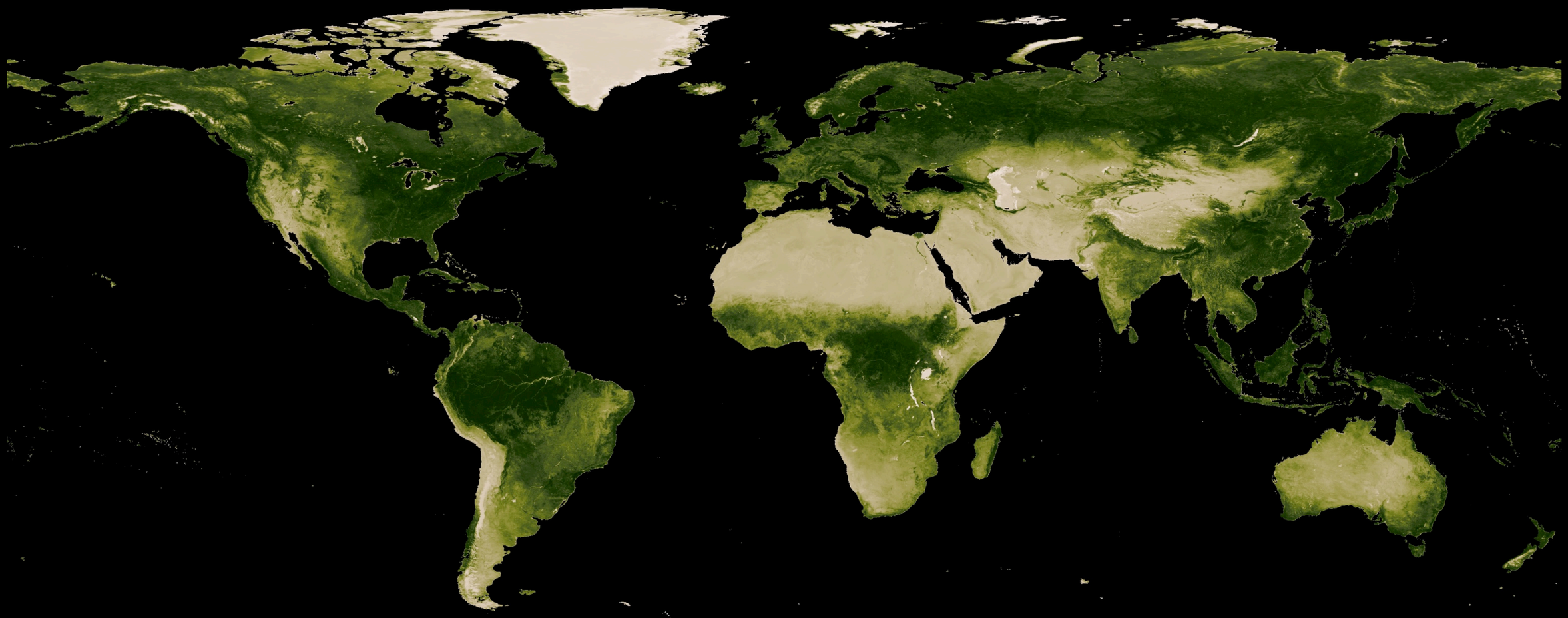
Who wins: testing competitive ability resulting from leaf plasticity responses to elevated CO_2 using FATES



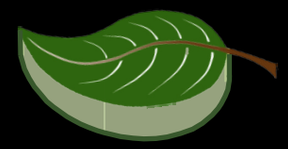
Marlies Kovenock (presented by A. Swann)
Ecoclimate Lab
Department of Biology
University of Washington

Funding from NSF

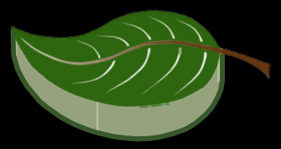
Image: NASA Earth Observations

Work with:
Abigail L.S. Swann, University of Washington
Charles D. Koven, LBNL
Ryan G. Knox, LBNL
Rosie A. Fisher, NCAR

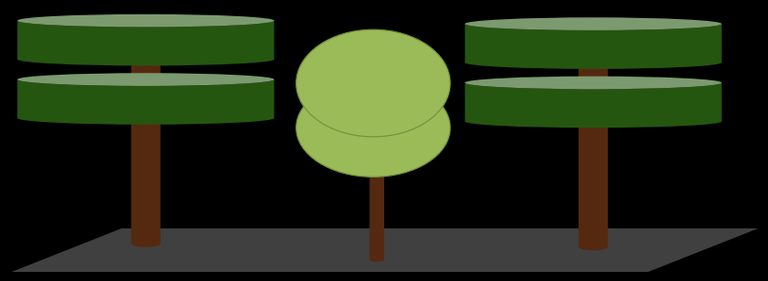
↑ Carbon Dioxide (CO_2) → ΔPlant Leaves → ΔClimate



↑ Carbon Dioxide (CO_2) → ΔPlant Leaves → ΔClimate



↓ ΔAbundance of Plant Types

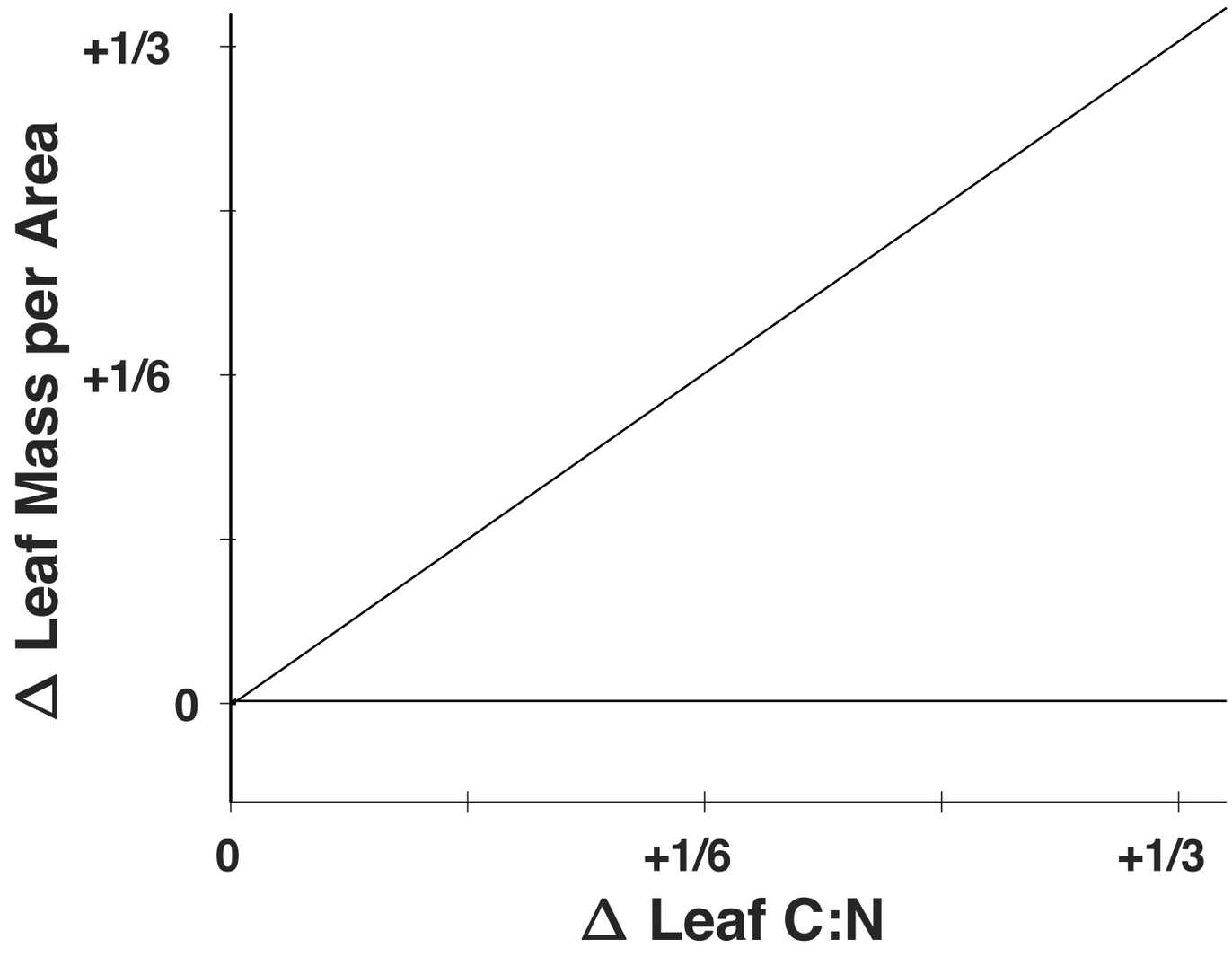


Levels of leaf responses informed by observations: Tropical trees treated with $2xCO_2$

$2xCO_2$ => 9 species of tropical trees grown together in
open top chamber experiments in Panama's National Metropolitan Park

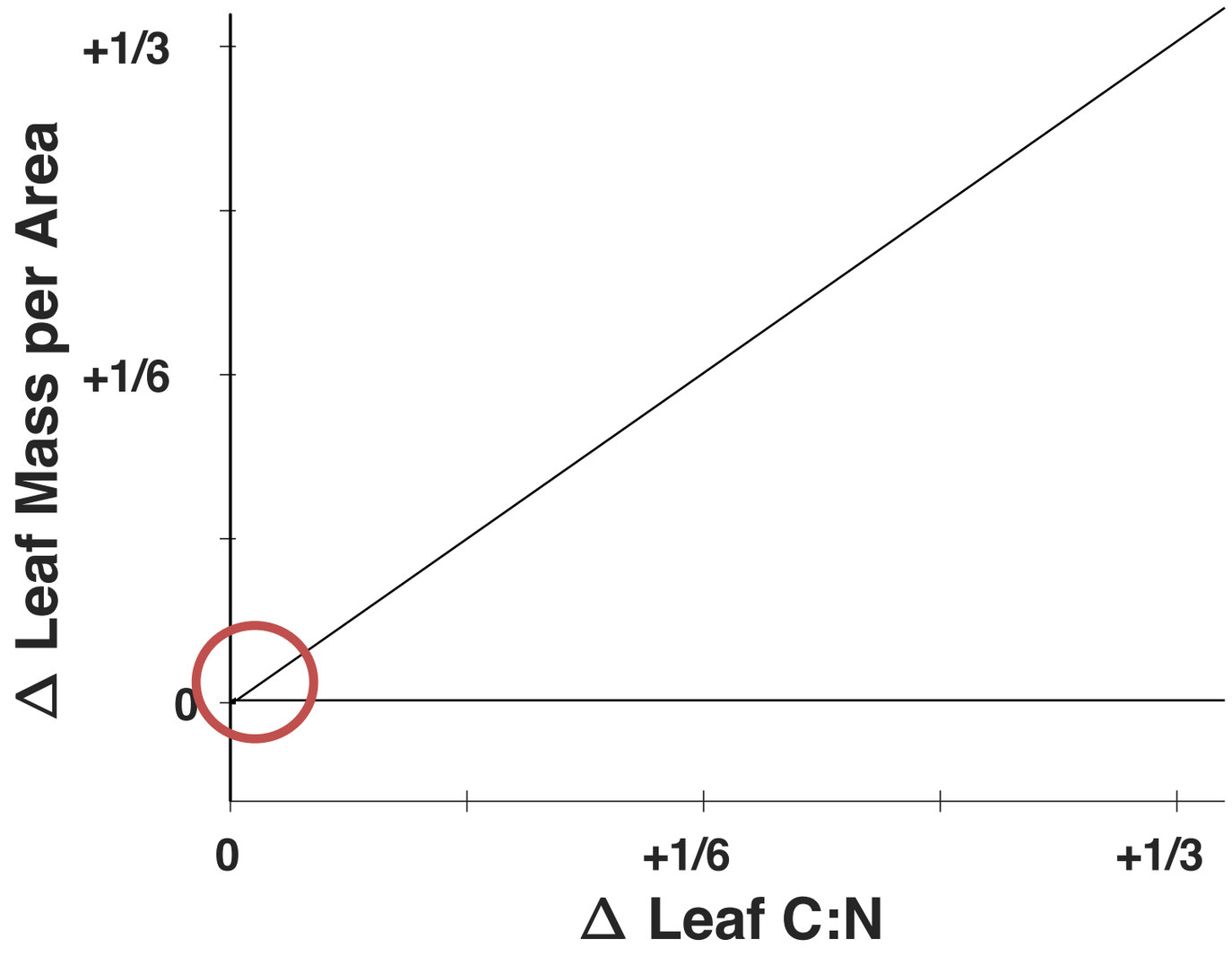
Lovelock et al., 1998; Photo: Klaus Winter Lab

