OCP Policy Center Conference series

Functional integration of renewable energy and food production systems for the Mediterranean countries

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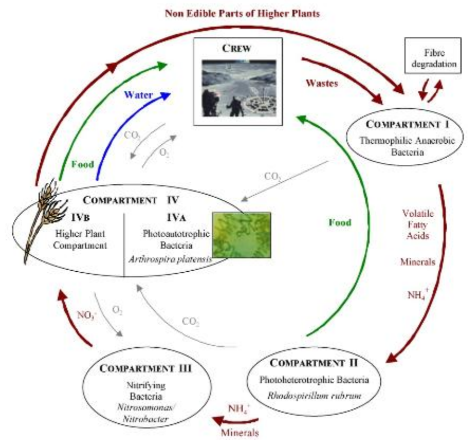
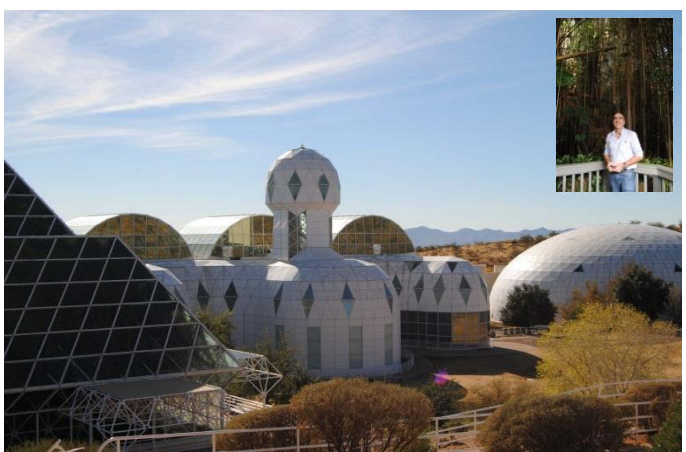
20-21 November 2014

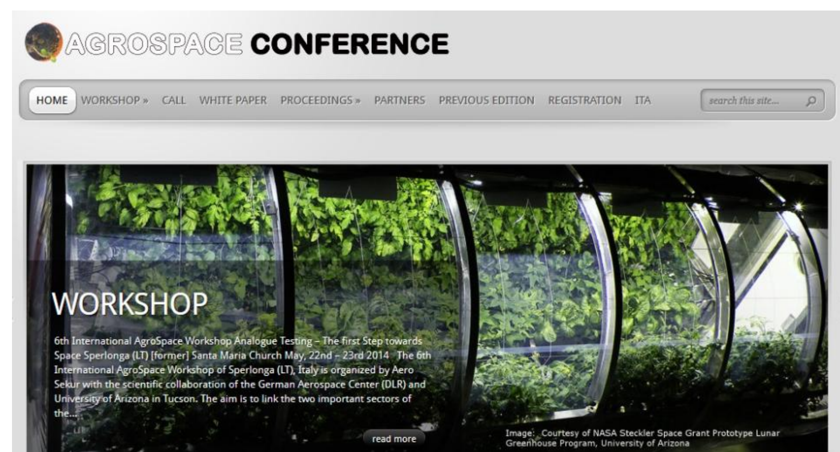
Who are we?

We are part of an international group of stakeholders interested on Biorigenerative Life Support Systems (BLSS) for Space

The MELiSSA concept







Why are we here?

We are not here to provide an immediate solution for food sustainability for the Mediterranean area

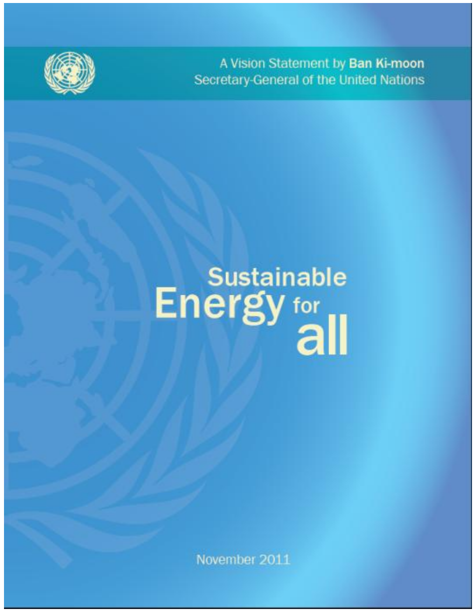
but to discuss our conceptual exercise

A BLSS for space is the most challenging system that we can imagine in terms of

food security
and
sustainable use of resources

Our aim is to transfer on earth agriculture lessons learned with work on BLSS

Functional integration of renewable energy and food production systems for the Mediterranean countries.



Energy enables. The historic energy transitions – first from human power to animal power, and then from animal power to mechanical power – were major shifts in the human journey toward greater productivity, prosperity, and comfort. It is unimaginable that today's economies could function without electricity and other modern energy services. From job creation to economic development, from security concerns to the status of women, energy lies at the heart of all countries' core interests.

Scientists warn that if the world continues on the current path, global temperatures could rise by more than four degrees Celsius by the end of this century. That will affect everything from the world economy to the health of our citizens and the health of the ecosystems that sustain life on Earth, from energy ,food, and water security to international security. **We know now that we cannot continue to burn our way to prosperity**.

Sustainable development is the imperative of the 21st century. Protecting our planet, lifting people out of poverty, advancing economic growth – these are different aspects of the same fight. We endeavor to create new business and market opportunities, new jobs, and new possibilities for human advancement. **We will not achieve any of these goals without energy – sustainable energy for all.**

Thhree linked objectives underpin the goal of achieving sustainable energy for all by 2030:

- • Ensuring universal access to modern energy services.
- • Doubling the rate of improvement in energy efficiency.
- • Doubling the share of renewable energy in the global energy mix.

Energy enters the agenda

Food and Agriculture Organization of the United Nations

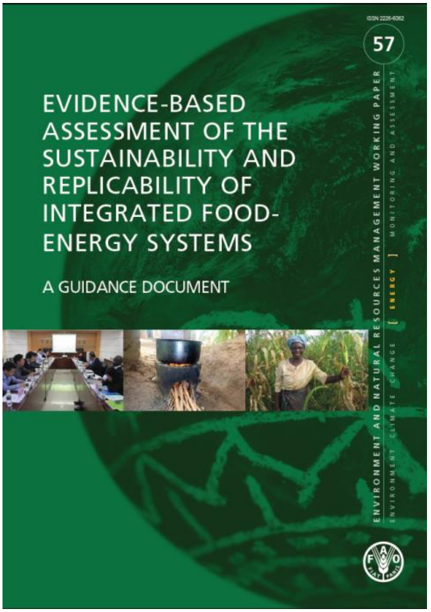
What is the post-2015 development agenda?

The post-2015 development agenda is a United Nations member state-led process aimed at defining a global development framework that will succeed the 8 Millennium Development Goals when they reach their target date at the end of 2015. At the same time as accelerating efforts to meet MDG targets, FAO has embraced the post-2015 process, identifying 14 thematic areas in which it can support member states in arriving at new goals.

