General info on ZuGabe Project (E. Dimkou)

University of Thessaly, Department of Agriculture Crop Production & Rural Environment,

Laboratory of Agricultural Constructions and Environmental Control

UTH-LACEC

Director: Nikolaos Katsoulas

Sustainable agriculture production in controlled environment – Greenhouse

- ✓ Design optimisation of greenhouse structures
- ✓ Rational management of hydroponic 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)

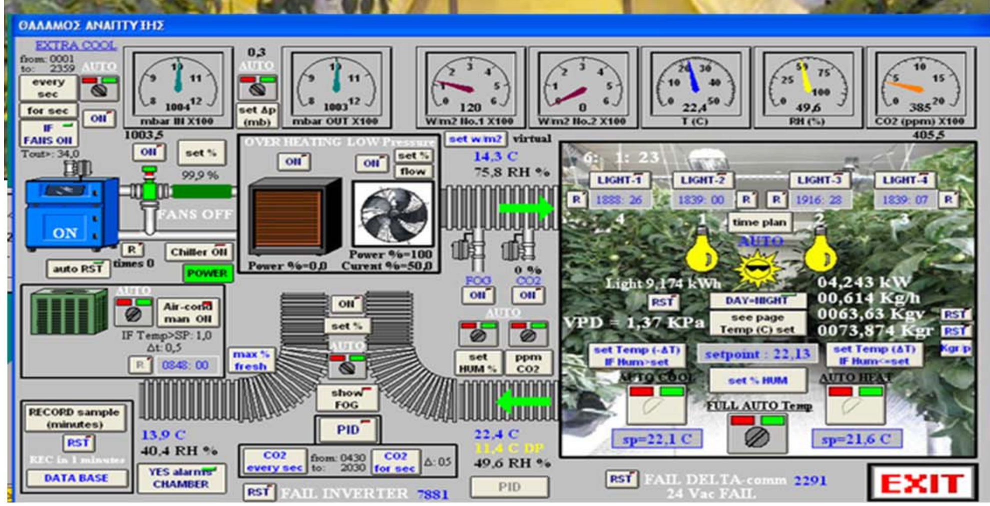
UNIVERSITY OF THESSALY

Research facilities at University experimental farm in Velestino

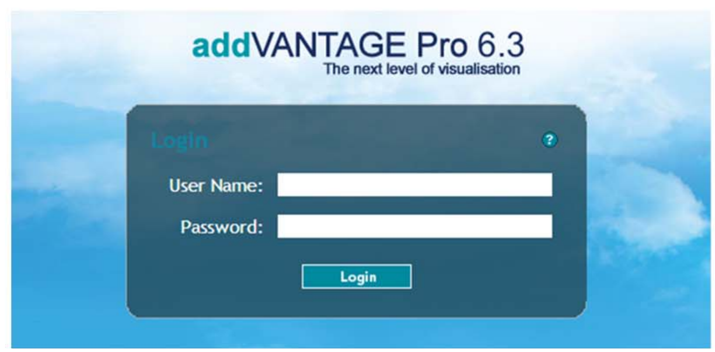
UNIVERSITY OF THESSALY
FOUNDED 1984

Controlled environment growth chamber

Lab for analysing water, nutrients and plants

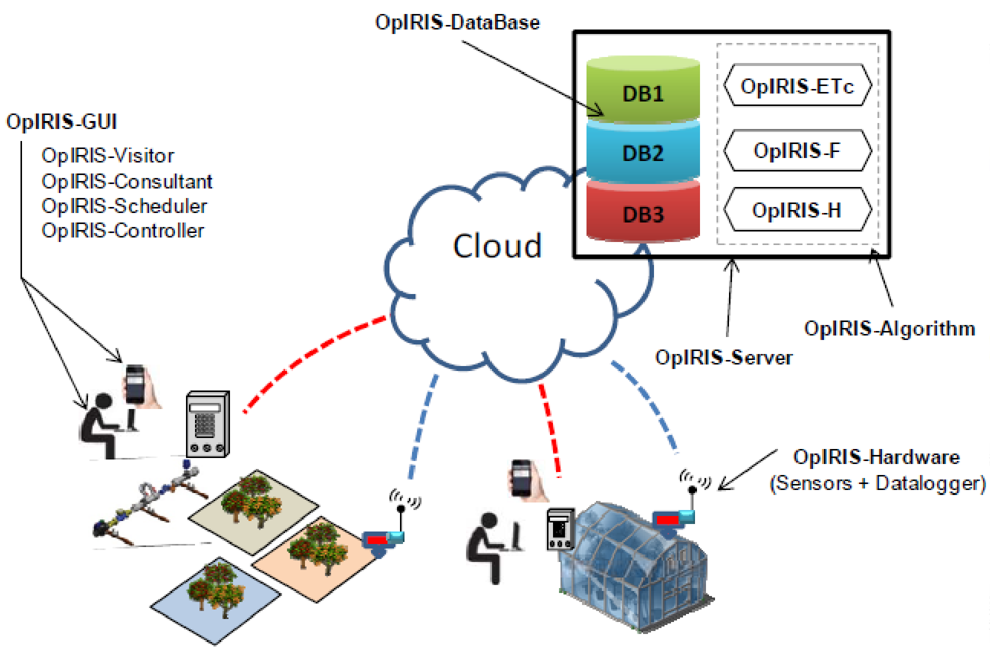


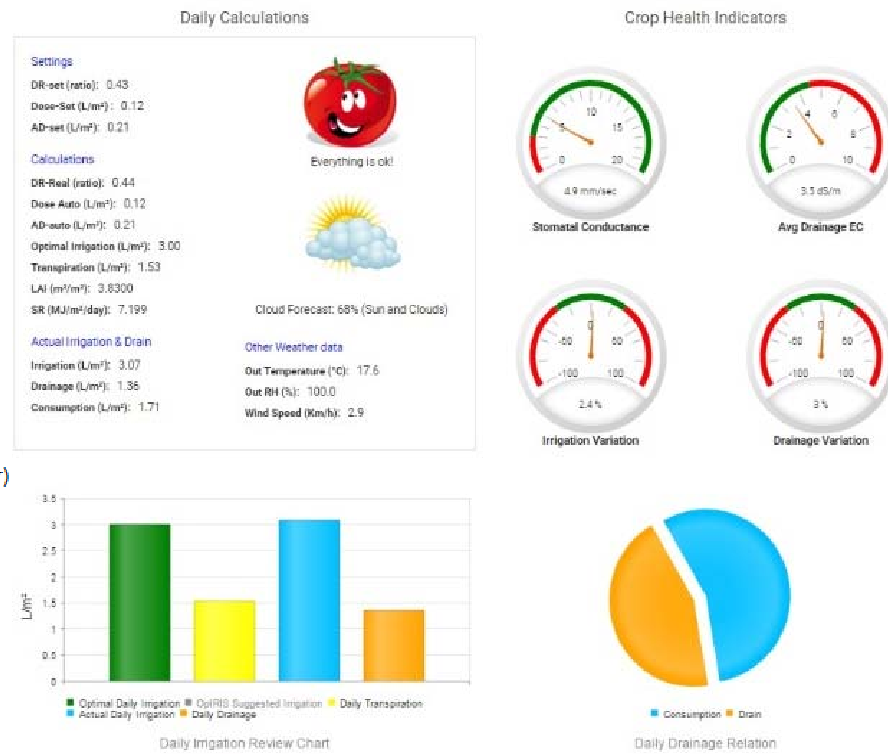
On line monitoring of microclimate in greenhouses and of water and air quality



State of the art facilities for study the behavior of crop under cover in parallel with novel sensors enabling the study of the crop under cover in view of climate change and water shortage. ITEMA has a full equipped lab for analyzing water and hydroponics samples which will soon certified by the 17025 ISO

Rational use of water resources





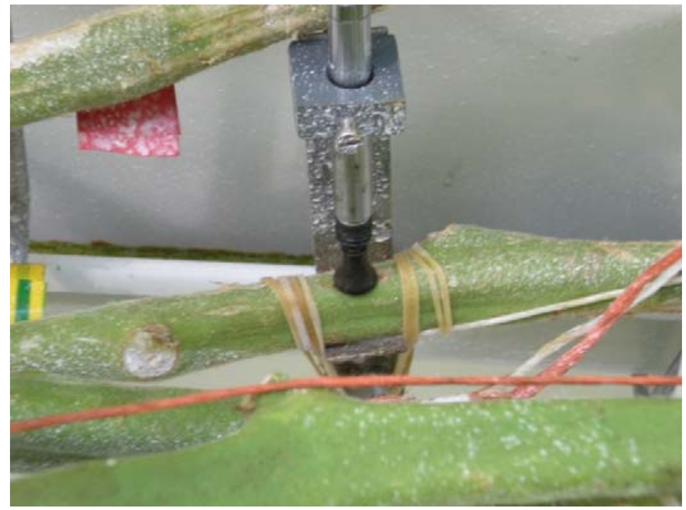
Major projects:

- Development of an integrated system for monitoring and management of water resources in Karla Lake (Cooperation 2009)
- Sustainable use of Irrigation Water in the Mediterranean Region (FP7, KBBE)
- Online Professional Irrigation Scheduling Expert System (FP7, KBBE)

Sensors for crop growth and development

Sapflow

Stem diameter



Leaf aerodynamic conductance

Leaf temperature

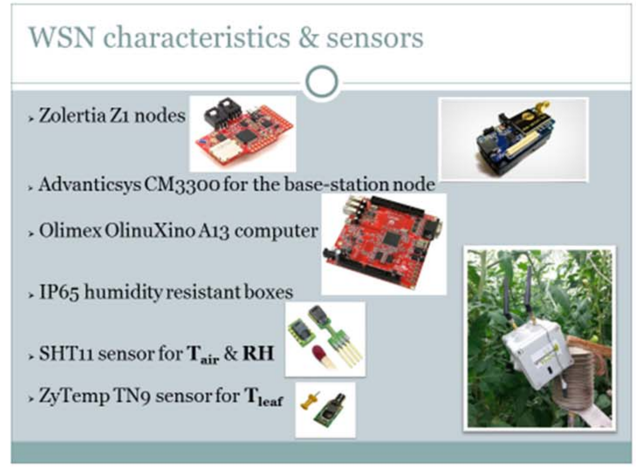
Wirelles Systems

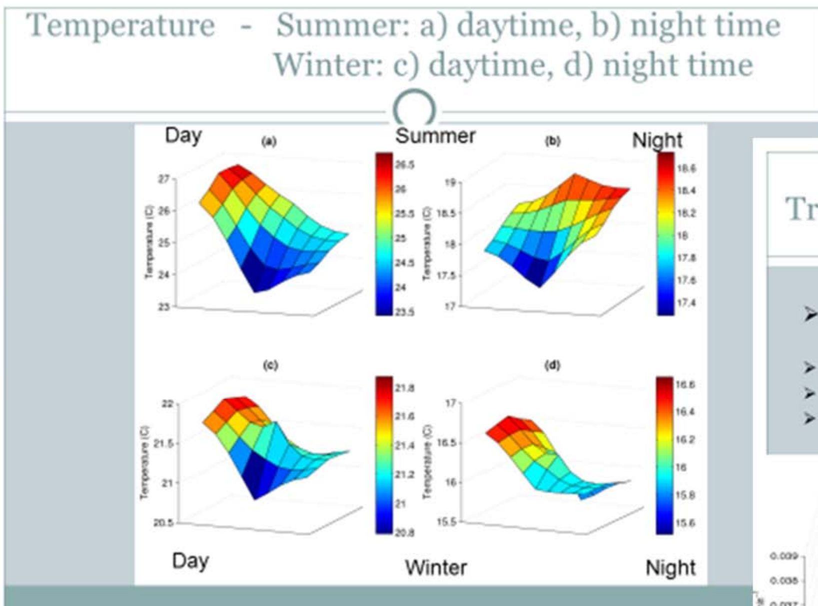
Air temp and relative humidity

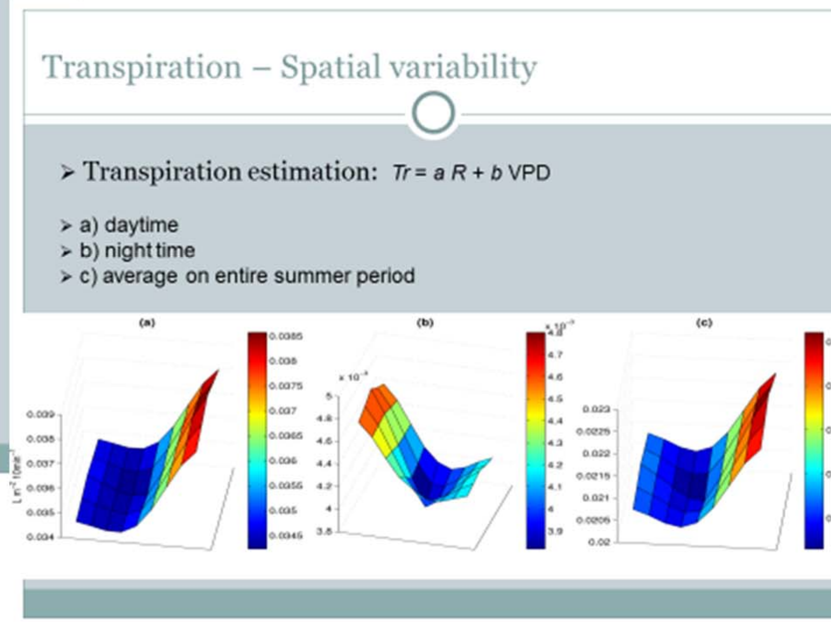
Leaf temperature

GreenSense

Spatially distributed greenhouse climate control based on wireless sensor network measurements



