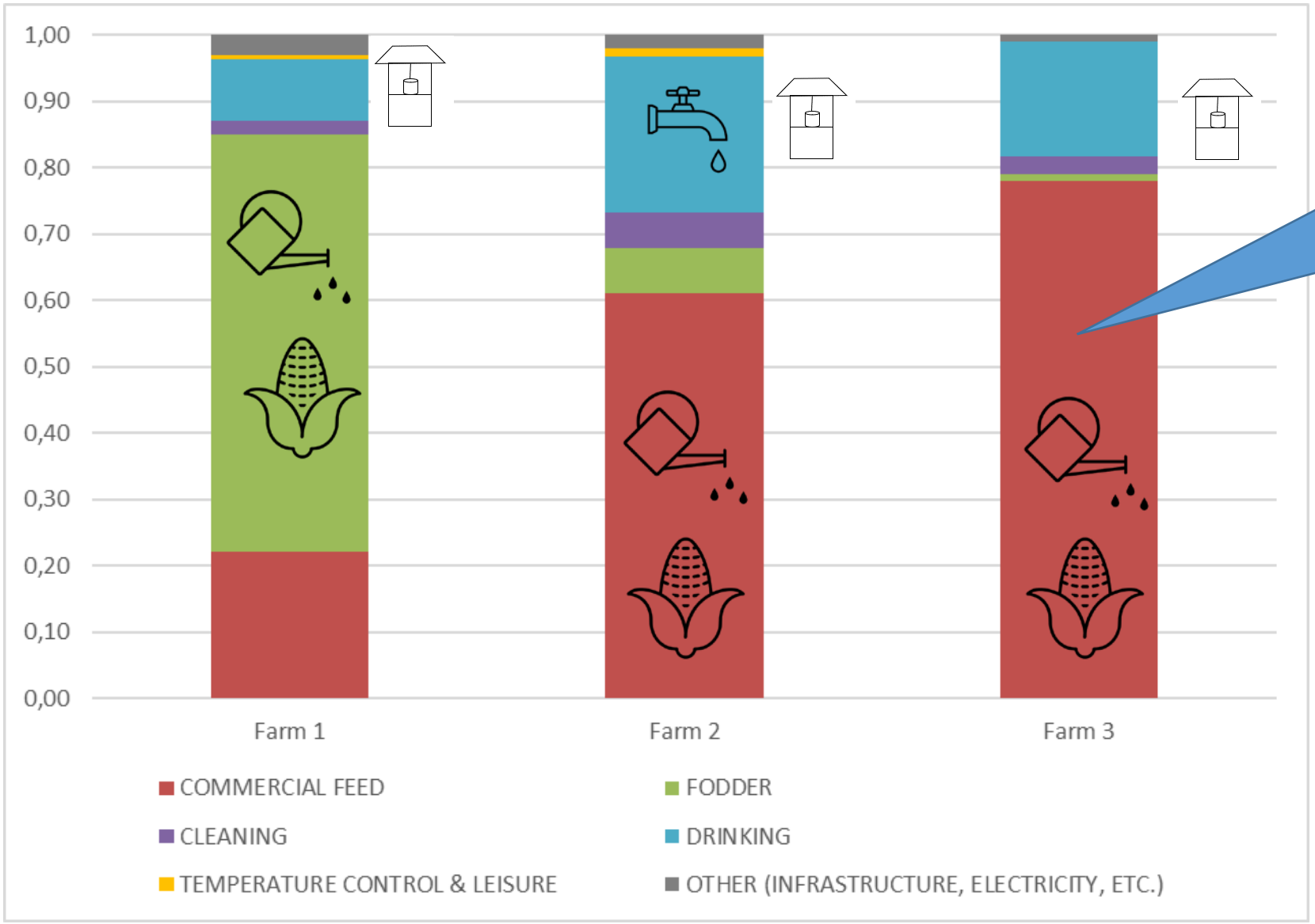
X10 Benchmark value

Benchmark value: 311 m3 depriv. tonne-1 FPCM milk.

Literature: 0,20E+03 (5% percentil) to 8,1E+04 (95% percentil) m^3 tonne milk (Poore & Nemecek, 2018).



Difference between max & min = 290 m3 depriv. tonne-1 FPCM milk. -> almost reaching the benchmark value(311 m3 depriv. tonne-1)



Geographically representative datasets or proxys

Origin not known: Average (regional, world, product group average)

Origin known: dataset from another country with similar BW availab. + climate cond; similar crop (water needs and period); product group

DISCUSSION: regionalization level of CFs

Water footprint *(m^3 eq world)* = Water consumption "inventory" *(m^3 consumed)* × AWARE *(m^3 eq world / m^3 consumed)*

- EC requires using CF at country-level and year.*

Dairy farms	Farm 1	Farm 2	Farm 3
National CF (Spain)	77.7		
m^3 depriv. $tonne^{-1}$ FPCM milk	3.23E+03	2.94E+03	3.09E+03

**"Notwithstanding the characterization factors of AWARE are available at different temporal and spatial scales (month/year, watershed/country) as well as water use types (agriculture/non- agriculture), due to applicability reasons, they are not part of the recommendation" (Sala et al 2019 - Suggestions for the update of the Environmental Footprint Life Cycle Impact Assessment. Impacts due to resource use, water use, land use, and particulate matter. JRC Publication N°: JRC106939).*

Country level

France

CF: 6,98(*) m^3 eq world /m^3 consumed

Spain

CF: 77,7(*) m^3 eq world/m^3consumed

(*)Rang: 0.1 – 100 m^3 eq world/m^3 consumed

BASIN	CONCA	YR_TOT
31897	**Muga, Fluvià**	**3,44**
32250	Tordera	**62,50**
32251	**Ter**	**74,21**
32601	Sud	**95,08**
32602	Garraf-Foix	**6,81**
32603	Llobregat	**5,60**
32963	Ebre	**88,95**
CATALUNYA		**80,86**

DISCUSSION: use of different regionalization level

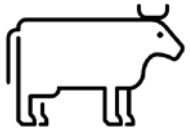
Dairy farms	Farm 1	Farm 2	Farm 3
milk	986	2734	2863

DISCUSSION: Inventory

IRTA

Water footprint *(m^3 eq world)* = Water consumption "inventory" *(m^3 consumed)* × AWARE *(m^3 eq world / m^3 consumed)*

- Inventory includes "blue" water consumption (tap water, well, etc.).
- Consumed water: water withdrawal where release back to the source does not occur, e.g. due to evaporation, evapotranspiration, product integration or discharge into a different drainage basin (ISO 14046:2014; FAO, 2019).



Water use for **animal production** includes drinking water and cleaning water, cooling water, Consumption predicted by indirect means. **When no specific data on water withdrawal and release is available, 83% of water use is considered consumed (i.e. 17% is released)** (Shaffer 2008).

