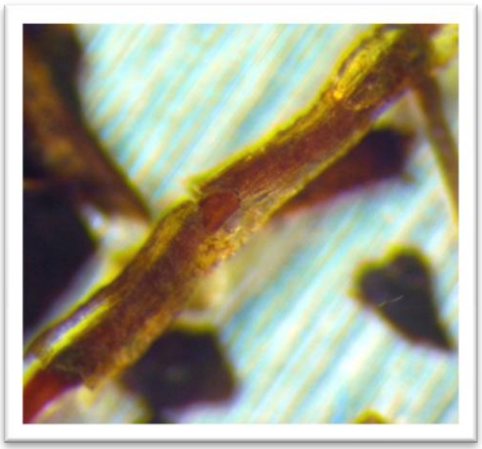
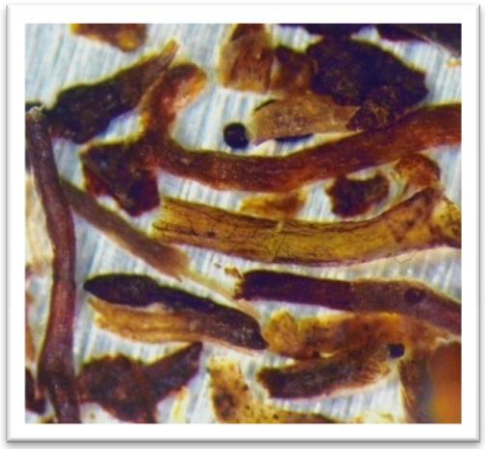
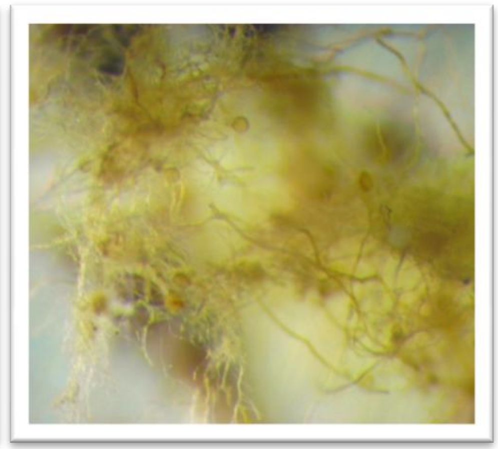
CO_2 enrichment increases carbon and nitrogen input from fine roots in a deciduous forest

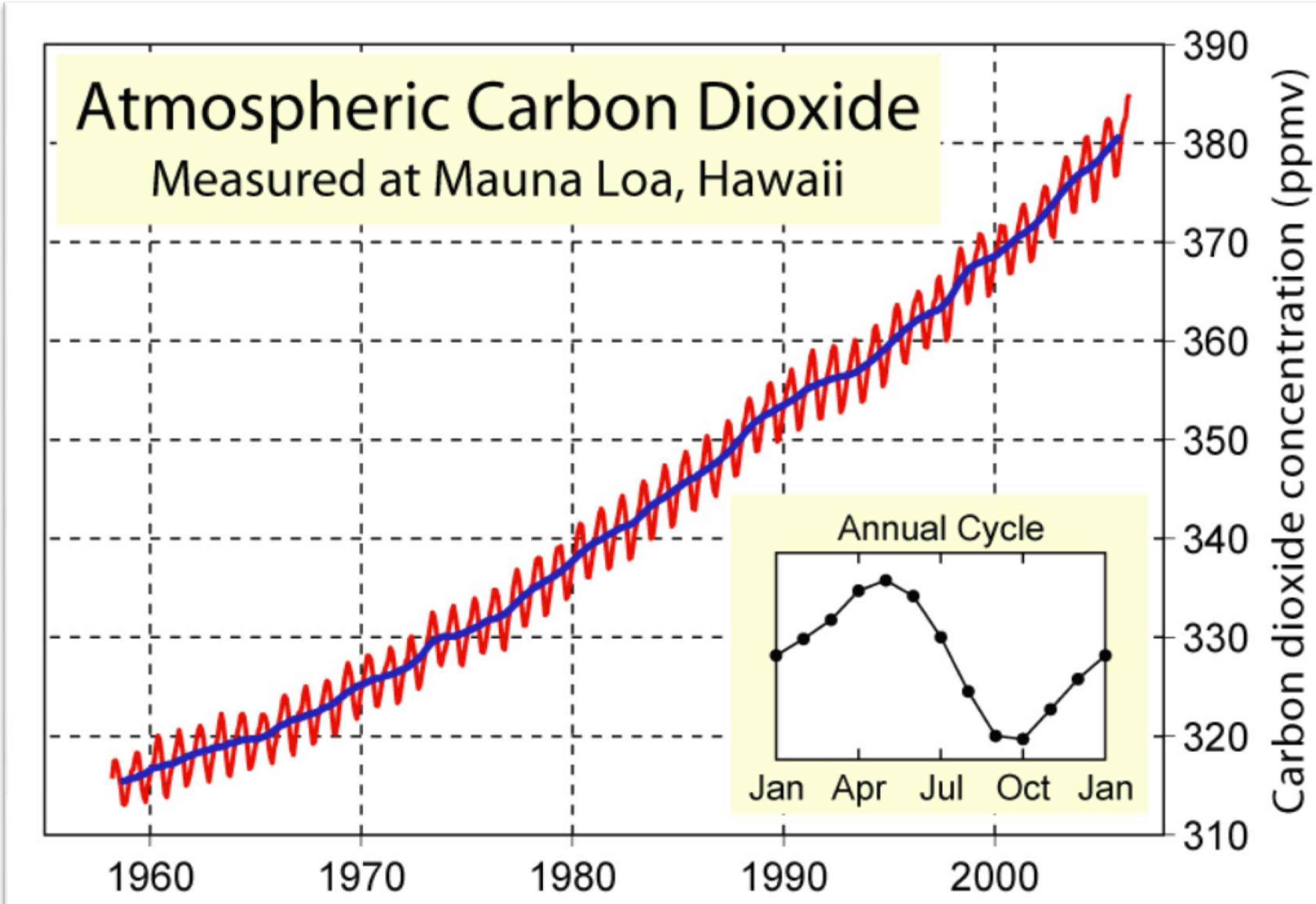




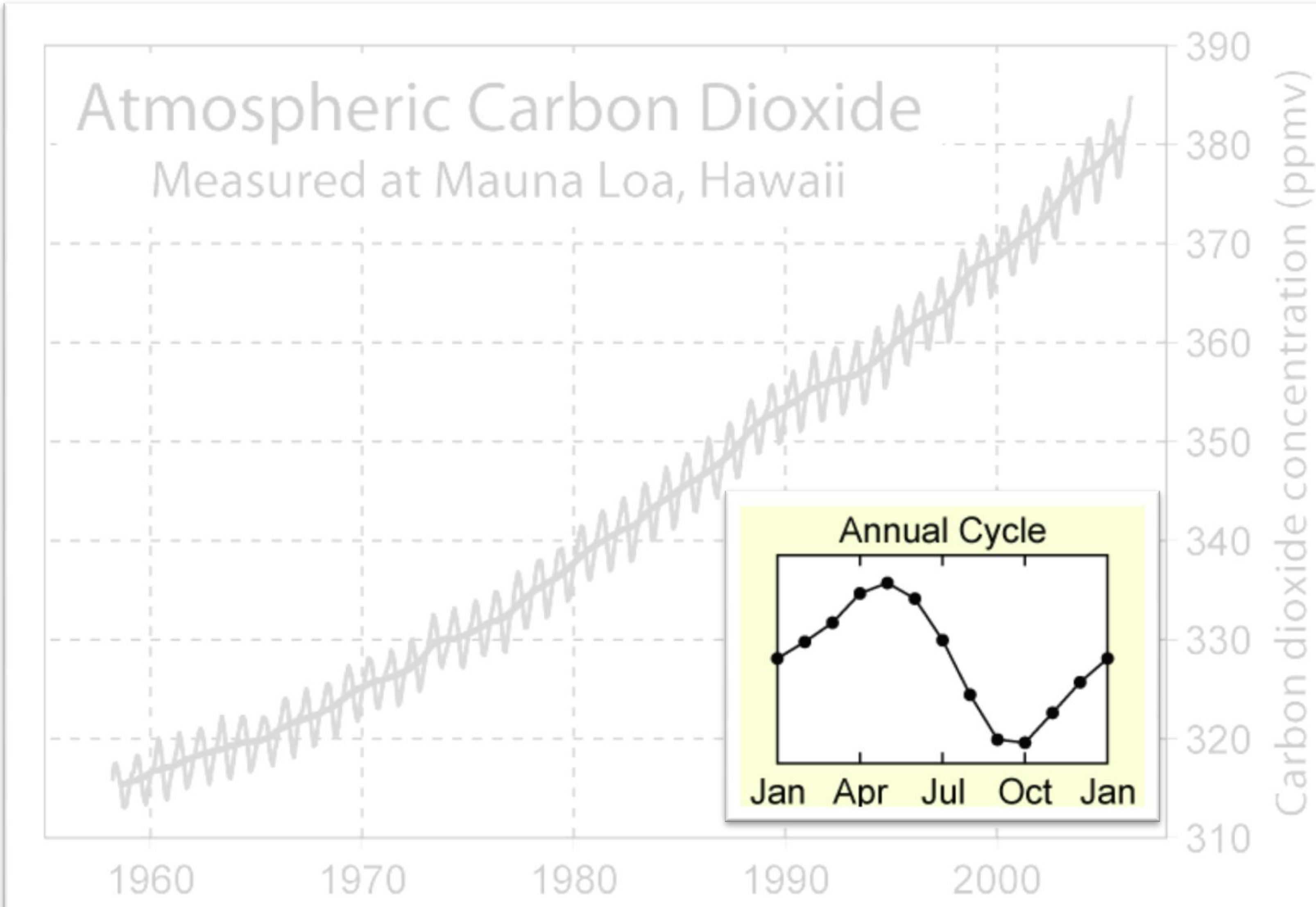


Colleen Iversen[1,2], Joanne Ledford[2], and Richard Norby[2]
University of Tennessee[1] and Oak Ridge National Laboratory[2]