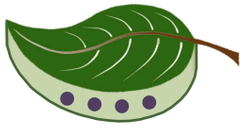
Leaf Response Space



Kovenock et al., *in prep*

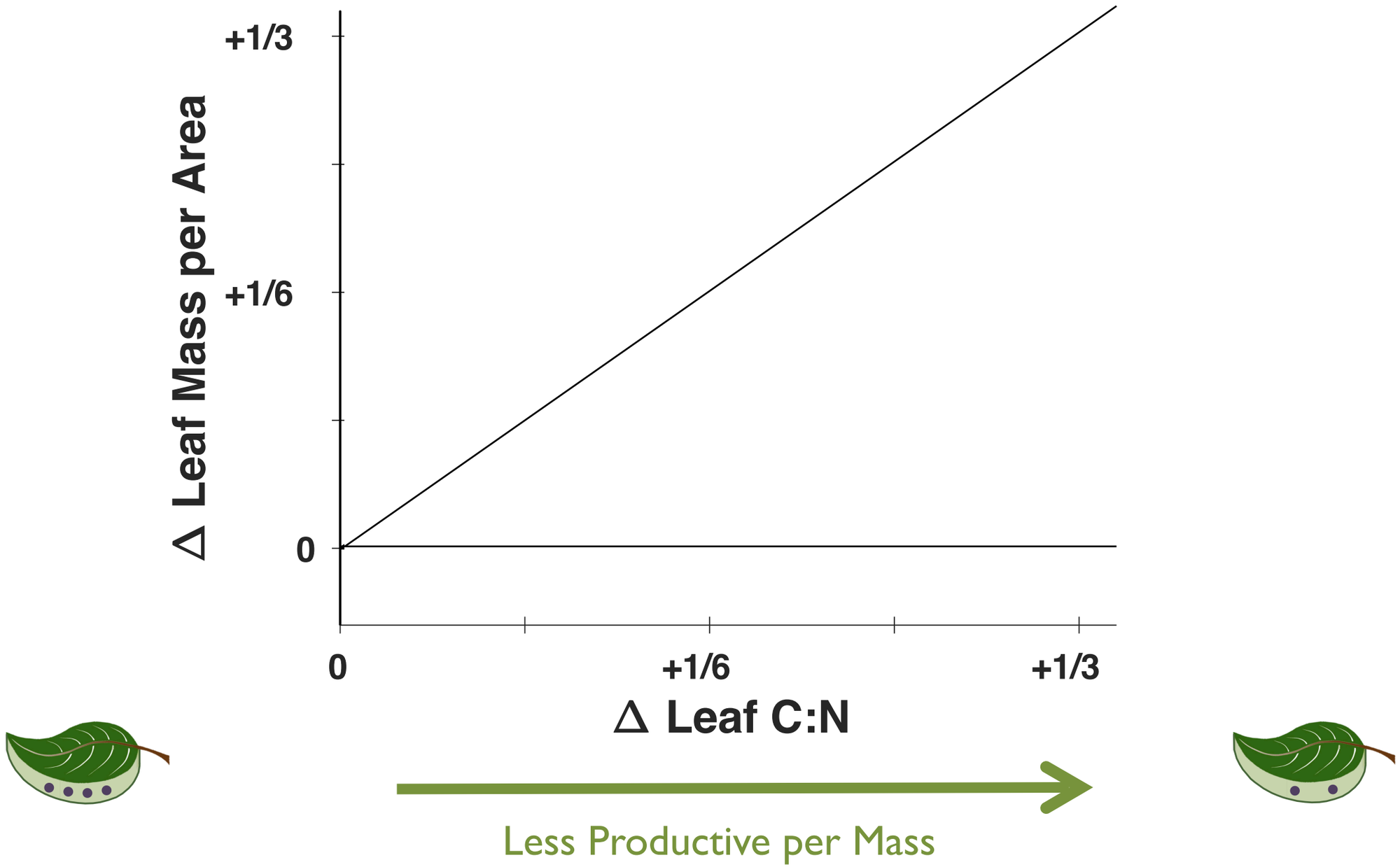
Leaf Response Space





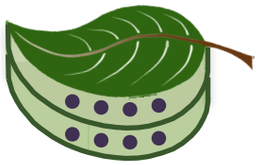
Kovenock et al., *in prep*

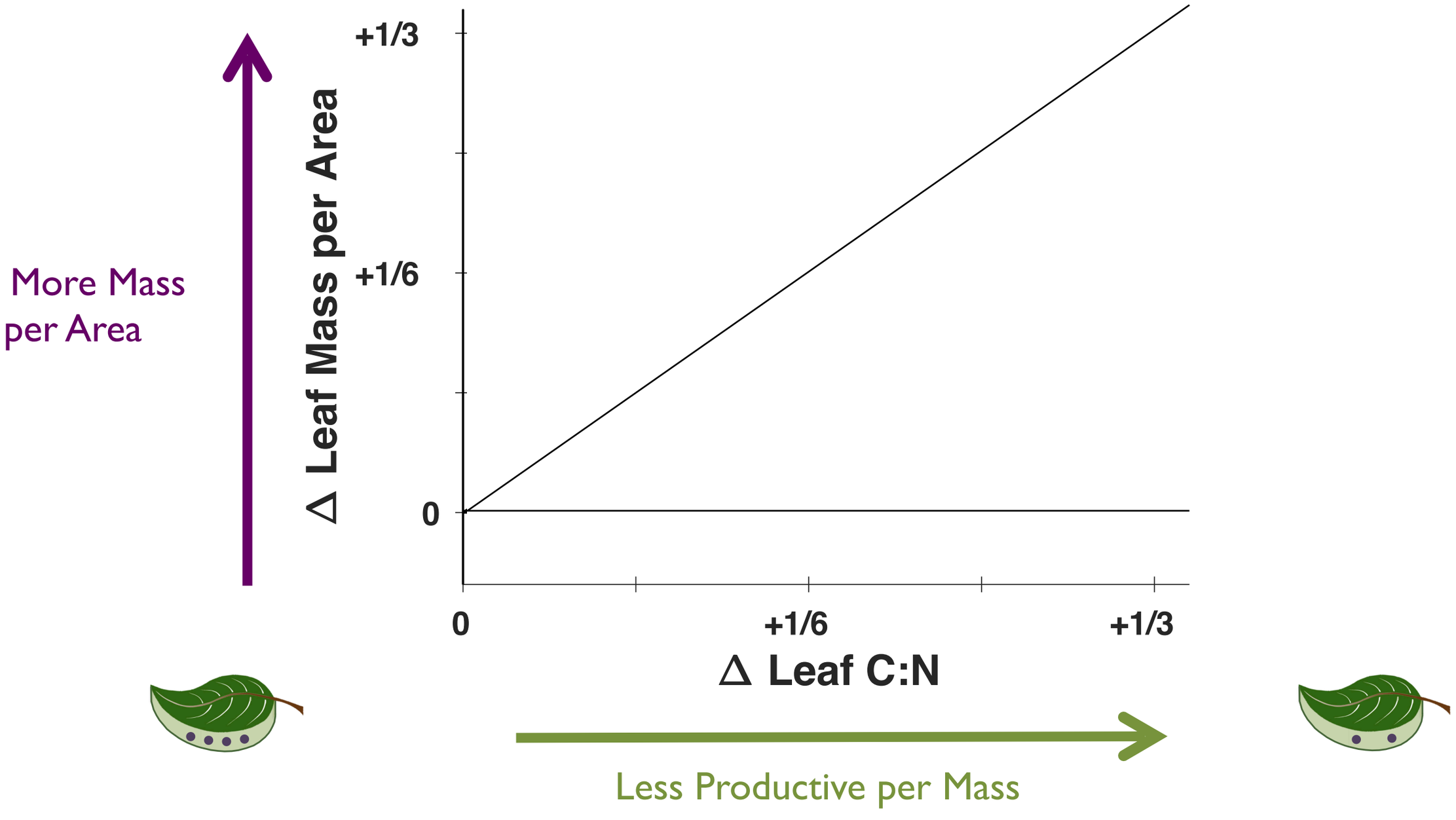
Leaf Response Space



Kovenock et al., *in prep*

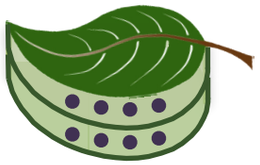
Leaf Response Space

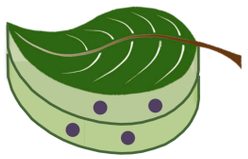




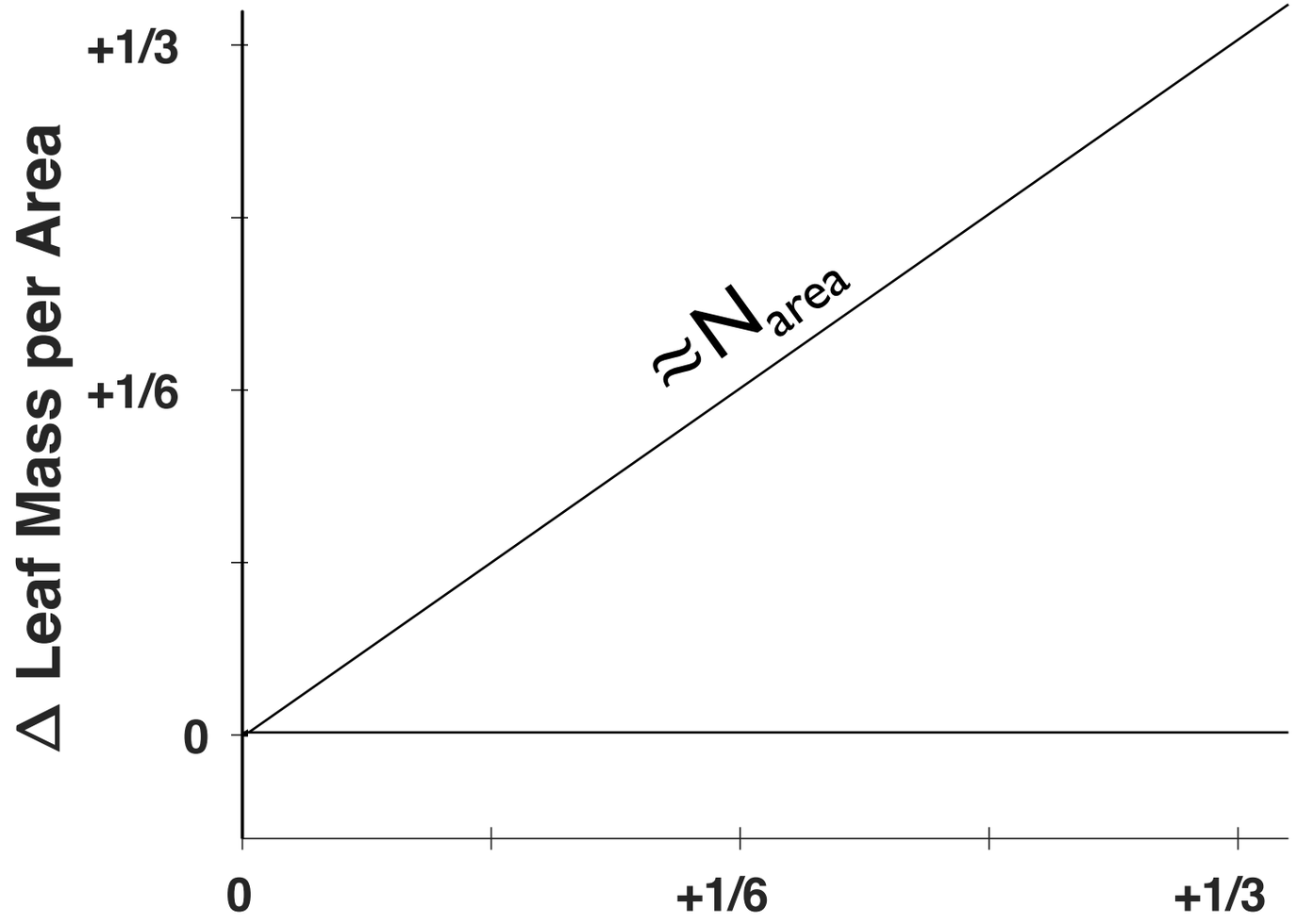
Kovenock et al., *in prep*

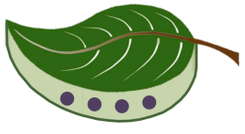
Leaf Response Space

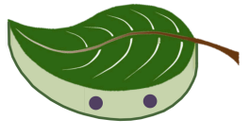




More Mass per Area



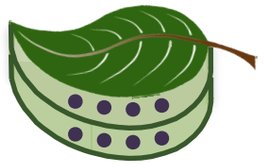


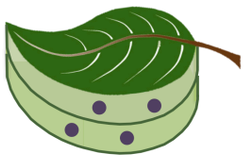


Less Productive per Mass

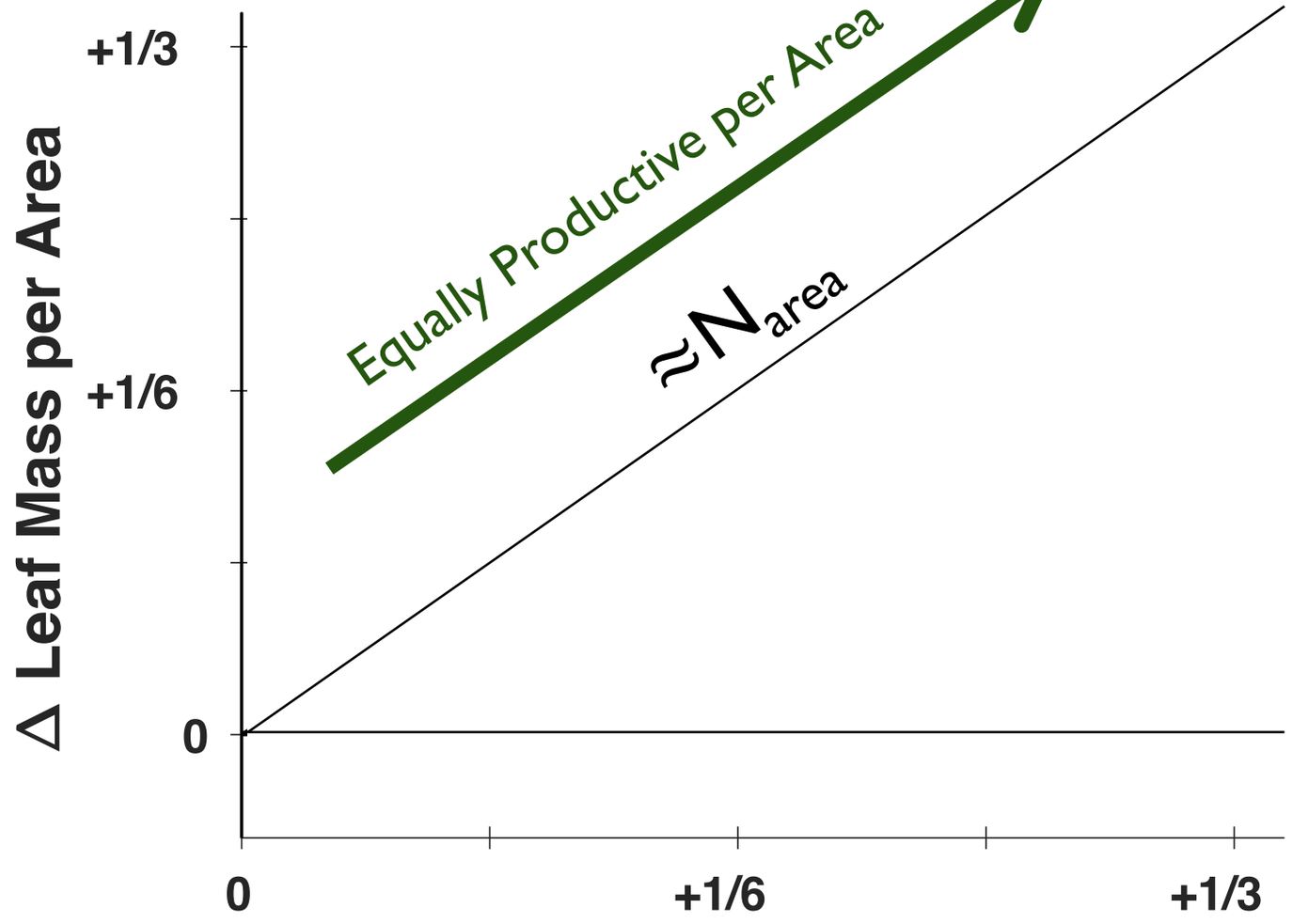
Kovenock et al., *in prep*

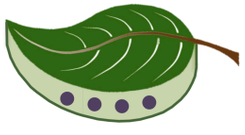
Leaf Response Space

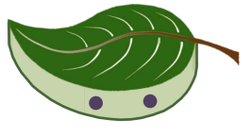




More Mass per Area



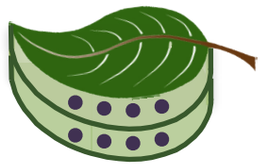


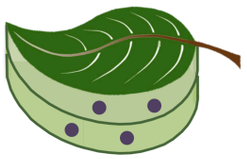


Less Productive per Mass

Kovenock et al., *in prep*

Leaf Response Space





More Mass per Area

Δ Leaf Mass per Area

+1/3

+1/6

0

+ N_{area}

Equally Productive per Area

≈N_{area}

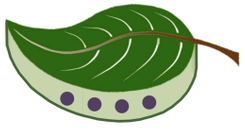
− N_{area}

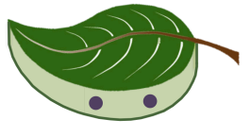
0

+1/6

+1/3

Δ Leaf C:N

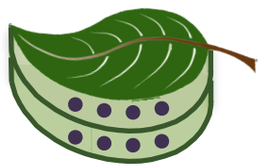




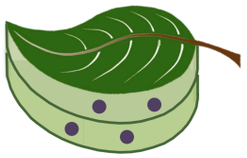
Less Productive per Mass

Kovenock et al., *in prep*

Observed leaf responses across 9 tropical tree species



● = Different tropical tree response



More Mass per Area

Δ Leaf Mass per Area

+1/3

+1/6

0

+ N_{area}

Equally Productive per Area

≈N_{area}

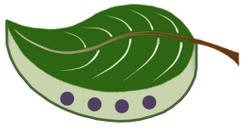
− N_{area}

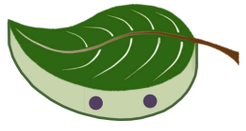
0

+1/6

+1/3

Δ Leaf C:N





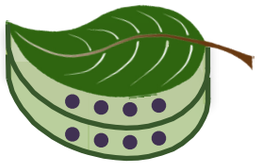
Less Productive per Mass

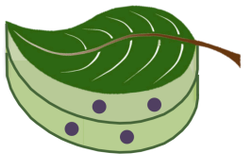