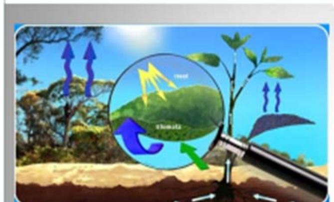


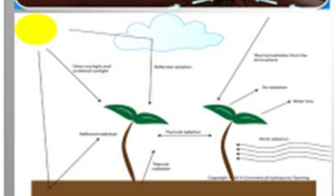


GreenSense

Reflectance and temperature indices for crop water status assessment

Crop temperature





➢Plant temperature correlated

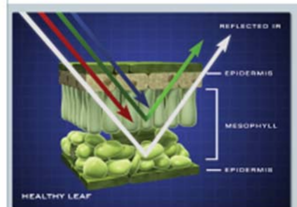
•Plant transpiration and

•Stomatal conductance

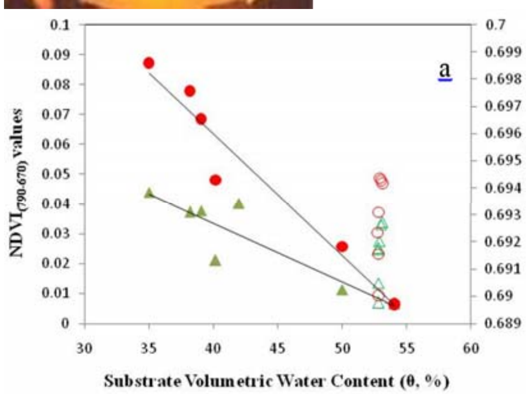
In water stress conditions, it manifests

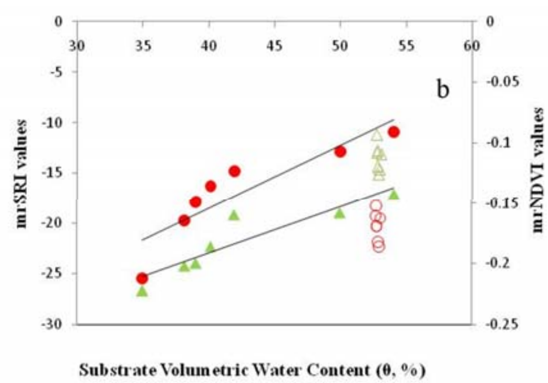
- closure of stomata and adaptation of transpiration rate in order to be protected from various irreparable physiological damages

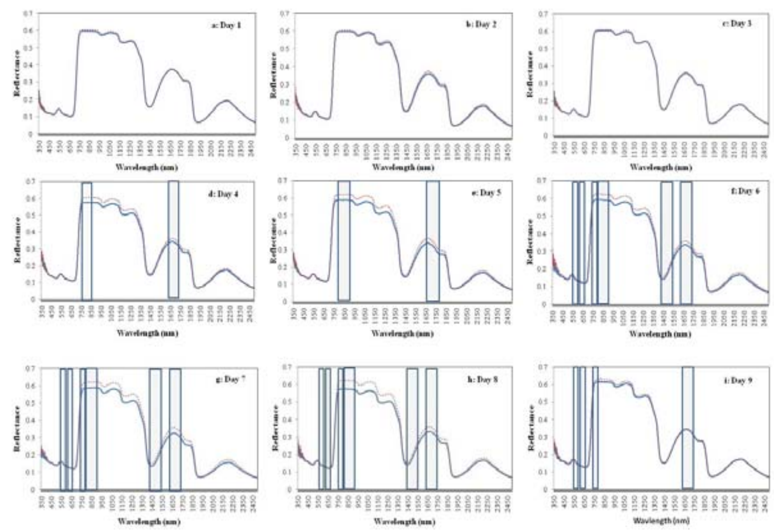
Remote sensing in greenhouses for plant reflectance measurement

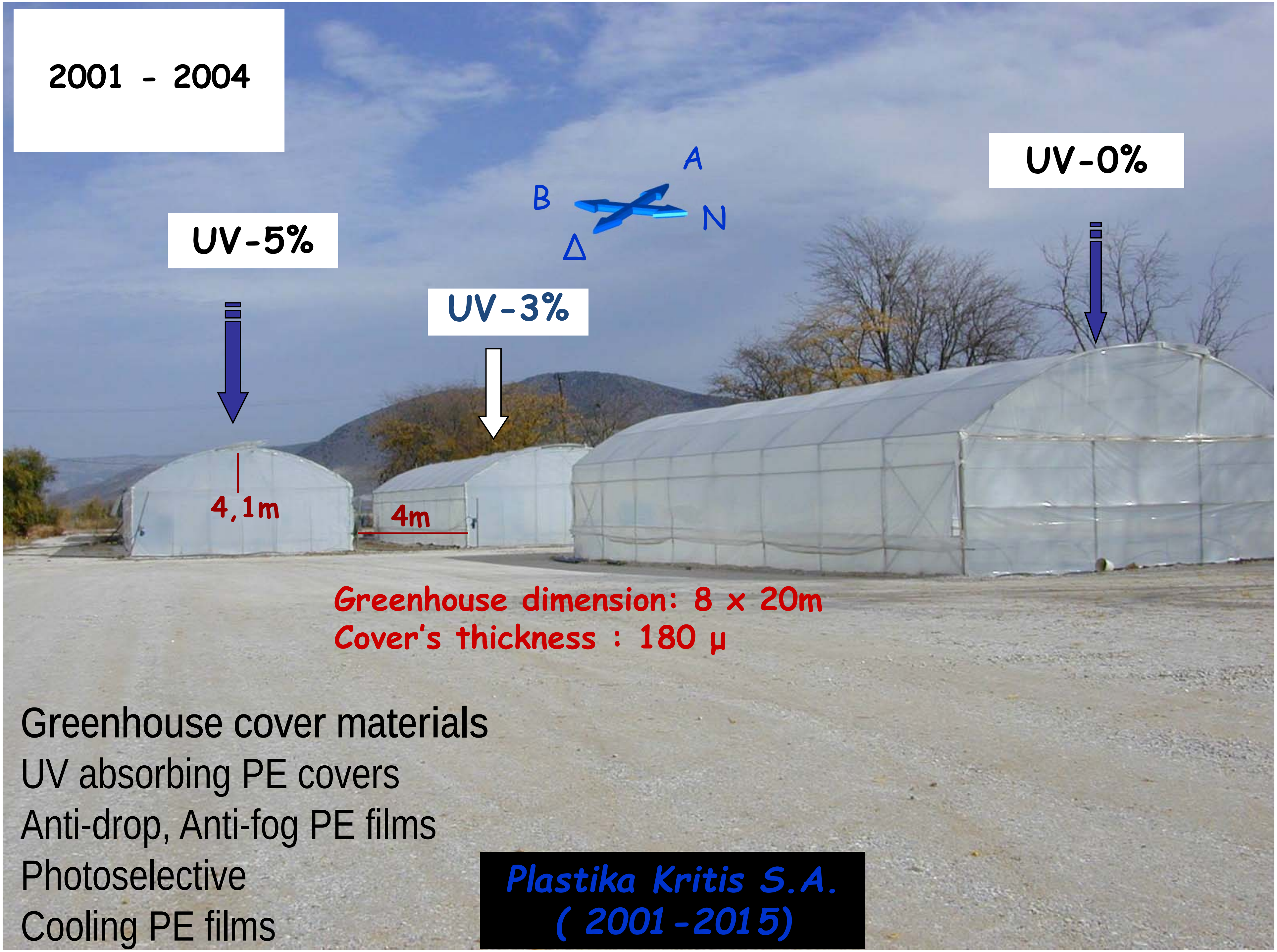


➢ Different types of effective reflectance sensors can detect plant water status in real time by monitoring plant reflectance








2001 - 2004
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

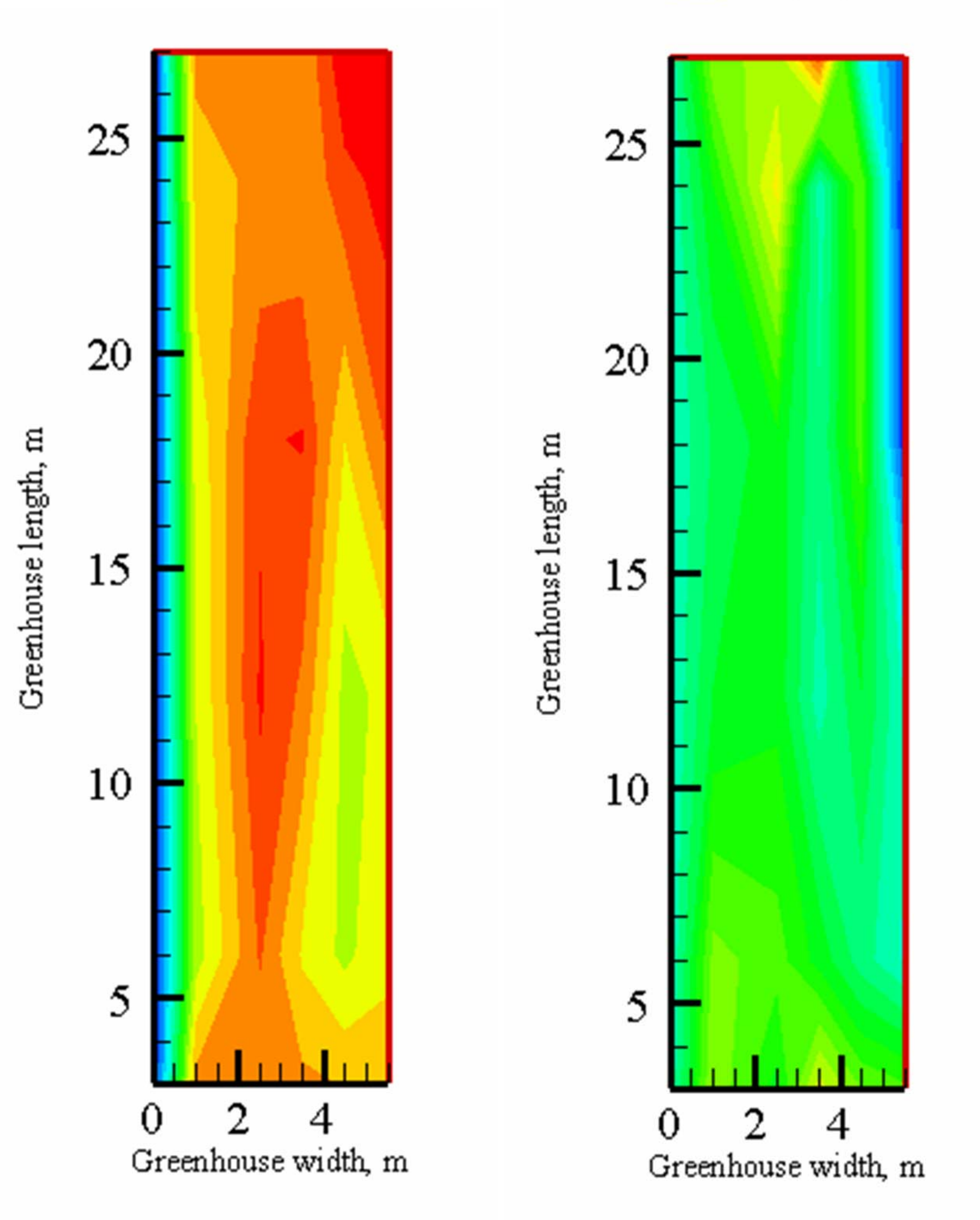
Measurements

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

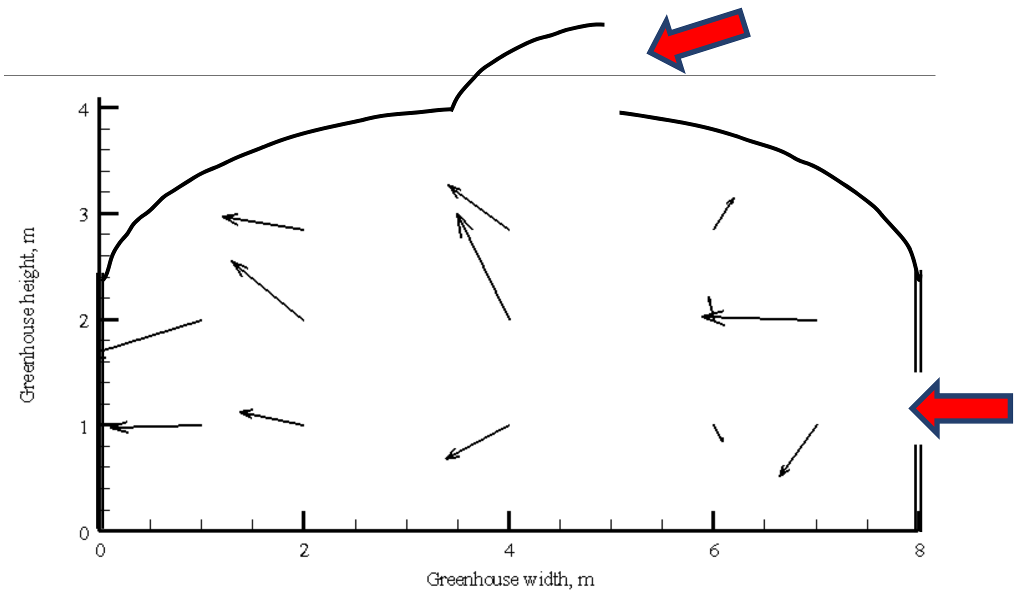
(a) natural ventilation or

(b) fog cooling

Katsoulas et al. (2012)