FAO's 14 themes in sustainable development

- Food security and the right to food
- Nutrition
- Poverty eradication
- Resilience
- Social protection
- Climate change
- Ecosystems, biodiversity, genetics
- Energy
- Fisheries, aquaculture, oceans, seas
- Forestry and mountains
- Land and soils
- Sustainable agriculture
- Tenure rights
- Water

Functional integration of food and renewable energy production became a focus



Energy is vital for food security and resilient livelihoods; nevertheless, **the linkages between energy and food security and the importance of energy for food security are often overlooked**.

FAO argues that to mitigate such risks (*the risk that production of bioenergy reduces food security)* and to harness the potential benefits of bioenergy production, one is well advised to apply good practices of bioenergy production in the first place. **The production of bioenergy in Integrated Food-Energy Systems (IFES) is one of such good practices as IFES by their very nature allow one to meet both food and energy demand.**

An IFES is defined as a diversified farming system that incorporates agrobiodiversity and builds on the principles of sustainable production intensification, which aims to maximize primary production per unit area without compromising the ability of the system to sustain its productive capacity. More particularly, the concept of IFES combines the sustainable production of food and other biomass across different ecological, spatial, and temporal scales, through multiple-cropping systems, or systems mixing **annual** crop species with perennial plants, i.e. agroforestry systems.

FIGURE 3.

Examples of IFES typologies

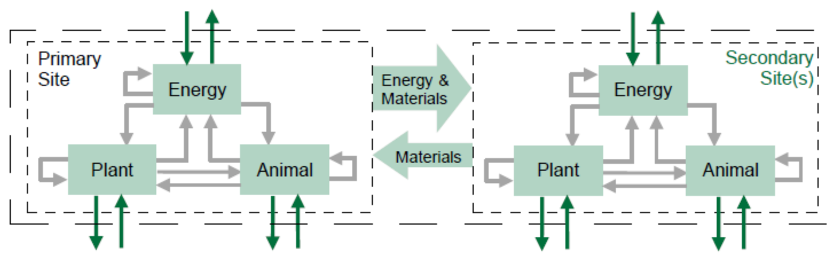
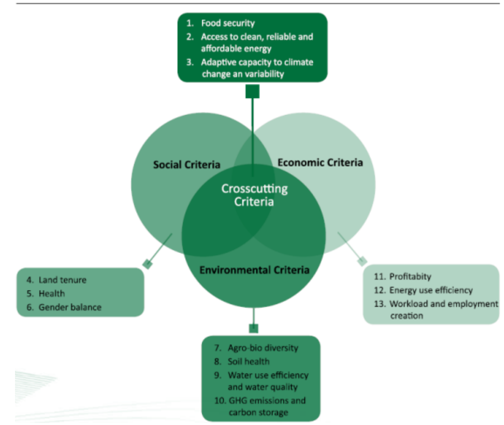


Figure 3a. General schematic of the potential flows among IFES plant, animal, and energy subsystems and primary and secondary sites. Dashed box indicates the IFES boundary. Dotted boxes delineate sites within IFES. If more than one site exists, then the primary site takes in materials from the secondary site and possibly returns energy and materials. Solid arrows represent material and energy flows, where black arrows are products sold off-site and gray arrows are on-site exchanges (Gerst *et al.*, no date).

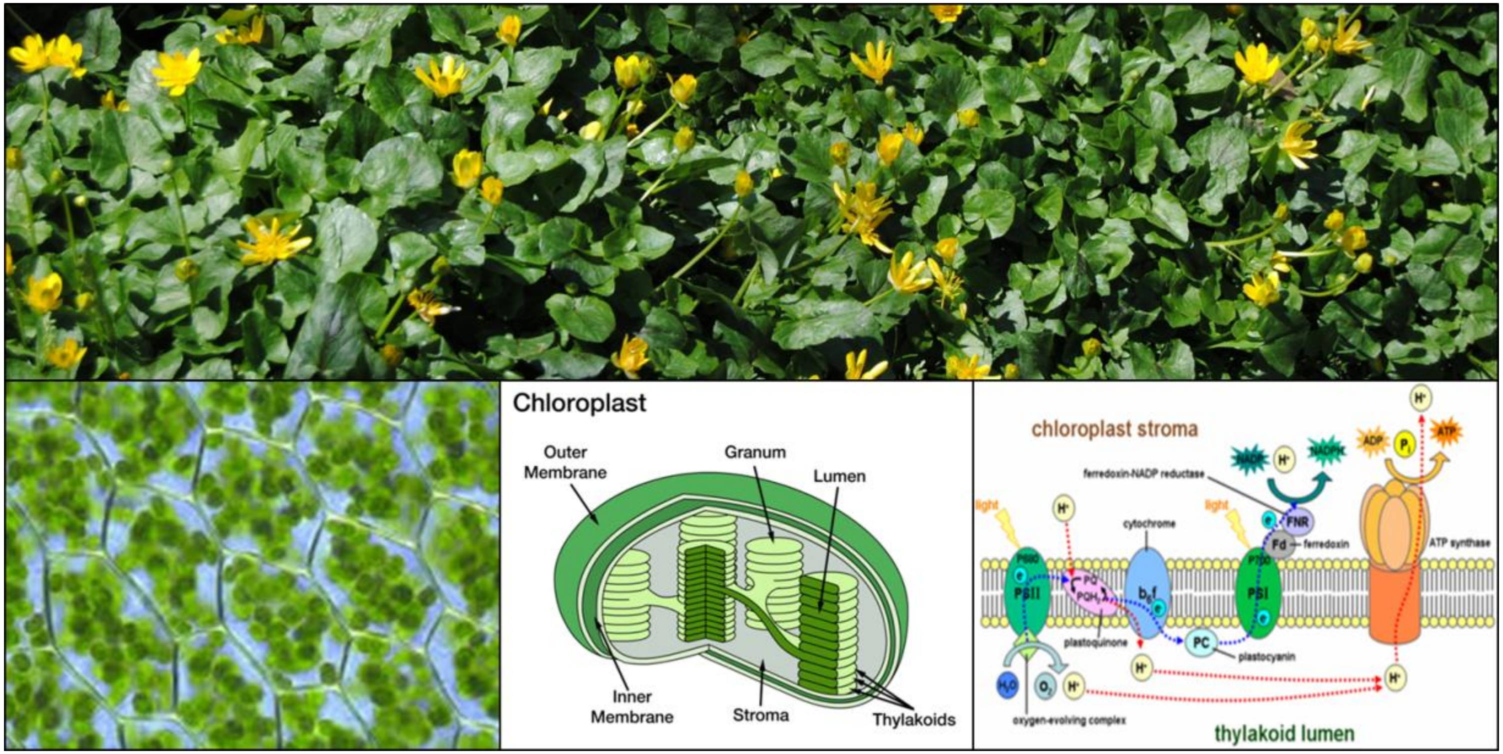
FIGURE 4.

Sustainability criteria for assessing IFES



FAO only consider bio-energy in this Guidance Document
BUT
We can think to integrate any type of renewable energy to obtain the same goal, Many different systems can be planned from very simple to very complex.

Photosynthesis VS photovoltaic



What does a plant do with the sun light?

Plants use light to produce electron transport

What does a photovoltaic cell do with the sun light?