Ecological Society of America, 2008



Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
Annual Cycle
Jan
Apr
Jul
Oct
Jan
390
380
370
360
350
340
330
320
310
Carbon dioxide concentration (ppmv)
1960
1970
1980
1990
2000



Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii
390
380
370
360
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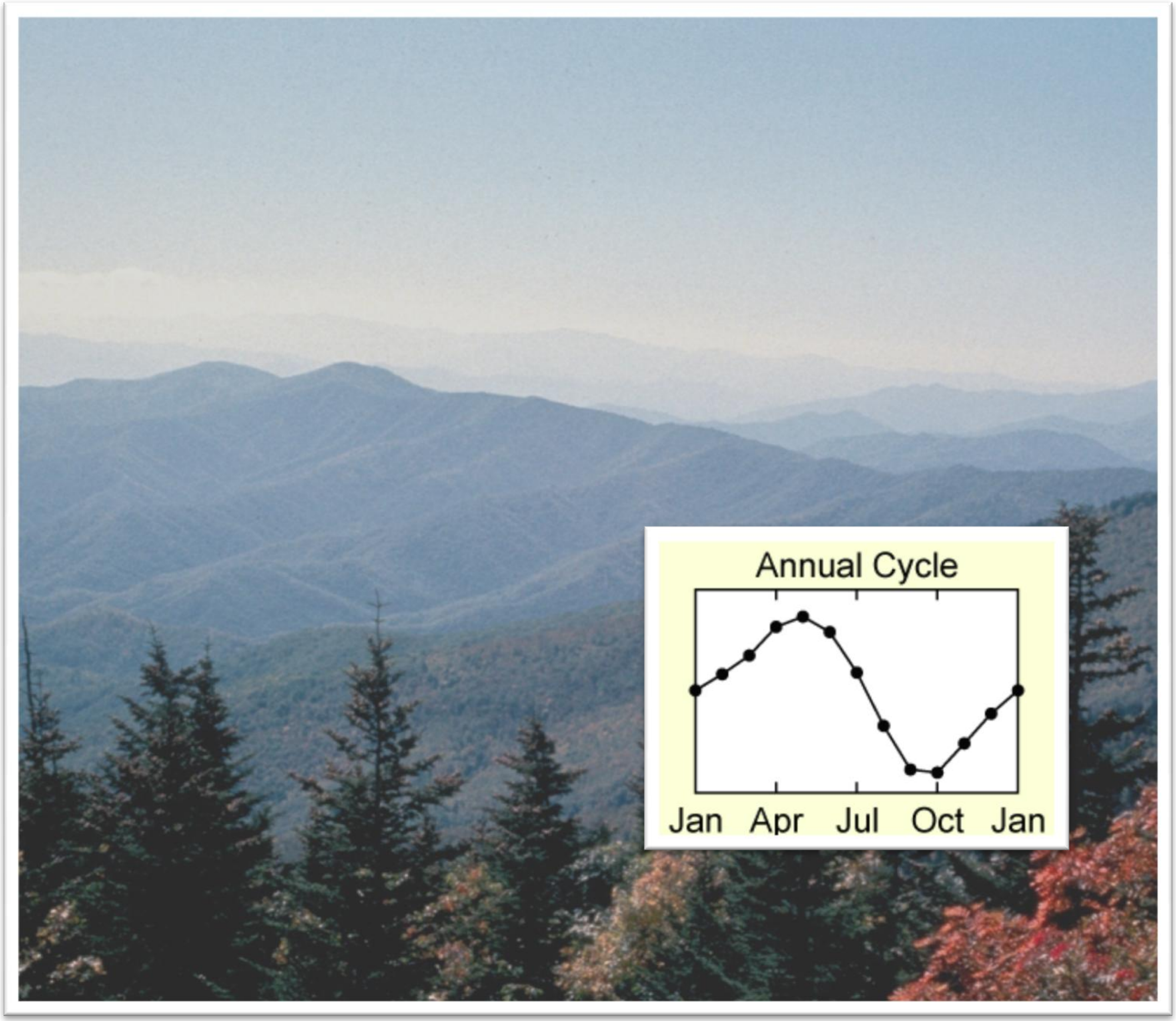
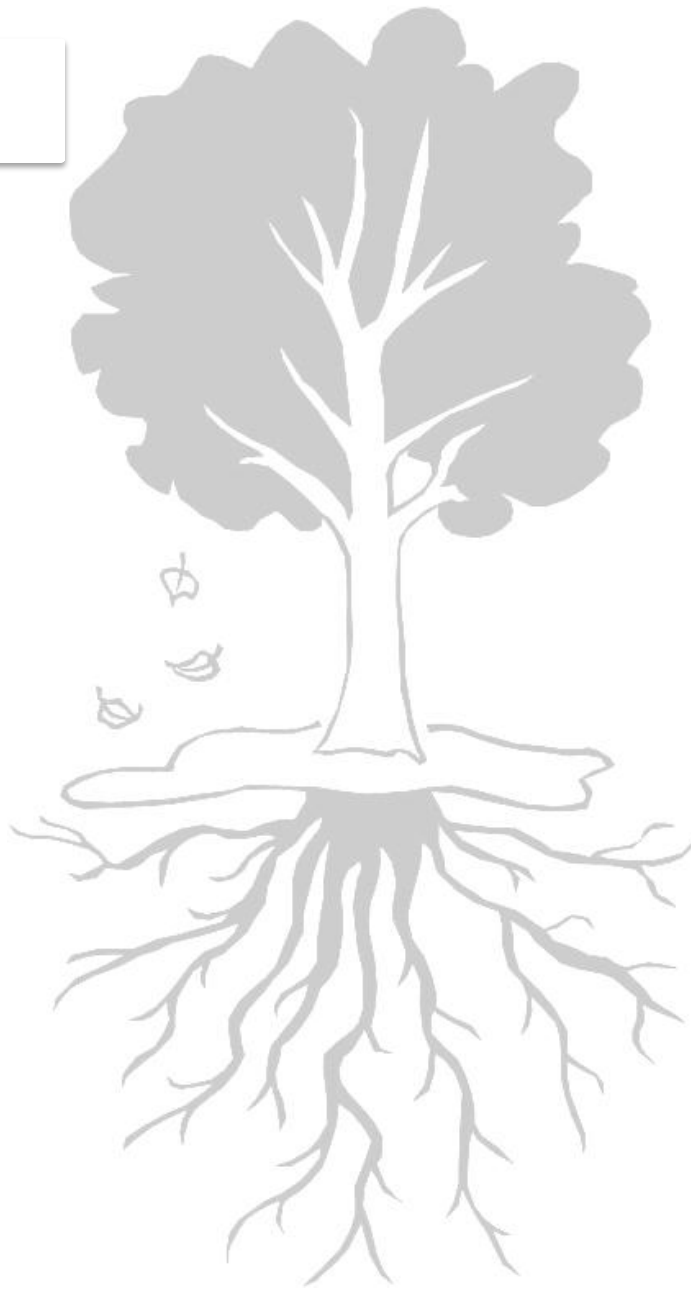
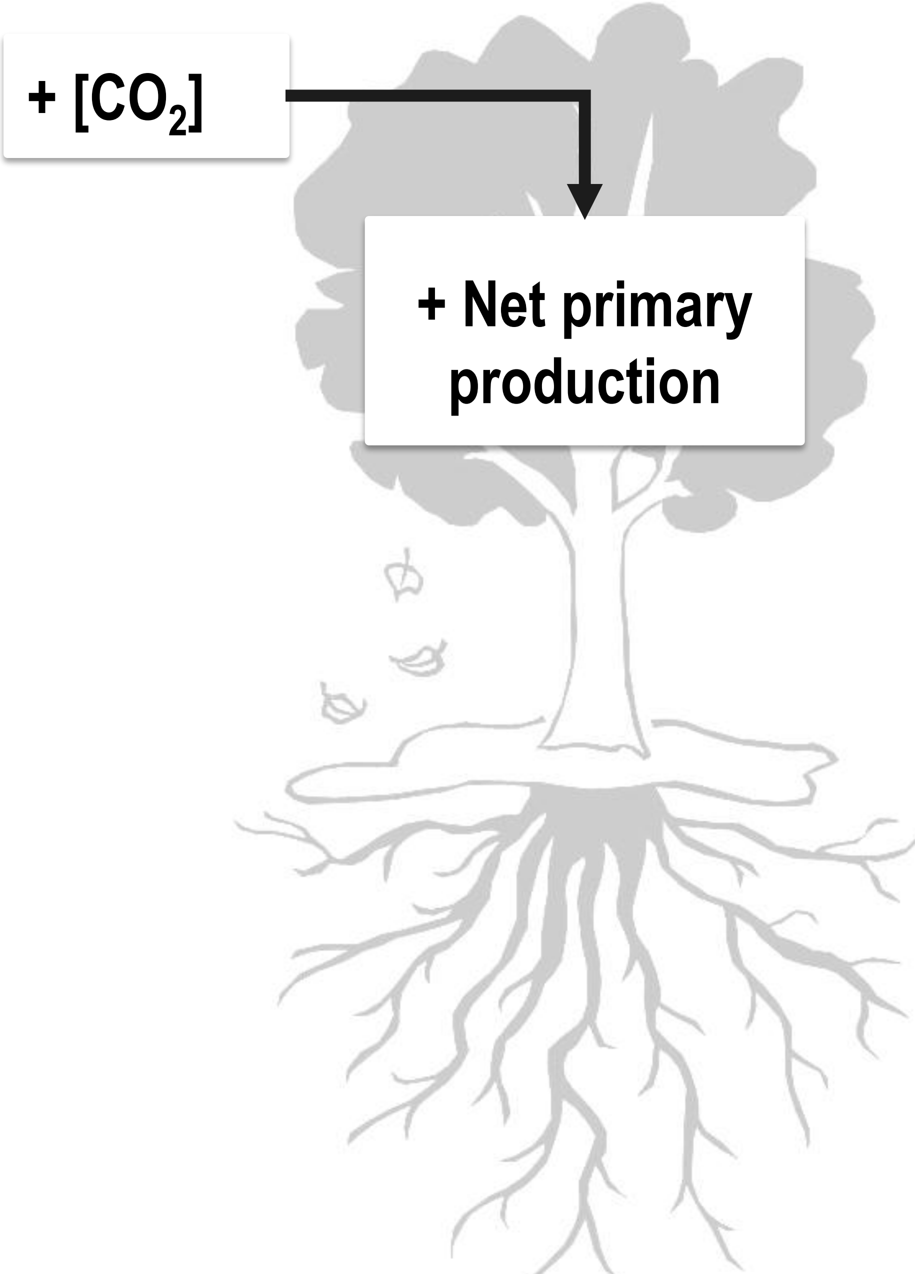
340
330
320
310
Carbon dioxide concentration (ppmv)
1960
1970
1980
1990
2000
Annual Cycle
Jan
Apr
Jul
Oct
Jan