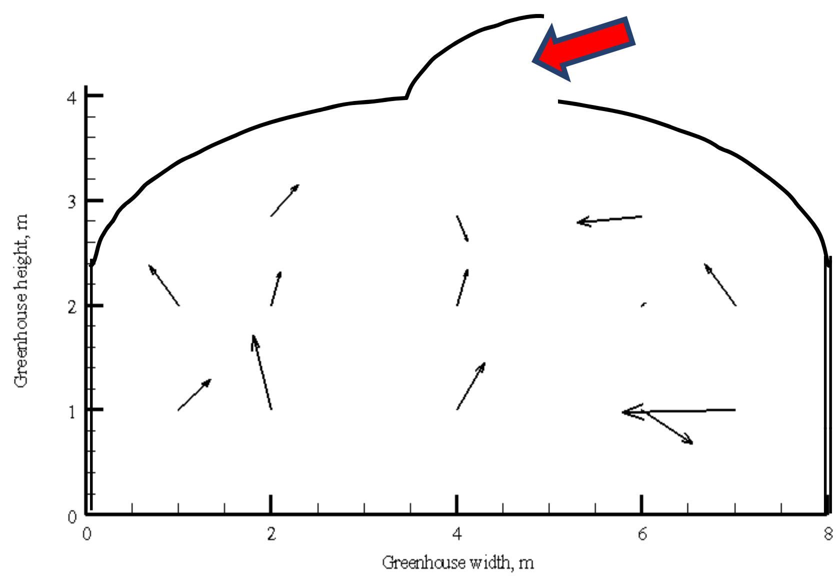


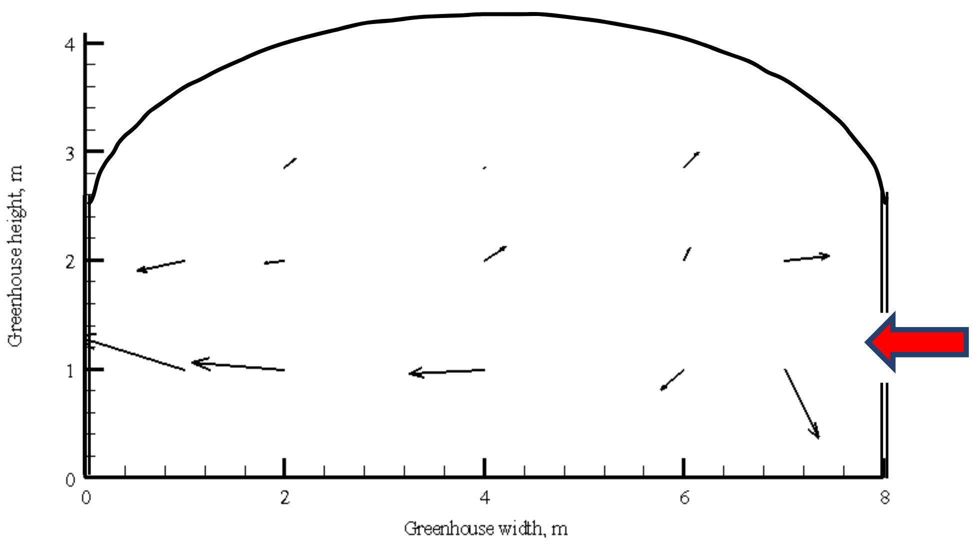
Intelligent climate control – Ventilation



Ventilation

effect of vent configuration on air velocity





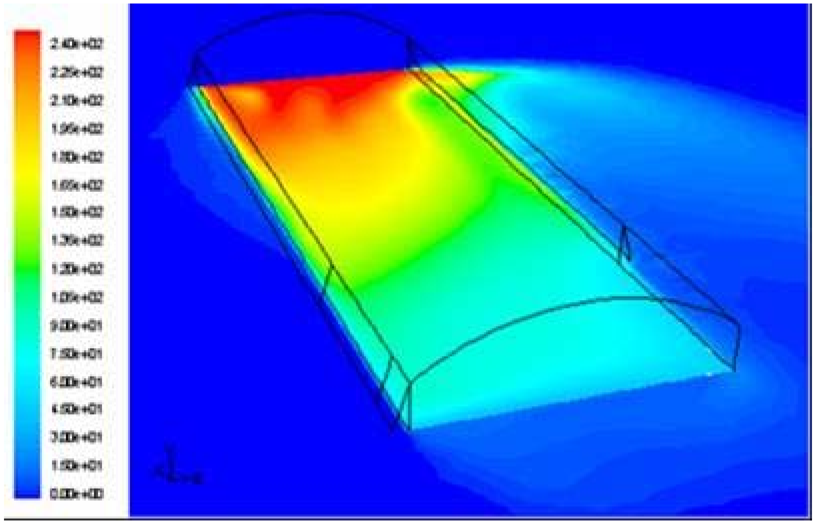
Integrated crop production

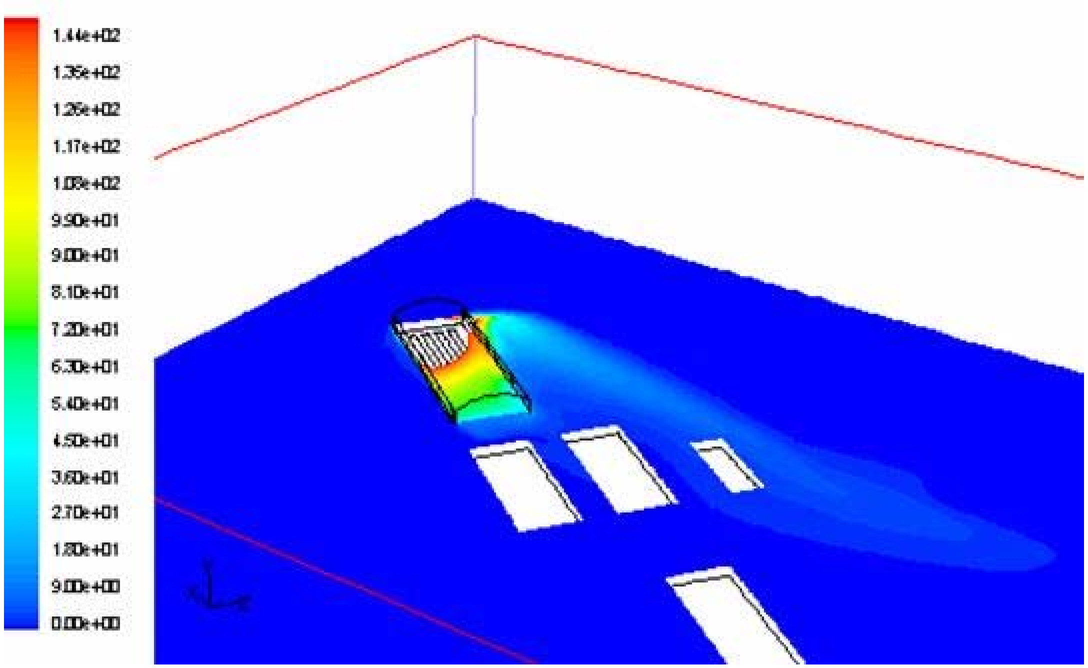
- Optimisation of insect screens in greenhouses
- Screenhouses




Hochschule Geisenheim University

Pesticides emission from greenhouse

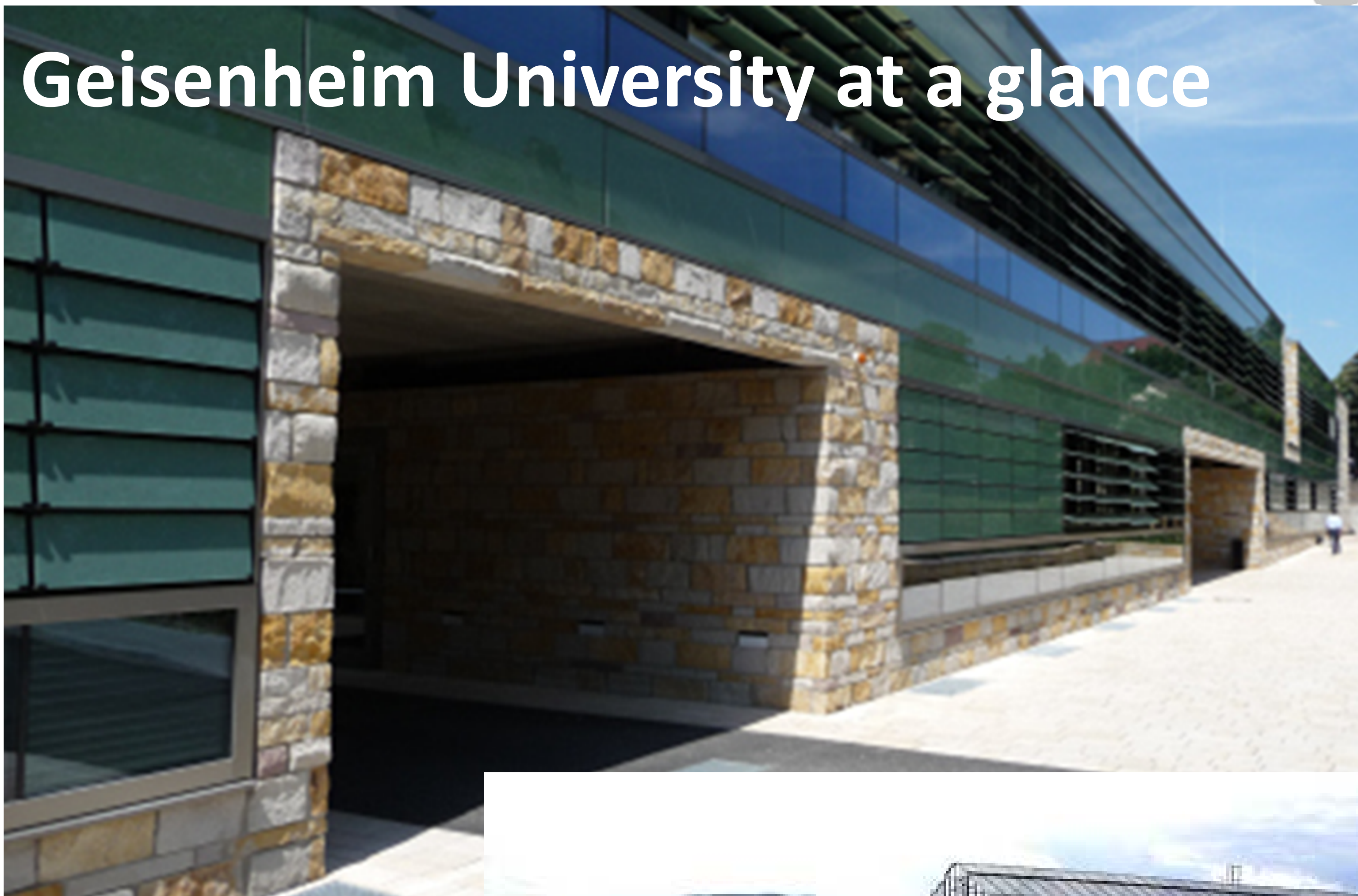




RUNNING PROJECTS

- CasH, www.cascade-hydroponics.eu (bilateral Greece-Germany)
- AgriTexSil, www.agritexsil.eu (bilateral Greece-Germany)
- FoodOASIS, www.foodoasis.eu Alga4Fule&Aqua, Fotokipia, InGreco (Greek national EDK)
- Med Greenhouses https://medgreenhouses.interreg-med.eu/ (Interreg MED)
- Organic PLUS https://organic-plus.net/ (H2020)

Geisenheim University at a glance



Hochschule Geisenheim University

Entrance to UNESCO Heritage "Mittelrheintal" (Upper Middle Rhine Valley)

Campus Geisenheim University

Hochschule Geisenheim University

Hochschule Geisenheim University

Research center Geisenheim (founded 1872)

Rhein-Main University of applied Sciences (Campus Geisenheim)

01.01.2013

Geisenheim University

Currently approximately ca. 1700 Students

61 PhD-Students

480 Employees

85 scientists
45 Professors
350 technical and administrative staff

6 Centers

- Applied Biology
- Viticulture and Horticulture
- Wine Science and Beverage Processing Technology
- Analytical Chemistry and Microbiology
- Economics
- Landscape Architecture and Urban Horticulture

Center of Applied Biology

- Soil Science and Plant Nutrition
- Botany
- Phytomedicine
- Grapevine Breeding

Center of Viticulture and Horticulture

- General and Organic Viticulture
- Pomology
- Vegetable Crops
- Viticultural/Horticultural Engineering

Center of Wine Science and Beverage Processing Technology
- Enology
- Modeling and Systems Analysis
- Beverage Processing Technology and Food Safety

Analytical Chemistry and Microbiology
- Microbiology and Biochemistry
- Wine Chemistry and Beverage Research
- Chemistry and Sensory Evaluation of Food Products

Economics
- Business Administration and Market Research
- Management and Marketing

Landscape Architecture and Urban Horticulture
- Urban Horticulture and Ornamental Plant Research
- Open Space Planning
- Vegetation Technology and Landscaping
- Environmental Conservation and Assessment

