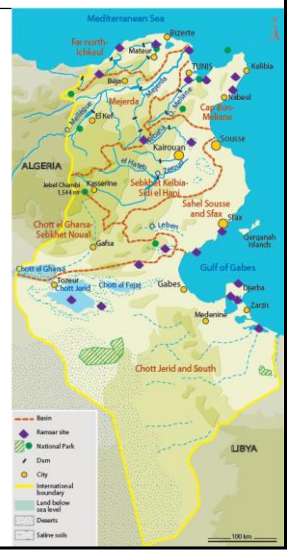
Water and Trade Strategic Workshop,
25-26 November, 2010, Amsterdam, The Netherlands

Controlling water scarcity by optimizing blue and green virtual water fluxes: the case of Tunisia



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References

- ***Besbes M., Chahed J., Hamdane A. (2007),*** Bilan intégral des ressources en eau de Tunisie, sécurité hydrique et sécurité alimentaire, Communication at Académie d'Agriculture. Paris, séance du 4-4-2007 (l'Avenir des Eaux Continentales)
- ***Chahed J., Hamdane A., Besbes M.,(2007),*** Bilan intégral des ressources en eau de Tunisie, sécurité hydrique et sécurité alimentaire, La Houille Blanche N°3,2007
- ***Chahed J., Hamdane A., Besbes M.,(2008),*** A Comprehensive Water Balance of Tunisia: Blue Water, Green Water, Virtual Water, Water International, 33:4, pp. 415-424
- ***Besbes M., Chahed J., Hamdane A., De Marcily G. (2009)***, Changing Water Ressources and food supply in arid zones : Tunisia, Water and sustainability in Arid regions, Schneier-Madanes and Courel, Editors, Springer , 2009

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Tunisian water resources

Pluvial water resources

36000 Mm^3 225 mm/year

Renwable Water Resources

4850 Mm^3 < 500 m3/cap/year

- **Surface water** : 2700 Mm^3
- **Ground water** : 2150 Mm3

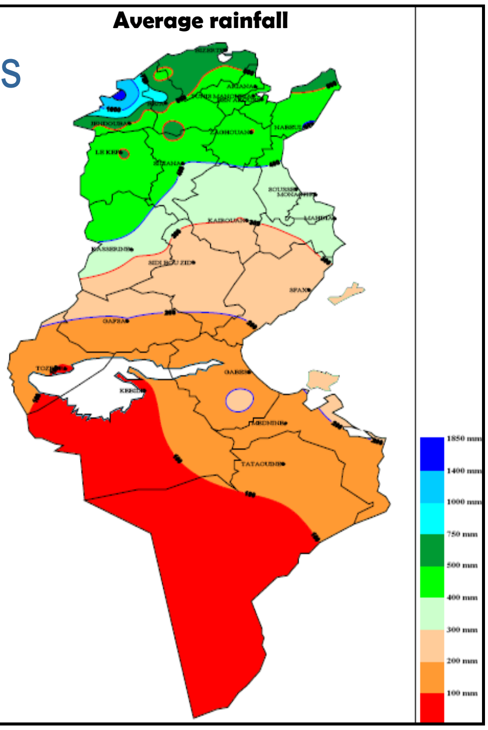
Withdrawal resources

3150 Mm^3

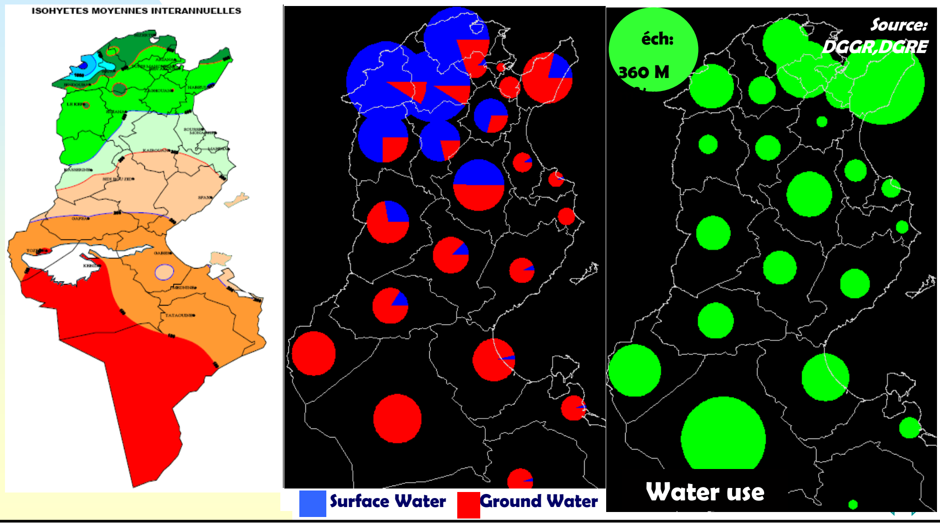
600 Mm^3 Reserve for drought

+120 Mm^3 TWW (Treated Waste Water)