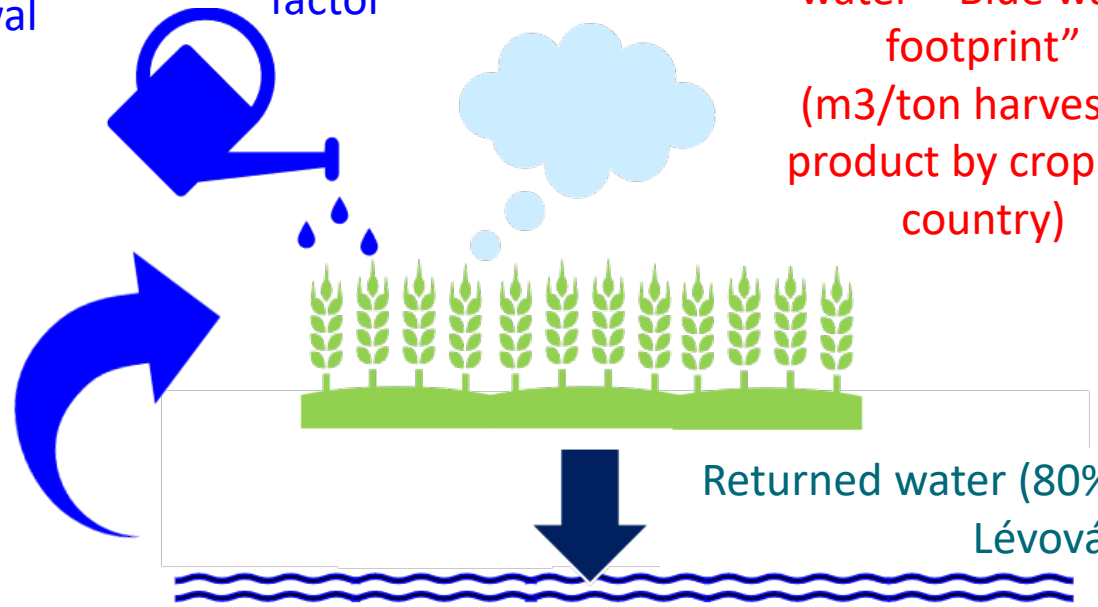
Irrigation water consumption from the **crop production** at the farms is calculated based on consumed blue water which depends on **evapotranspiration** from irrigation (Pfister et al., 2011) and irrigation efficiency factors (FAO, 1989).

WFLDB_MethodologicalGuidelines_v3.0.pdf

CROP PRODUCTION

Water use = input irrigation water= water withdrawal

Irrigation efficiency factor



Evapotranspiration from irrigation="consumed water"=Blue water footprint" (m3/ton harvested product by crop and country)

$I_{withdrawal} = ET_{irr} / EF_{irr}$ [m^3/t]

With:

ET_{irr} = Evapotranspiration from irrigation [m^3/t]

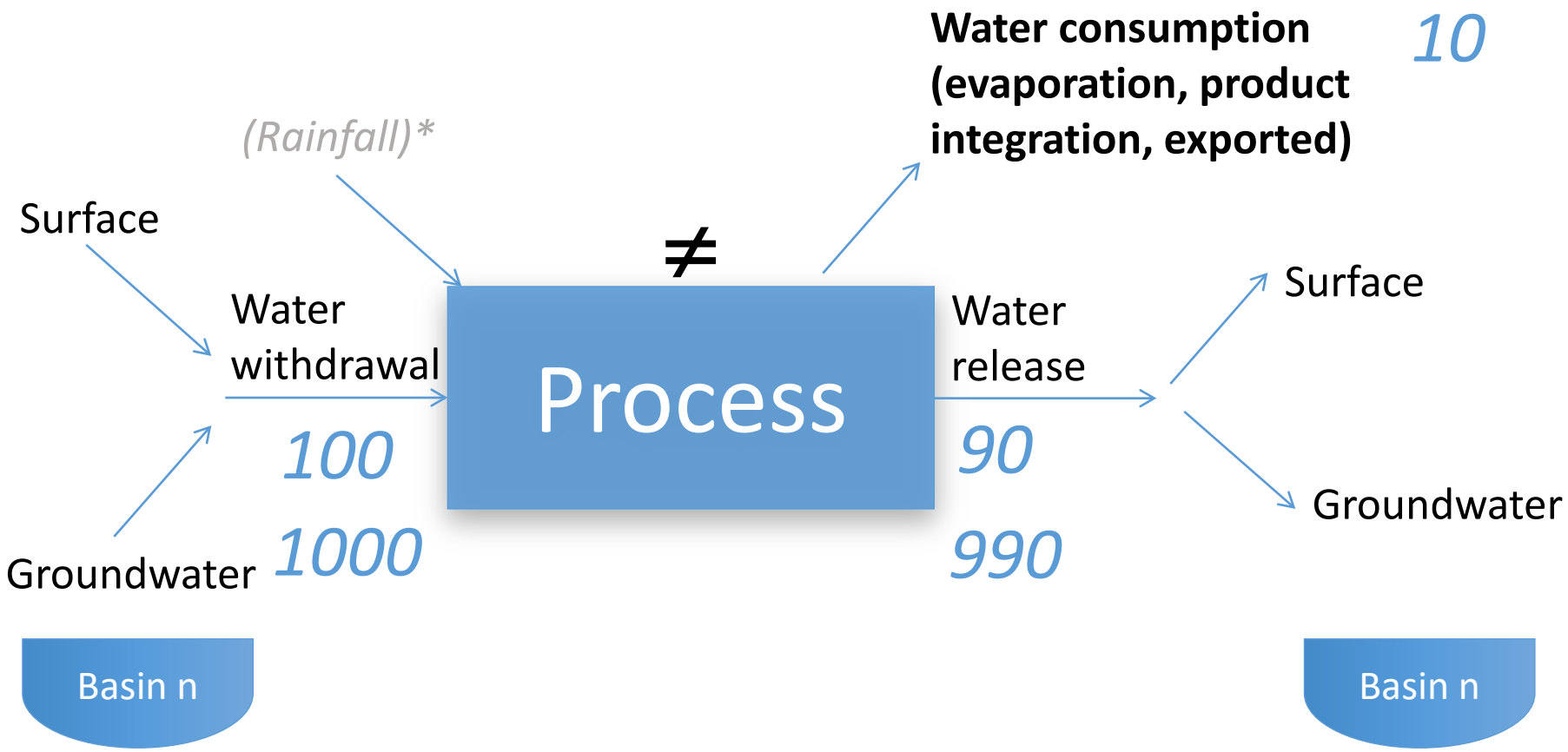
EF_{irr} = Irrigation efficiency factor [-]

Returned water (80% surface and 20% ground water).
Lévová and Pfister (2012),

ISO 14046 (2016). Gestió Ambiental. Petjada hídrica-Principis, requeriments i Guia. UNE-EN ISO 14046:2016

CROP	BLUE WATER EXPECTED CONSUMPTION SPAIN (Pfister et al 2011) (m3/ton) ET_{irr}	IRRIGATION TYPE	Irrigation efficiency WFDB (2015) EF_{irr}	Water use/withdrawal WFDB ET_{irr} / EF_{irr} [m^3/ton]	WATER USE (irrigation), (m3/ton)	REFERENCE
WHEAT	399,7	sprinkler	0,75	532,9	0	Desherb 21
WHEAT	399,7	surface	0,45	886,7	0	
CORN	326,02	sprinkler	0,75	434,7	222,4	Desher 21
BARLEY	370,46	sprinkler	0,75	493,9	0	Desherb 21- Agriclo 20
APPLE	242,74	drip	0,90	269,7	30-125	Agriclo 20-PMA 19
APPLE	242,74	surface	0,45	539,4		
PEAR	251,22	drip	0,90	279,1	200	PMA 19
PEAR	251,22	surface	0,45	558,27		
ORANGE	144,97	drip	0,90	161,1	183,3	PMA 20
TOMATO	21,8	drip	0,90	24,22	16-40	DIBA 22- PMA 21

Inventory: water consumtpion ≠ water use



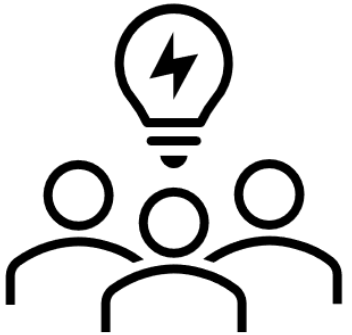
Rainfall ("green wàter") is considered only for the mass balance (i.e., inventory only includes "blue" wàter consumtpion)