Photovoltaic cells use light to produce electron transport

The similarity between plants and photovoltaic cell have inspired artistic visions of technology

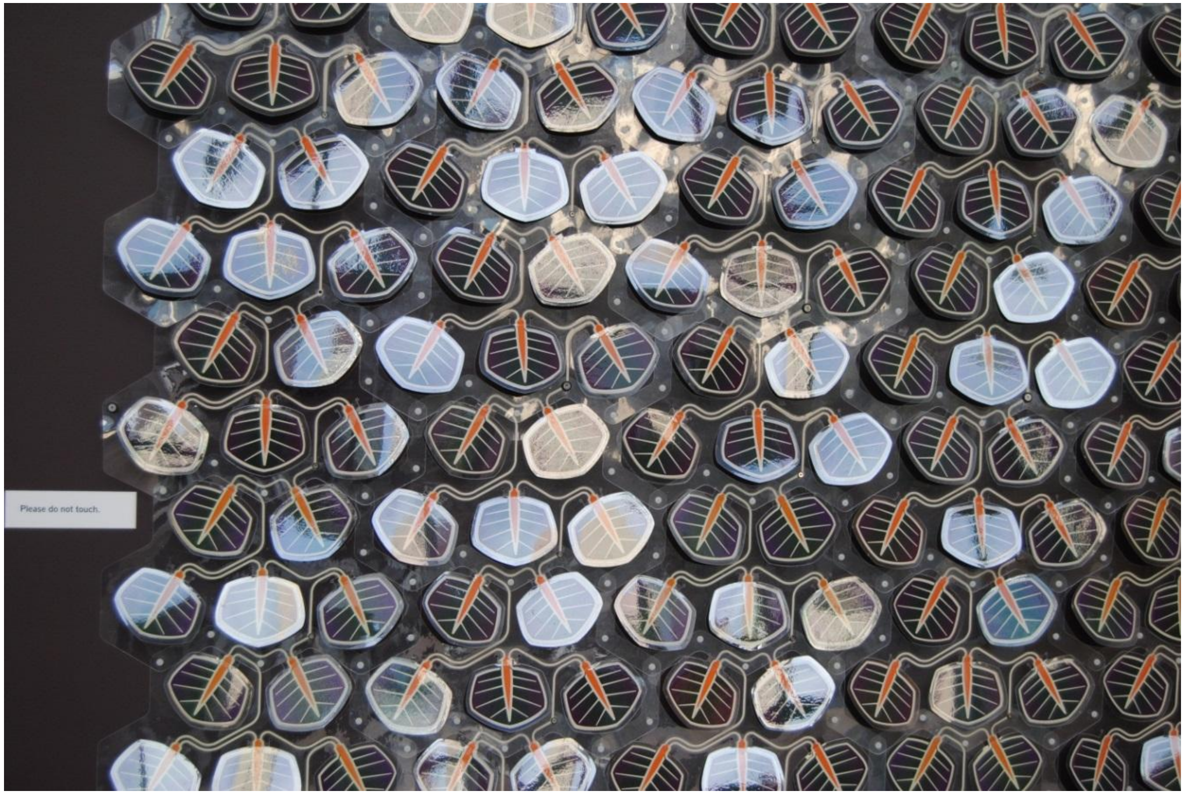


Figure 3. GROW: by Samuel Cabot Cochran and Benjamin Wheeler Howes SMIT Sustainable Minded Interactive Technology (USA – 2005) - Inspired by ivy, its "leaves" are flexible photovoltaic panels that generate solar power. MoMA, New York - USA

Conflict or synergies?

Plants and photovoltaic cells use the same renewable energy, the sun light.
With current technology plants and photovoltaic cells cannot coexist on the same land to share the sun light.

This highlight the potential competition among the production of food and the production of renewable energies.

The aim of our work is to test the hypothesis that a fraction of the incident radiation on a crop can be used by a new concept photovoltaic (NCPV) module with limited direct effects on quantity and quality of the product.

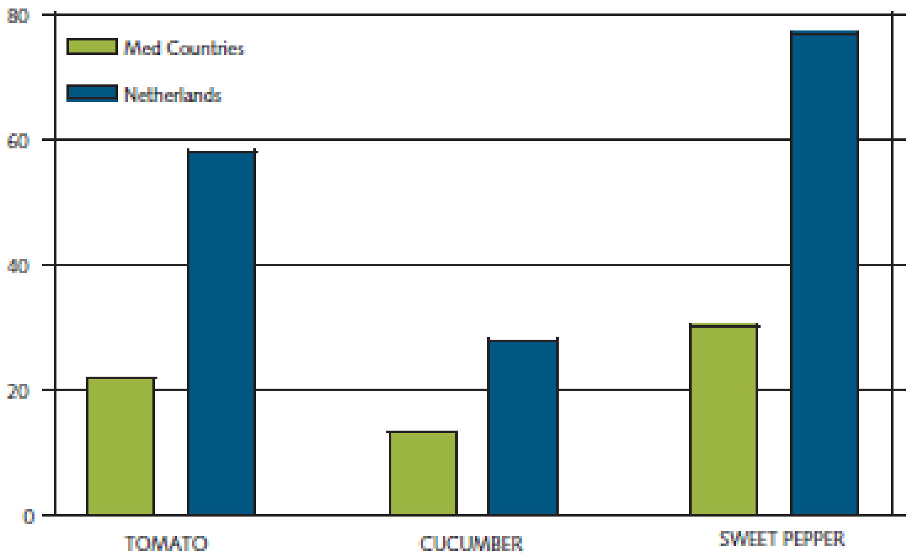
Furthermore the renewable energy produced can be used to increase the productivity and the efficiency of the production system

The Mediterranean Area receive an intense solar radiation during large part of the year
Mediterranean greenhouses need to be shaded for a relevant fraction of the year to avoid excess temperature

Our working hypothesis is that NCPV modules can be used to partially shade Mediterranean greenhouses meanwhile producing renewable energy for the greenhouse environmental control and for the grid.

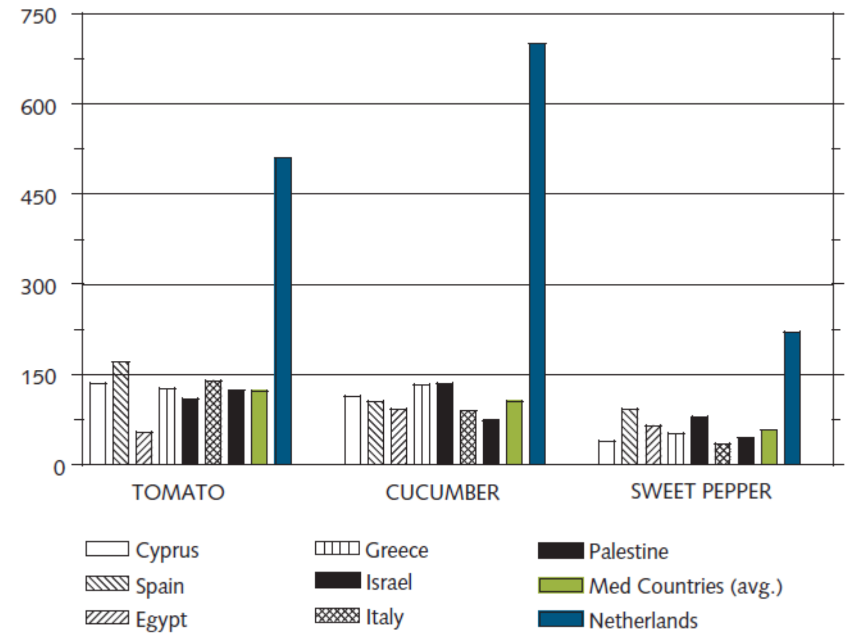
Mediterranean greenhouse

Figure 5. Water use efficiency (WUE) of some greenhouse crops in the Mediterranean countries (soil culture; mean value for Cyprus, Egypt, Greece, Israel, Italy, Spain) and in The Netherlands (soilless culture). Data were provided by different institutions in the selected countries.