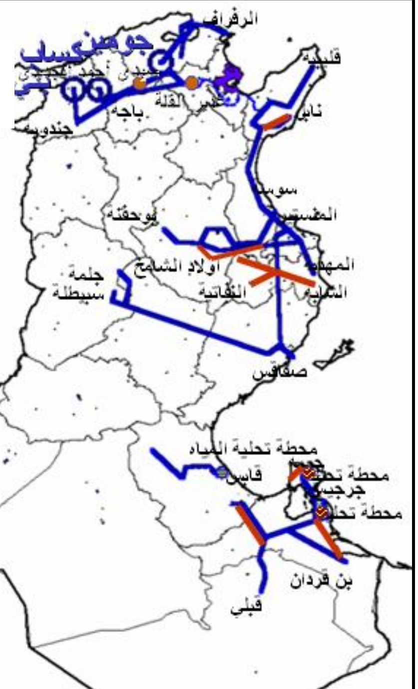
3870 Mm^3 < 400 m3/cap/year



Tunisian water resources distribution



Tunisian water resources : Transfers and Water uses



Water Uses

Drinking Water:
300 Mm^3 ≈ (30 m^3/Cap/year)

Water for Industry:
100 Mm^3 ≈ (10 m^3/Cap/year)

Water for Tourism:
20 Mm^3 ≈ (2 m^3/Cap/year)

Water for Agriculture :
2100 Mm^3 ≈ (210 m^3/Cap/year)

Rate of water withdrawal

Global ≈ 80 %
Surface water ≈ 75 %
Groundwater ≈ 90 %

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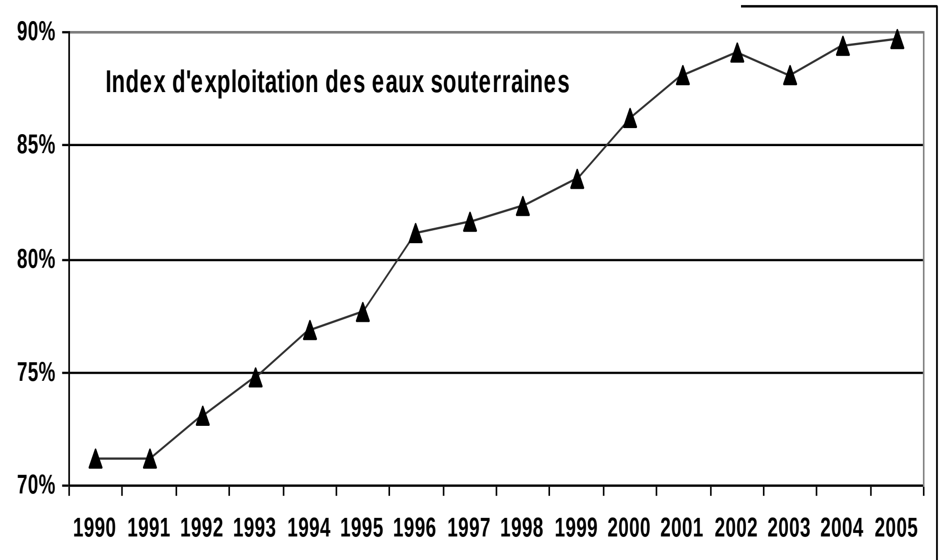
Groundwater Abstraction Index



