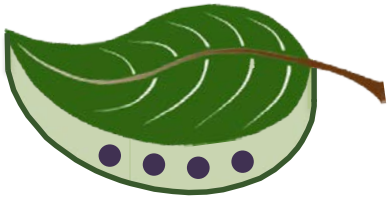
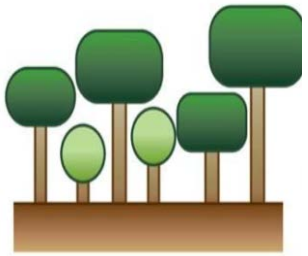
Do leaf trait responses to elevated carbon dioxide alter projections of tropical ecosystem composition and fuctioning?





Marlies Kovenock[1], Rosie Fisher[2], Charles D. Koven[3], and Abbigail L.S. Swann[4,1]

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[3] Climate and Ecosystems Division, Lawrence Berkeley National Laboratory
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Roadmap

1. Leaf Traits & CO_2 Responses
2. Why alter ecosystem composition & functioning?
3. CLM-FATES Experiments
4. Next Steps

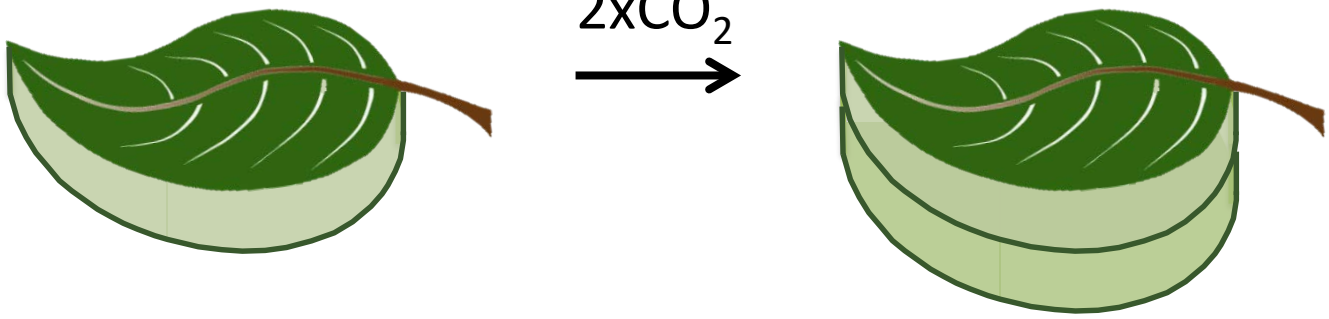
Take Home Point:

Leaf trait responses to elevated CO_2 could have large impacts on tropical ecosystem composition & functioning!

1. Leaf Mass Per Area

(gC / m^2 leaf area)
Amount carbon required to build one unit of leaf area.

Low → $2xCO_2$ → **High**

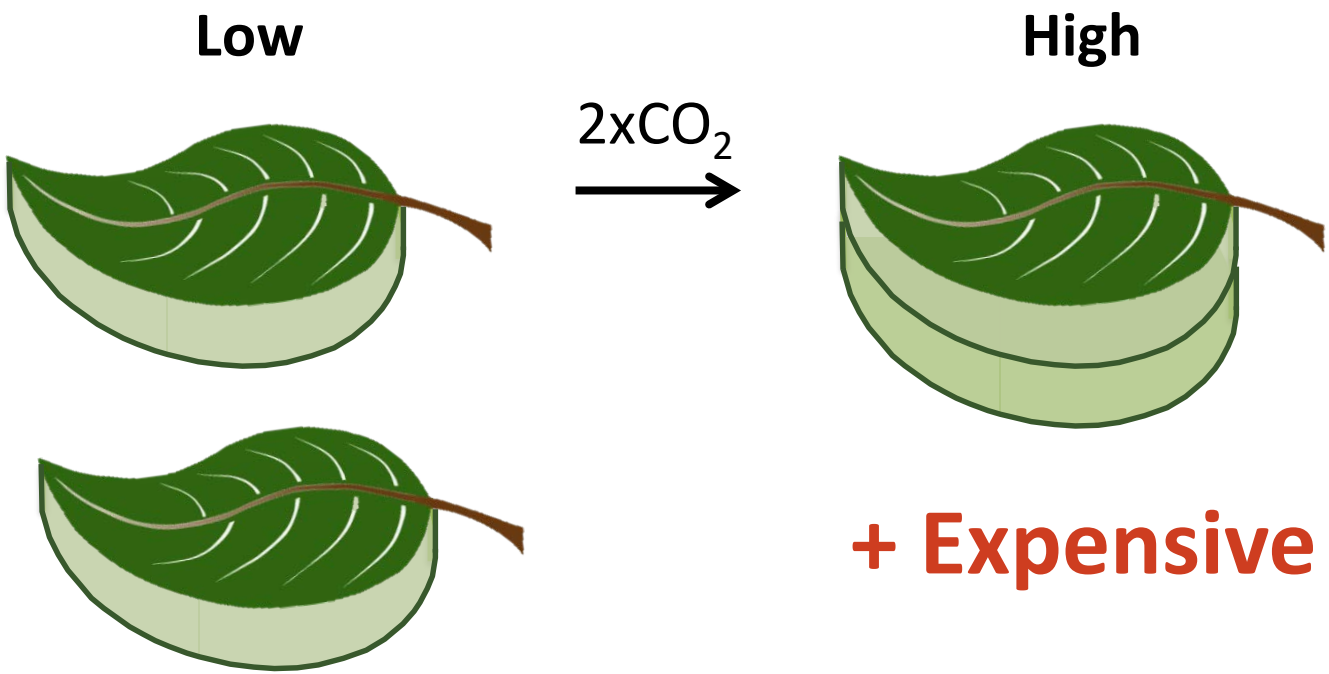


+ Expensive

Leaf Area (m^2)
Leaf Mass per Area (gC/m^2)
N per Area (gN/m^2)

1. Leaf Mass Per Area

(gC / m^2 leaf area)
Amount carbon required to build one unit of leaf area.



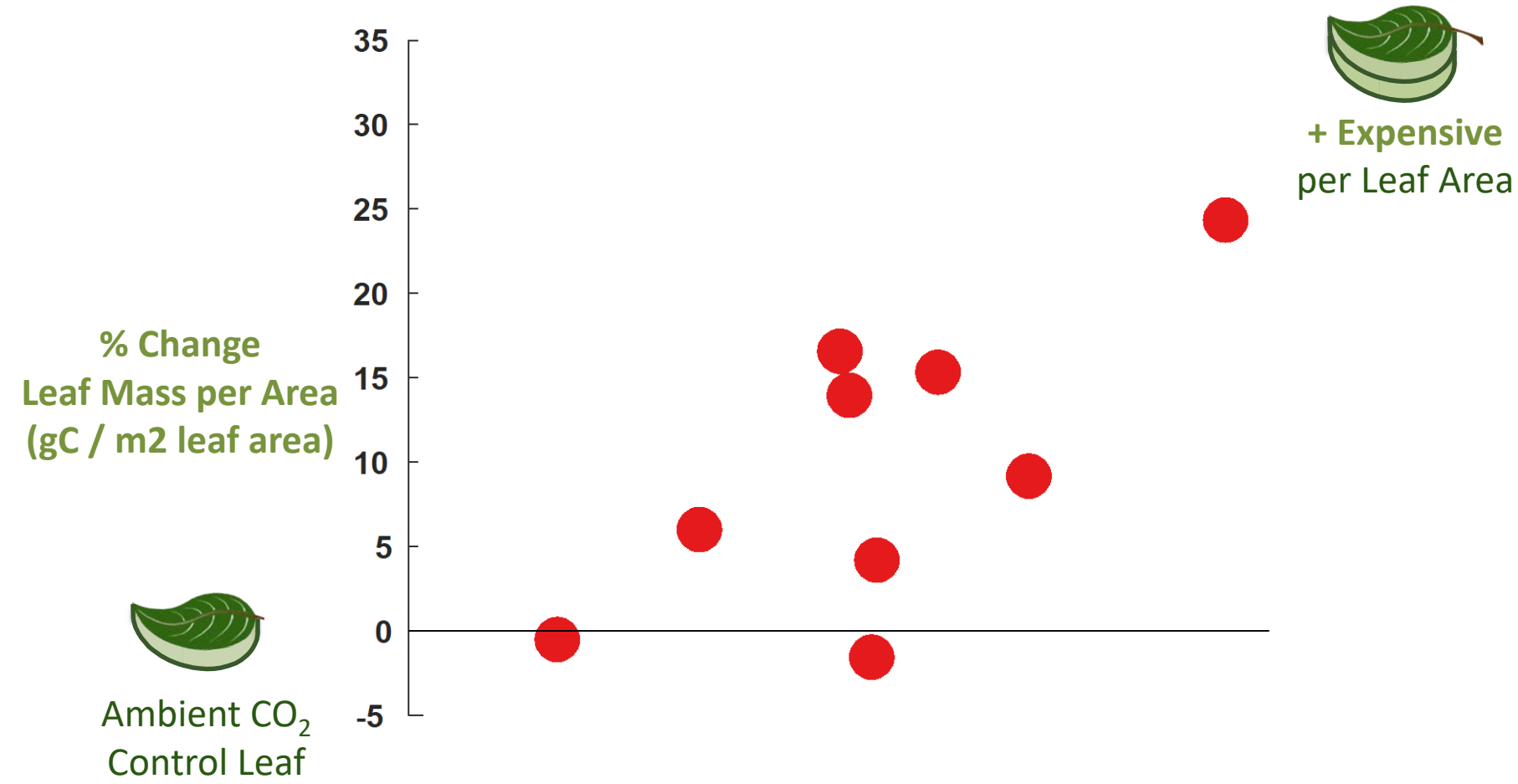
Leaf Area (m^2)
Leaf Mass per Area (gC/m^2)
N per Area (gN/m^2)

Observations:
Tropical trees treated with 2xCO_2

Open top chamber experiments in Panama's National Metropolitan Park treat sappling communities of 9 tropical tree types with 2xCO_2.