DISCUSSION

Water is ~~going to be~~ crucial in Mediterranean countries

Parameter Uncertainty (inventory):

- Availability of primary water use data -> promote work towards better consumption registry
- Water use vs consumption. -> Could water saving be valorised by using “water use” in the inventory rather than the “water consumption”?
- Secondary datasets -> promote work towards traceability of feed compound ingredients and towards having geographically representative datasets (proxies increase uncertainty; adapting datasets create inconsistencies)

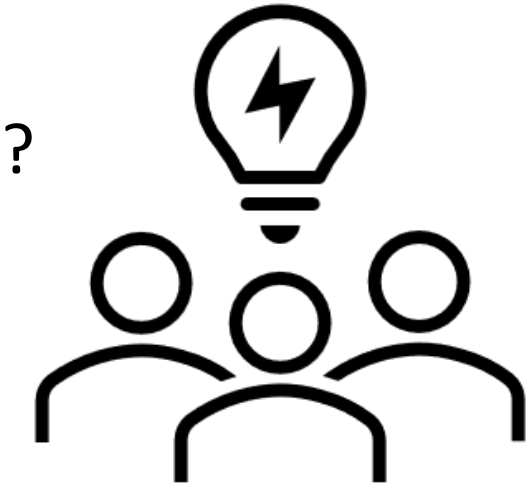


DISCUSSION

Water is ~~going to be~~ crucial in Mediterranean countries

Model Uncertainty (regionalization level of CF):

- Spatial representativeness: characterization by watershed (and month) vs boundary effect. -> What level of spatial detail of CF is more suitable for the assessment: watershed, regional, or some type of average?
- Better if CFs not too sensitive to small changes in spatial boundaries-> Can this be solved by some type of interpolation? Could it be better using a conservative global CF?



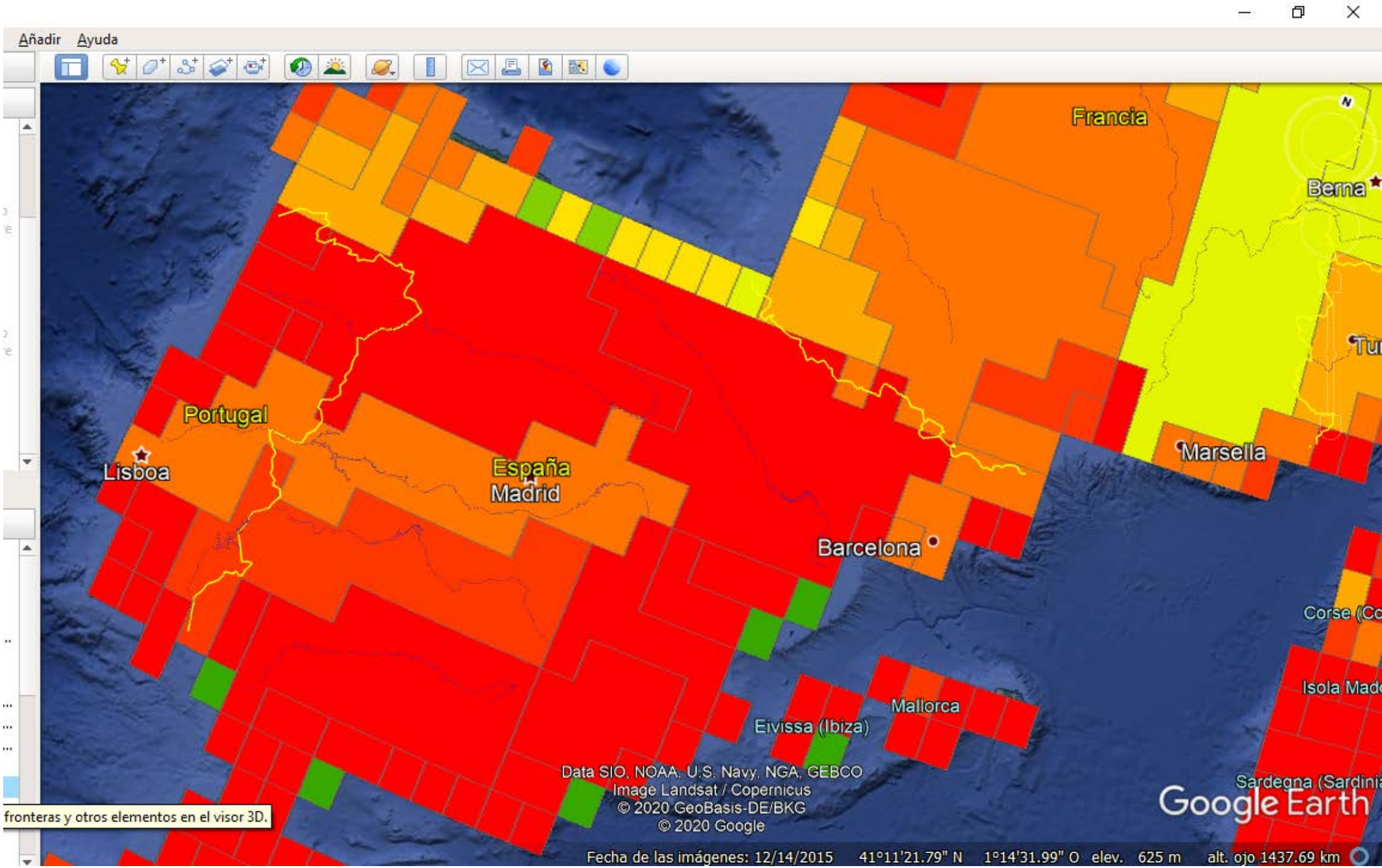
SUPPLEMENTARY MATERIAL

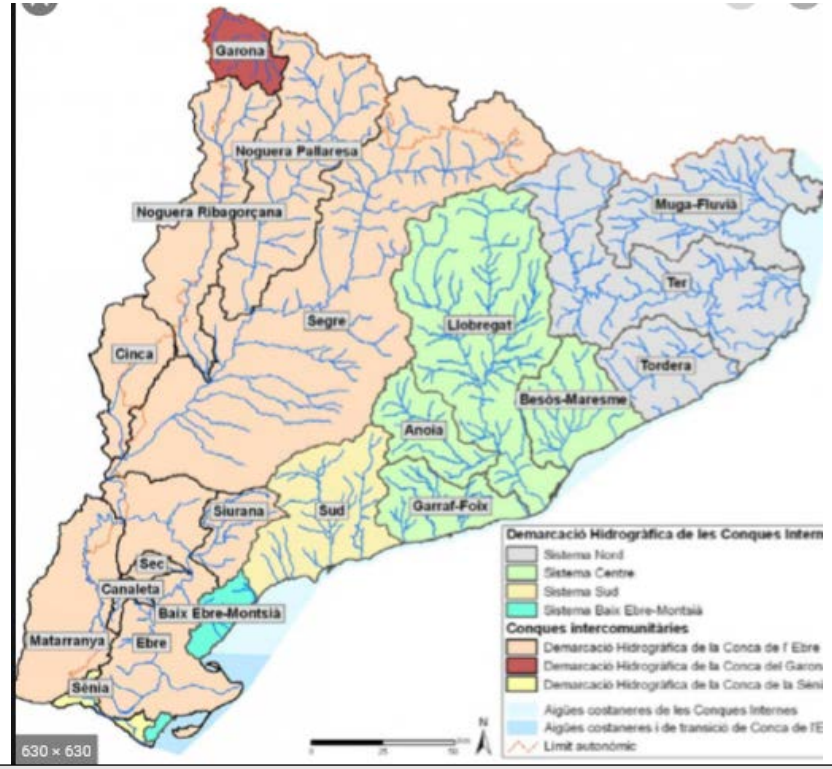
Factors de caracterització mensuals i anuals per diferents àrees geogràfiques d'acord a la metodologia AWARE

