Advanced, Intelligent, and Functional Environmental Control for Managing Regenerative Plant Gas Exchange Fluxes in Bioregenerative Life Support Systems.

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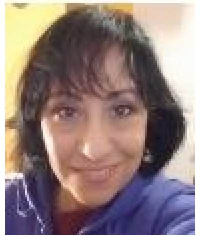

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THE BIOLUNA TEAM

Prime Contractor and Study Management
Bio-regenerative life support system (BLSS) modelling

- Mission scenario selection
- BLSS design and sizing
- Development of the BLSS software model
- Implementation of the software's controller model
- Integration of AI algorithm in the controller model

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Plant compartment

- Agronomical aspects
- Crop selection
- Testing with plants

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Environmental controls and producers

- Environmental control variables definition
- Impact of the controlled variables on the products quality
- Testing with plants

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CNR IRET

AI control algorithm

- Selection and design
- Implementation and training

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AIKO
INFINITE WAYS TO AUTONOMY

Microalgae photo-bioreactor compartment

- Reactor design and algae selection
- Testing with algae

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STAM
MASTERING EXCELLENCE

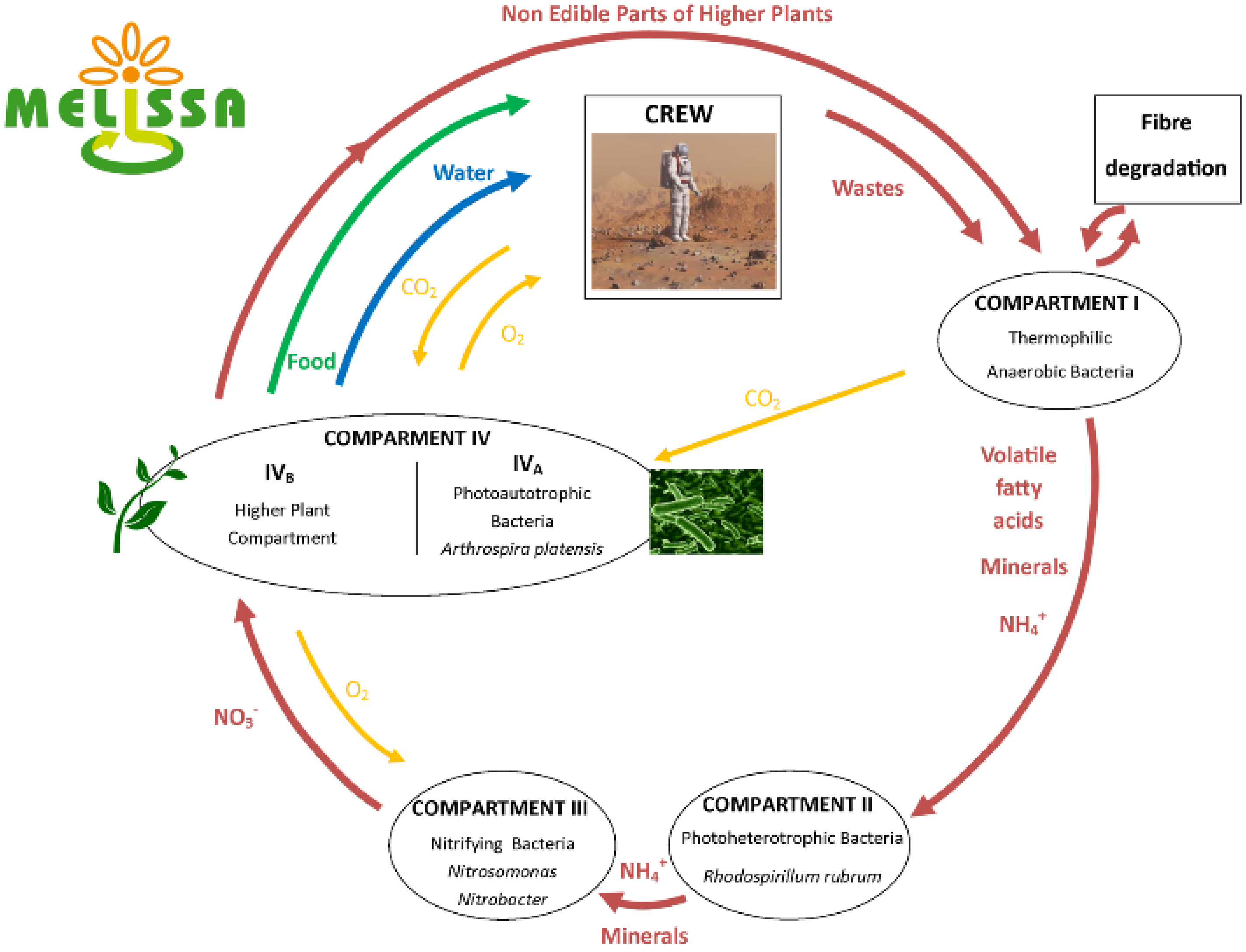
National Recovery and Resilience Plan

https://www.italiadomani.gov.it/content/sogei-ng/it/en/home.html

agritech

National Research Center for
Technology in Agriculture

https://agritechcenter.it/



Credits: ESA Melissa

Traditional environmental control design for space greenhouses

EDEN ISS

Fixed baselines (Environmental variables as targets) → Design the environmental control to meet baseline values → Evaluation of results (mostly final)