Photo: Klaus Winter Lab website (http://www.stri.si.edu)

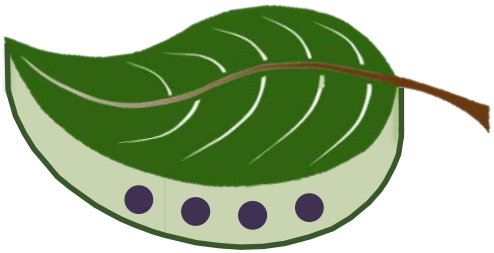
Leaf Mass per Area increases with $2xCO_2$



2. Leaf Carbon:Nitrogen Ratio

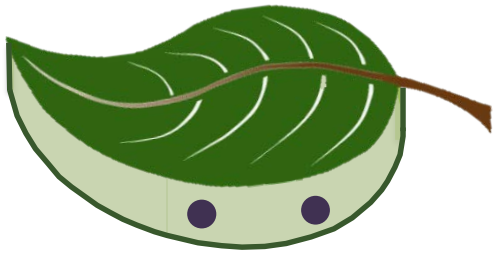
(gC / gN)
Measures the amount of nitrogen per leaf mass.

Low C:N



High [N]

$2xCO_2$



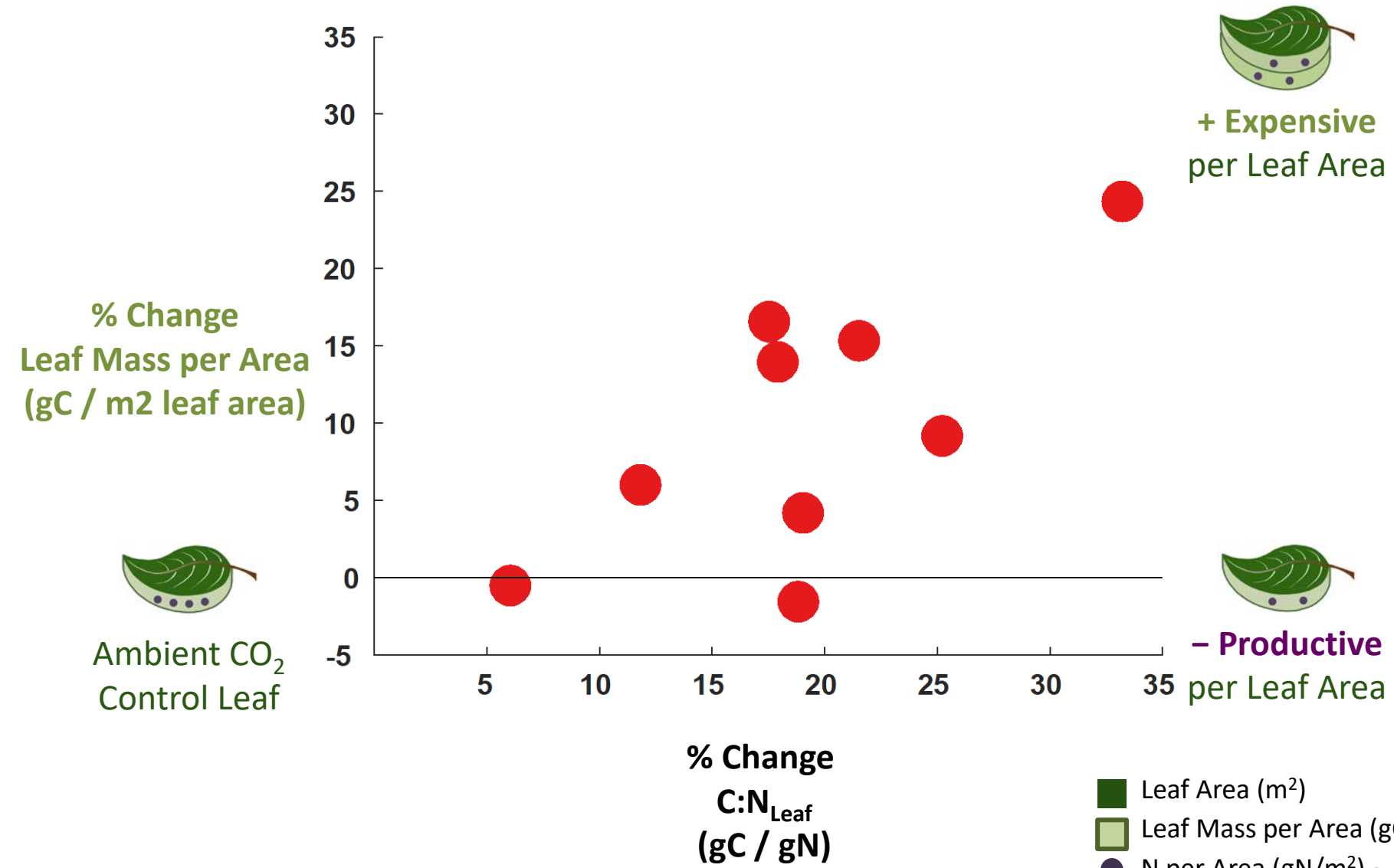
High C:N

Low [N]

– Productive

Leaf Area (m^2)
Leaf Mass per Area (gC/m^2)
N per Area (gN/m^2)

$C:N_{leaf}$ decreases with $2xCO_2$



3. Nitrogen per Area

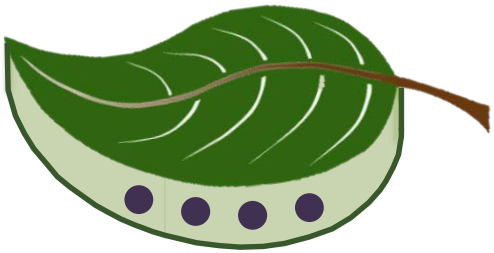
(gN / m^2 leaf area)
Measures the amount of nitrogen per leaf area.

$$N_{area} = \frac{\text{Leaf Mass per Area } (gC/m^2 \text{ leaf area})}{C{:}N_{leaf}\,(gC/gN)} = gN/m^2 \text{ leaf area}$$

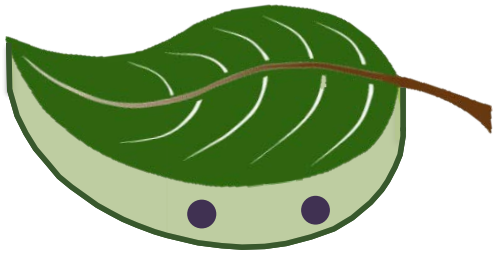
3. Nitrogen per Area

(gN / m^2 leaf area)
Measures the amount of nitrogen per leaf area.

High N_{area}



$2xCO_2$



Low N_{area}

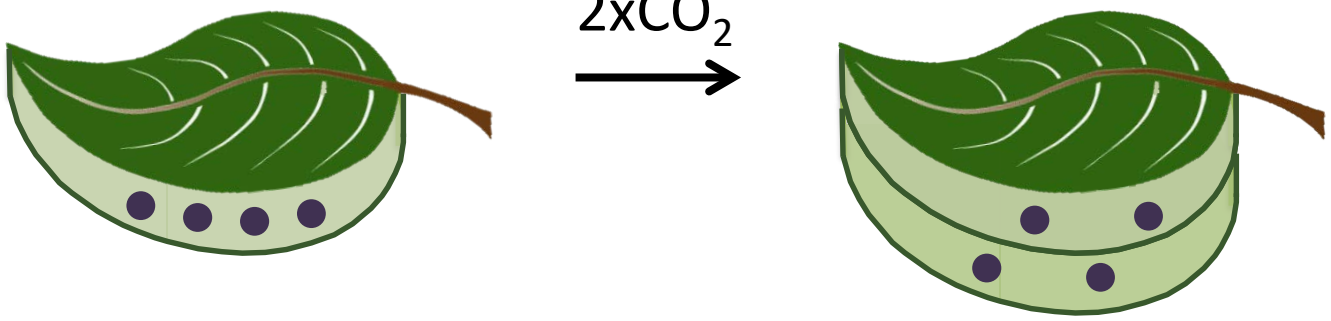
– Productive

Leaf Area (m^2)
Leaf Mass per Area (gC/m^2)
N per Area (gN/m^2)

3. Nitrogen per Area

(gN / m^2 leaf area)
Measures the amount of nitrogen per leaf area.