CONCA	BASIN	Gen	Feb	Mar	Abr	Mai	Jun	Jul	Ago	Set	Oct	Nov	Des	Annual
Muga, Fluvià	31897	0,63	0,63	0,73	0,63	0,62	1,09	4,14	6,30	3,07	1,13	0,85	0,68	3,63
Ter	32251	3,16	2,71	3,97	6,78	9,87	27,08	100,0	100,0	100,0	5,90	6,13	4,14	80,59
CATALUNYA		1,04	1,16	1,29	1,84	11,76	90,95	92,63	92,54	85,18	43,12	1,81	1,21	84,45
ESPANYA		23,44	29,77	21,39	31,30	54,83	71,92	92,62	86,10	73,62	50,70	100,00	7,66	79,13

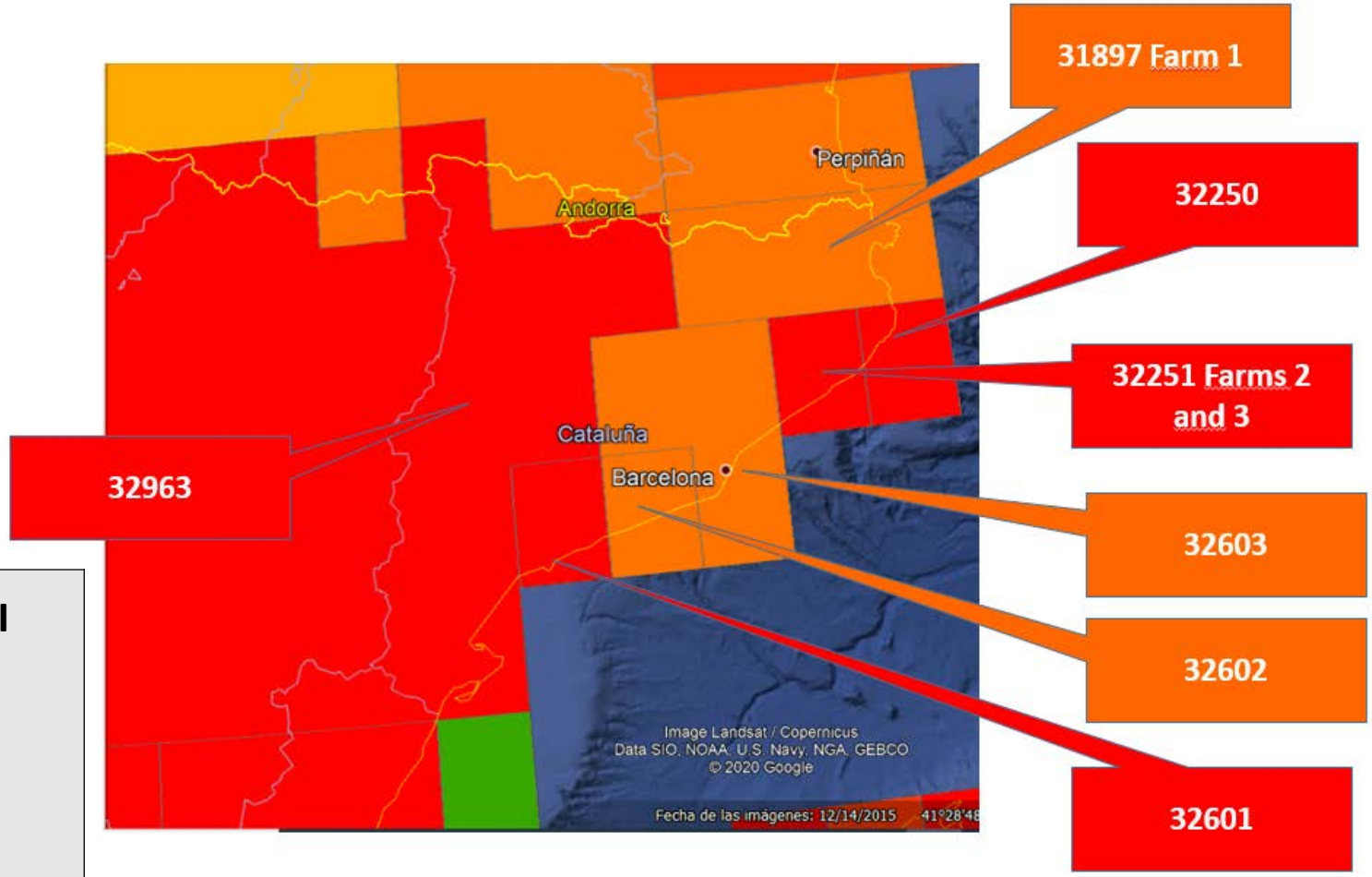
	Drinking wtater	Cooling water	Cleaning water	Crop
Farm 1 and 3	Literature, depending in animal type and age (for example: Vaca lactante bebe 4,5/L producido (4,5*38,38L leche *67animales) ; Vaca seca: 50L/día; Novilla<1m: 5L; Novilla 15m 24L; Novilla 24m: 40L	Calculated with usage time and low rates (for ex.: 1160ml/min x 13 surtidors; 4 meses/año con ºC maxima >24º, 8h/día >24ºC, aspersión 1 min, reposo 2min	Estimation: Total water – drinking water – cooling water	Surcos inundados. Estimation: 1,4ha, 1 pozo, bomba 60000L/h. 14h cada 15d. Period: to Aug (5 times). 90 días=100l/campaign & m2
Farm 2	Experimental farm			