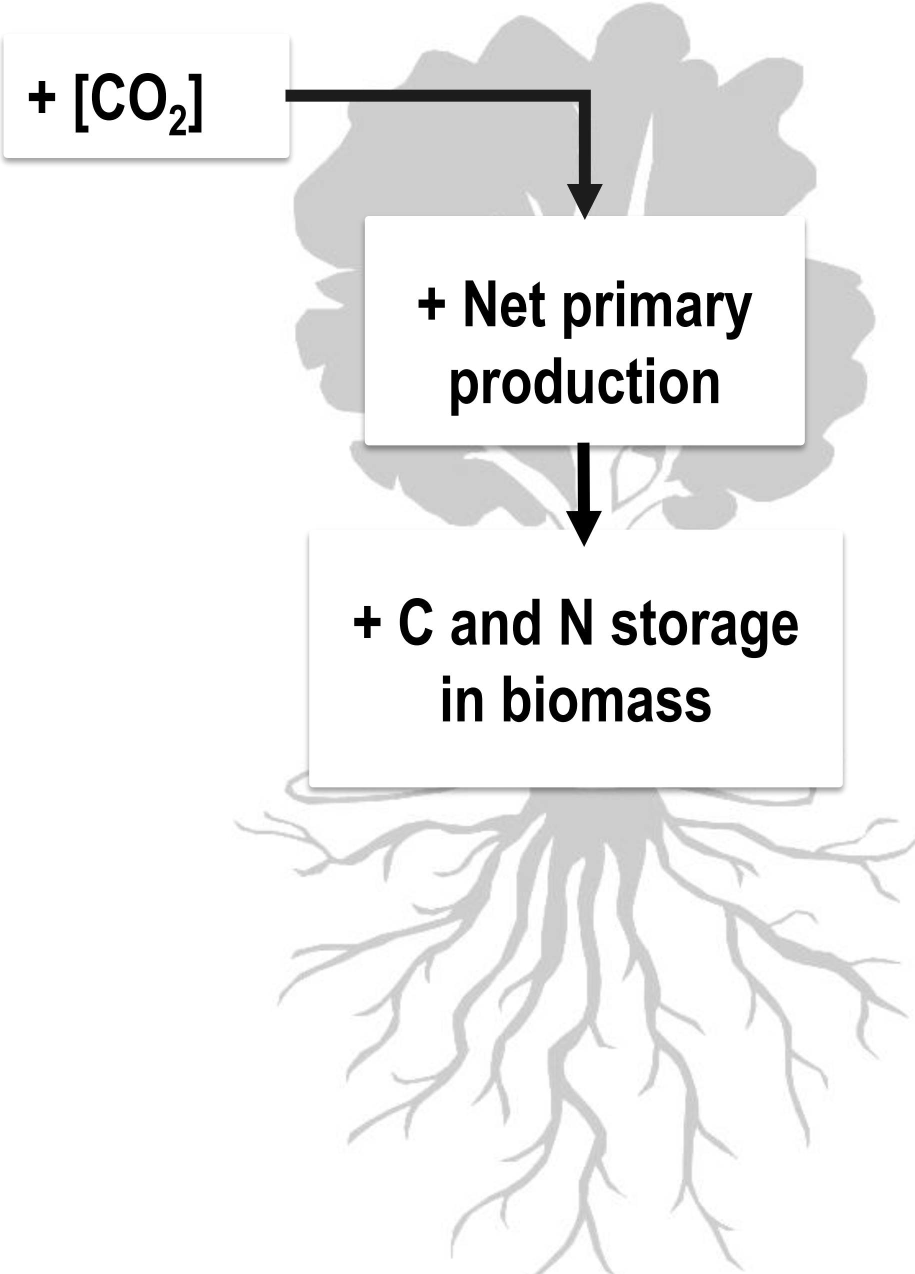


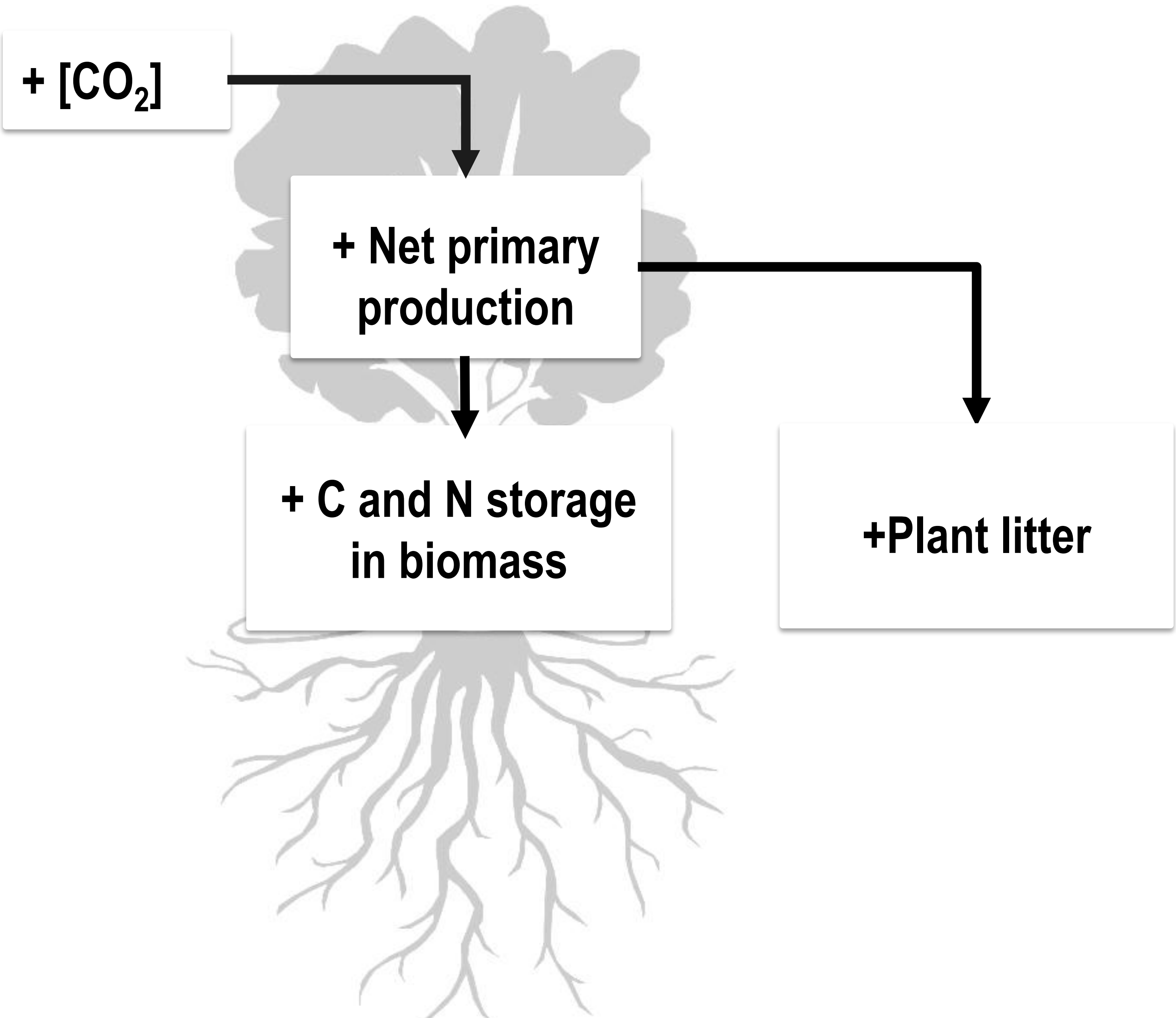
Annual Cycle
Jan
Apr
Jul
Oct
Jan

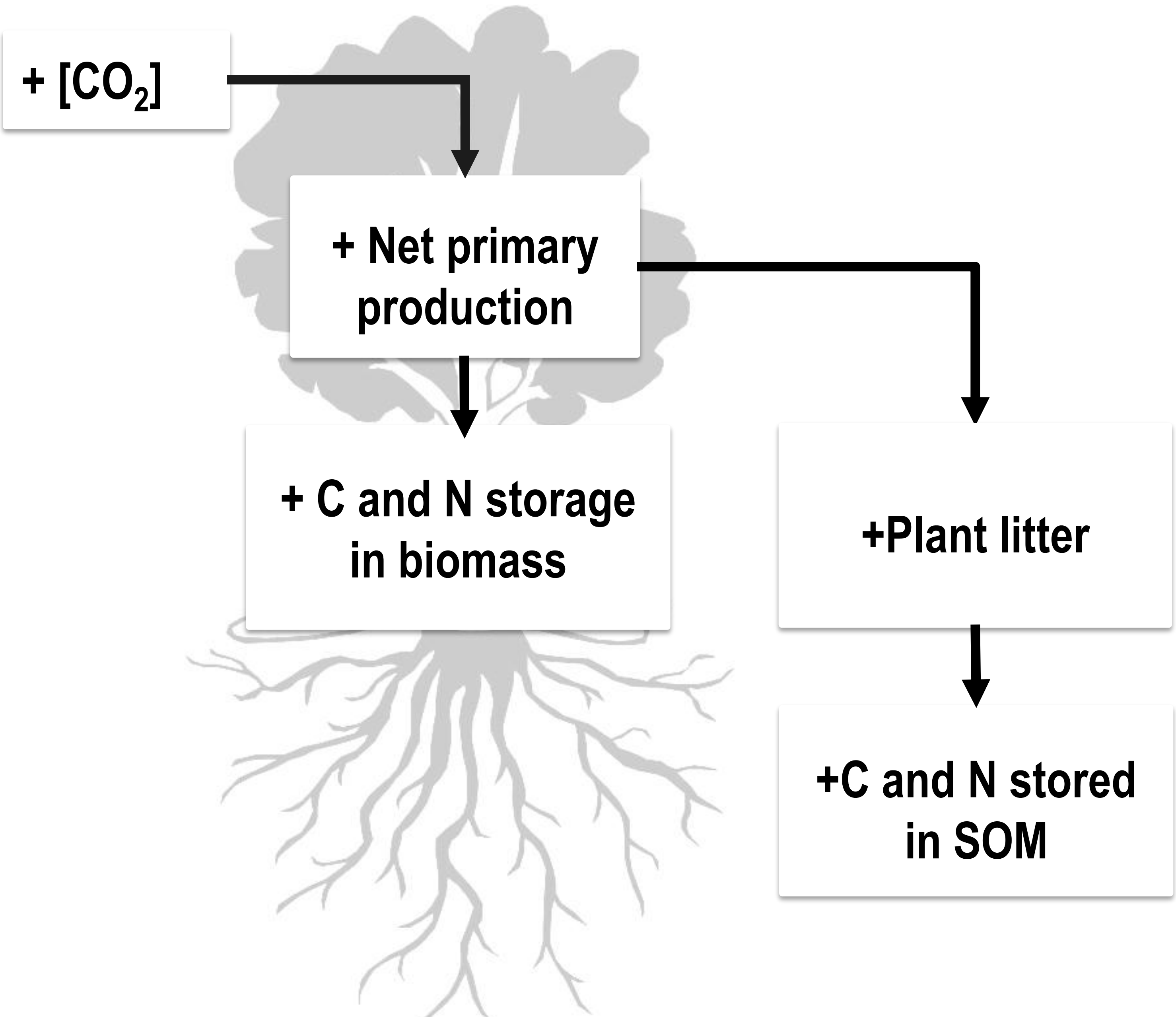
+ [CO_2]