Same N_{area} → $2xCO_2$ → **Same N_{area}**

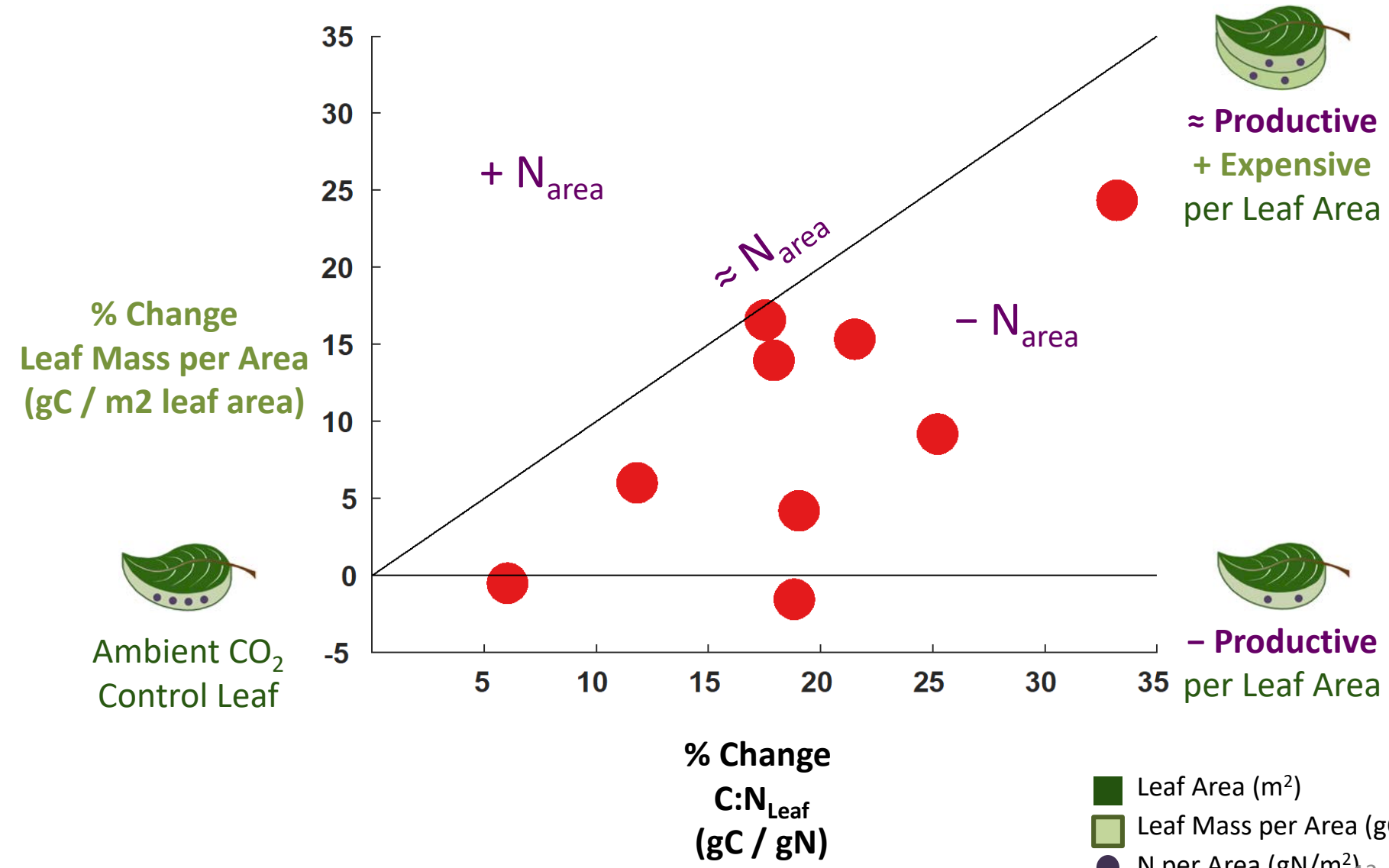


+ Leaf Mass per Area

+ Expensive

≈ Productive per Area!

N_{area} generally decreases with $2xCO_2$

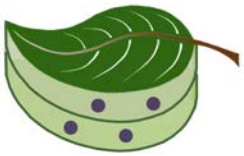


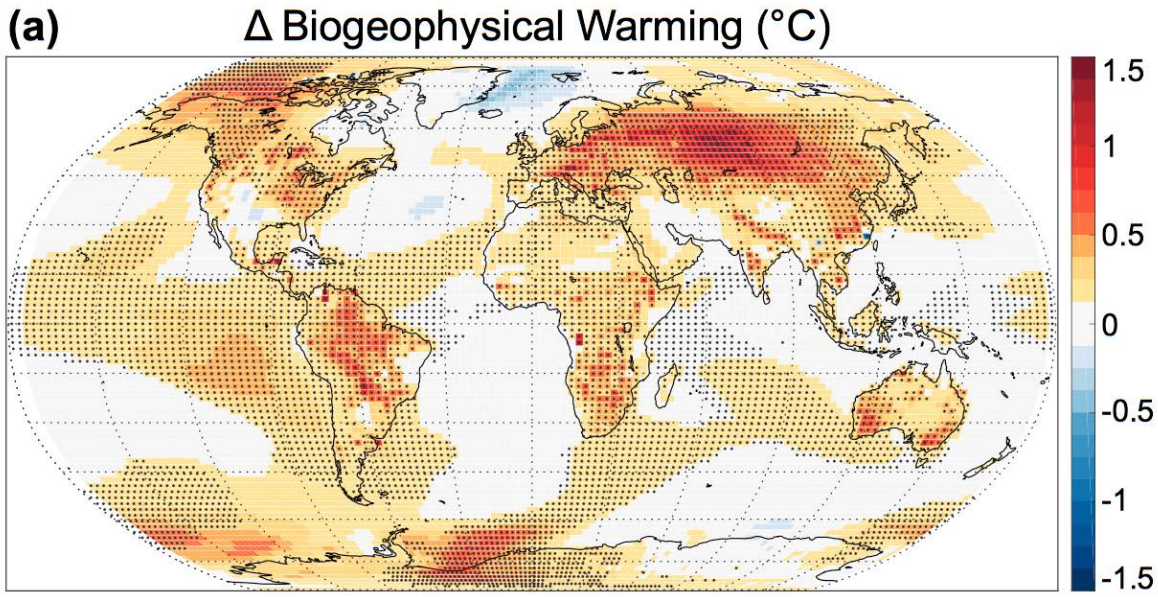
Leaf trait responses => Large scale climate implications

Ambient CO_2
Leaf

$2xCO_2$

≈ Productive, + Expensive per Leaf Area

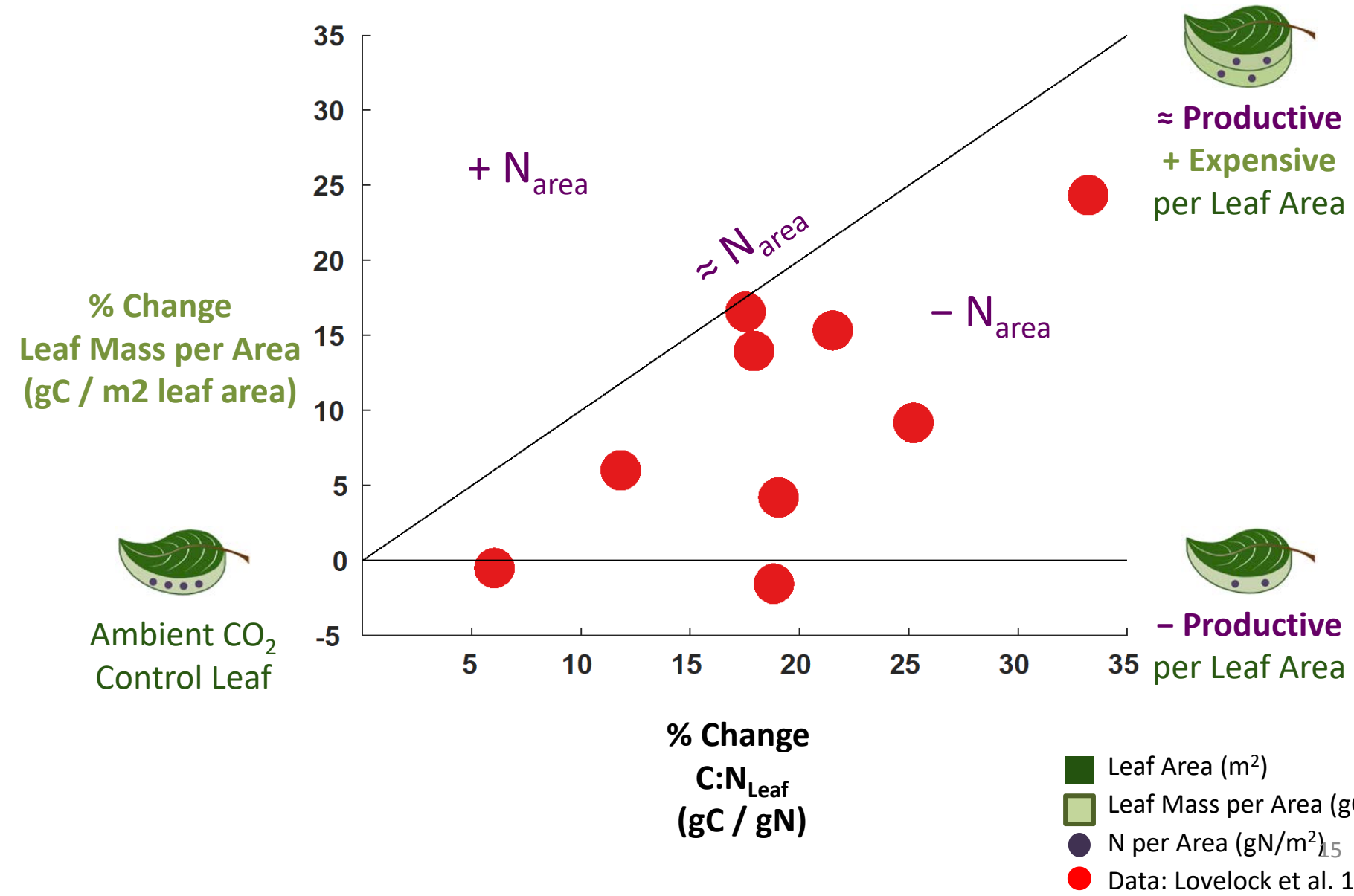




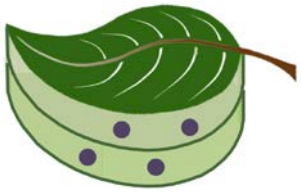
Kovenock & Swann 2018 (EarthArXiv Preprint)

Could leaf trait acclimations to CO_2 alter ecosystem composition?

Tropical leaf trait responses to elevated CO_2

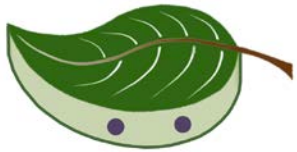


Could leaf trait acclimations to CO_2 alter ecosystem composition?