Observations from Lovelock et al., 1998

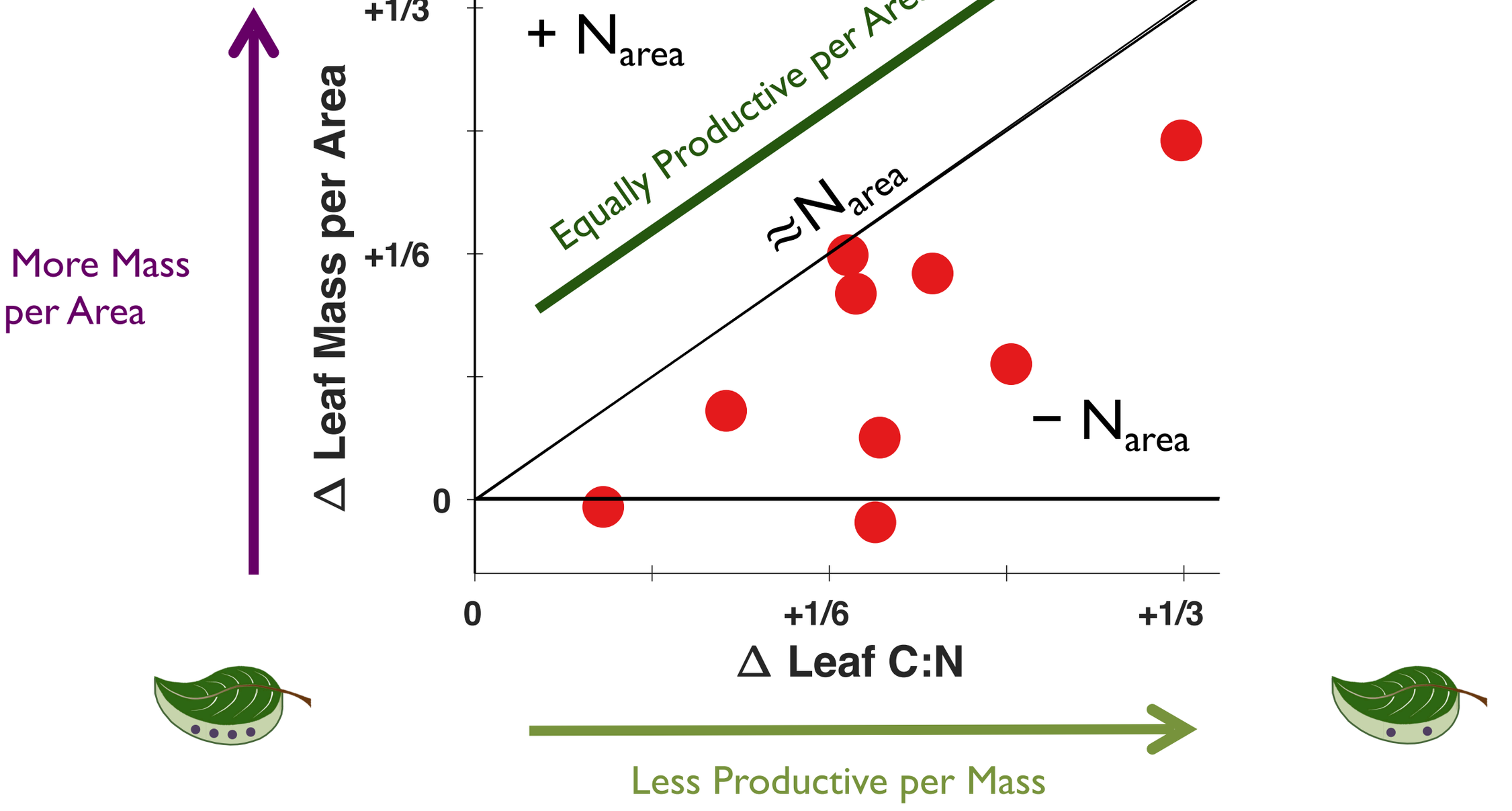
Kovenock et al., *in prep*

1. In general, leaves increase C:N

● = Different tropical tree response



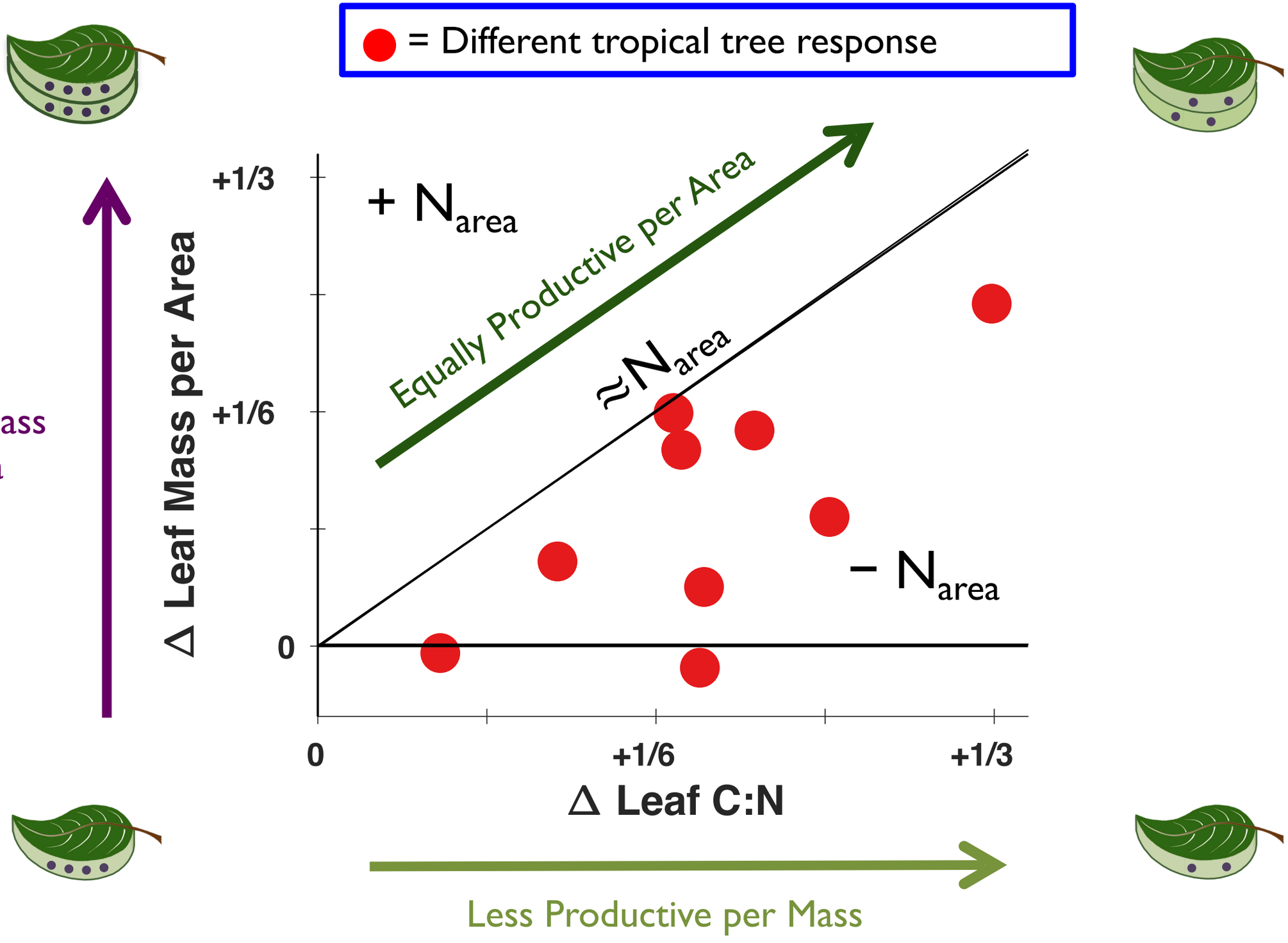




Observations from Lovelock et al., 1998

Kovenock et al., *in prep*

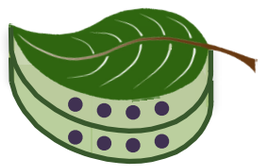
2. In general, leaves increase in thickness



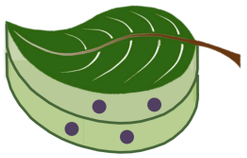
Observations from Lovelock et al., 1998

Kovenock et al., *in prep*

3. Helps maintain N_{area} but, less productive per area than control



● = Different tropical tree response



More Mass per Area

Δ Leaf Mass per Area

+1/3

+ N_{area}

Equally Productive per Area

≈N_{area}

− N_{area}

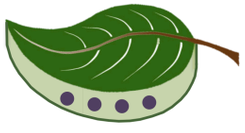
0

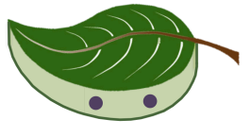
0

+1/6

+1/3

Δ Leaf C:N



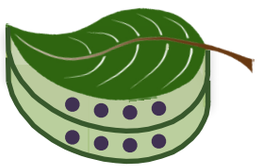


Less Productive per Mass

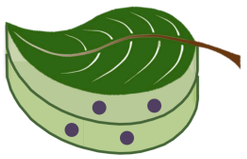
Observations from Lovelock et al., 1998

Kovenock et al., *in prep*

4. Variation in responses => differential competitive ability



● = Different tropical tree response



More Mass per Area

Δ Leaf Mass per Area

+1/3

+1/6

0

+ N_{area}

Equally Productive per Area

≈N_{area}

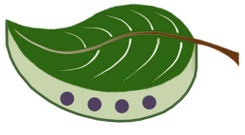
– N_{area}

0

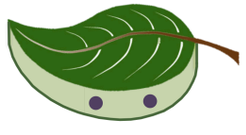
+1/6

+1/3

Δ Leaf C:N



Less Productive per Mass



Observations from Lovelock et al., 1998

Kovenock et al., *in prep*

Test how leaf responses => competitive ability

FATES Dynamic Vegetation Model

Tropical forest site: Barro Colorado Island, Panama

Run with Meteorological Data 2003-2016 (Faybishenko et al., 2018)

Simulations:

<u>CONTROLS (no leaf changes):</u>

1xCO_2

2xCO_2

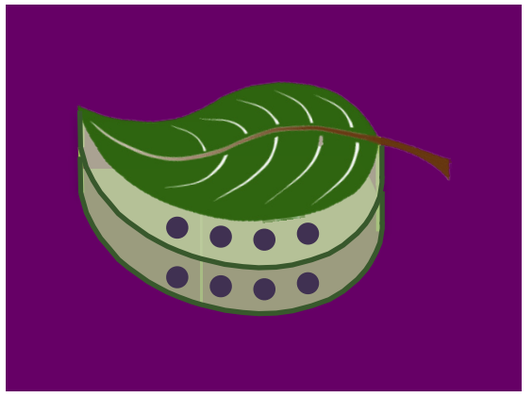
<u>EXPERIMENTS:</u>

Test different levels of leaf responses to +CO_2 informed by observations

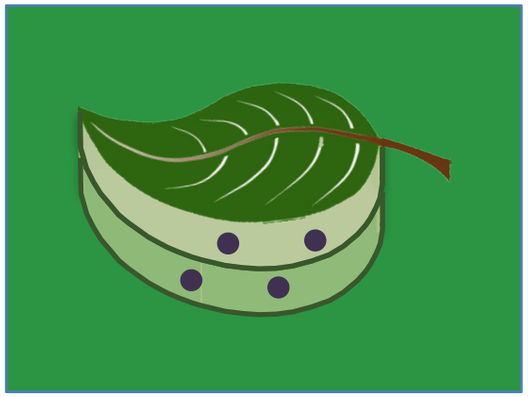
(Lovelock et al., 1998)