Hochschule Geisenheim University

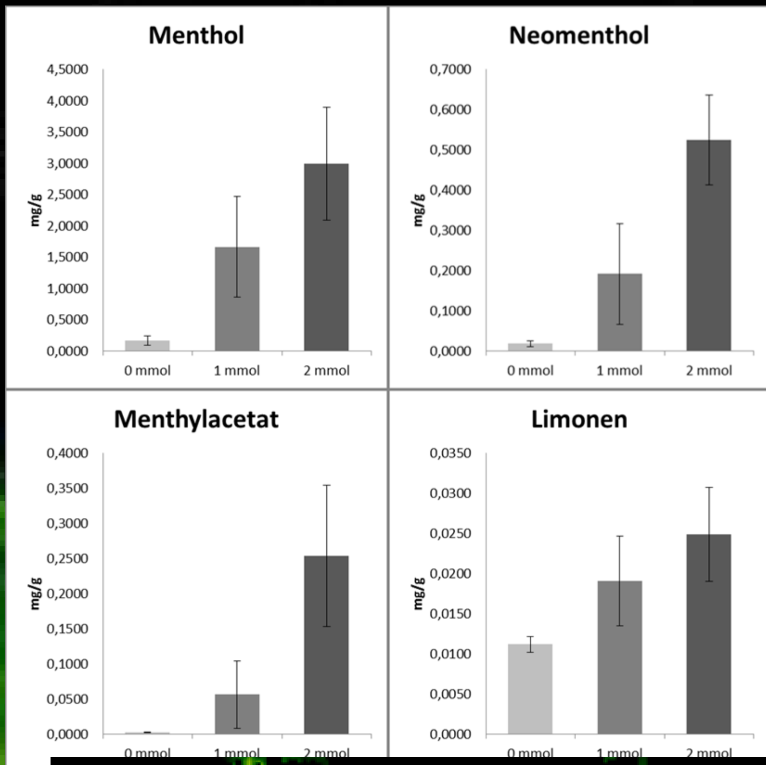
Department of Soil Science and Plant Nutrition

Viticulture

Horticulture

Dr. Johannes Max

Current research subjects



Influence of environmental factors (stressors) on plant secondary metabolism

NMR-images: Carel Windt

Hochschule Geisenheim University

Strategies for Adaption to / Mitigation of climate change


Photo: Hannah Klostermann


Photo : Hannah Klostermann

Horticulture in the Tropics and Subtropics

Currently running research project:
Reuse of pre-treated and untreated wastewaters for the irrigation of agricultural crops in (semi-)arid regions (Outapi, Northern Namibia)

Hochschule Geisenheim University

Project: „EPoNa“

Since March 2017

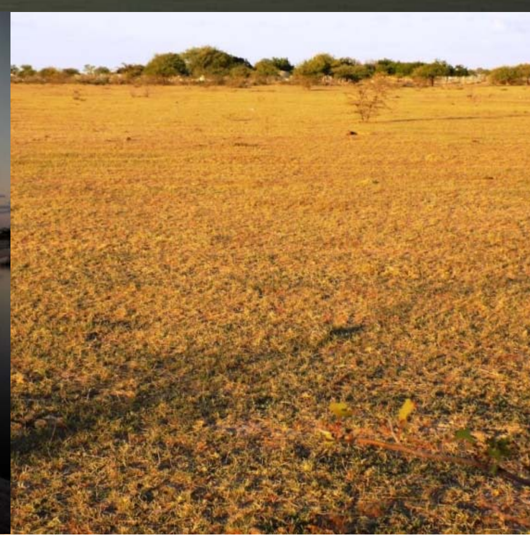
Partner:

TECHNISCHE UNIVERSITÄT DARMSTADT

IWAR

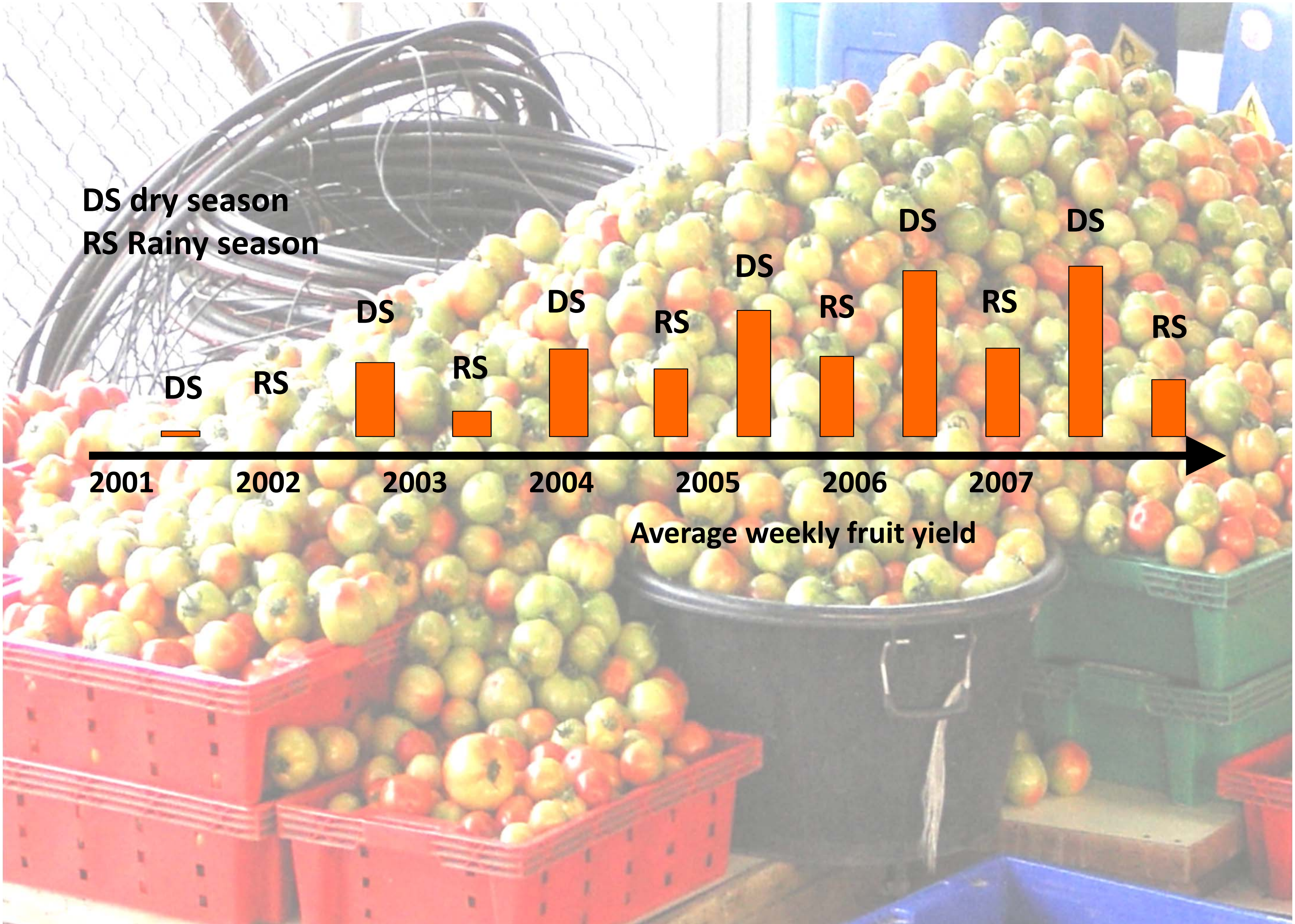
Gauff Ingenieure

universität

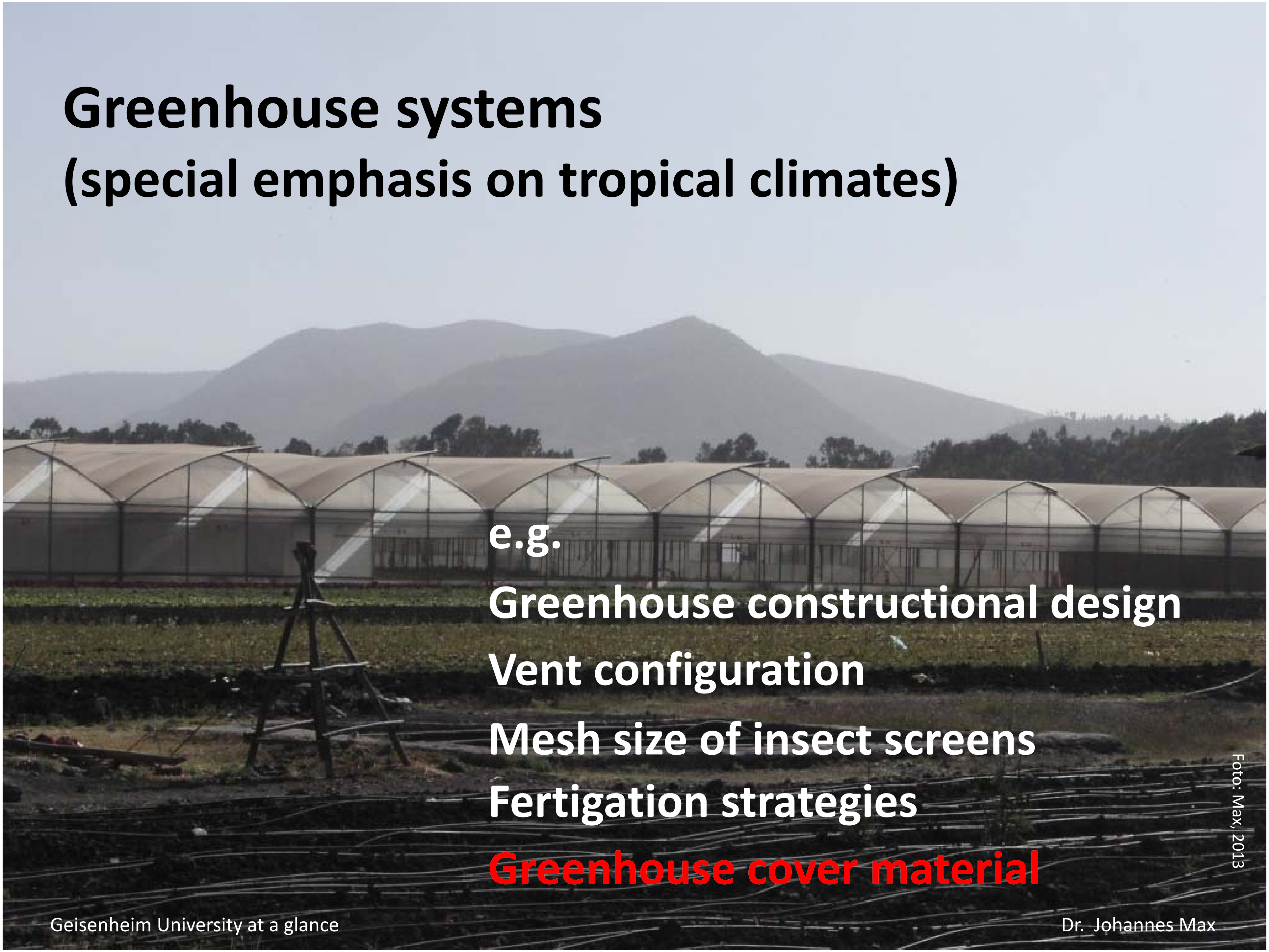


Hochschule Geisenheim University

Development/Adaption of greenhouse Technology to tropical climate conditions


DS dry season
RS Rainy season
DS
RS
DS
RS
DS
RS
DS
RS
DS
RS
DS
RS
2001
2002
2003
2004
2005
2006
2007
Average weekly fruit yield

Greenhouse systems
(special emphasis on tropical climates)



e.g.

Greenhouse constructional design

Vent configuration

Mesh size of insect screens

Fertigation strategies

Greenhouse cover material

Foto: Max, 2013

Cover Materials for Greenhouses

University of Thessaly, Volos, 24 – 30 September 2018

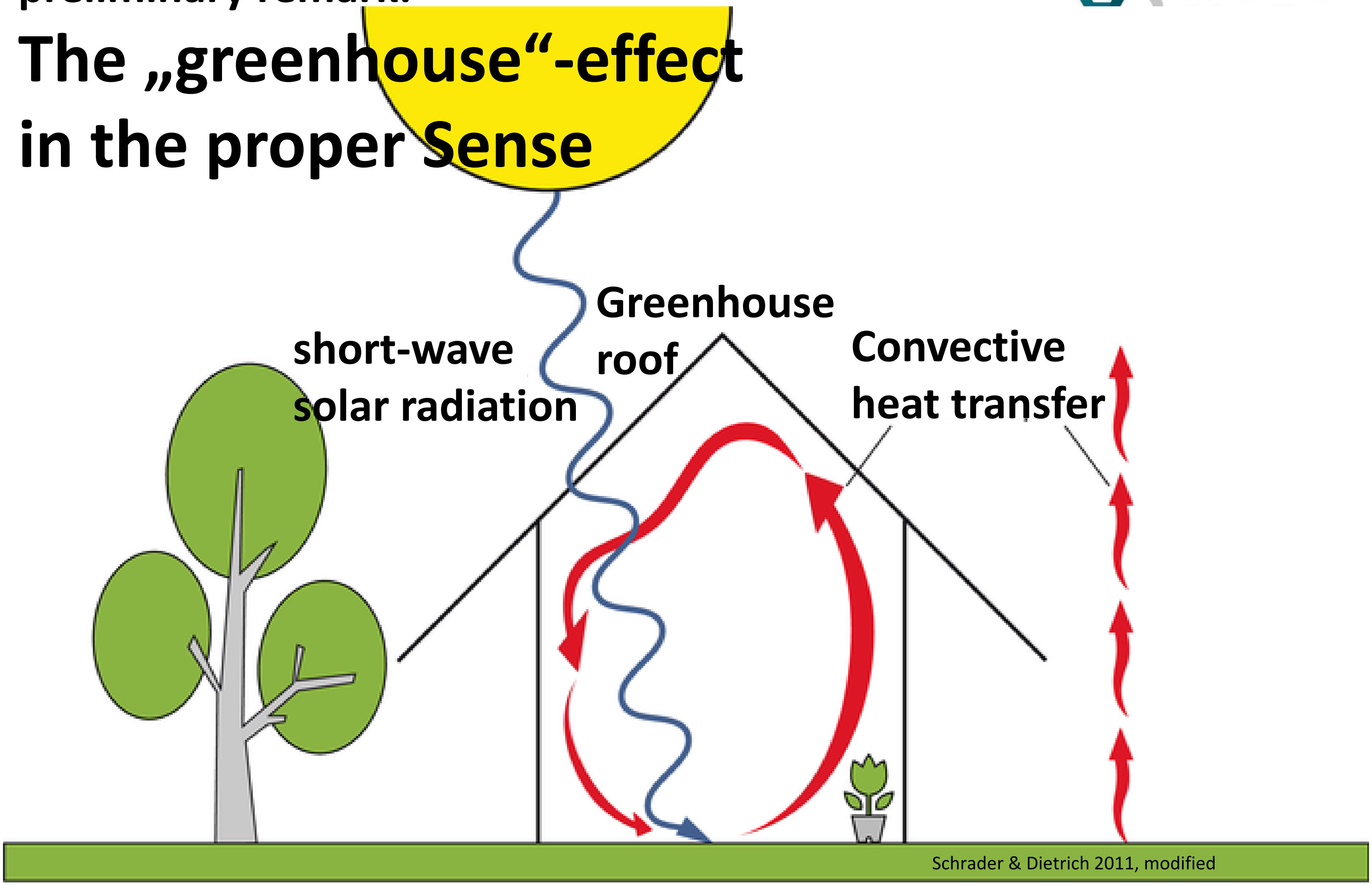
www.richel.fr, 06/2015

Dr. Johannes Max, Prof. Dr. Nikoloas Katsoulas

General overview: global situation of protected cultivation

preliminary remark:

The „greenhouse“-effect in the proper Sense



Therefore, the use of the terms "greenhouse-effect" and "greenhouse gas" in the context of global climate change is entirely incorrect!