Productive
+ Expensive
per Leaf Area

vs.

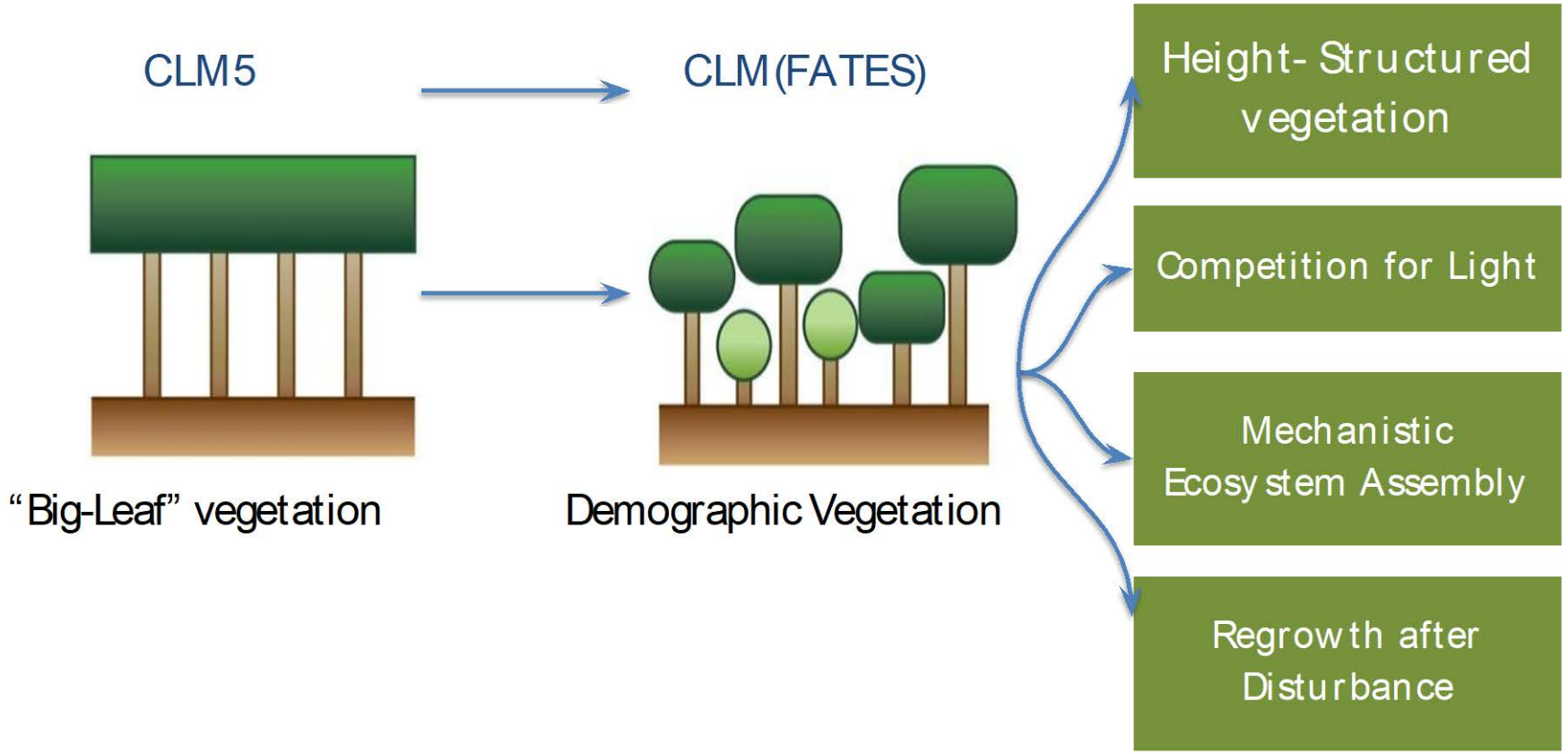


– Productive
Inexpensive
per Leaf Area

Higher productivity per area could outcomptete competitors?

More leaf area per carbon could shades out competitors?

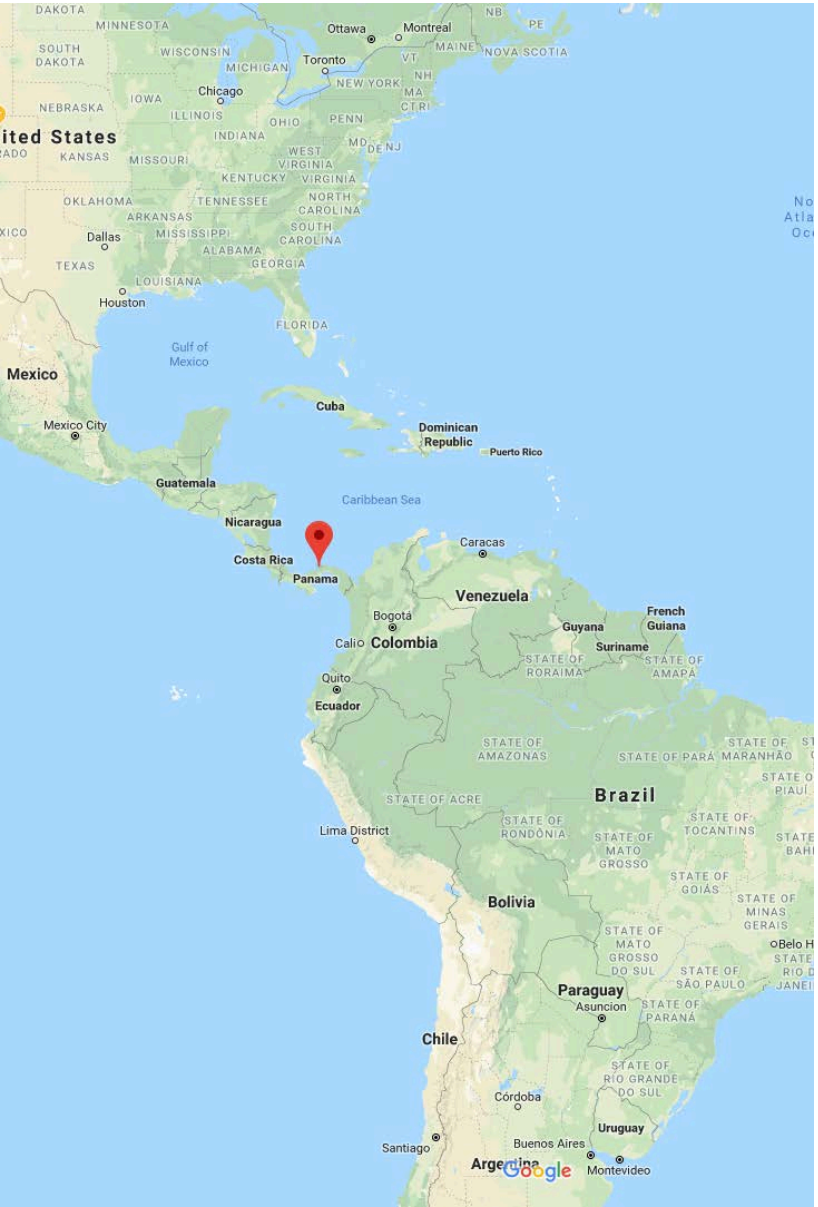
Methods: CLM-FATES



Fisher et al. Geoscientific Model Development 2015

Slide: Charles Koven

CLM5-FATES Simulations



2 Identical Plant Functional Types

+ Leaf trait changes

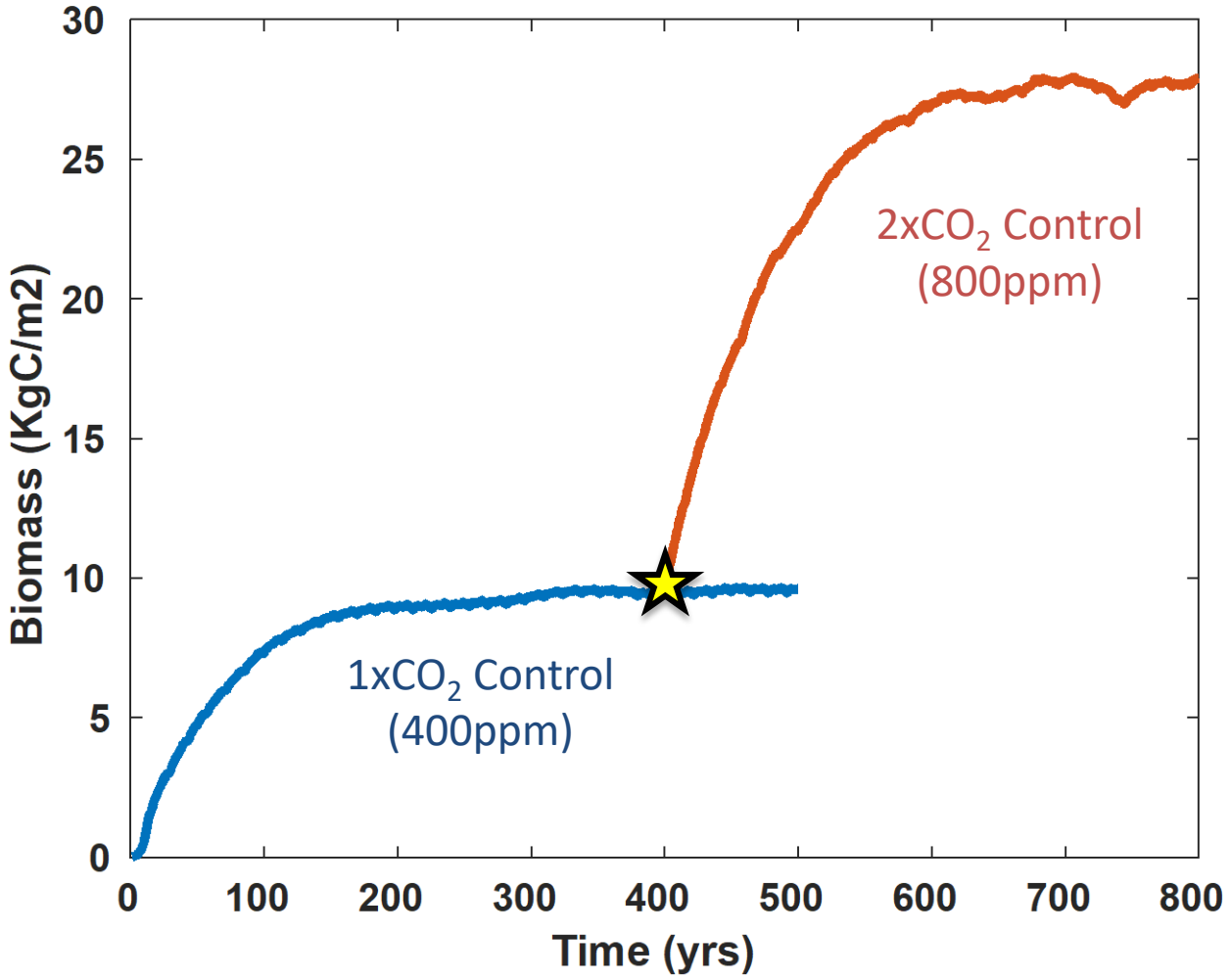
informed by observatons of 2xCO_2 responses