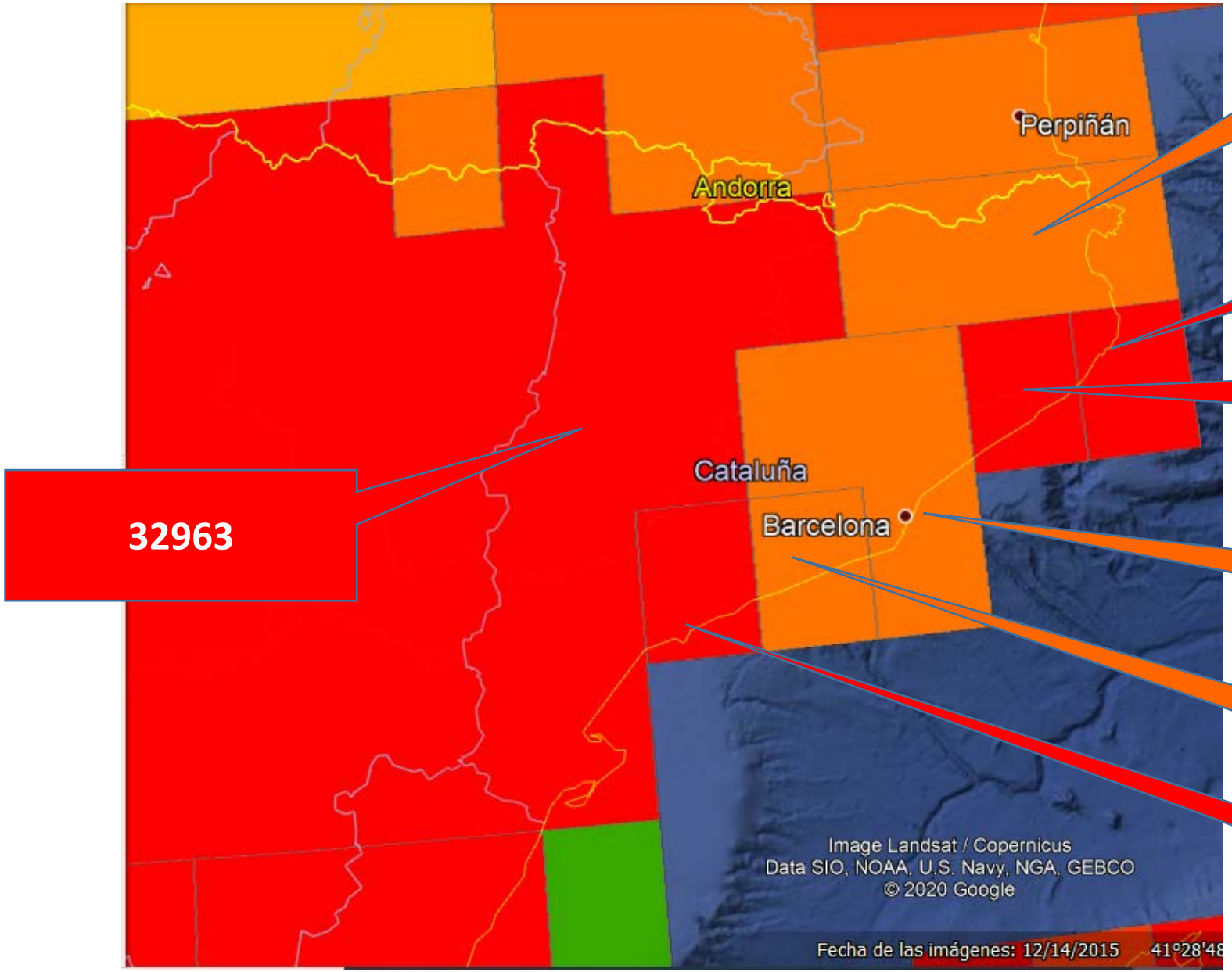
AWARE


Añadir
Ayuda
Francia
Berna
Portugal
Lisboa
España
Madrid
Marsella
Barcelona
Corse (Co
Isola Mad
Mallorca
Eivissa (Ibiza)
Sardegna (Sardini
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
© 2020 GeoBasis-DE/BKG
© 2020 Google
Google Earth
fronteras y otros elementos en el visor 3D.
Fecha de las imágenes: 12/14/2015
41°11'21.79" N
1°14'31.99" O
elev. 625 m
alt. ojo 1437.69 km



BASIN	CONCA	YR_IRRI
31897	**Muga, Fluvià**	**3,63**
32250	Tordera	69,20
32251	**Ter**	**80,59**
32601	Sud	98,01
32602	Garraf-Foix	8,59
32603	Llobregat	8,19
32963	Ebre	90,00
CATALUNYA		84,5





31897 Farm 1

32250

32251 Farms 2 and 3

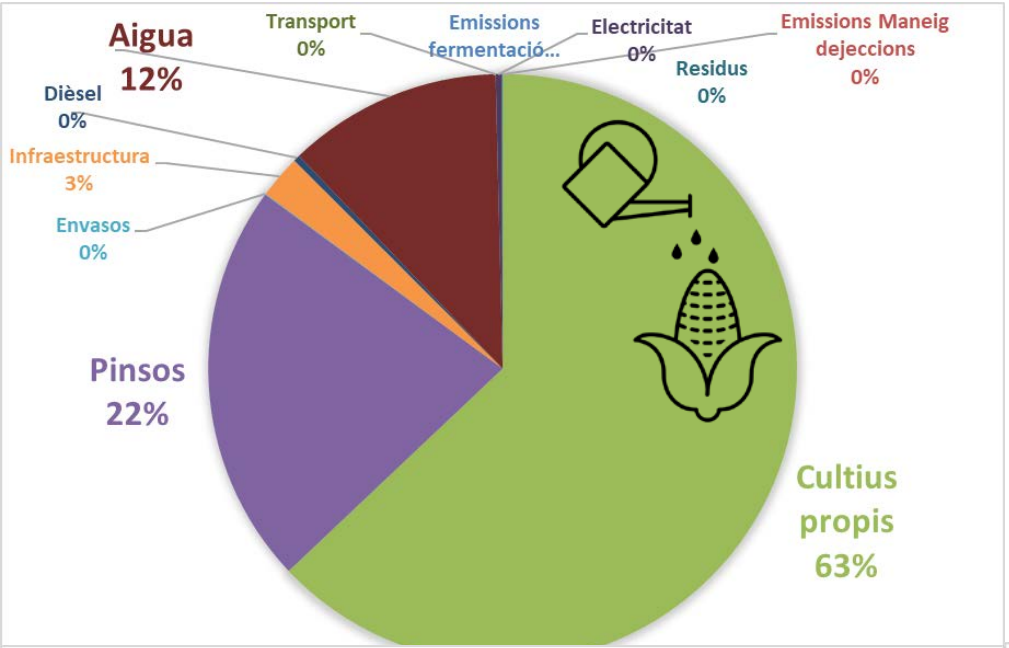
32963

32603

32602

32601

Uso de agua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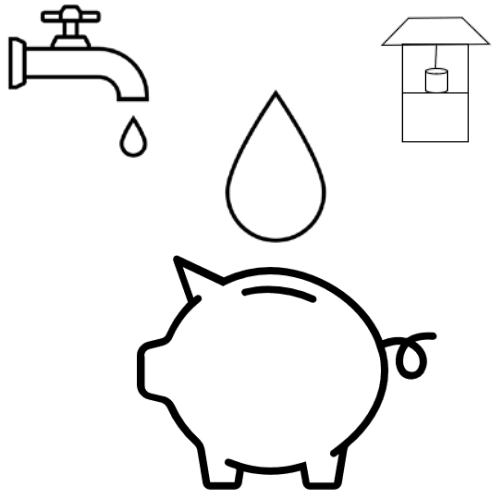