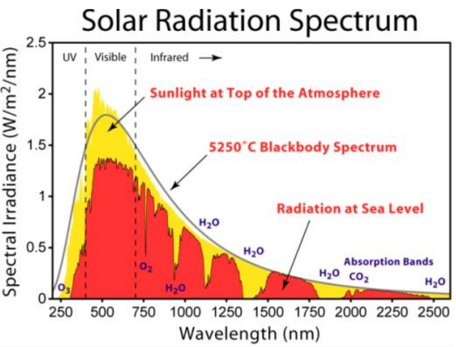
Pardossi et al. 2004 Mediterranean greenhouse technology Chronica Horticulturae, 44:28-34.

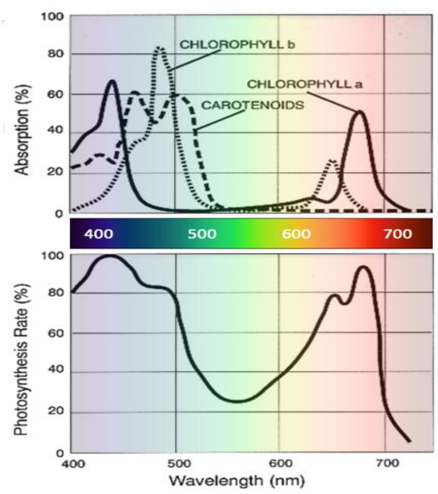
Figure 4. Productivity of a few greenhouse crops in some Mediterranean countries and in The Netherlands. Data were provided by different institutions in the selected countries.

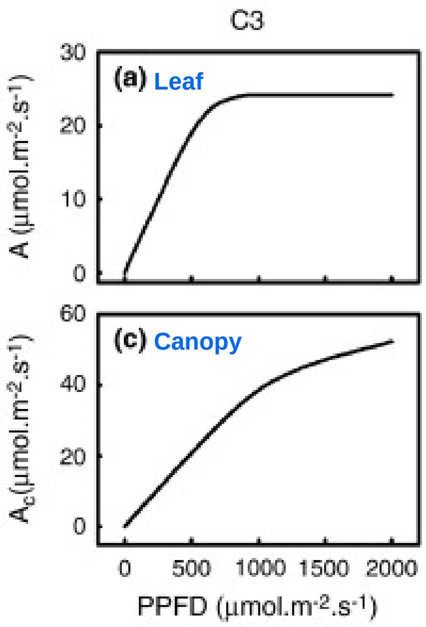


Pardossi et al. 2004 Mediterranean greenhouse technology Chronica Horticulturae, 44:28-34.

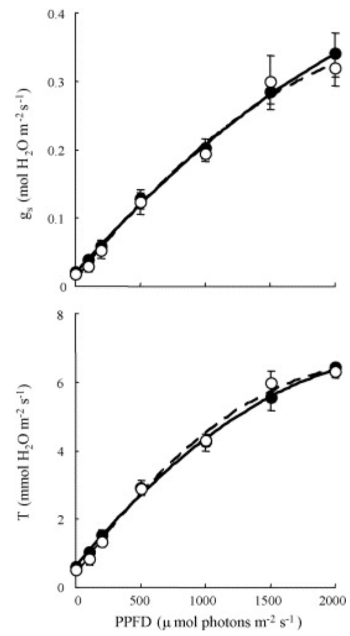
Basic knowledge







X-G. Zhu, et al. 2012 Curr. Op. Plant Biol.2012.



T. Hattori et al. 2007 Env. Exp Bot.

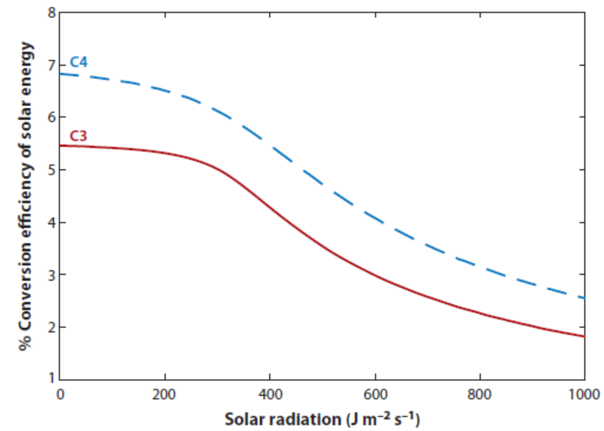
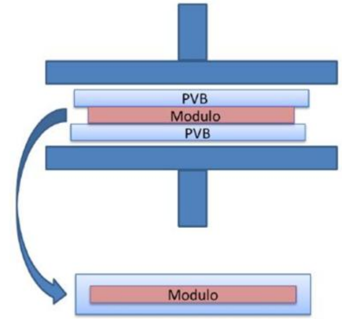


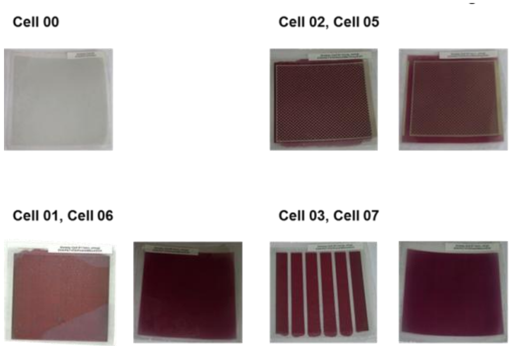
Figure 3

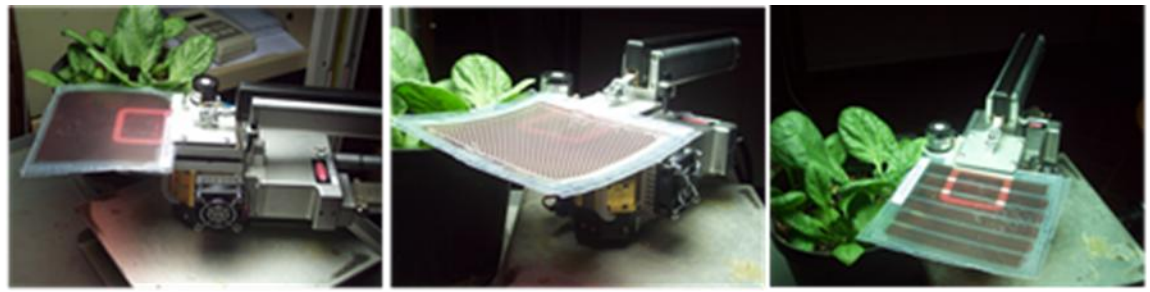
Decline in conversion efficiency of photosynthesis at the leaf level with increasing incident solar radiation. The lines are calculated using maximum observed quantum efficiencies and maximum leaf photosynthetic rates for C4 and C3 species.

