



# Virtual Water Values (ViWA)

Multiscale Monitoring of Global Water Resources and Options for their Efficient and Sustainable Use

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# The water cycle

*Water moves from upstream to downstream and is stored across the land surface at varying rates.*



Reference figure: <https://thechartroom.co/2019/05/20/are-we-travelling-upstream-or-downstream/>

## *Economic relevance*

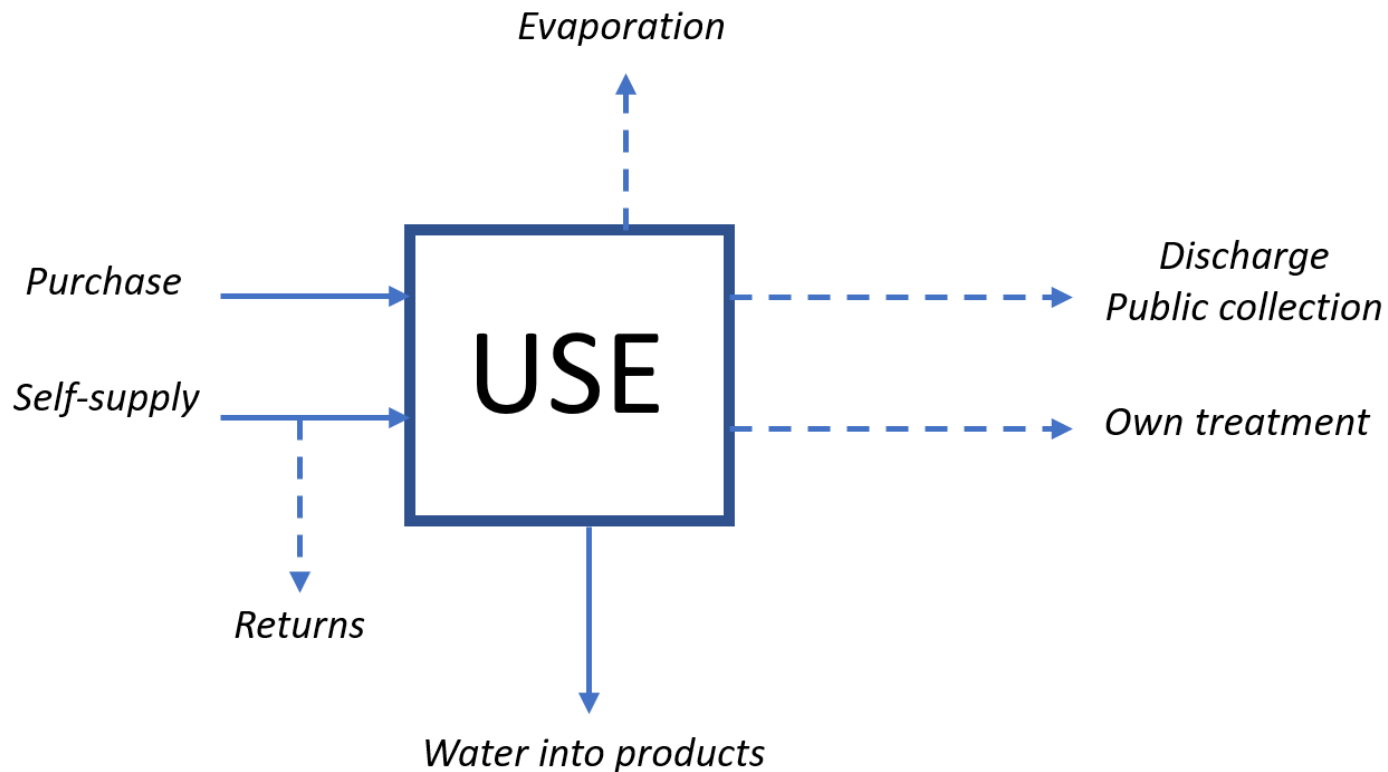
*Agriculture: Largest water user for crop production.  
Blue water (irrigation); Green water (rainfed agriculture).*

*Ecosystems: Rainfall for natural growth, ecosystem services, sustain water levels of rivers and lakes.*

*Industry: Energy production, cooling, water from rivers to support industrial production.*