92 simulations in total

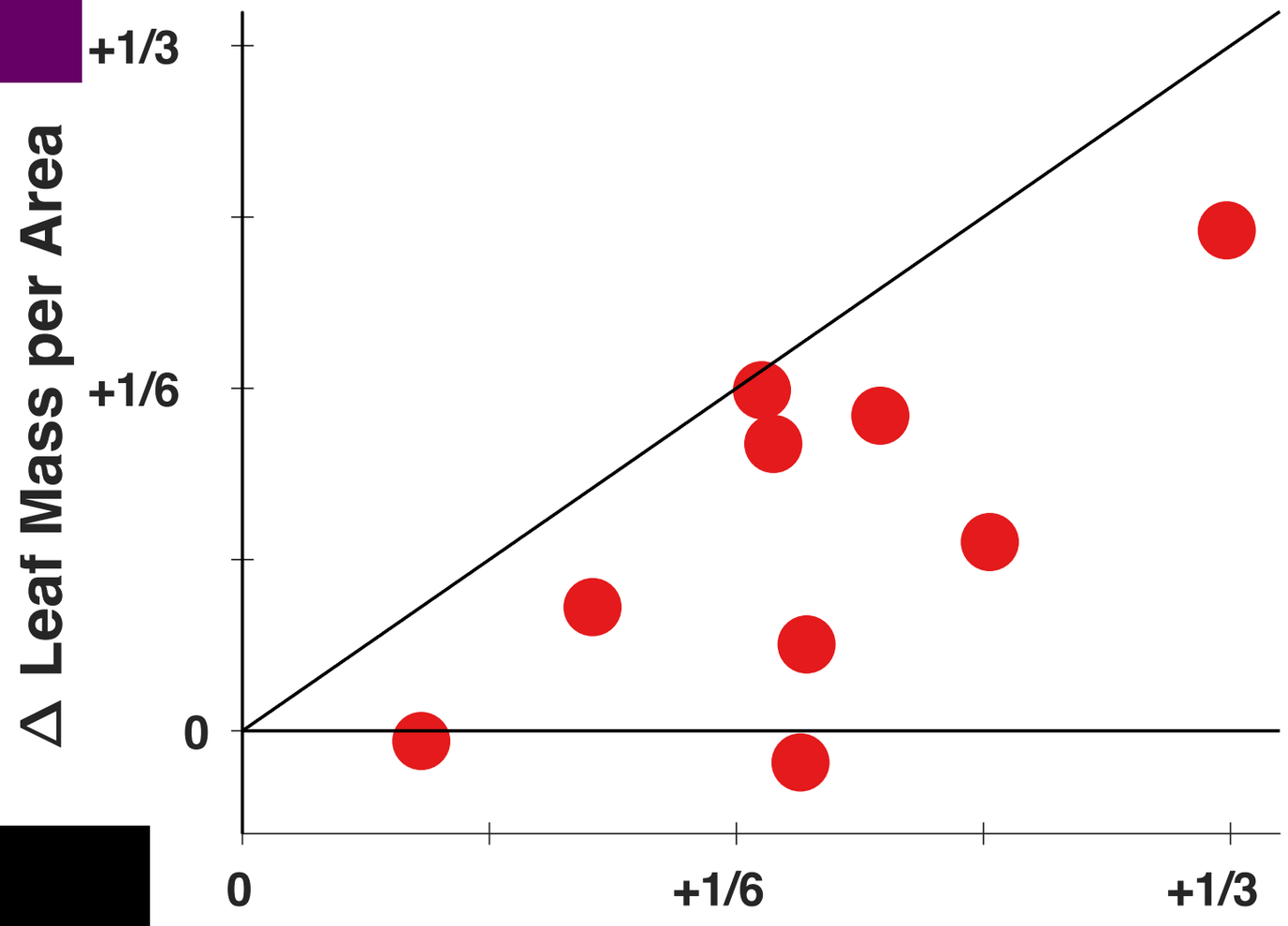
Leaf Response Space

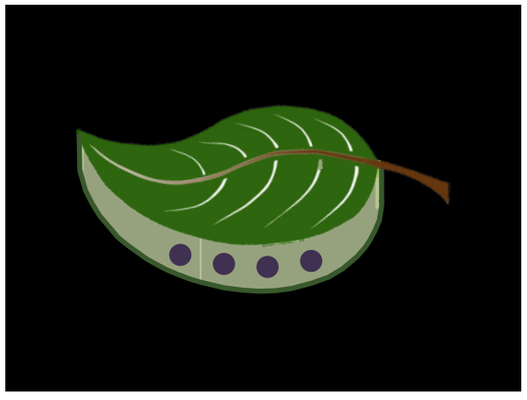


+LMA

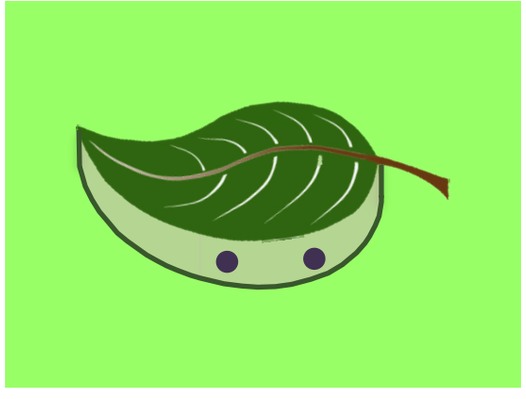


+CN+LMA





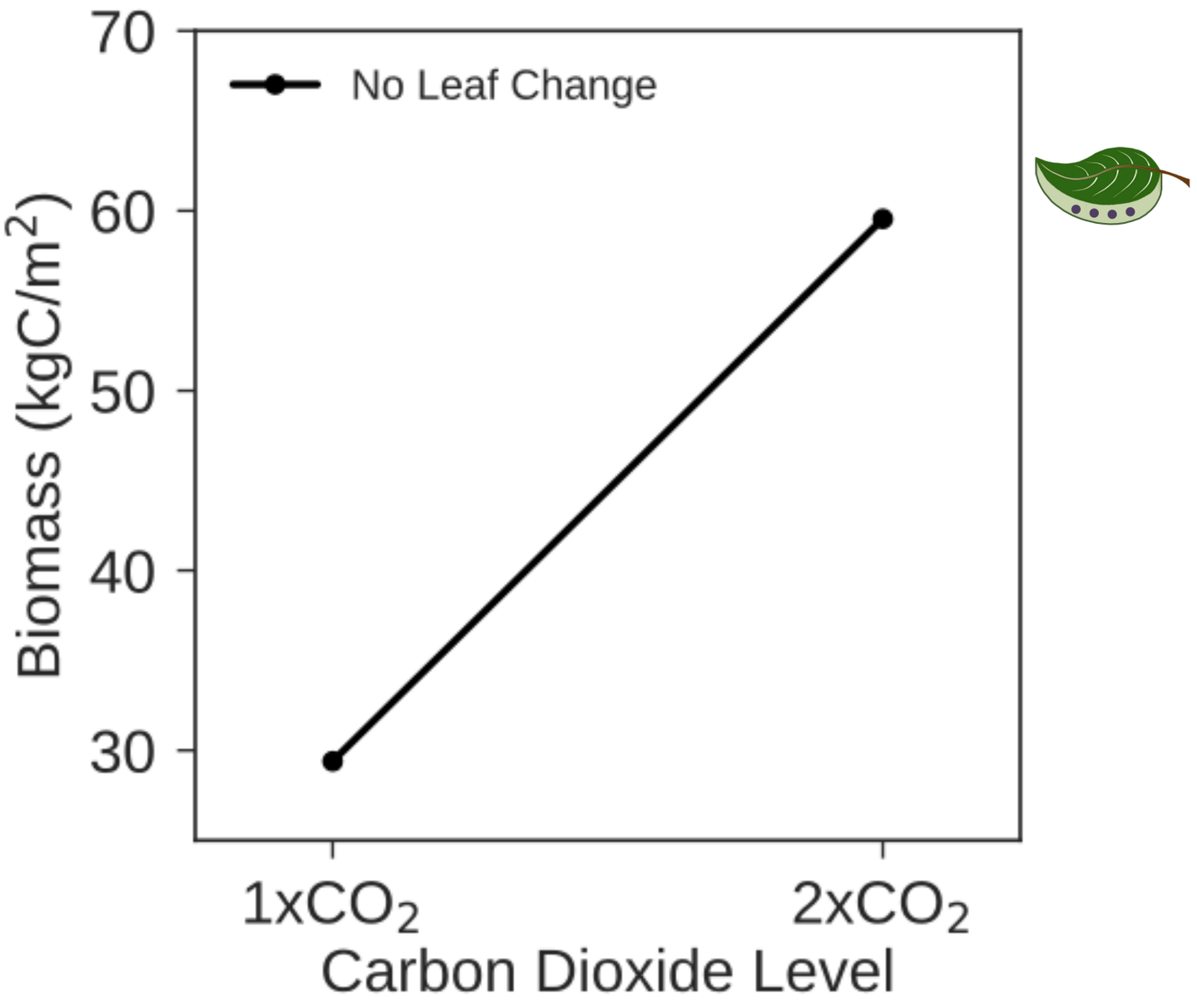
Control



+CN

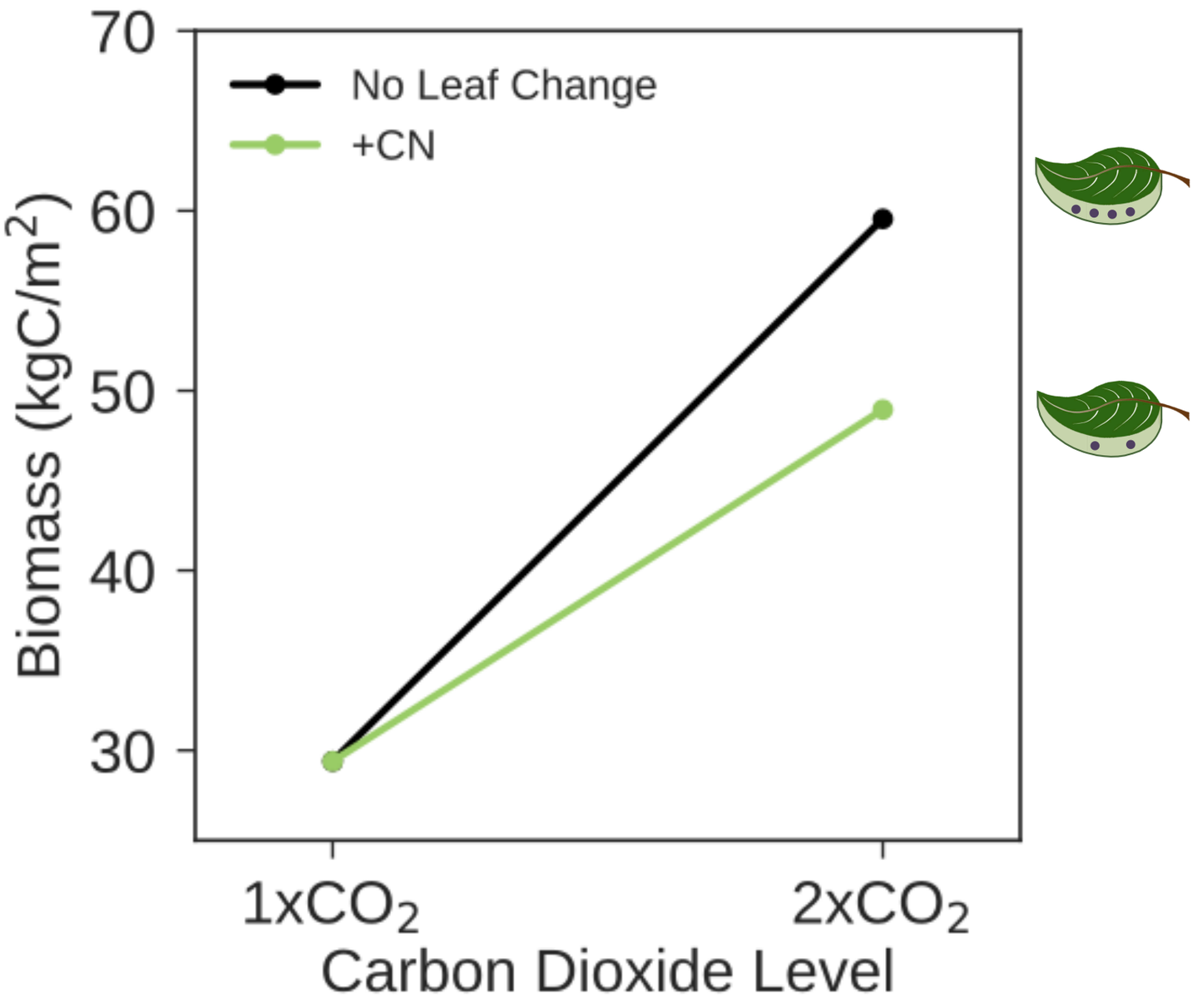
Observations from Lovelock et al., 1998

Elevated CO_2 increases biomass



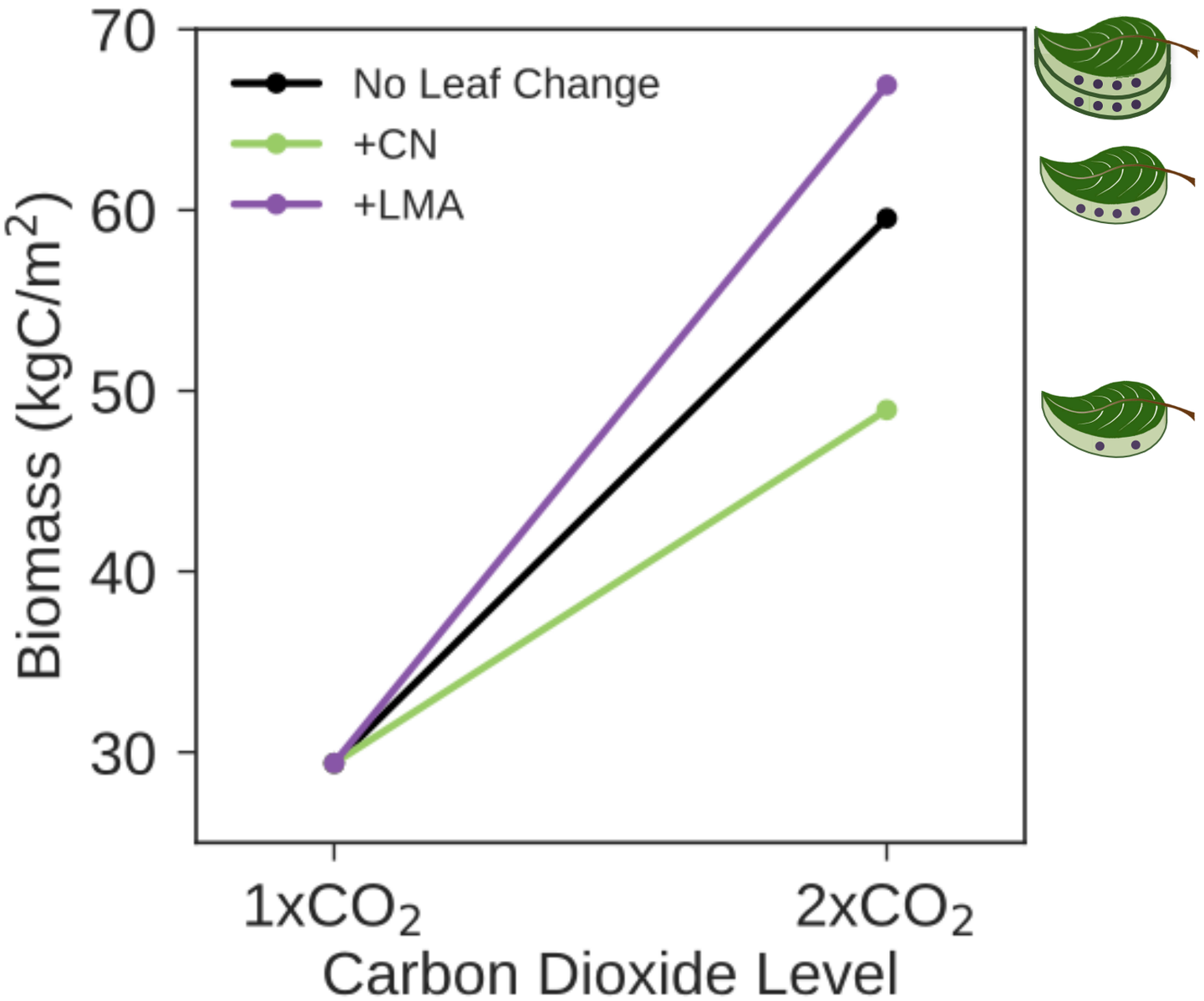
Kovenock et al., *in prep*

Higher leaf C:N reduces biomass response to CO_2



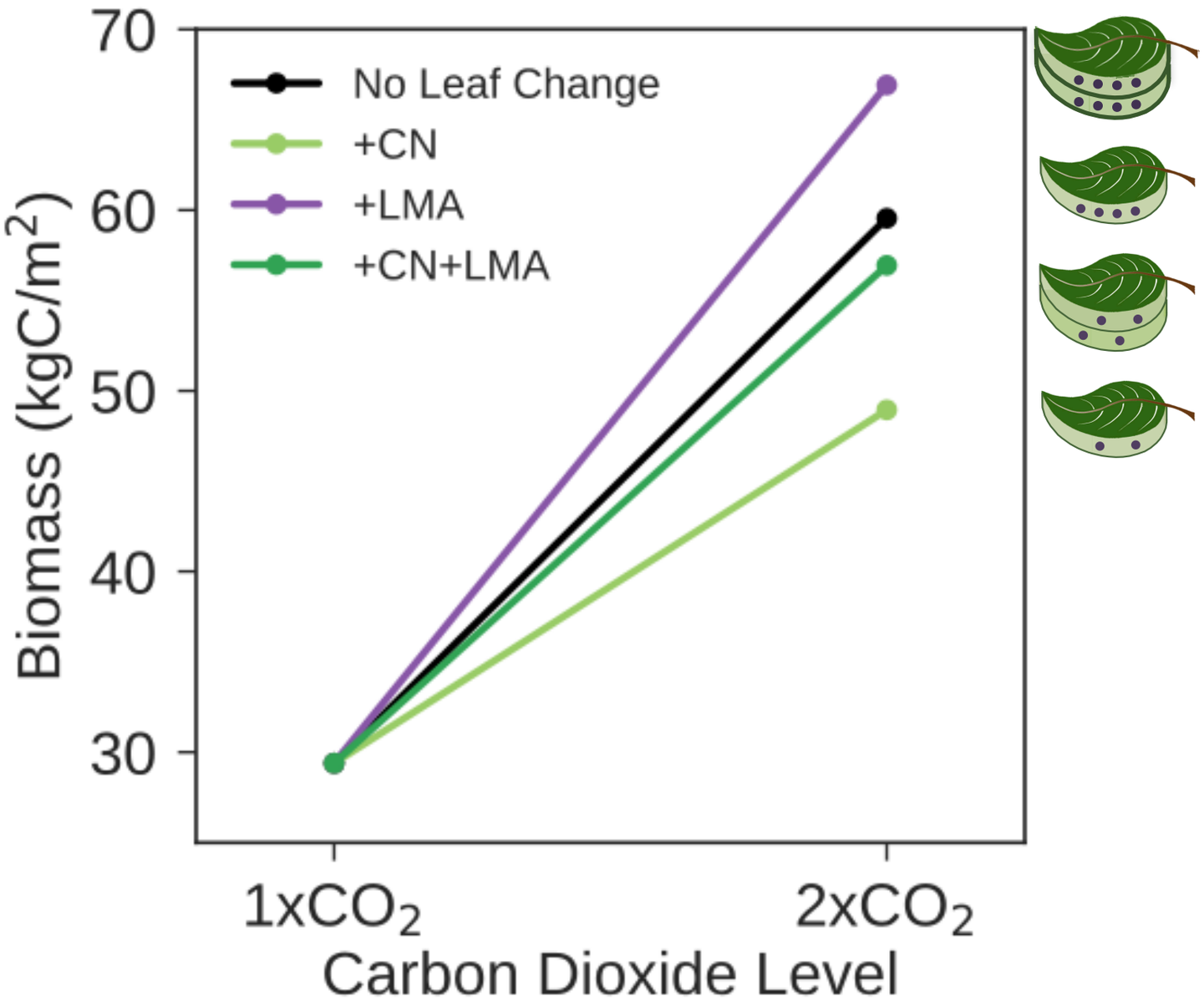
Kovenock et al., *in prep*

Higher leaf mass per area <u>enhances</u> biomass response to CO_2



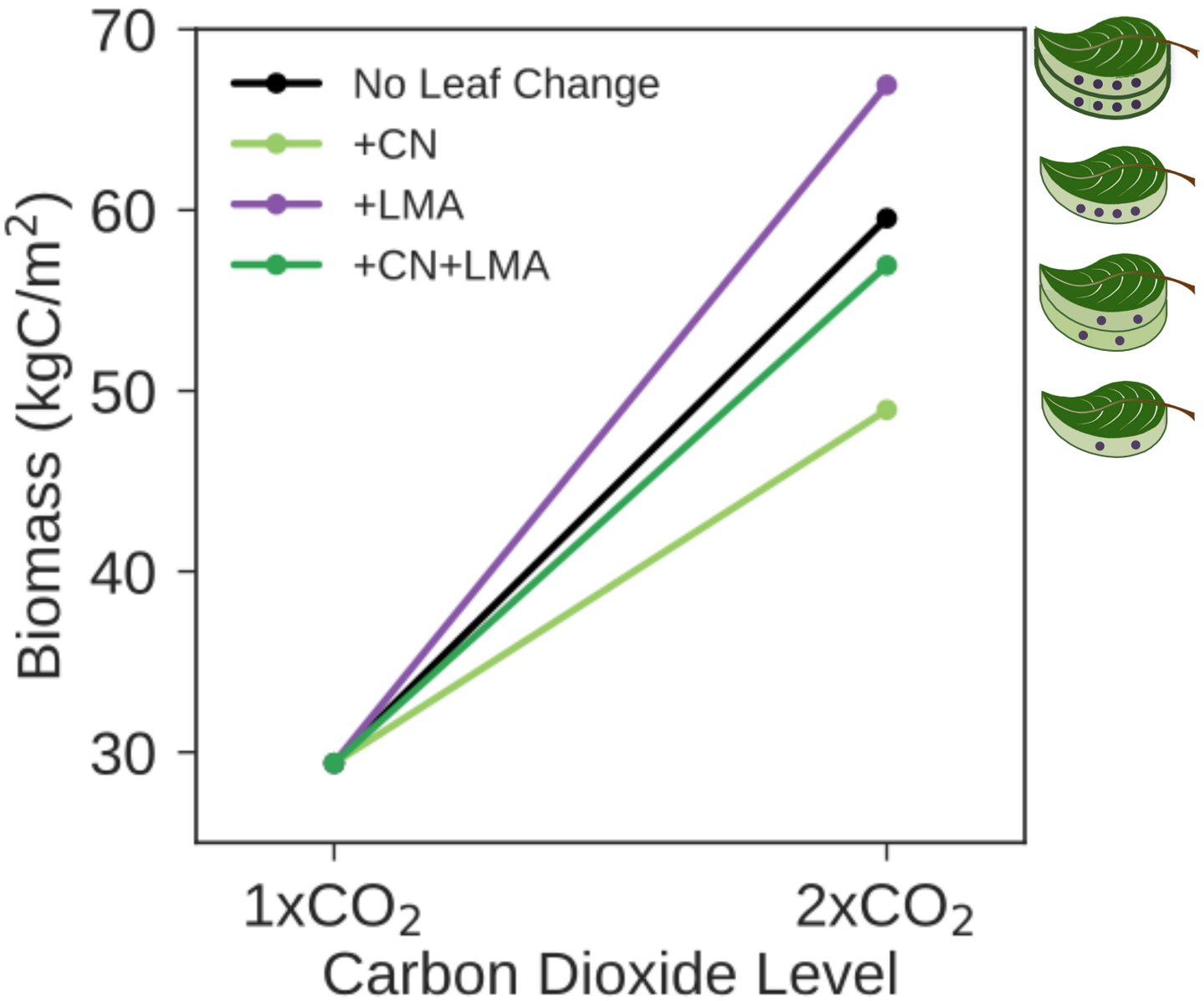
Kovenock et al., *in prep*

Higher leaf mass per area offsets C:N reduction in biomass



