Greenhouse Hydroponics
Types of Hydroponic Systems and Automations

Nikolaos Katsoulas
Associate Professor

UNIVERSITY OF THESSALY

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Team presentation

University of Thessaly,

Department of Agriculture Crop Production & Rural Environment,

Laboratory of Agricultural Constructions and Environmental Control

UNIVERSITY OF THESSALY

Director:

Nikolaos Katsoulas

Associate Professor

nkatsoul@uth.gr

T:+302421093249

M:+306948575954

Members:

Dr. A. Elvanidi,

PhD st. M. Metsoviti

PhD st. V. Anestis

PhD st. E. Karatsivou,

PhD st. A. Bari

MSc S. Bouras

MSc G. Miliokas

MSc P. Xiradakis

MSc st. M. Aslanidou

MSc st. S. Faliaga

BSc E. Armyra (Secretary)

and several BSc students

Collaboraors:

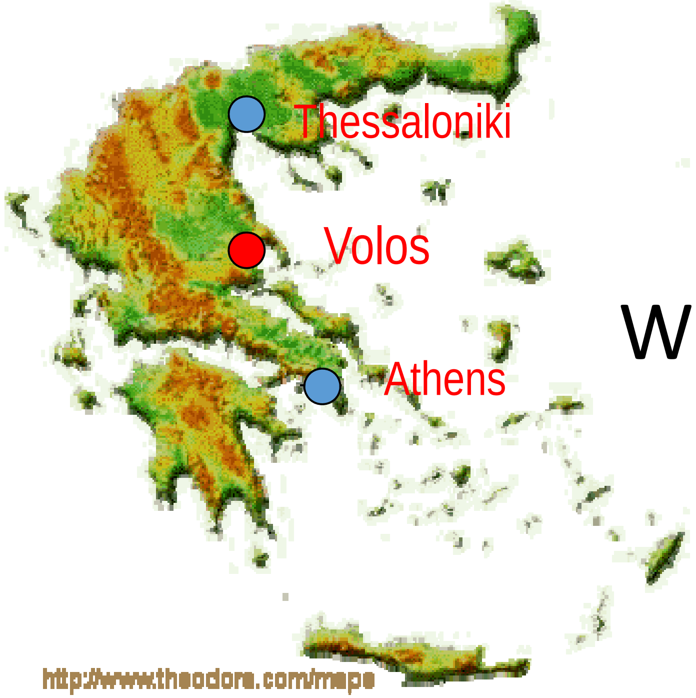
Prof. C. Papaioannou

Dr. D. Antoniadis,

Dr. D. Papanastasiou

Dr. D. Feidaros

Dr. A. Baxevanou



Where we are....

Latitude: 39.22

Longitude: 22.44

Sustainable agriculture production in controlled environment – Greenhouse

- ✓ Design optimisation of greenhouse structures
- ✓ Rational management of hydroponic and aquaponic systems
- ✓ Development and evaluation of greenhouse climate control systems
- ✓ Plant based greenhouse climate control
- ✓ Development and evaluation of crop stress indices

Major projects:

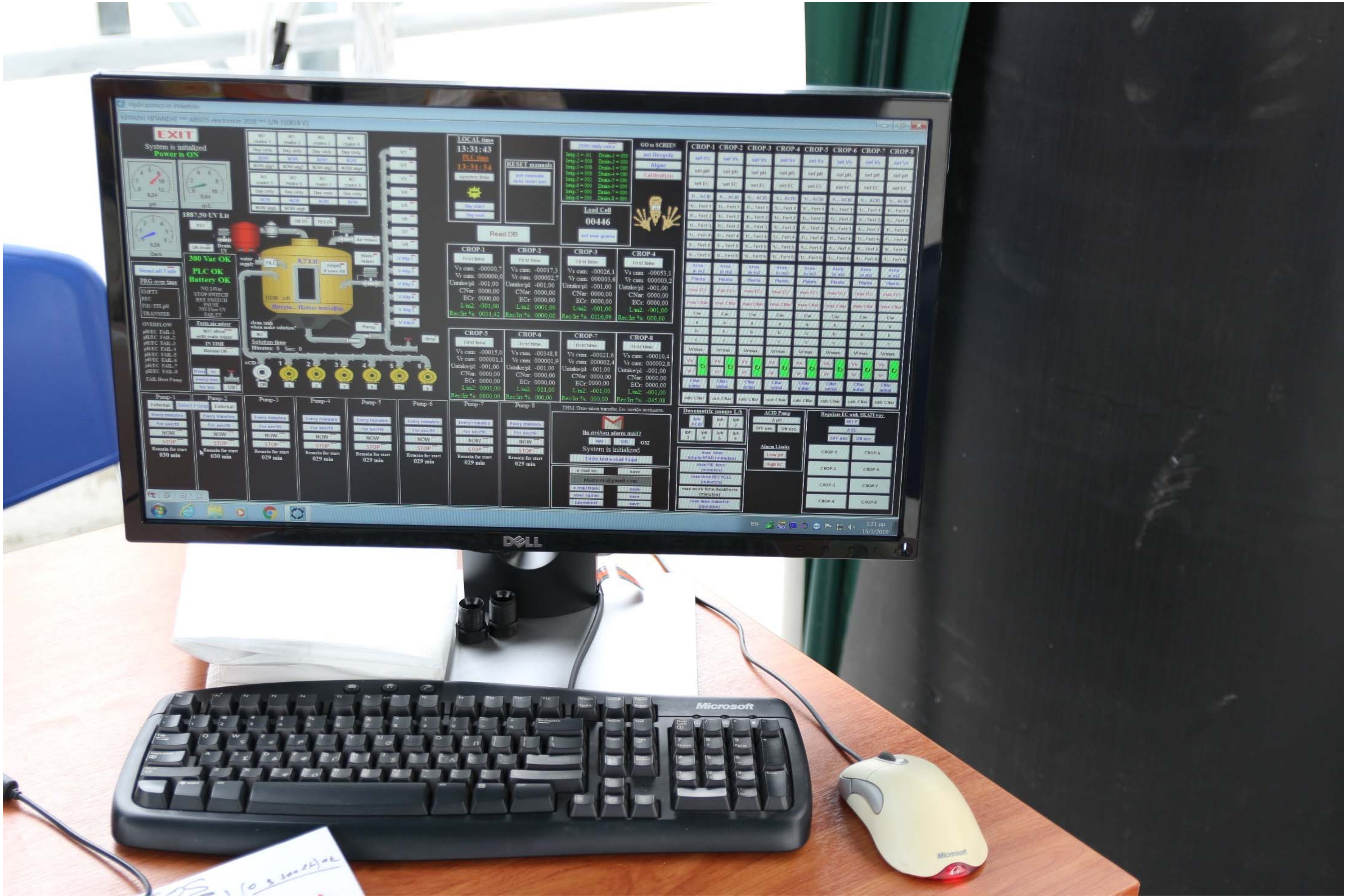
- Intelligent crop-based environmental monitoring and control of sustainable greenhouse eco-systems (GSRT, Excellence)
- Optimisation of greenhouse climate control in high salinity soils using omic technologies (GSRT, Cooperation 2009)
- Sustainable use of Irrigation Water in the Mediterranean Region (FP7, KBBE 2009)
- Smart Controlled Environment Agriculture Systems (FP7, Marie Curie, IRSES)
- Online Professional Irrigation Scheduling Expert System (FP7, KBBE 2013)

University of Thessaly

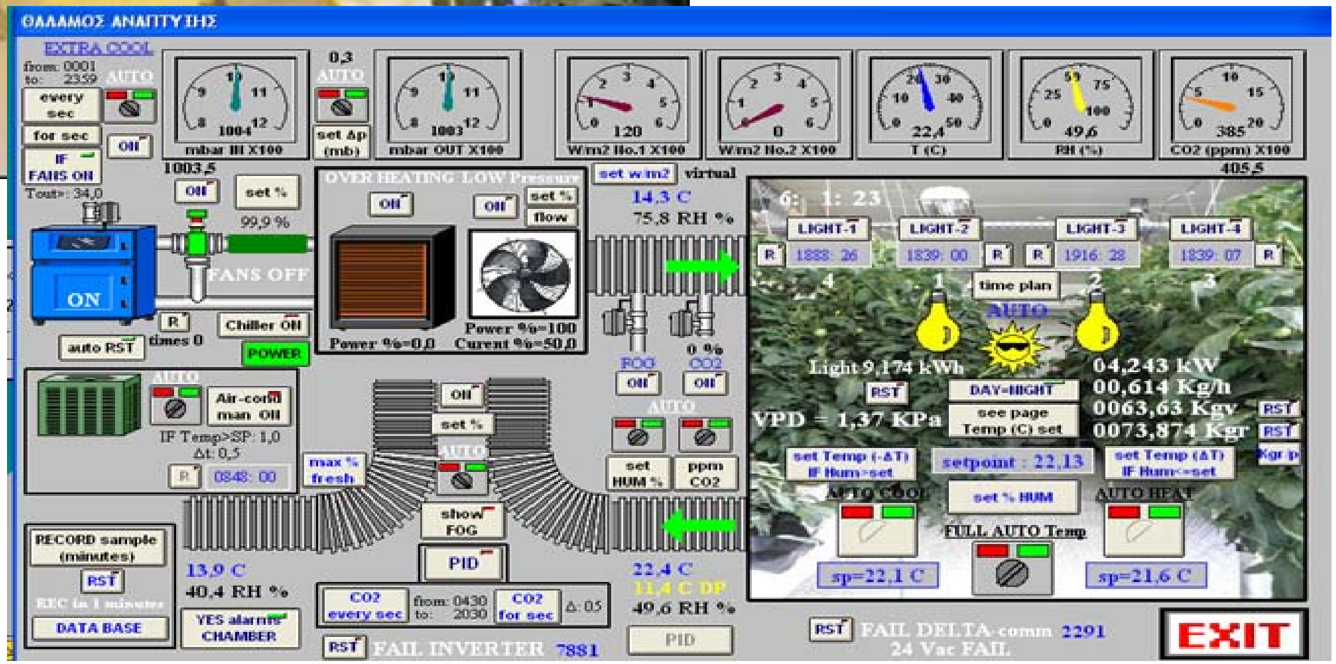




grodan Classic

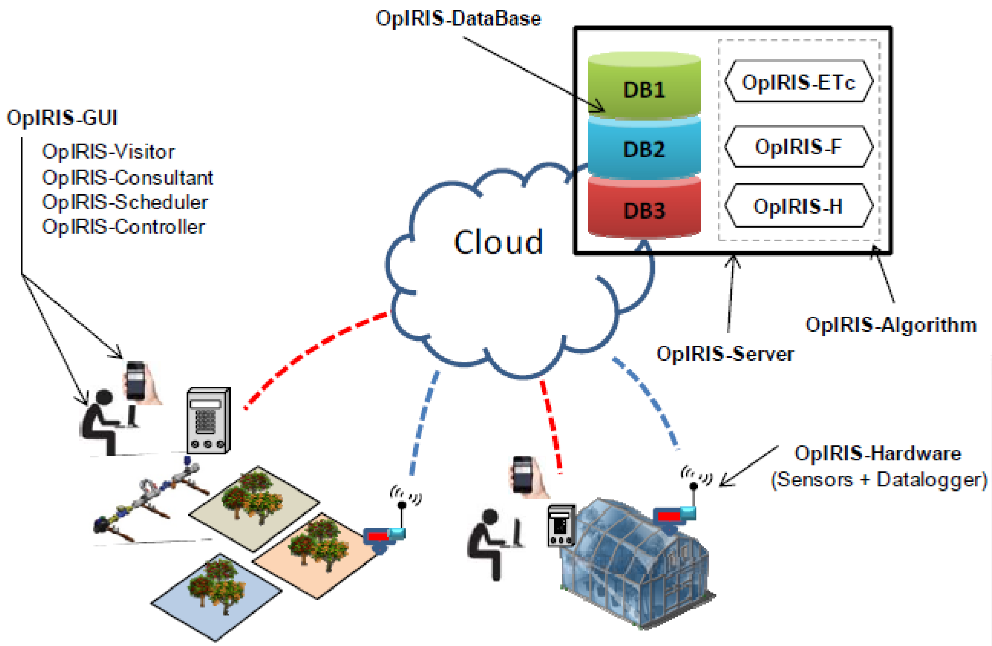

EXIT
System is initialized
Power is ON
380 Vac OK
PLC OK
Battery OK
LOCAL time
13:31:43
Load Cell
00446
Read DB
CROP-1
CROP-2
CROP-3
CROP-4
CROP-5
CROP-6
CROP-7
CROP-8
Microsoft

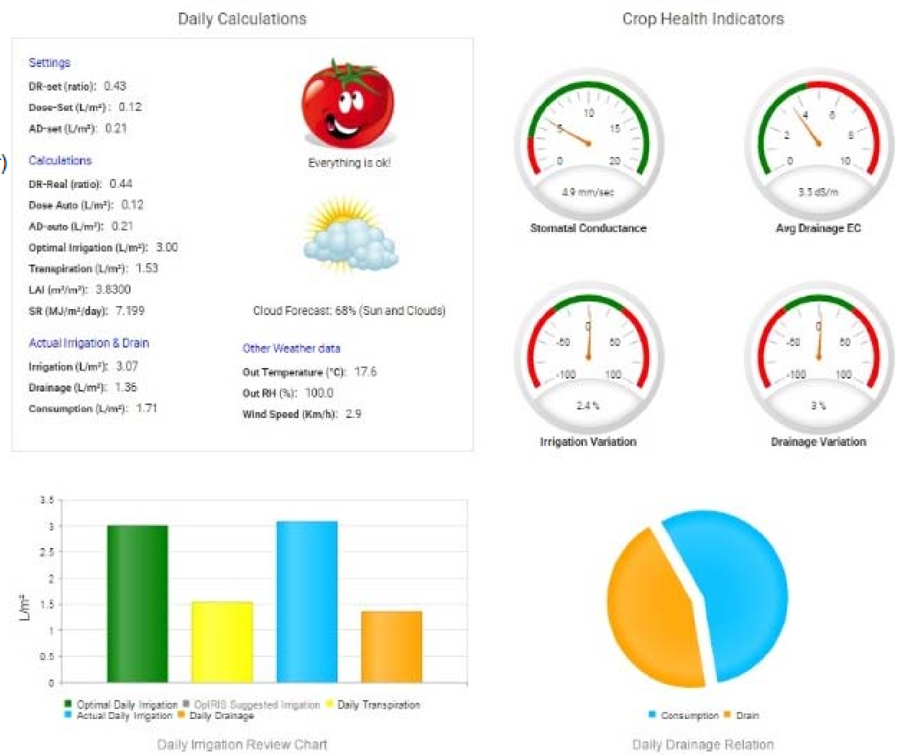
Research facilities at University experimental farm in Velestino



Controlled environment growth chamber

Rational use of water resources





Sensors for crop growth and development

Sapflow

Stem diameter

Leaf aerodynamic conductance

Leaf temperature

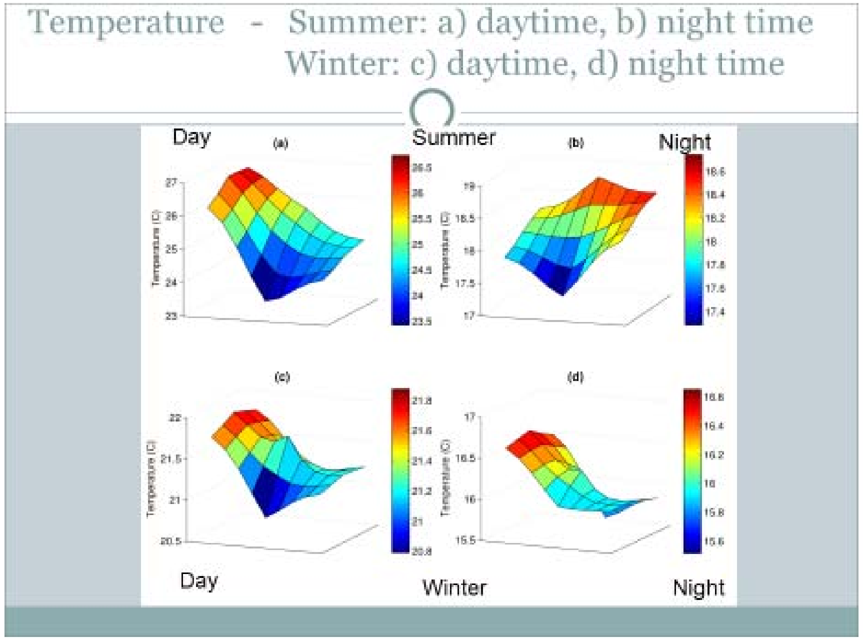
Wirelles Systems

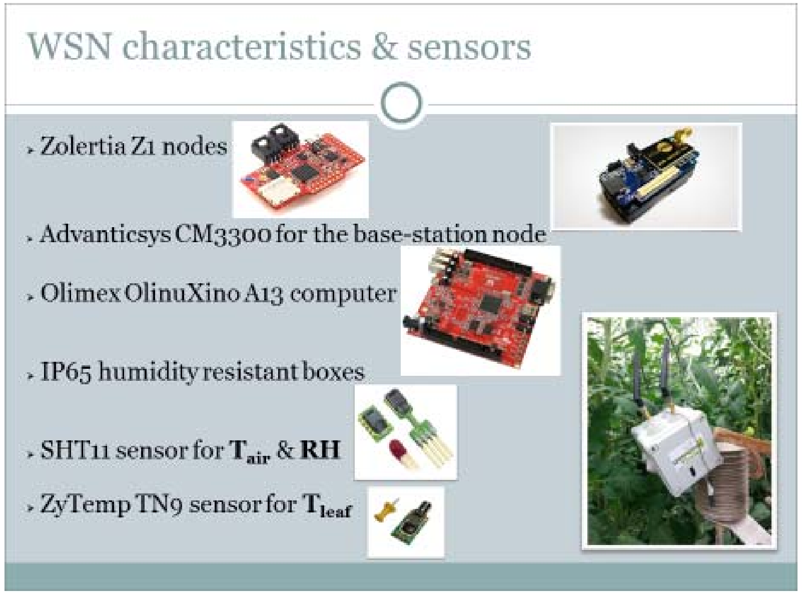
Air temp and relative humidity

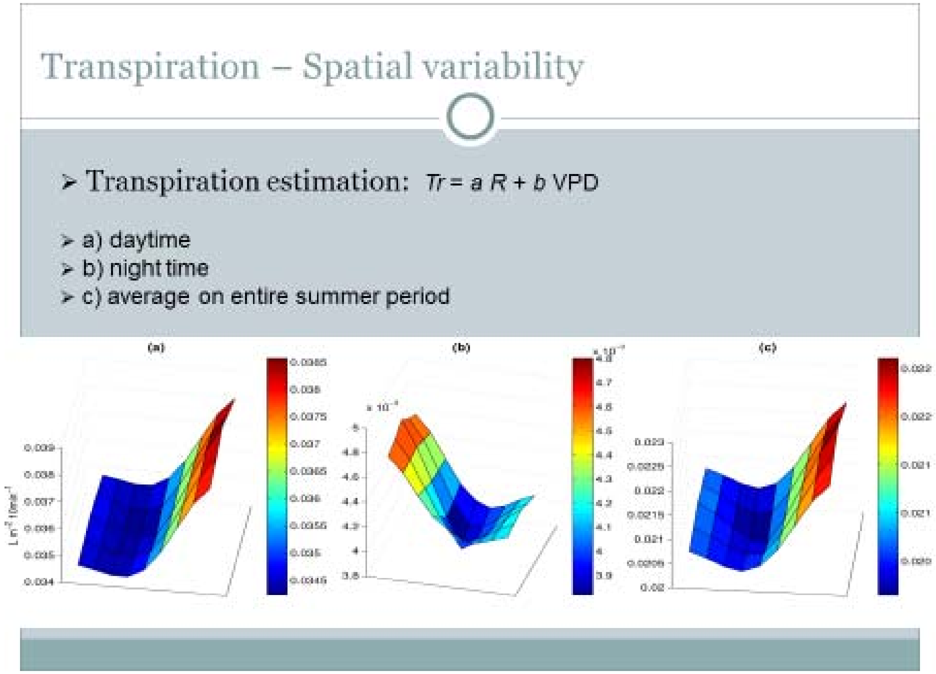
Leaf temperature

GreenSense

Spatially distributed greenhouse climate control based on wireless sensor network measurements



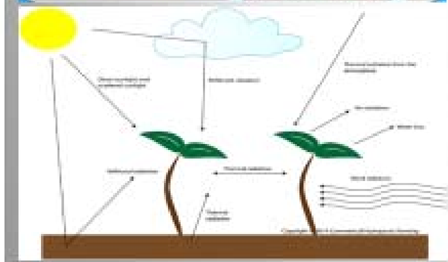




Reflectance and temperature indices for crop water status assessment

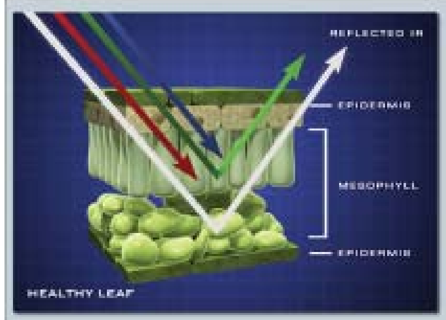
Crop temperature

➢Plant temperature correlated
- •Plant transpiration and
- •Stomatal conductance

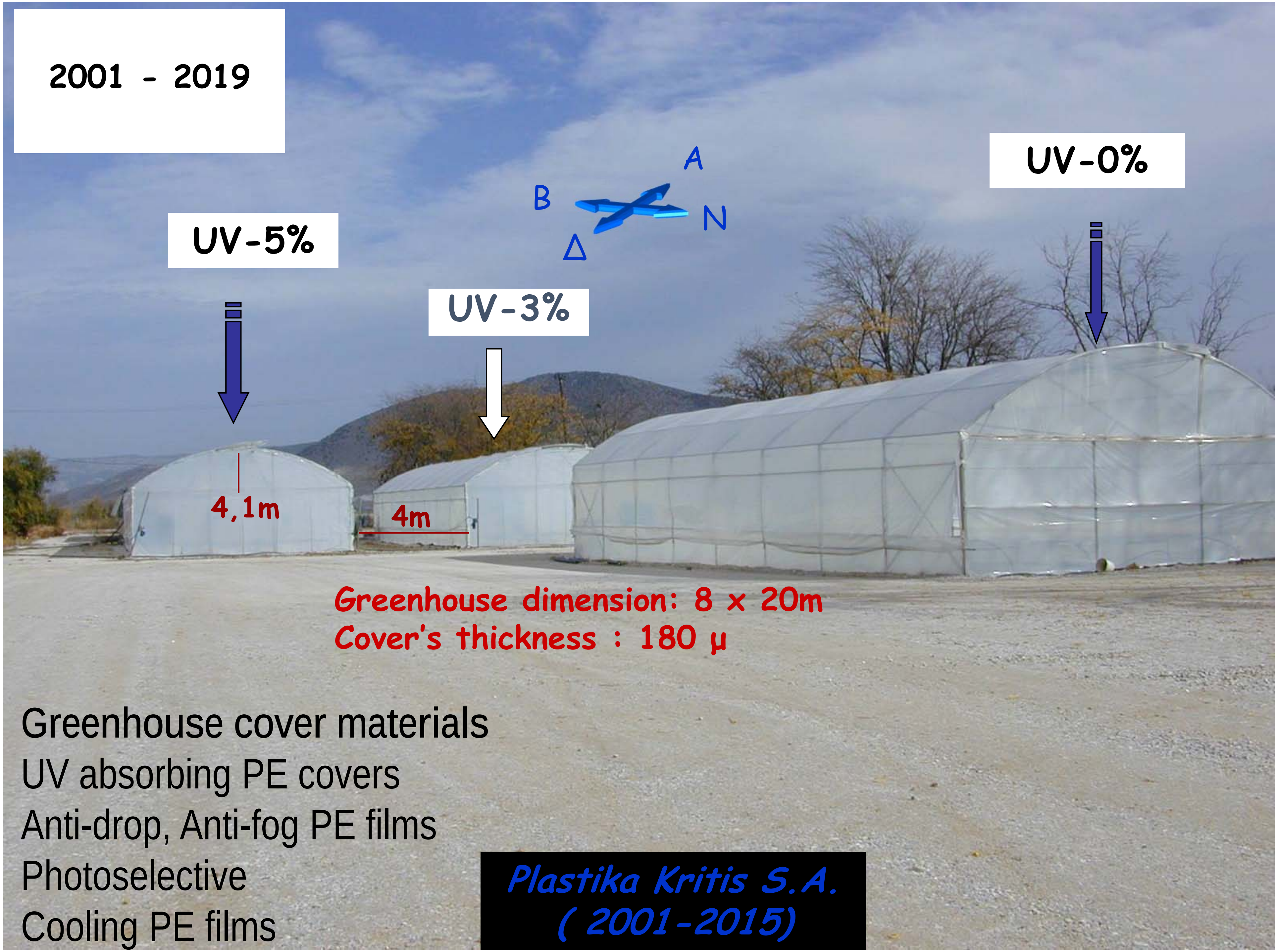


In water stress conditions, it manifests
- closure of stomata and adaptation of transpiration rate in order to be protected from various irreparable physiological damages

Remote sensing in greenhouses for plant reflectance measurement



➢ Different types of effective reflectance sensors can detect plant water status in real time by monitoring plant reflectance


2001 - 2019
UV-5%
UV-3%
UV-0%
A
B
N
Δ
4,1m
4m
Greenhouse dimension: 8 x 20m
Cover's thickness : 180 μ
Greenhouse cover materials
UV absorbing PE covers
Anti-drop, Anti-fog PE films
Photoselective
Cooling PE films
Plastika Kritis S.A.
(2001-2015)