# Water flows in Industries



## Definitions

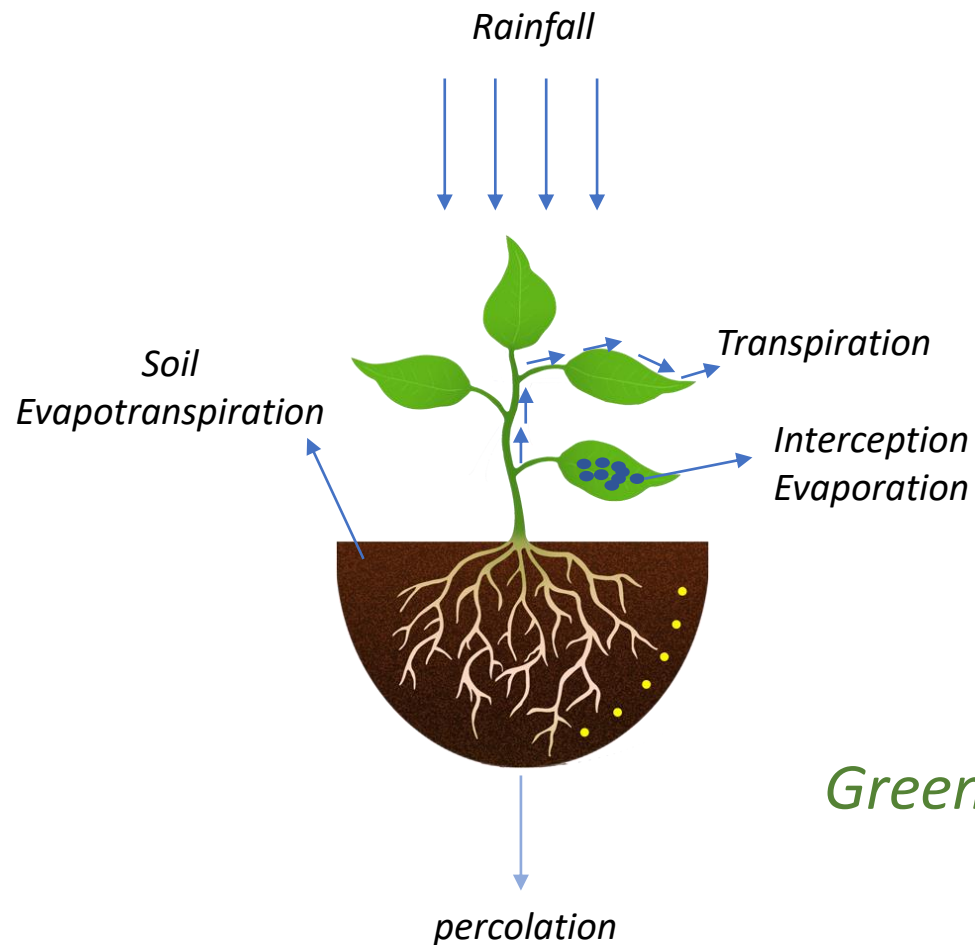
*Withdrawal: Water abstraction from nature + external procurement of water.*

*Use: Water withdrawal – unused returned water.*

*Consumption: Water use – discharges – evaporation.*

# Water in Agriculture

## *Evapotranspiration of natural land cover*



*Evaporation:* Physical water phase-change from solid or liquid to gas.

*Transpiration:* Physical water phase-change from liquid to water vapor.

*In living plant cells*

*Green water: Rainfall water subjected to evapotranspiration.*



# Green and Blue water

## *Why differentiate between blue and green water?*

- Evaporation of green water is key to agricultural production worldwide
- Blue water is the the main consumptive water use in industries.
- Irrigation (blue water) is to support food production in areas where green water is scarce.