Is it possible to use a fraction of the incident light in a sunny area, with minor direct effects on crop yield, meanwhile contributing to reduce the water loss?

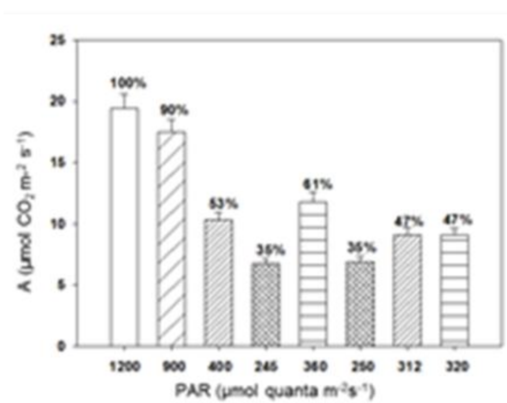


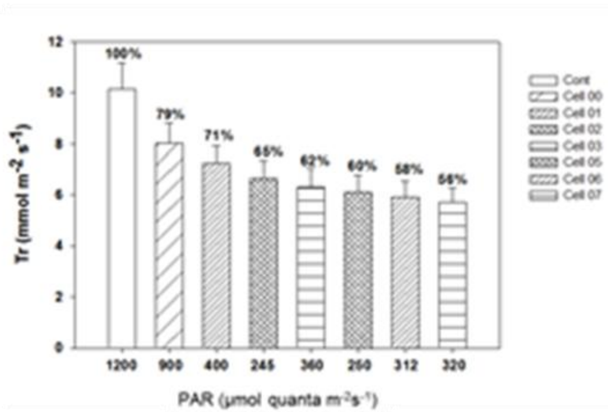
New concept photovoltaic modules (NCPM) can be built with variable absorbance rate





Cell 01-06 Cell 02-05 Cell 03-07



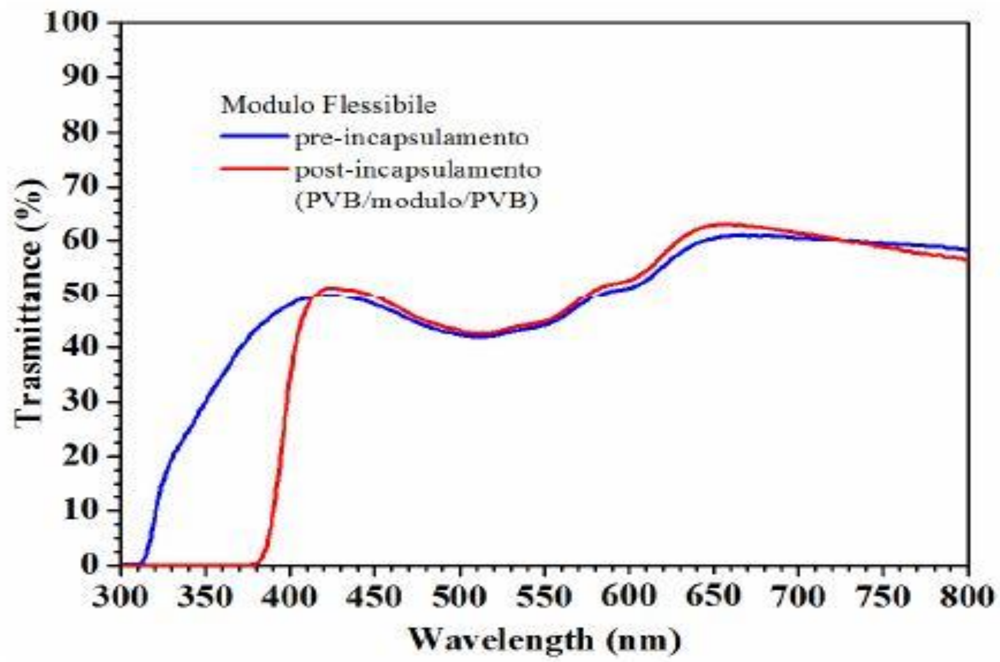


Different types of NCPM with different sun light absorbance rate can differentially affect the leaf gas exchange and water use efficiency (E/A)

Ecoflecs

Shading plants to avoid damages

- **50% shading**
- **Producing electrical power (2% efficiency)**
- **Being flexible**



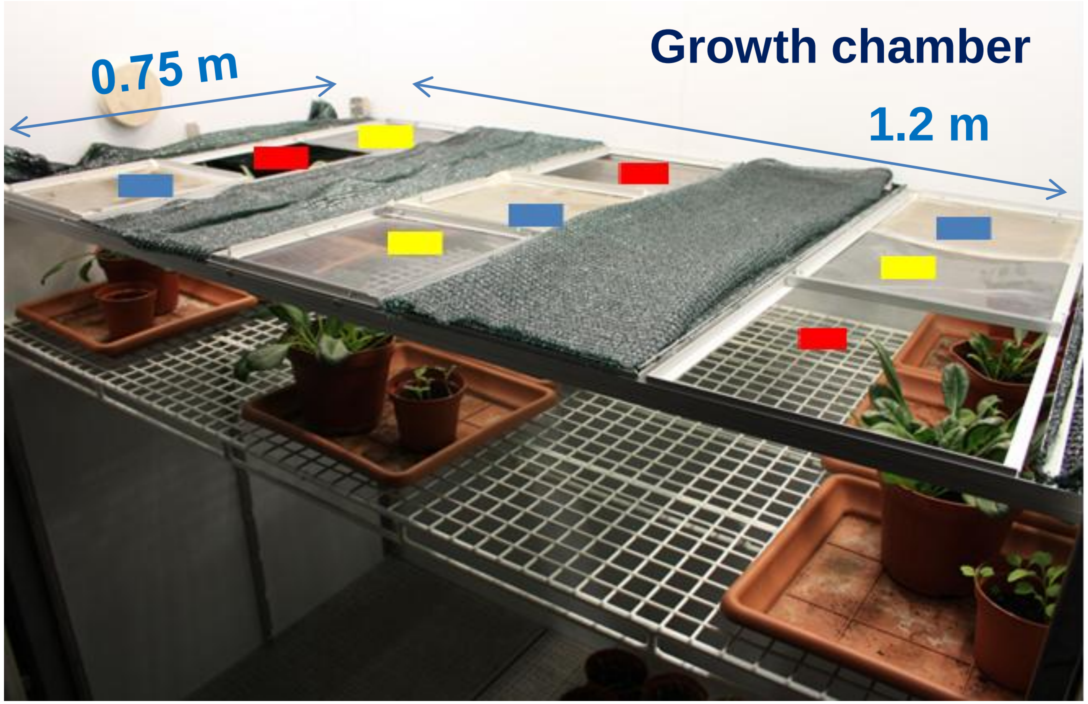
Tested species

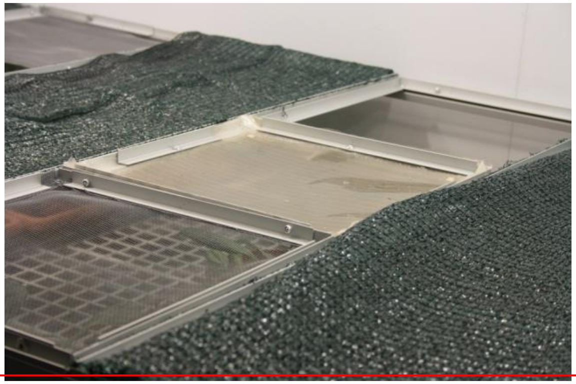
Tomato (var. Micro Tom)
(*Solanum lycopersicum*

Rocket
(*Eruca sativa Mill.)*

Spinach
(*Spinacia oleracea* L.)