Main plant functions in BLSS, time response and control drivers

Function			
	Physiological	**Acclimatory**	**Main drivers**
Electron transport and O_2 evolution	Even very small fractions of seconds	h-days	Light intensity, spectrum, photoperiod, metabolism, stress…
CO_2 fixation	**Seconds to minutes**	Days (?) - weeks	Light environment, CO_2 partial pressure, temperature, source-sink balance, stress…
Transpiration	**Minutes to days**	Days (?) - weeks	VPD, light environment, CO_2 partial pressure, source-sink balance, stress…
Water use efficiency (CO_2/H_2O)	Minutes to hours	Days - weeks	Water availability, CO_2 partial pressure, light environments…
Biomass accumulation	Days	Days - weeks (months-years)	Photosynthesis respiration source-sink, stress…
Accumulation of nutritional compounds	**Hours to days**	Days - weeks	Photosynthesis, light environment, temperature, stress….

Gas exchange

- CO_2 assimilation (O_2 evolution)
- Transpiration

All environmental variables in a growth facility affect these two plant functions directly and via a complicated network of interactions

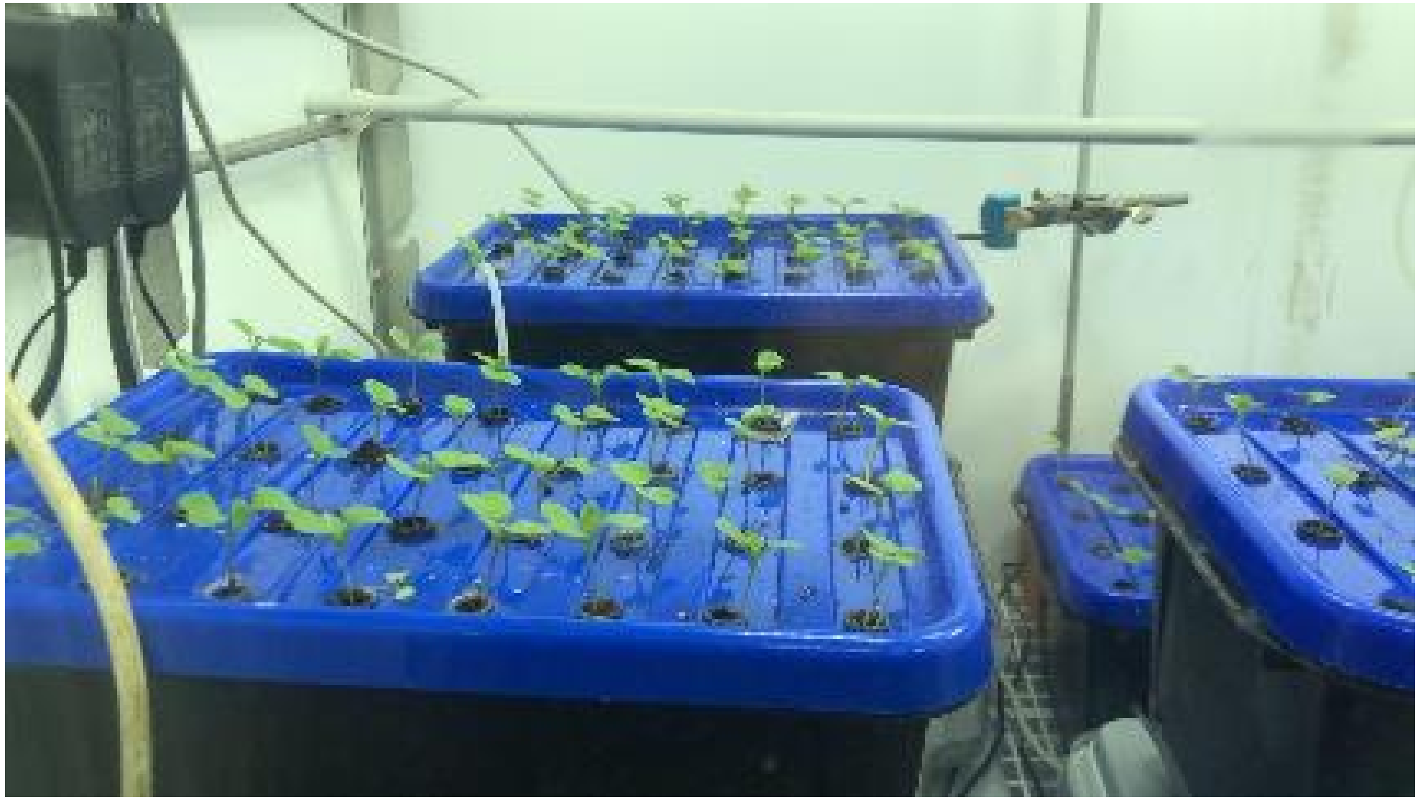
Modelling the role of the growth environment on gas exchange is particularly challenging