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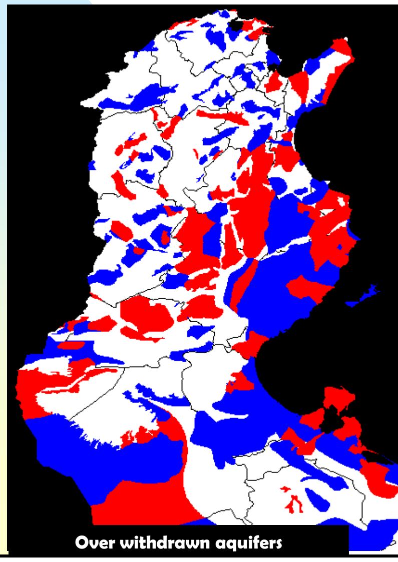
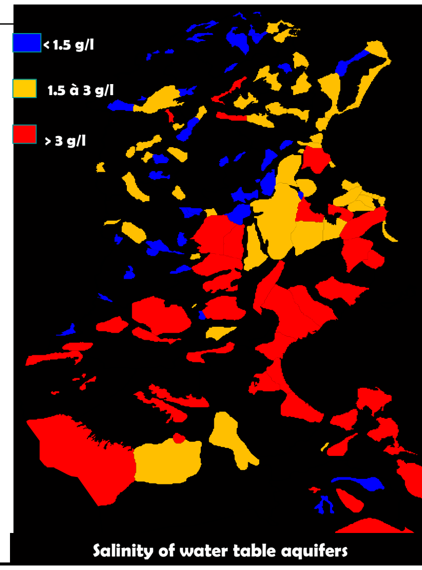
Water quality constrains





Water resource development and management in Tunisia

- Water resources in Tunisia are scares, not uniformly distributed and highly withdrawn
- Water withdrawal has reached the water potential especially for groundwater
- The direct demand (drinking water, industry, tourism) is incompressible and increases with the population but still moderate
- An important part of water «**Blue Water**» is used in agriculture : As water supply stabilizes agricultural water allocations will be reduced

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Modelling Food Demand Water Footprint

Irrigation Water Volume at constant flux

$$IW = EWR - (1 - RI)DD - ENV$$

IW : Irrigation Water Volume
EWR : Exploitable Water Resources (EWR) « **Blue Water** »
DD : Direct Water Demand (collectivities, tourism, industry) ;
RI : Rate of Water Recycling
ENV : Environmental Water demand

$$FD = \lambda\underbrace{(EWR + (1 - RI)DD - ENV)}_{\text{Blue Water}} + \underbrace{GW}_{\text{Green Water}} + \underbrace{VW}_{\text{Virtual Water}}$$

Equivalent Water of Food Demand

FD : Equivalent Water for Food demand
GW : Equivalent-Water of rainfed agricultural production « **Green Water** »
VW : deficit in Equivalent-Water related to foodstuffs trade « **Virtual Water** »
λ: Global Irrigation Factor

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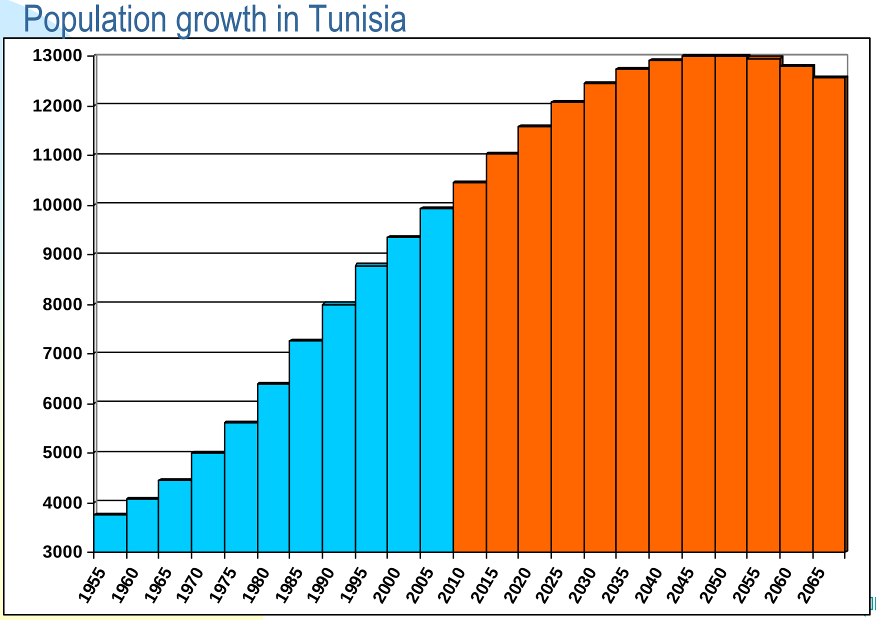
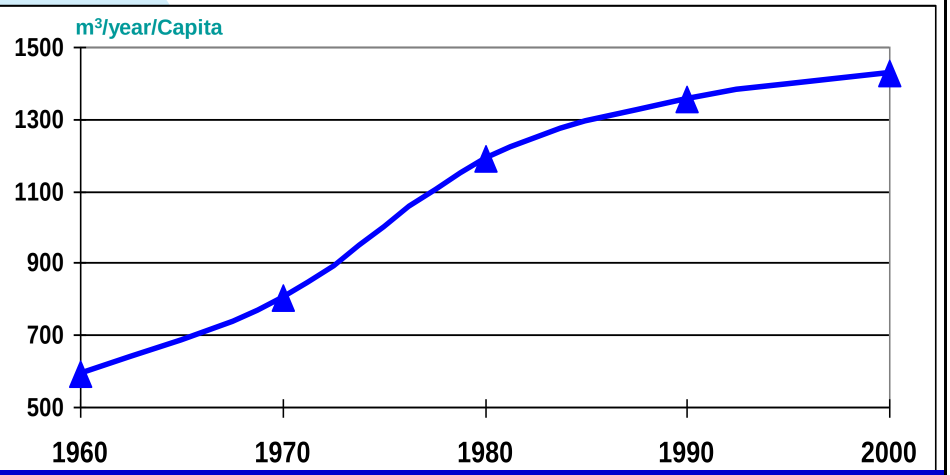
Equivalent Water of Food Demand (FD)