Material and methods





- Dummy 400 PAR
- Net 400 PAR
- Control 800 PAR

Temperature = 25°C

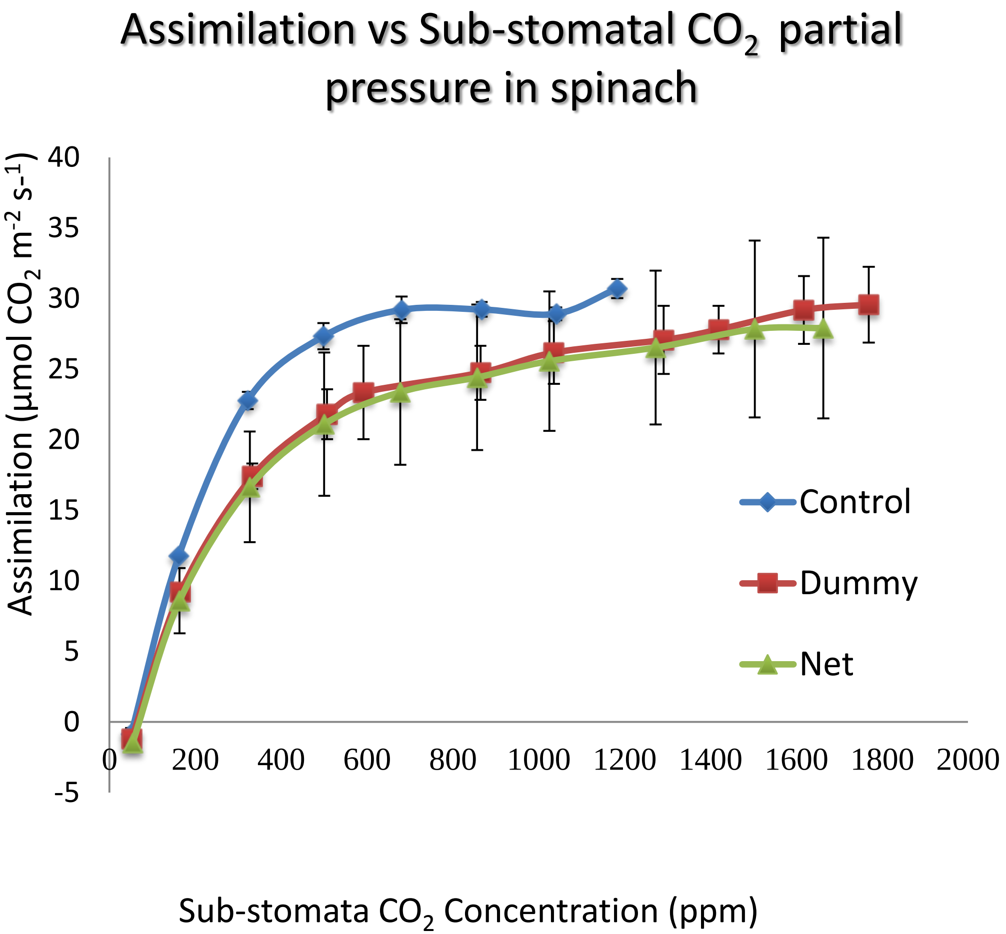
UR = 70%

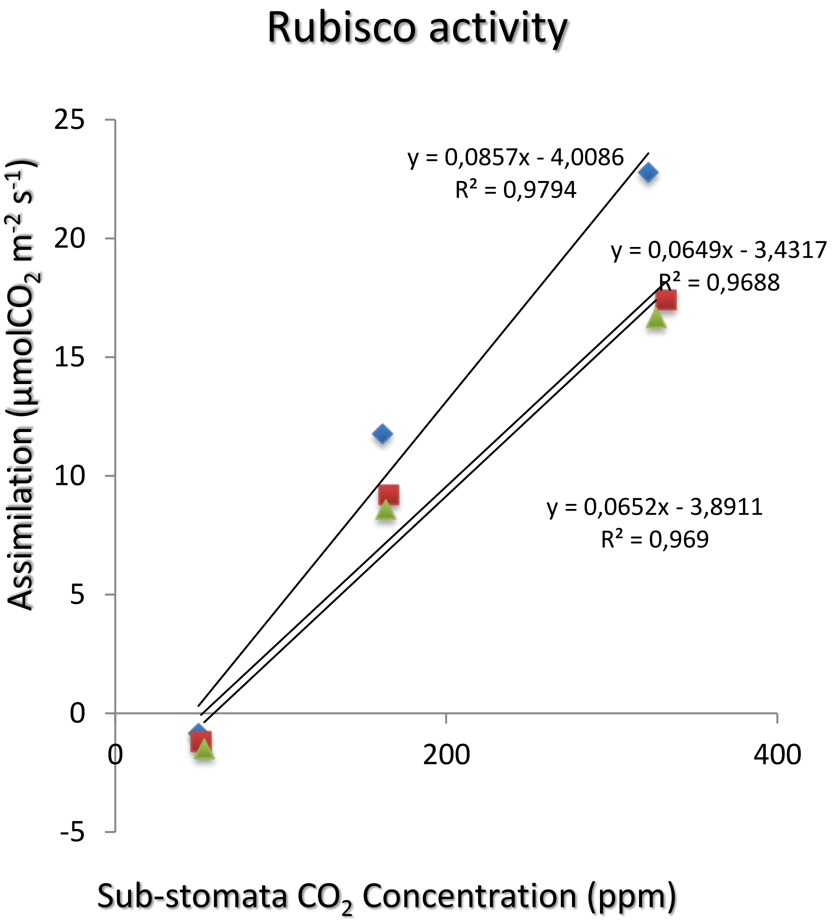
Light = 12 h

CO_2 = 400ppm

Gas exchange

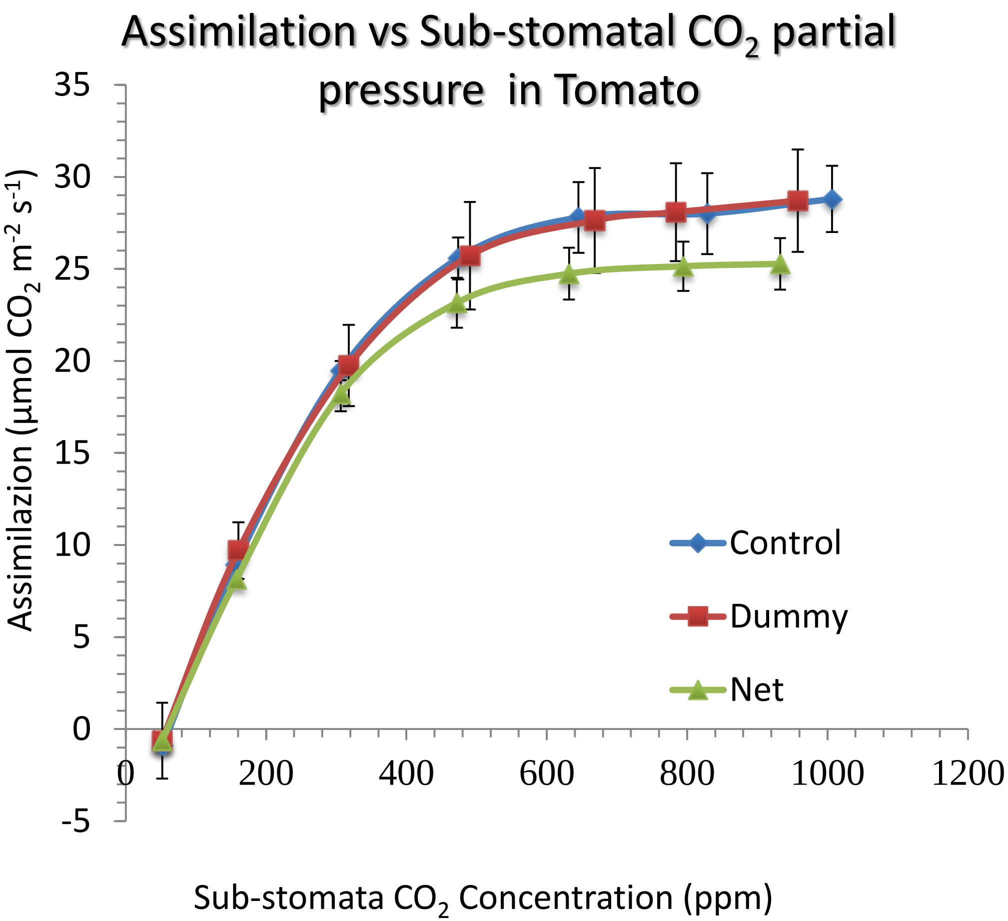
Spinach

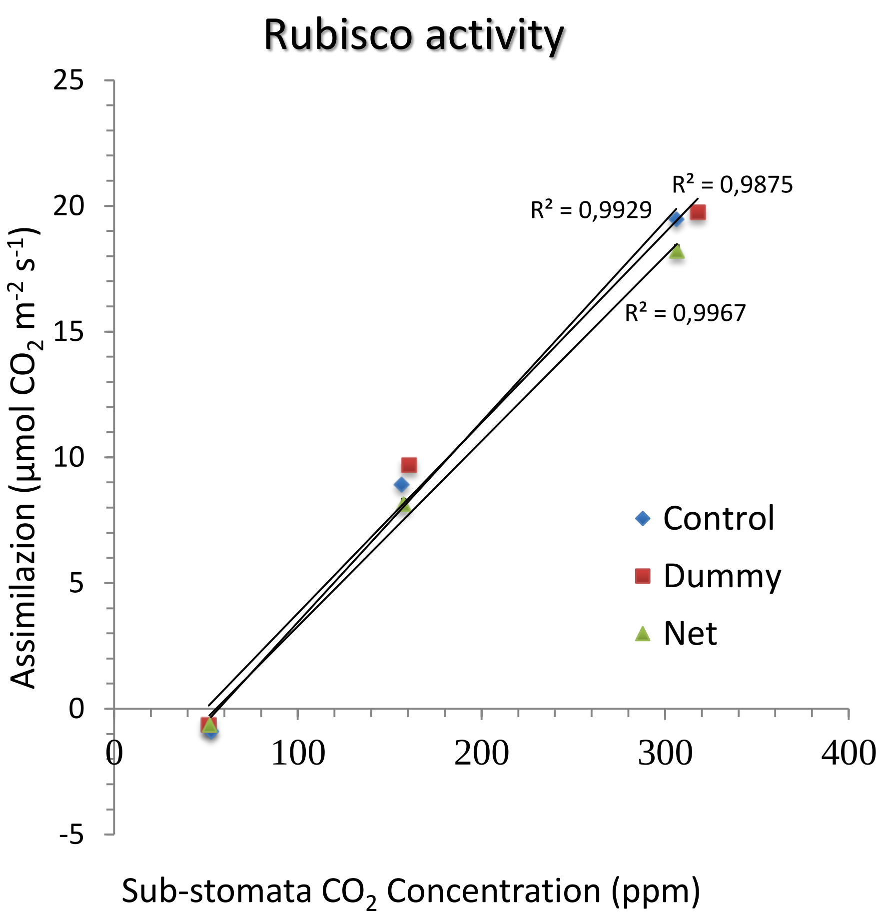




Gas exchange

Tomato





