Regional water footprint and water management: the case of Madrid region (Spain)

Jose Soler-Rovira, Juan Manuel Arroyo-Sanz, Hugo Conde-Marcos, Carlos Sanz-Zudaire, Alfredo Mesa-Moreno, Sergio Gil-Pascual

Department of Agronomy

Technical Agricultural Engineering School

Technical University of Madrid

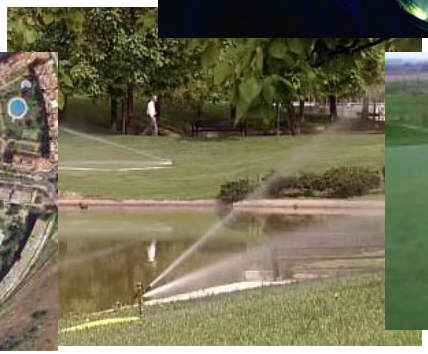
Spain

Introduction

Water resources

- Water is an essential element in the environment but also for economic activity and human development.
- In a high-density populated area as Madrid region water is a key element.
- Water demand in Madrid is driven by urban supply, and it is increasing due to population growth and changes in societal lifestyles:
  - Swimming pools
  - Private gardens irrigation
  - Public parks irrigation
  - Sport facilities irrigation
  - Amusement parks