Kovenock et al., *in prep*

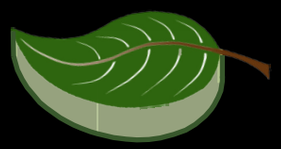
Higher leaf mass per area offsets C:N reduction in biomass



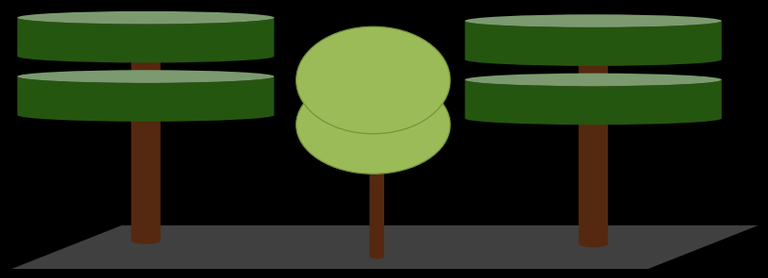
Leaf area index => similar pattern!

Kovenock et al., *in prep*

↑ Carbon Dioxide (CO_2) → ΔPlant Leaves → ΔClimate



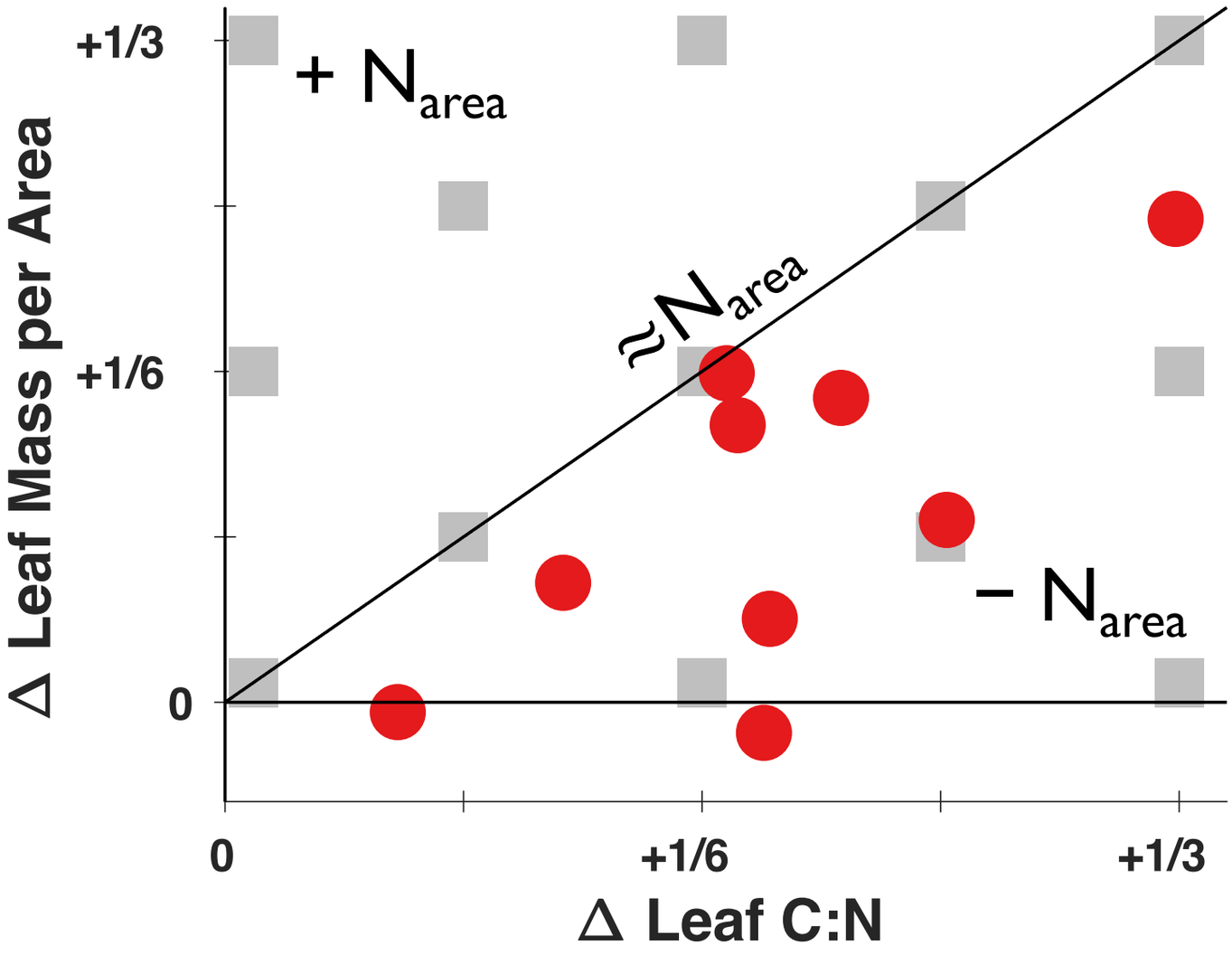
ΔAbundance of Plant Types



Simulate all pairwise competitions between sampled leaf responses (gray squares)

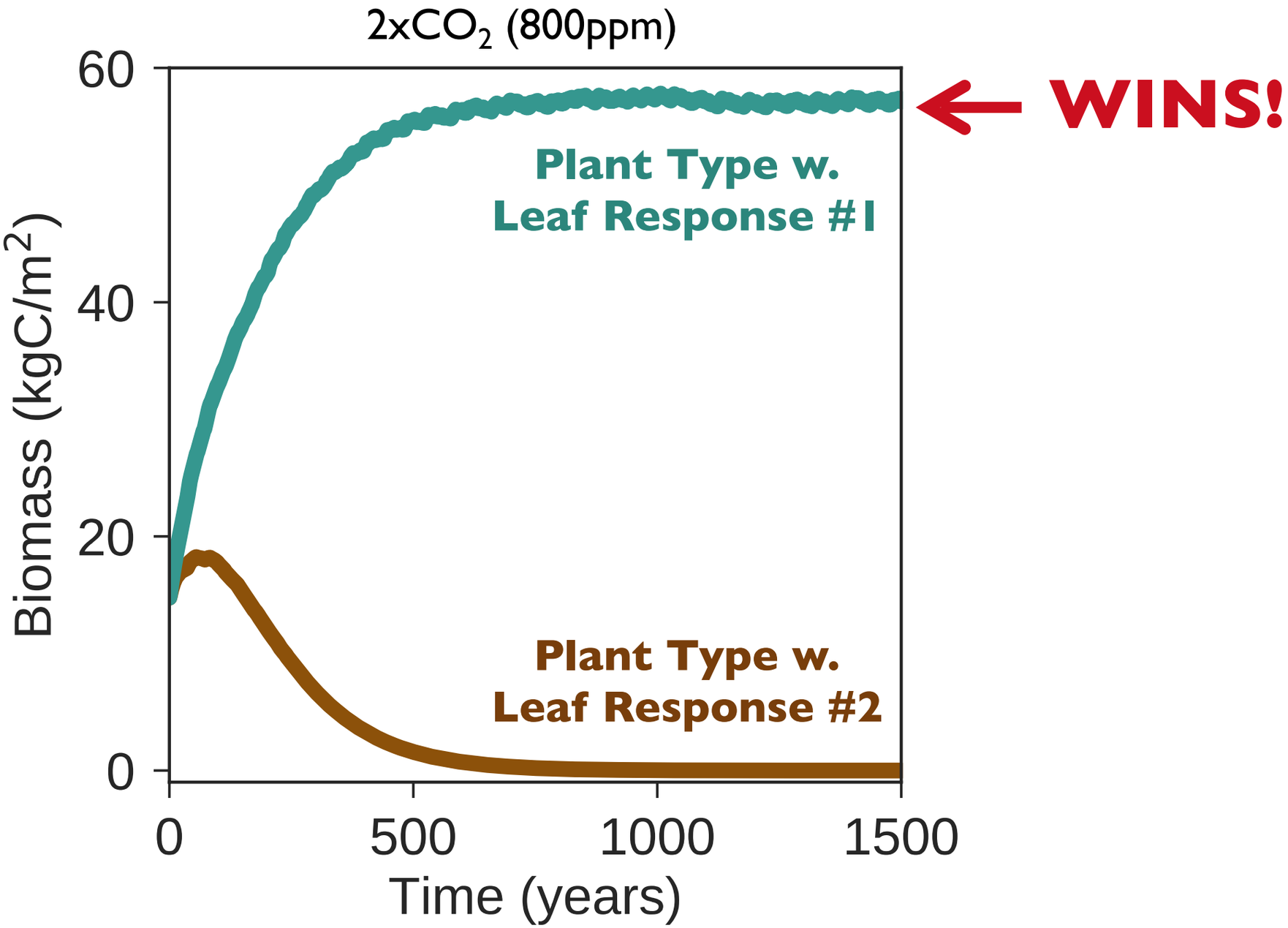
Observed leaf responses (Lovelock et al., 1998)

Sampled leaf responses

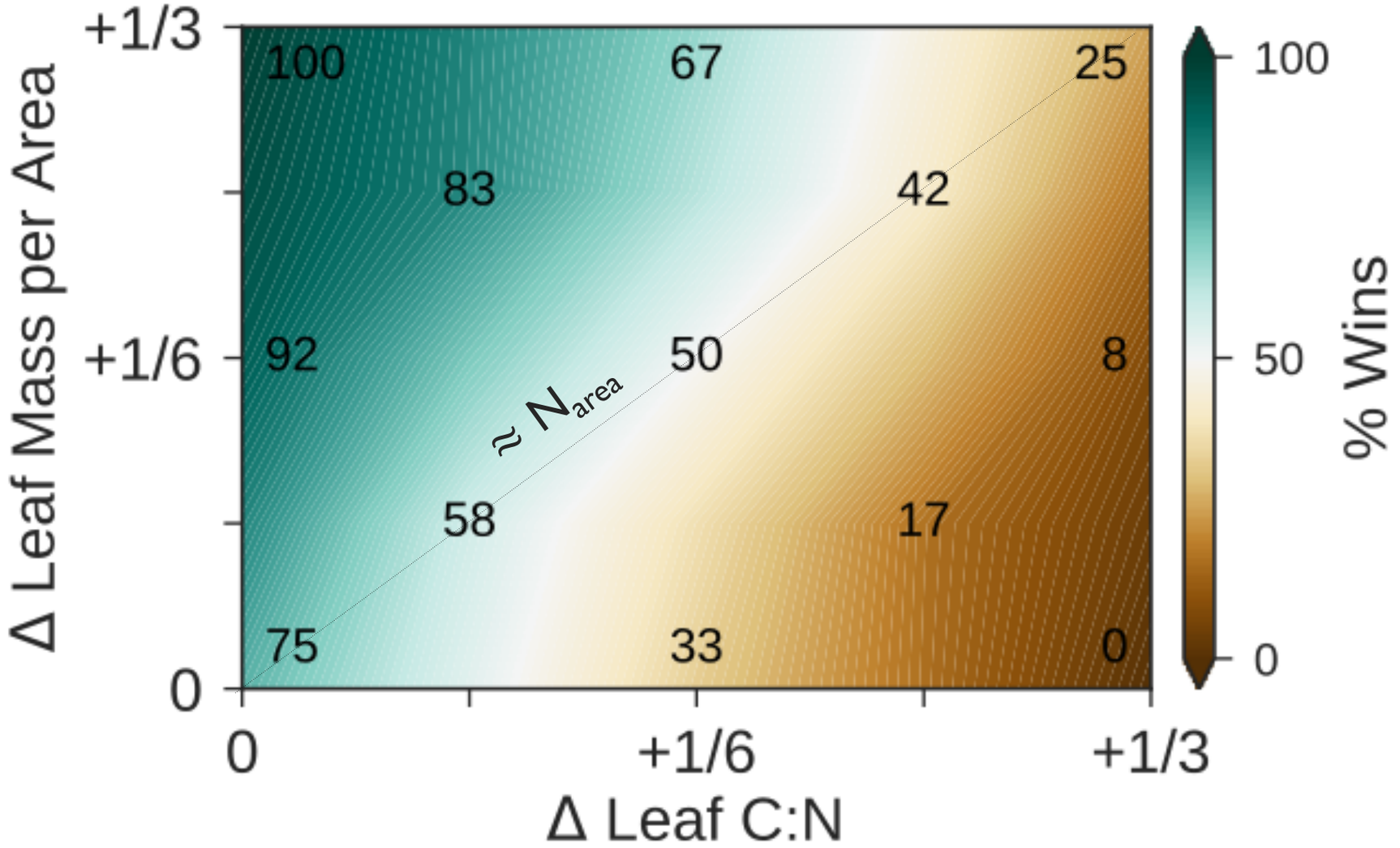


Kovenock et al., *in prep*

In pairwise competitions, one of the leaf response levels always confers a competitive advantage