UPGRADING

Traditional growth chambers → AI controlled growth chamber

↓

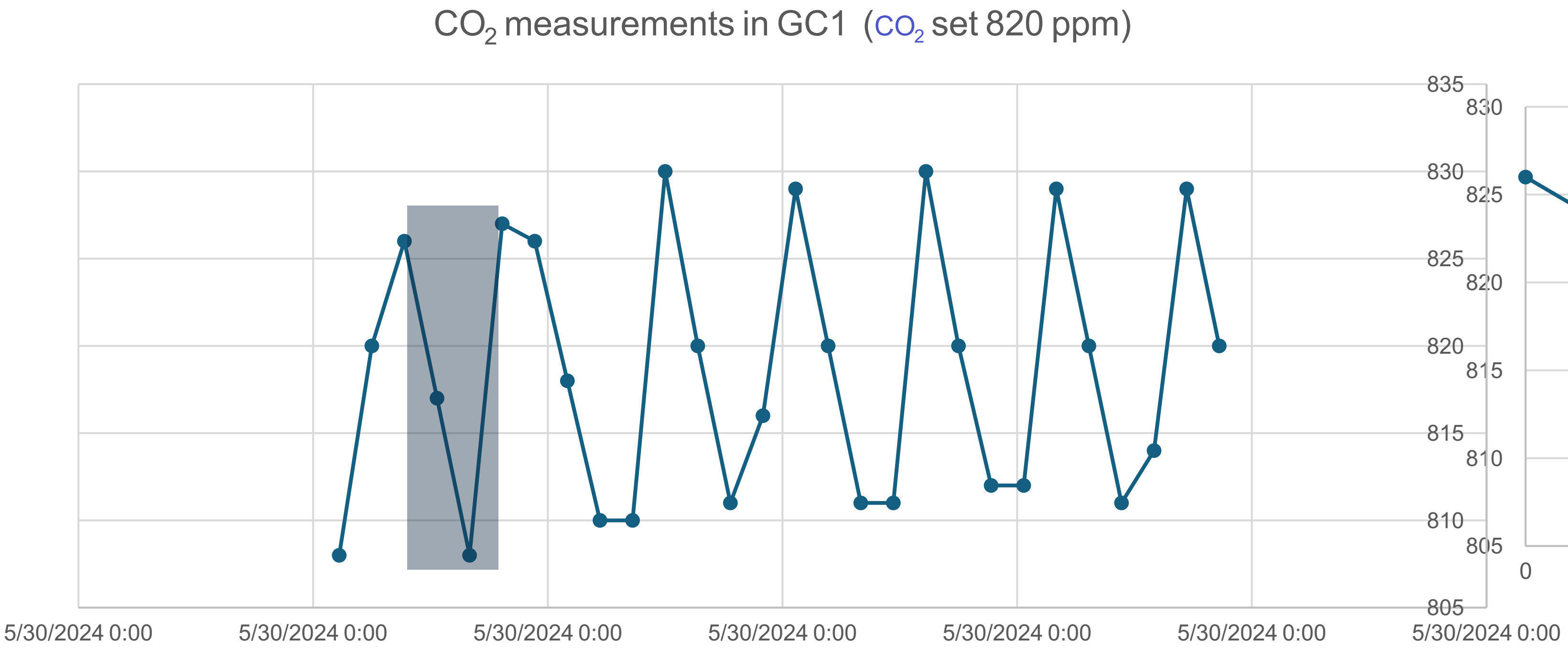
TESTING

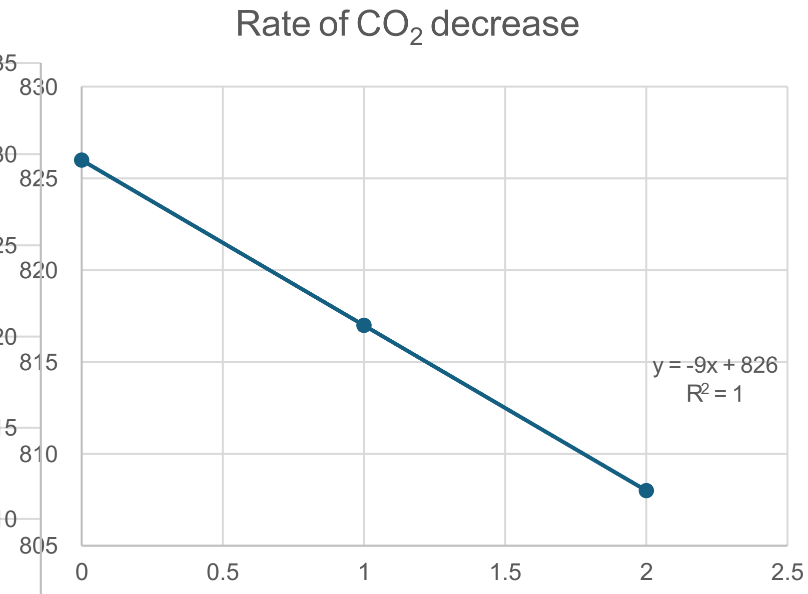


a) The chambers can effectively function as a semi-closed system for measuring the canopy gas exchange

b) The response of the technological system and the canopy to changes in