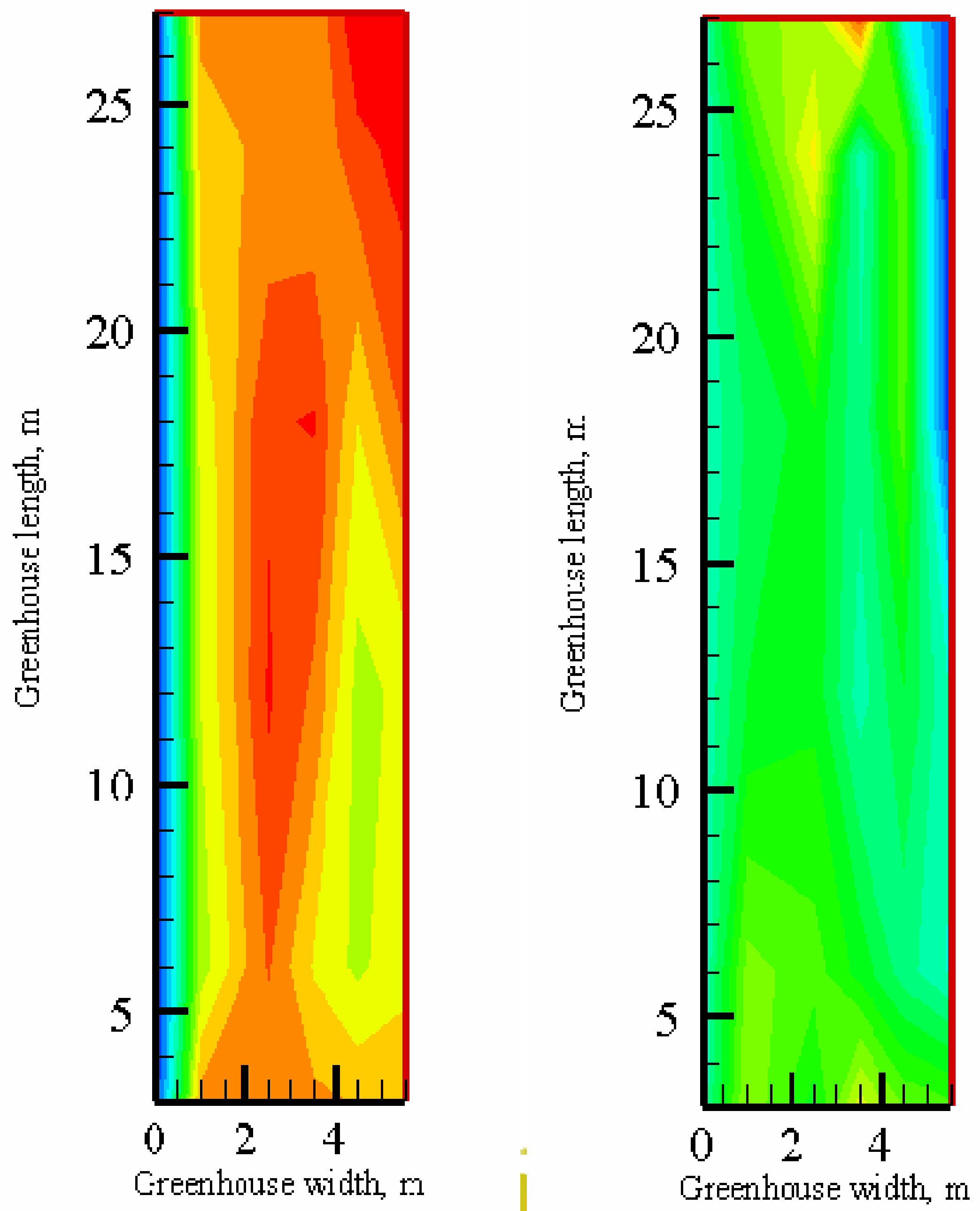
Microclimate distribution

Measurements

inside to outside greenhouse air temperature difference (°C) with

(a) natural ventilation or

(b) fog cooling



Katsoulas et al. (2012)

Current projects of the Lab

- MED Greenhouses (Interreg MED) https://medgreenhouses.interreg-med.eu/
- Organic+ (H2020) https://organic-plus.net/

- FoodOASIS (EDK) http://foodoasis.eu/
- Alga4Fuel&Aqua (EDK) http://alga4fuel-aqua.eu/
- InGreco (EDK)
- Fotokipia (EDK)

Co-financed by Greece and the European Union

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- CasH (Greece-Germany) http://cascade-hydroponics.eu/
- AgriTexSil (Greece-Germany) http://www.agritexsil.eu/

- ENSURE (EACEA)

Co-funded by the Europe for Citizens Programme of the European Union

Greenhouses: why?

How to increase circularity in horticulture?

Linear *vs* Circular economy

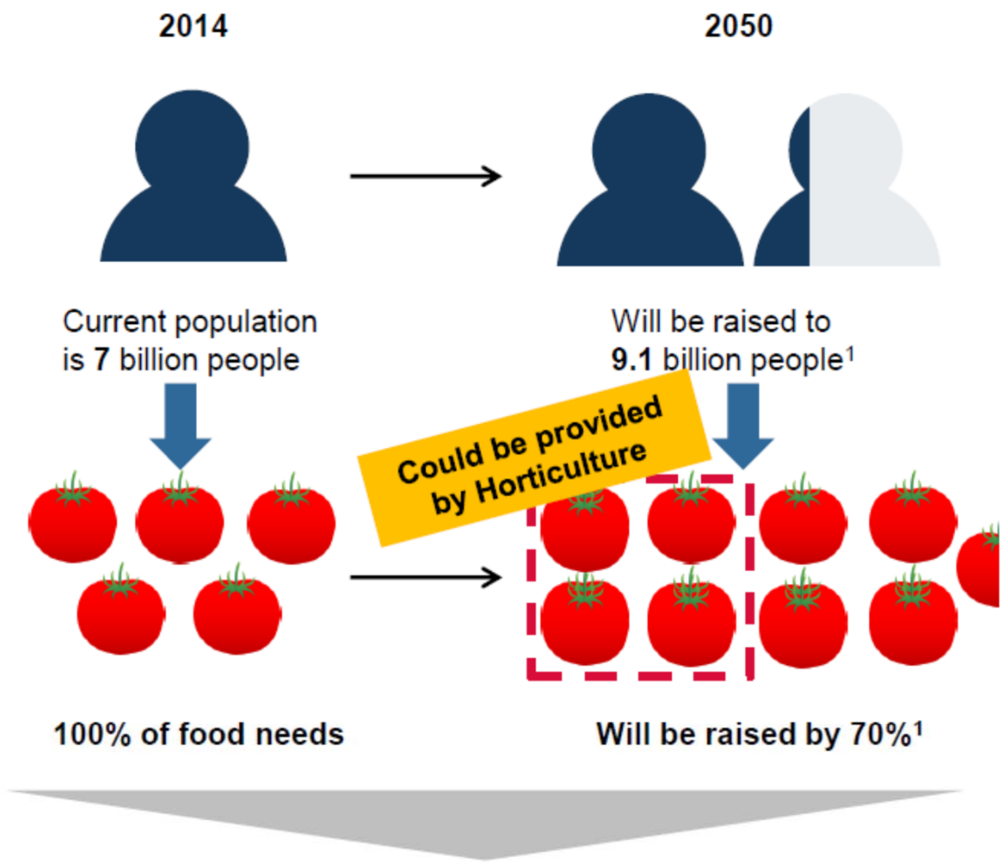
LINEAR ECONOMY “take-make-dispose” model

CIRCULAR ECONOMY

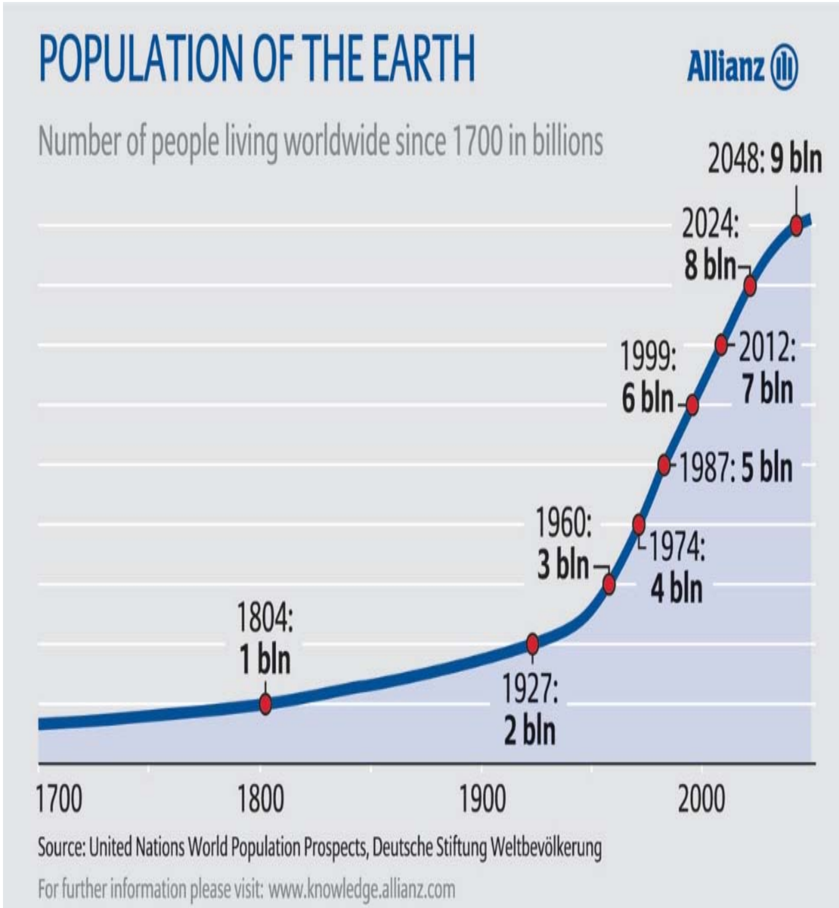
Regenerative system:
resource input and waste,
emission, and energy leakage
are minimized.
Long-lasting design,
maintenance, repair, reuse,
remanufacturing,
refurbishing, and recycling.

Need for Circularity in Horticulture

Globally, agriculture needs are expected to rise significantly the next 35 years

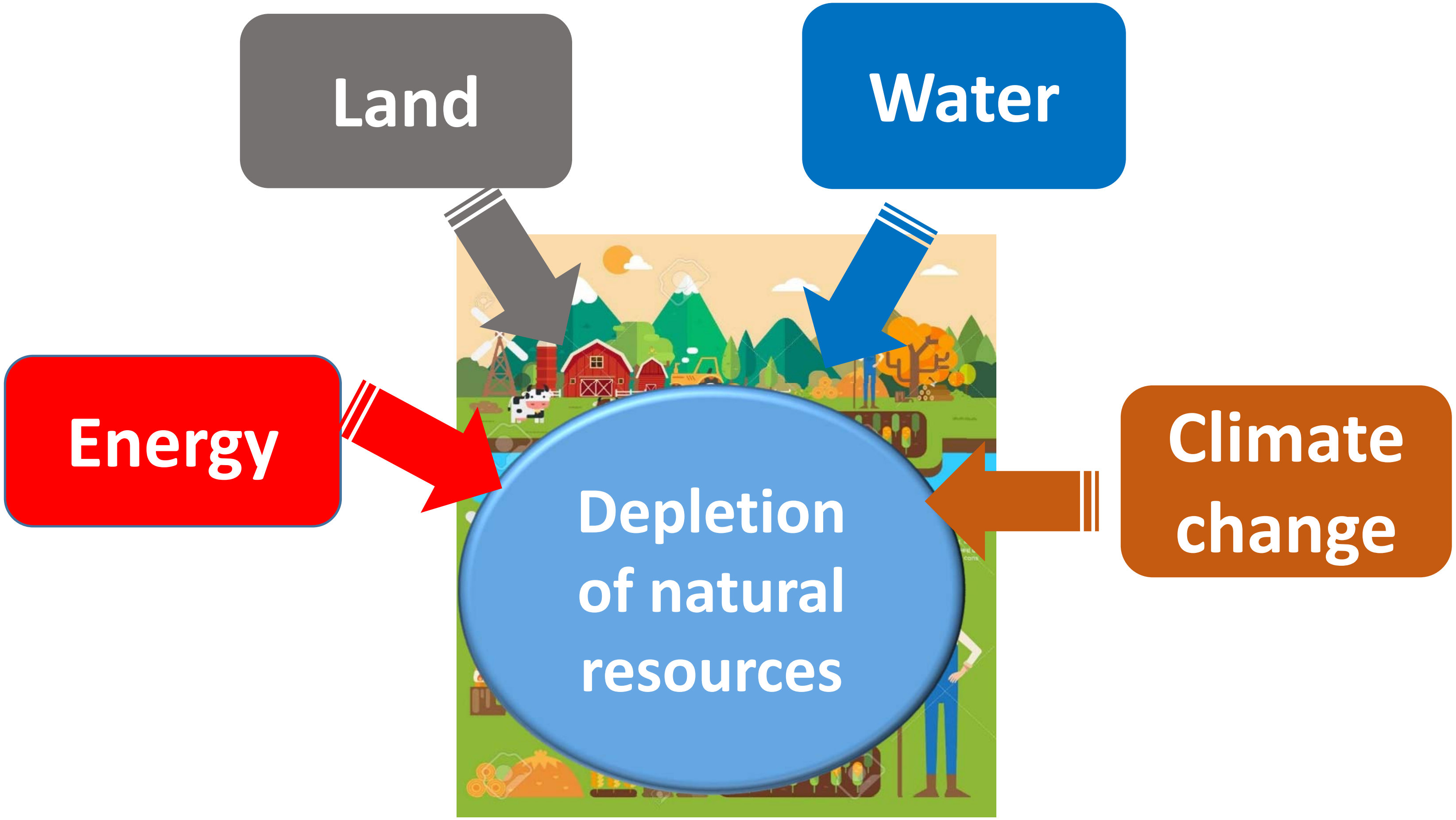


- Rise in food needs by 2050 will be disproportionate to the rise of world population.



1. Food and Agriculture Organization of the United Nations (hereinafter FAO)
2. United Nations
3. International Horticultural Congress

Need for Circularity in Horticulture

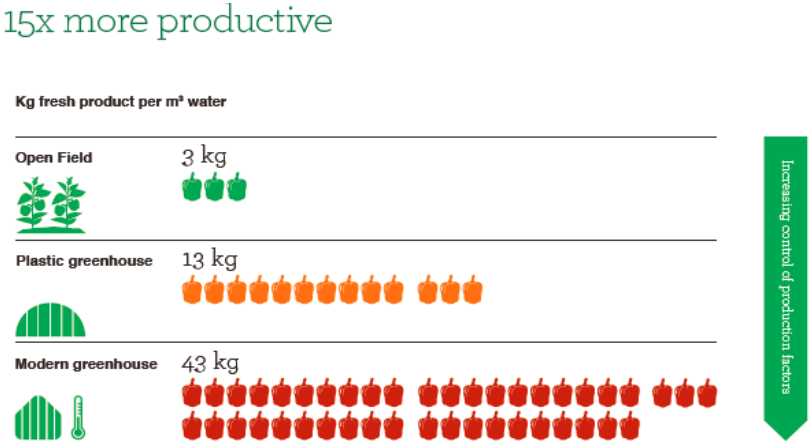


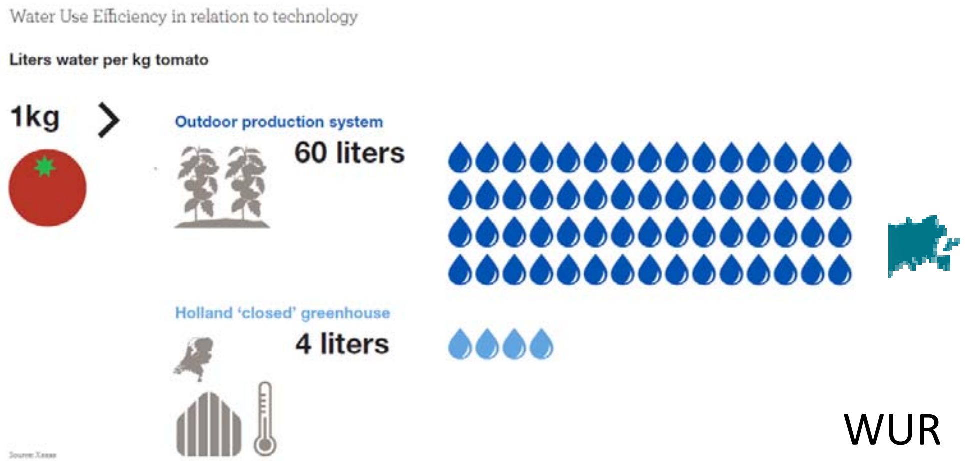
Protected cultivation: why?

- Out-of-season/year round production
- Higher productivity per unit soil surface
- More reliable production (less affected by climate)
- Improved control of pests and diseases
- Higher quality/uniformity of production

Means:

- Improved control of:
  - Temperature; Light; Humidity; CO_2
  - Irrigation and fertilization
  - Pests and fungi

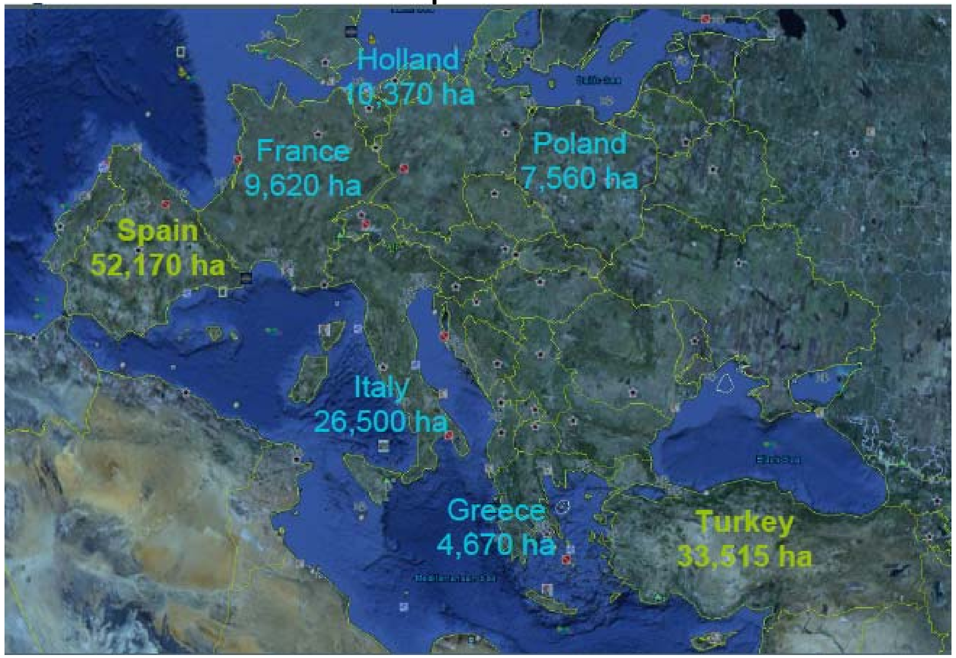




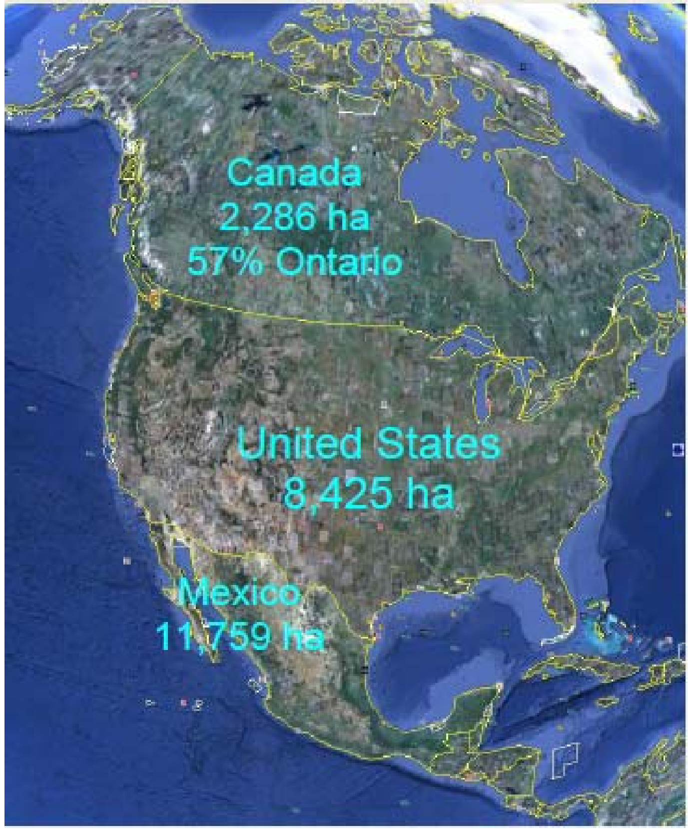
WUR

Worldwide greenhouse areas

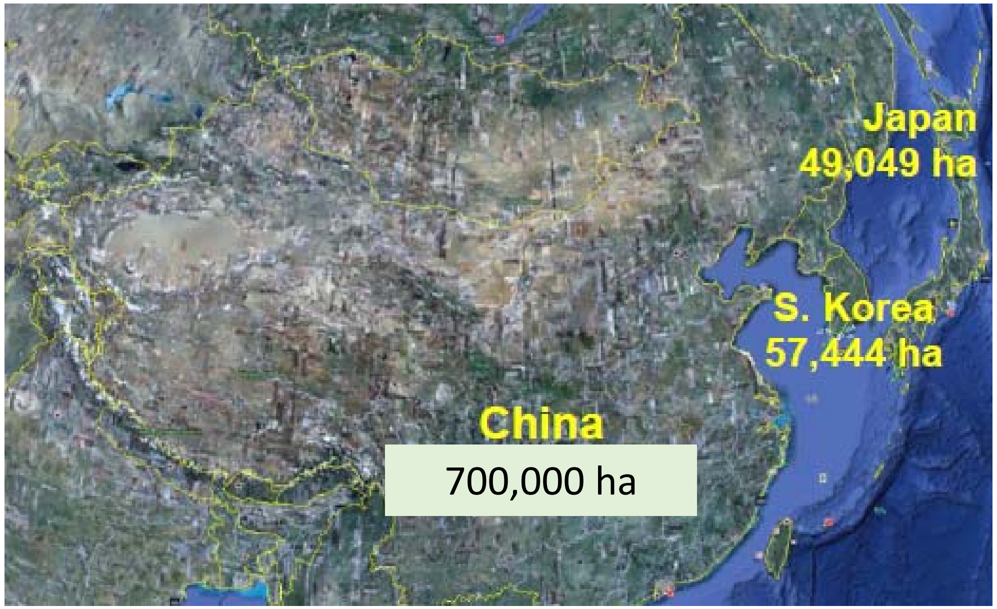
Europe



North America



Asia



Top 5 Countries by Area (ha)

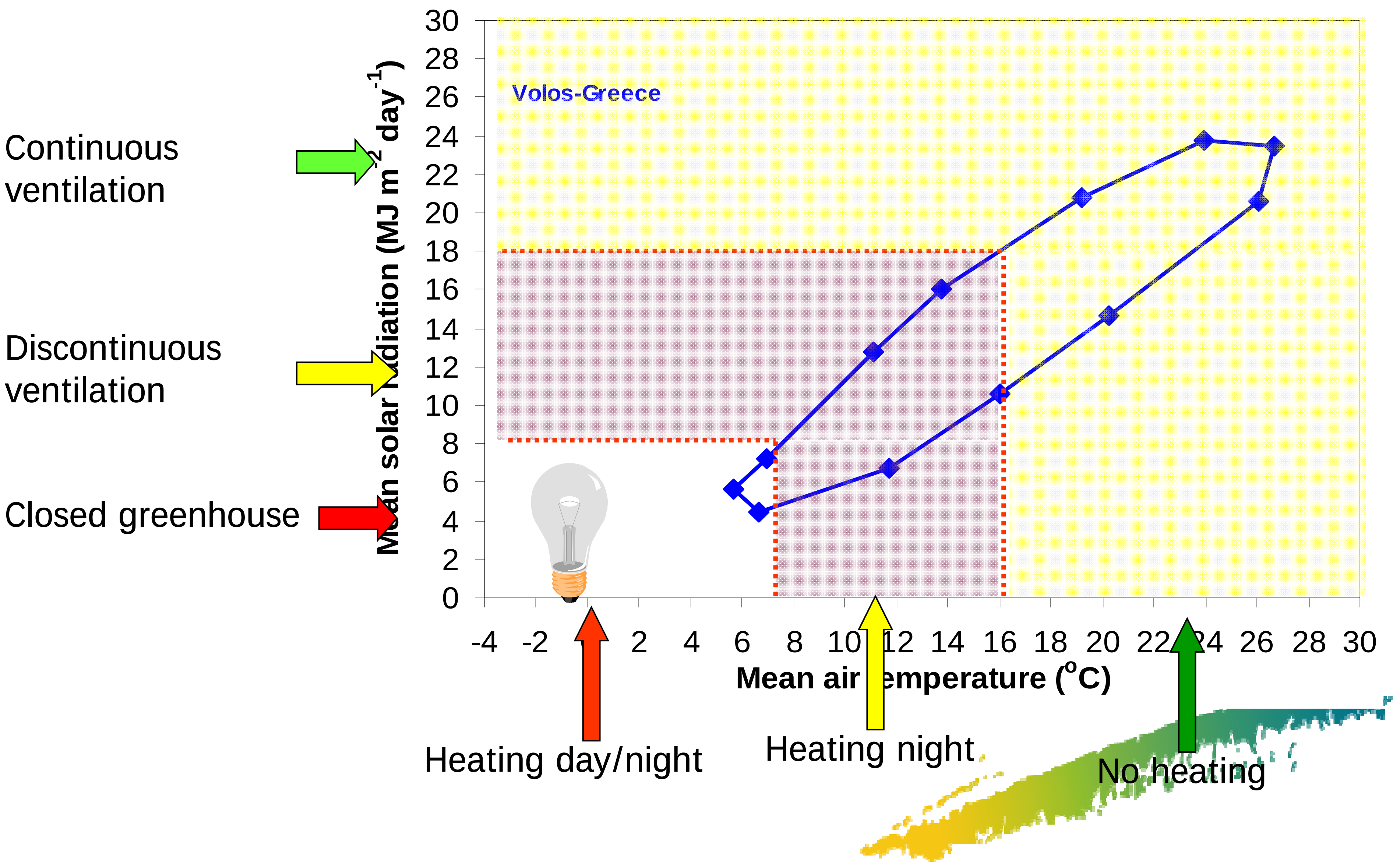
Almeria - Spain

Low and High-tech greenhouses

- PE covered greenhouses
- Ventilation, shading, evaporative cooling
- Soil grown crops
- Fertigation