Meterological Forcing:

Barro Colorado Island, Panama 2003-2016

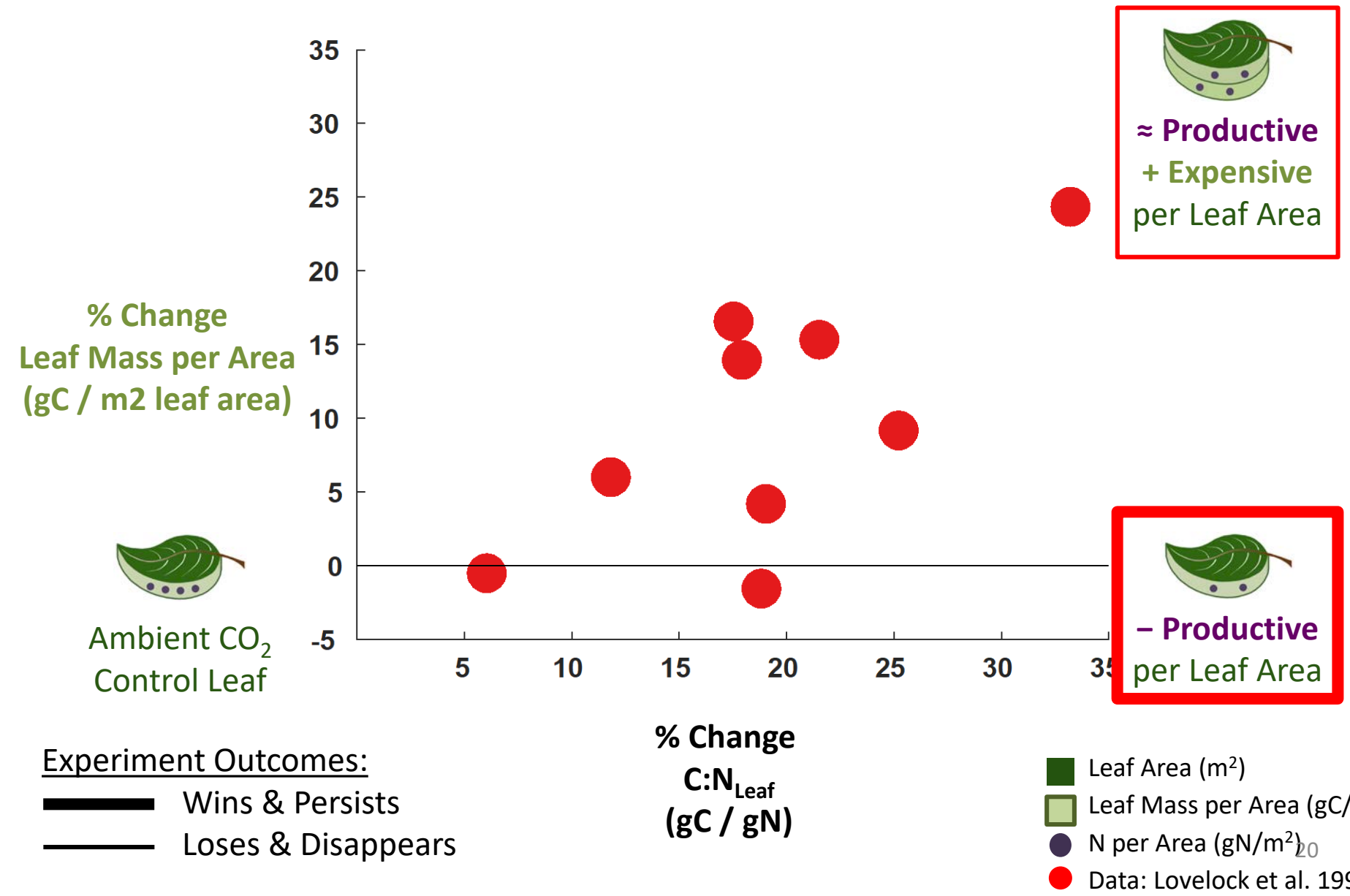
Photo: Klaus Winter Lab website (http://www.stri.si.edu)

Control Simulations (CLM-FATES)

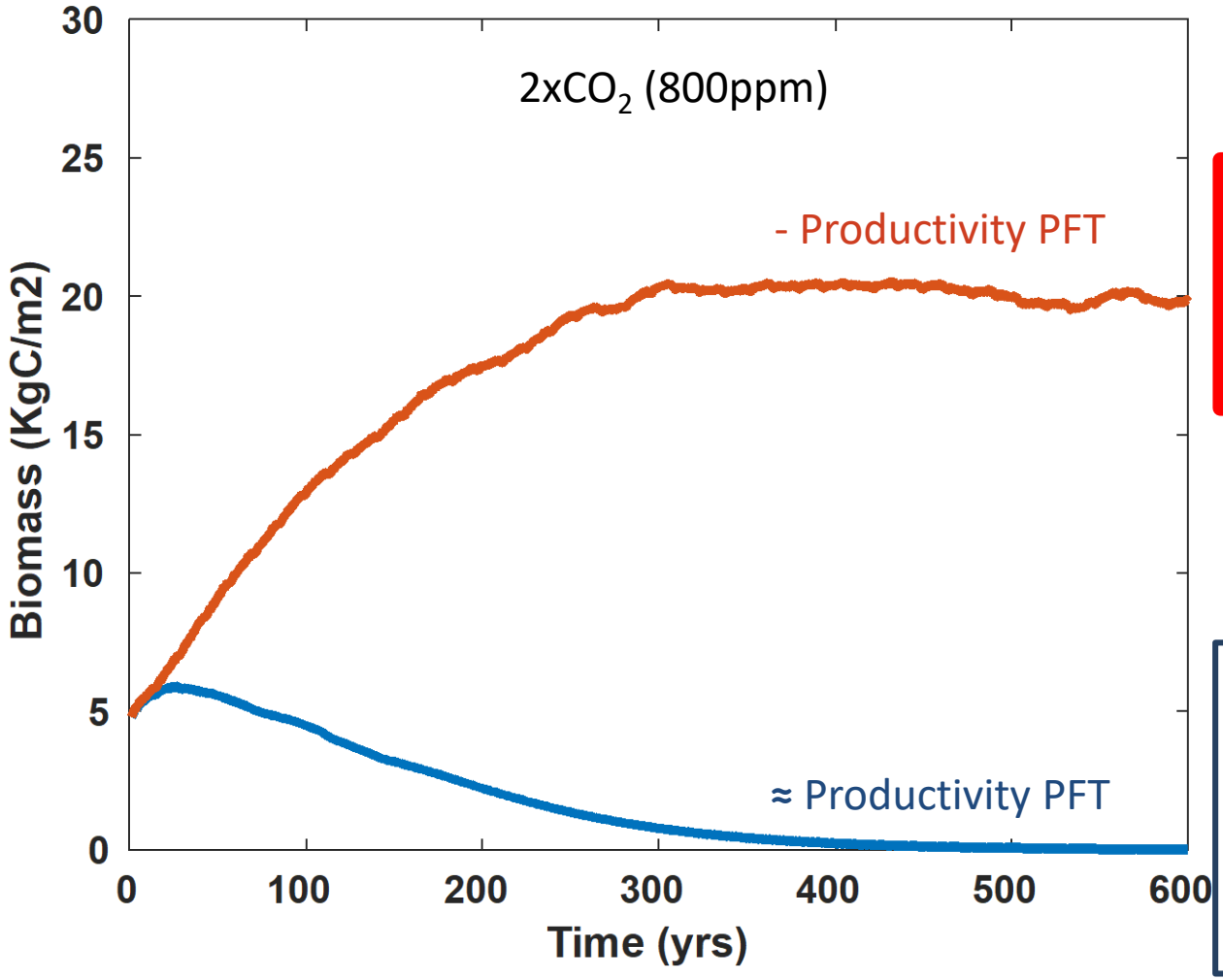


Ambient CO_2
Control Leaf

Competition #1:
Expensive Leaf vs. Low Productivity Leaf



Experiment Simulations (CLM-FATES)