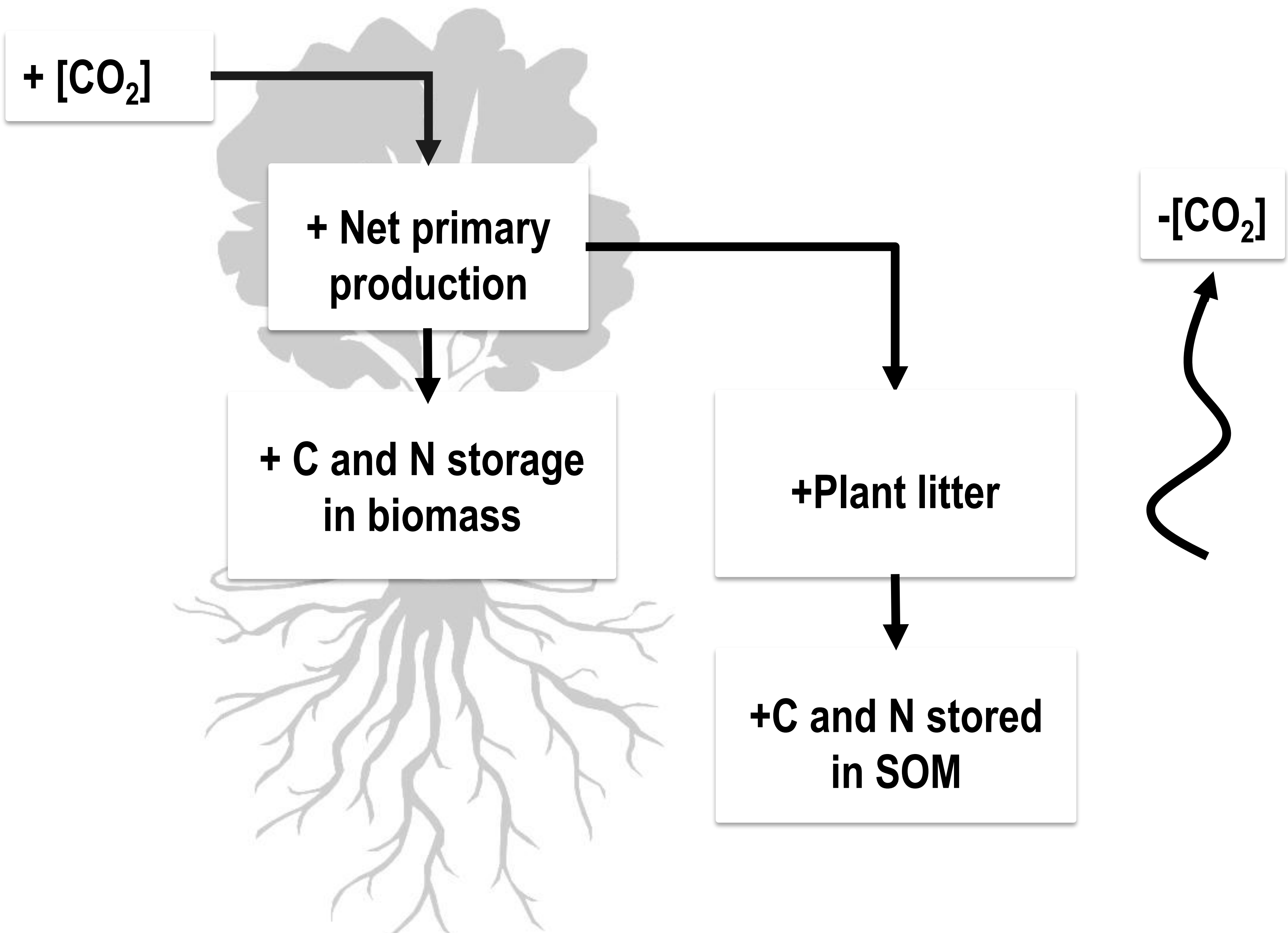



+ [CO_2]
+ Net primary production


+ [CO_2]
+ Net primary production
+ C and N storage in biomass


+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter

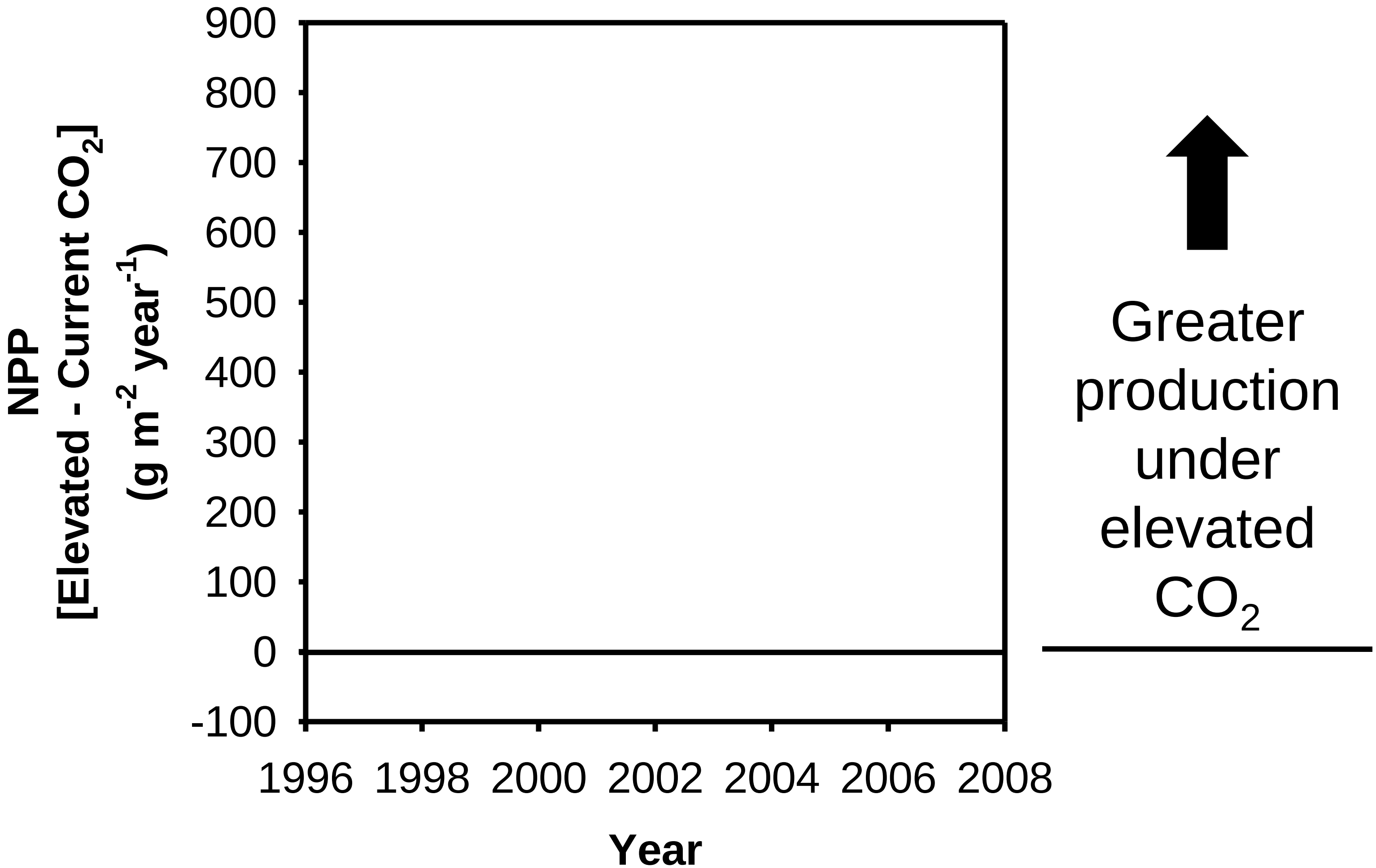

+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM