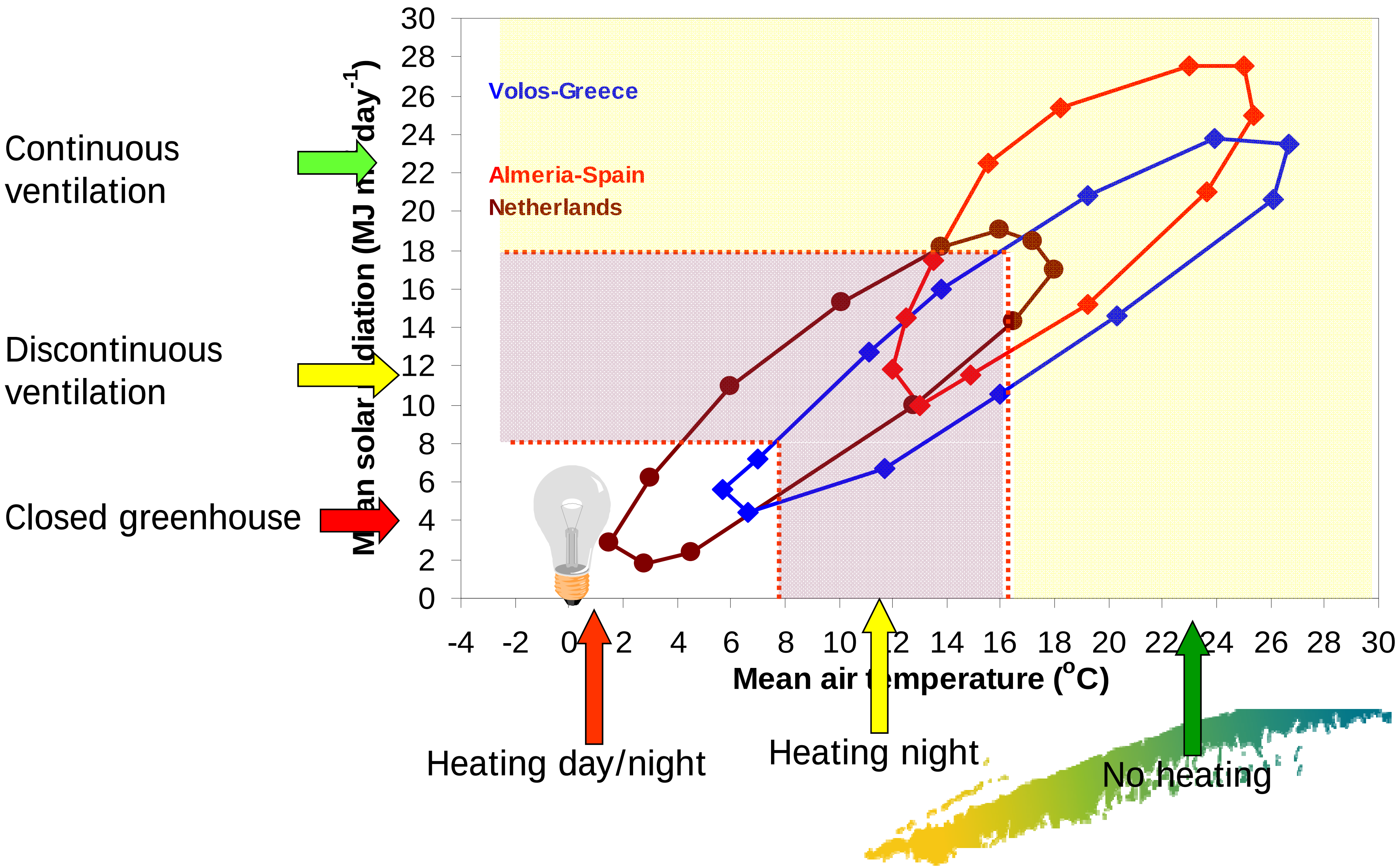
- PE or glass covered greenhouses
- Heating, energy shaving systems, ventilation, shading, evaporative cooling, air mixing, insect proof screens
- Soil or soilles crops in open or closed systems, Fertigation
- DSSs and automations

Regional suitability-needs

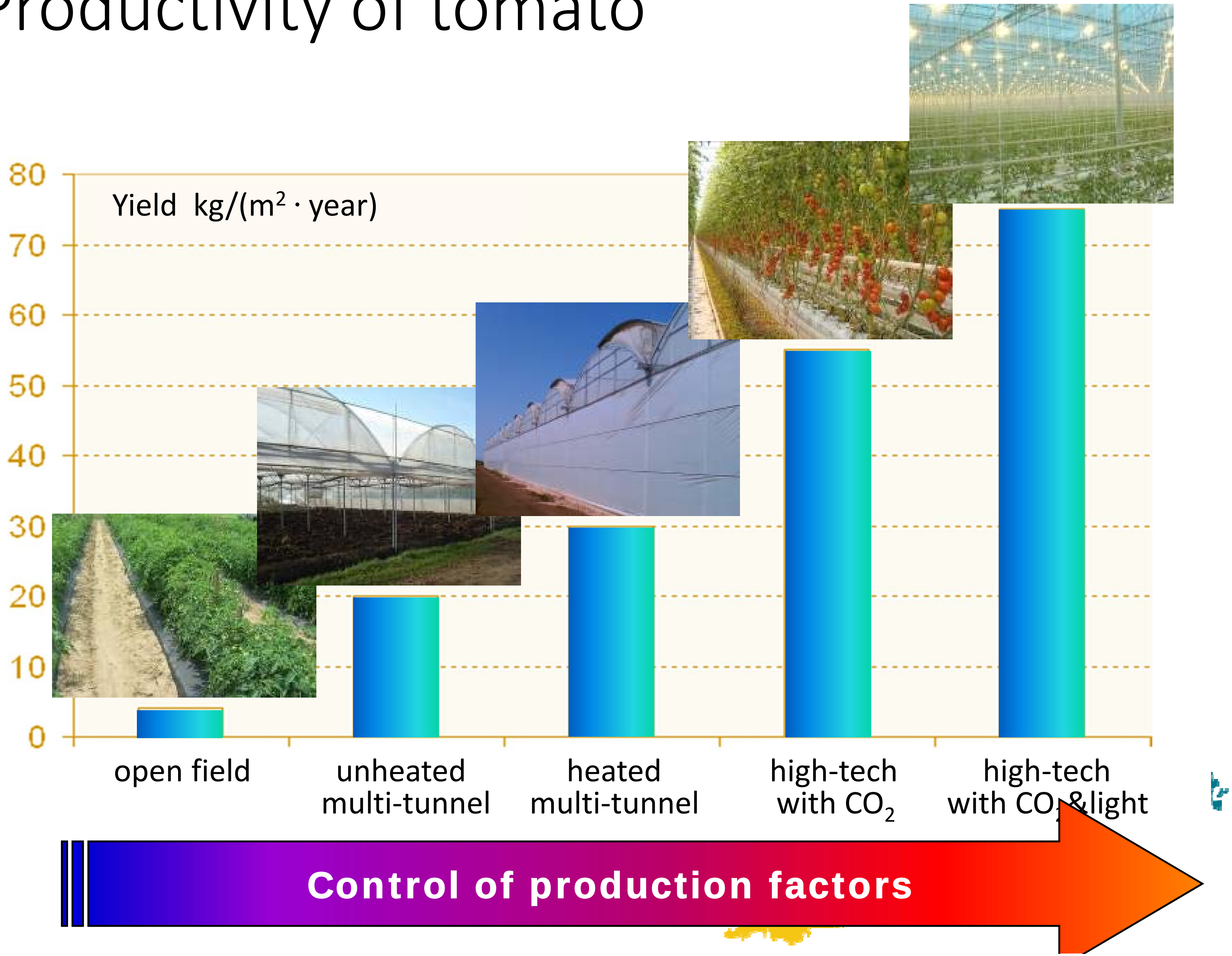



Amsterdam,
Latitude 52,22
Volos,
Latitude 39,22
Almeria,
Latitude 37

Regional suitability-needs



Productivity of tomato



Farm balance for a truss tomato crop under two production strategies

	Netherlands (Venlo)	Spain (Multitunnel)
Production (kg/m²)	55	16
Value (€/kg)	0.93	0.65
Gross income (€/m²)	51.15	10.40

Affected mainly by product value

Affected mainly by outside climate

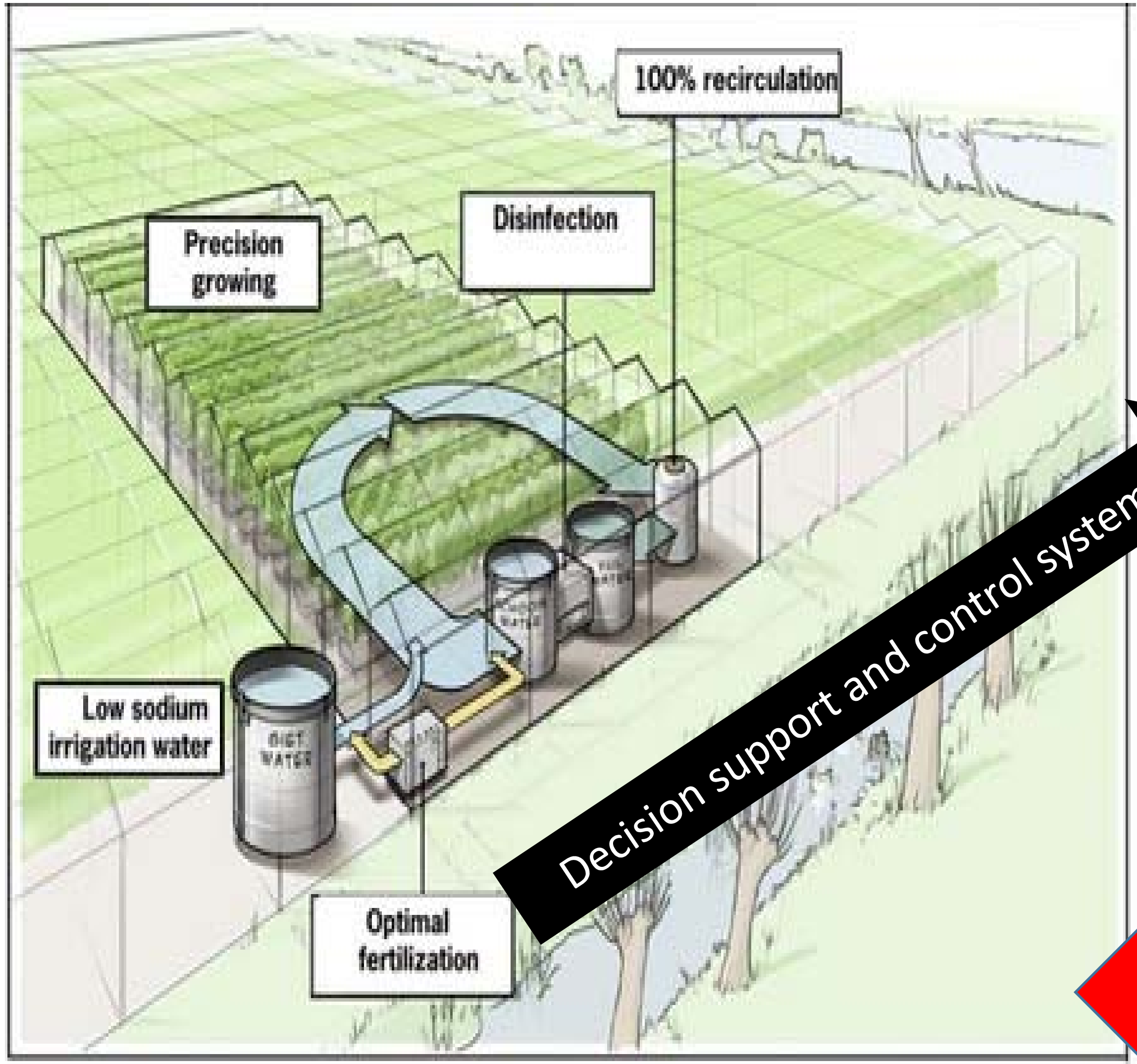
(Vanthoor et al., 2011)

Inputs-waste: degree of circularity?

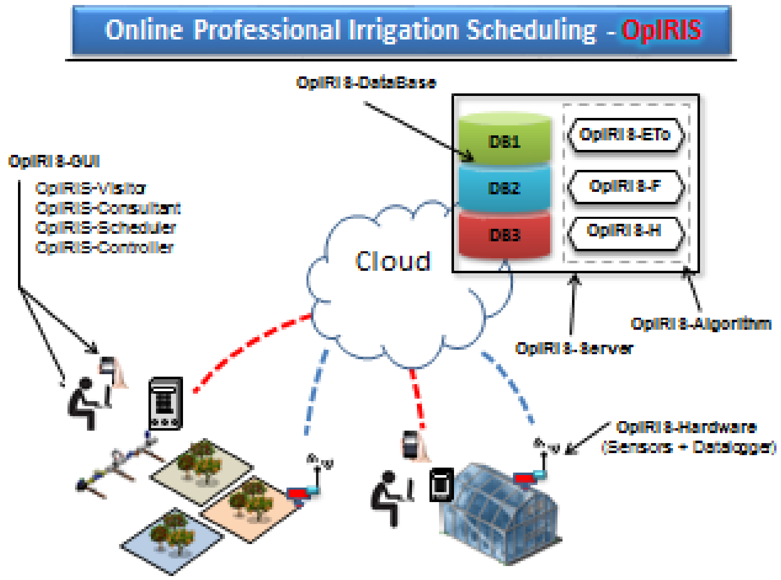
Input
Water
Nutrients-fertilisers
Energy
Soil-substrate
Plastic
Paper

Waste
Water
Nutrients-fertilisers
Energy
Substrate
Plastic
Biomass

Water and nutrients circularity in greenhouses

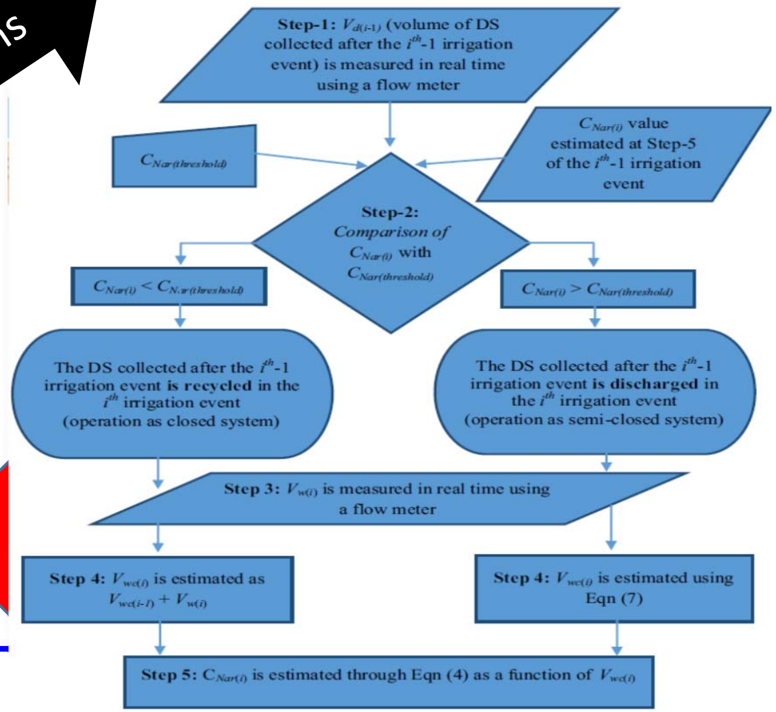


Decision support and control systems

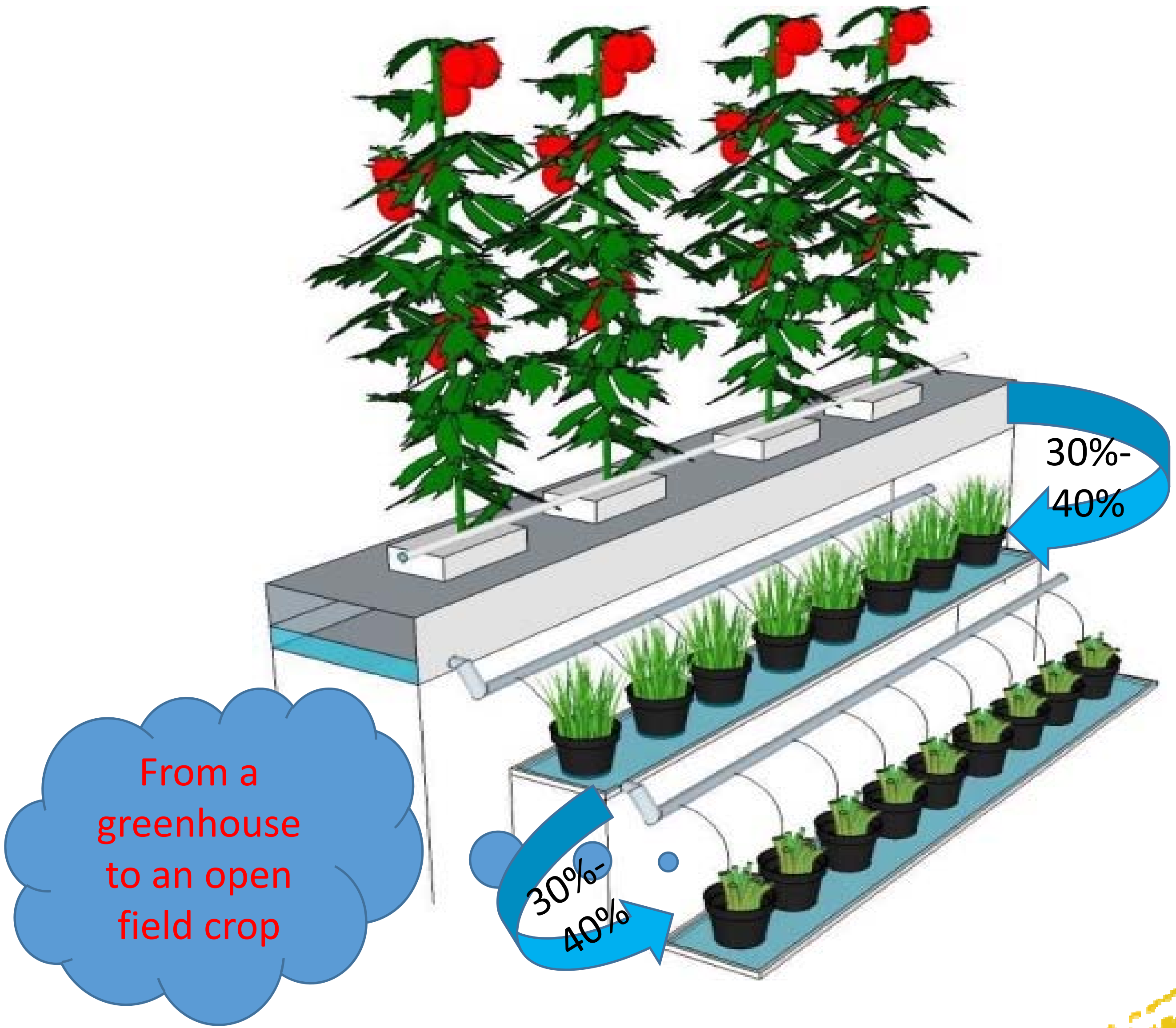


DB1: Data from previous IP projects; DB2: Users' archive; DB3: Historical ETo records and crop coefficients (Kc); OpIRIS: Online Professional Irrigation Scheduling ( ) Irrigation Programmer; ( ) Sensors + device-to-web datalogger; ( ) Smart_Phone application

N. Katsoulas et al./Computers and Electronics in Agriculture 113 (2015) 61–71



Cascade hydroponics



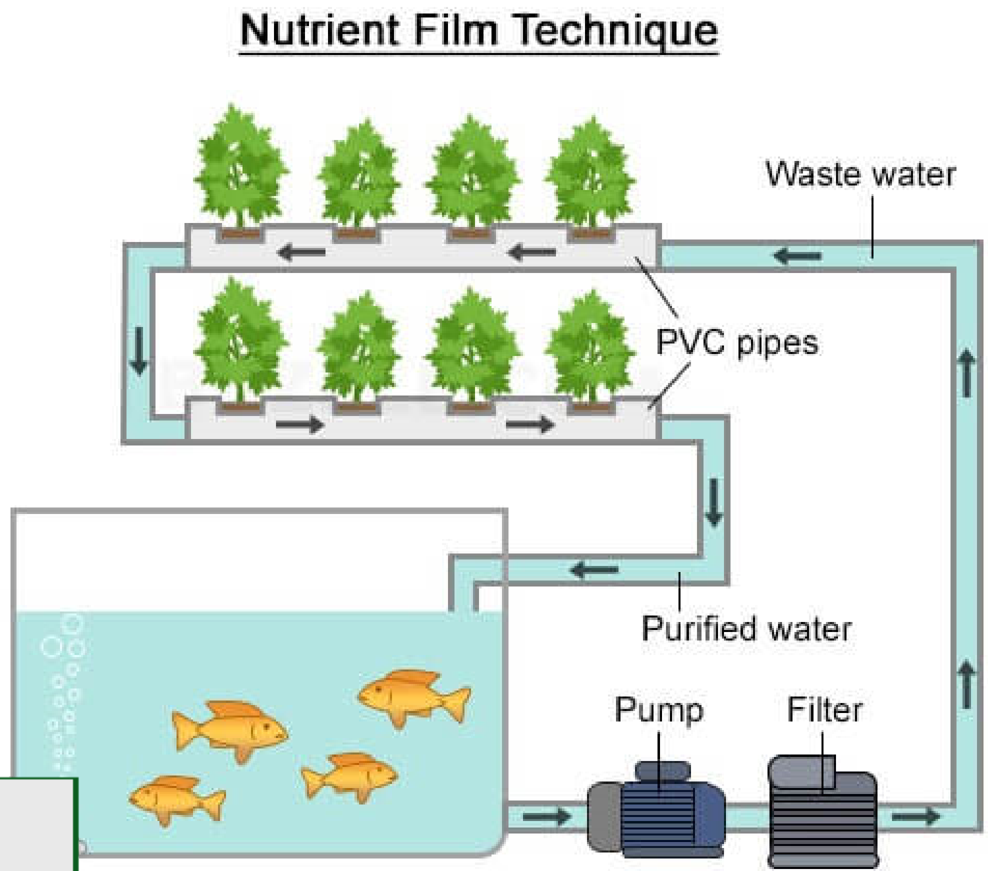
The nitrogen balance for the two combined systems shows an important decrease in N leachate.