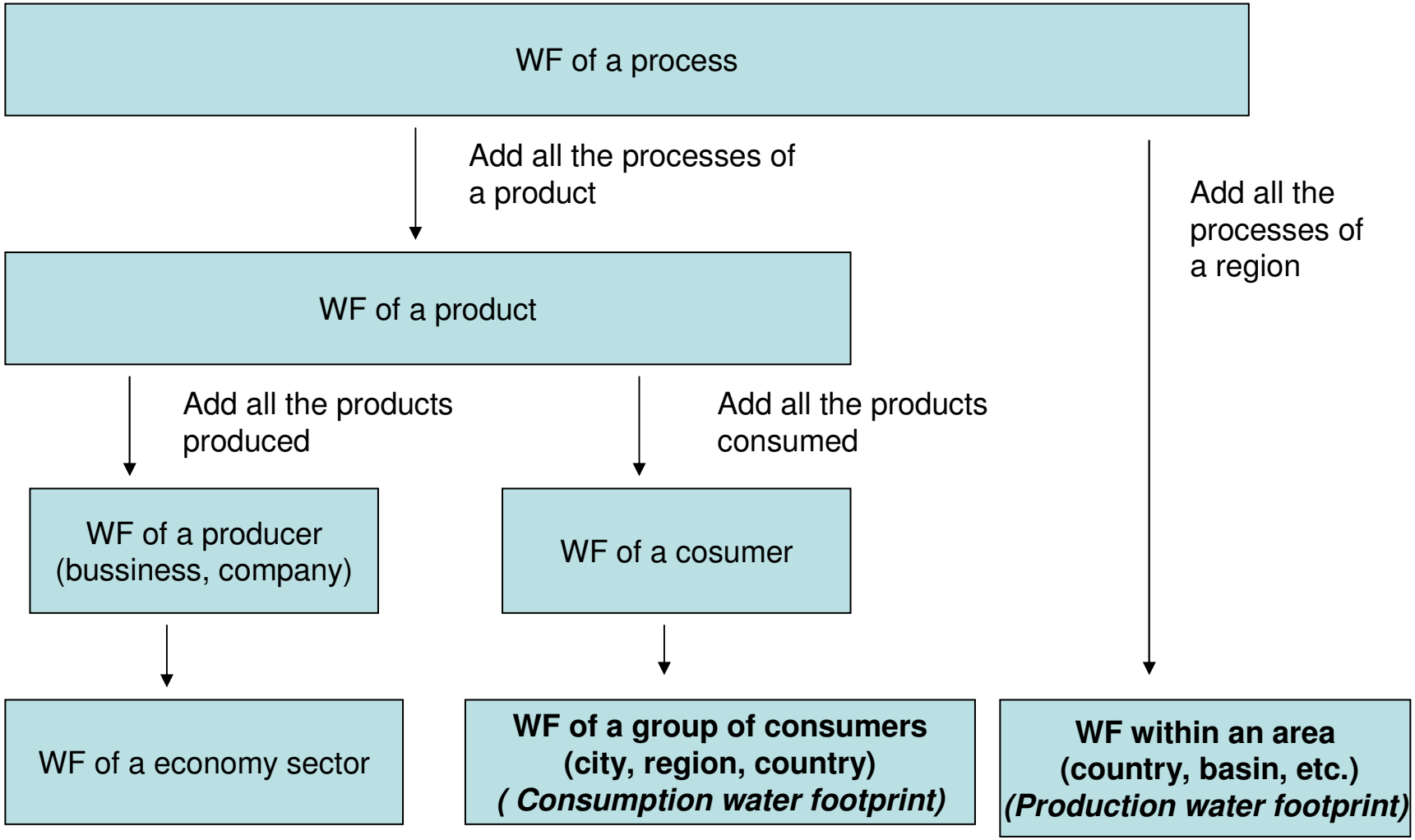
Introduction

Water footprint

- Water resources are usually studied as water cycle, water quality or water prices and markets, but green water or virtual water are not included.
- Virtual water concept was introduced by Allan (1998): water required to produce a certain product.
- Water footprint is an indicators of freshwater use that consider the direct and indirect water use of a consumer or producer.
- Water footprint is made up of three components: blue, green and grey water.
- Blue water is the consumption of water resources (from surface and ground water).
- Green water is the consumption of the rainfall stored in the soil as soil moisture.
- Grey water is the volume required to assimilate the load of pollutants based on existing water quality standards (Hoekstra et al., 2009).