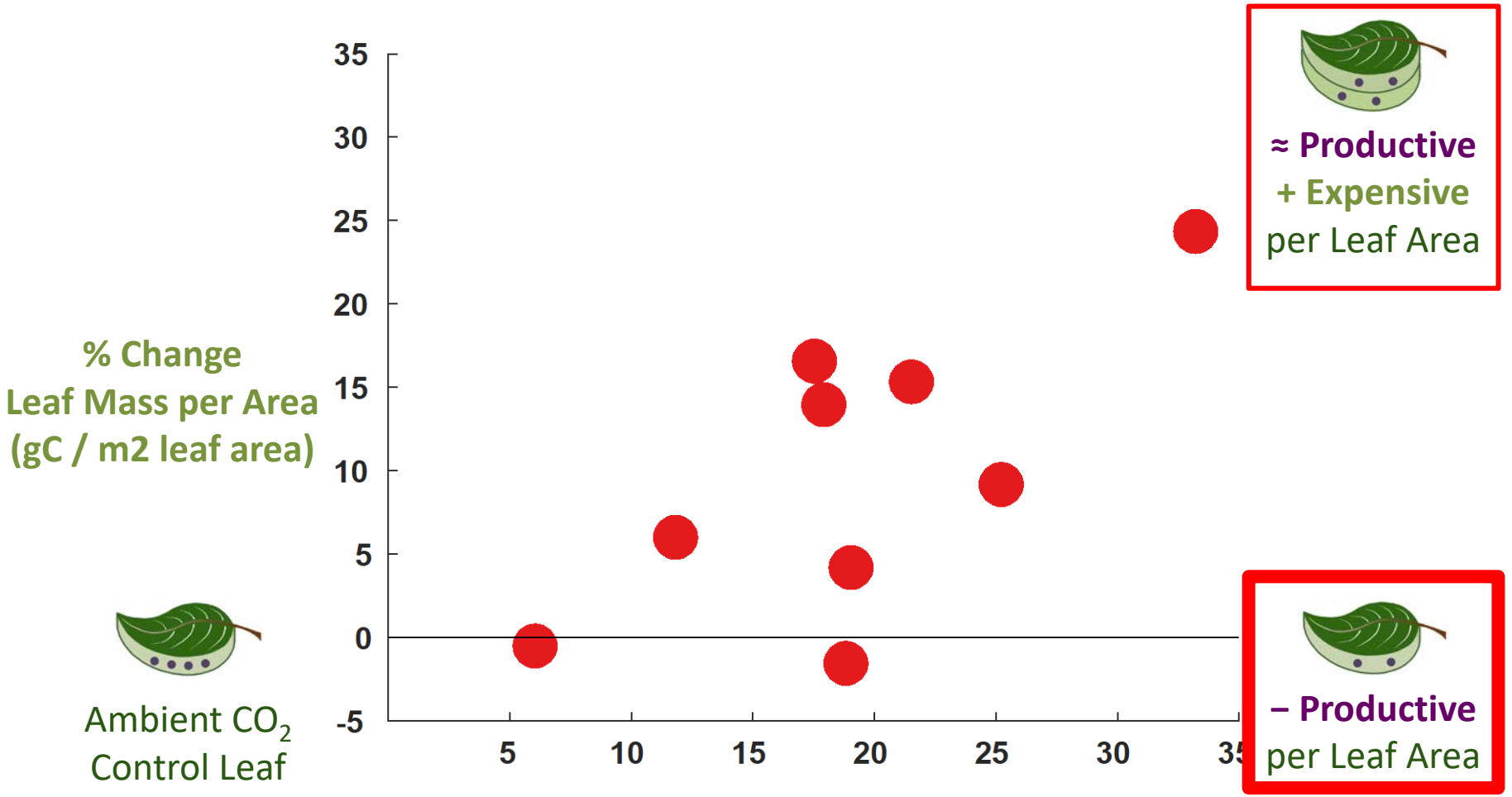


WINS!