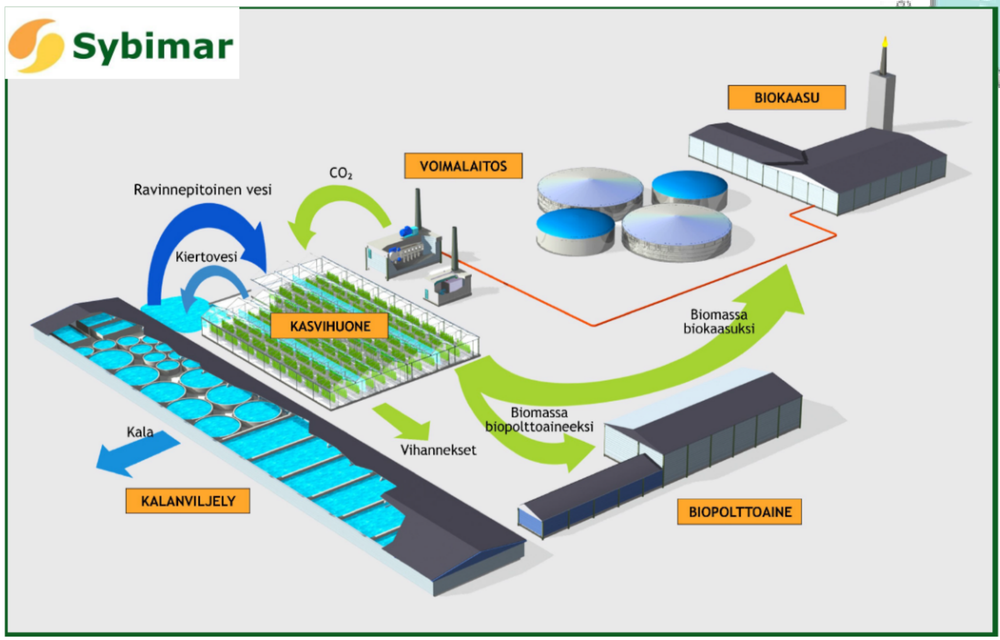
The adoption of the 'cascade' crop system reduced environmental impact for climate change category by 21%, but increased eutrophication category by 10% because of the yield reduction.
Muñoz et al. (2012)

Aquaponics

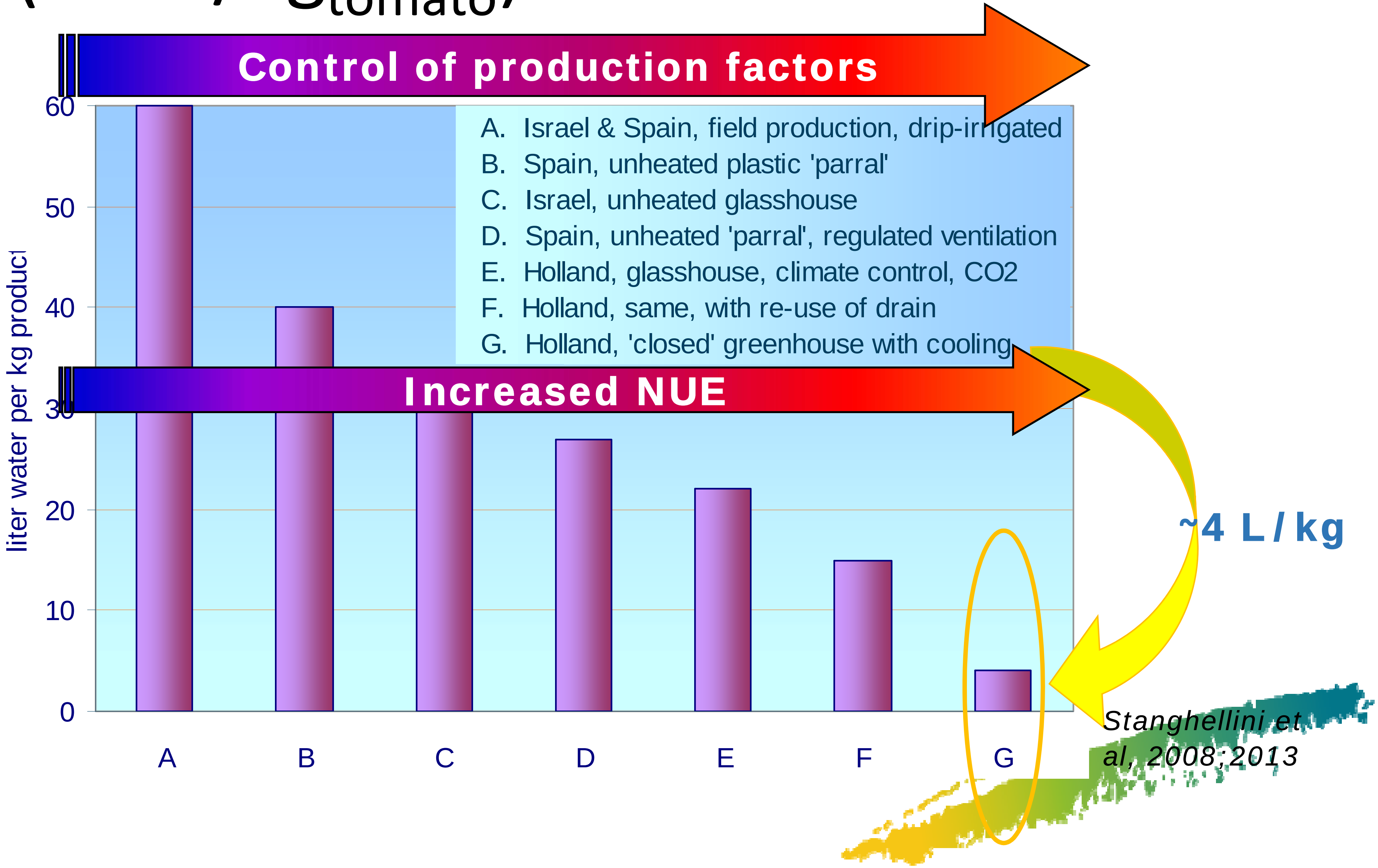
Integration of aquaculture and hydroponics.

Symbiotic growing of fish and vegetables in recirculating water systems – is emerging as one important area of sustainable agriculture.





Water use efficiency (liters/kg_{tomato})

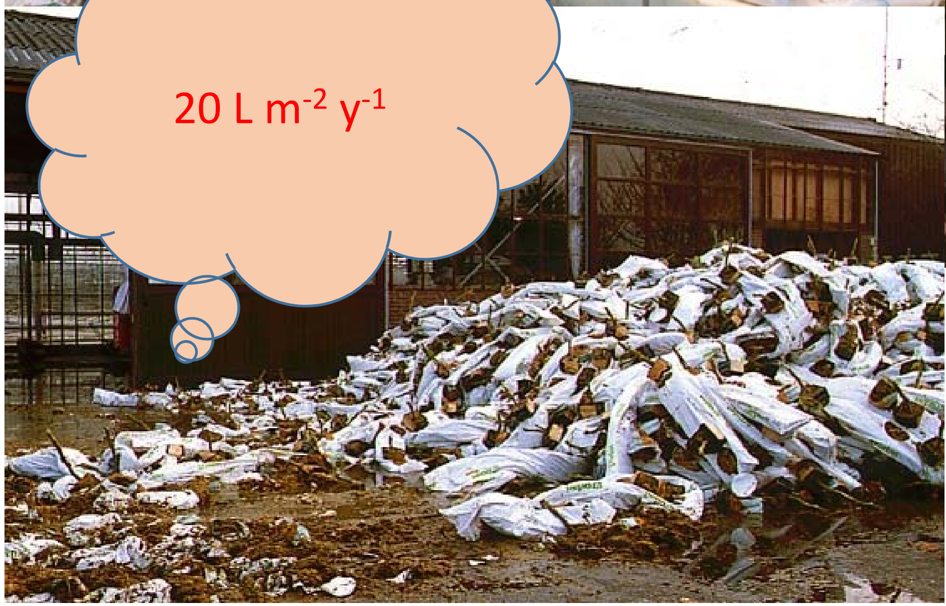


Stanghellini et al, 2008;2013

Plastic (greenhouse and soil cover, pots, fertilizer containers, other)

>0.18 kg m^{-2} y^{-1}

Substrates



20 L m^{-2} y^{-1}

Introduction to greenhouse hydroponics

History of Hydroponics

- Hanging gardens of Babylon
- Aztec floating gardens
- World War II-hydroponics in western Pacific
- Plastics changed everything!
- Boom in 1990's
  - Space program
  - Growing in deserts
  - Vertical farming
  - Large scale production

Advantages

- Crops can be grown where soil is unsuitable
- Reduced plant disease
- More control
- Higher yield

Disadvantages

- Initial costs higher
- Deeper knowledge is needed
- If introduced, diseases can easily spread
- Needs more attention

The basics

- Growing substrates
- Nutrient solution
- System designs

Growing Substrates

- What makes a good media?
  - Provides support
  - Good pore size
  - Does not clog system
  - Does not affect nutrient solution

Photo: /www.aquaponicsusa.com

Growing Substrates

- Rockwool
- Perlite
- Coconut fiber
- Expanded clay pellets
- Coarse Sand
- Pea Gravel
- Vermiculite

Rockwool

- Widely used
- High-water holding capacity
- Good aeration
- Needs a pre-soak to lower pH
- Irritant when dry
- Not easily recyclable, not reusable

- Specific weight 52-75 kg/m^3
- 87%-96% air filed capacity
- pH =7

Photo: grodan101.com


Cultilène
HR

Cultilène HR


Cultilène® MaXXima
40048
Cultilène

Perlite

- Specific weight 94-128 kg/m^3
- 65%-82% air filed capacity
- pH =6,5-7,5

Expanded Clay

- Hydroton/Grow Rocks
- Can be reused (wash and sterlize)
- Free-draining
- May get too dry for ebb & flow systems
- Not good for starting seed

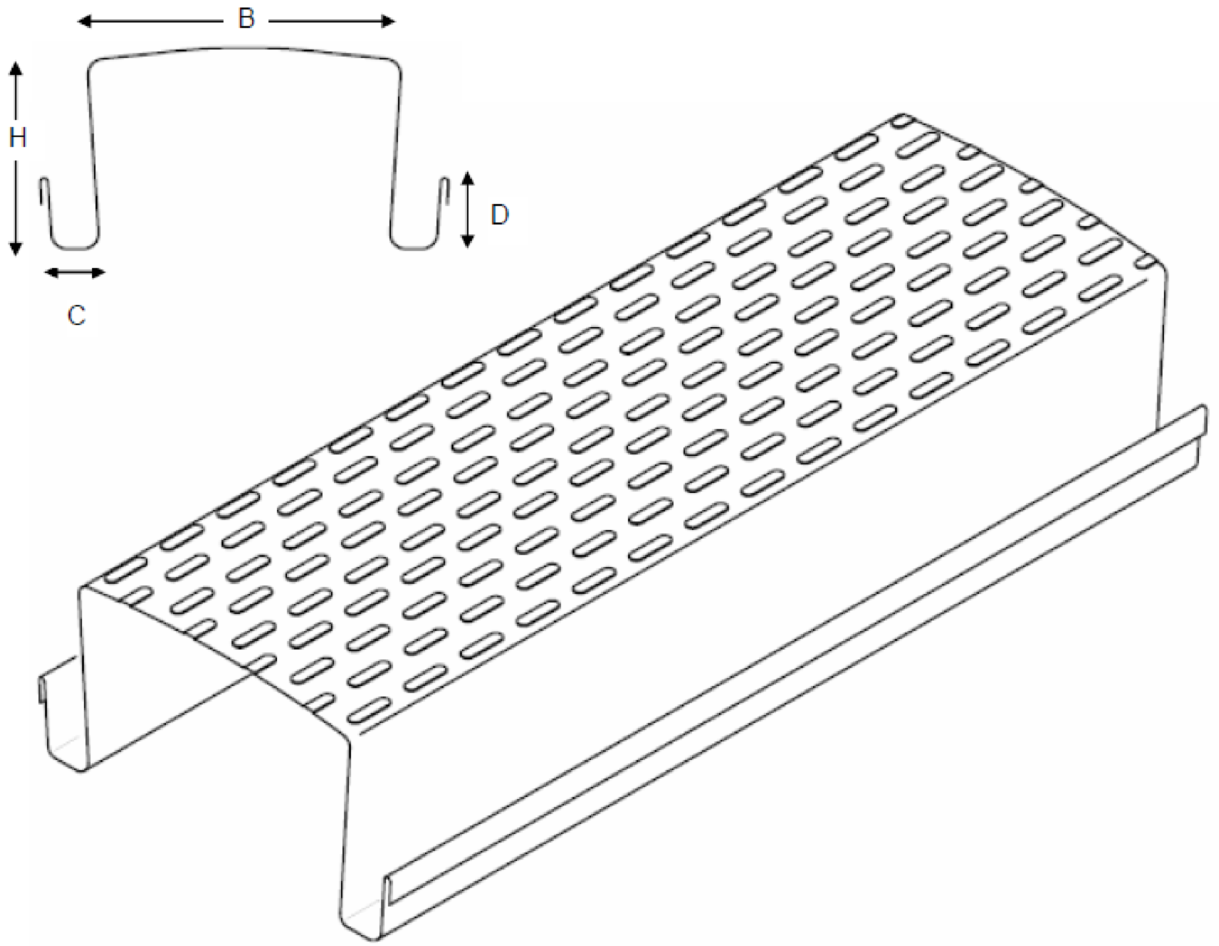
Photo: /www.aquaponicsusa.com

Coconut Fibers (Coir)

- Many different sizes
- Good water holding capacity
- Different grades

Photo: www.kalyx.com/store/images/images_J/J_713170.jpg

Colour	: outside, white; underside, off white



- This grow gutter (FormFlex-Metazet) enjoys exclusive protection on grounds of intellectual ownership rights in the Netherlands and a number of other countries in Europe and beyond.

Gutter size	: Gutter width (W)	210	mm
	Gutter height (H)	120	mm
	Drain channels depth (D)	45	mm
	Drain channels width (C)	30	mm

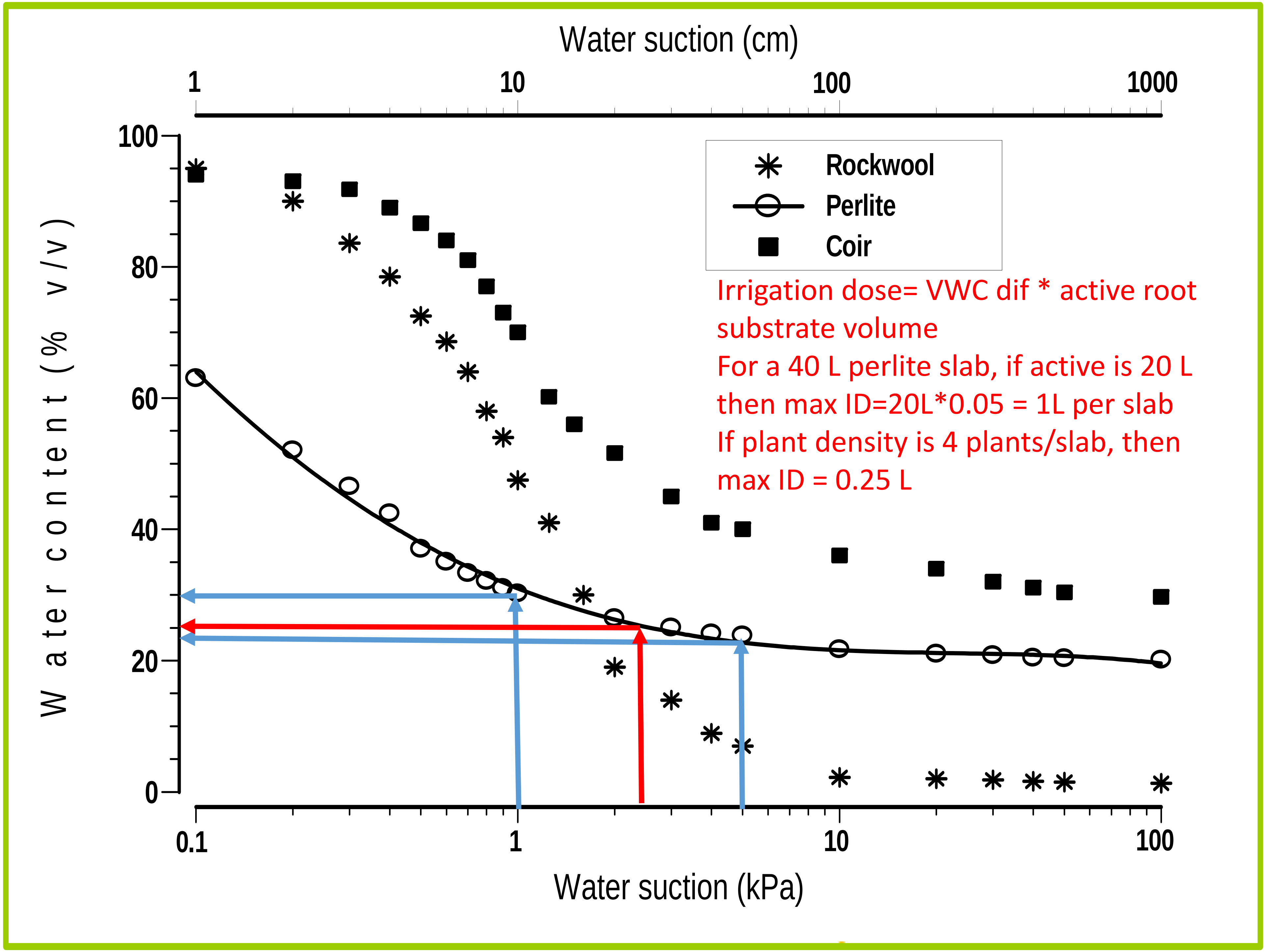
Max. load	: for the mentioned gutter, the maximum load is 15 kg per m^1


Grotop
expert
WPK
grodan
Delta
221

Irrigation scheduling

Dose

Frequency



Water suction (cm)
1
10
100
1000
100
80
60
40
20
0
Water content (% v/v)
Rockwool
Perlite
Coir
Irrigation dose= VWC dif * active root substrate volume
For a 40 L perlite slab, if active is 20 L then max ID=20L*0.05 = 1L per slab
If plant density is 4 plants/slab, then max ID = 0.25 L
0.1
1
10
100
Water suction (kPa)

Base Nutrients

Macro Nutrients

- Nitrogen - (N) is primary to foliage plant growth.
- Phosphorus - (P) Phosphorus helps build strong roots and is vital for flower and seed production.
- Potassium (K) - Potassium increases chlorophyll in foliage and helps regulate stomata openings so plants make better use of light and air

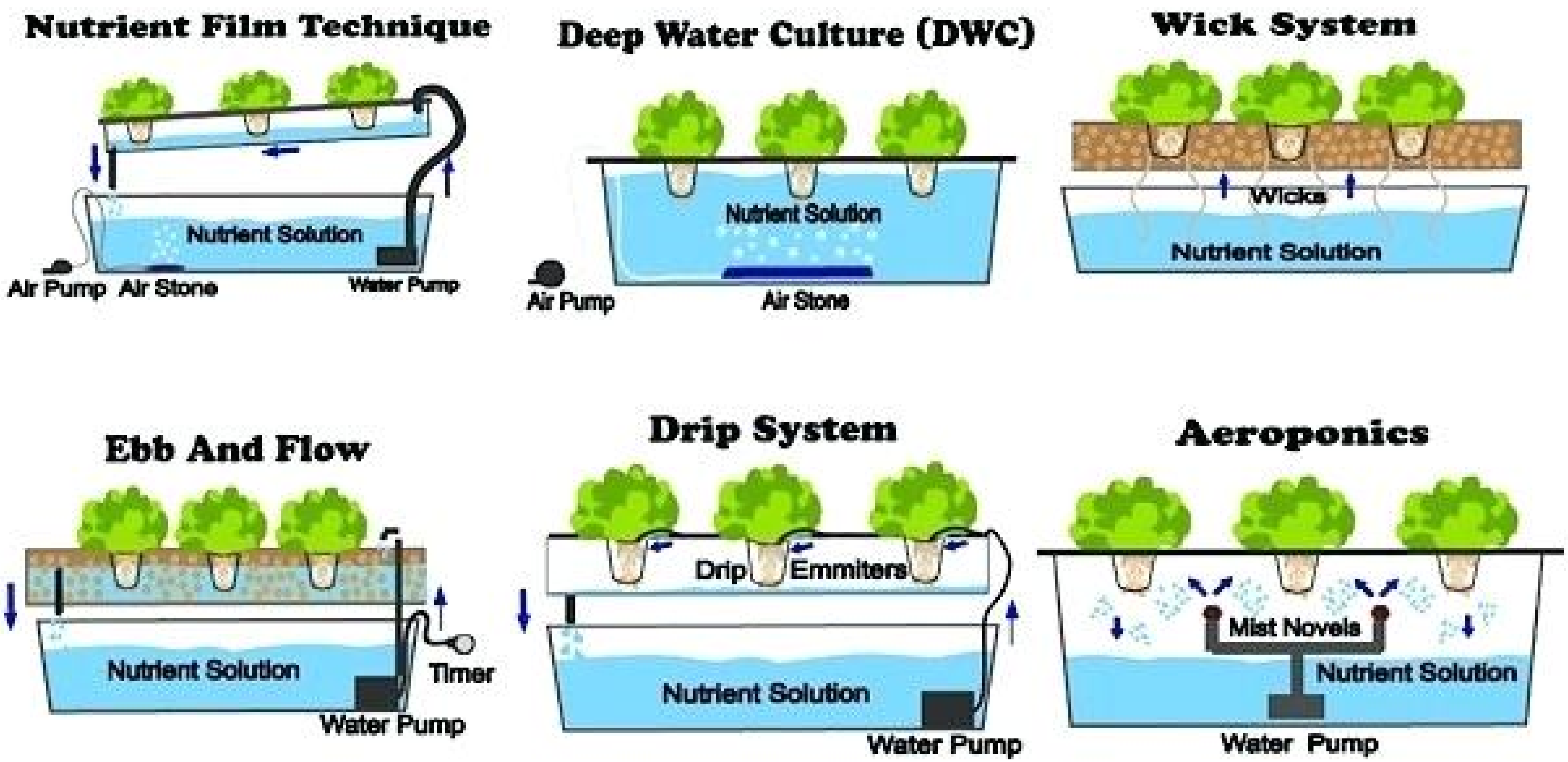
Secondary Nutrients

- Magnesium (Mg), Calcium (Ca)

Trace Elements

- Sulphur (S), Iron (Fe), Manganese (Mg), Zinc (Z), Copper (C), Boron (B), Molybdenum (Mn)