→ The mechanisms responsible for the warming of the earths' atmosphere differ fundamentally from those responsible for the fact that daytime temperatures in greenhouses (without cooling and or ventilation) are usually warmer then ambient air

The higher temperatures, initially, were the primary reason to employ greenhouses and remain to be a major reason in temperate climates

The **first greenhouses** in Europe were erected at the **end of the 17th century** in so-called

Orangeries

The first Orangeries were constructed in central Europe (Vienna 1549) and later also in northern Europe for the exhibition of “exotic” plants such as orange and other citrus trees and for the production of (sub)tropical fruits or the rich and privileged…

...the first greenhouses...

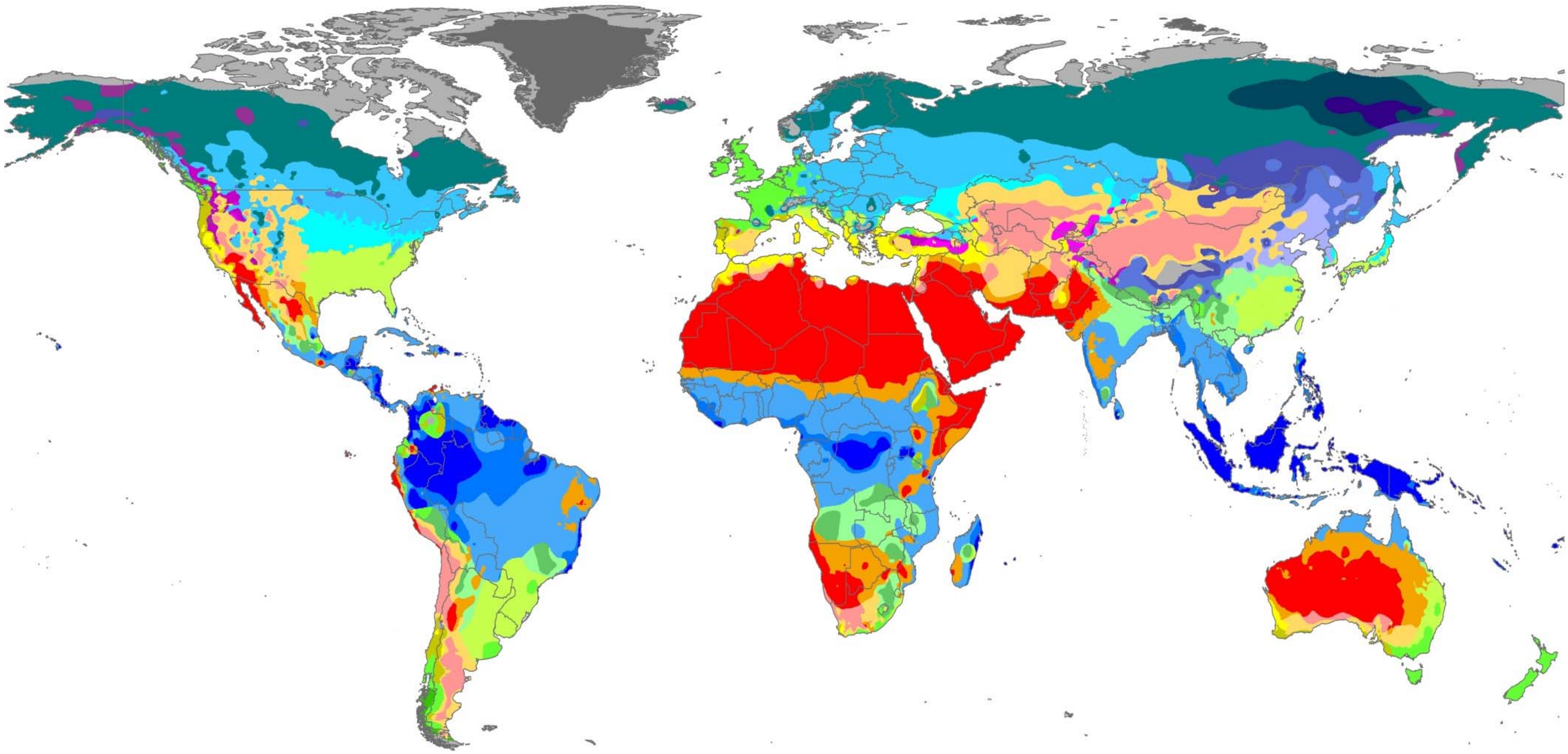
The first greenhouses…

…in the **Mediterranean**
and in the **USA:** } **around 1850**

…in the **Tropics**: Late 1950s (development of a greenhouse industry of relevant scale only during the last 2-3 decades)

purposes to employ greenhouses fundamentally differ between temperate and (sub)tropical climates

Different climate conditions…



…require different greenhouses!

…Netherlands…

: www.horconex.nl, 06/2015


Looije Tomaten B. V.
www.gabot.de, 09/2018

…Spain…

…Greece…

…Thailand…

...Kenya...


…Namibia…


…Israel…

Temperate Climates

main purpose: increasing the indoor temperatures during cooler times of the year to enable year round production

Tropical climates:

protecting crops from

- **heavy rain**
- **storms**
- **excess solar irradiation**
- **pest organisms (insects & vectored viruses, mites, birds, rodents etc.)**


Max, 2006


Max, 2006

Do you have any questions, so far

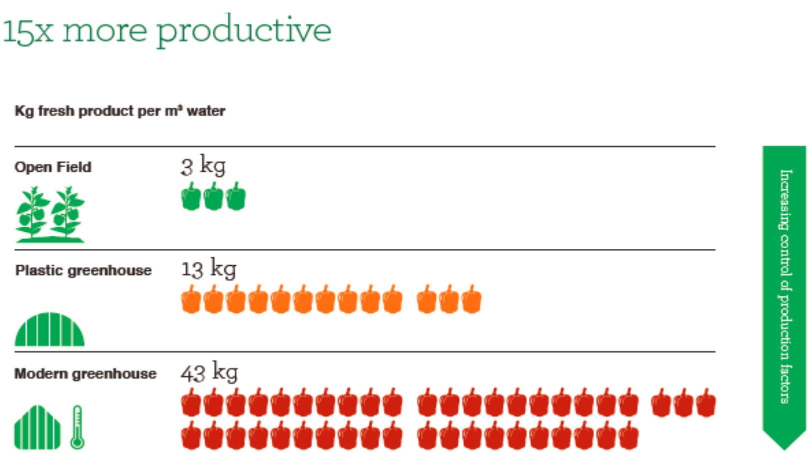
www.weddbook.com, 04/2018

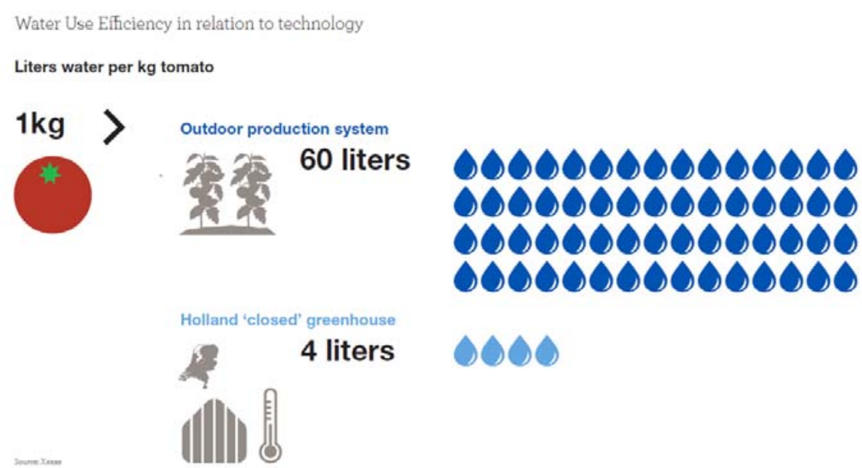
PROTECTED CULTIVATION: WHY?

- 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

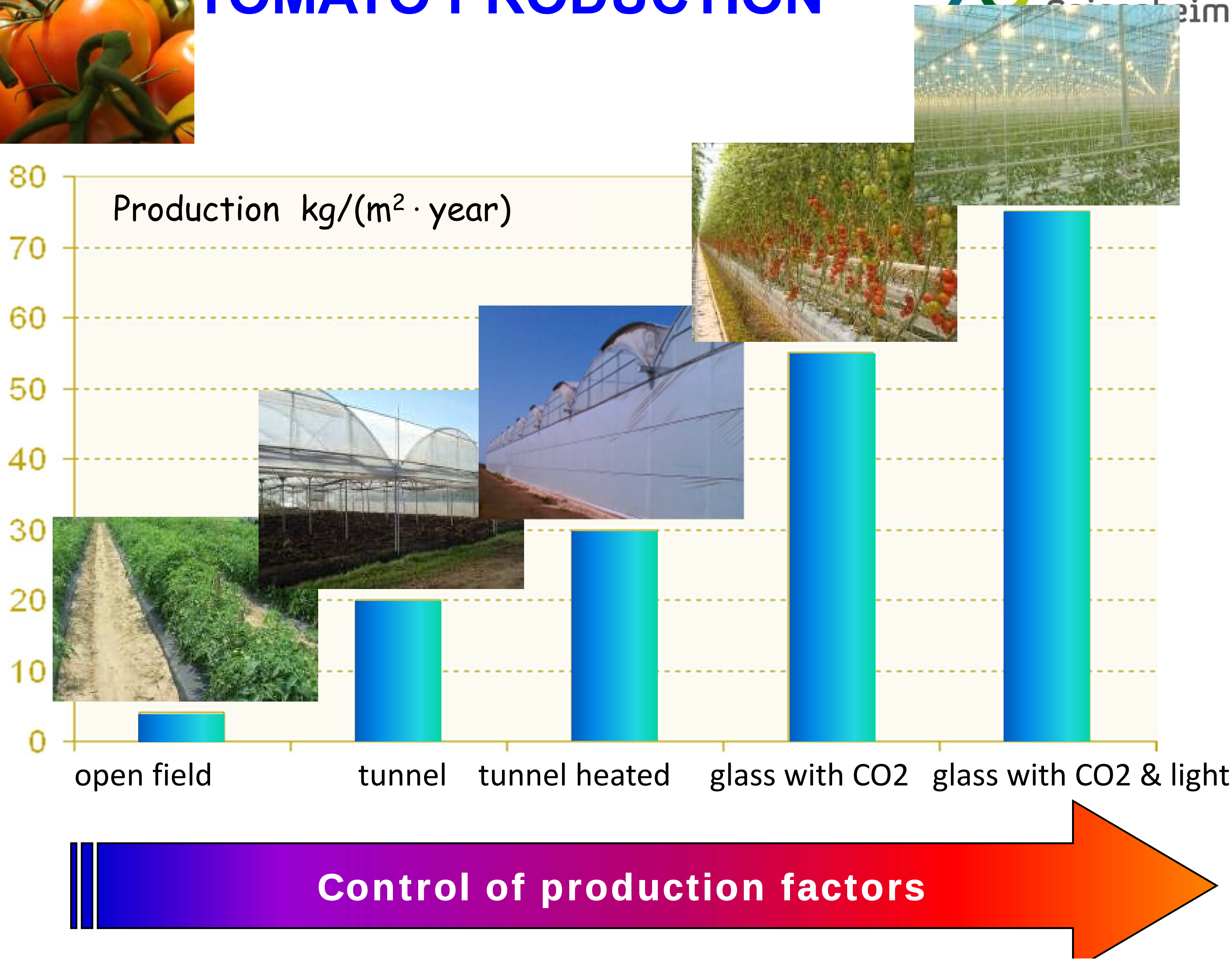
Means:

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

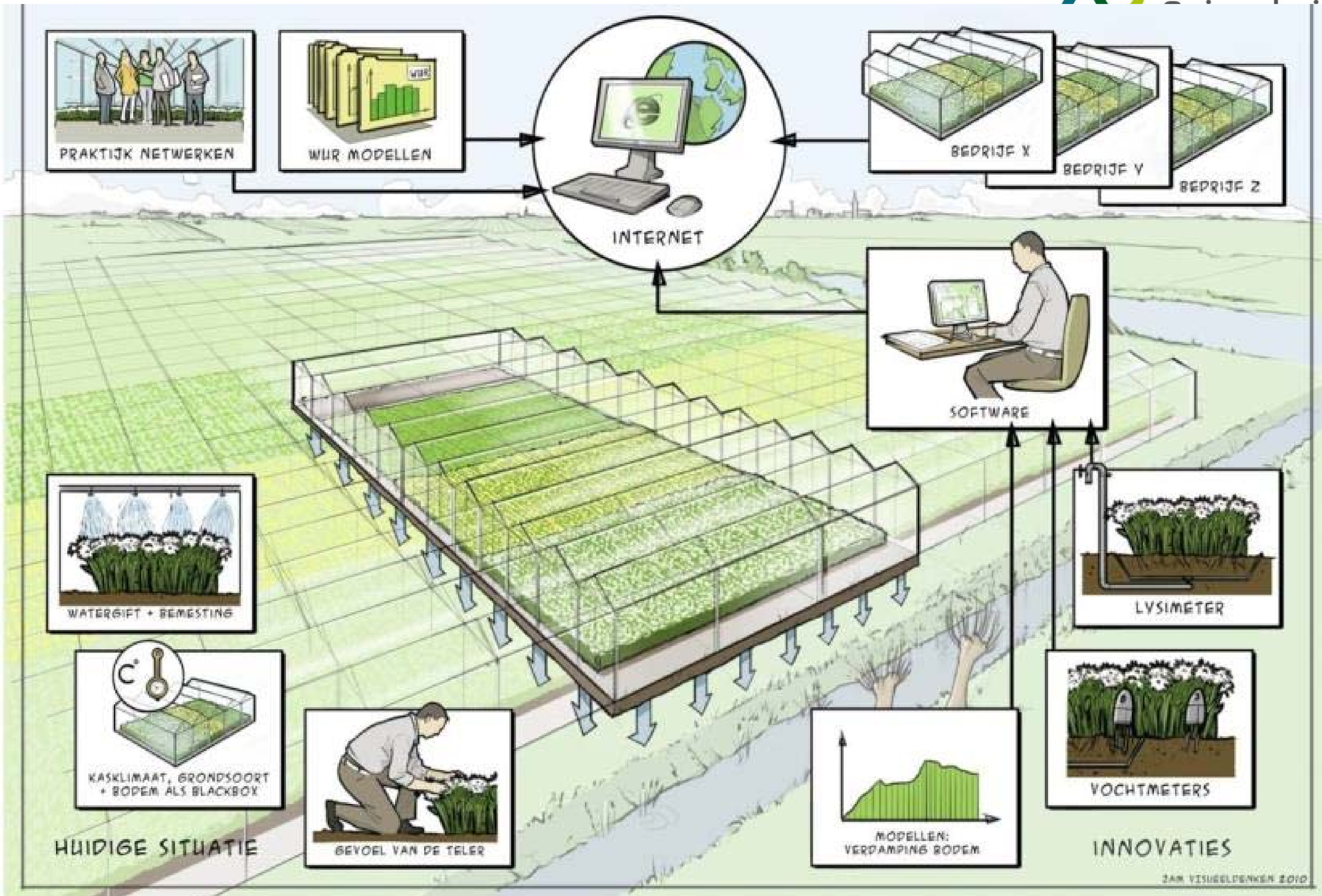




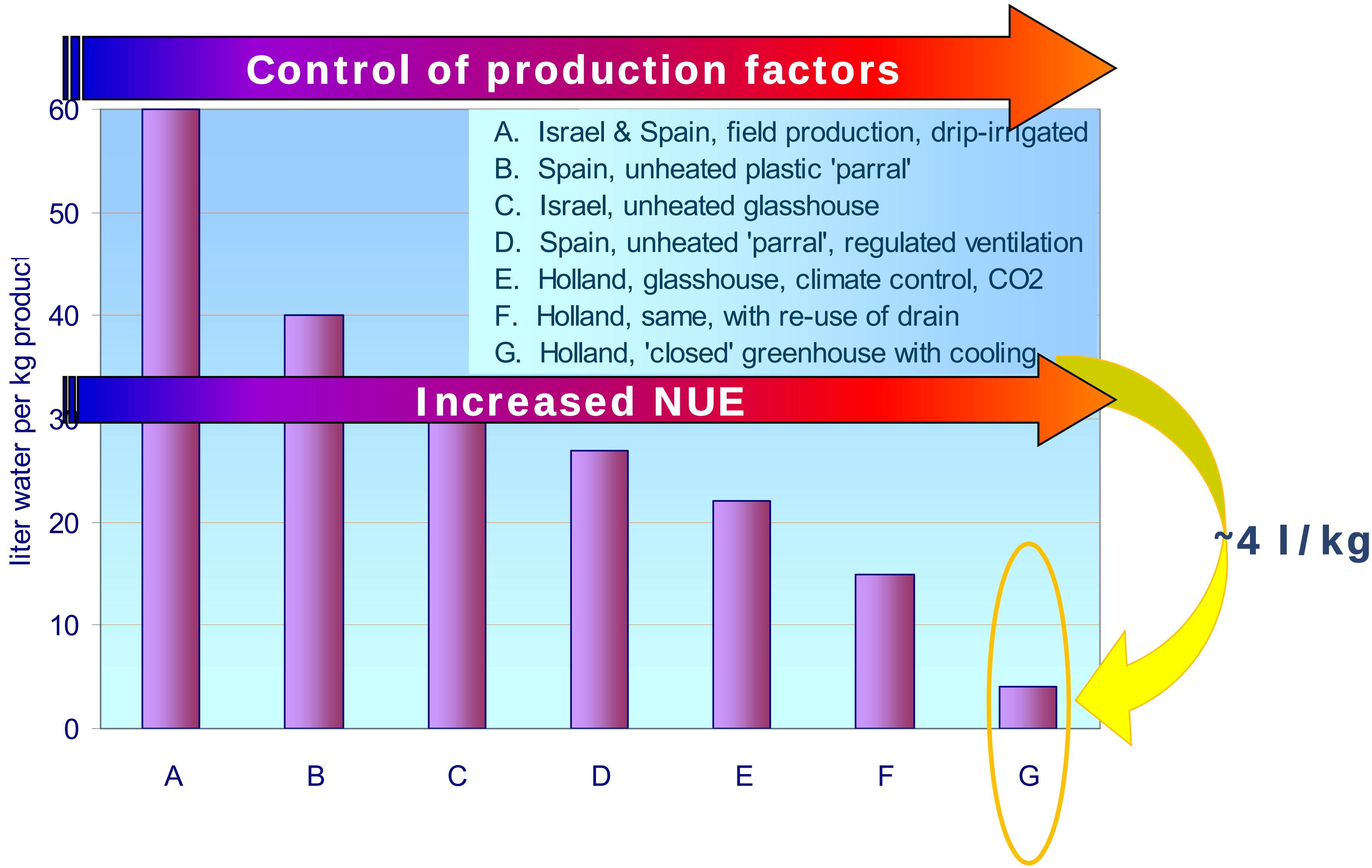
TOMATO PRODUCTION



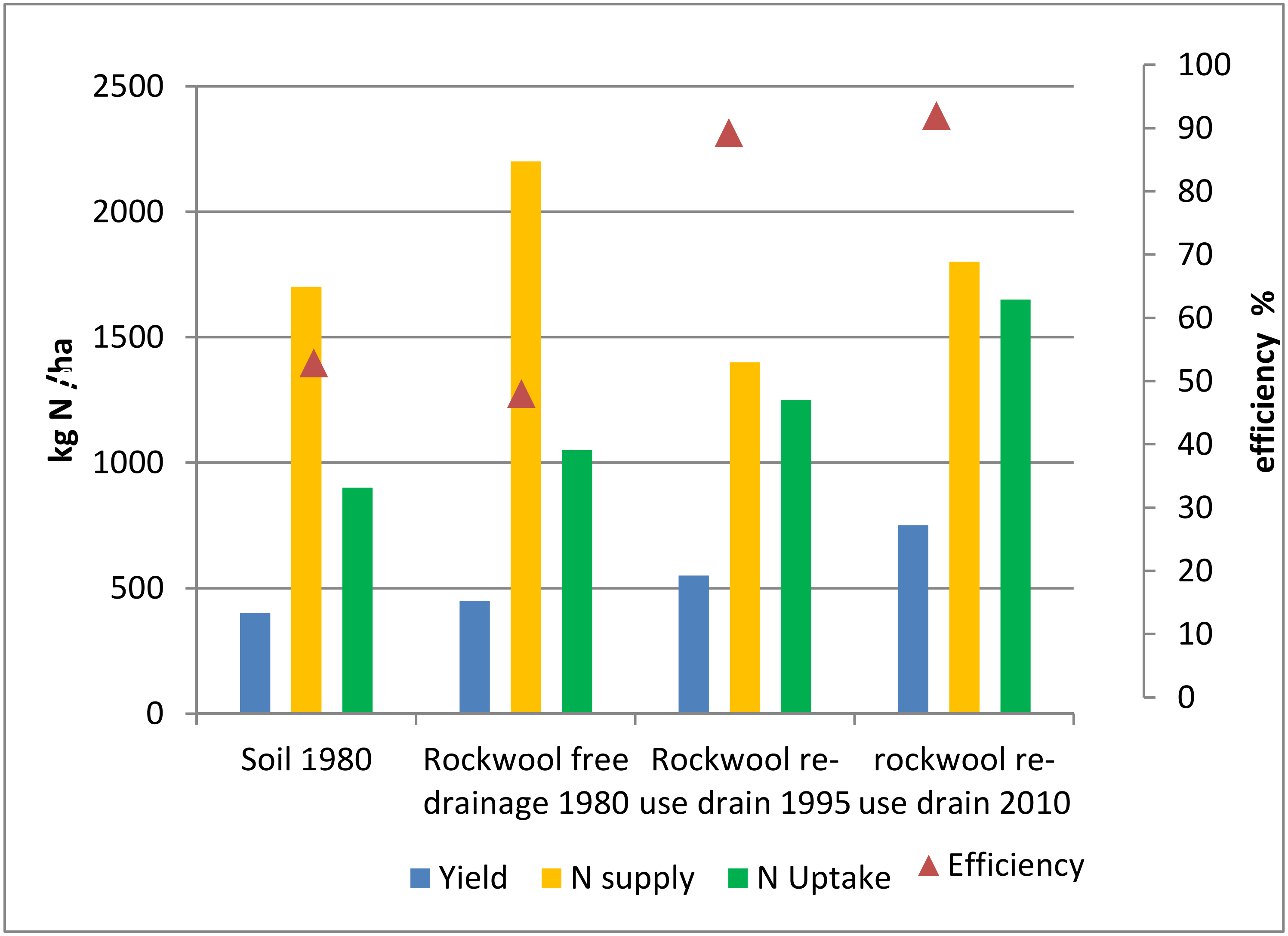
Hochschule


PRAKTIJK NETWERKEN
WUR MODELLEN
INTERNET
BEDRIJF X
BEDRIJF Y
BEDRIJF Z
SOFTWARE
WATERGIFT + BEMESTING
KASKLIMAAT, GRONDSOORT
+ BODEM ALS BLACKBOX
GEVOEL VAN DE TELER
HUIDIGE SITUATIE
MODELLEN:
VERDAMPING BODEM
LYSIMETER
VOCHTMETERS
INNOVATIES
JAM VISUEELDENKEN 2010

WATER USE EFFICIENCY (LITERS/KG$_{TOMATO}$)



EVOLUTION OF N USE EFFICIENCY IN GREENHOUSE HORTICULTURE



Tomato yield (kg/m2) and the N supply (kg N/ha) and the N use efficiency (%) in soil and in rockwool in the early 80-ies, 1995 and today.

IMPACT

AD: Abiotic depletion; AA: Air acidification; EU: Eutrophication; GW: Global warming 100 years; PO: Photochemical oxidation; CED: Cumulative energy demand

Hochschule Geisenheim University

LCIA results per FU, for tomato greenhouse crop Spain.