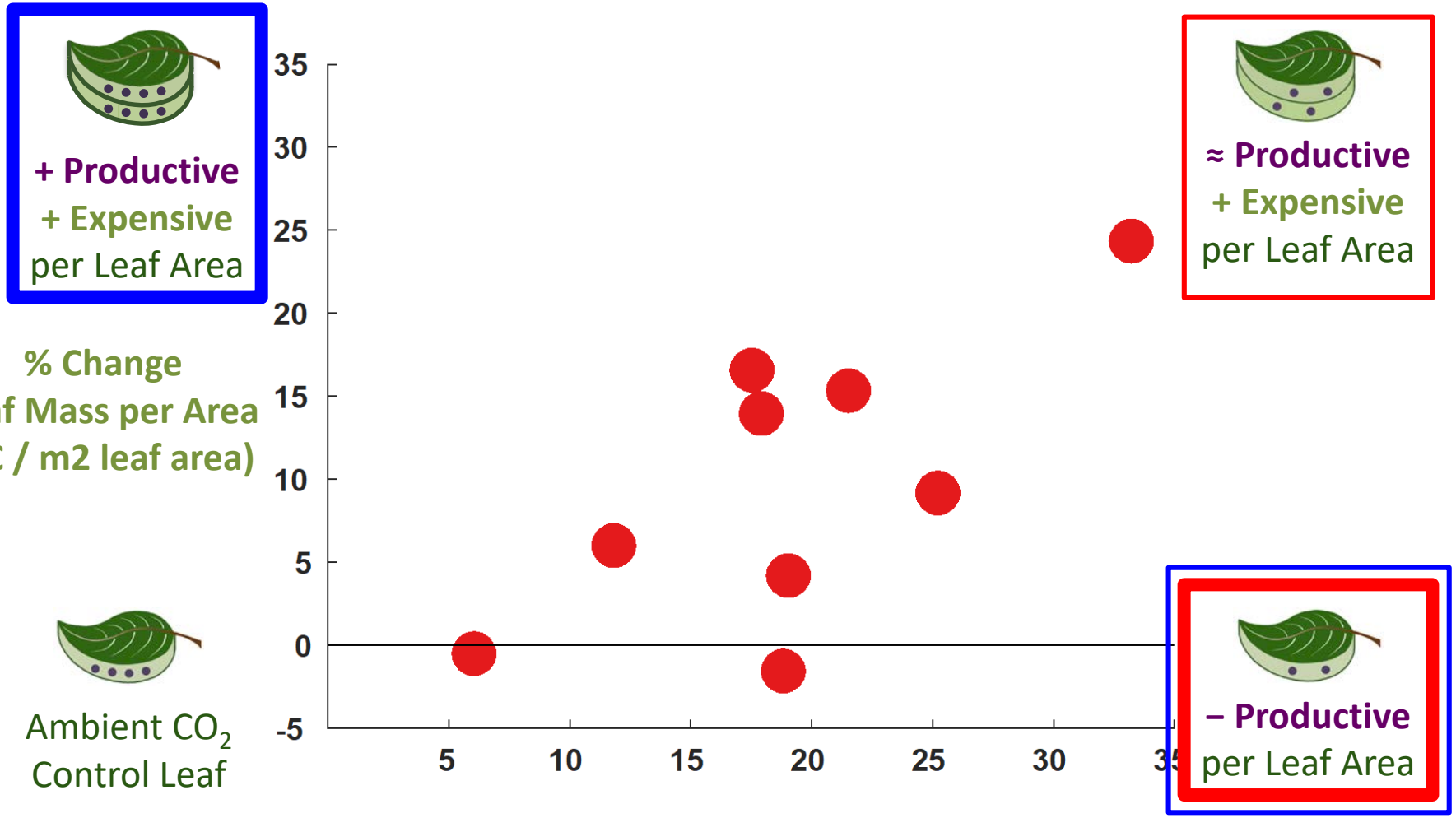
– Productive
per Leaf Area

≈ Productive
+ Expensive
per Leaf Area

Winner: Inexpensive, Low Productivity Leaf



Winner: Very Productive, Expensive Leaf

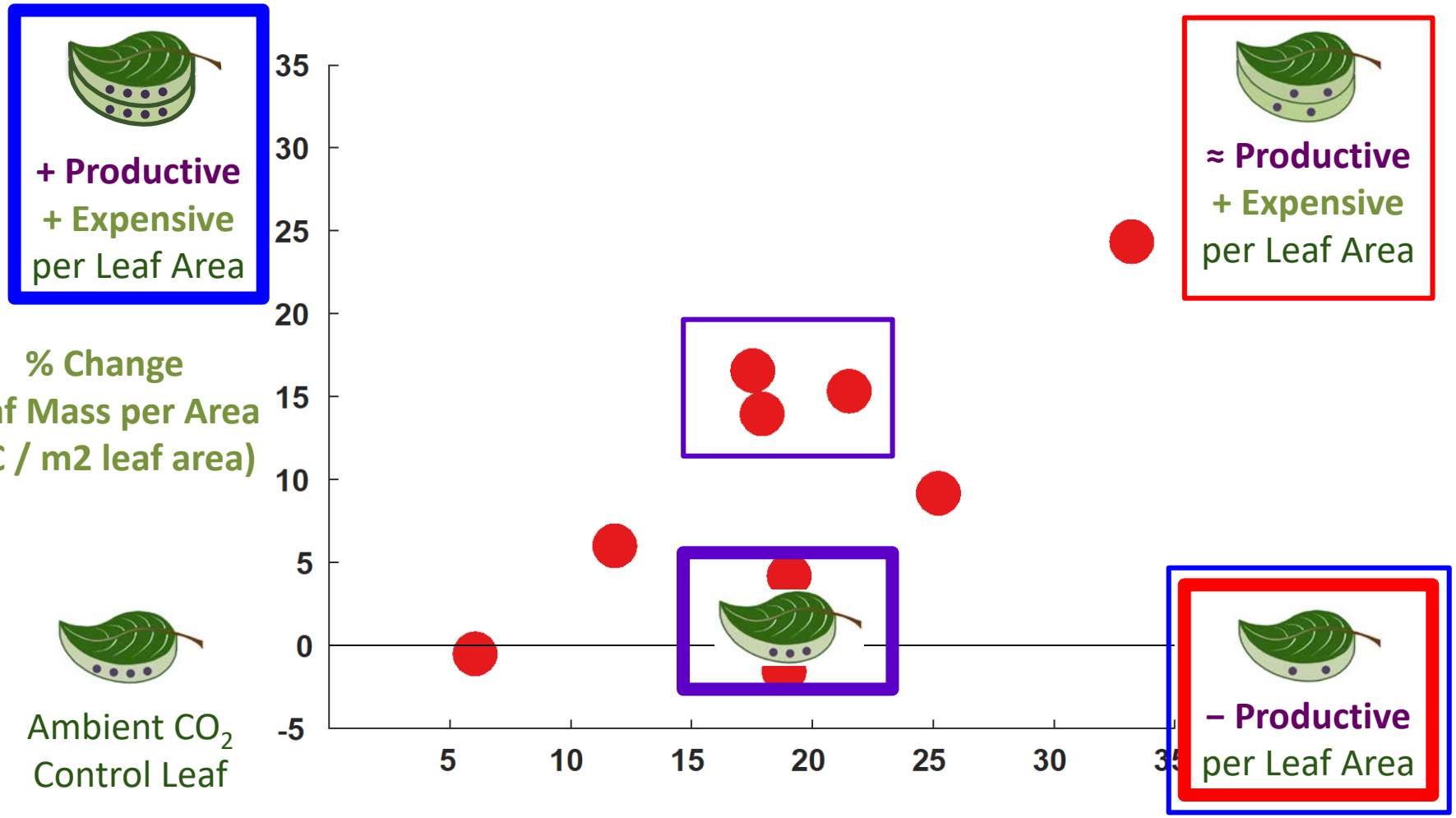


Experiment Outcomes:

- Wins & Persists
- Loses & Disappears

- Leaf Area (m^2)
- Leaf Mass per Area (gC/m^2)
- N per Area (gN/m^2)
- Data: Lovelock et al. 1998

Winner: Inexpensive, Low Producvitiy Leaf



Experiment Outcomes:

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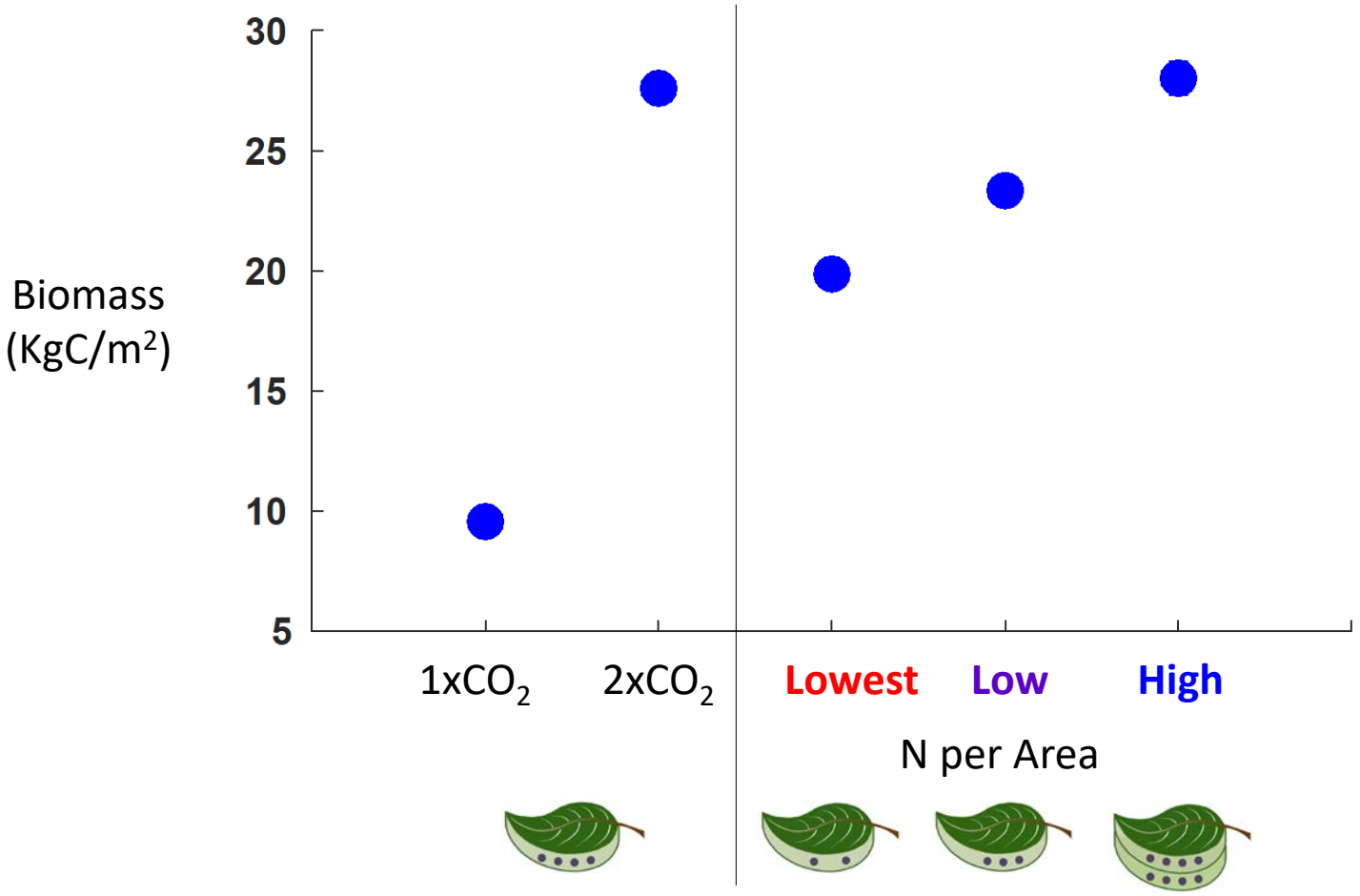
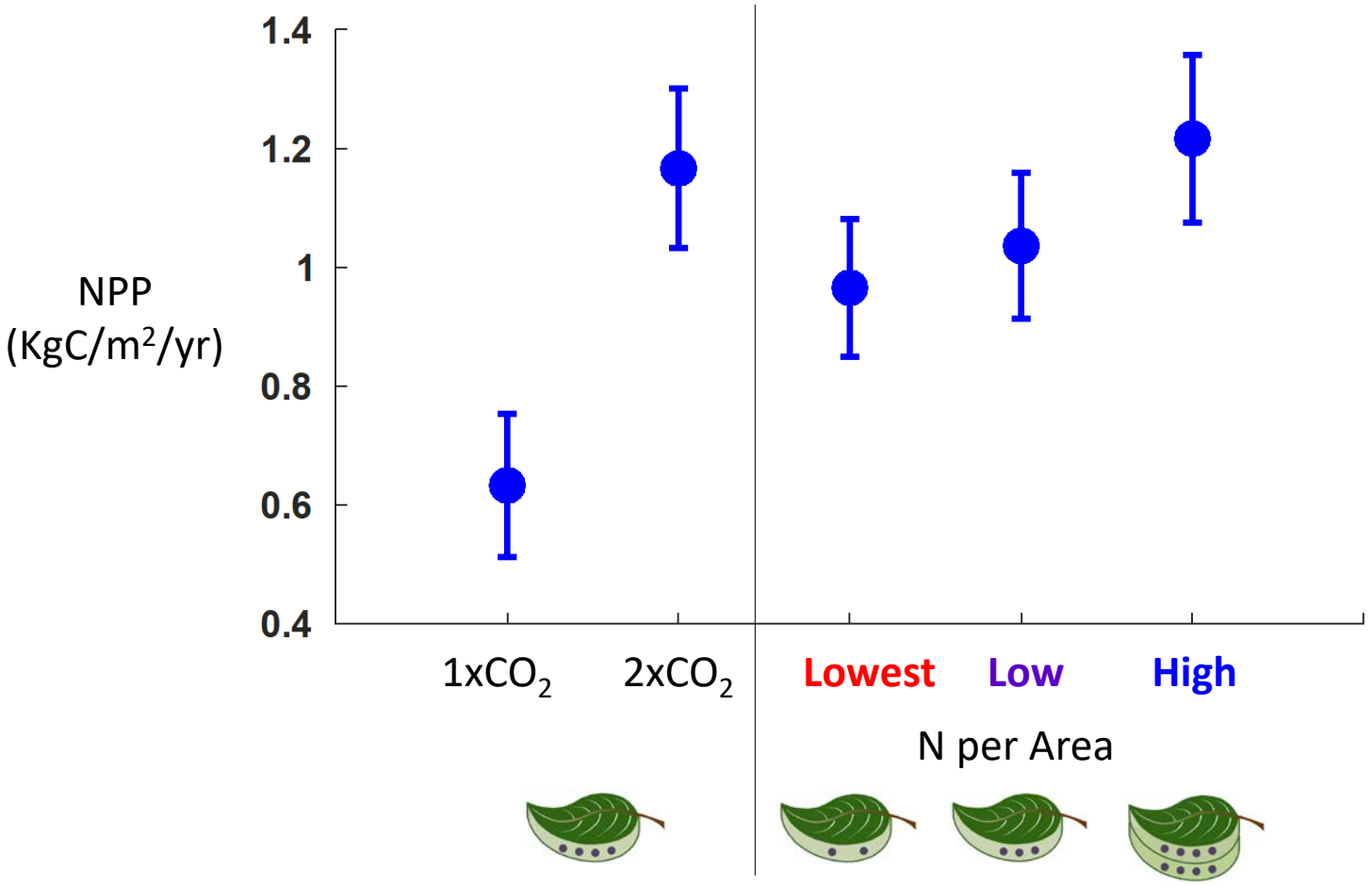
- Data: Lovelock et al. 1998

Could leaf trait and community composition responses to CO_2 alter ecosystem functioning?