Population growth in Tunisia



Equivalent Water of Food Demand (FD)

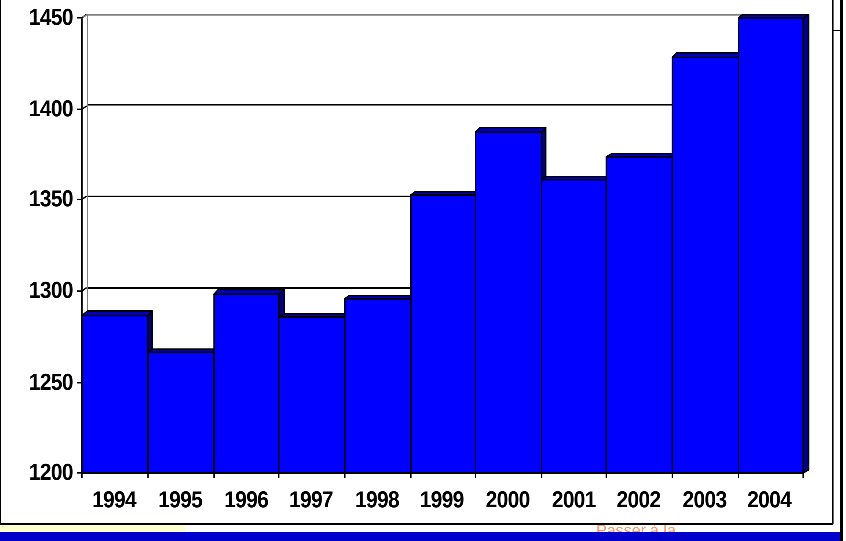
Evolution of the specific equivalent Water demand for food



Data: FAO www.fao.org/countryprofiles & INS Tunisia

Equivalent Water of Food Demand (FD)

Evolution of the specific equivalent Water demand for food in Tunisia



Data : FAO www.fao.org/countryprofiles & INS Tunisie

Blue Water for Irrigation (BW)

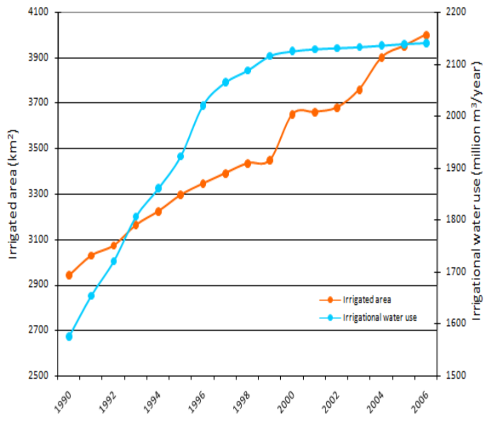
Trends in agricultural water use, 1990–2006

Direct water uses (collectivities, tourism, industry) represent less than 20 % of water uses.

Agriculture water uses represent more than 80 % of water uses.