Types of Systems

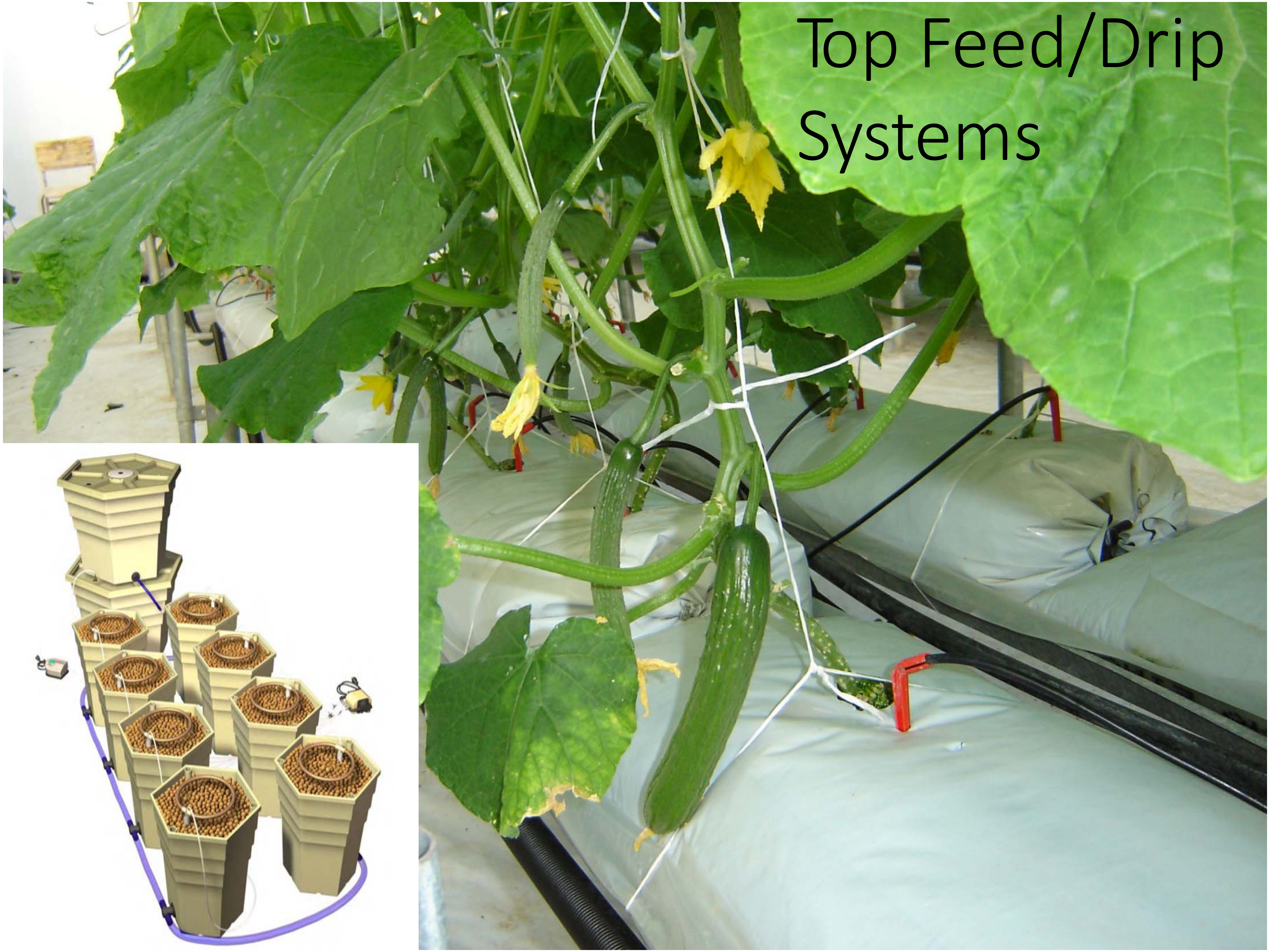


Deep water culture

Photo: Geoff Wilson, Aquaponics Network Australia


Discovery

Top Feed/Drip Systems



NFT

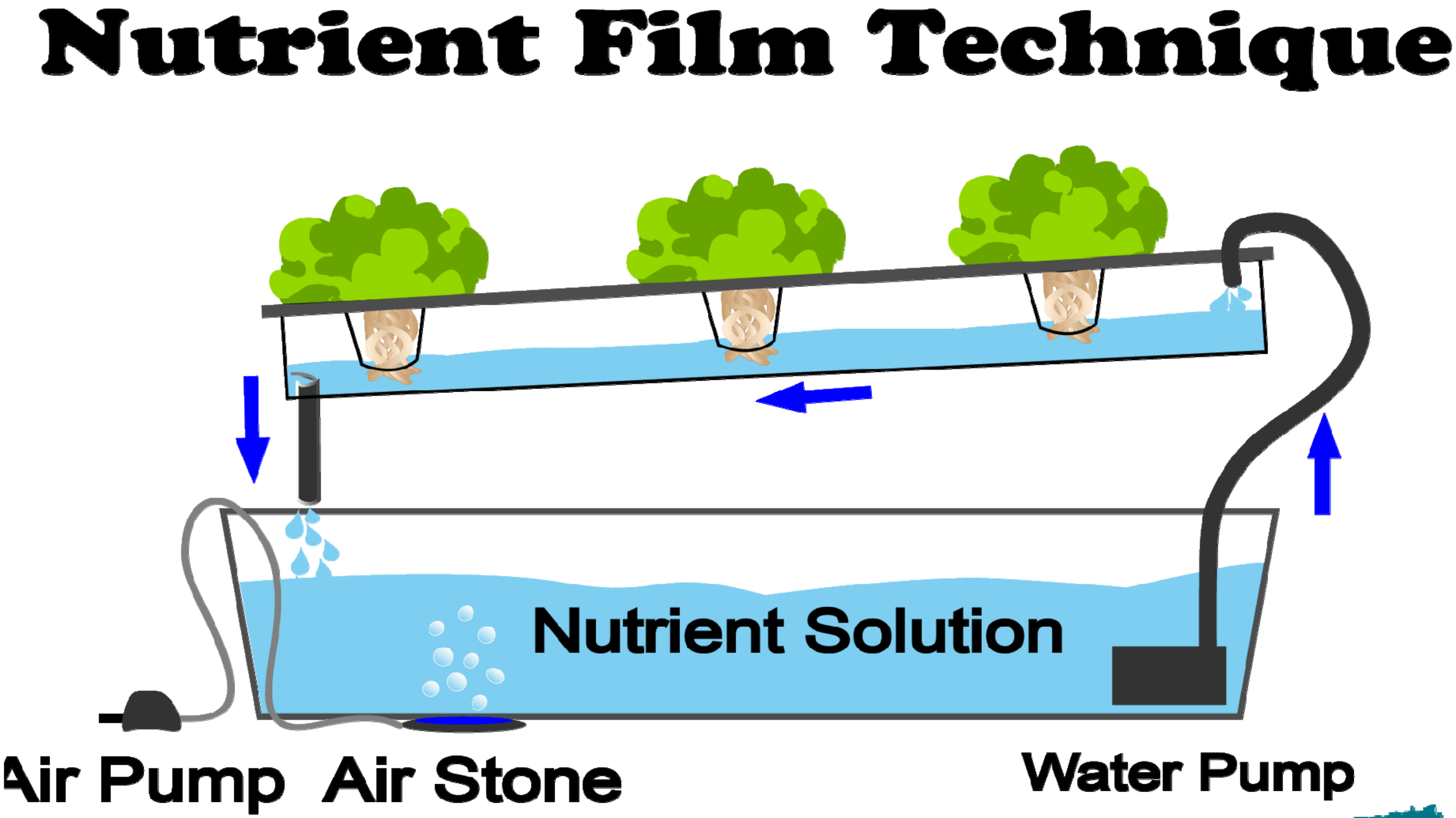

Nutrient Film Technique
Nutrient Solution
Air Pump
Air Stone
Water Pump

Photo: Crop King


SIEMBRA
25.03.10
PLANTADA
04.05.10


TLC200 PRO 2016/07/19 04:56:49

Managing the nutrient solution

- pH
- EC
- Oxygen
- Temperature

pH

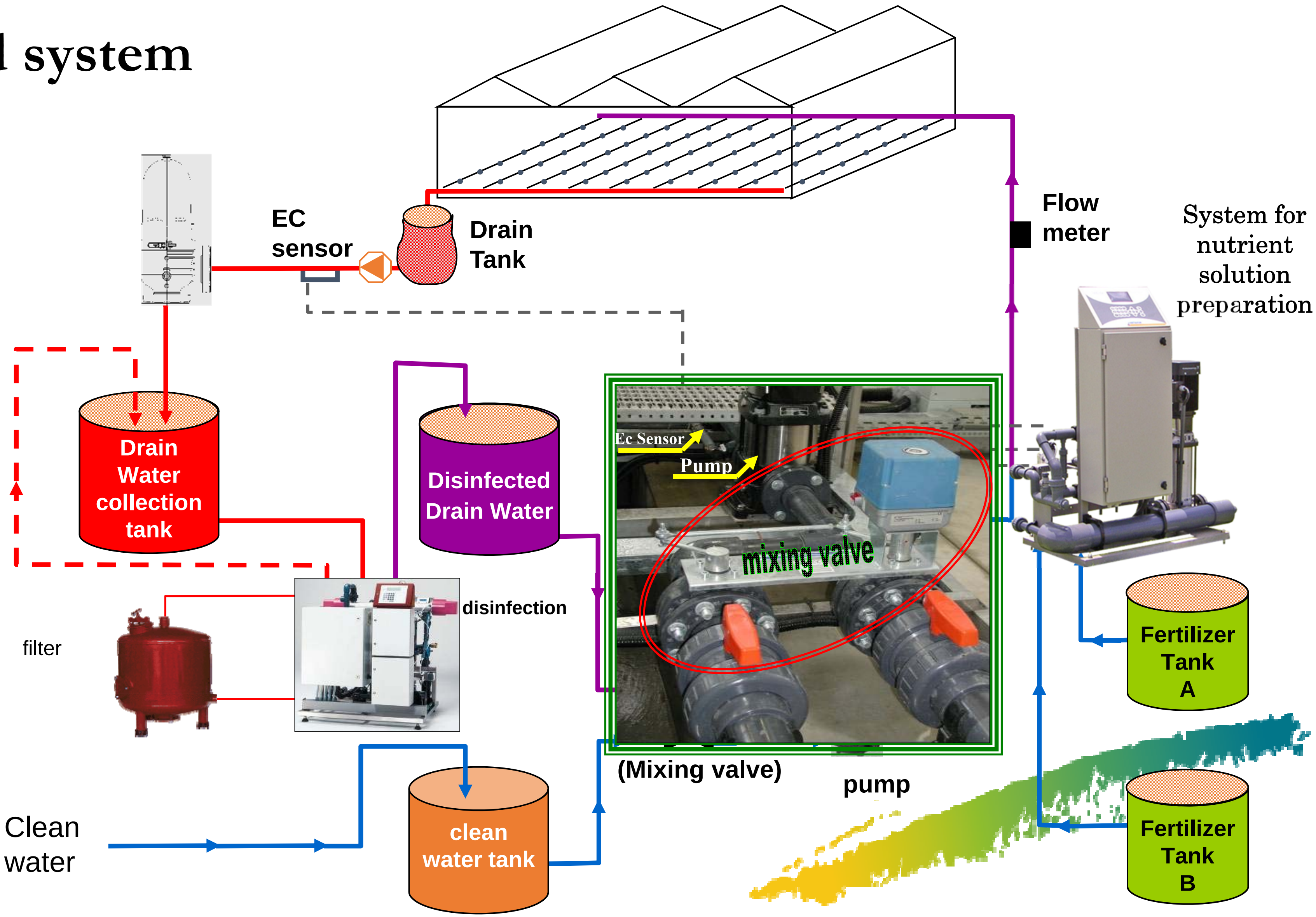
- Measure of how acidic or basic the nutrient solution is
- 0 (acidic) to 14 (basic)
- Most plants prefer 5.8-6.5
- Can change over time
- Affects nutrient uptake

What is EC?

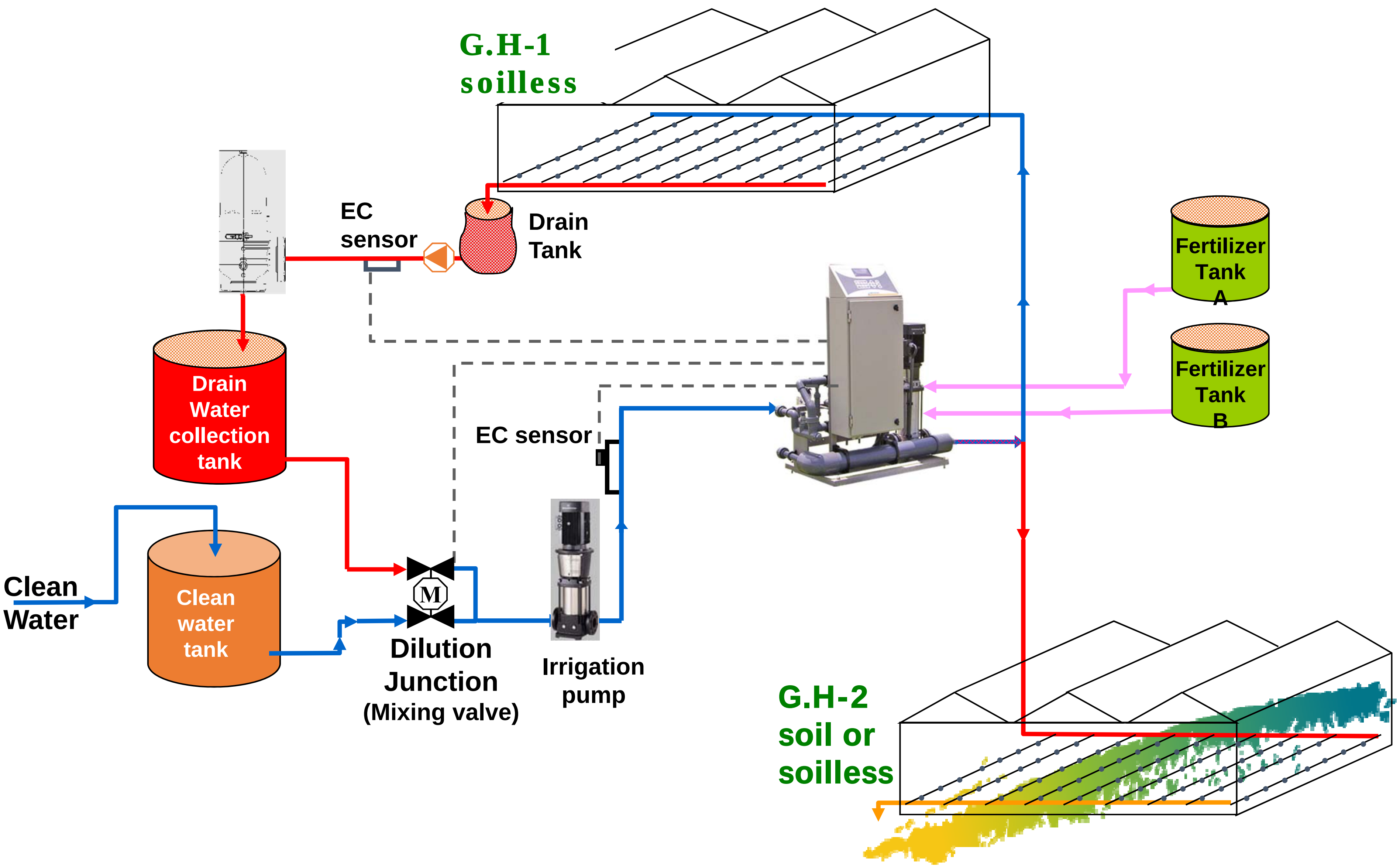
- EC=Electrical Conductivity
- General idea of soluble salts
- Can’t tell you the individual N-P-K

Open, closed or semiclosed systems

Closed system



Semi closed
(1/3 - 2/3)




ATTENZIONE
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ATTENZIONE


A1
A2
B1
multi-K GG
Haifa
743

Nutrient solution preparation

Nutrients

Macro	Chemical type	Micro	Chemical type
Nitrogen (N)	NO_3^-, NH_4^+	Iron (Fe)	Fe^{2+}
Phosphorus (P)	$H_2PO_4^-$	Manganese (Mn)	Mn^{2+}
Sulphate (S)	SO_4^{2-}	Zinc (Zn)	Zn^{2+}
Potassium (K)	K^+	Copper (Cu)	Cu^{2+}
Calcium (Ca)	Ca^{2+}	Boron (B)	H_3BO_3
Magnesium (Mg)	Mg^{2+}	Molybdenum (Mo)	MoO_4^{2-}

In mmol/L or meq/L

EC

$$[NH_4^+] + [K^+] + [Ca^{++}] + [Mg^{++}] + [H_3O^+] =$$

$$[NO_3^-] + [H_2PO_4^-] + [SO_4^{--}] \quad = \; C$$

Concentrations in meq/L,

C total concentration of anions or cations.

C = EC * 10

Where EC is in dS/m

Typical concentrations

Macro Nutrient (mmol/L)	Hoagland & Arnon	Sonneveld & Straver, cucumber	Micro Nutrient (µmol/l)	Hoagland & Arnon	Sonneveld & Straver, cucumber
NO_3^-	14.0	16.00	Fe	25.00	15.00
$H_2PO_4^-$	1.0	1.25	Mn	9.10	10.00
SO_4^{2-}	2.0	1.40	Zn	0.75	5.00
K^+	6.0	8.00	Cu	0.30	0.75
NH_4^+	1.0	1.25	B	46.30	25.00
Ca^{2+}	4.0	4.00	Mo	0.10	0.50
Mg^{2+}	2.0	1.40			

Nutrient solution preparation

- We prepare concentrated nutrient solutions (100-200 times) to avoid very often preparation of the solution.
- Then, the basic nutrient is diluted with water to prepare the ready for irrigation nutrient solution
- The simplest system must include three concentrated nutrient solution tanks, two with nutrients [calcium can not be mixed with phosphates and sulfates to avoid $Ca(H_2PO_4)_2$ and $CaSO_4$ formation] and one with acid [usually HNO_3] for pH control.

Concentrated nutrient solution tanks

Concentrated tank A	
1	Calcium Nitrate
2	Potassium Nitrate
3	Ammonium Nitrate
4	Iron

Concentrated tank B	
1	Potassium Nitrate
2	All the rest
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	

Difficulties in preparing a nutrient solution

Fertilizers (salts) contain both anions and cations

For example (K) can be added by:

$KNO_3 \rightarrow K^+ + NO_3^-$

$KH_2PO_4 \rightarrow K^+ + H_2PO_4^-$

$K_2SO_4 \rightarrow K^+ + SO_4^-$

$KCl \rightarrow K^+ + Cl^-$

Nutrient solution preparation
Macronutrients

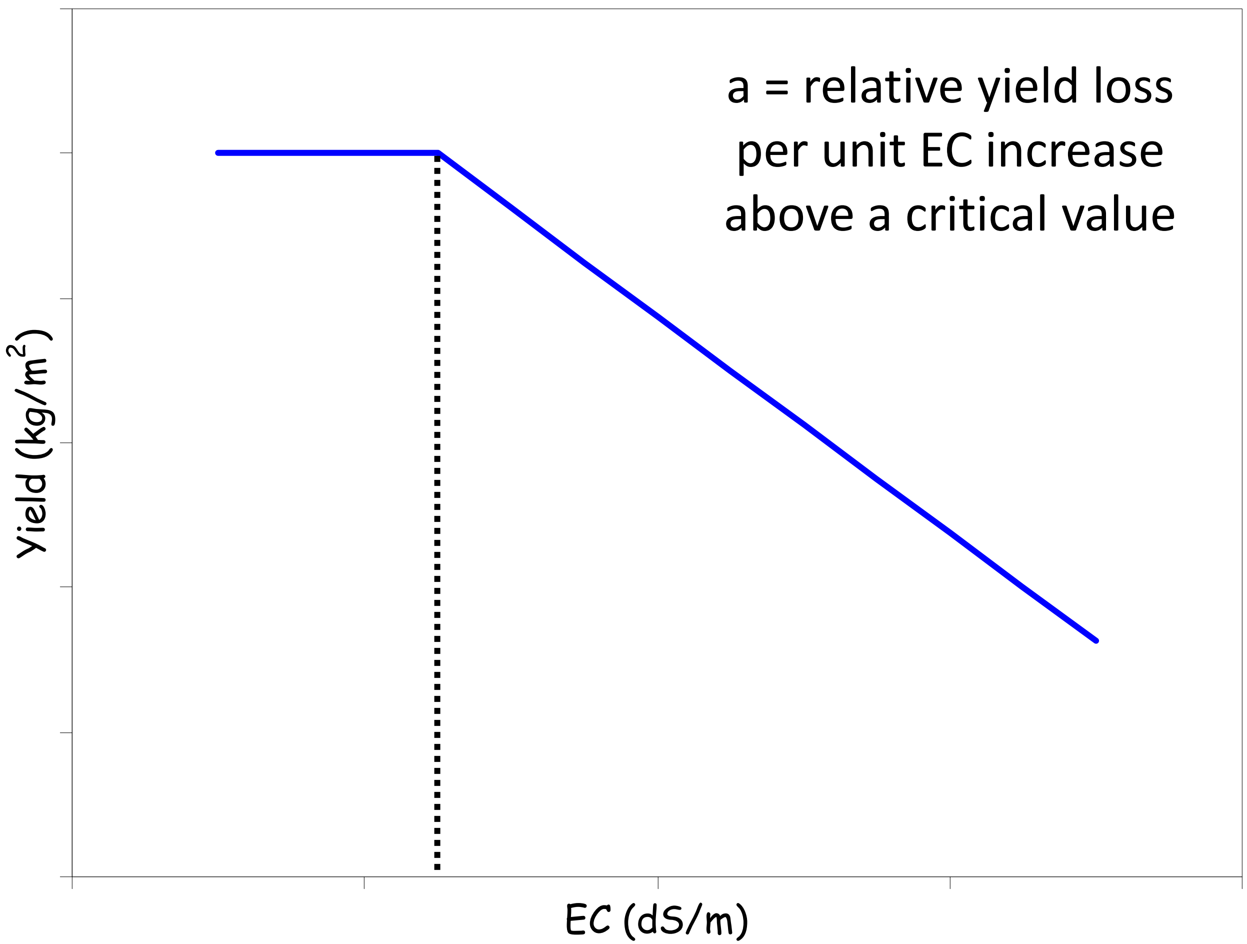
	NO_3^-	$H_2PO_4^-$	SO_4^{--}	H_3O^+	NH_4^+	K^+	Ca^{++}	Mg^{++}
Επιθ. Συγκ.	11.75	1.25	1		0.5	5.5	3.5	1
mmol / l								
$Ca(NO_3)_2$	7						3.5	
$MgSO_4$			1					1
$Mg(NO_3)_2$	0							0
K_2SO_4			0			0		
NH_4NO_3	0.5				0.5			
H_3PO_4		0		0				
KH_2PO_4		1.25				1.25		
KNO_3	4.25					4.25		
HNO_3	0			0				
	11.75	1.25	1	0	0.5	5.5	3.5	1

Absorption concentration

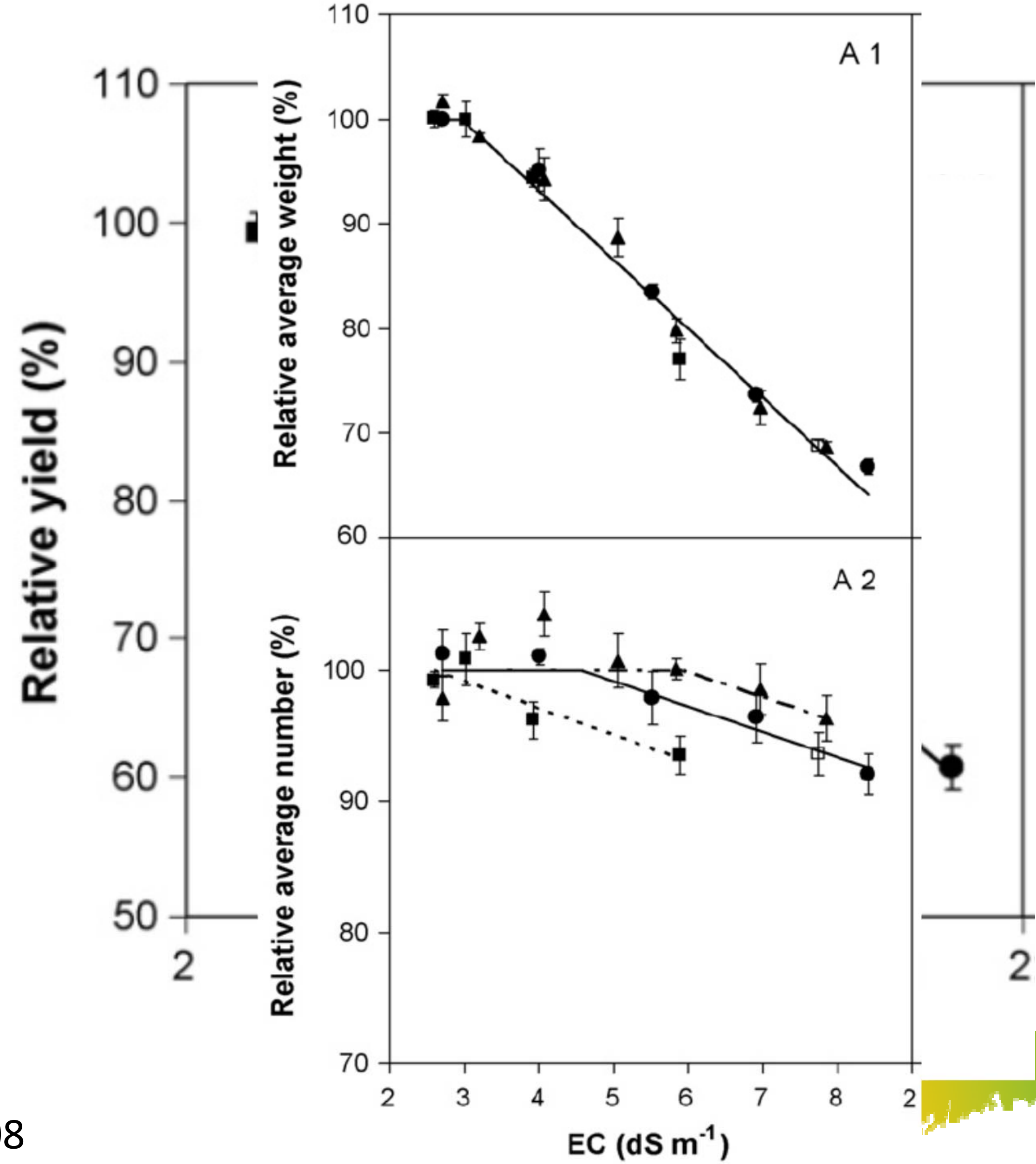
- mmol of a nutrient absorbed per liter of water absorbed.
- Lets assume that the concentration of K^+ in the irrigation solution is 6 mmol/L and that the absorption concentration is 5 mmol/L.
- If the drainage rate is 30%, which percentage of the applied K^+ is drained?
- $K_{applied}=6*V$
- $K_{drained}= 0.7*(6-5)*V + 0.30 *6*V= 2.5*V$
- $K_{drained}$ =2.5V/6V = 42% of $K_{applied}$

Salinity management

Salinity effects on crop yield



Salinity effects on crop yield

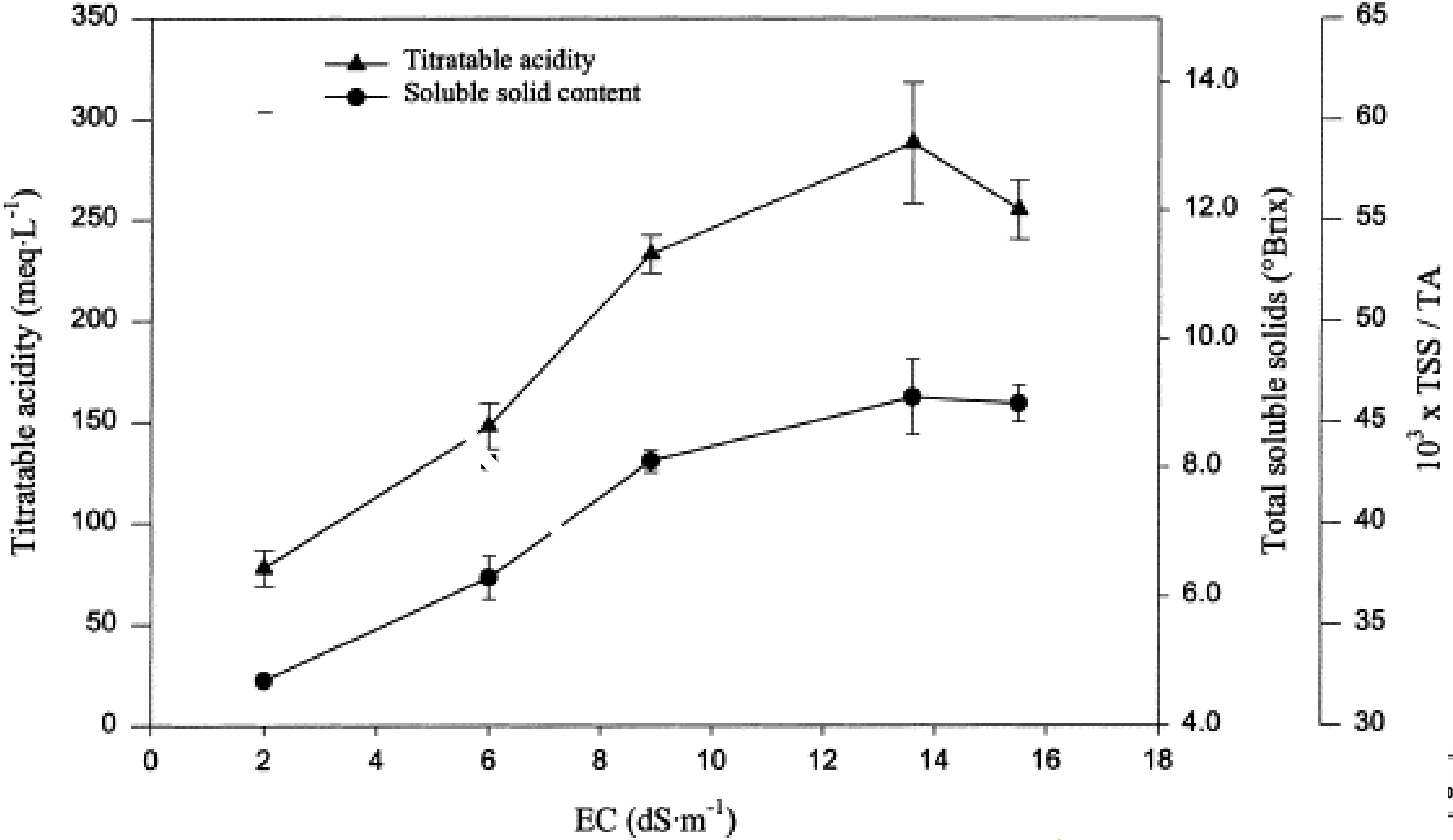


tomato

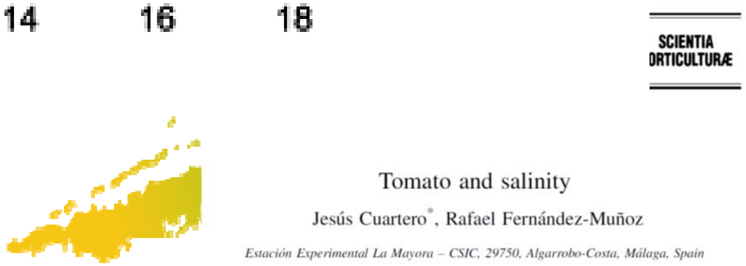

Effects of salinity on fruit yield and quality of tomato grown in soil-less culture in greenhouses in Mediterranean climatic conditions

Magan et al., 2008

Salinity effects on product quality



Cuartero and Fernandez-Munoz, 1999



Alternatives to overcome Salt Accumulation- <u>Practical Management</u>

- Desalination
- Dealing with salinity
- Control
- Others

Desalination

- Desalination technologies do exist but it's a matter of cost if and when we have to apply them.
- Semi-closed soilless system will help to make des. more economically feasible
- Mix of rain water, surface water or water from any other source to delay salt accumulation.