environmental variables set is very rapid and fully compatible with the task of functionally control gas exchange via an AI algorithm

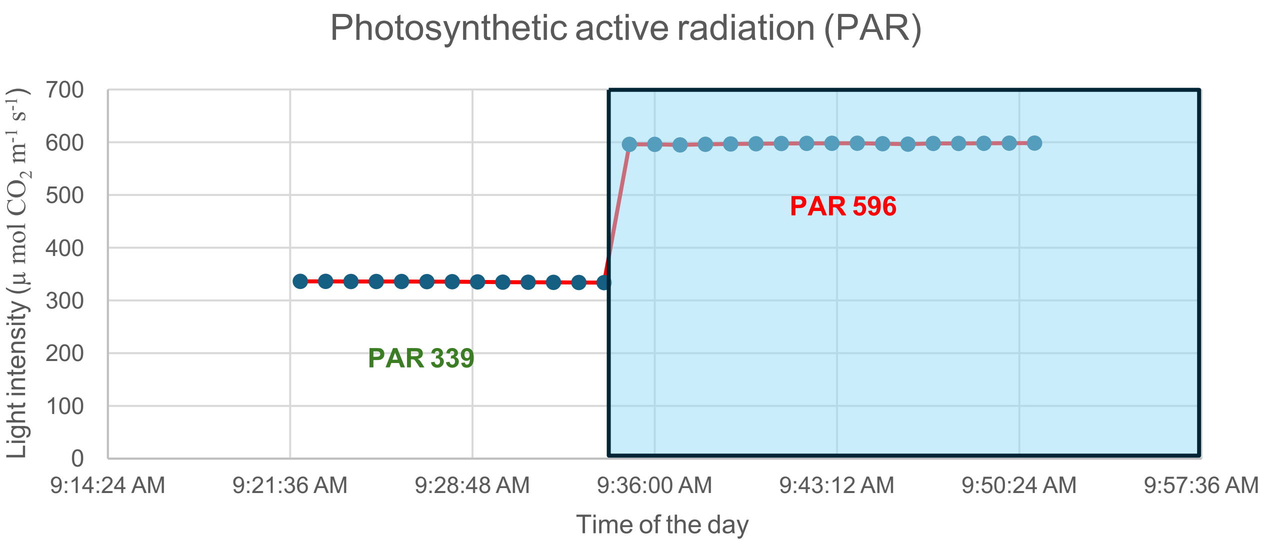
c) The system is capable of accurately calculating the rate of photosynthesis over a three-minute period by performing linear regression on the CO_2 concentration data.