Irrigation

occupies less than 1/10 of cultivated areas and produces around 1/3 of food production



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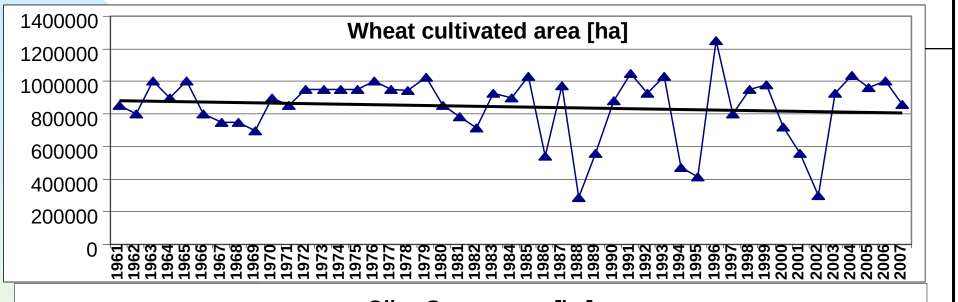
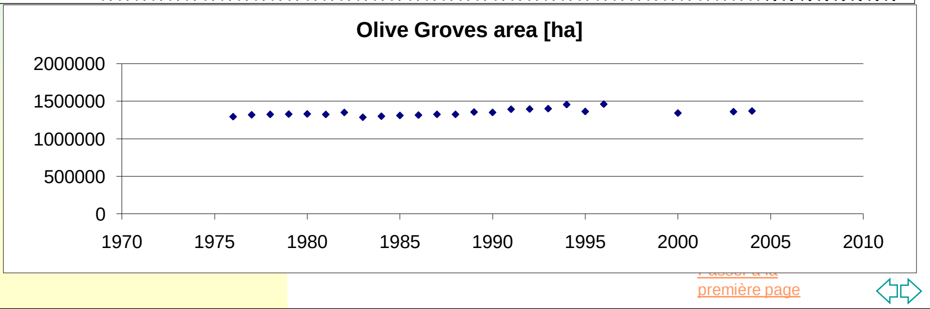
Green Water (GW)

Rainfed agriculture : Olive groves and wheat sown area





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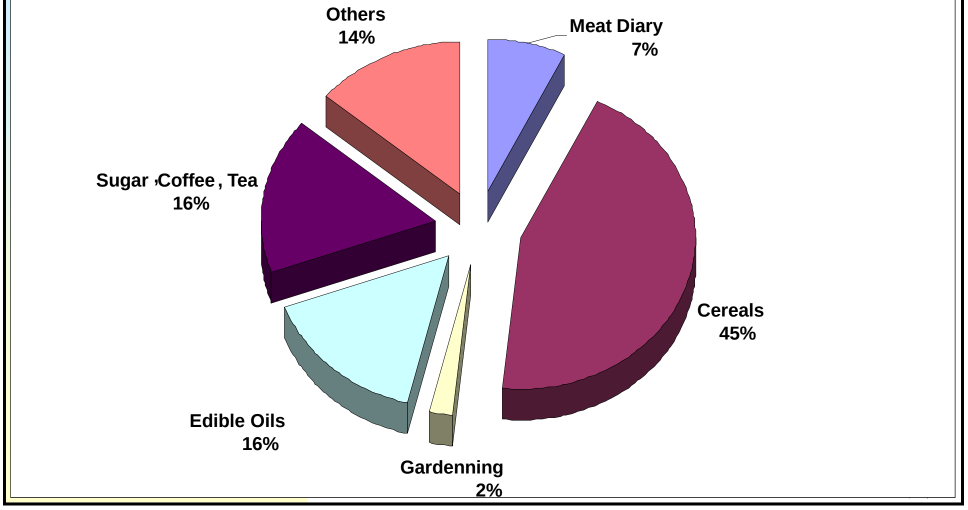
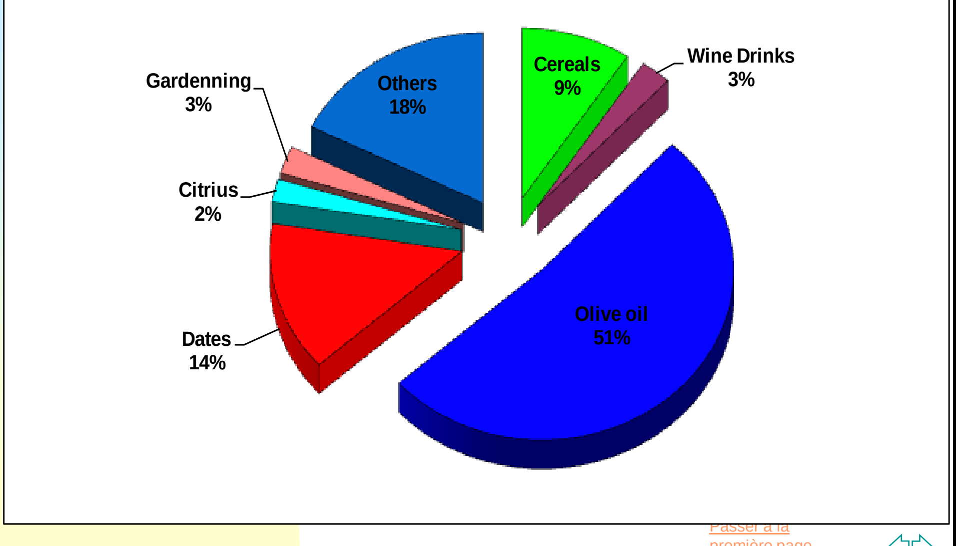
Virtual Water (VW)