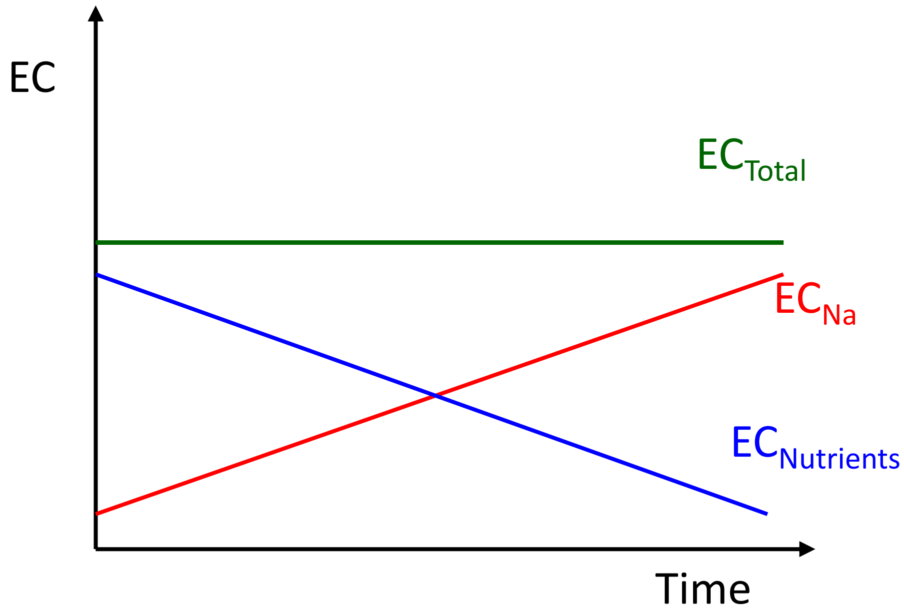
Dealing with Salinity

- Open or semi-closed: economize drainage fraction
  - Use drainage for other purposes/crops
  - Cascade solution
- Closed systems: discharge
- Optimise nutrient solution (basic input, analysis, adjustments in time)
- Maximise the acceptable accumulation for Na^+ / Cl^- / SO_4^{--} … by depleting the concentrations of nutrients to lowest acceptable minima

Standard methods for NS recirculation

- preparation of a nutrient solution with a composition corresponding to the estimated nutrient to water uptake ratios (de Kreij et al. 1999)
- the NS is blended with the DS to be recycled.

Mixing strategies



Elements	Accumulation of NaCL	
	Without	Maximum
K	8.0	4.0
Na	0	22.0
Ca	10.0	4.0
Mg	4.5	1.5
NO_3	23.0	10.5
Cl	0	22.0
H_2PO_4	1.0	0.5
SO_4	6.5	2.0

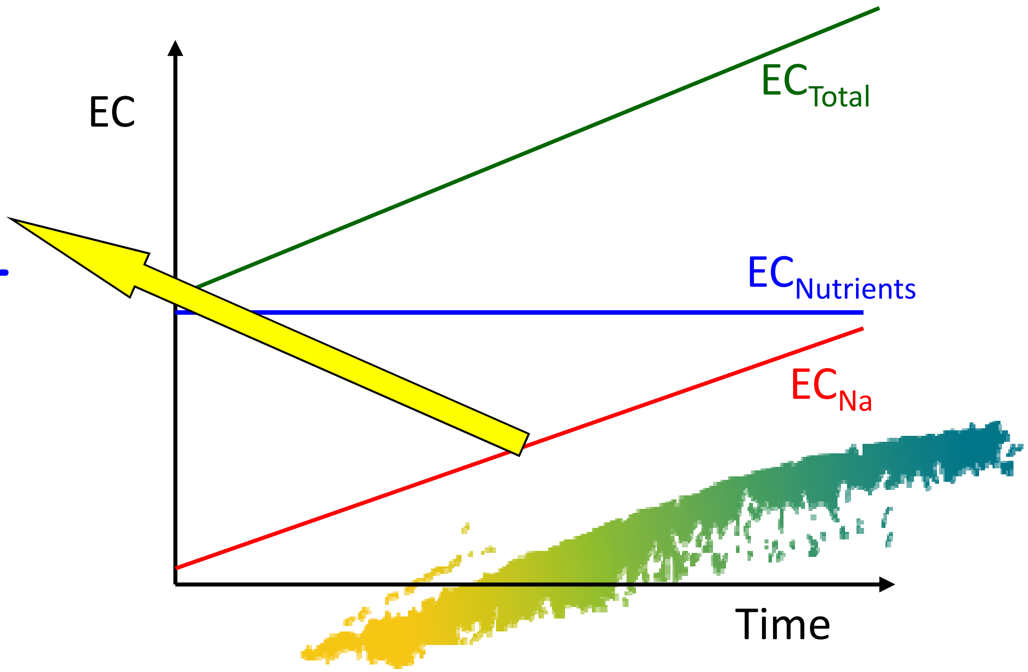
Standard methods for NS recirculation

- preparation of a nutrient solution with a composition corresponding to the estimated nutrient to water uptake ratios (de Kreij et al. 1999)
- the NS is blended with the DS to be recycled.

Mixing strategies

How to estimate C_{Na} ?

- Analysis of NS in the Lab
- On-line monitoring of salt ion concentrations (ion-selective electrodes)
- Model based estimations



How to estimate C_{Na} ?

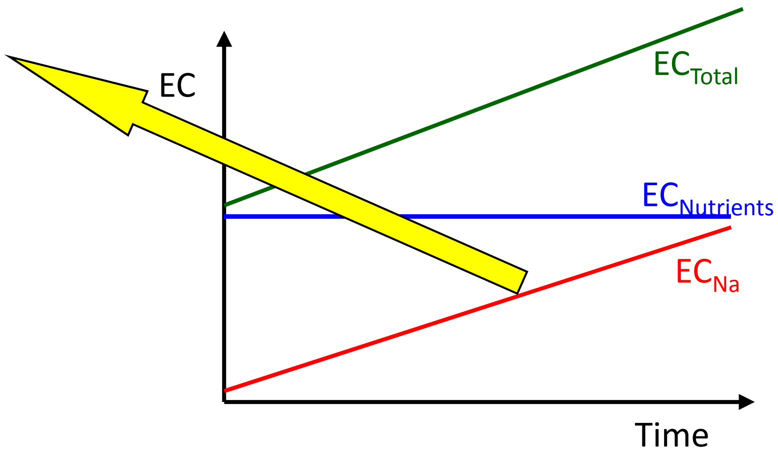
On-line monitoring of salt ion concentrations (ion-selective electrodes)

.

Attractive for practical applications as it allows the use of small size sensor, low cost in real time.

However, there are practical limitations:

- min, max time needed/allowed in the solution
- regular calibration
- special attention to maintenance
- accuracy



DSS for on-line control of [Na^+]

A decision-support-system for management of the drainage solution in semi-closed hydroponic systems was developed (Katsoulas et al., 2015).

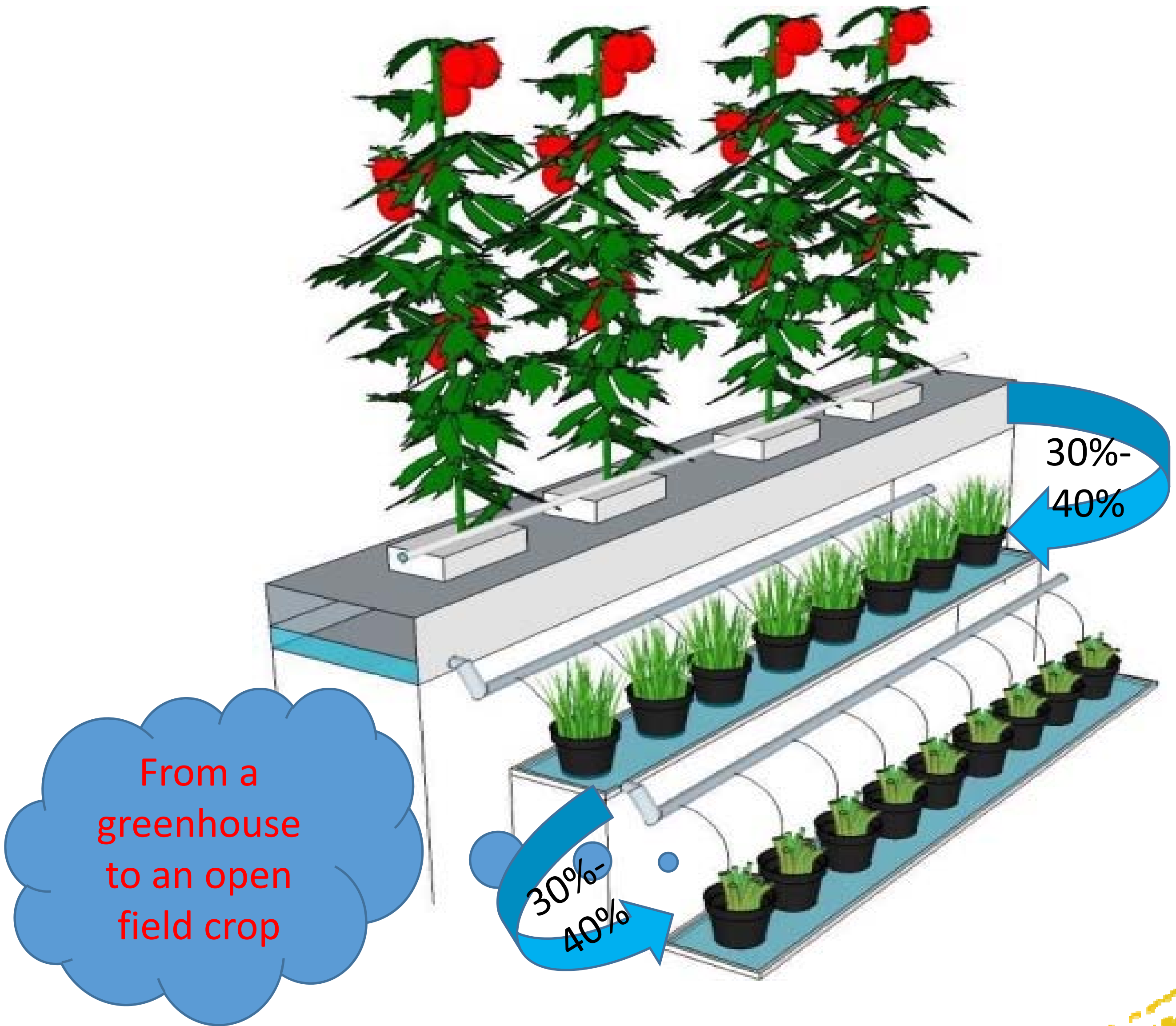
The system is based on:

- Na^+ mass-balance model (Savvas et al., 2007; 2008; Varlagas et al., 2010) and

- measurements of water flow in the system

Kittas et al., 2013. Key on-farm irrigation techniques to save water. Sustainable use of irrigation water in the Mediterranean Region (Sirrimed). Project report. WP1.

Cascade hydroponics



The nitrogen balance for the two combined systems shows an important decrease in N leachate.

The adoption of the 'cascade' crop system reduced environmental impact for climate change category by 21%, but increased eutrophication category by 10% because of the yield reduction.
Muñoz et al. (2012)

INTERNATIONAL SYMPOSIUM ON ADVANCED TECHNOLOGIES AND MANAGEMENT FOR INNOVATIVE GREENHOUSES
GreenSys 2019
16th to 20th June 2019 ANGERS FRANCE

Reuse of cucumber drainage nutrient solution in 'secondary' crops in greenhouses: preliminary results

N. Katsoulas, A. Elvanidi, E. Gourzoulidou,

University of Thessaly, Dept. of Agriculture Crop Production and Rural Environment, Laboratory of Agricultural Constructions and Environmental Control, Volos, Greece

J.F.J. Max, C.M. Demmelbauer-Benitez

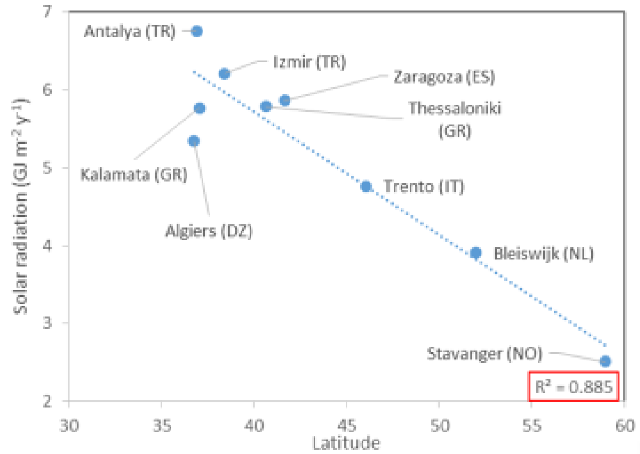
Hochschule Geisenheim University, Dept. of Soil Science and Plant Nutrition, Hochschule Geisenheim University, Dept. of Vegetable Crops, Geisenheim, Germany

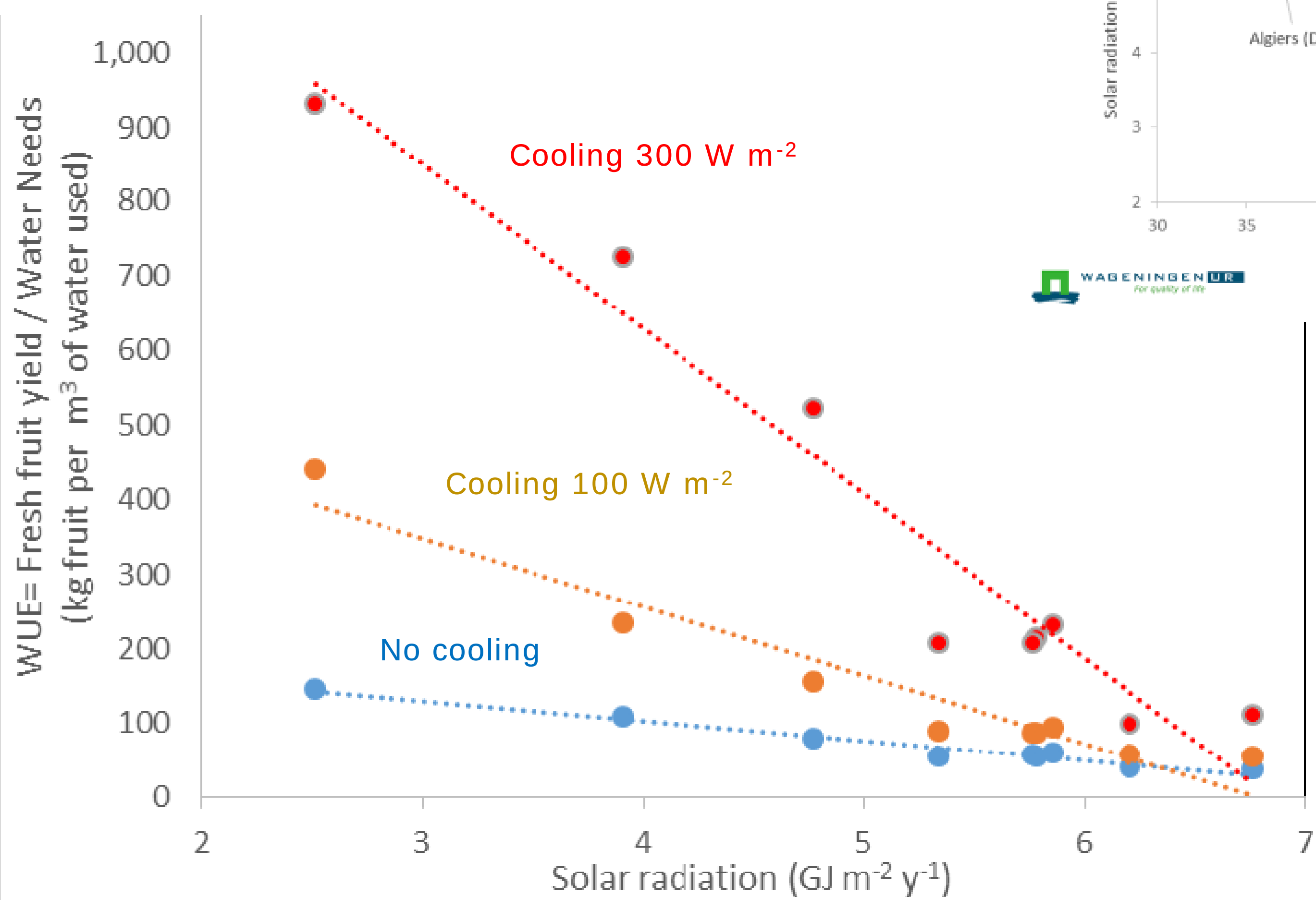
European Union European Regional Development Fund
HELLENIC REPUBLIC Ministry of Education, Research and Religious Affairs
GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY
EPAnEK 2014-2020 OPERATIONAL PROGRAMME COMPETITIVENESS ENTREPRENEURSHIP INNOVATION
HELLENIC REPUBLIC MINISTRY OF ECONOMY & DEVELOPMENT SPECIAL SECRETARY FOR ERDF & CF MANAGING AUTHORITY OF EPAnEK
ΕΣΠΑ 2014-2020 Partnership Agreement 2014 - 2020

Co-financed by Greece and the European Union

Effect of location on greenhouse WUE

Region characterisation





Greece-Germany bilateral project:
Cascade Hydroponics: an integrated approach to increase productivity, resource use efficiency and sustainability of protected cultivation-CasH

- Develop and investigate "cascade" fertigation approaches as novel, integrated production concepts for intensive greenhouse soilless horticulture.
- Tomato and cucumber will be used as main (="primary") crops, less demanding,"secondary" crops (e.g. basil) will be integrated and fertigated using the drainage nutrient solution of the primary crop. Salt tolerant vegetables will conclude this serial production system at the "downstream-end" as the "tertiary" crops.

European Union European Regional Development Fund
HELLENIC REPUBLIC Ministry of Education, Research and Religious Affairs
GSRT GENERAL SECRETARIAT FOR RESEARCH AND TECHNOLOGY
EPAnEK 2014-2020 OPERATIONAL PROGRAMME COMPETITIVENESS ENTREPRENEURSHIP INNOVATION
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ΕΣΠΑ 2014-2020 ανάπτυξη - εργασία - αλληλεγγύη Partnership Agreement 2014 - 2020
Co-financed by Greece and the European Union

Objective of this work

- Creation of multiculture hydroponic system and reuse the drainage solution of a "primary" crop for the fertigation of a "secondary" and "tertiary" crop so that drainage leaching to the environment is minimized.
- Assessment of "secondary" crop productivity (basil, rosemary, mint)

Materials and Methods

Greenhouse facilities

Experimental farm of the University of Thessaly, Volos, Greece (39º 44’ N, 22º 79’ E)

- Plastic single-span greenhouse, 160 m^2
- Experimental period: September to December

- Soilless crop in perlite slabs
- Fertigation and drainage management automatically controlled

Plant Material

- **Main crop:** cucumber (*Cucumis sativus*)
  - 2 crop lines: 2 plants/m^2

  Target EC=2.8 dS m^{-1} and pH=5.6

- **Secondary crops:**
  - Rosemary (*Rosmarinus officinalis*),
  - Basil (*Ocimum basilicum*) and
  - Mint (*Mentha* x piperita)

- **3 fertigation treatments:**

  plants irrigated with
  - FS: standard nutrient solution
  - D+FS: 15% drainage solution + 85% standard solution (15 - 85)
  - D+W: 30% drainage solution + 70% water (30 - 70)

- Each treatment: 3 slabs/crop (totally 9 perlite slabs/line)
- 3 plants/slab (totally 9 plants/crop/treatment)
- 2 replications (totally 18 plants/crop/treatment)

Measurements

- **Irrigation and drainage solution:**
  Electrical Conductivity, pH, volume of water supplied and drained from the primary and secondary crops, nutrients concentration
- **Plant measurements:**
  Plant height
  Fresh-Dry matter
  Nutrients content