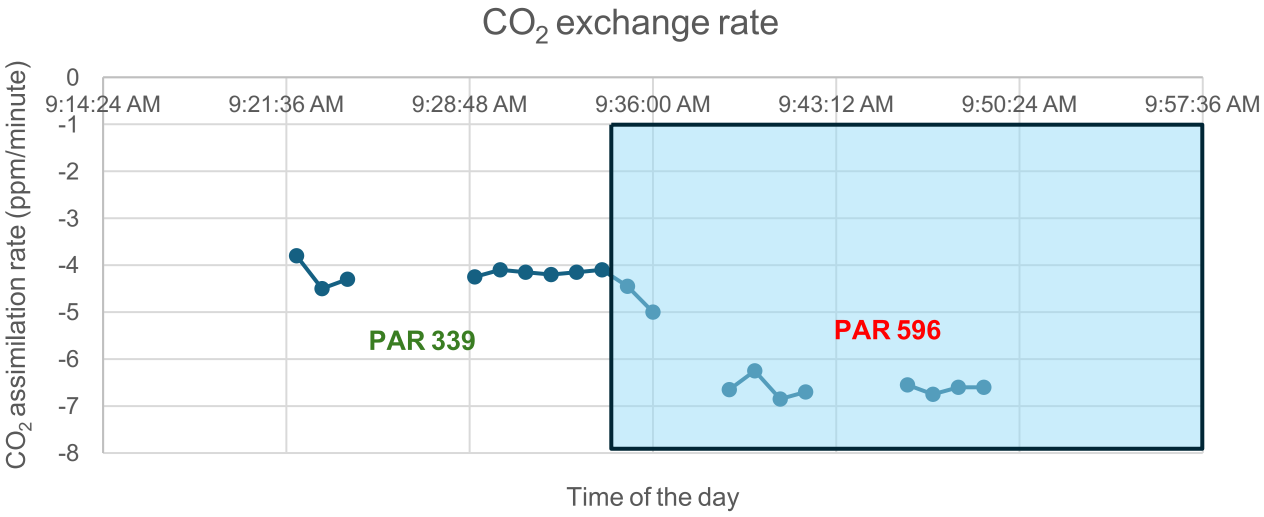




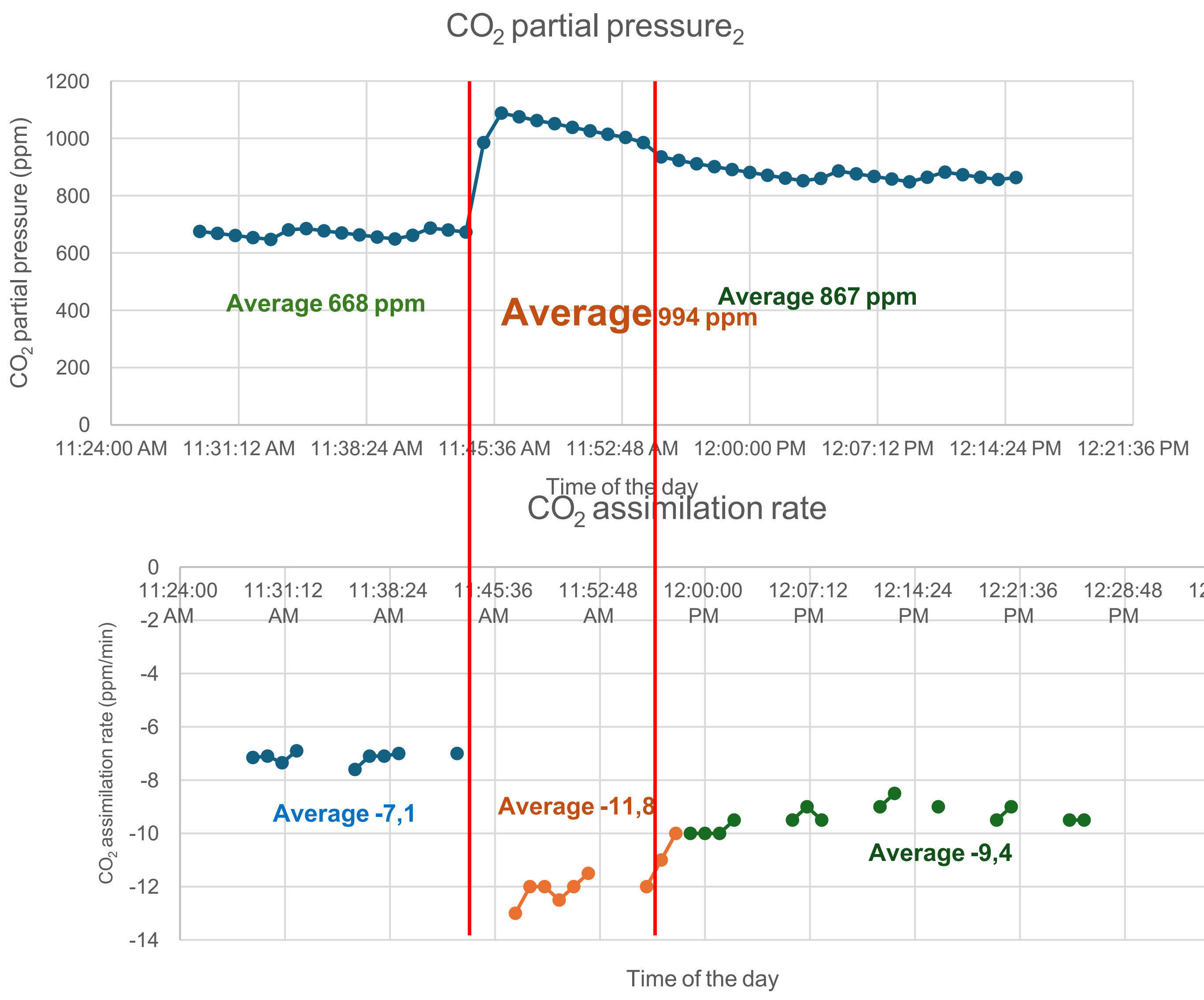
Estimated rate of photosynthesis 9 ppm min^{-1}

Example of full system response to changes in light intensity.