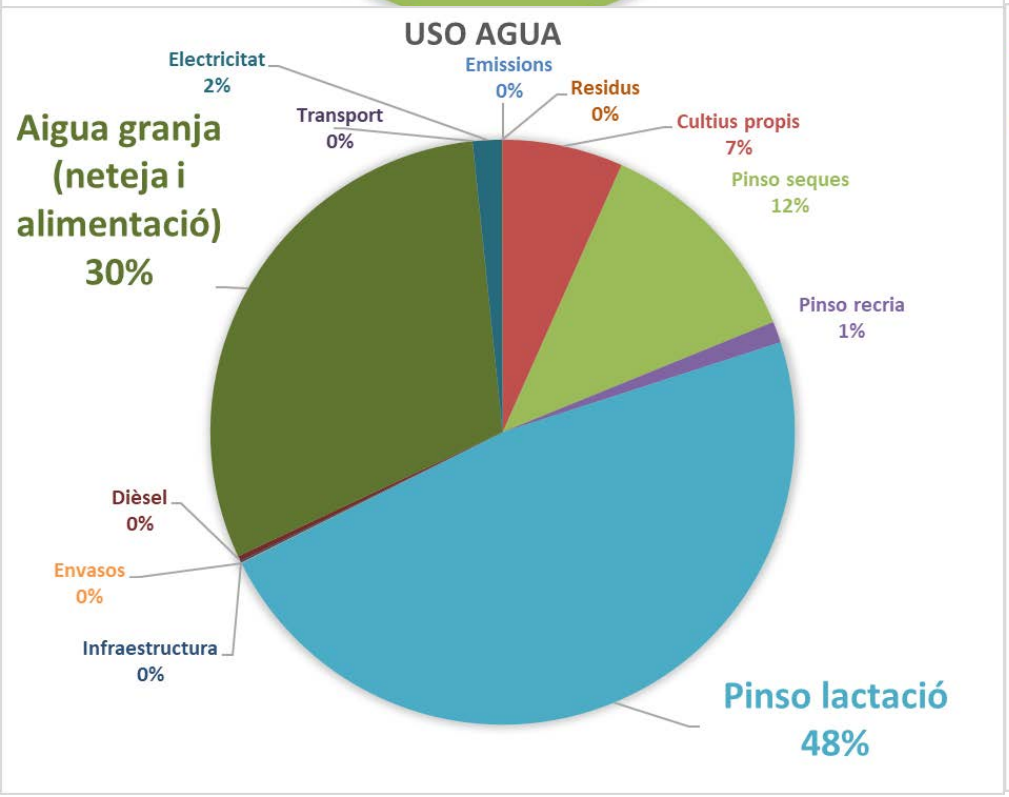
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Cultius propis
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Aigua granja
(neteja i
alimentació)
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12%
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Dièsel
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Envasos
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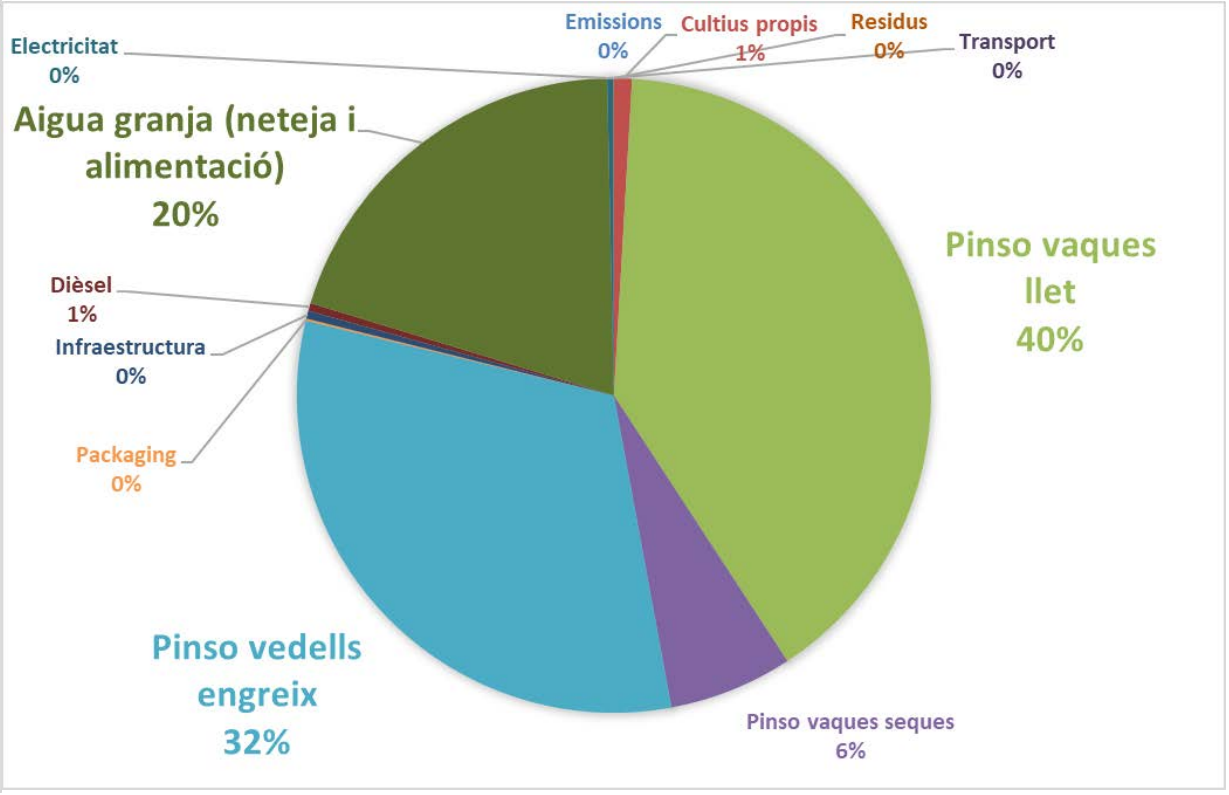
Infraestructura
0%
Pinso lactació
48%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Transport
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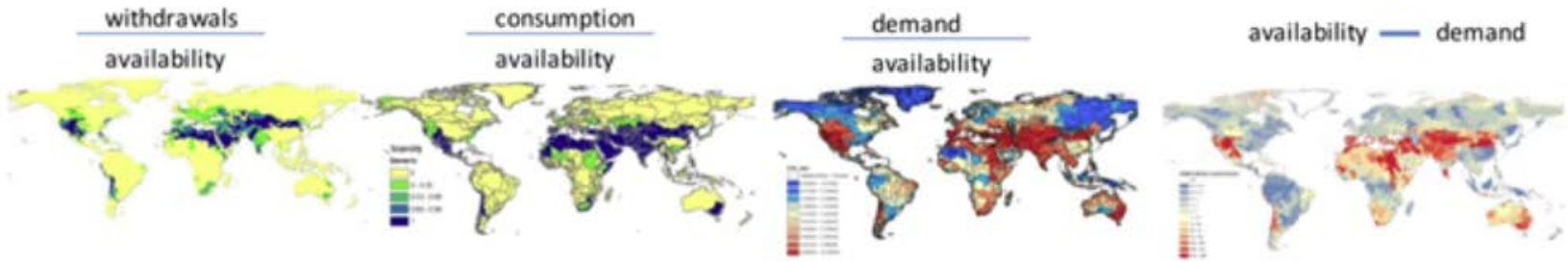
Aigua granja (neteja i
alimentació)
20%
Pinso vaques
llet
40%
Dièsel
1%
Infraestructura
0%
Packaging
0%
Pinso vedells
engreix
32%
Pinso vaques seques
6%

	Granja 1		Granja 2		Granja 3	
Total (Pt)	**1,39E-01**	**%**	**1,70E-01**	**%**	**2,11E-01**	**%**
Canvi climàtic	**3,77E-02**	27,06	**3,81E-02**	22,34	**5,92E-02**	28,06
Esgotament capa Ozó	**8,34E-05**	0,06	**9,69E-05**	0,06	**1,07E-04**	0,05
Radiació ionitzant, humans	**8,13E-04**	0,58	**1,60E-03**	0,94	**1,04E-03**	0,49
Formació fotoxidants	**4,37E-03**	3,14	**5,97E-03**	3,51	**6,94E-03**	3,29
Formació micropartícules	**1,83E-02**	13,16	**3,06E-02**	17,95	**3,96E-02**	18,79
SHnc: Salut humana, contaminants no cancerígens						
SHc: Salut humana, contaminants cancerígens						
Acidificació	**5,94E-03**	4,26	**9,08E-03**	5,33	**8,76E-03**	4,16
Eutrofització aigua dolça	**2,97E-03**	2,13	**3,04E-03**	1,79	**4,79E-03**	2,27
Eutrofització marina	**6,48E-03**	4,64	**1,19E-02**	7,01	**1,30E-02**	6,18
Eutrofització terrestre	**6,99E-03**	5,01	**1,15E-02**	6,78	**1,34E-02**	6,35
Ecotoxicitat aigua dolça						
Ús del sòl	**5,91E-03**	4,24	**1,21E-02**	7,09	**1,37E-02**	6,48
Consum aigua	**2,44E-02**	17,52	**1,85E-02**	10,88	**2,17E-02**	10,29
Esgotament recursos fòssils	**7,75E-03**	5,56	**1,03E-02**	6,03	**1,05E-02**	4,97
Esgotament recursos minerals i metalls	**1,76E-02**	12,64	**1,76E-02**	12,64	**1,81E-02**	8,6
		80,95		84,69		84,75