Foodstuffs imports in value 1990-2004



Virtual Water (VW)

Foodstuffs exports in value 1990-2004



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Water and food security issues in Tunisia

- An important part of withdrawal water «***Blue Water***» is used in agriculture (more than 80%). As the mobilized «Blue Water» is stabilized, agricultural water allocations will be reduced
- Rainfed agriculture «***Green Water***» plays an important role in food security. It takes an important part in food trade balance. But rainfed agriculture has not received the same attention as irrigated agriculture and its contribution is not directly taken into account in the global balance of water resources
- Imports of cereals, edible oil and other basic foodstuffs «***Virtual Water***» is required to fill the deficit of the local production. The part of Virtual Water is already important and it is expected to increase significantly.

How in these conditions we may improve Food Security ?

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Global Water Dependency Index

Virtual Water contribution

$$VW = FD - GW - \underbrace{\lambda(EWR + (1 - RI)DD - ENV)}$$

Virtual Water ↑ Green Water ↑ Blue Water

Lets Define the Water Dependency Index (WDI)

$$WDI = \frac{VW}{FD}$$

With constant Blue Water contribution

$$\lambda(EWR + (1 - RI)DD - ENV) = BW = Const$$

$$WDI = 1 - \frac{GW}{FD} - \frac{BW}{FD}$$

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Global Water Dependency Index

Evolution of Virtual Water contribution

$$\Delta VW = \Delta FD - \Delta GW$$

$$\Delta WDI = -\Delta\left(\frac{GW}{FD}\right) = \frac{GW}{FD}\left[\frac{\Delta(FD)}{FD} - \frac{\Delta(GW)}{GW}\right]$$

Short time Analysis : FD almost constant

$$\Delta VW = -\Delta GW$$

$$\Delta WDI = -\frac{GW}{FD}\left[\frac{\Delta(GW)}{GW}\right]$$

- Virtual Water and Green Water are not well known and are not directly taken into account in the planning of water resources
- More investigations are required in order to precise the Green Water contribution: its potential, its spatial distribution and its variability

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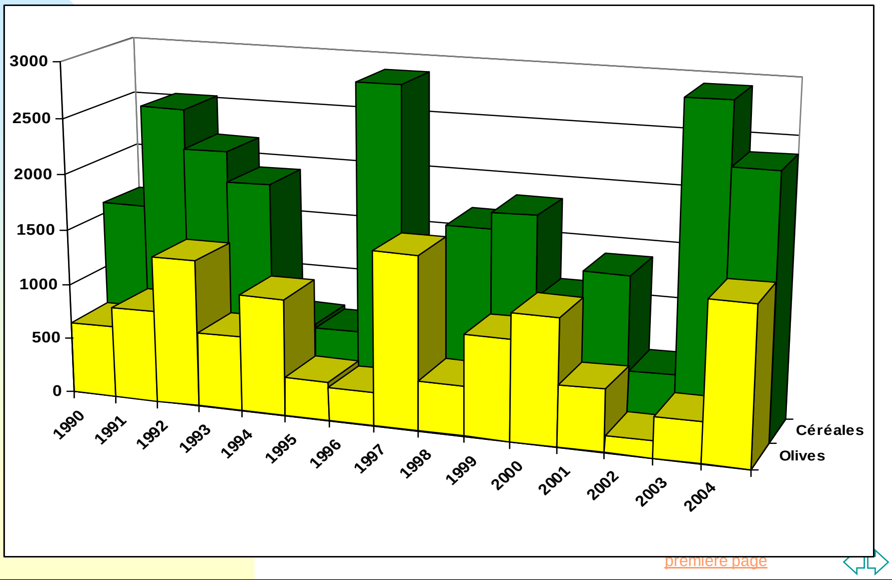
Green Virtual Water Variability