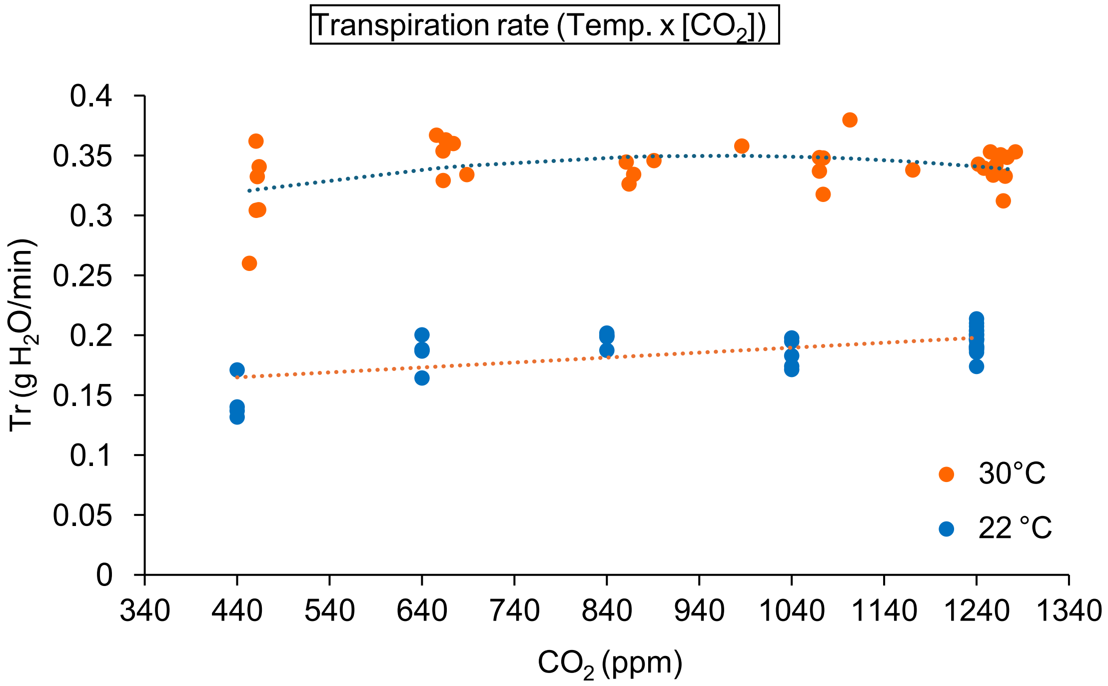


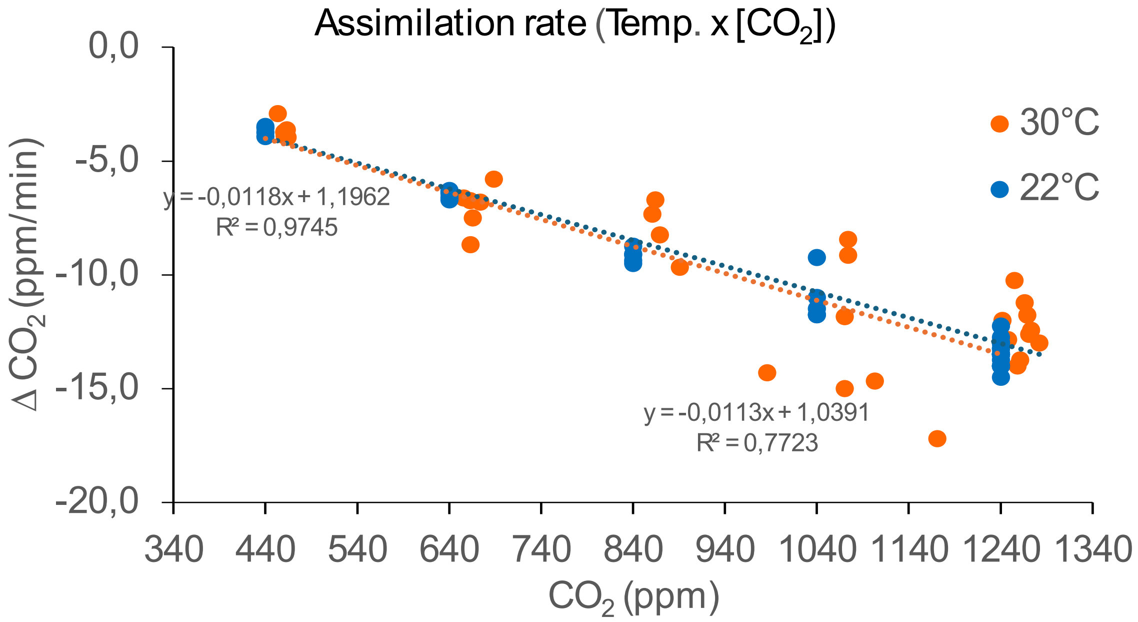


Example of full system response to changes in the CO_2 partial pressure.