Evolution of scarcity indicators modeled in LCA



WTA → CTA → DTA → AWARE (Available Water Remaining)

WTA: Withdrawal-to-availability
CTA: Consumption-to-availability
DTA: Demand-to-availability (includes humans and ecosystems demand)

2006 — 2011 — 2013 — 2014 — 2015 — ***WULCA Recommendation***

Methodology: AWARE

Water footprint *(m³ eq world)*	=	Water consumption "inventory" *(m³ consumed)*	×	AWARE *(m³ eq world / m³ consumed)*

- It is based in the available water per surface unit and time after human (agriculture + industrial + house + energy production) and aquatic ecosystems demands are fulfilled, per watershed (>11000 worldwide).
- The indicator is calculated at the sub-watershed level and monthly time-step, and then aggregated (It may completely exclude large regions where no/very low consumption occur; It represents where/when water is most consumed: often in dryer months/regions)
- Range: 0.1 (minimum impact) to 100 (maximum impact) m3 eq world/m3 consumed
- A value of 1 corresponding to the world average*, and a value of 10, for example, representing a region where there is 10 times less available water remaining per area than the world average.

Methodology: AWARE

Water footprint *(m³ eq world)*	=	Water consumption "inventory" *(m³ consumed)*	×	AWARE *(m³ eq world / m³ consumed)*

- The AWARE value:

1. water Availability Minus the Demand (AMD) of humans and aquatic ecosystems and is relative to the area (m3 m-2 month-1)
2. the value is normalized with the world average result (AMD = 0.0136m3m-2 month-1)
3. the value is inverted: represents the relative value in comparison with the average m3 consumed in the world (the world average is calculated as a consumption-weighted average).

CROP PRODUCTION

$I_{withdrawal} = ET_{irr} / EF_{irr}$ [m^3/t]

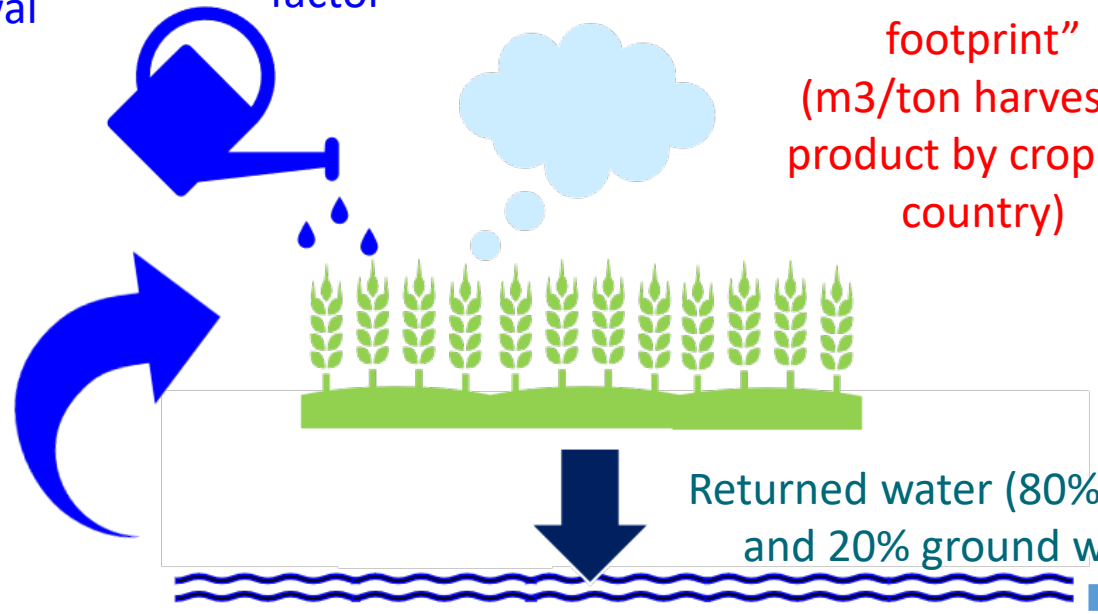
With:

ET_{irr} = Evapotranspiration from irrigation [m^3/t]

EF_{irr} = Irrigation efficiency factor [-]

Water use = input irrigation water= water withdrawal

Irrigation efficiency factor



Evapotranspiration from irrigation="consumed water"=Blue water footprint" (m3/ton harvested product by crop and country)

Technique	EFirr (Efficiency factor)
Surface irrigation	0.6
Gutters	0.65
Canons	0.7
(Micro-)Sprinkler	0.75
Sprinkler with fixed or mobile cover	0.8
Pivot	0.85
Drip	
Located and bur	

Irrigation methods	Field application efficiency
Surface irrigation (border, furrow, basin)	60%
Sprinkler irrigation	75%
Drip irrigation	90%

Conveyance efficiency (FAO 1989)

	Earthen canals			Lined canals
Soil type	Sand	Loam	Clay	
Canal length				
Long (> 2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (< 200m)	80%	85%	90%	95%

ISO 14046 (2016). Gestió Ambiental. Petjada hídrica-Principis, requeriments i Guia. UNE-EN ISO 14046:2016

FCs anuals vs mensuals; País vs Conca

Espanya

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YR_IRRI
23,44	29,77	21,39	31,30	54,83	71,92	92,62	86,10	73,62	50,70	100,00	7,66	**79,13**

32963 Ebre

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YR_IRRI
1,13	1,41	1,40	1,39	2,02	100,0	100,0	100,0	100,0	100,0	2,5	1,33	**90,0**

31897 Muga-Fluvià

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YR_IRRI
0,63	**0,63**	**0,73**	**0,63**	**0,62**	**1,09**	**4,14**	**6,30**	**3,07**	**1,13**	**0,85**	**0,68**	**3,63**

Example

	Gen	Feb	Mar	Abr	Mai	Jun	Jul	Ago	Set	Oct	Nov	Des	TOTAL
REG, m^3/ha	0	115	230	402	575	748	1150	1035	869	403	230	0	**5757**