No	Unit	Total	Structure	Climate system	Auxiliary equipment	Fertilizers	Pesticides	Waste
AD	kg Sb eq	**1,7E+00**	**7,8E-01**	1,1E-03	6,3E-01	2,0E-01	1,7E-02	2,3E-02
AA	kg SO2 eq	**1,0E+00**	3,9E-01	1,5E-03	**4,2E-01**	[illegible]	[illegible]	[illegible]
EU	[illegible]	[illegible]	1,5E-01	2,7E-04	8,0E-02	[illegible]	[illegible]	[illegible]
GW	[illegible]	[illegible]	**8,8E+01**	1,5E-01	7,7E+01	[illegible]	[illegible]	[illegible]
PO	[illegible]	[illegible]	2,0E-02	5,4E-05	**2,7E-02**	[illegible]	[illegible]	[illegible]
CE	[illegible]	[illegible]	**1,9E+03**	3,1E+00	1,6E+03	[illegible]	[illegible]	[illegible]

The total impact is higher in Dutch than in Almeria greenhouses

Higher impact in: Fertilizers, pesticides, waste

LCIA res… …omato greenhouse crop in the Netherlands, with cogeneration … …n of electricity is considered "avoided electricity")

No	Unit	Total	Structure	Climate system	Auxiliary equipment	Fertilizers	Pesticides	Waste
AD	kg Sb eq	**5.6E+00**	[illegible]	[illegible]	[illegible]	9.9E-02	1.6E-03	3.3E-03
AA	kg SO_2 eq	**1.2E+00**	[illegible]	[illegible]	[illegible]	1.1E-01	1.8E-03	2.3E-03
EU	kg PO_4^{---}eq	**-1.1E+00**	[illegible]	[illegible]	[illegible]	1.6E-02	6.1E-04	9.1E-04
GW	kg CO_2 eq	**7.8E+02**	[illegible]	[illegible]	[illegible]	4.8E+01	2.0E-01	2.1E+00
PO	kg C_2H_4	**1.9E-01**	[illegible]	[illegible]	[illegible]	2.2E-03	1.1E-04	7.6E-05
CED	MJ	**1.2E+04**	8.2E+02	**1.1E+04**	3.1E+02	2.0E+02	3.9E	[illegible]

Higher impact due to Structure, climate system and auxiliary equipment

Montero et al. (2011)

CO_2-Emissions per kg product) in heated greenhouse in Central / northern Europe

Product	CO_2-Emissions (in g per kg product) Heated greenhouses	Open field production
Beans	6.360	220
Leek	5.430	190
Lettuce	4.450	140
Cucumber	2.300	170
Tomato	9.300	85

Estimated area under protected cultivation (2010)

www.foodqs.cn/news, 09/2018

Estimated area (ha) of protected crops per region and type of structure			
	Greenhouses + Tunnels		
	Plastic	Glass	Total
Asia	440 000	3 000	443 000
Mediterranean	97 000	8 000	105 000
Americas	15 600	4 000	19 600
Europe*	16 700	25 800	42 500
Africa + Middle East*	17 000	-	17 000
Total	586 300	40 800	627 100
*Excludes European countries on the Mediterranean Sea.			

Note though, that the figures, especially for Asia and Africa may vary tremendously depending on the data sources

Estimated area of greenhouse vegetable production

worldwide:	**2015: 473.466 hectares**
	2017: 497.815 hectares
Europe	**2017: 173.561 ha**
South America:	**12.502 ha**
North America:	**7.288 ha**
Asia:	**224.974 ha**
Africa:	**36.993 ha**
Oceania:	**2.036 ha**

(Cuesta Roble (Oak hill) consulting, 2018)

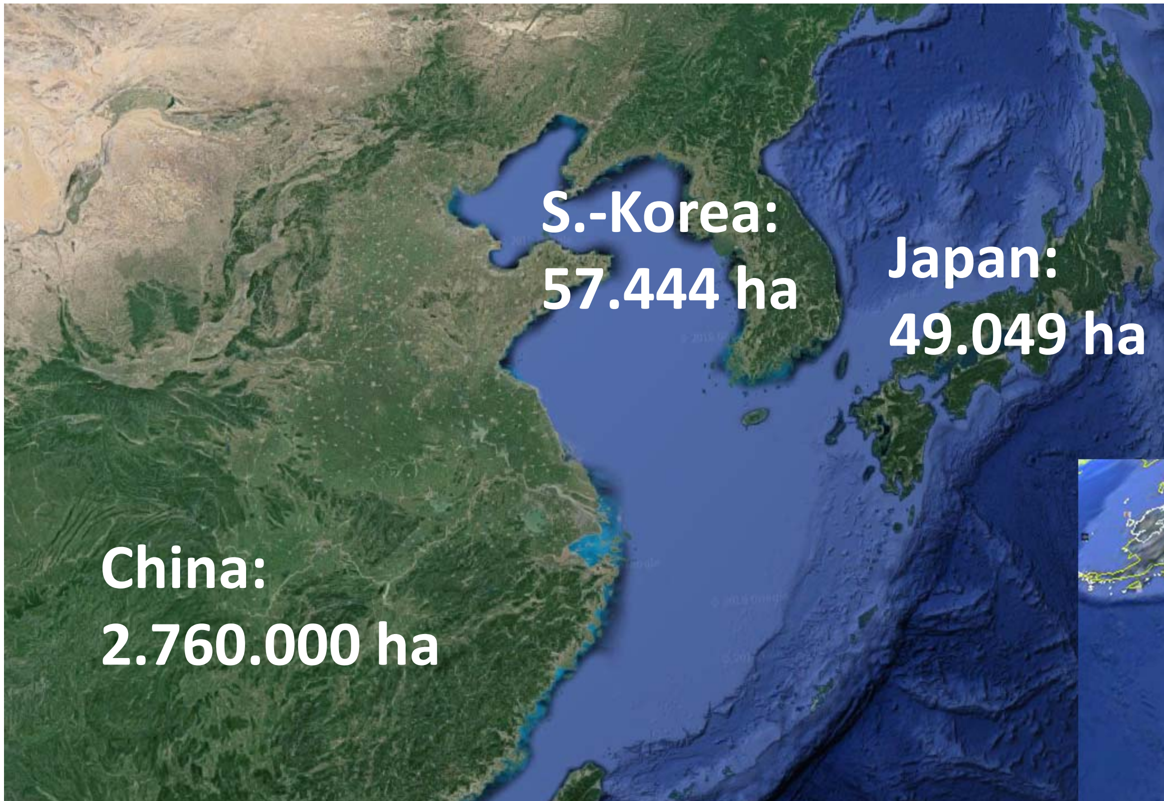
Estimated Greenhouse area and important crops (2010)

www.foodqs.cn/news, 09/201800

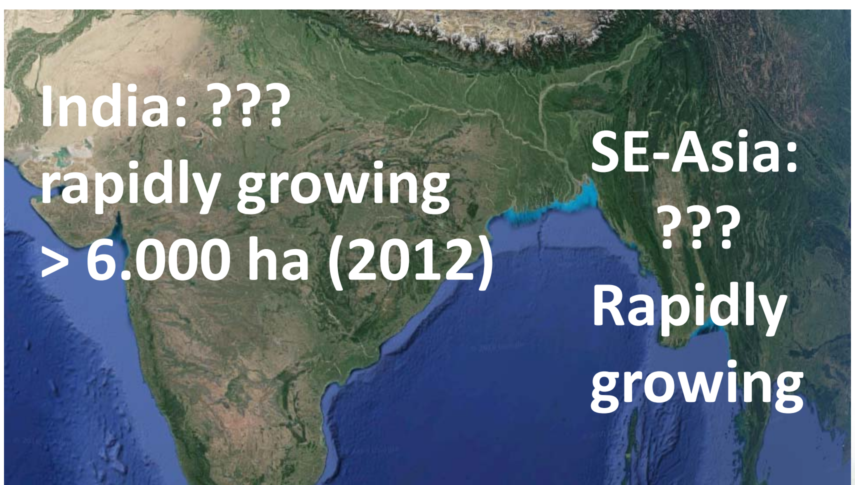
Estimated greenhouse area (ha) and important food crops grown in greenhouses worldwide

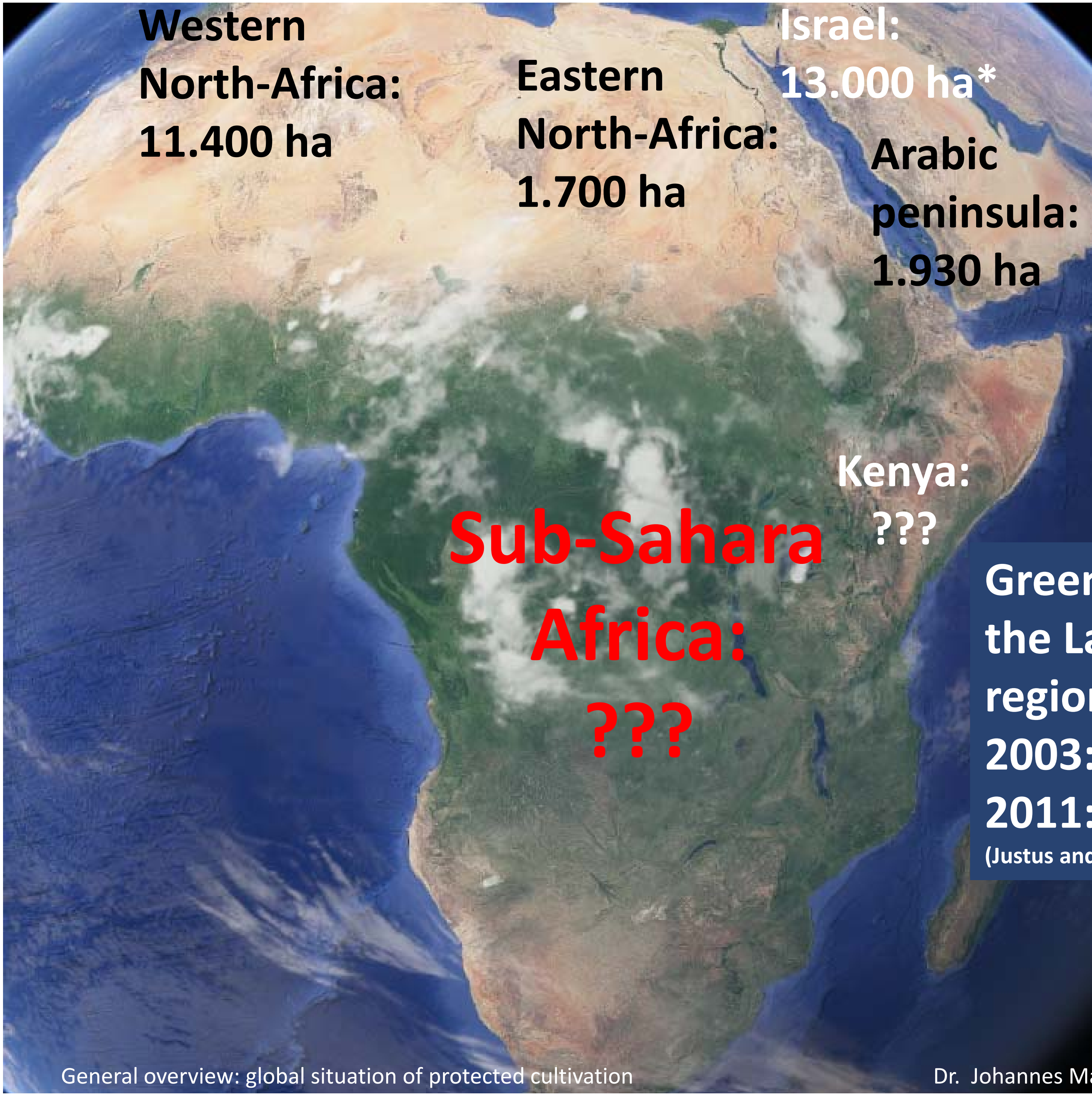
Country	Total area	Food crops area	Hydroponic		Important food crops	
China	360 000	(-)[z]	140[y]	Cucumber (-)[x]	Tomato (-)[x]	Sweet pepper (-)[x]
Spain	55 000	> 50 000	4 000 (10)	Melons (-)	Tomato (-)	Sweet pepper (-)
Japan	52 571	43 950 (84)	655 (1.5)	Tomato (15)	Cantaloupe (13)	Strawberry (13)
Italy	26 000	21 000 (81)	400 (1.9)	Tomato (-)	Zucchini (-)	Sweet pepper (-)
Korea	21 061	(-)	(-)	Cucumber (-)	Chinese cabbage (-)	Tomato (-)
Western North Africa[w]	11 400	> 7 900	(-)	Tomato (47)	Sweet pepper (25)	Cucumber (8)
Turkey	10 800	9 000 (83)	(-)	Tomato (-)	Cucumber (-)	Melon (-)
The Netherlands	10 800	4 335 (40)	2 895 (72)	Tomato (30)	Sweet pepper (23)	Cucumber (16)
France	9 100	6 500	(-)	Tomato (-)	Cucumber (-)	Strawberry (-)
United States	5 000	300 (6)	300 (100)	Tomato (-)	Cucumber (-)	Lettuce (-)
Greece	4 620	3 790 (82)	60 (1.6)	Tomato (-)	Cucumber (-)	Eggplant (-)
Middle East[v]	4 300	3700 (86)	(-)	Tomato (65)	Cucumber (21)	Sweet pepper (10)
Germany	3 300	(-)	(-)	Tomato (-)	Cucumber (-)	Lettuce (-)
Belgium	2 250	1 600 (71)	850 (53)	Tomato (38)	Lettuce & herbs (19)	Cucumber (5)
United-Kingdom	1 600	(-)	(-)	Tomato (-)	Cucumber (-)	Lettuce (-)

www.google.com/maps, 09/2018


S.-Korea:
57.444 ha
Japan:
49.049 ha
China:
2.760.000 ha


Canada:
2.286 ha
USA:
8.425 ha
Mexico:
11.759 ha


India: ???
rapidly growing
> 6.000 ha (2012)
SE-Asia:
???
Rapidly
growing



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*Israel Ministry of Agriculture and Rural Development, 2013

Greenhouse area in the Lake Naivasha region (central Kenya)

2003: 376 ha

2011: 683 ha

(Justus and Yu, 2014)

While the area under protected cultivation
is remaining relatively constant in central and northern Europe,
the US, Canada and Australia,

it is constantly increasing

at moderate rates in the Mediterranean and

at high rates in some Countries in Sub-Sahara Africa
and especially in
South- (India),
South East- and
East- Asia (China)

The covering material is one of the most decisive parameters determining the performance and efficiency of a protected cultivation / greenhouse system

There are several **Groups of materials used as Greenhouse covers**

roughly, they can be divided into

- **rigid materials**
  - **Glass**
  - **plastic sheets**
- **material combinations**
- **Insect screens**
- **plastic films**

Aus: Reisinger & Max 2011

…Insect screens…

photo: Max, 2005

key parameters for the assessment of greenhouse covering materials

Light transmission

Spectral, PAR, UV, IR, NIR…

durability (service life)