Response of TR and A to changes in CO_2 partial pressure at two temperatures.
Temp. = 22°C and 30°C;
RH= 70%;
Light intensity= 300 PPFD





A different response allows differential control of fluxes

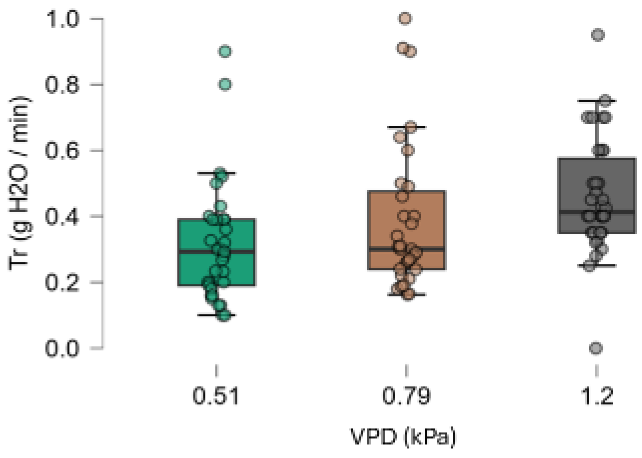
Example of TR modulation by combined changes of environmental variables.

Modulated variables

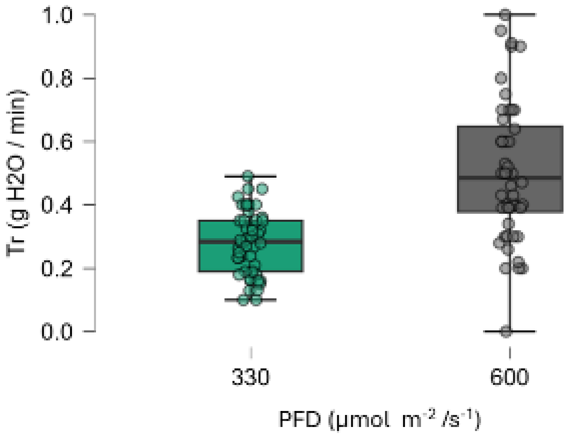
PFD (μmol m^2 s^{-1})	CO_2 (ppm)
300	440
600	940

RH (%)	Temp. (°C)	VPD (kPa)
70	15	0,51
70	22	0,79
70	29	1,12

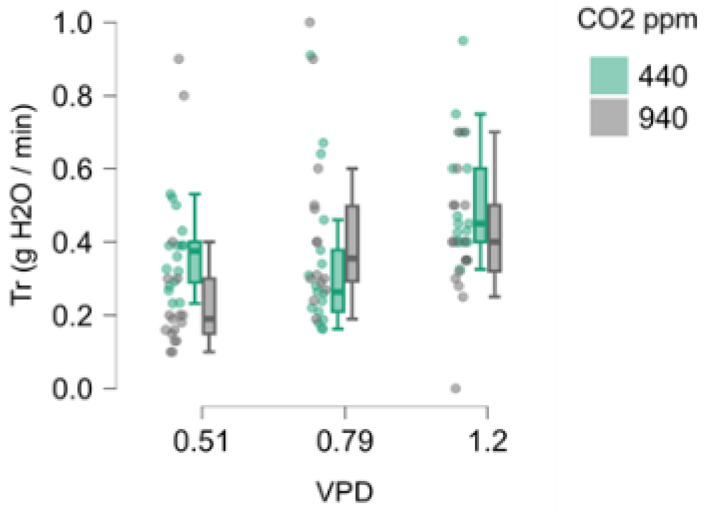
ANOVA - Tr (g H2O / min)	
Cases	**p**
CO2 ppm	0,18
VPD	0,002
PFD	1,506×10-9
CO2 ppm ✻ VPD	0,05
CO2 ppm ✻ PFD	0,875
VPD ✻ PFD	0,848
CO2 ppm ✻ VPD ✻ PFD	0,407