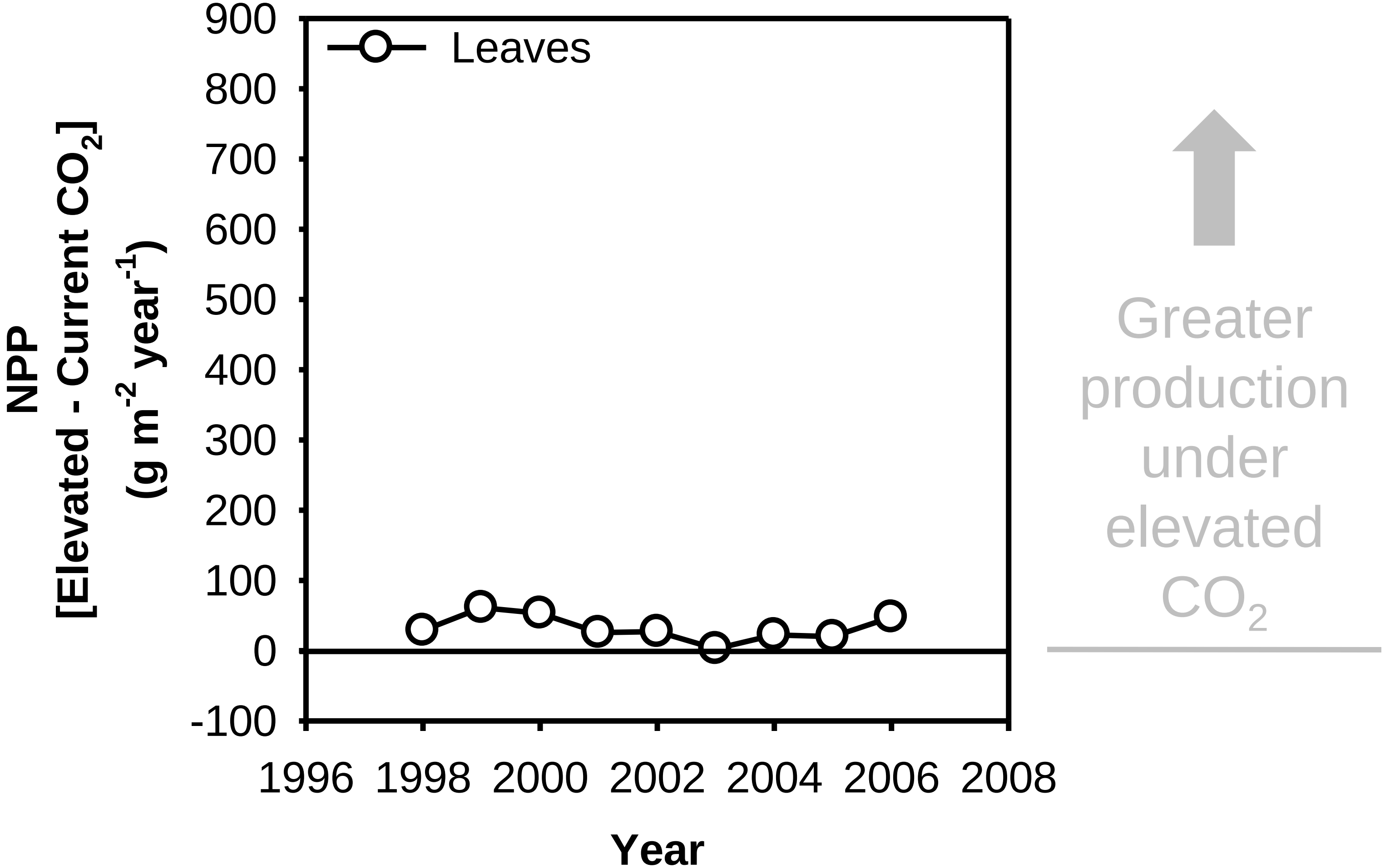
+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM
-[CO_2]

Free-Air CO_2 Enrichment provides a unique opportunity

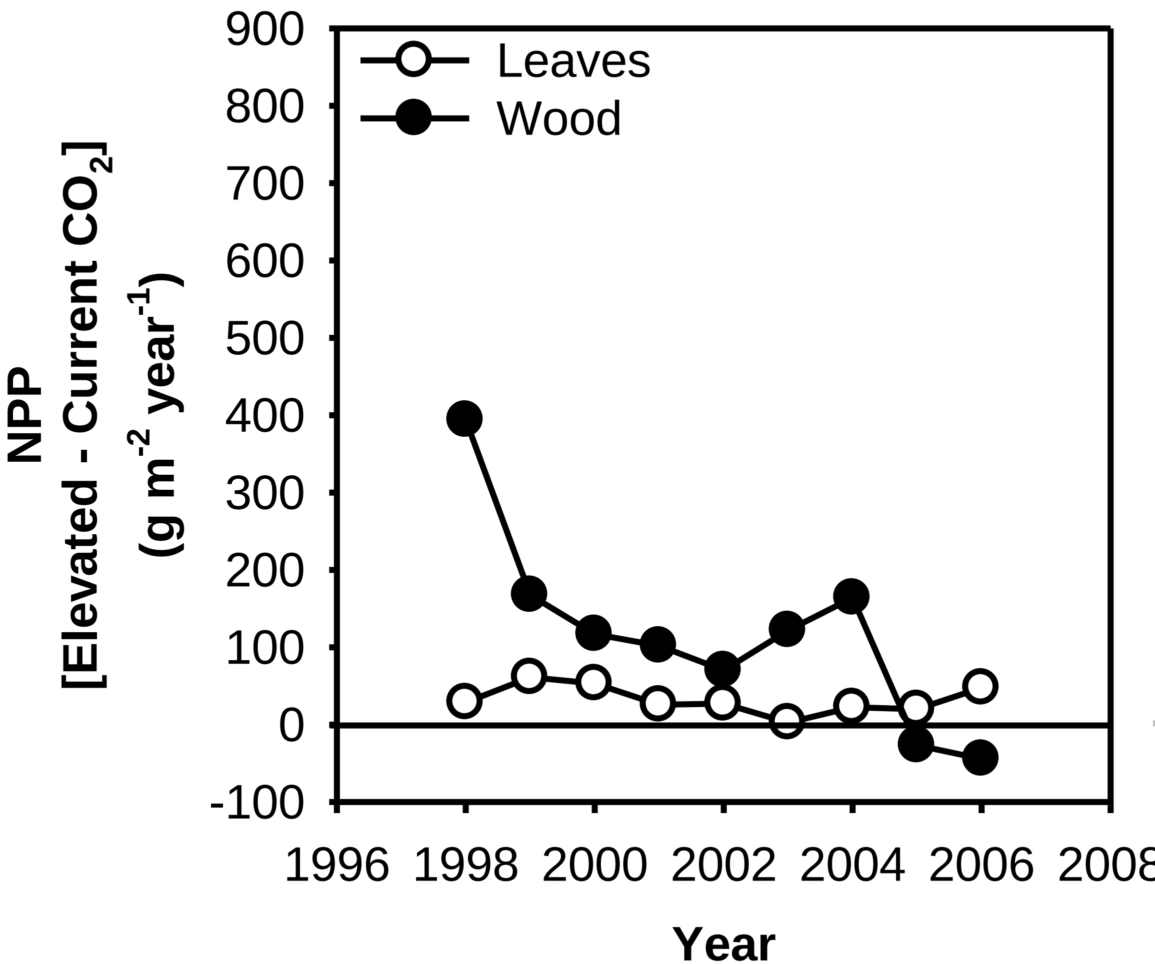
Has elevated [CO_2] increased net primary production?