Agricultural systems in all hot and arid areas of the world are struggling with the need to provide water to crops, an issue that can be exacerbated by climate change

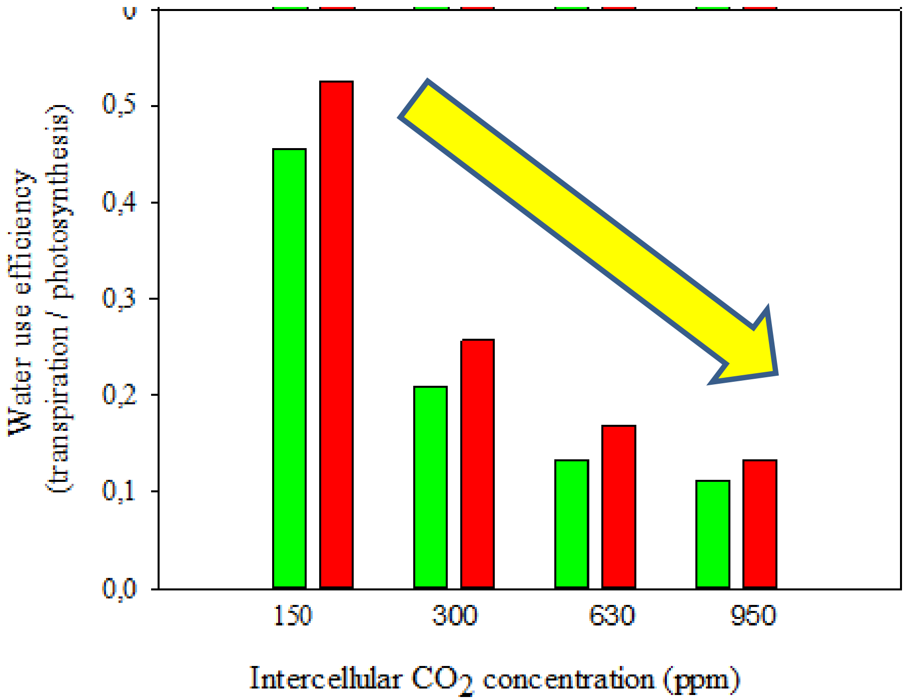


Figure 7. Gas Exchanges parameter of tomato plants grown under control or under dummy light environment to changing CO_2 partial pressure during measurements.