Introduction

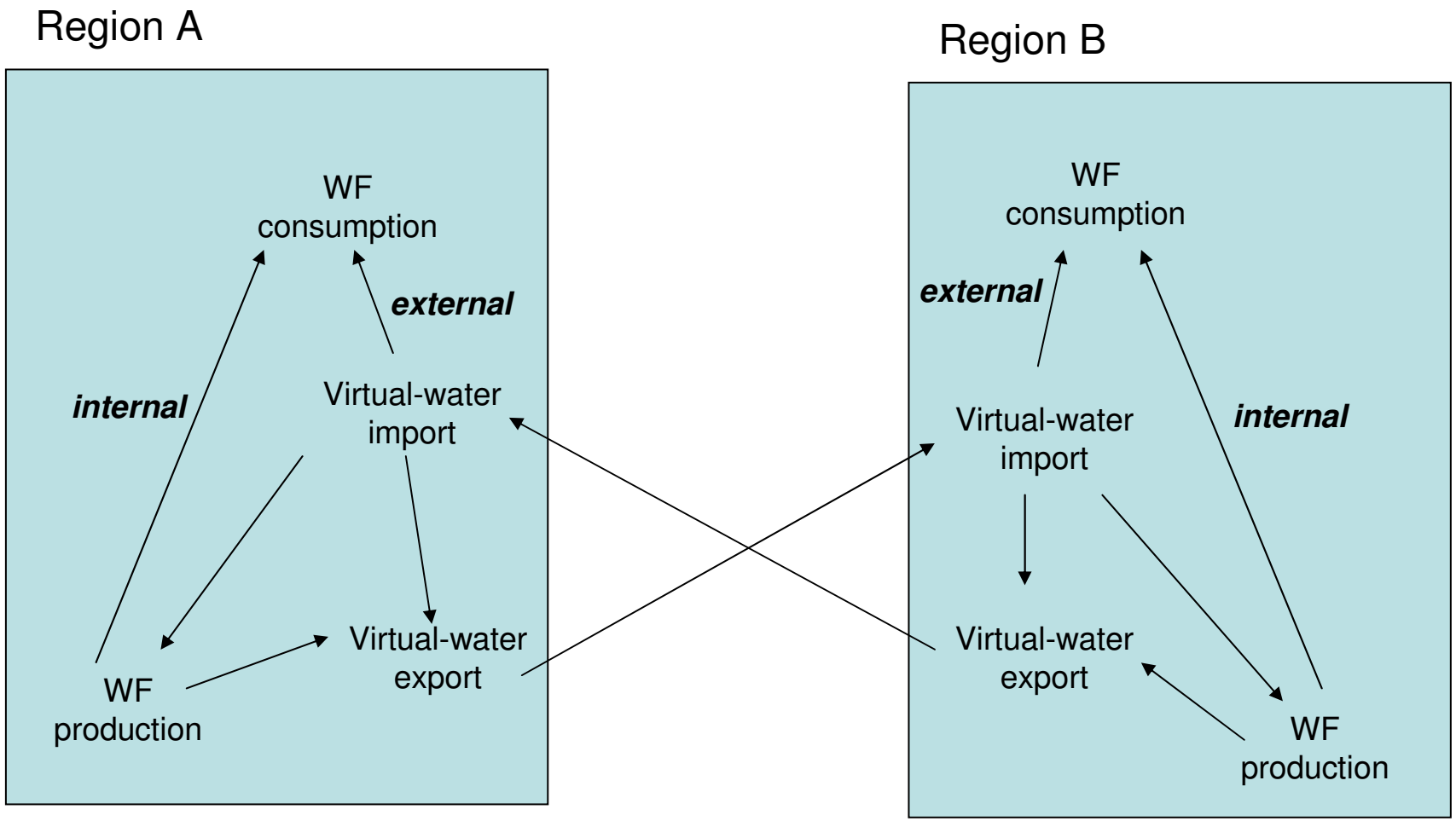
Water footprint



After Hoeskstra et al. (2009)

Introduction

Water footprint: internal and external



After Hoeskstra et al. (2009)

Objective

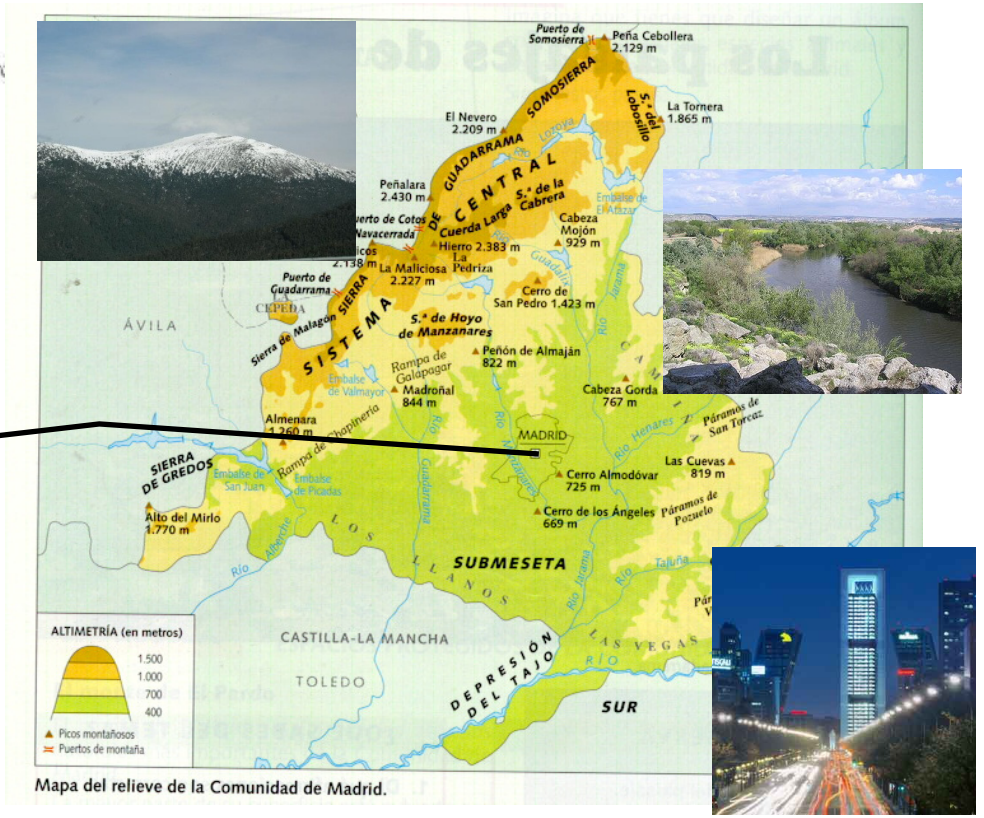
- The aim of this work is:
  - To study the **water footprint** of the production and consumption in Madrid region (Spain), and
  - To evaluate the implication for **water management** in that area.

Methods

Madrid region

Surface: 8,022 km²
Semiarid climate
Annual P (Madrid City): 436 mm
Annual P (Mountains): 1,326 mm
ETo: 1,241 mm/year

Population: 5.5 10⁶ inhabitants
Population density: 744 people/km²
Services 77% of gross added value
Madrid: capital of the country



Mapa del relieve de la Comunidad de Madrid.