Elevated [CO_2] increased sweetgum NPP

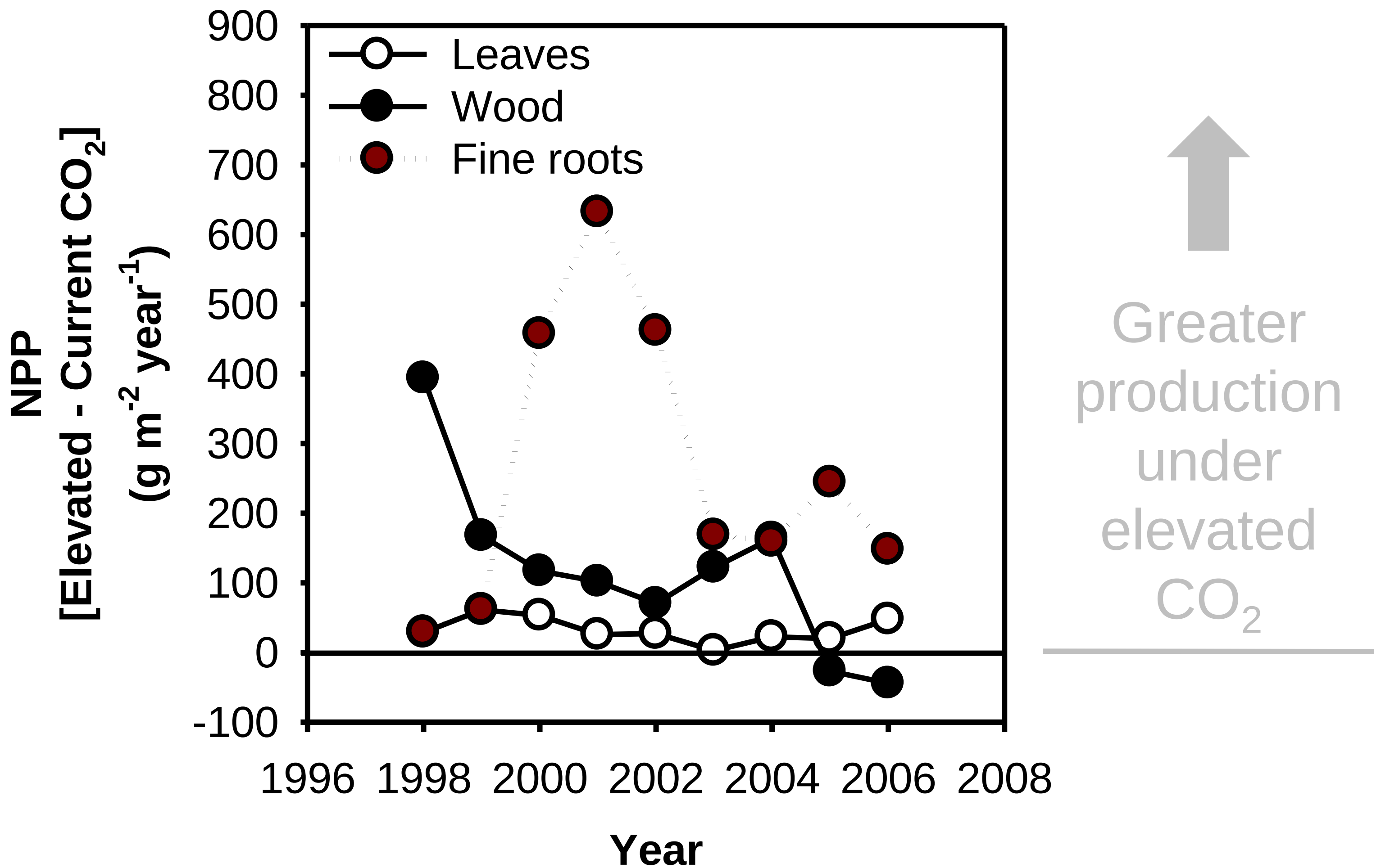


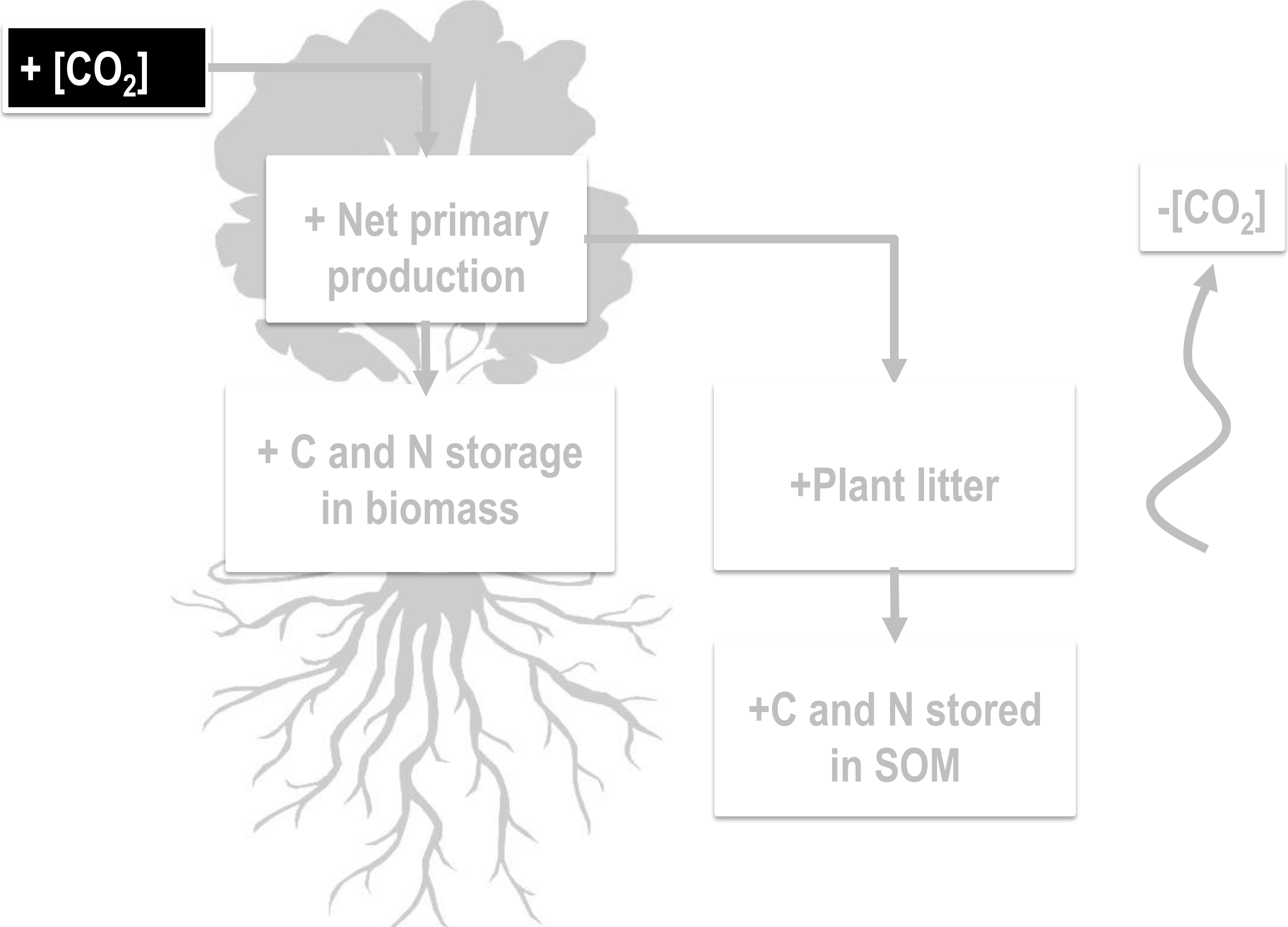
Elevated [CO_2] increased sweetgum NPP

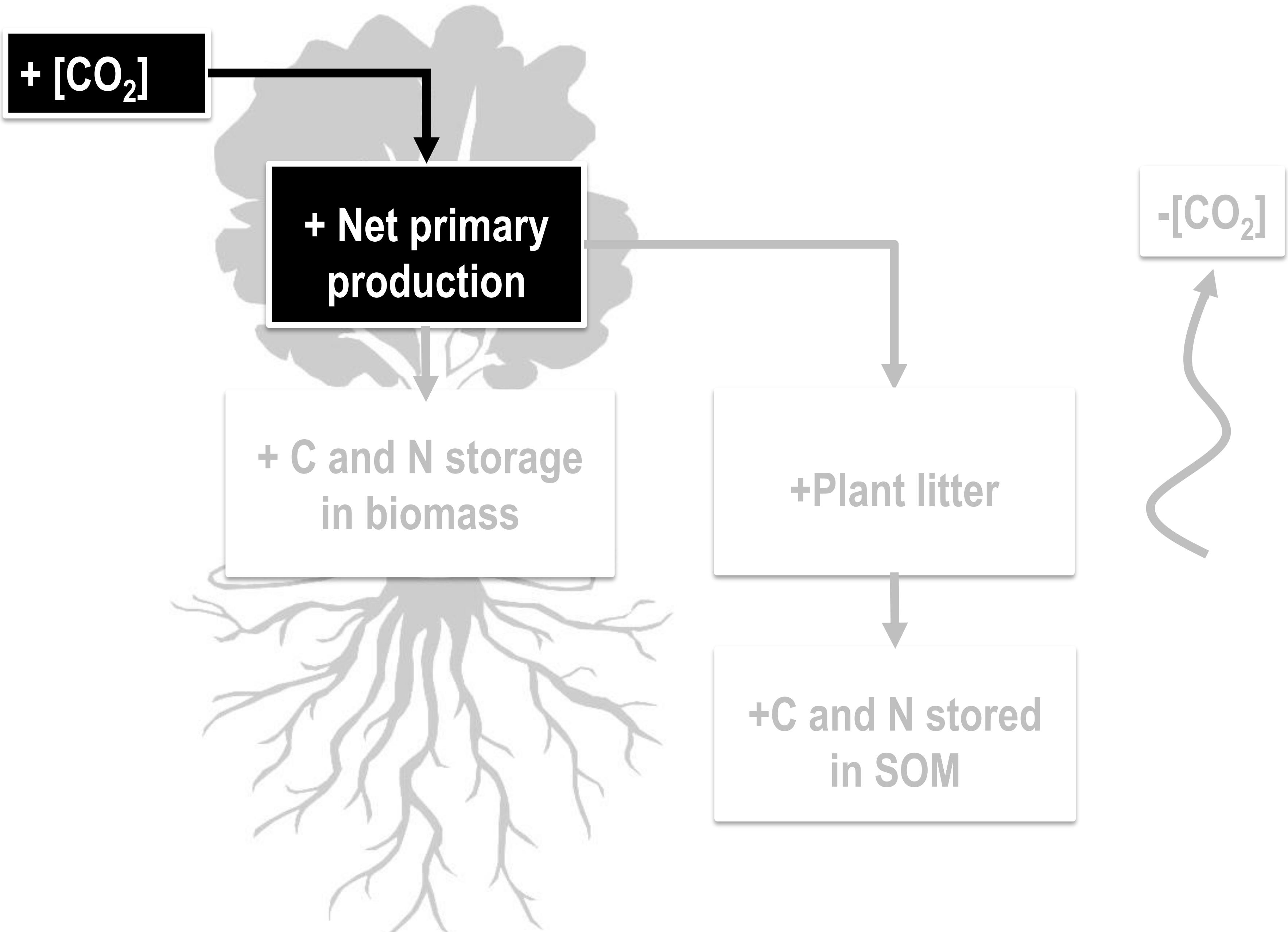