New greenhouse

New greenhouse

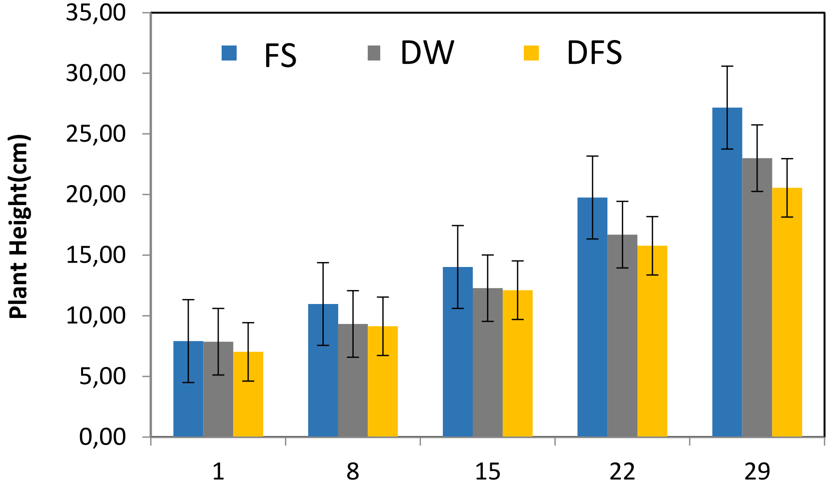

grodan


grodan Classic

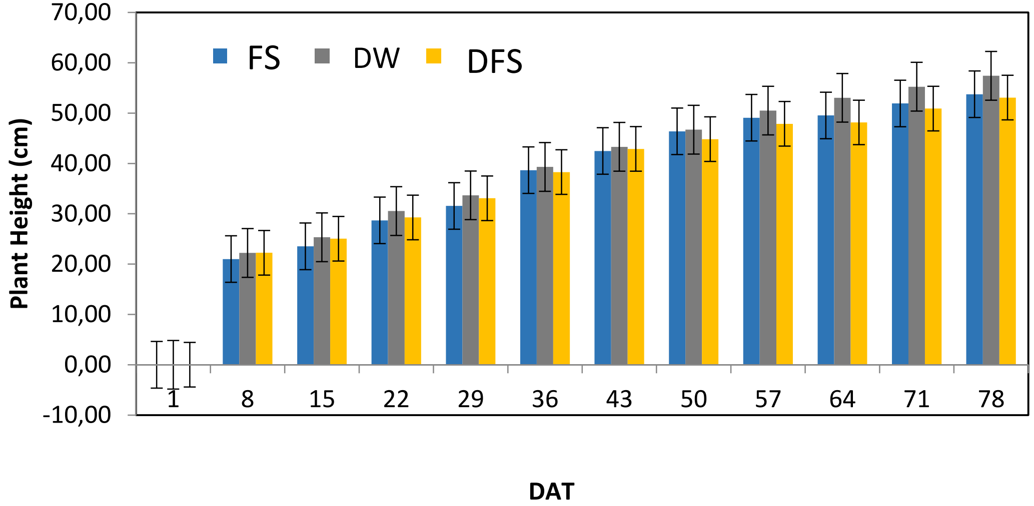
Results

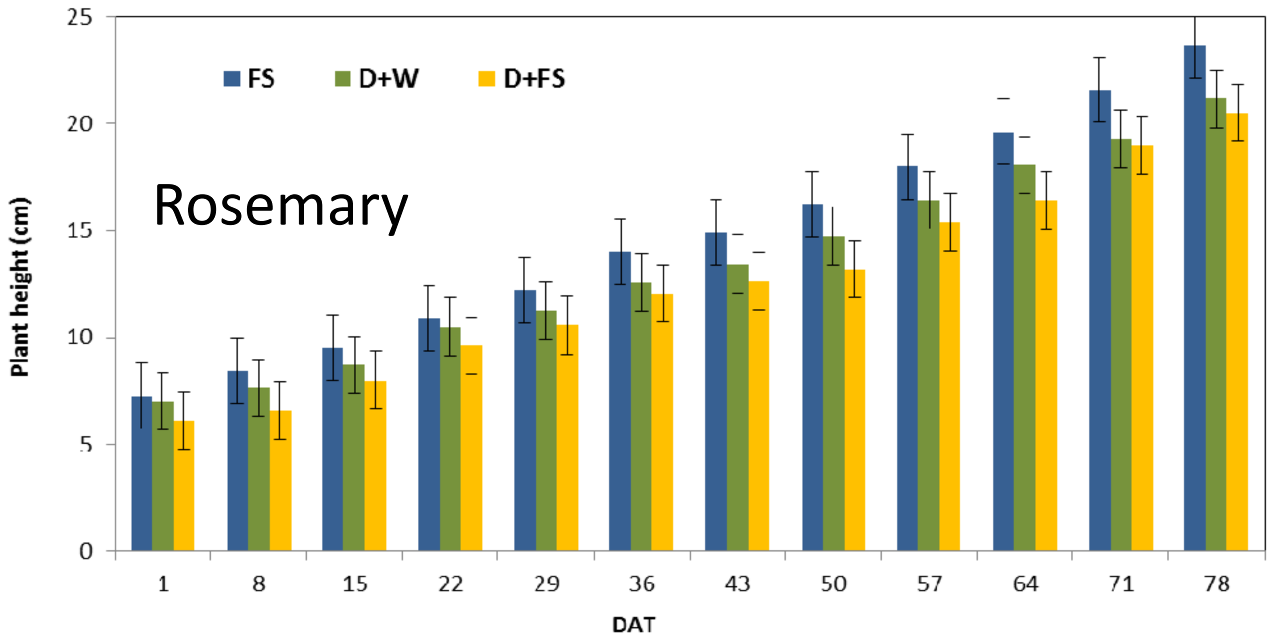
Plant height

Mint

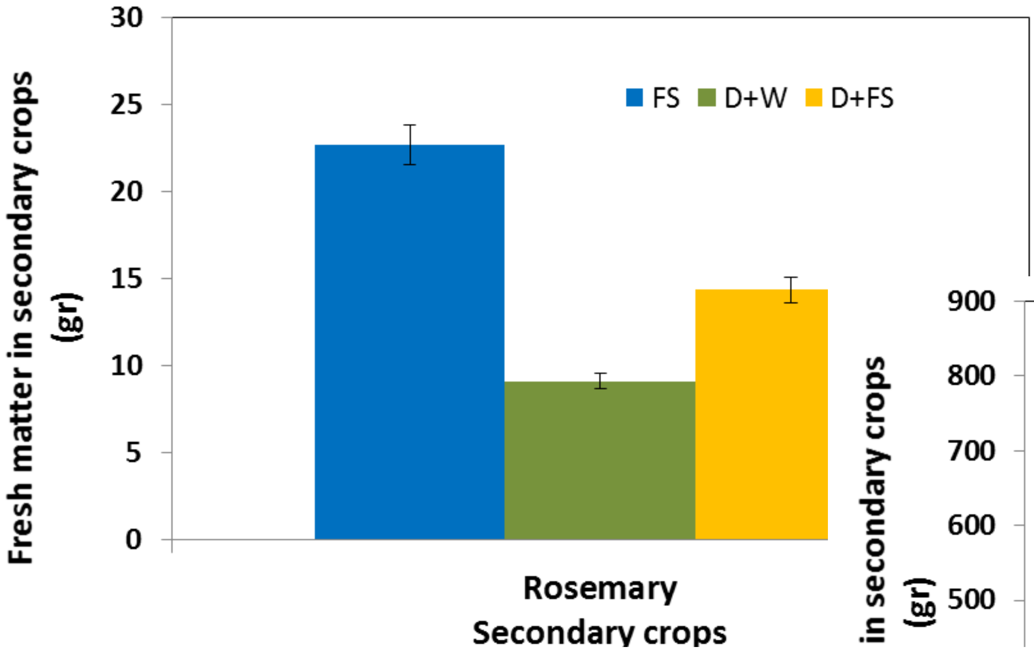


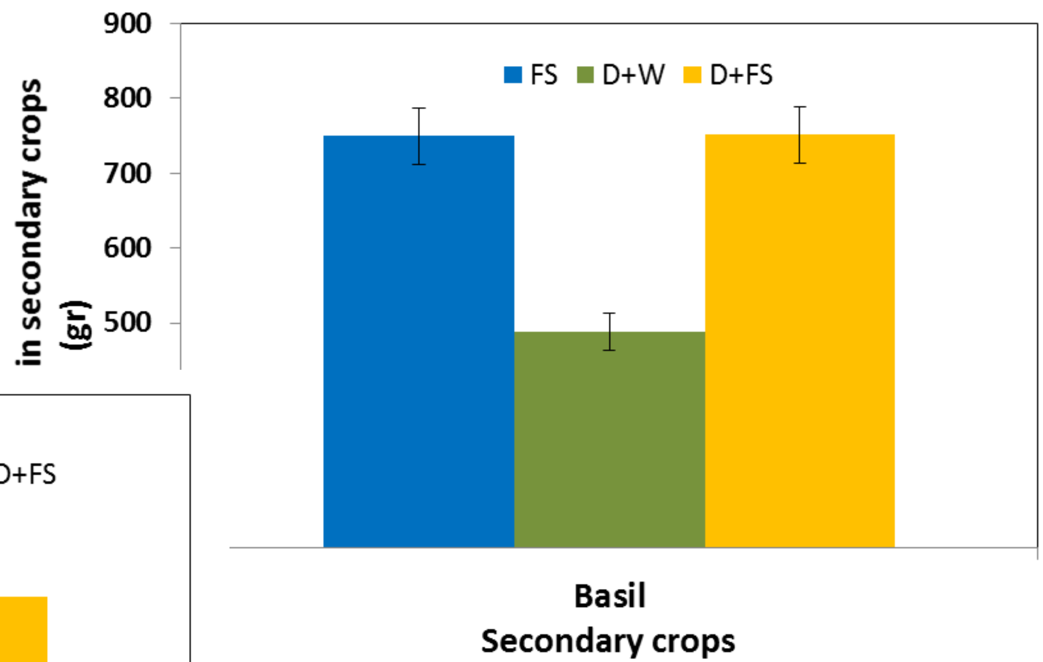
Basil

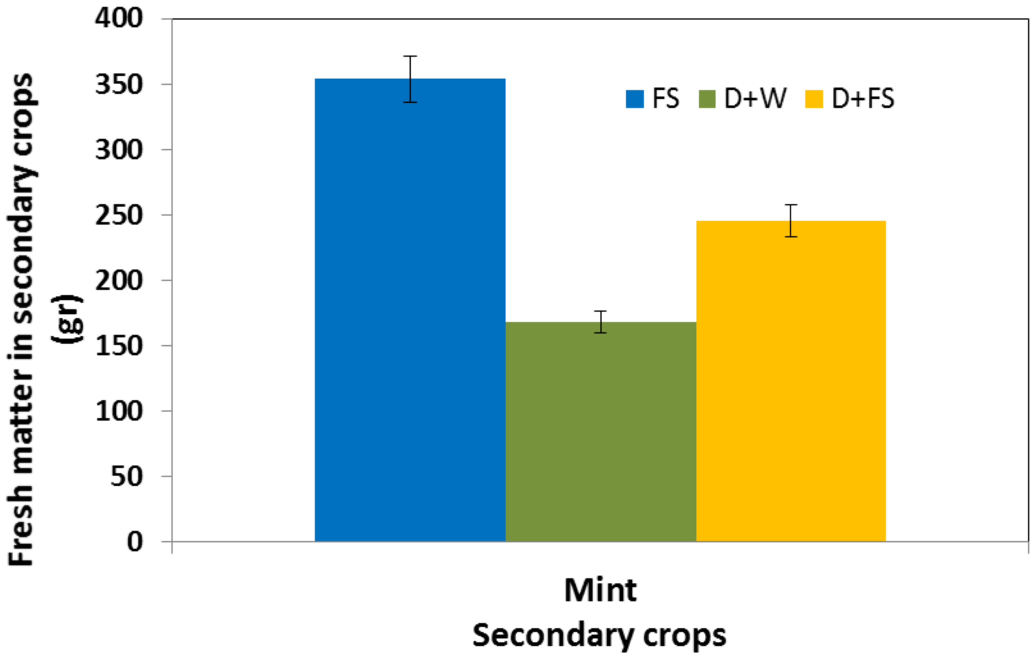




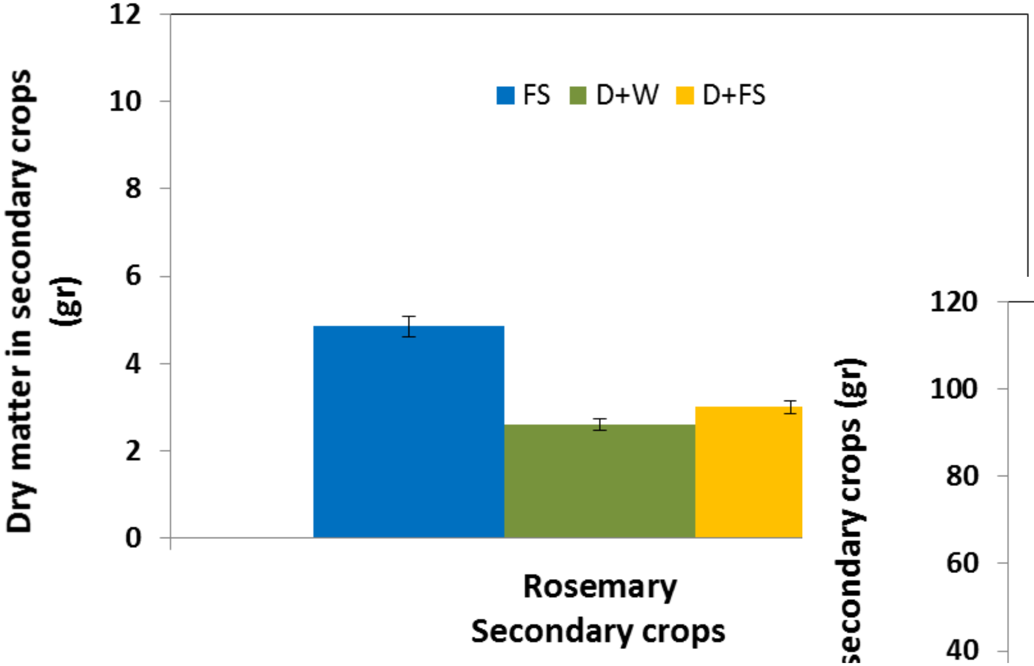
Fresh matter -secondary crops

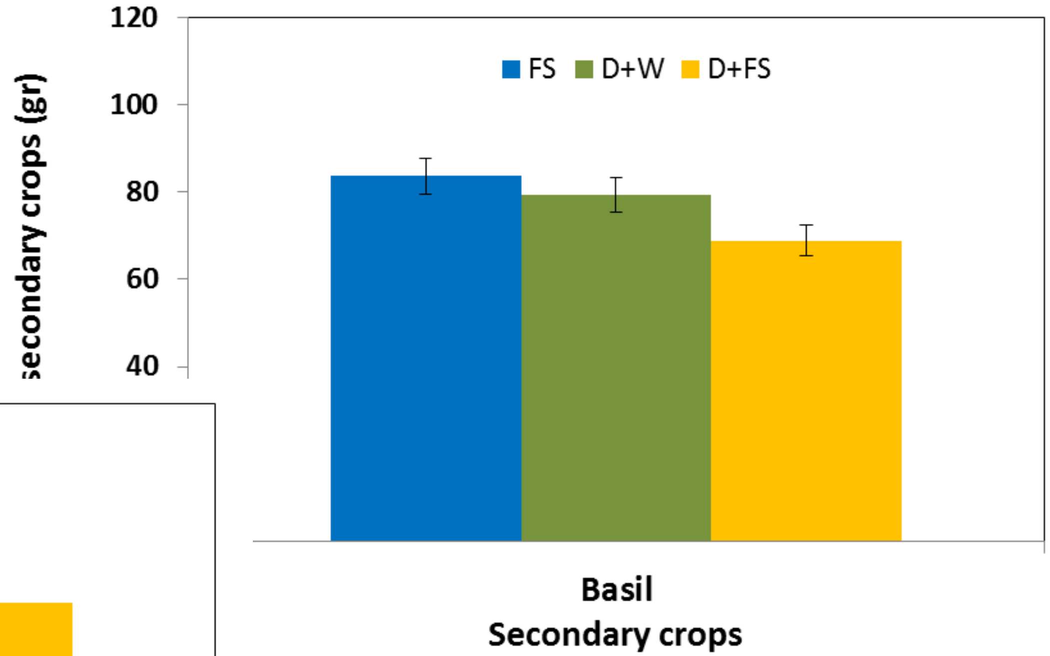


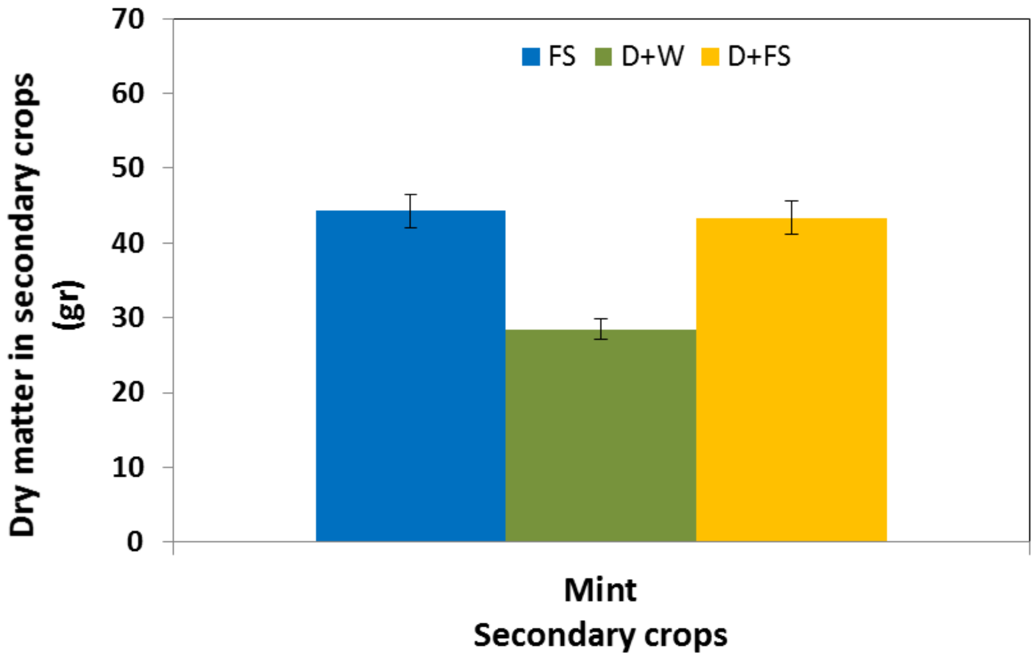




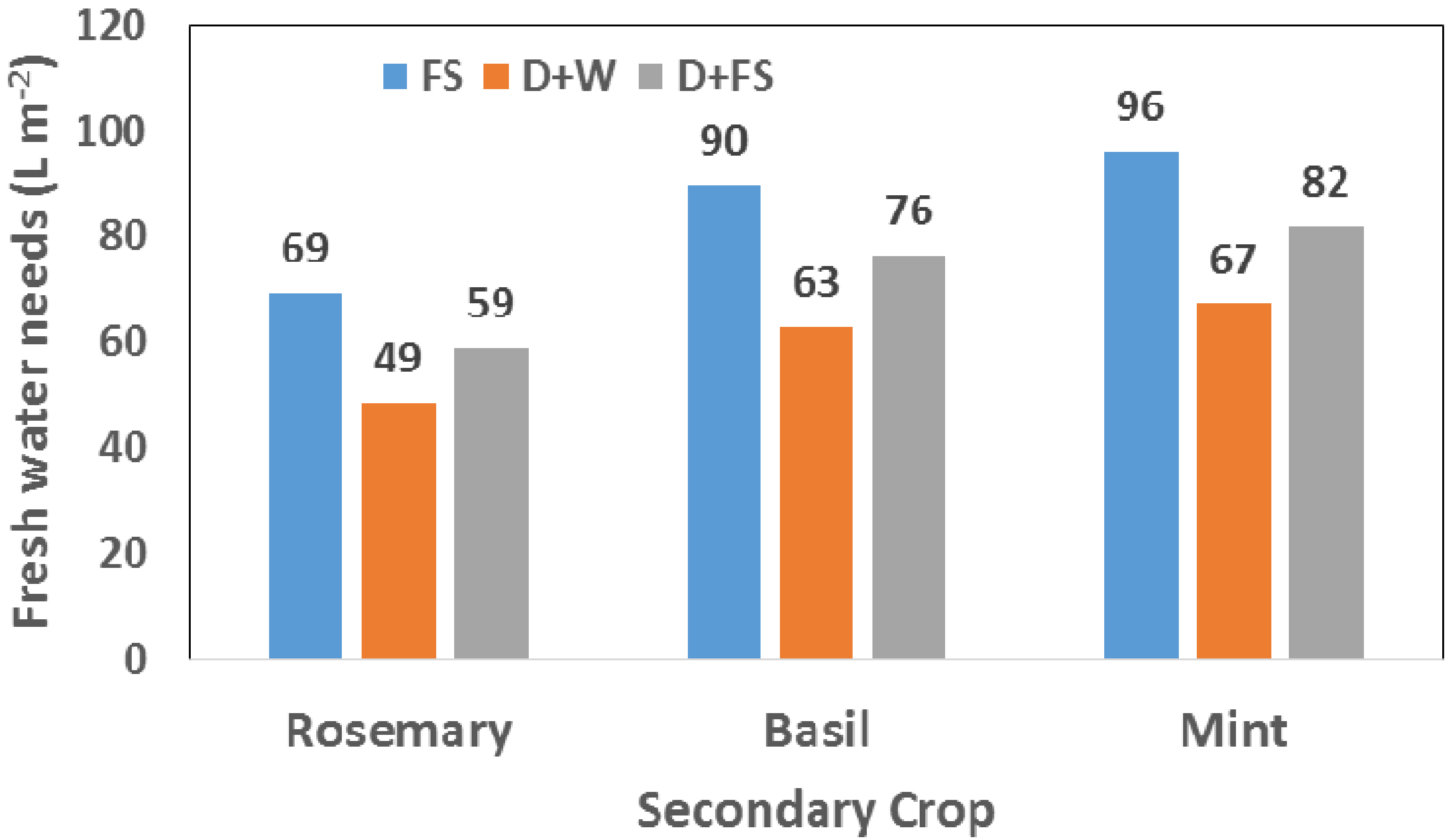
Dry matter -secondary crops





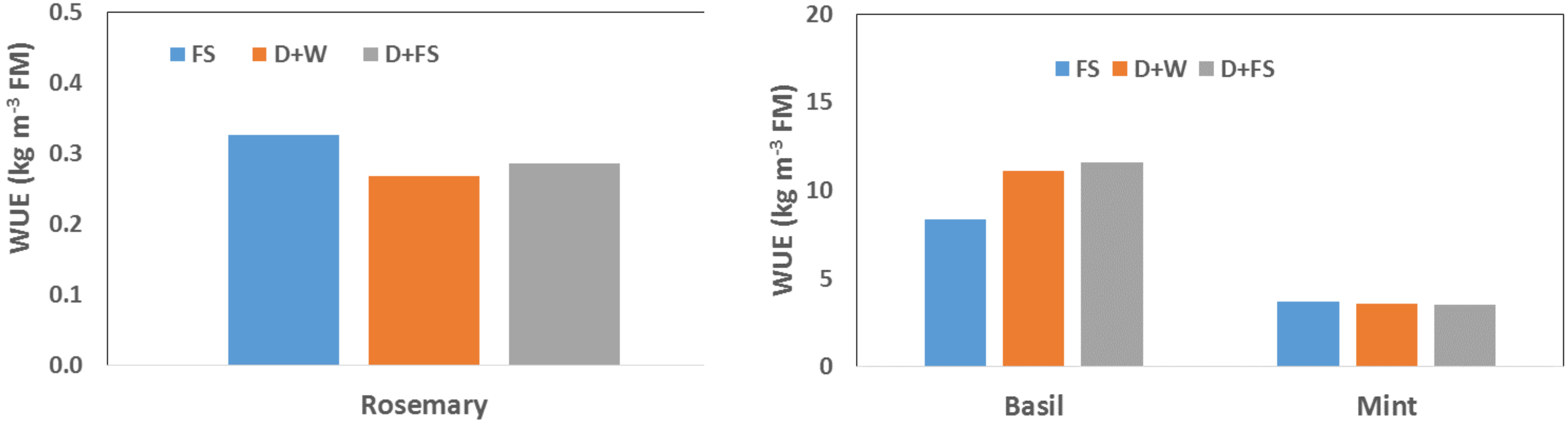


Water needs

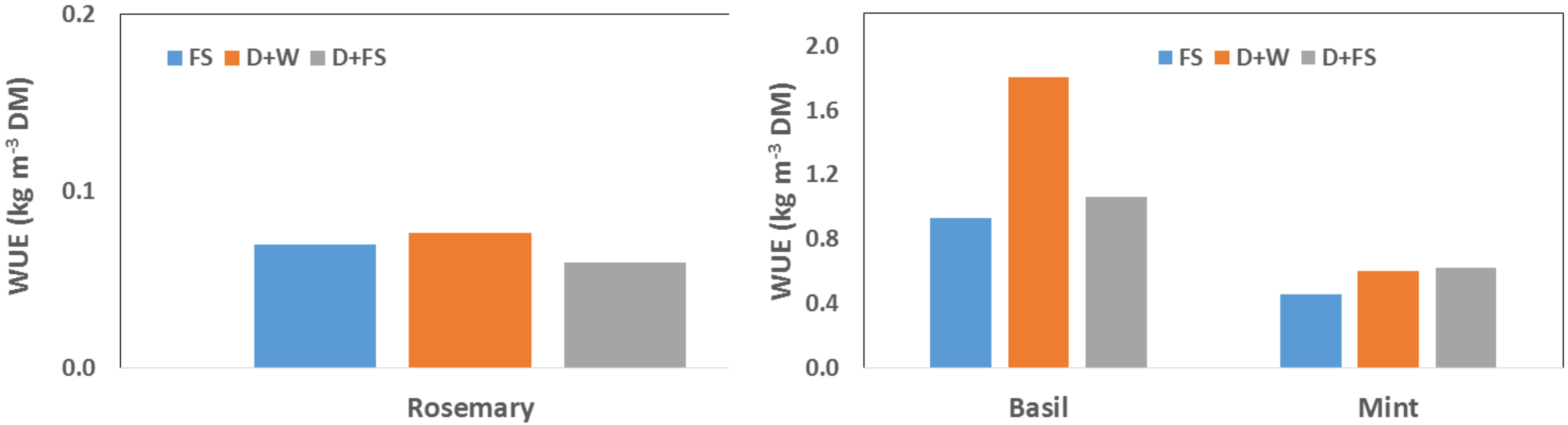


FS
D+W
D+FS
Fresh water needs (L m-2)
120
100
80
60
40
20
0
69
49
59
90
63
76
96
67
82
Rosemary
Basil
Mint
Secondary Crop

WUE



Fresh matter basis



Dry matter basis

Concluding remarks

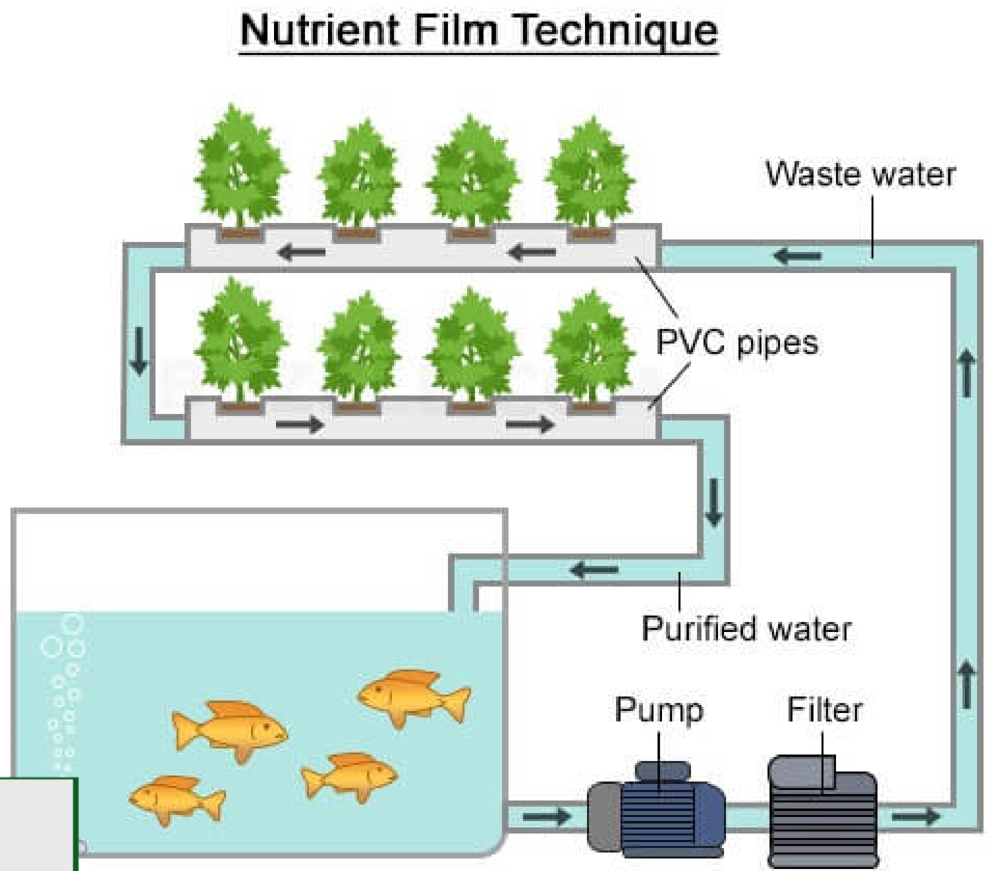
The cascade system

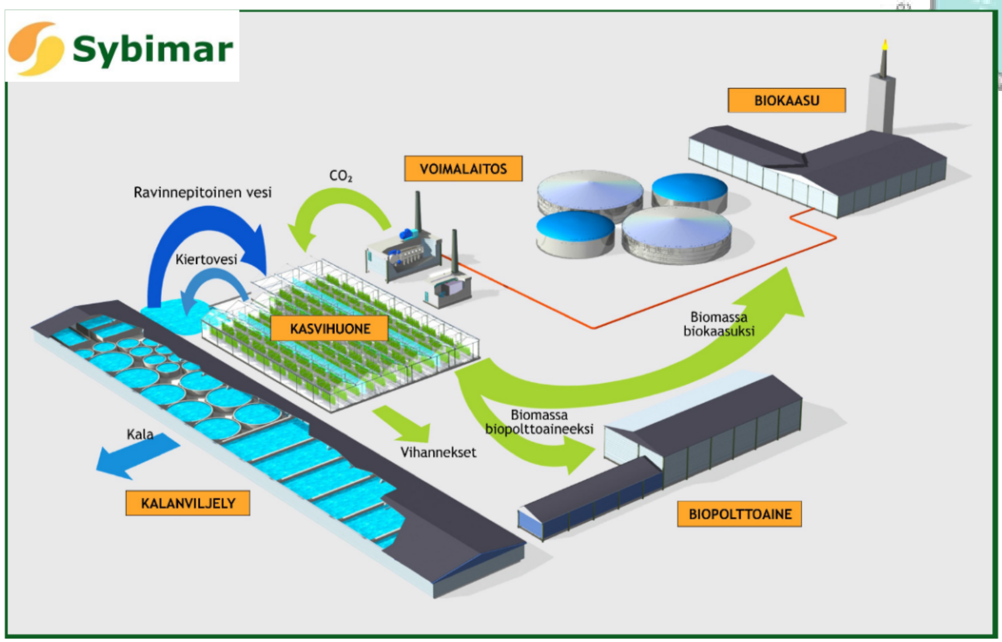
- decreased the needs for fresh water in the secondary crops
- decreased the fresh biomass produced
- did not significantly affected the dry matter production
- did not affected or increased the WUE

Aquaponics

Integration of aquaculture and hydroponics.