Methods

Water footprint

- Water footprint was estimated considering:
  - Water resources
  - Water footprint of production
  - Water footprint of consumption
- Average statistical data were used for the years 2000-05.
- Years 1971-2000 climatic series data were used for rainfall and ETo calculations.
- All the results were computed in a yearly basis as hm^3 (1 hm^3 = 10^6 m^3).

Methods

Water resources

- Surface and ground water resources were obtained from literature and goverment statistics.
- Water evaporation from reservoirs was computed as:
  - ETo in the zone where the reservoir is located. Hargreaves method was used as temperature data was the only available.
  - Evaporation coefficient (Doorenbos and Pruitt, 1979).
  - Rainfall, from climatic data.
  - Reservoir surface, from statistics.

Methods

Green water

- It was calculated as the evapotranspirated water from rainfall stored as soil moisture by:
  - Rainfed crops (water evapotranspirated from soil moisture).
  - Irrigated crops (difference of crop evapotranspiration and the calculated irrigation water requirements).
  - Fallow land (yearly soil water balance with an evaporation coefficient as a function of rainfall frequency).
  - Pastures and meadows (considering rainfed and irrigated land).
  - Parks and green areas (considering irrigated and non irrigated).
- CROPWAT software from FAO was used with site specific climatic data and crop coefficients.

Methods

Blue water

- It was calculated as the water withdrawals from statistics:
  - Households and municipalities (Instituto de Estadística Madrid, 2010).
  - Industry (INE, 2010).
  - Agriculture (INE, 2010).
  - Livestock: number of heads (INE, 2010) and average consumption per species (MIMAM, 2007).
  - Network losses (Instituto de Estadística Madrid, 2010).

Methods

Grey water

- It was calculated for:
  - Nitrate leaching from crops:
    - Average N fertilization rate per crop (MAPA, 2004).
    - Leaching fraction for each type of crop from literature.
    - Nitrate content of 50 mg/L (Nitrates Directive).
  - N loads from treated wastewater:
    - Volume of treated wastewater (Instituto de Estadística Madrid, 2010).
    - Nitrogen composition of treated wastewater (INE, 2010).
    - N limits in Wastewater Directive.
  - N deposition in reservoirs:
    - Deposition rates of NHy and NOx in the region (EMEP, 2010).
    - Surface of reservoirs (Instituto de Estadística Madrid, 2010).
    - Drinking water quality standards for nitrate and ammonium.

Methods

Water footprint of consumption

- It was calculated considering:
  - Food production (MARM, 2008) and trade (Instituto de Estadística Madrid, 2010).
  - Feed production and trade (Instituto de Estadística Madrid, 2010).
  - Virtual water content of crop and livestock products (Chapagain and Hoekstra, 2004).
  - Industry production (INE, 2010), industrial products trade (Instituto de Estadística, Madrid 2010) and water use in industry (INE, 2010).
  - Water use in households and municipalities (Instituto de Estadística Madrid, 2010).
  - Network losses (Instituto de Estadística Madrid, 2010).
  - Water use in parks and gardens.

Results

Water resources in Madrid region

Natural resources (hm^3 $year^{-1}$)	
Rainfall	4,195
Tertiary aquifer	3,000,000

Infrastructures capacity (hm^3 $year^{-1}$)	
Reservoirs (17)	1,154
Pumping	106
Total	**1,260**

Available resources (hm^3 $year^{-1}$)	
Reservoirs	515
Pumped water	87
Soil moisture	1,119
Total	**1,721**

- The aquifer has an enormous potential as resource, but it is pumped only a small volume and it is used in drought emergencies.
- Resources relay mainly on surface water, and hence in rainfall.
- Periodic droughts implies water supply scarcity and conflicts between uses.
- Green water (soil moisture) is almost two times the blue water resources.