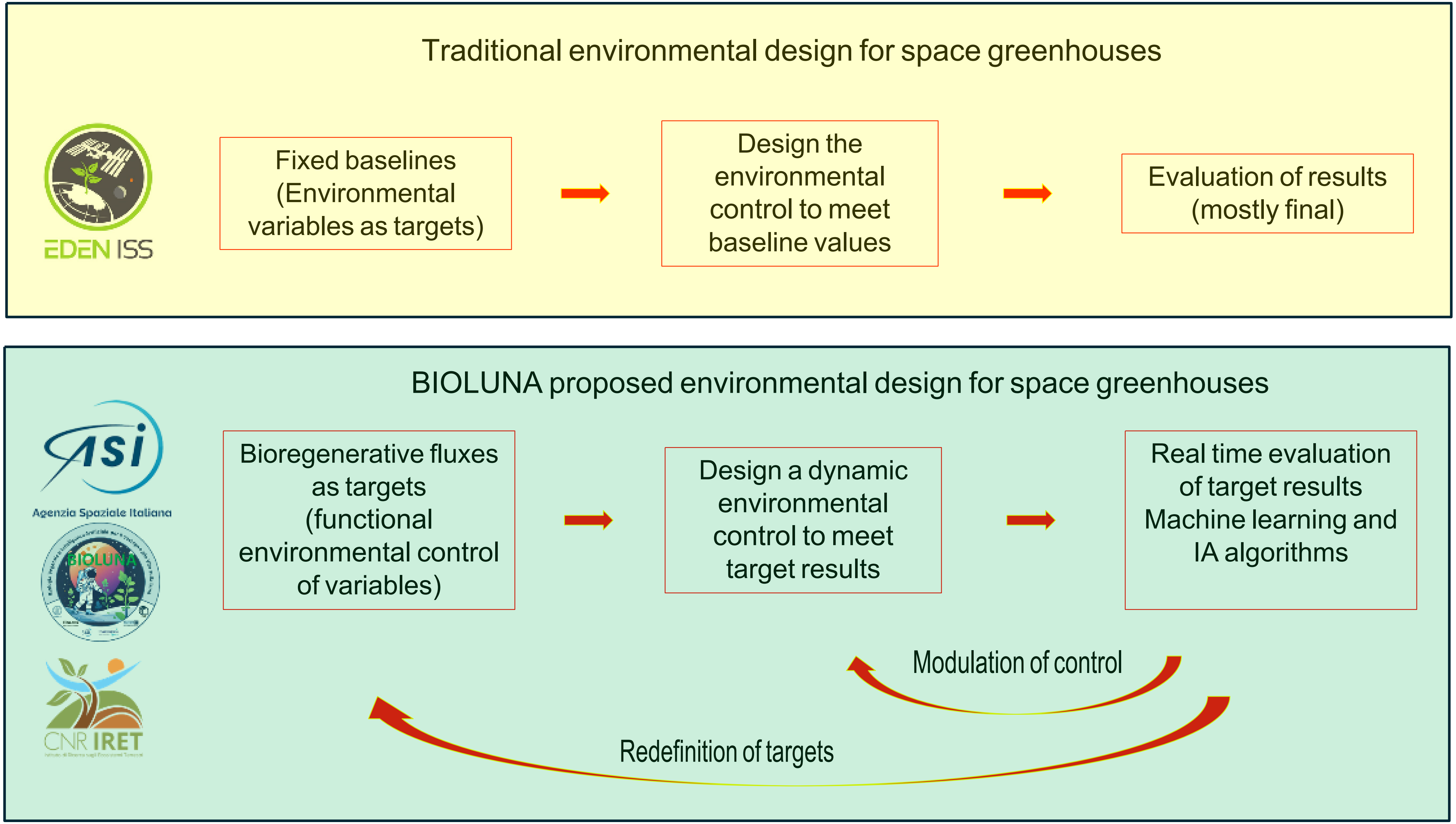
ANOVA- : VPD (p = 0,002)



ANOVA- : PFD (p < 0,001)



VPD and light intensity had the strongest effect on TR. CO_2 partial pressure and VPD shoved a complex interaction.



Traditional environmental design for space greenhouses
EDEN ISS
Fixed baselines (Environmental variables as targets)
Design the environmental control to meet baseline values
Evaluation of results (mostly final)
BIOLUNA proposed environmental design for space greenhouses
ASI
Agenzia Spaziale Italiana
BIOLUNA
CNR IRET
Bioregenerative fluxes as targets (functional environmental control of variables)
Design a dynamic environmental control to meet target results
Real time evaluation of target results Machine learning and IA algorithms
Modulation of control
Redefinition of targets

Next steps

- Acquire datasets
- Complete the AI based algorithm for BLSS control
- Adapt and test the AI algorithm in the IRET growth chambers

CONCLUSIONS: ???


Thank you for your attention