Symbiotic growing of fish and vegetables in recirculating water systems – is emerging as one important area of sustainable agriculture.

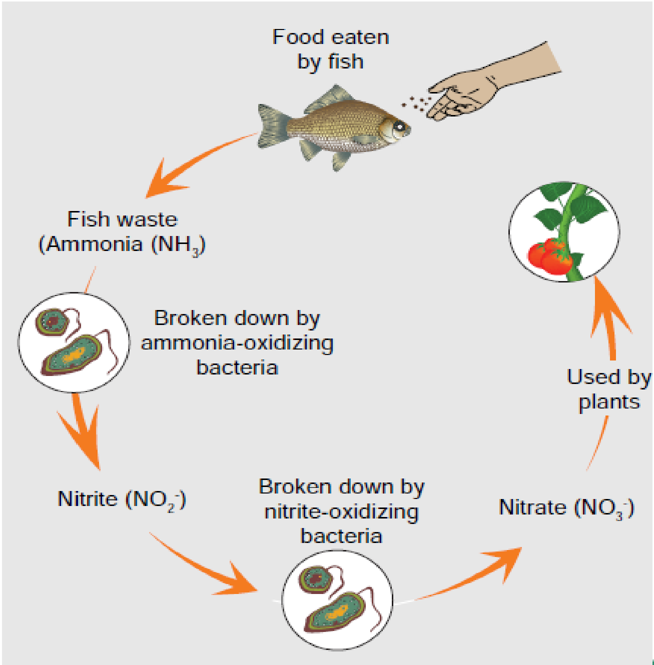




Aquaponics Nitrogen Cycle

- Insert fish food
- Fish release ammonia in their waste
- Bacteria in the water convert ammonia to nitrites and then nitrites to nitrates
- Plants need nitrates to grow so they filter them
- Clean water is pumped back into fish pond

Nitrogen flow chart in an aquaponic system

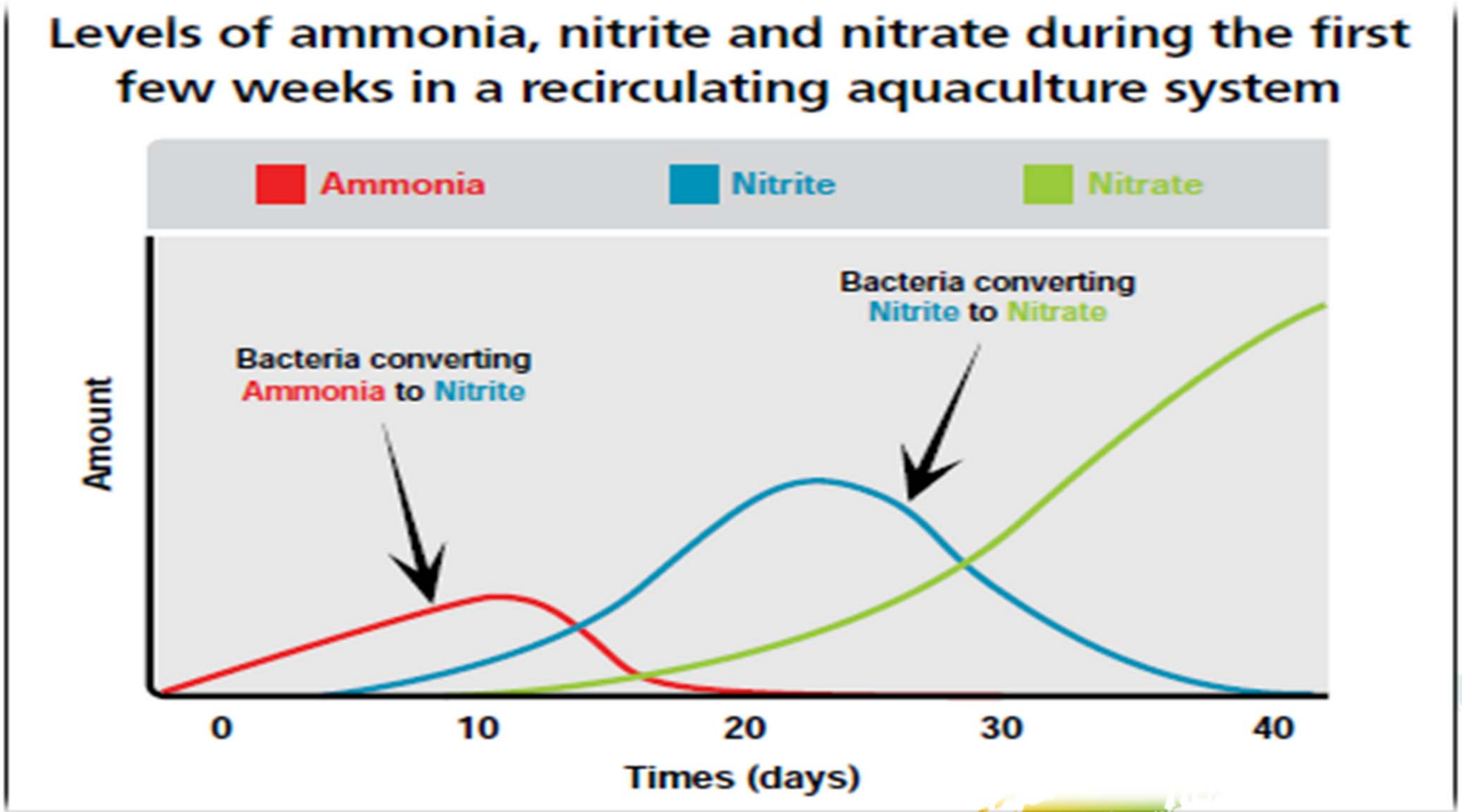


Main Parameters (1)

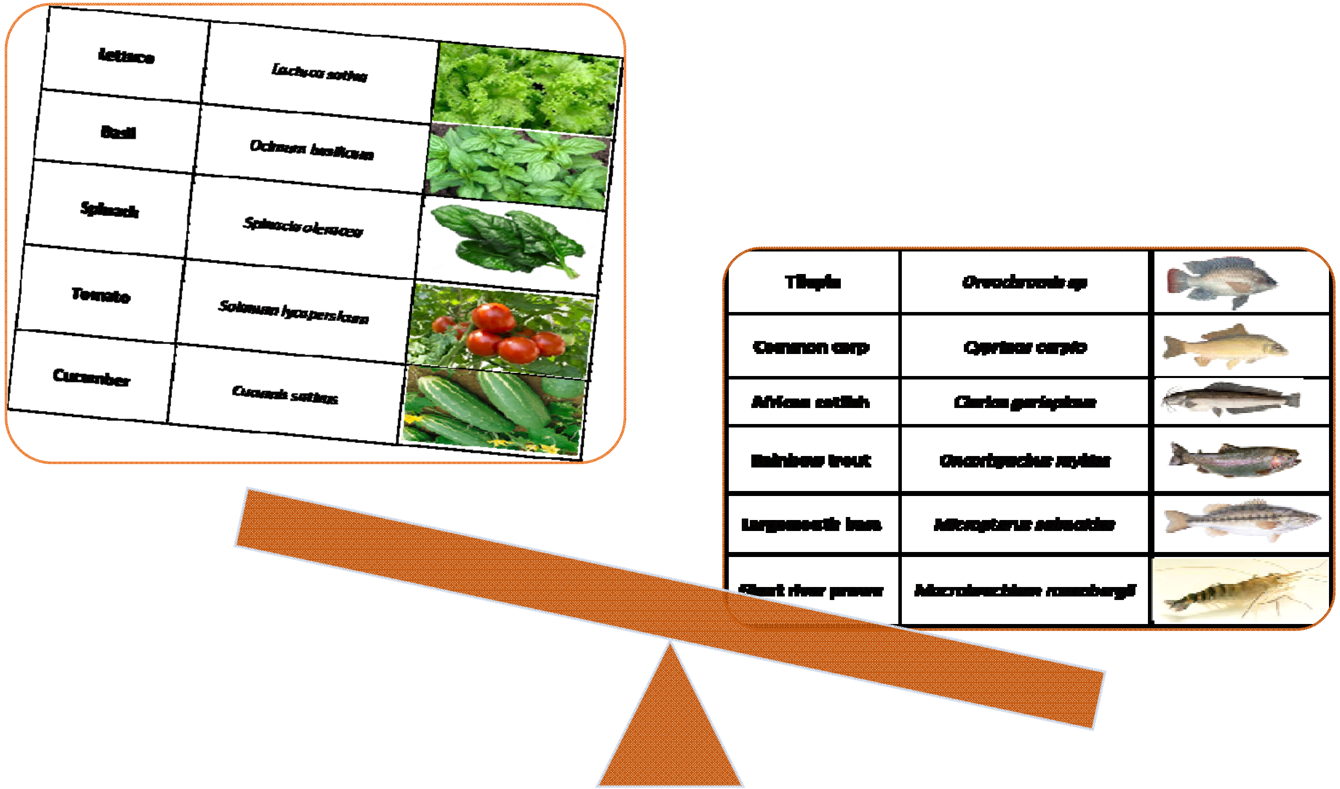
General water quality tolerances for fish (warm- or cold-water), hydroponic plants and nitrifying bacteria

Organism type	Temp (°C)	pH	Ammonia (mg/litre)	Nitrite (mg/litre)	Nitrate (mg/litre)	DO (mg/litre)
Warm water fish	22–32	6–8.5	< 3	< 1	< 400	4–6
Cold water fish	10–18	6–8.5	< 1	< 0.1	< 400	6–8
Plants	16–30	5.5–7.5	< 30	< 1	-	> 3
Bacteria	14–34	6–8.5	< 3	< 1	-	4–8

Main Parameters (2)



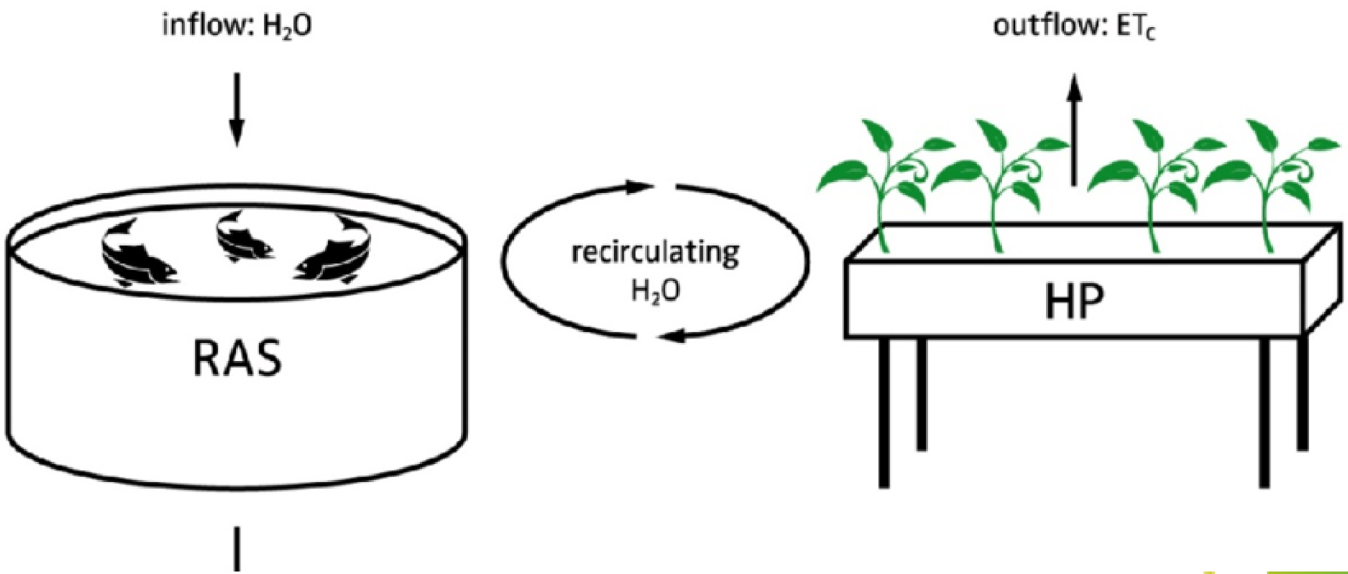
Main Parameters (3)



- ✓**Fish Stocking density**
- ✓**Number of plants/m²**
- ✓**Feed rate ratio**

Aquaponic System types (1)

- **One-loop aquaponic system**



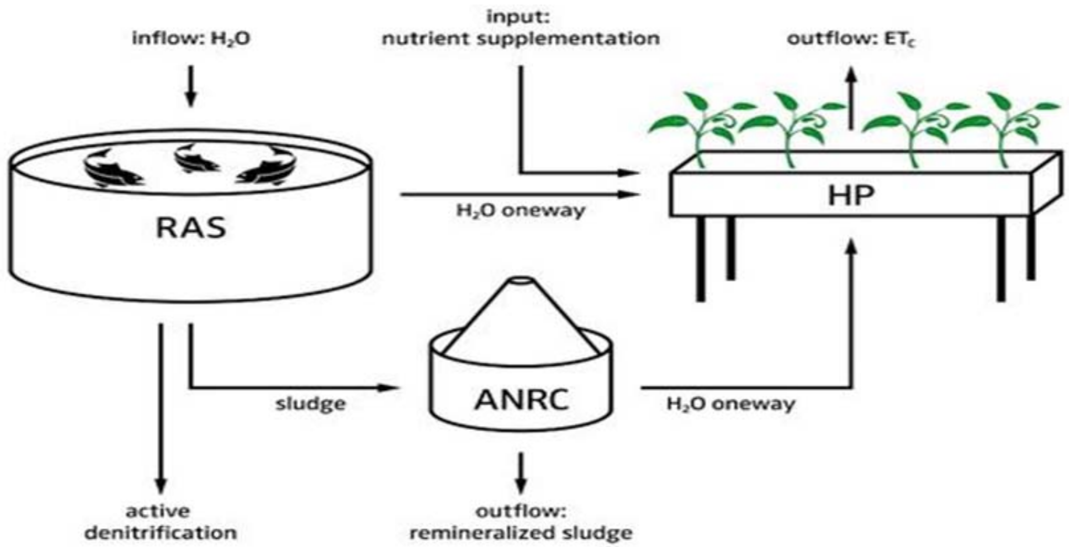
Aquaponic System types (2)

- **Multi-loop or de-coupled aquaponic system**

✓ Better environmental control for each organism, so less problems (Goddek, 2016)

✓ More autonomous system

✓ There was a 39% increase in plant growth compared to plants produced in one-loop aquaponic system (Jijakli et al., 2016)



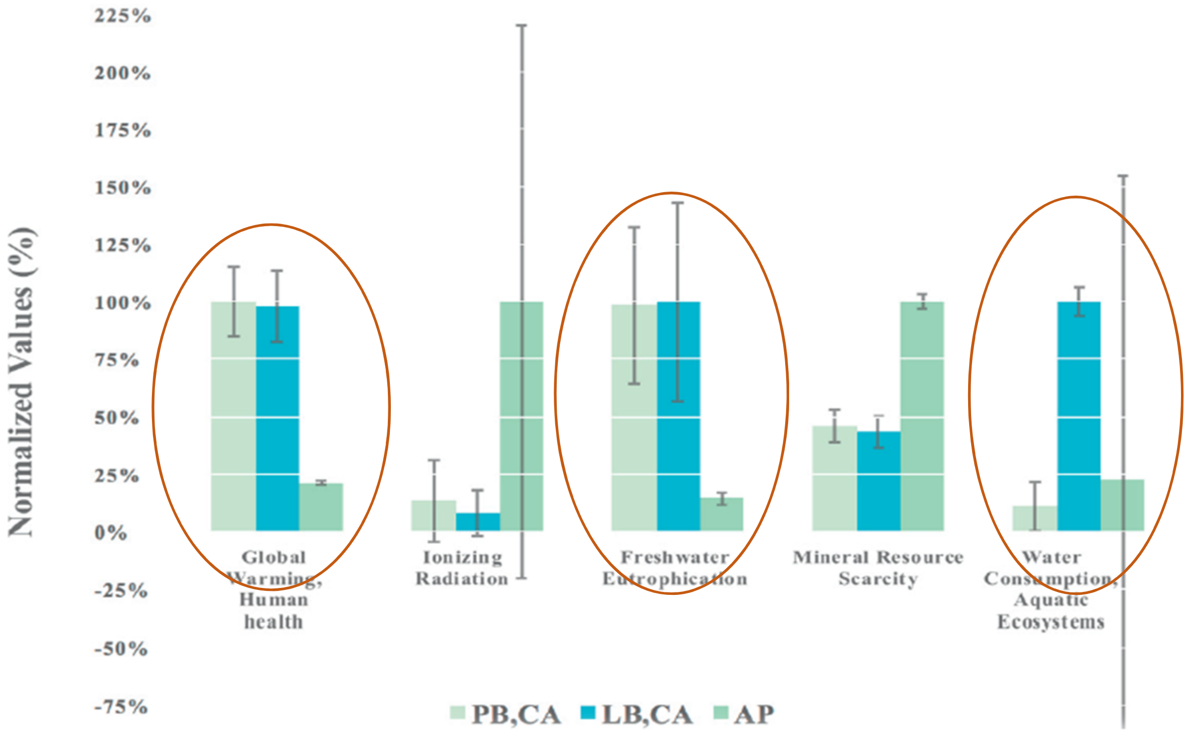
Advantages (1)

1. **90% Less water consumption:** (40-45 lit/m^2/day for conventional cultivation, 8-11 lit/m^2/day for aquaponic cultivation)
2. **75% less energy consumption**
3. **Less Fertilizer inputs:**

   Provided that the system is stocked with enough fish, it is not necessary to add nutrients for plants with short cropping cycle which do not produce fruits (e.g. lettuce) (Bittsanszky,2016)
4. **Nutrient Recycling:** Aquaponics has the potential to reduce net impact of fish cultivation through plant biofiltration:

- 99% of the dissolved P and 60% of the nitrate from the flow (Adler et al., 2000, Endut, 2006).
- Recycling rates of 32–40% for N and 22–27% for P.(Graber 2009)

Advantages (2)

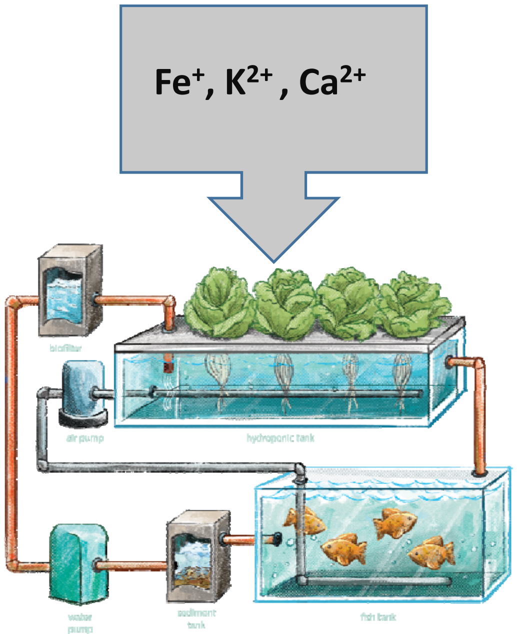


(LB,CA):lake-based aquaculture and conventional agriculture
(PB,CA): pond-based aquaculture and conventional agriculture
(AP): media-based aquaponics which uses an expanded clay grow media instead of soil.

Food functional unit: 1 tn (1000 kg) of tilapia and 5 tn of lettuce production from each system.

Aquaponic Nutrition

Star Milling Co. Tilapia Feed Proximate Analysis (% composition)	
Crude Protein	35%
Crude Fat	5%
Crude Fiber	4%
Ash	9%
Nutrients (% dry diet)	
N	5.97%
P	1.53%
K	1.46%
Ca	1.61%
Mg	0.26%
Na	0.24%
S	0.46%



- Fish simply do not need the same amounts of iron, potassium and calcium that plants require.
- As such, deficiencies in these nutrients may occur. This can be problematic for plant production, yet there are solutions available to ensure appropriate amounts of these three elements.

Conclusion

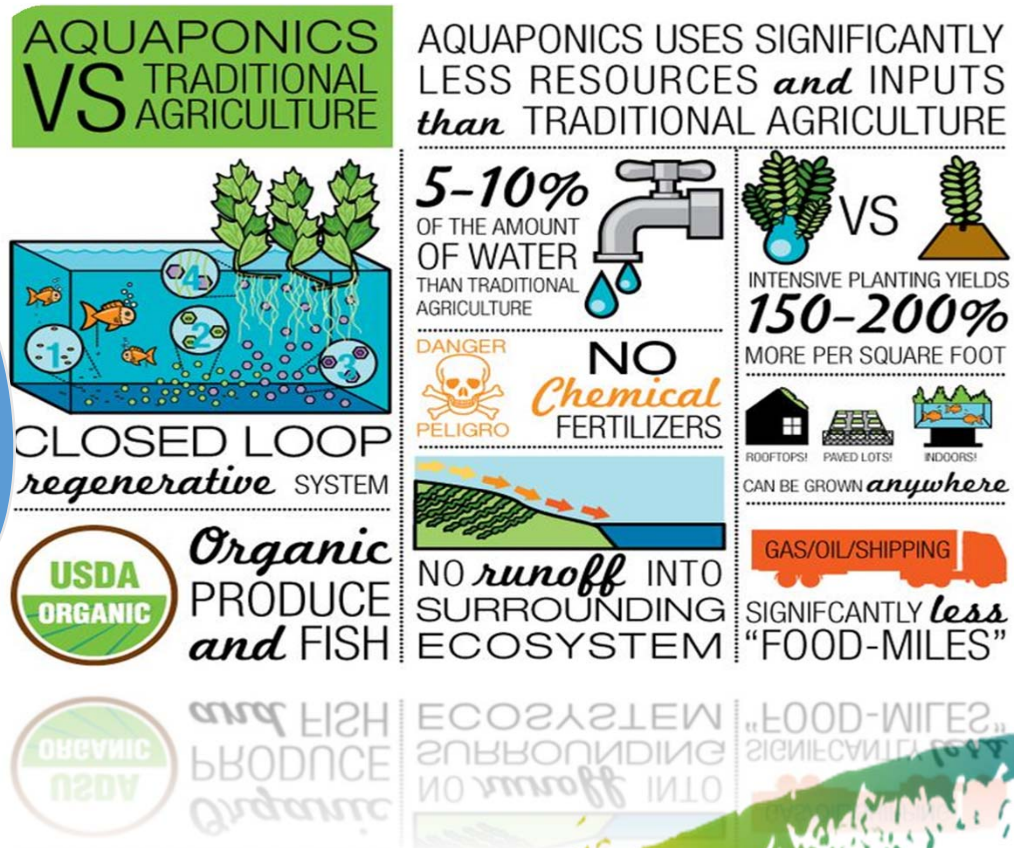
✓ Domestic

✓ Small Scale

✓ Pilot Scale

- Agronomists
- Ichthyologists

Promising System!!!



Thank you
for your attention