Cereals and olive production (1000 Tons)



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Green Virtual Water assessment

$$GW(i,n) = 1000\,\zeta(i) Y_G(i,n) S_G(i,n)$$

GW(i,n) : Green Water of rainfed production (region (i), year (n))
ζ : Specific Equivalent Water [m3/kg];
Y_G(i,n) : Yield of rainfed production [ton/hectare]
S_G(i,n) : Environmental Water demand

$$h_G(i,n) = h_W(i,n) - h_S(i) = 100\,\zeta(i) Y_G(i,n)$$

$$h_W(i,n) = \alpha h_p(i,n) + \beta h_p(i,n-1)$$

At the national level

$$\overline{\zeta} < \overline{Y_G} > = \frac{1}{100}(< \overline{h_w} > - \overline{h_S})$$

$$< \overline{Y_G} > = < \sum_i Y_G(i,n) s_G(i) >$$

$$< \overline{h_W} > = < \sum_i h_W(i,n) s_G(i) >$$

$$s_G(i) = < \frac{S_G(i,n)}{\sum_i S_G(i,n)} >$$

$$\overline{h_S} = \sum_i h_S(i) s_G(i)$$

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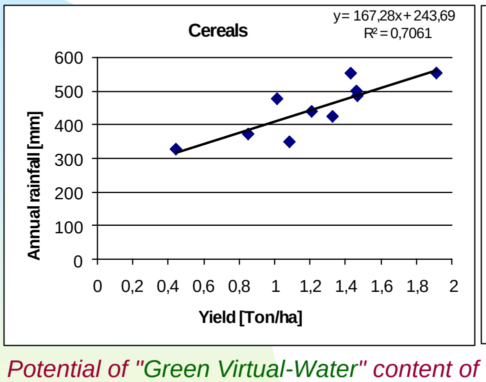
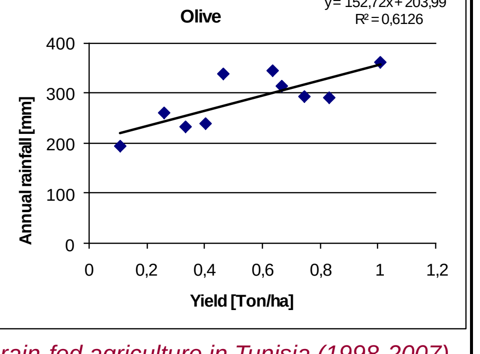
Green Water assessment (Cereals Olives)





Potential of "Green Virtual-Water" content of rain-fed agriculture in Tunisia (1998-2007).

	Weighted Rainfall [mm] $<\overline{h_W}>$	Water threshold [mm] $\overline{h_S}$	Equivalent water per Kg [m³/kg] $\overline{\zeta}$	Green Water height [mm] $<\overline{h_G}>$	Rainfed Area potential [10⁶ ha]	Green-Water Potential [km³]
Cereals	448	244	1,67	204	1,64	3,4
Olive	287	204	1,53	84	1,54	1,3
Rain-fed crops	(Total)				4,5	6,6

Sources: MARH, FAOSTAT

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Average Global Water Balance

Blue Water	**3,3**
Irrigation	2,1
Urban [Cities, tourism]	0,4
Industry	0,1
Environment [conservation of humid areas]	0,1
Water Bank [Storage in dams for droughts]	0,6
Green Water	**12,1**
Rainfed agriculture	6,6
Forests and Rangelands	5,5
Virtual Water	**6,3**
Deficit of food balance[Imported Virtual Water]	6,3
Total Water Demand	**21,7**
Food Water Demand	15
Direct Water demand (Collectivities, Industry, Tourism)	0,5
Water Bank [Storage in dams for droughts]	0,6
Environmental Water demand	5,6