In a closed controlled environment, with high CO_2 high relative humidity and optima temperature, the transpiration can be strongly reduced. More crucially, water vapor released by plants, can be condensed back to be used again for cultivation, thereby working in a closed loop.

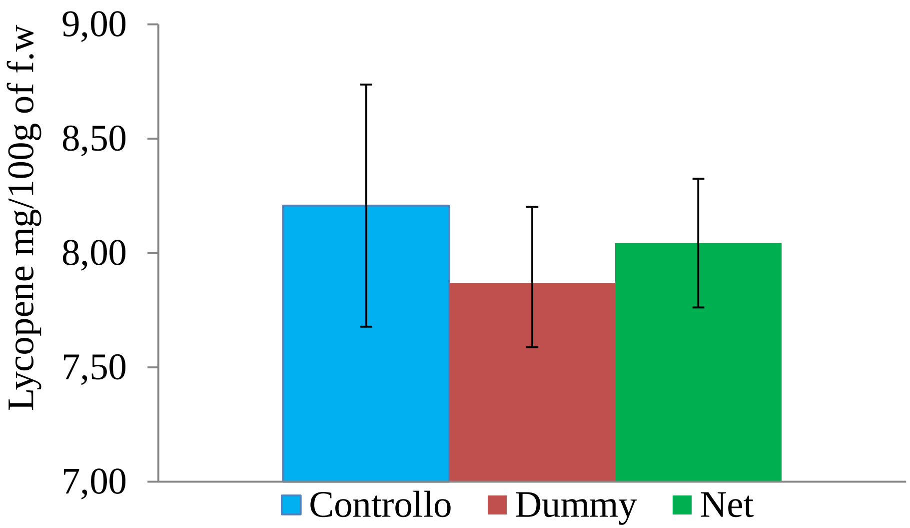
	Control	Dummy
Rocket		
Fresh leaves (g/plant)	5.5	4.2
Leaf area (cm^2/plant)	124	118
Chlorophylls + Carotenoids (mg/m^2 of leaves)	208	185
Spinach		
Fresh leaves (g/plant)	9.3	5.0
Leaf area (cm^2 /plant)	136	86
Chlorophylls + Carotenoids (mg/m^2 of leaves)	470	444
Tomato		
Edible fruit (g fresh weight/plant)	28	29
Dry matter content (%)	10.5	10.5
Soluble sugars (% of fresh weight)	4.8	3.8
Sucrose/starch	2.1	5.1
Lycopene (% of fresh weight)	0.95	0.92

Table 1 Effect of growth of rocket, spinach and tomato plants under NCPV dummies on quantity and quality parameter of the products.

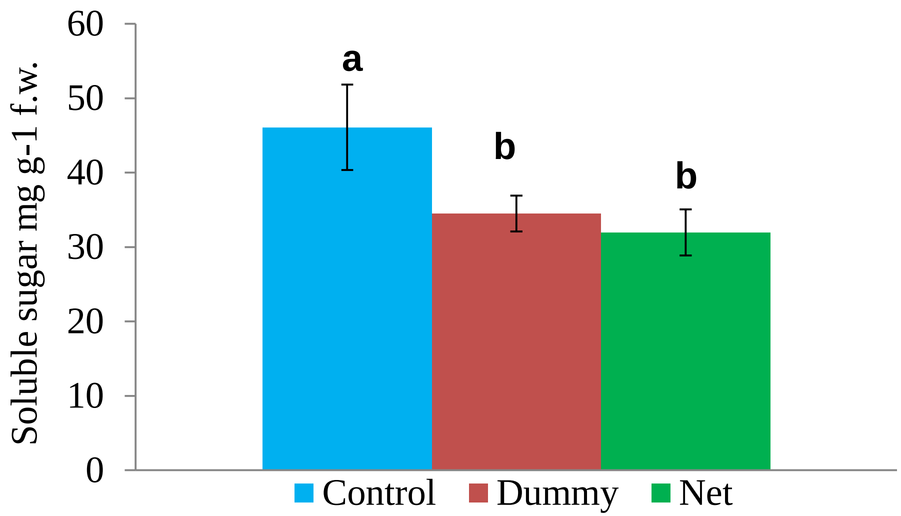
Even in our stringent growing conditions (relatively low light, similar CO_2 partial pressure, relative humidity and temperature for both treatments) the there was a limited loss of productivity and quality for leafy vegetables and none for tomato

Quality in Tomato pulp

Lycopene content in Tomato pulp



Total soluble sugars in Tomato pulp



Conclusion

Science and technology can rapidly change the future perspectives of human activities, this is true also for agriculture, and food safety.

Controlled environment agriculture can increase sustainable food production and food safety by:

a) **reducing the use of natural resources to produce food, like land and water;**
b) **allowing cultivation in unsuitable land and environments (e.g.: arid and salinized land, cities, high elevation areas, polluted land)**
c) **increasing food nutritional quality of vegetables; d) stabilizing seasonal productivity and reducing risks due to extreme events and climate change;**
d) **increasing the income per unit land, rising the monetary revenue of family farmers with small size farm.**

To achieve this, we need

a) **new knowledge;**
b) **new, efficient, easy and affordable technology,**
c) **new efficient, easy and affordable ways to produce renewable energy;**
d) **new, efficient, easy, tailor made and coordinated policies favoring science, technology transfer, education, renewable energy production, incentives to farmers.**

Coordinated policies between EU and the non-EU Mediterranean Countries can help to build synergies, which would benefit all stakeholders.

Perspectives

EDEN –ISS
H2020 Project Just signed

Part B: Description of Work

EDEN ATS

Validation of Plant Cultivation Technologies at multiple Analogue Test Sites

to support bio-regenerative Life Support Systems
for future Human Space Exploration

Type of funding scheme: Collaborative Project - Small or medium-scale focused research project

Work programme topics addressed: SPA.2013.2.1-02 Earth-analogue research preparing for space exploration

Name of coordinating Person: Dr. Oliver Romberg – DLR (German Aerospace Centre)
Email: Oliver.Romberg@dlr.de
Phone: +49-421-24420-1105

List of Participants:

Participant No.	Participant organisation name	Short name	Country
1	Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	Germany
2	LIQUIFER Systems Group GmbH	LSG	Austria
3	Consiglio Nazionale delle Ricerche	CNR	Italy
4	University of Guelph	UoG	Canada
5	Sadler Machine Company	SMC	USA
6	Alfred-Wegener-Institut für Polar- und Meeresforschung	AWI	Germany
7	EnginSoft S.p.A.	ES	Italy
8	Astrium GmbH	AST	Germany
9	Thales Alenia Space Italia S.p.A.	TAS-I	Italy
10	Aero Sekur S.p.A.	AS	Italy
11	PlantLab / HTWD	PL	The Netherlands

Thank you for your attention