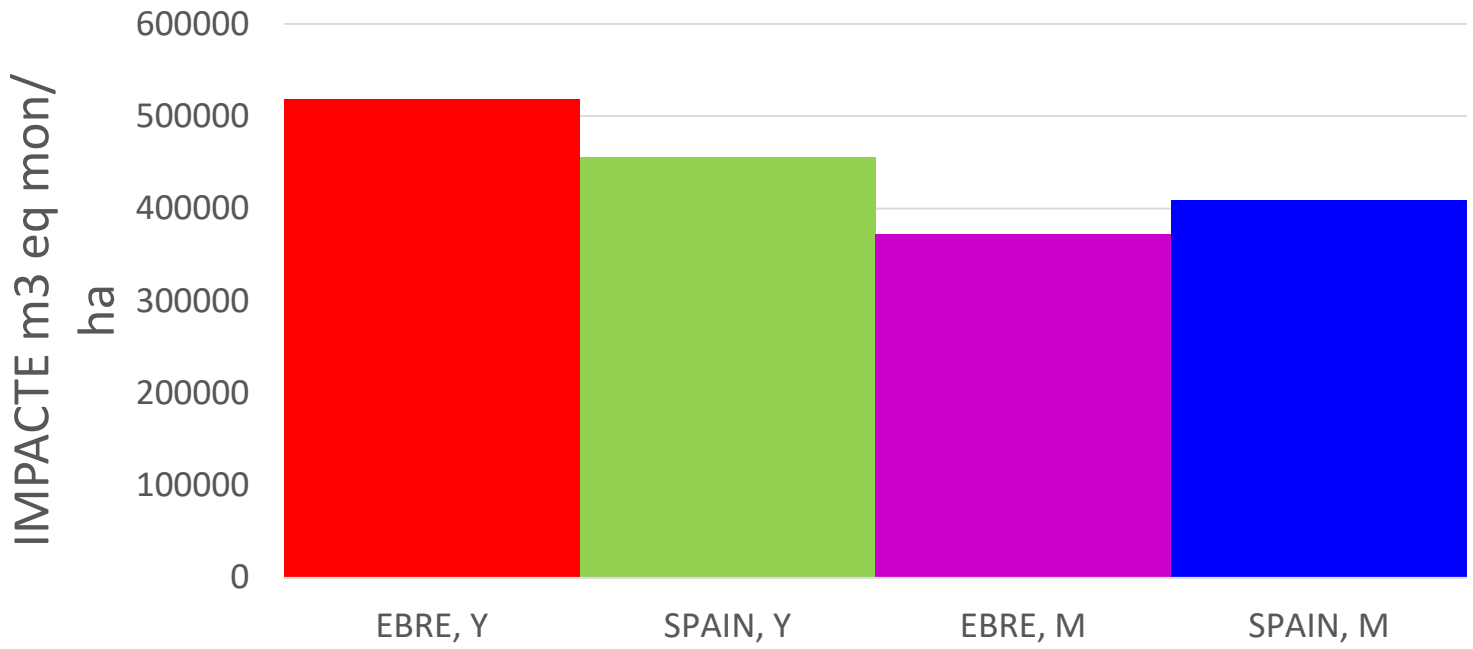
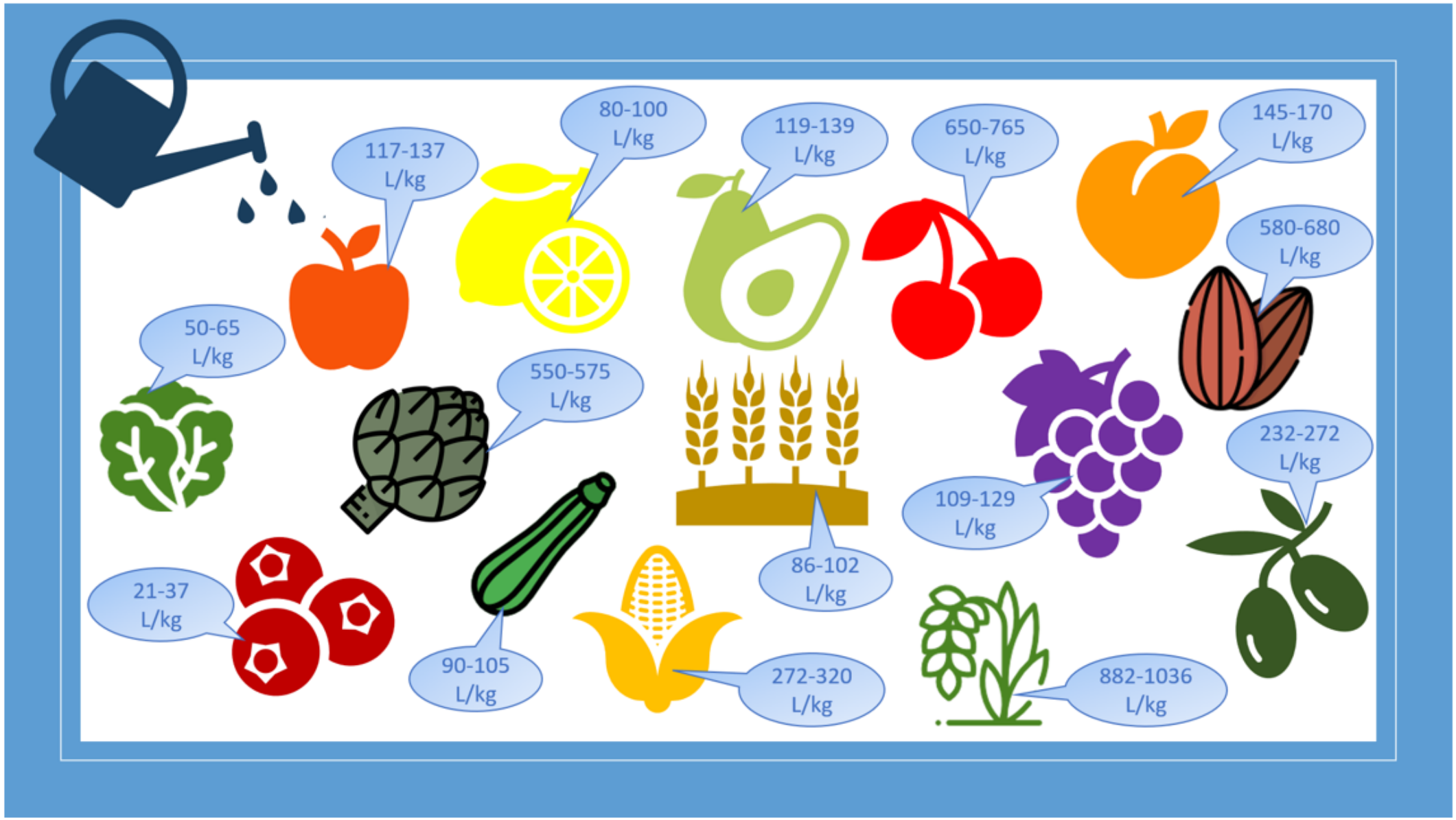
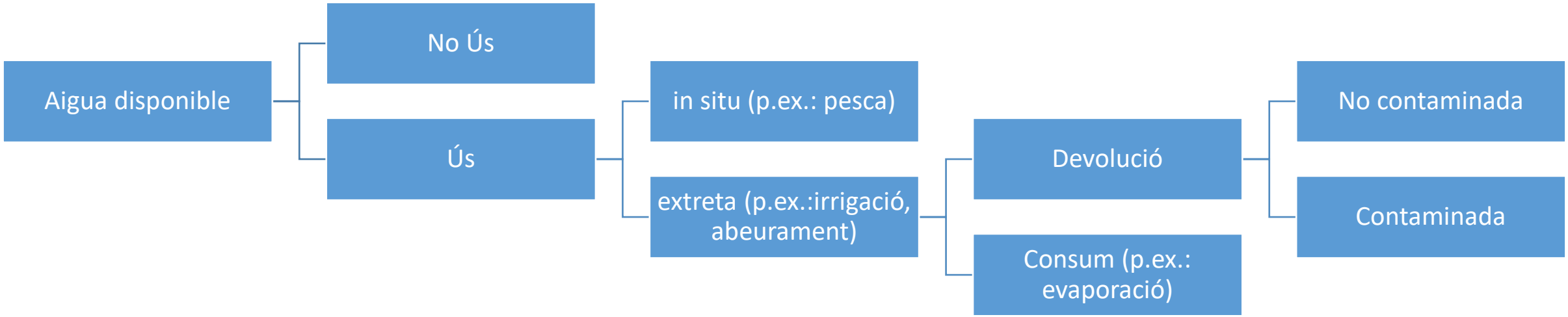


Figura 1. Consum d'aigua de reg, aigua blava, expressada en L/kg de producte, referenciada per alguns productes de Catalunya*.




Aigua disponible
No Ús
Ús
in situ (p.ex.: pesca)
extreta (p.ex.:irrigació, abeurament)
Devolució
Consum (p.ex.: evaporació)
No contaminada
Contaminada