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Green Virtual Water trade balance
Cereals and edible oil trade balance

Average "Green Virtual-Water" trade balance in Tunisia (1998-2007)

		Average amount [10^3 Ton]	Average Value [Million $]	Equivalent water per Kg [m^3/Kg]	Equivalent water [10^6 m^3]	Specific value Price (2007) [$/ m^3]
Imports	**Cereals**	1842	307	1,67	3,1	0,100
	Edible oils	224	131	7,11	1,6	0,082
	Total		438		4,7	0,093
Exports	**Olive oil**	133	339	7,11	0,9	0,358

Sources: MARH, FAOSTAT

Variability of "Green Virtual-Water" of rain-fed agriculture in Tunisia (1998-2007)

	Green Water potential [km^3]	Average Value [Million $]	Value of Green-Water Potential [Million $] Frequency 20% High - Low	Frequency 10% High - Low	Frequency 5% High - Low	Frequency 2% High - Low
Cereals	3,4	340	440 - 240	480 - 200	520 - 160	570 - 110
Olive tree	1,3	465	679 - 250	786 - 143	858 - 72	964 - - -

Sources: MARH, FAOSTAT

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Green Virtual Water trade balance

Cereals and edible oil trade balance

	Imports	Exports	Coverage Rate
Equivalent-Water , Mm^3/year	4700	900	19%
Value , M$/an	438	339	77%
Price , $\$/m^3$	0,093	0,358	

1 m3 "Green Water Exports"

For almost

4 m3 "Virtual Water Imports"

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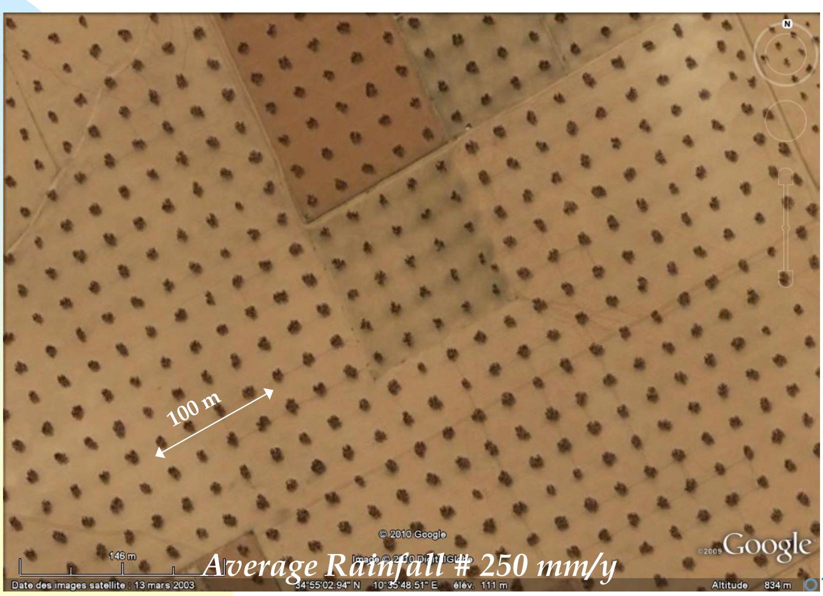
A field of olive trees, near Sfax, Tunisia



Improvement of the global water balance

- **Enlargement** of the **Water Resource** notion to all kind of the contributions to the **Global Water Balance** : «**Blue Water**», «**Green Water**», «**Virtual Water**», «**Non-conventional Water**».
- **Enlargement** of the **Demand Management** notion to all kind of water uses including the water requirements for food demand
- **Optimization** of all water uses including the water involved in the rainfed agriculture production «**Green Water**», and in the international trade exchange «**Virtual Water**»,

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Conclusions

- The development of irrigation sector is limited by the availability of water: irrigated agriculture is increasing its efficiency and promoting better use of water.
- The potential of "Green Water" is large. Its development requires the implementation of a coherent strategy to promote the sector of rainfed agriculture, vulnerable to rainfall variability:

1. Development of technical tools for better assessment of the Green Water resource in order to make it more visible: identification, mapping, etc.
2. Establishment of regulatory and legislative measures: encourage soil water resources developments, promote foodstuffs storage, implementation of drought insurance mechanisms…
3. Analysis of the market conditions and prices for specific products (Edible oils, cereals ...)

But first, explain and convince …

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