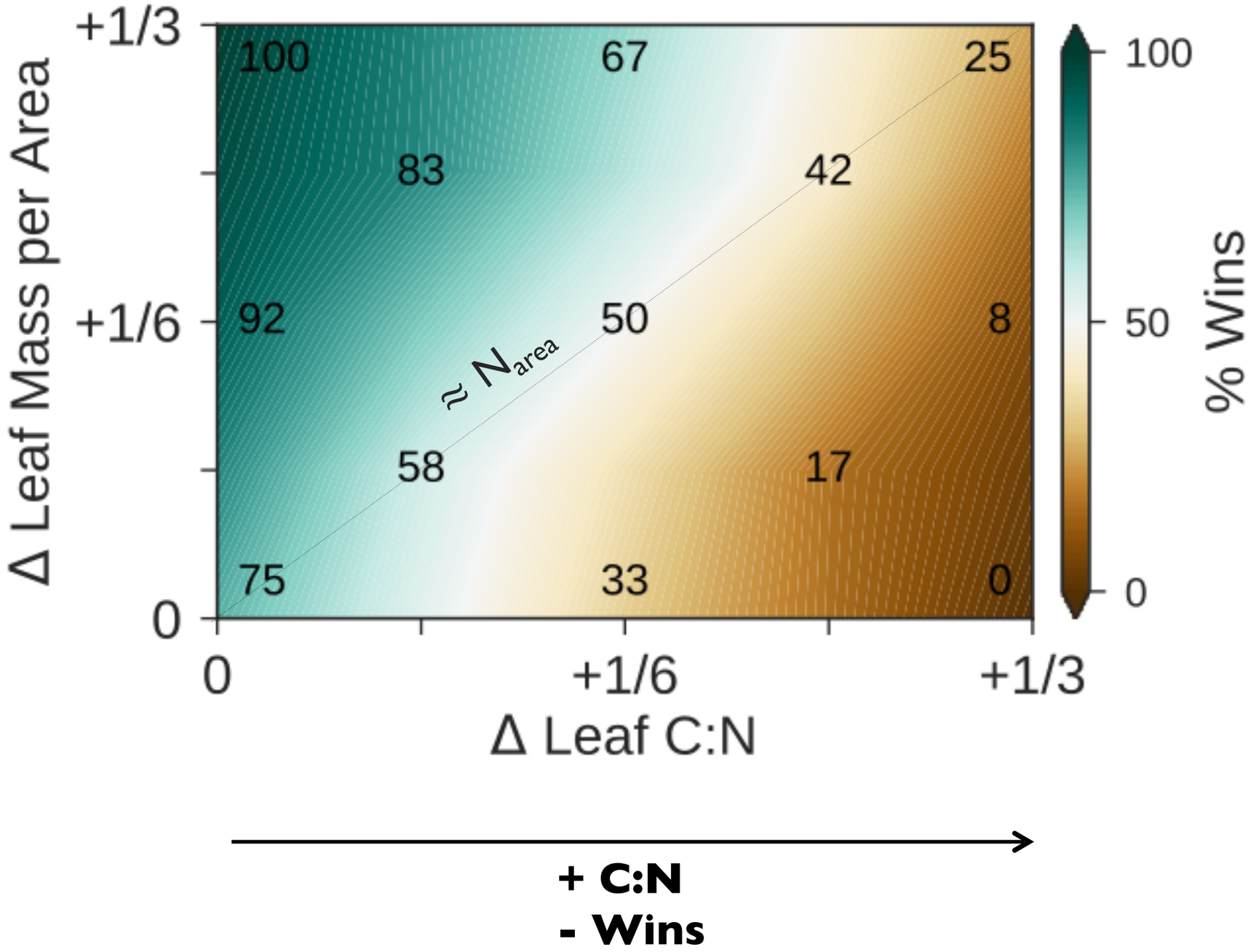


% Wins mapped onto Leaf Response Space



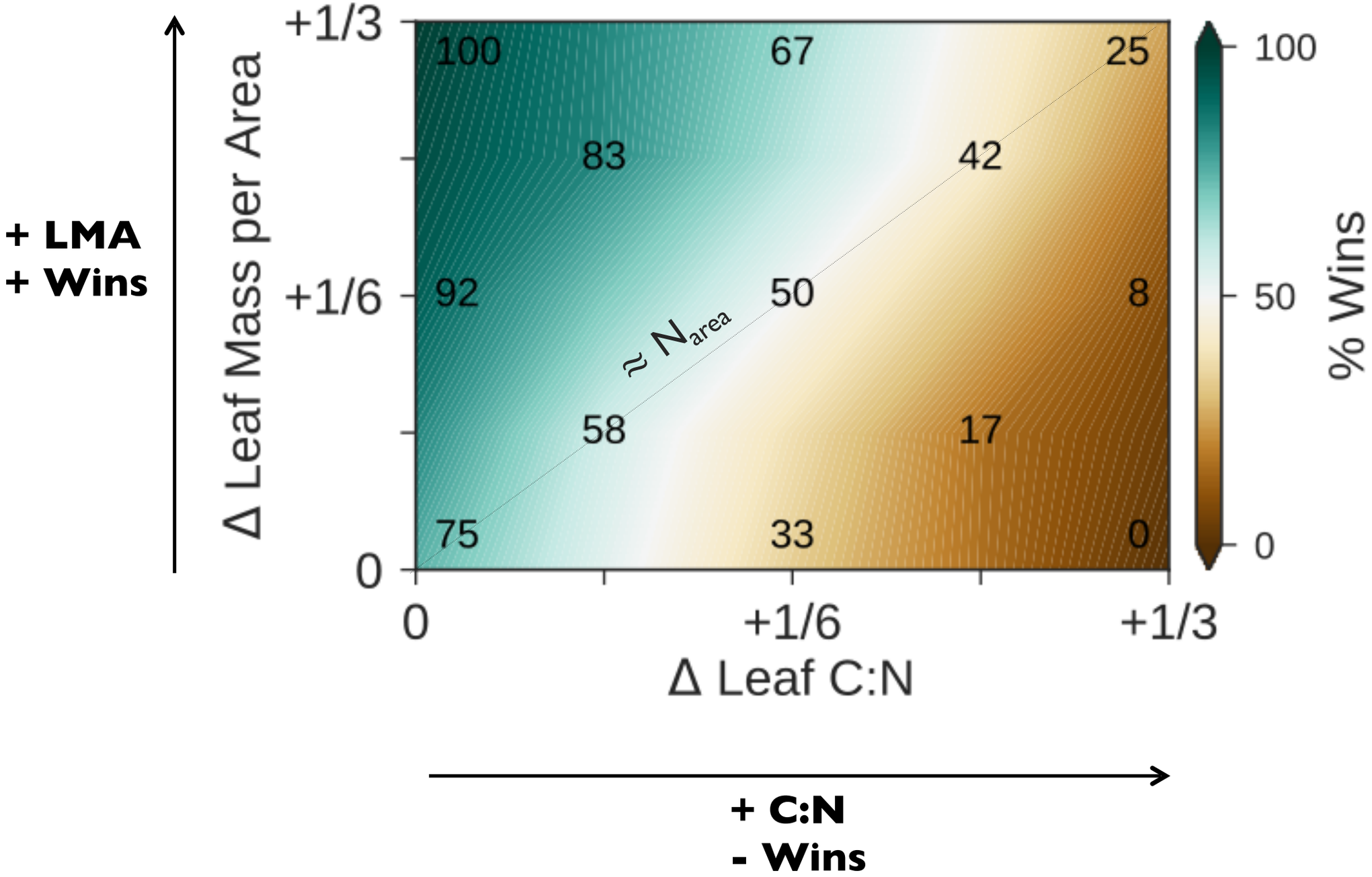
Kovenock et al., *in prep*

Higher leaf C:N reduces competitive ability



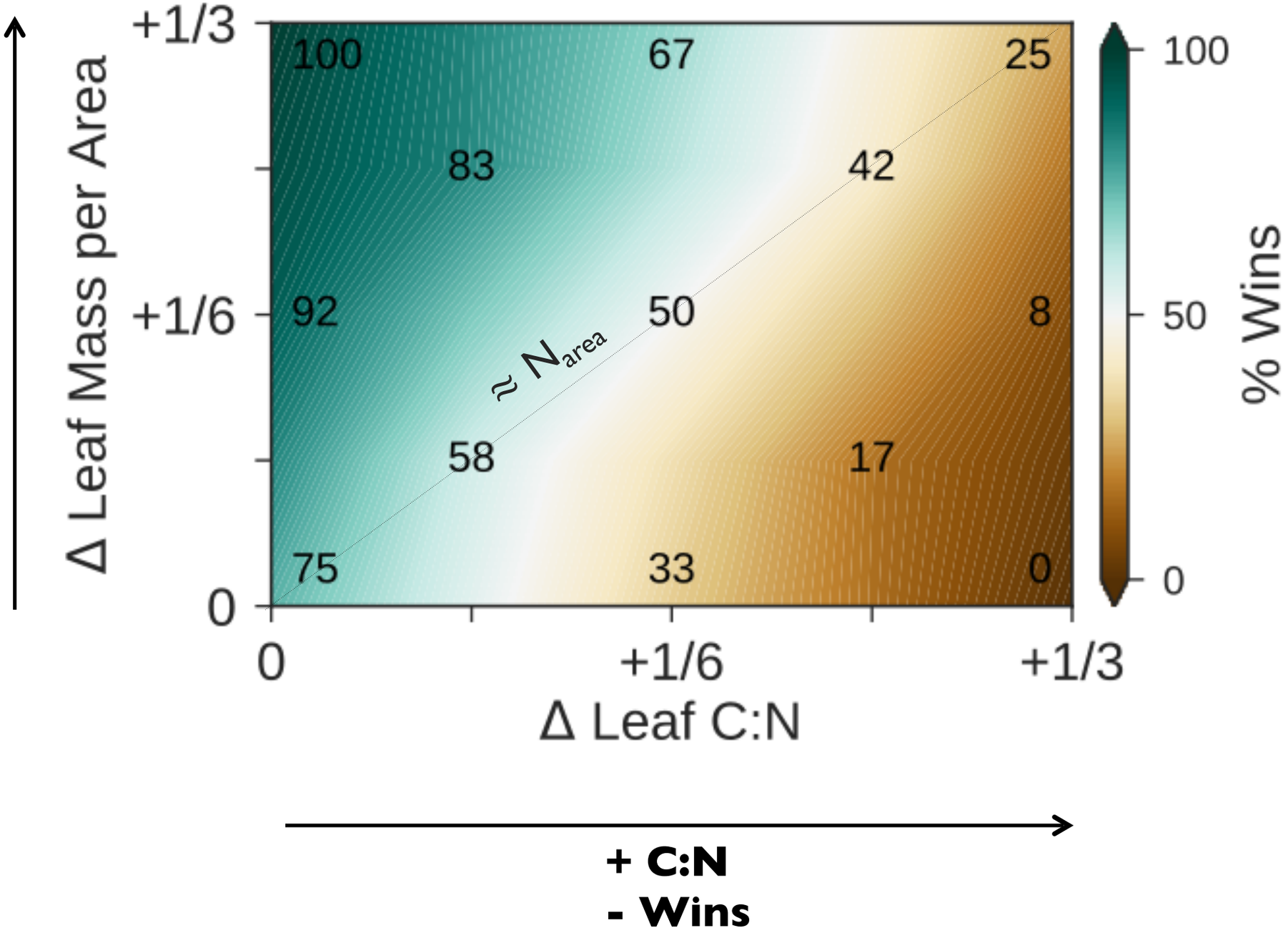
Kovenock et al., *in prep*

Higher leaf mass per area <u>enhances</u> competitive ability



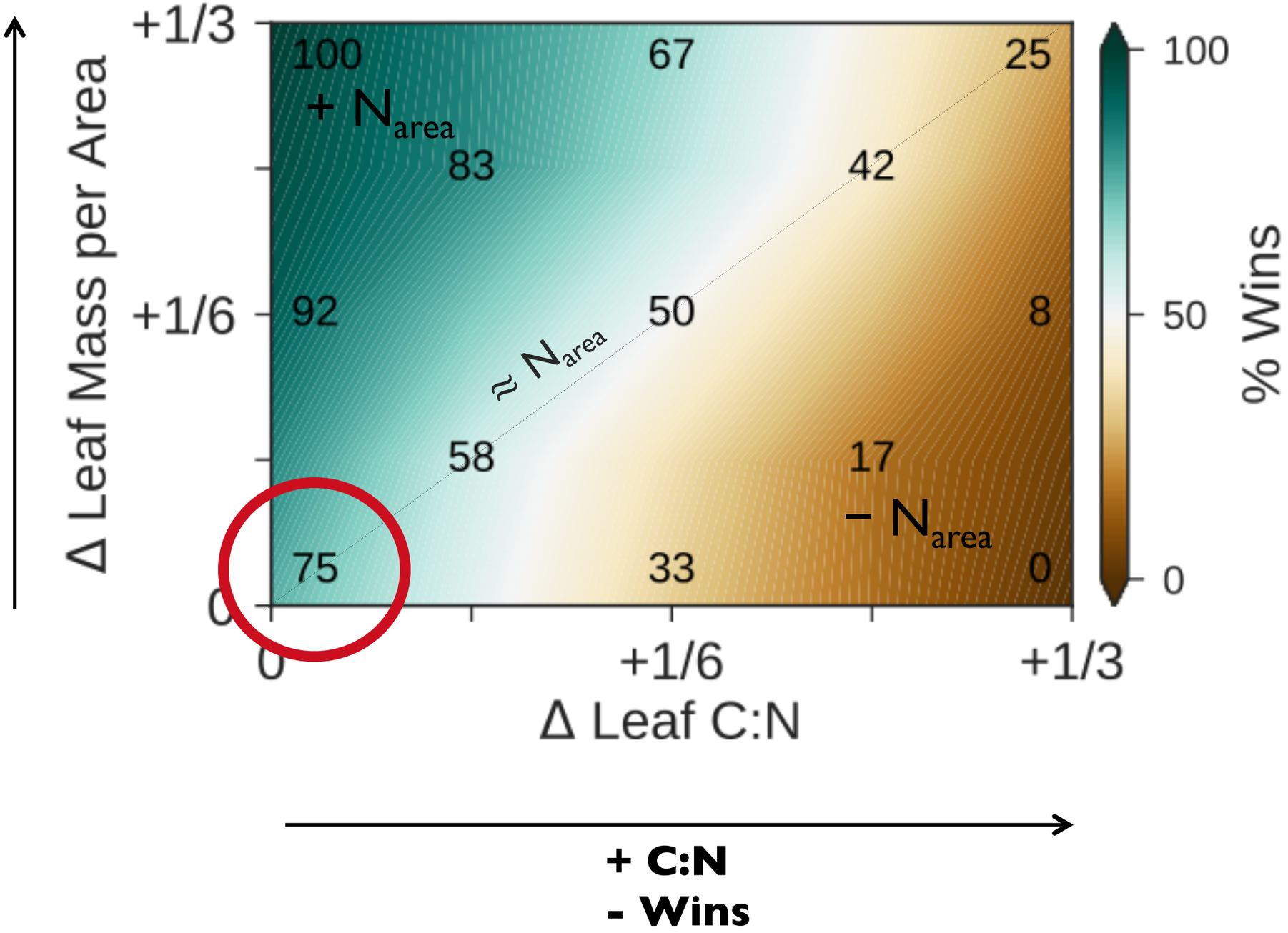
Kovenock et al., *in prep*

Diminishing benefit of increasing leaf mass per area at high C:N



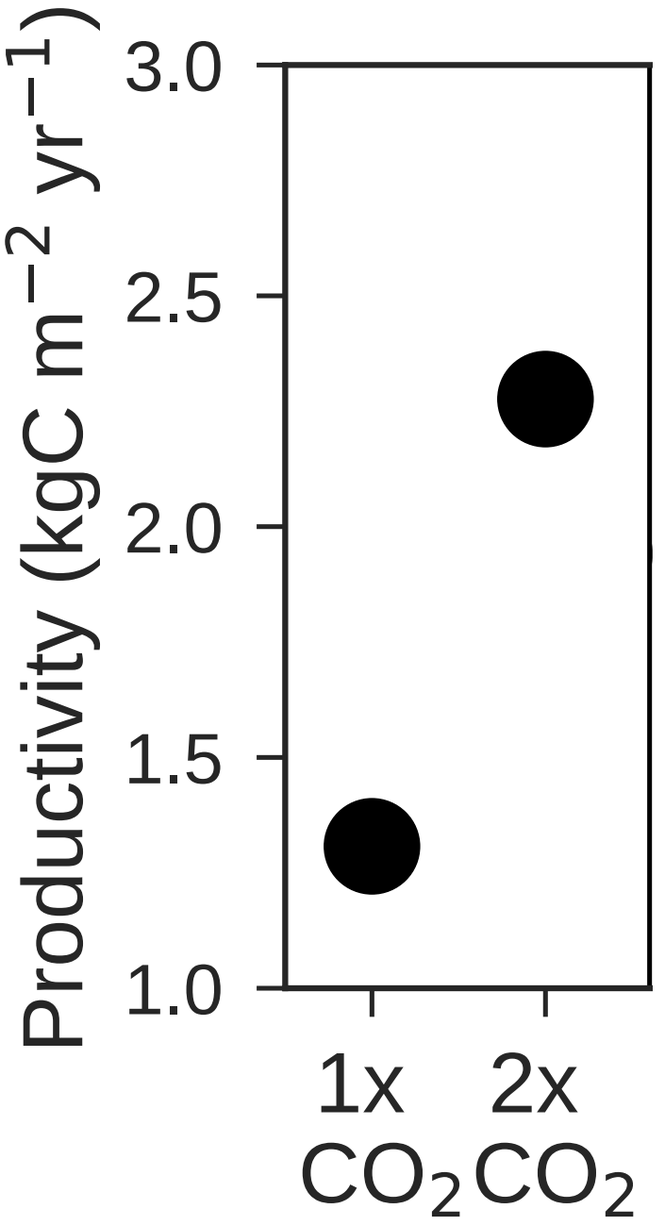
Kovenock et al., *in prep*

"No response" leaves outcompete all observed leaf responses



Kovenock et al., *in prep*