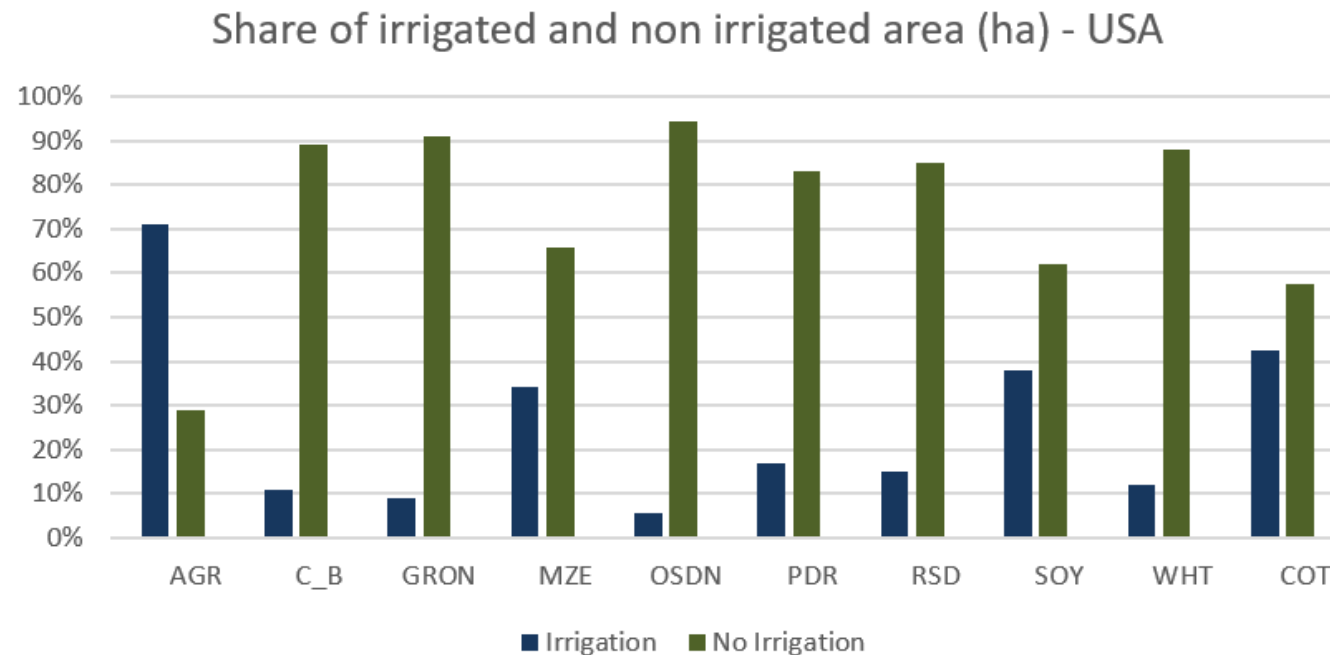
## *Competition between blue and green water*

- Evapotranspiration of blue water in irrigation may compete with industrial evaporation.
- Evapotranspiration of green water in agriculture may reduce levels of blue water in rivers and ground water.
- Evapotranspiration of green water may compete with downstream evapotranspiration of blue water in irrigation due to river flow reduction

# The Applied Regional Trade (ART)- Water

## Agriculture

- Explicitly model irrigated and non-irrigated agriculture  
Model green water → Link PROMET – LMU





# The Applied Regional Trade (ART)- Water

## Model Features

- Static multiregional Computable General Equilibrium (CGE) model  
*Comparison of the economy equilibrium before and after a shock*
- Data Global Trade Analysis Project (GTAP)  
*Version: GTAP 9; Extension: GTAP Power*
- Water is explicitly modelled as an input factor
- Irrigated and non-irrigated agriculture is distinguished  
*Green and Blue water in agriculture*
- Disaggregated electricity sector
- Model captures land heterogeneity  
*Land in 18 Agro-ecological Zones (AEZ)*



# The Applied Regional Trade (ART)- Water

## Model Features

- Reference year 2011
- Global coverage  
*22 regions*

**Table 1 List of regions in the static water CGE model (ART-Water)**

Europe		Middle East and Northern Africa	
GEU	Germany, Austria	MEA	Middle East, Northern Africa, Turkey
NWE	Denmark, Finland, Sweden, Ireland, United Kingdom, Rest of North Europe	AFR	Sub-Saharan Africa
WEU	Belgium, Netherlands, Luxemburg, France	MAI	Indonesia, Brunei, Darussalam, Malaysia, Rest of Southeast Asia (Myanmar, Timor)
MED	Spain, Portugal, Italy, Malta, Cyprus, Greece		<b>Africa</b>
RNE	Norway, Switzerland, Rest of EFTA (Iceland, Liechtenstein)	SAF	South Africa, Namibia, Botswana
REU	Czech Republik, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia, Bulgaria Croatia, Romania		<b>Asia</b>
FSU	Rest of Former Soviet Union and Rest of Europe	CHN	China, Hong kong
	<b>North America</b>	IND	India
USA	United States of America	EAS	Japan, South Korea, Singapore, Taiwan
CAN	Canada	RUS	Russian Federation
	<b>Central and South America</b>	ROA	Pacific Asia
BRA	Brazil		<b>Oceania</b>
PAC	Argentina, Chile, Paraguay, Uruguay	ANZ	Australia, New Zealand
LAM	Latin America		