Greater production under elevated CO_2

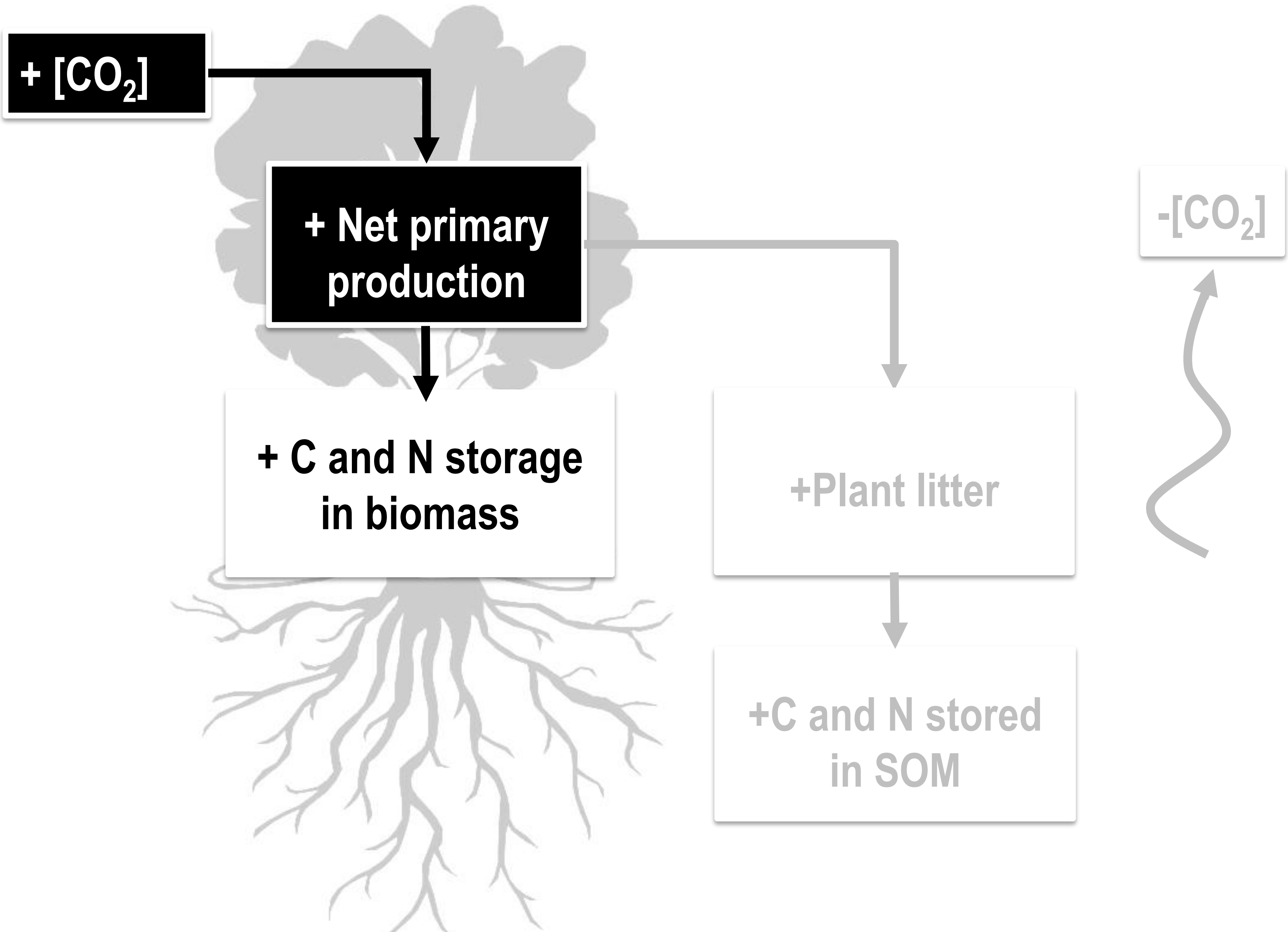
Elevated [CO_2] has changed C partitioning over time



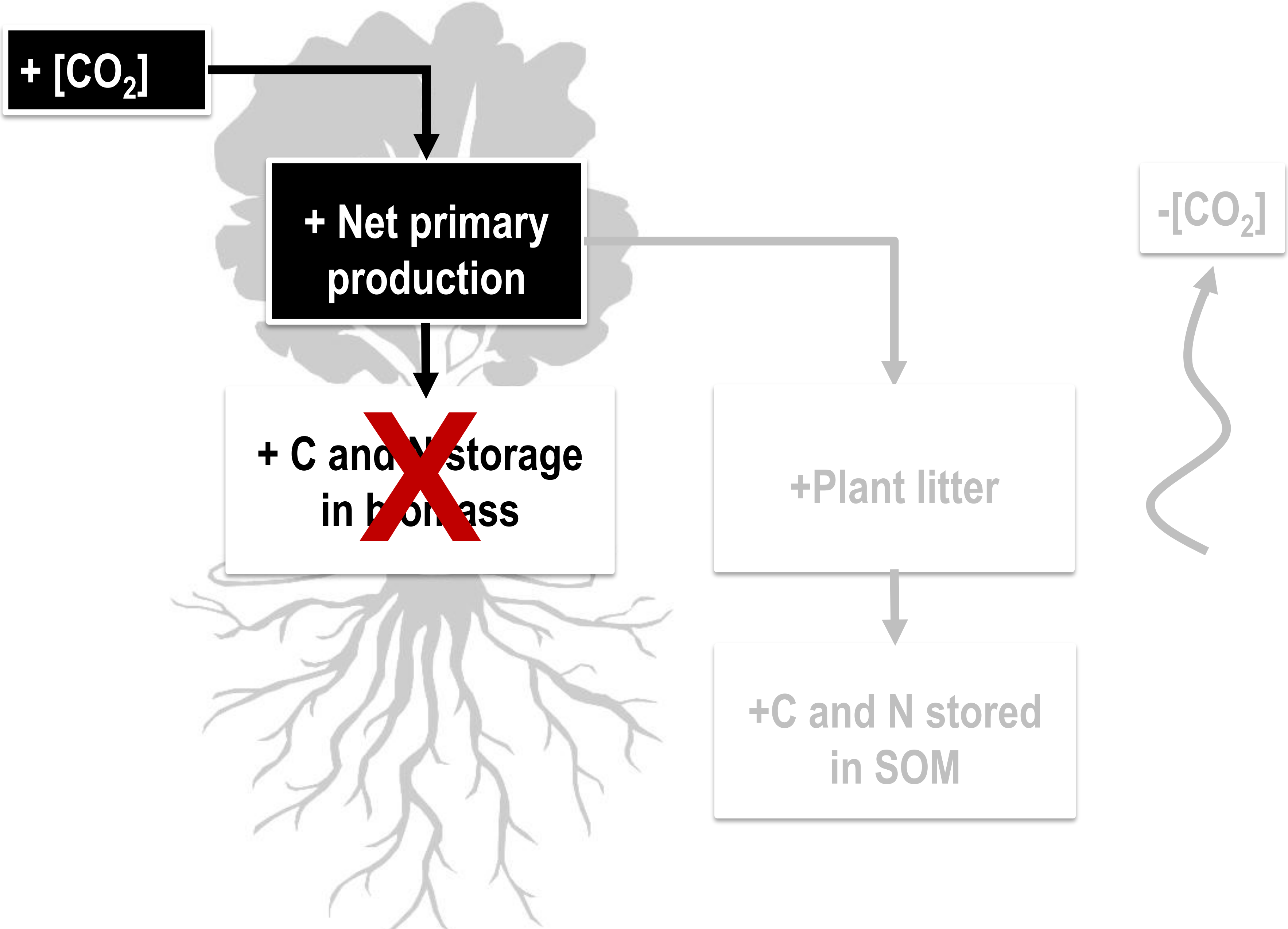

+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM
-[CO_2]