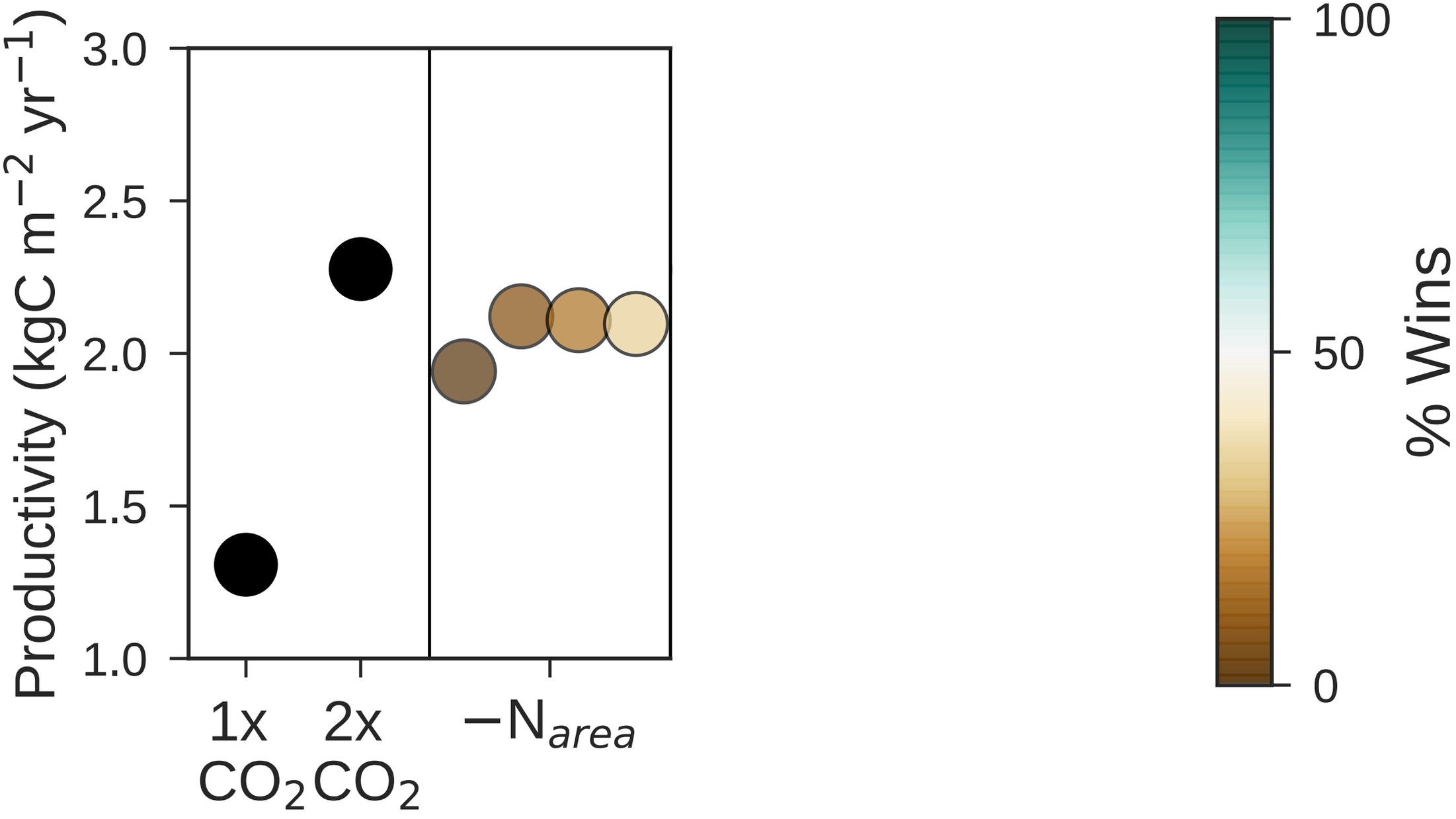
Carbon uptake increases with $+CO_2$



Kovenock et al., *in prep*

Observed leaf responses to +CO2

<u>reduce or maintain</u> projections of carbon uptake

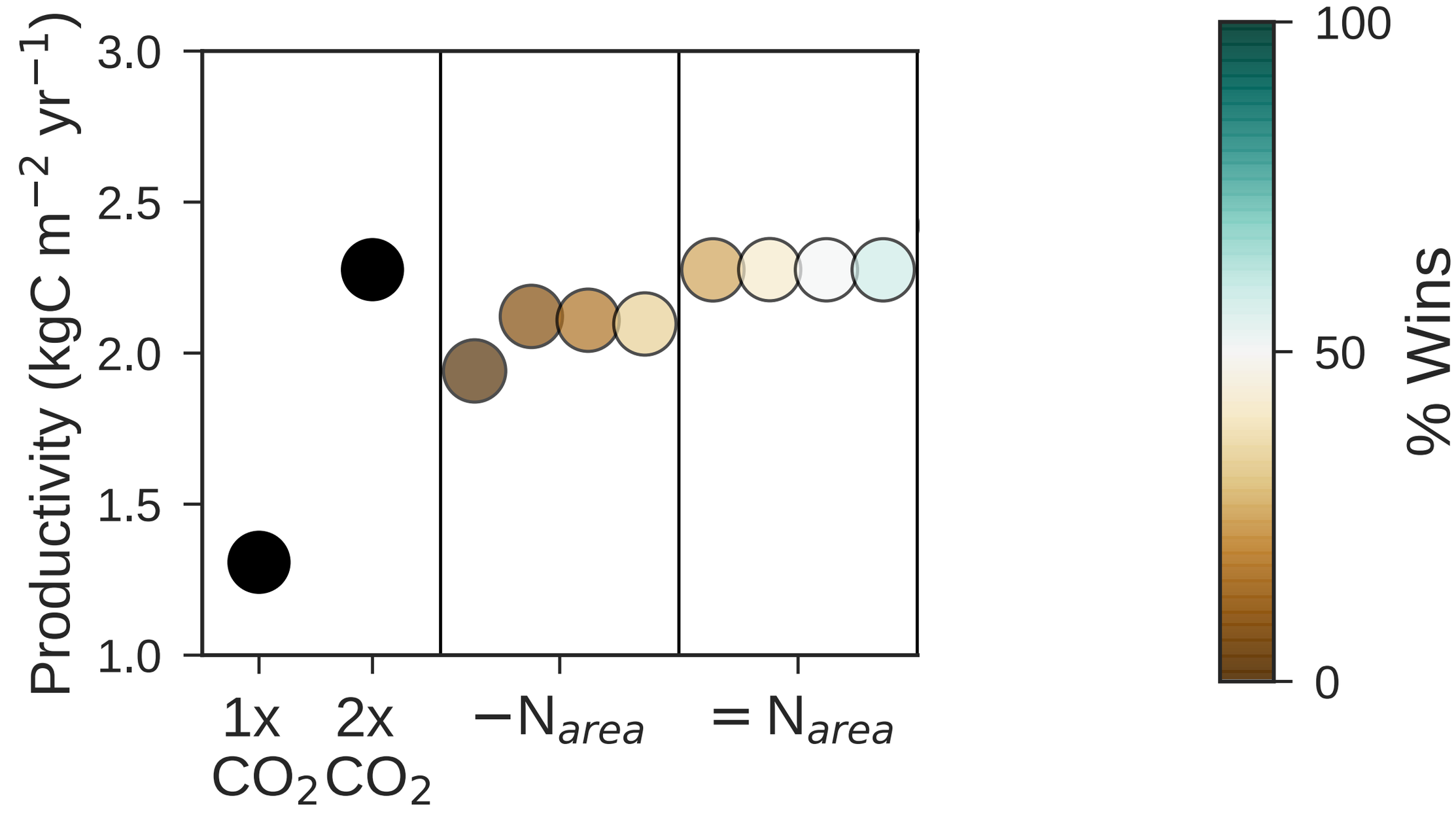


As much as -15% reduction in carbon uptake

Kovenock et al., *in prep*

Observed leaf responses to +CO2

reduce or maintain projections of carbon uptake

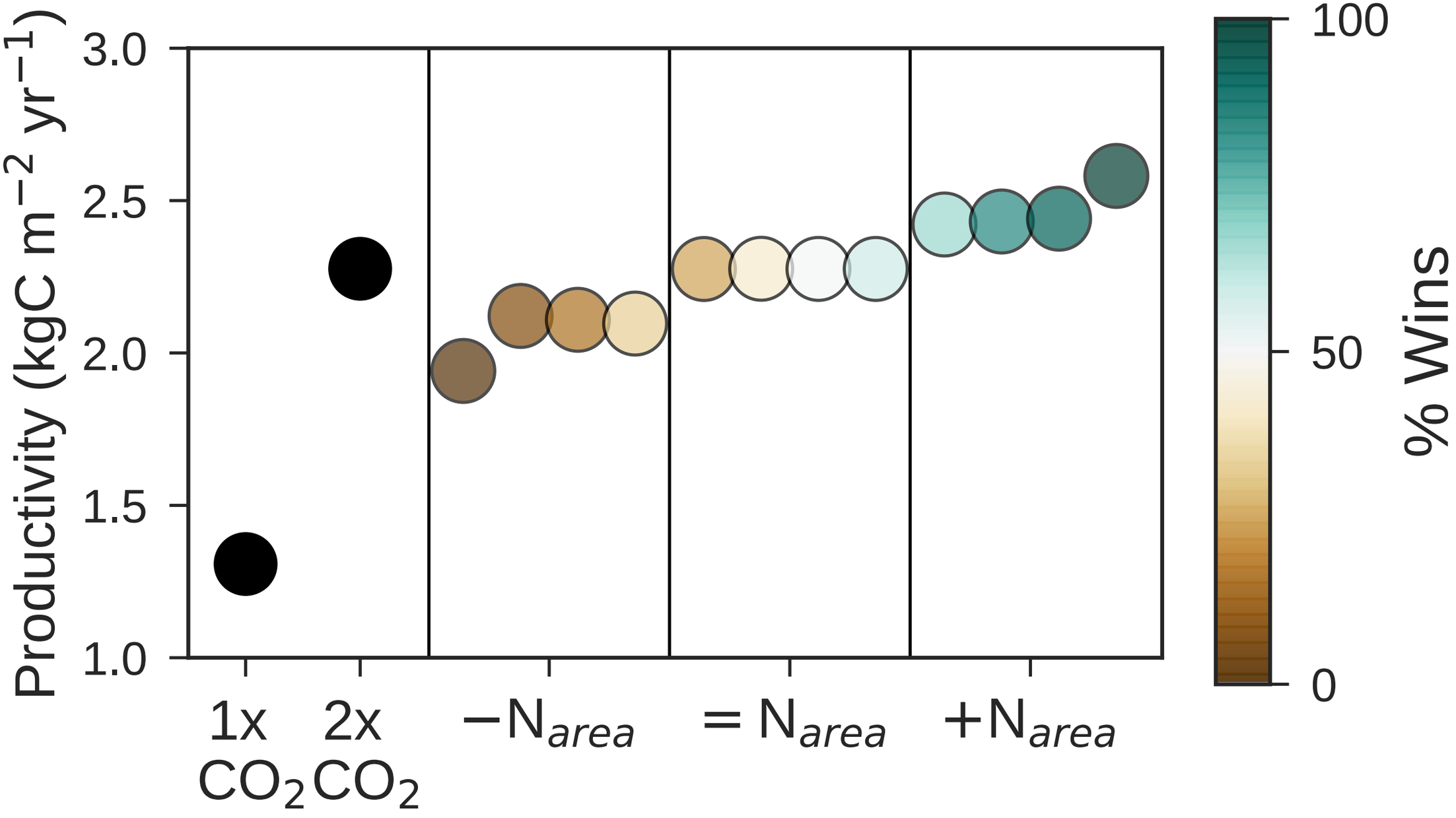


About neutral with equal N_{area}

Kovenock et al., *in prep*

Observed leaf responses to +CO2

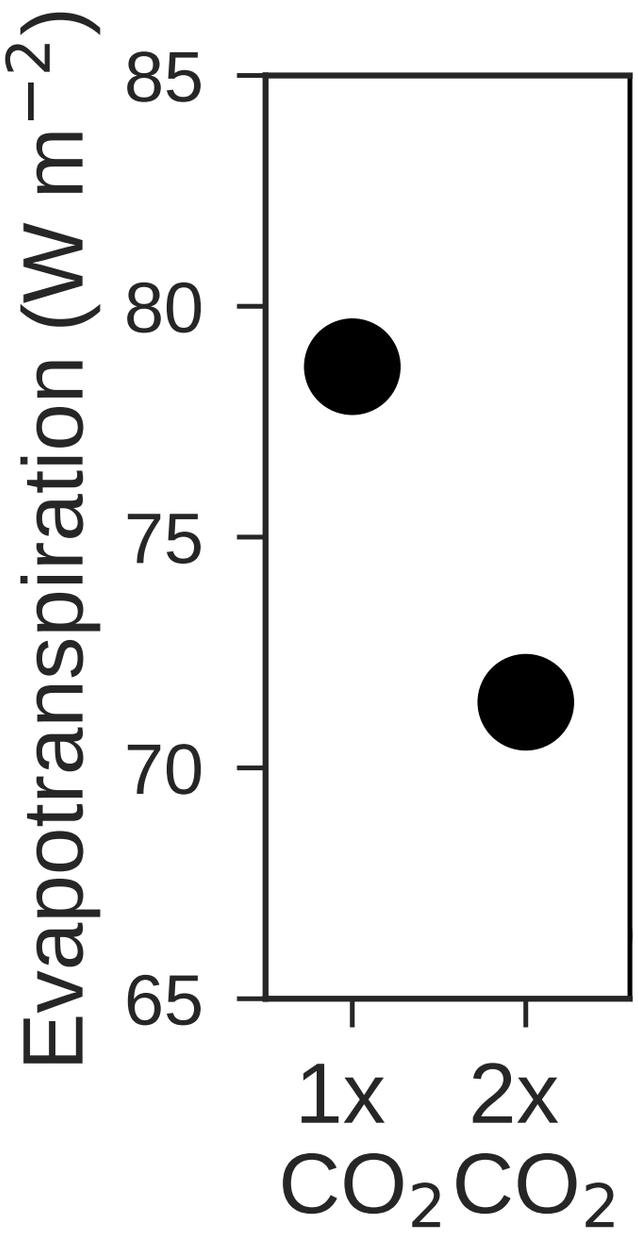
reduce or maintain projections of carbon uptake