# The Applied Regional Trade (ART)- Water

## Model Features

- 21 Agricultural Sectors
- 5 Meat and dairy Sectors
- 4 Industrial Sectors
- 2 Public Sectors
- 13 Energy Sectors

Table 2 List of sectors in the static water CGE model (ART-Water)

<i>Agricultural Sectors</i>		<i>Industrial Sectors</i>	
PDRir	Paddy rice irrigated	TEX	Textiles
PDRni	Paddy rice non-irrigated	PPP	Paper products publishing
WHTir	Wheat irrigated	CRP	Chemicals (include fertilizer)
WHTni	Wheat non-irrigated	OMF	Mineral products nec
MZEir	Maize irrigated	<i>Public Sectors</i>	
MZENi	Maize non-irrigated	PUB	Public services
GRONir	Rest of Cereals irrigated	WTR	Water
GRONni	Rest of Cereals non-irrigated	<i>Energy Sectors</i>	
PLMir	Palm oil irrigated	MIN	Mining
PLMni	Palm oil non-irrigated	CRU	Crude Oil
RSDir	Rapeseed irrigated	GAS	Natural gas
RSDni	Rapeseed non-irrigated	OIL	Refined petroleum and coal products
SOYir	Soybean irrigated	EGas	Gas based electricity
SOYni	Soybean non-irrigated	ECoal	Coal based electricity
OSDNir	Rest of oil seeds irrigated	EHydro	Hydro based electricity
OSDNni	Rest of oil seeds non-irrigated	ENuclear	Nuclear based electricity
C_Bir	Sugar cane sugar beet irrigated	Eoil	Oil based electricity
C_Bni	Sugar cane sugar beet non-irrigated	EOther	Other based electricity
COTir	Cotton irrigated	ESolar	Solar based electricity
COTni	Cotton non-irrigated	EWind	Wind based electricity
AGR	Other crops	TnD	Electricity transmission and distribution
<i>Meat and dairy Sectors</i>			
OLVS	Bovine byproducts		
ILVS	Indoor lvs		
FRS	Forestry		
FOD	Food products		
PCM	Meat cattle sheep goats horse		

# The Applied Regional Trade (ART)- Water

## Industry

- Water data sources: EUROSTAT and National Statistics
- Sectoral data assumption due to data issues.

Table 3: Sectoral mapping the ART-Water industrial sectors and Eurostat database.

ART-Water Industrial Sectors		Eurostat-Database
TEX	<i>Textiles</i>	Manufacturing
PPP	<i>Paper products publishing</i>	Manufacturing
CRP	<i>Chemical rubber plastic prods</i>	Manufacturing
OMF	<i>Mineral products nec</i>	Manufacturing
MIN	<i>Mining</i>	Electricity
CRU	<i>Crude Oil</i>	Electricity
GAS	<i>Natural Gas</i>	Services
OIL	<i>Refined petroleum and coal products</i>	Services
EGas	<i>Gas based electricity</i>	Services
ECoal	<i>Coal based electricity</i>	Electricity
EHydro	<i>Hydro based electricity</i>	Electricity
ENuclear	<i>Nuclear based electricity</i>	Electricity
EOil	<i>Oil based electricity</i>	Electricity
EOther	<i>Other based electricity</i>	Electricity
ESolar	<i>Solar based electricity</i>	Electricity
EWind	<i>Wind based electricity</i>	Electricity
TnD	<i>Electricity transmission and distribution</i>	Services

# The Applied Regional Trade (ART)- Water

## Industry

- Regional data assumption due to data issues

**Table 4 Regional assumption reference countries**

ART-Water	Reference	ART-Water	Reference
<i>Europe</i>		<i>Middle East and Northern Africa</i>	
GEU	Germany	MEA	Turkey
NWE	Denmark	AFR	Default
WEU	Belgium	MAI	Default
MED	Spain	<i>Africa</i>	
RNE	Switzerland	SAF	Default
REU	Czech Republic	<i>Asia</i>	
FSU	Lithuania	CHN	Default
<i>North America</i>		IND	Default
USA	Default	EAS	Default
CAN	Canada	RUS	Default
<i>Central and South America</i>		ROA	Default
BRA	Default	<i>Oceania</i>	
PAC	Default	ANZ	Australia
LAM	Default		