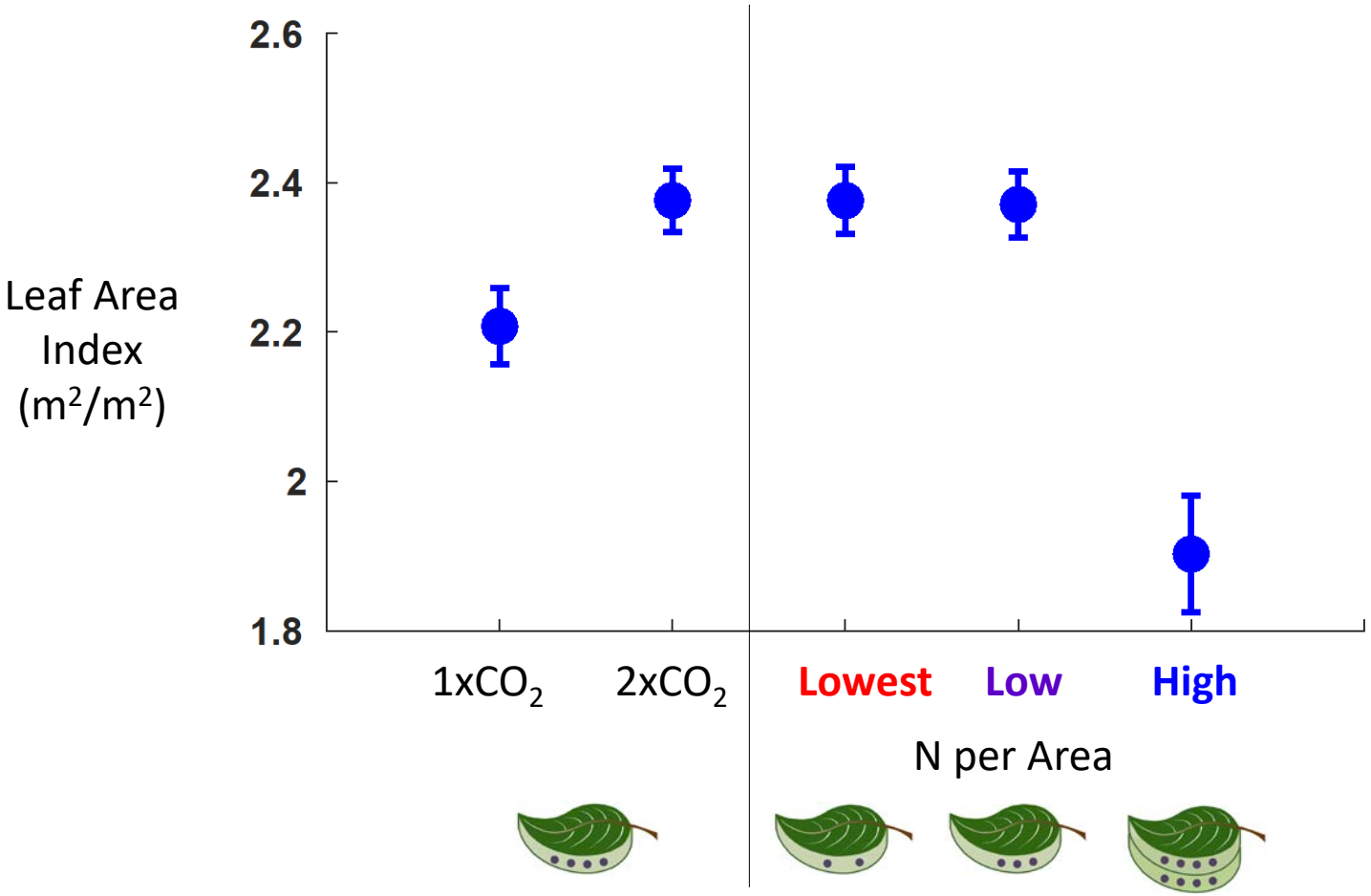
Leaf Trait and Community Composition changes alter Ecosystem Functioning



Leaf Trait and Community Composition changes alter Ecosystem Functioning



Leaf Trait and Community Composition changes alter Ecosystem Functioning



Next Steps

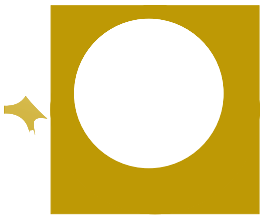
Test influence of:

- further sampling the trait response space
- higher temperatures
- initial plant types (e.g. successional stages)
- carbon allocation to leaves
- starting from bare ground vs. existing forest

Thanks!

Take Home Point:

Leaf trait responses to elevated CO_2 could have large impacts on tropical ecosystem composition & functioning!



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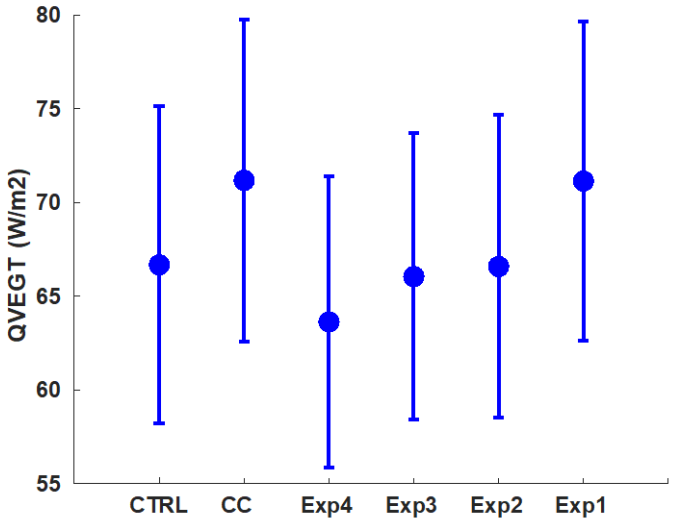
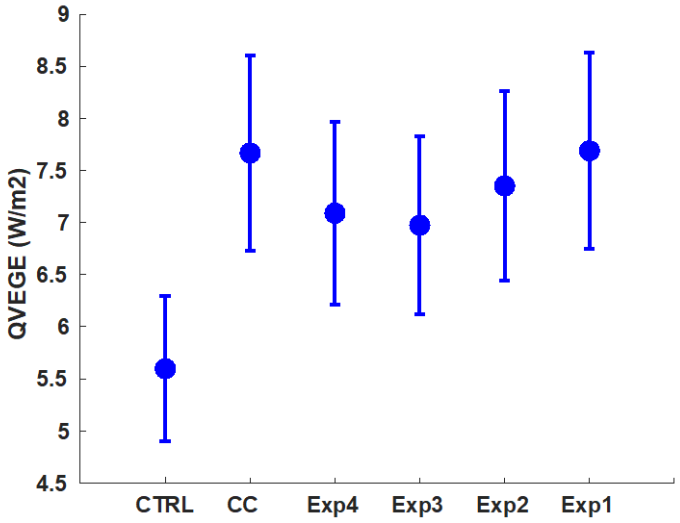
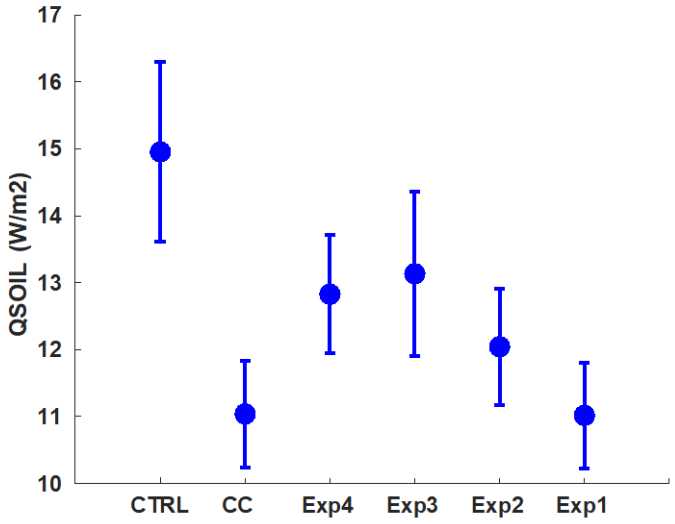
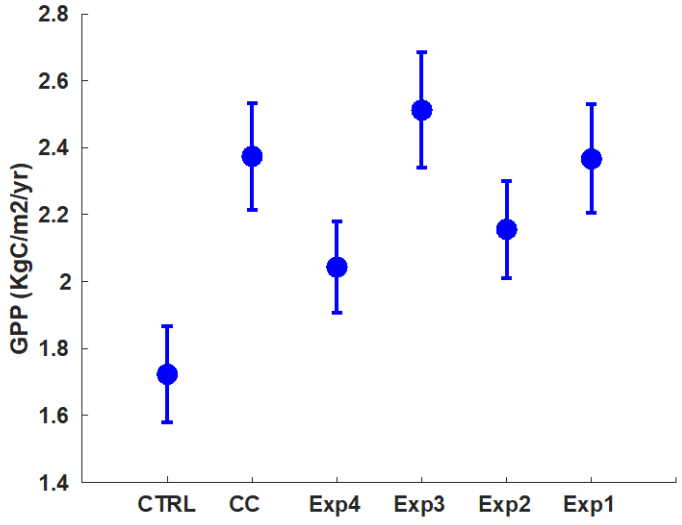

80
75
70
65
60
55
QVEGT (W/m2)
CTRL
CC
Exp4
Exp3
Exp2
Exp1


QVEGE (W/m2)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
CTRL
CC
Exp4
Exp3
Exp2
Exp1


QSOIL (W/m2)
17
16
15
14
13
12
11
10
CTRL
CC
Exp4
Exp3
Exp2
Exp1


GPP (KgC/m2/yr)
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
CTRL
CC
Exp4
Exp3
Exp2
Exp1