Results

Water use in Madrid region

Green water (hm^3 $year^{-1}$)	
Irrigated crops	54
Rainfed crops	1,007
Gardens and parks	58
Total	**1,119**

Blue water (hm^3 $year^{-1}$)	
Households	343
Agriculture	172
Other	82
Municipalities	49
Industry	49
Livestock	2
Network losses	70
Total	**697**

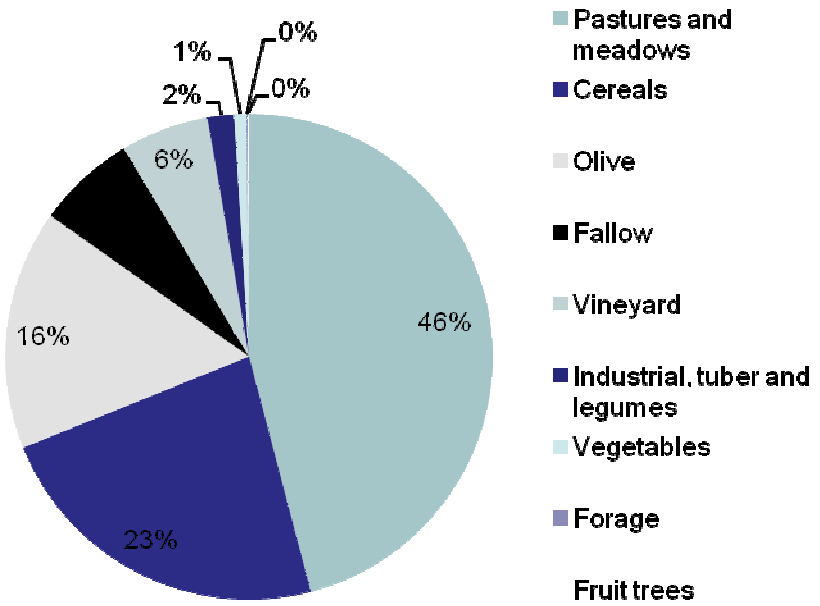
- **Green water** is mainly used by rainfed crops.
- It is noticeable the consumption in parks and gardens, that equals that of irrigated crops.

- **Blue water** is used by households and municipalities (urban use) and agriculture.
- They are also important the losses in the distribution network.
- Blue water use is almost the half of green water volume.

Results

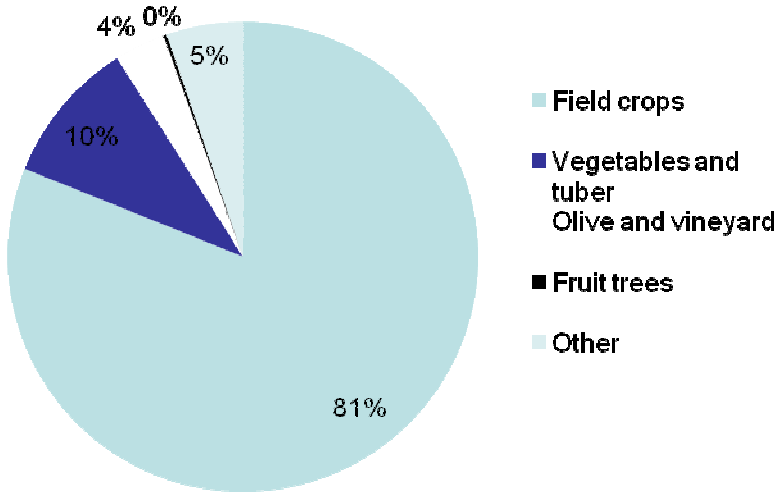
Water use in agriculture

Green water use in agriculture



- **Green water** is mainly used by pastures, meadows, cereals, olive trees, fallow land and vineyard.