*Default: 0.7 manufacture; 0.3 services; 0.9 electricity.*

*Overall approximated average of the data available*

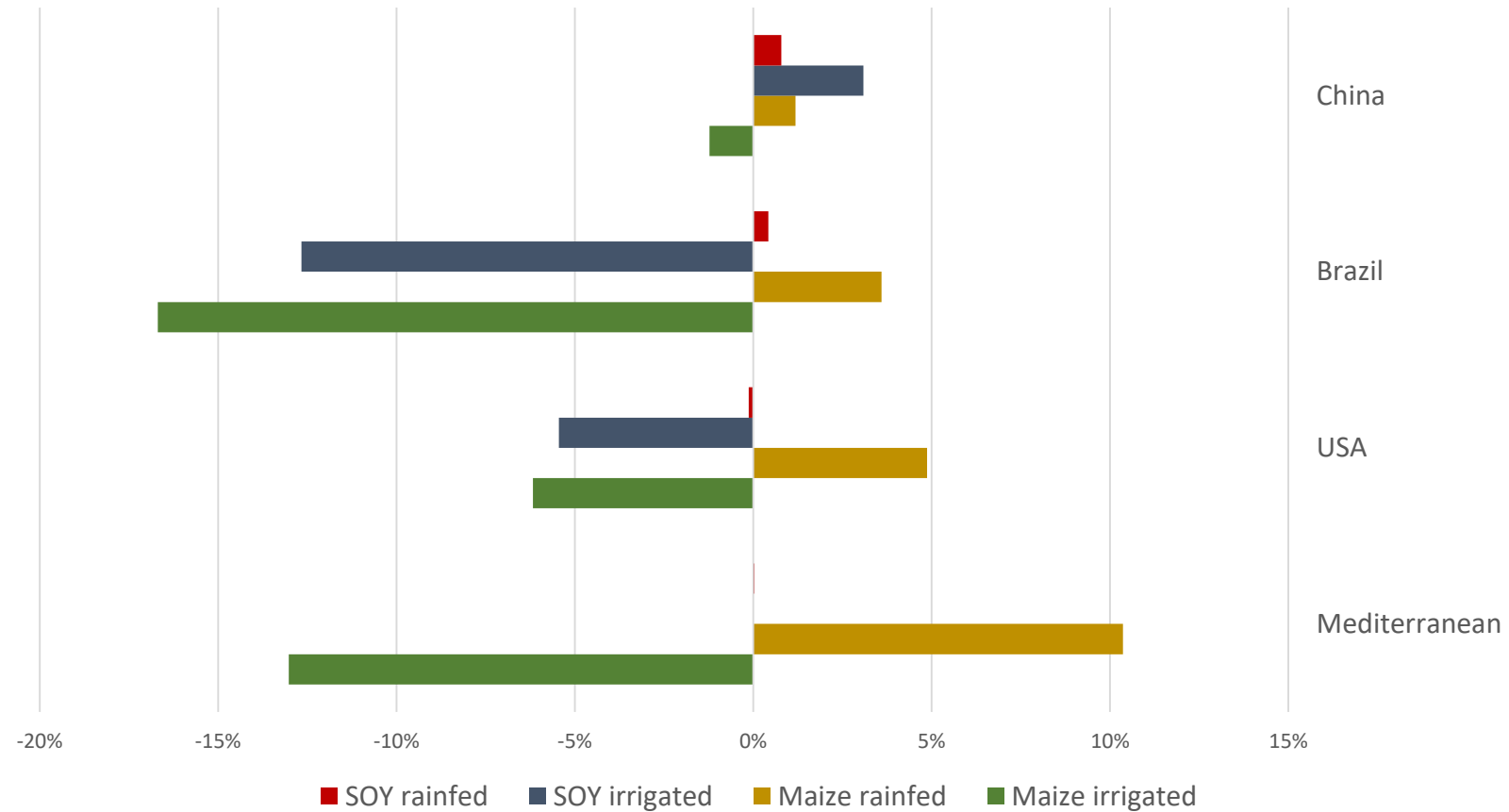


# The Applied Regional Trade (ART)- Water

*Model simulation example*