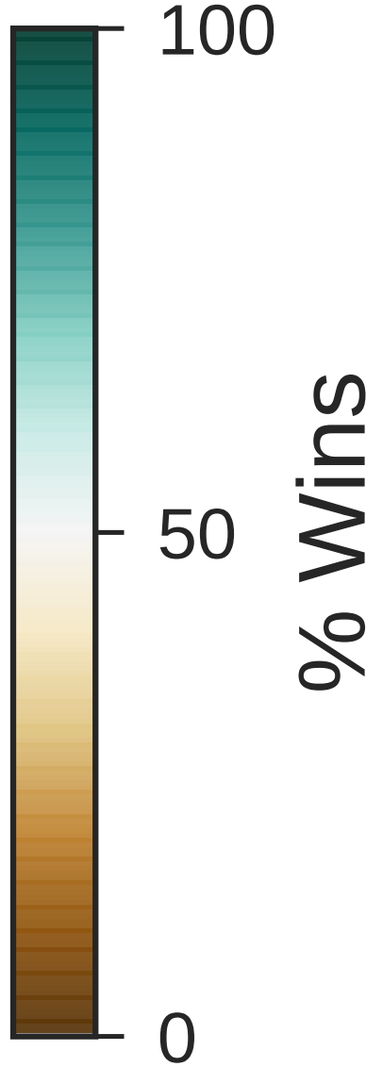


Up to +16% increase in carbon uptake

Kovenock et al., *in prep*

Evapotranspiration decreases with $+CO_2$

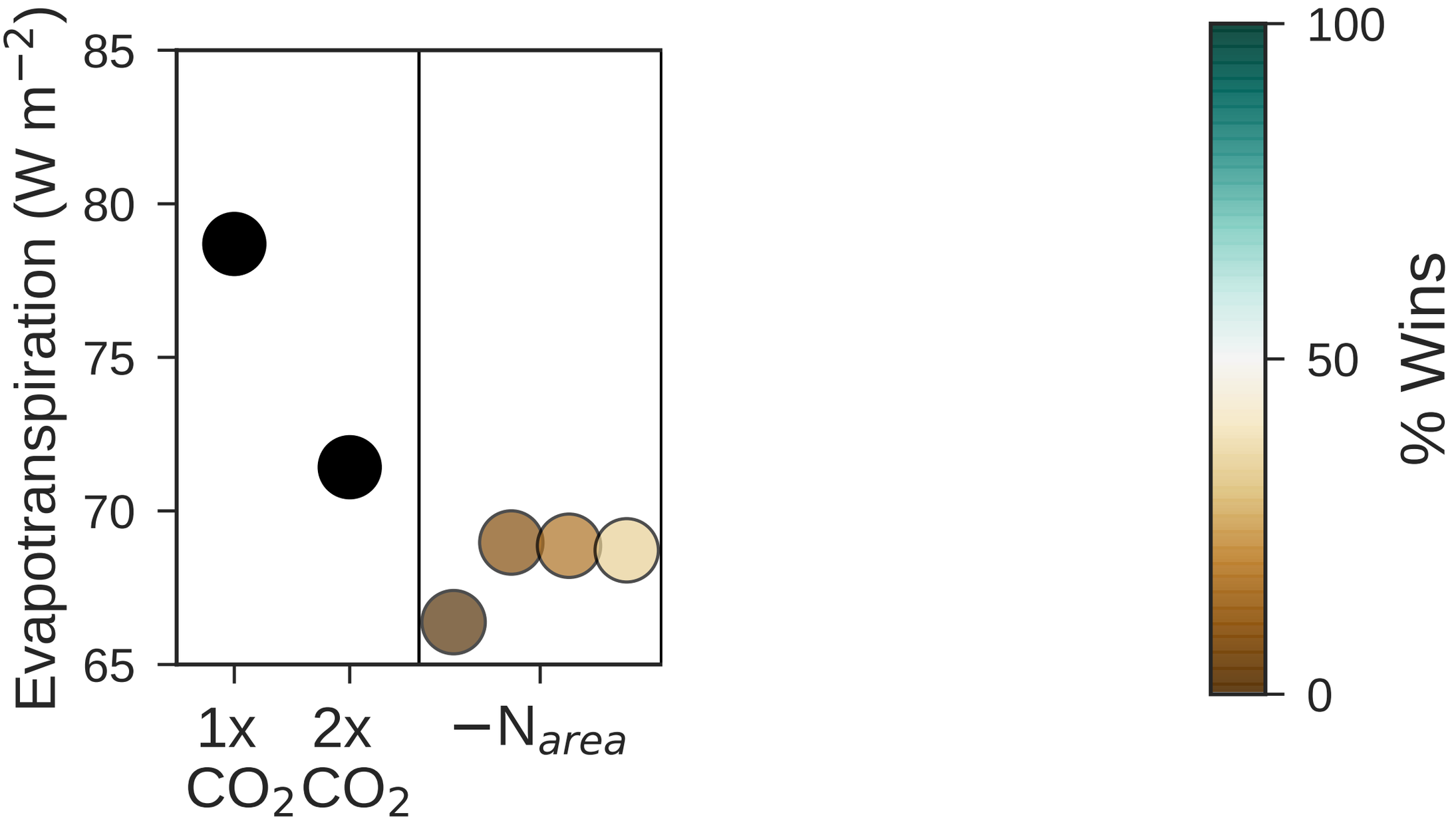




Kovenock et al., *in prep*

Observed leaf responses to +CO2

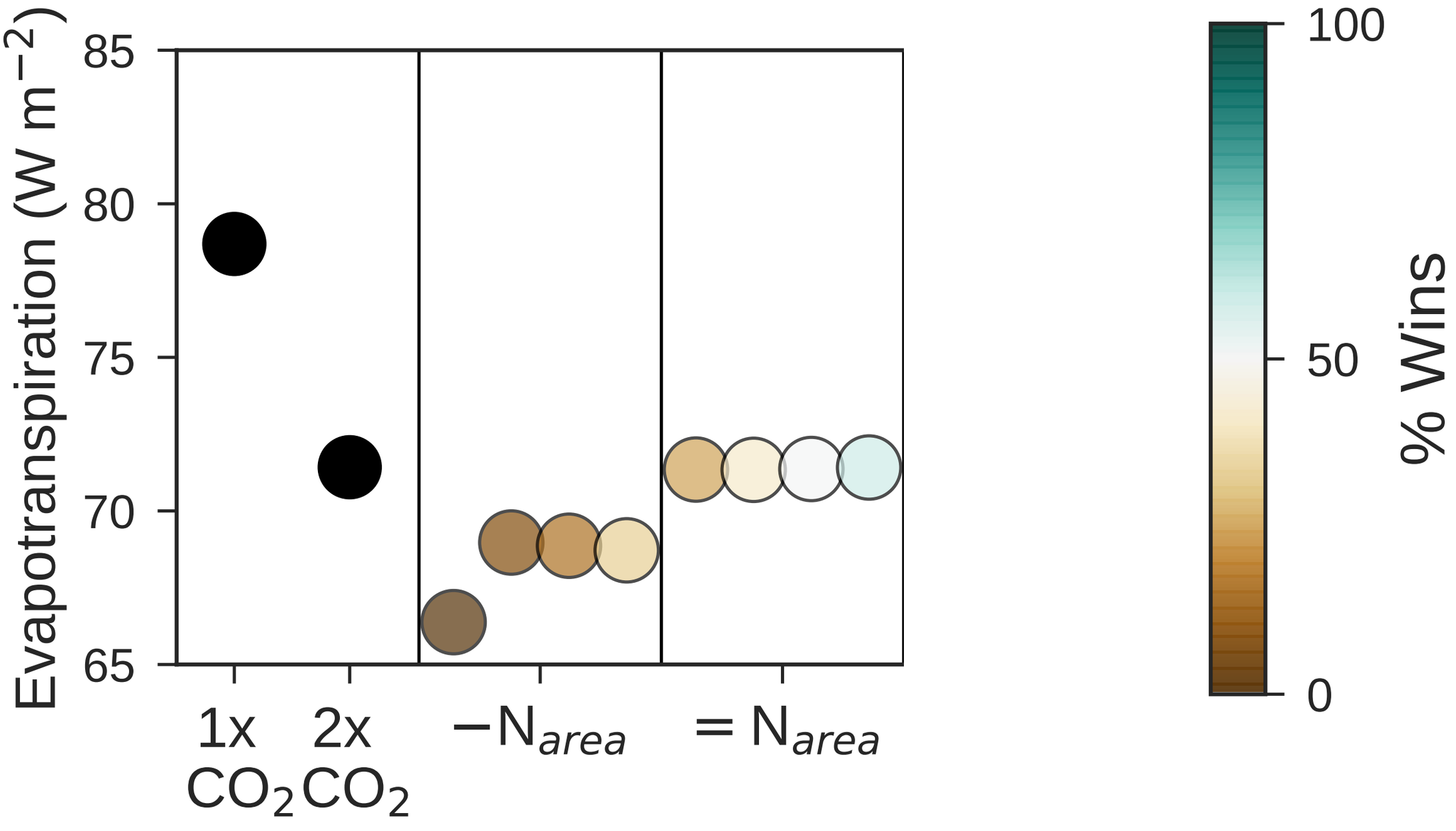
reduce or maintain projected evapotranspiration



Kovenock et al., *in prep*

Observed leaf responses to +CO2

reduce or maintain projected evapotranspiration

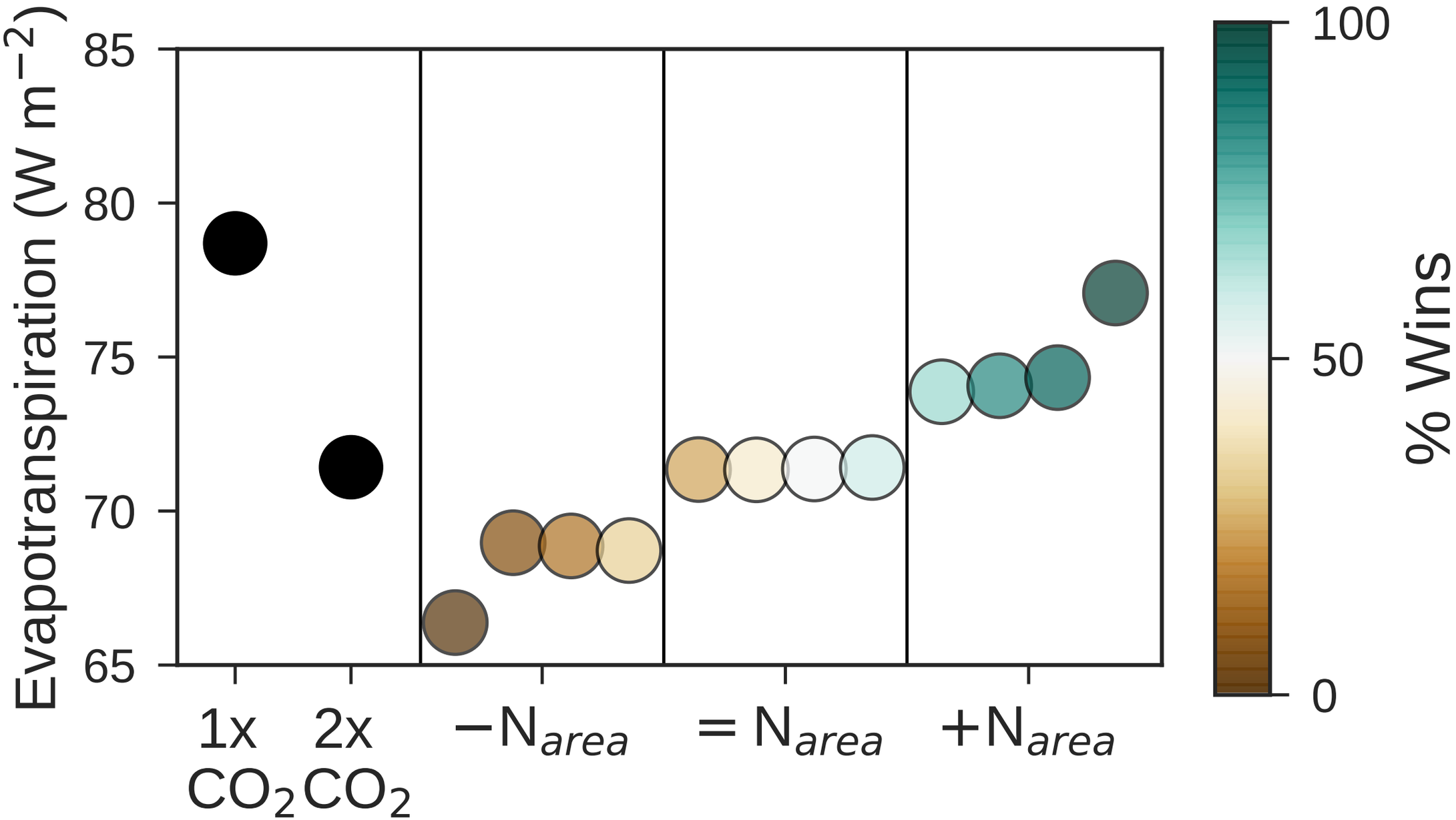


As much as -7% reduction in evapotranspiration

Kovenock et al., *in prep*

Observed leaf responses to +CO2

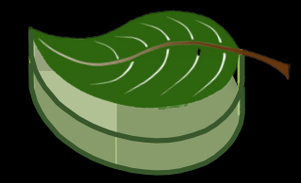
reduce or maintain projected evapotranspiration



Up to +8% increase in evapotranspiration

Kovenock et al., *in prep*

Take home points:



Leaf responses to 2xCO_2 alter competitive ability

Higher C:N => disadvantage

Higher LMA => can improve competitive ability

Leaves that do not respond => most competitively beneficial

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