Stability (Breaking resistance, tensile strength, shape retention …)

Insolation capacity

(heat transition coefficient, U-value, W [m^{-2} K^{-1}])

Weight (Dead loads)

soiling tendency

Condensation behaviour

coefficient of thermal expansion

fire behaviour

Price

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General overview: global situation of protected cultivation

Dr. Johannes Max, Prof. Dr. Nikoloas Katsoulas


Outlook:
Future perspective of protected Cultivation, by the example of the growing greenhouse industry in tropical regions

In many countries in tropical and sub-tropical Climates, the

- **Area under protected cultivation and**
- **Interest in employing greenhouse technology**

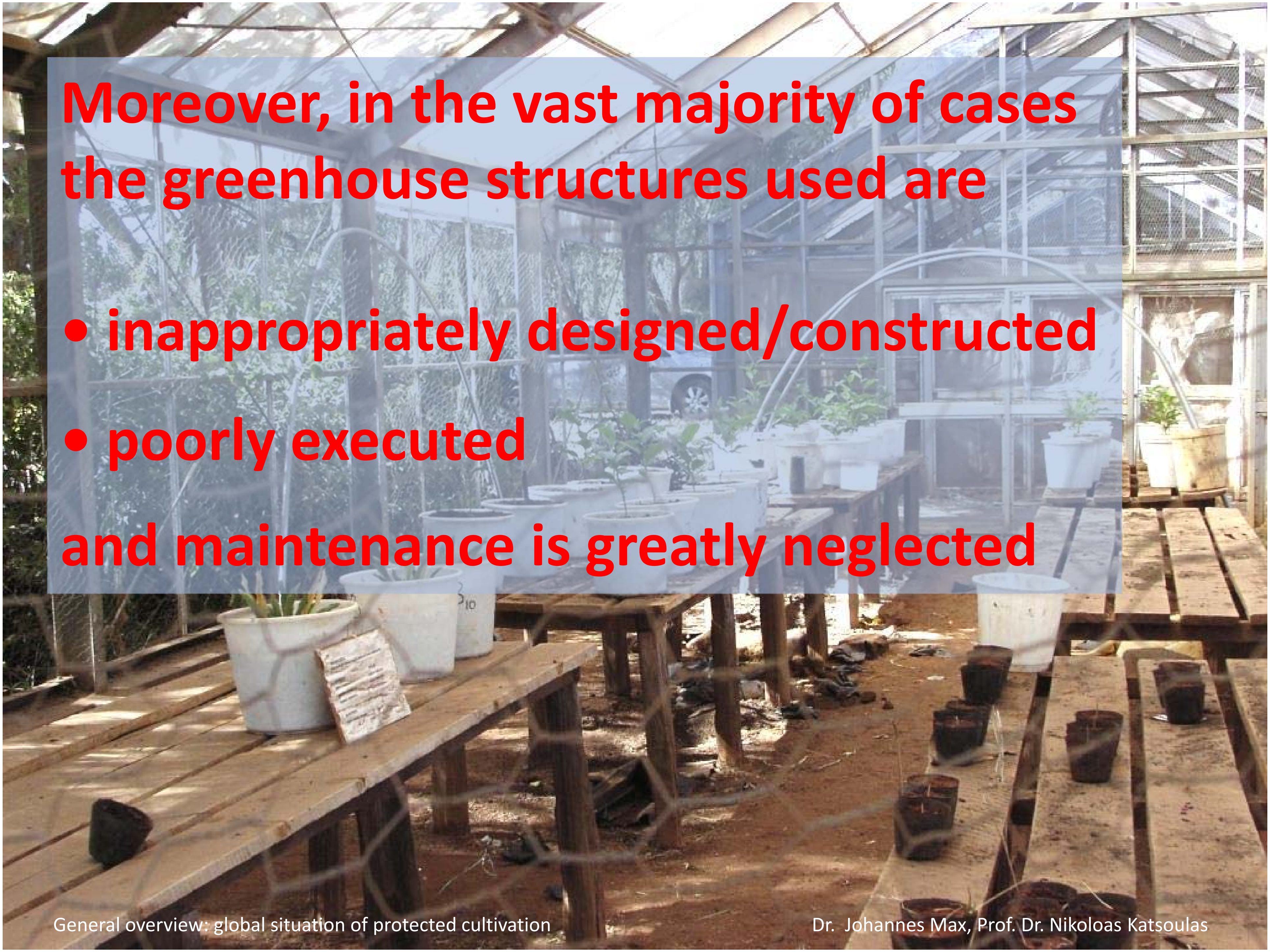
is steadily and rapidly increasing

But…

…research and developmental work on protected cultivation systems is still mostly done in industrialized countries mainly in temperate climates and to some extent in the Mediterranean

Accordingly,
greenhouses employed in tropical countries
are either imported
or
low-tech/low-cost structures
without any (scientific)
proof of concept / proof of principle

→ not specifically developed for /
adapted to tropical climate conditions



Moreover, in the vast majority of cases the greenhouse structures used are

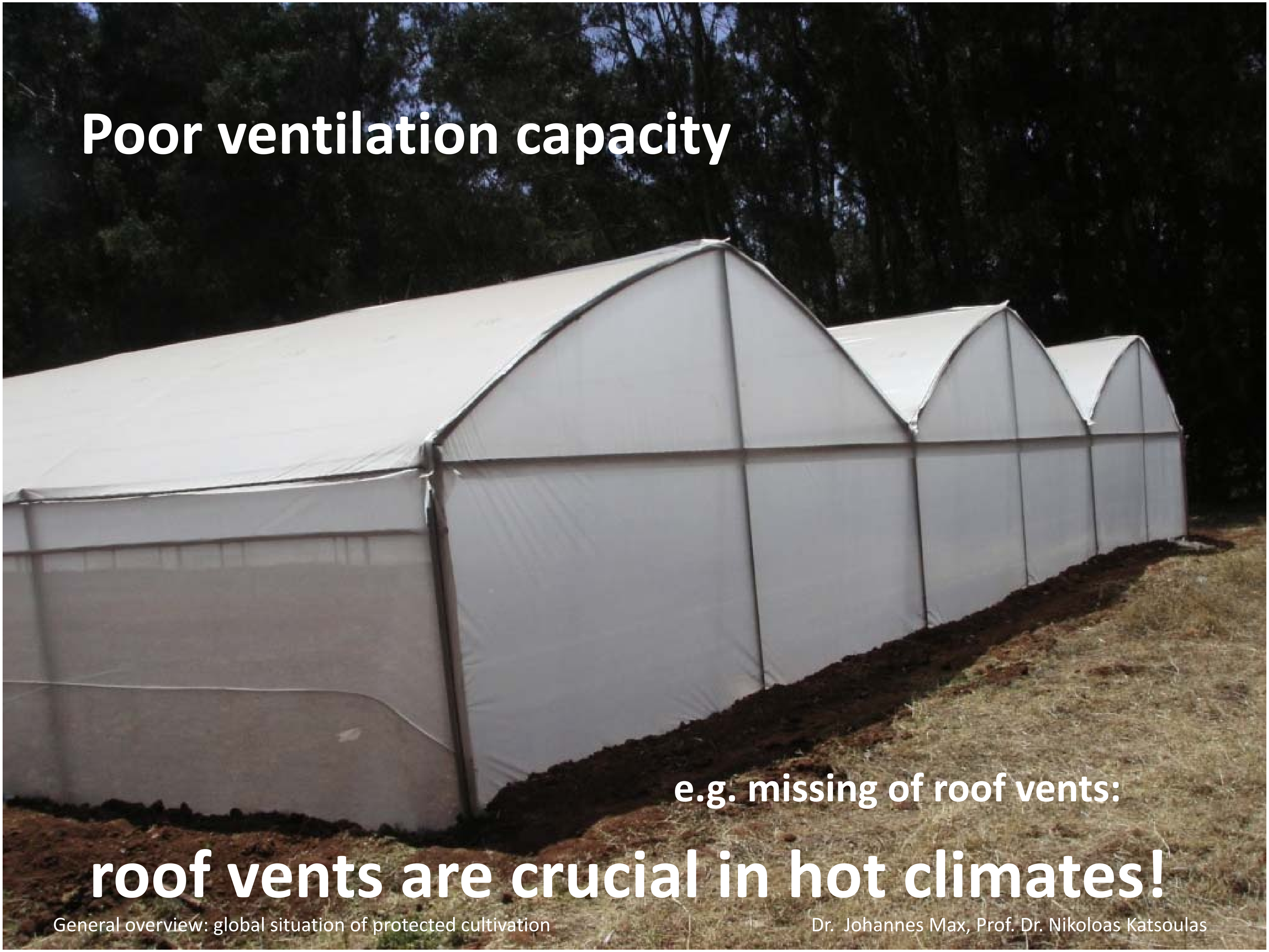
- inappropriately designed/constructed
- poorly executed

and maintenance is greatly neglected

Common Shortcomings

Inadequate Constructional Design

Poor ventilation capacity

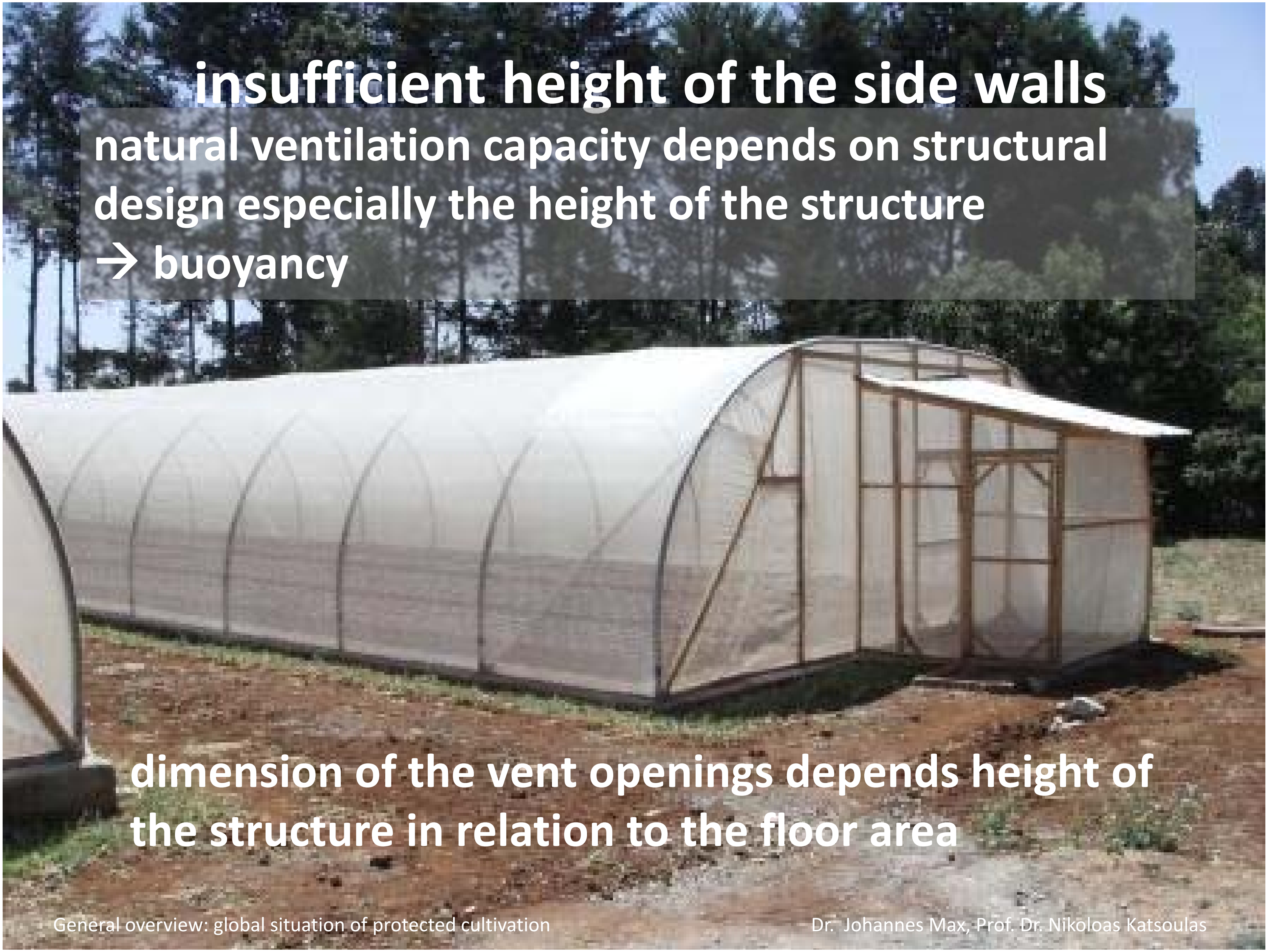


e.g. missing of roof vents:

roof vents are crucial in hot climates!

insufficient height of the side walls

natural ventilation capacity depends on structural design especially the height of the structure
→ buoyancy



dimension of the vent openings depends height of the structure in relation to the floor area


Ethiopia


Kenya


Thailand


Namibia

Improperly mounted or damaged plastic and net covers

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Missing of insect screens in the roof vents
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Unprotected entrance areas

Therefore,
the *enormous potential* of the region for vegetable production in protected cultivation systems remains *largely underused*

Main fields with high adaption / optimization potential:

- **Greenhouse constructional design**
  - Superstructures
  - Ventilation design
  - Covering materials
  - Cooling
- **Cultivation practices**
- **Phytopathology**
- **Irrigation-/Fertigation-Strategies**
  - Rain water harvesting
  - Water treatment


Thank you very much
for your attention!

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