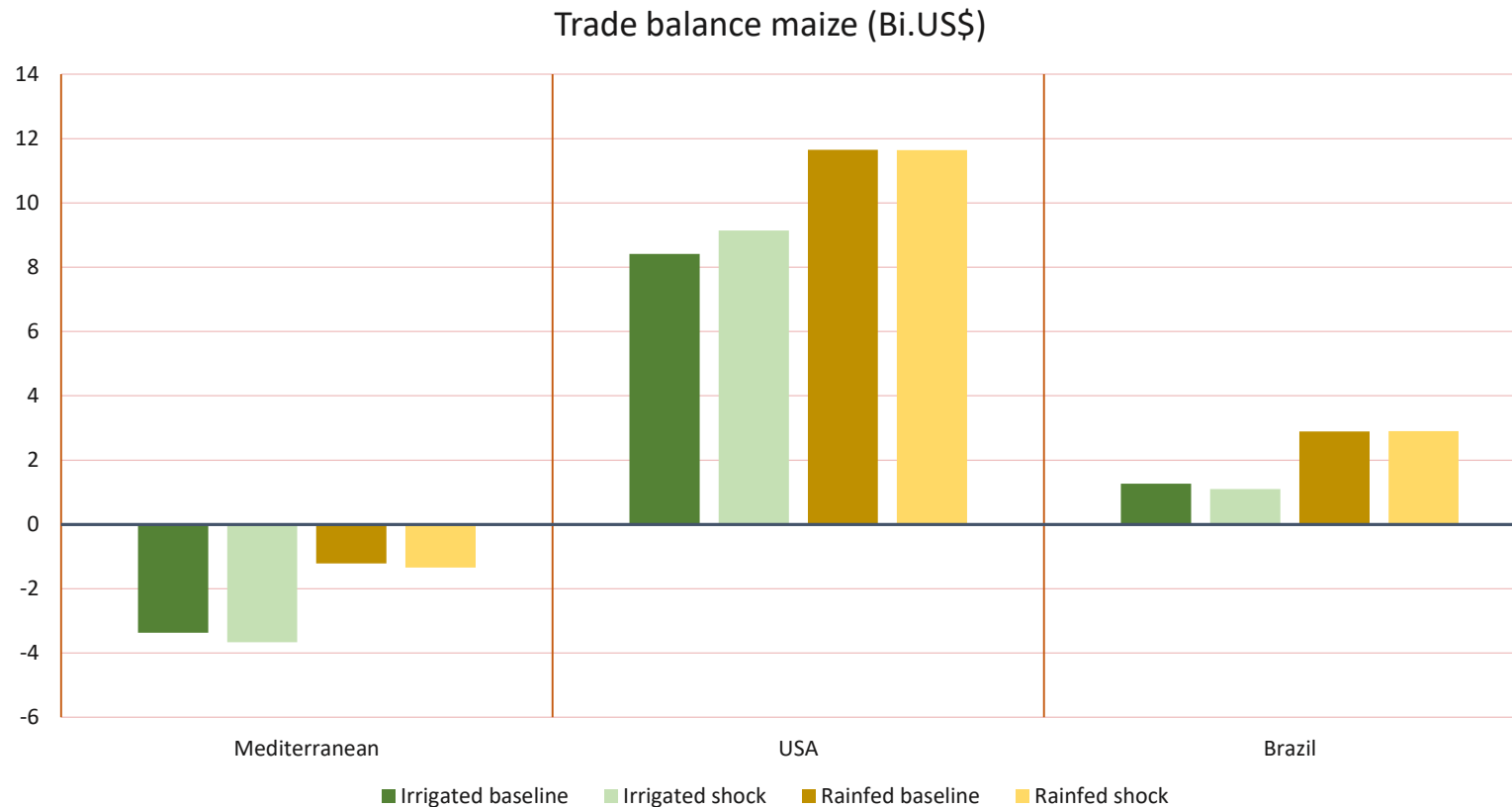
*Irrigation water pricing*

Supply of agricultural products



# The Applied Regional Trade (ART)- Water

*Model simulation example*      *Irrigation water pricing*





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