Blue water use in agriculture



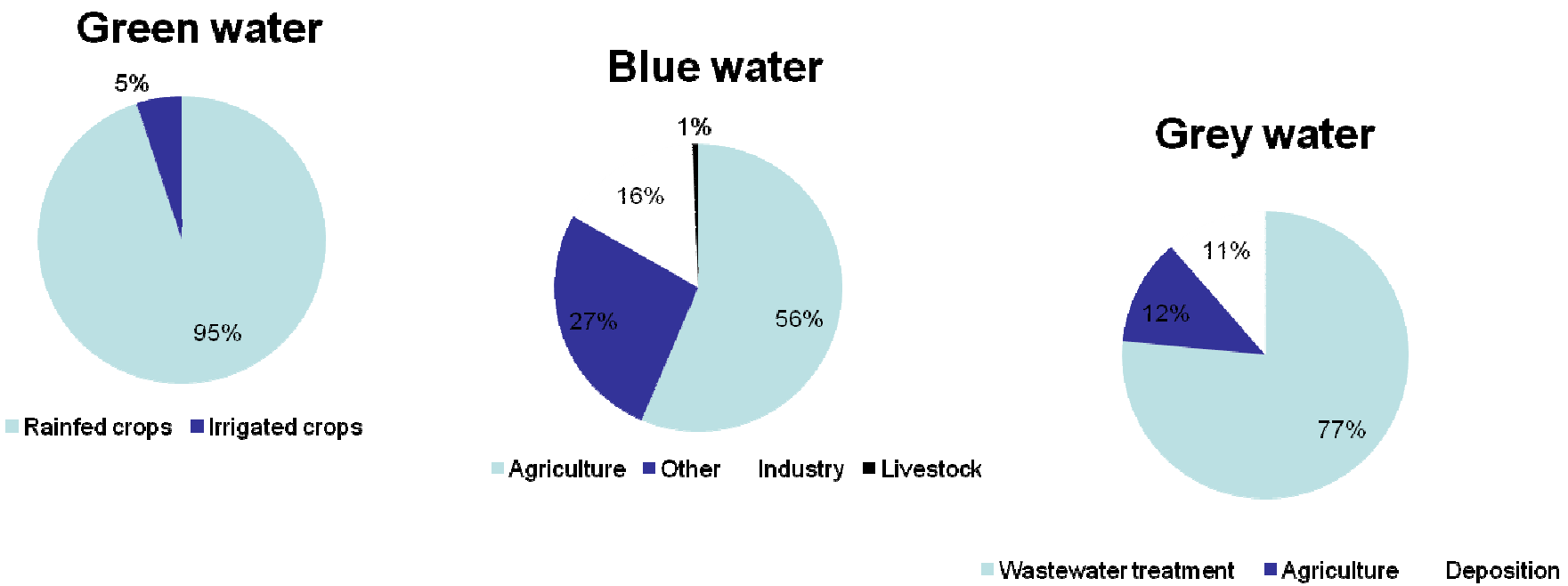
- **Blue water** is consumed by field crops (maize, barley, lucerne), that are irrigated by gravity systems with a low application efficiency.
- Other important irrigated crops are melon an lettuce (vegetables).

Results

Production water footprint

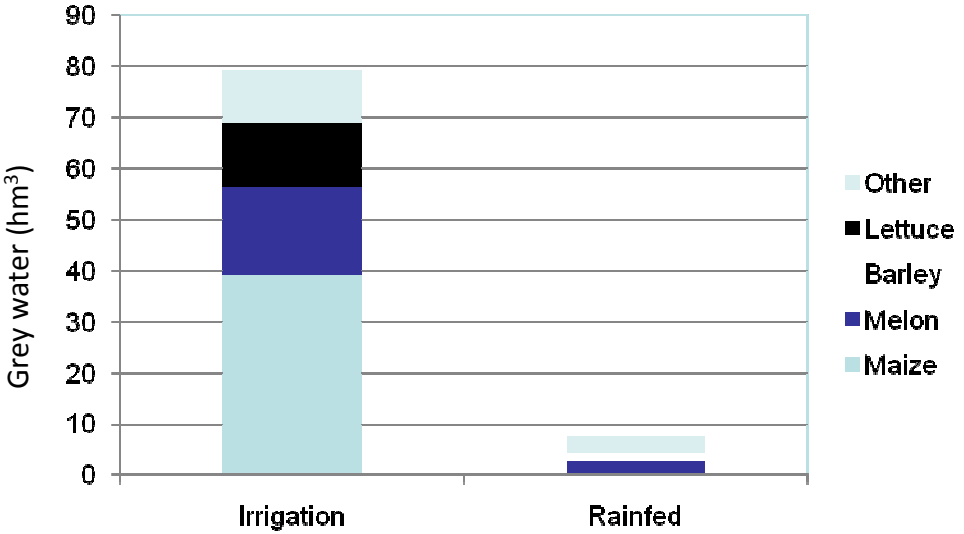
Water footprint (hm^3 $year^{-1}$)	
Blue	304
Green	1,061
Grey	720
Total	**2,085**

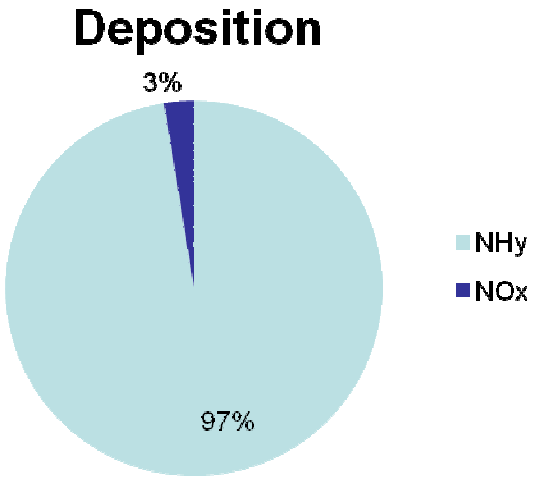
- Green water is three times higher than blue water.
- Grey water is twice blue water volume.
- Total production water footprint in Madrid is almost four times the blue water resources in the region.



Results

Production water footprint: grey water





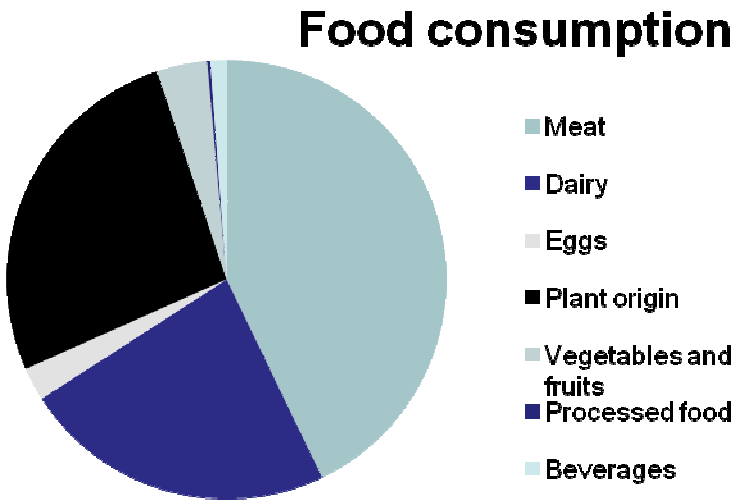
- Nitrate leaching is more important in irrigated crops: maize, melon and lettuce.
- Barley and melon are the more polluting rainfed crops.
- Deposition of NHy species is the most important.

Results

Consumption water footprint

(hm^3)	Production	Imports	Exports	Net imports	Consumption
Food	1234	11084	3930	7154	8388
Livestock feed	0	40	0	40	40
Industry	49	82	34	48	97
Households and municipalities	392	0	0	0	392
Parks and gardens	58	0	0	0	58
Losses	70	0	0	0	70
TOTAL	1803	11206	3964	7242	9045
	Internal			External	Consumption

- Food products account for 93% of consumption water footprint.
- The external water footprint is the 80% the total.
- A big proportion is from meat and dairy products.



Results

Implications for water management

- In order to **reduce** the inner blue water consumption the target sectors should be households and municipalities.
- Blue water used in agriculture should be reduce with more efficient irrigation systems. The virtual water exported is relatively low, because it is from previously imported food products.
- Within this framework the **self sufficiency** is not possible, because there is a very high dependence on external resources. This must be taken into account in the general water planning in Spain.
- A **more sustainable** consumption should be achieved considering the diet composition, as a high proportion of the footprint is from meat and dairy products.

Conclusions

- Production water footprint in Madrid region is circa 2,000 hm^3, almost 4 times the blue water resources.
- Green and grey water are important components of that footprint. Wastewater is the most important factor in grey water.
- Consumption water footprint is around 9,000 hm^3 from which 80% is imported, so Madrid depends on external resources.
- Food products account for 93% of consumption water footprint.
- Meat and dairy products account for a big proportion. A change in diet composition should improve sustainability.

LCA in the Agri-food sector

Regional water footprint and water management: the case of Madrid region (Spain)

Jose Soler-Rovira, Juan Manuel Arroyo-Sanz, Hugo Conde-Marcos, Carlos Sanz-Zudaire, Alfredo Mesa-Moreno, Sergio Gil-Pascual

Department of Agronomy
Technical Agricultural Engineering School
Technical University of Madrid
Spain

THANKS FOR YOUR ATTENTION

Any question?