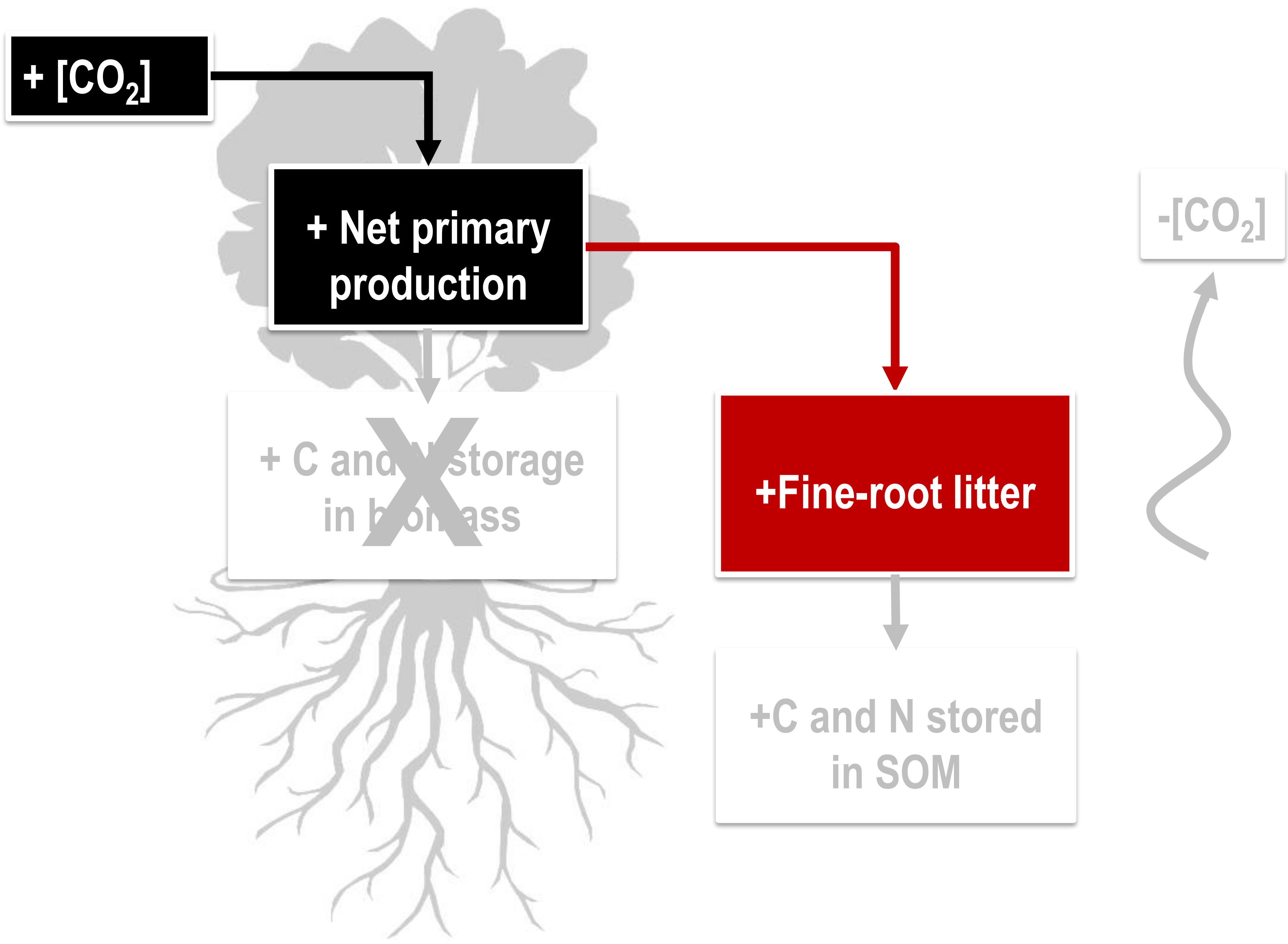
+ [CO2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM
-[CO2]



+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM
-[CO_2]



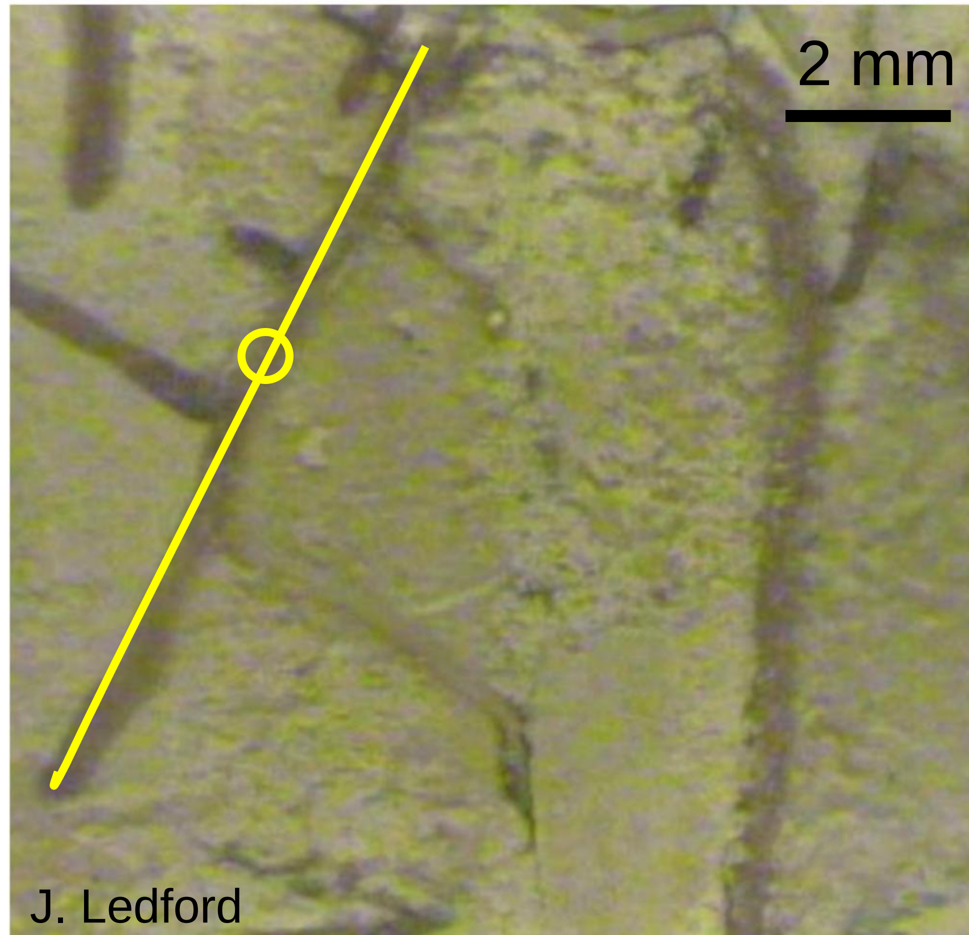
+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Plant litter
+C and N stored in SOM
-[CO_2]



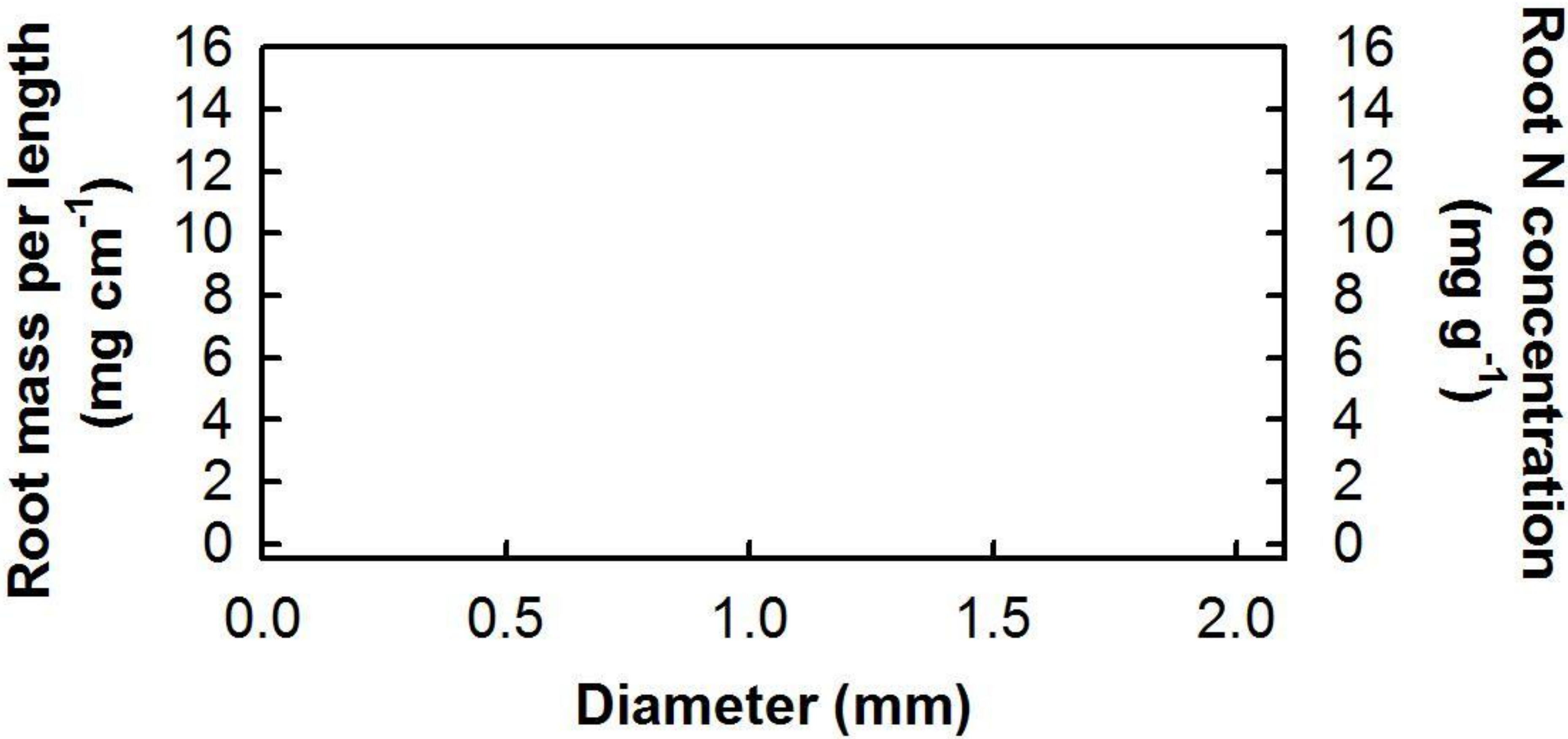
+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM
-[CO_2]

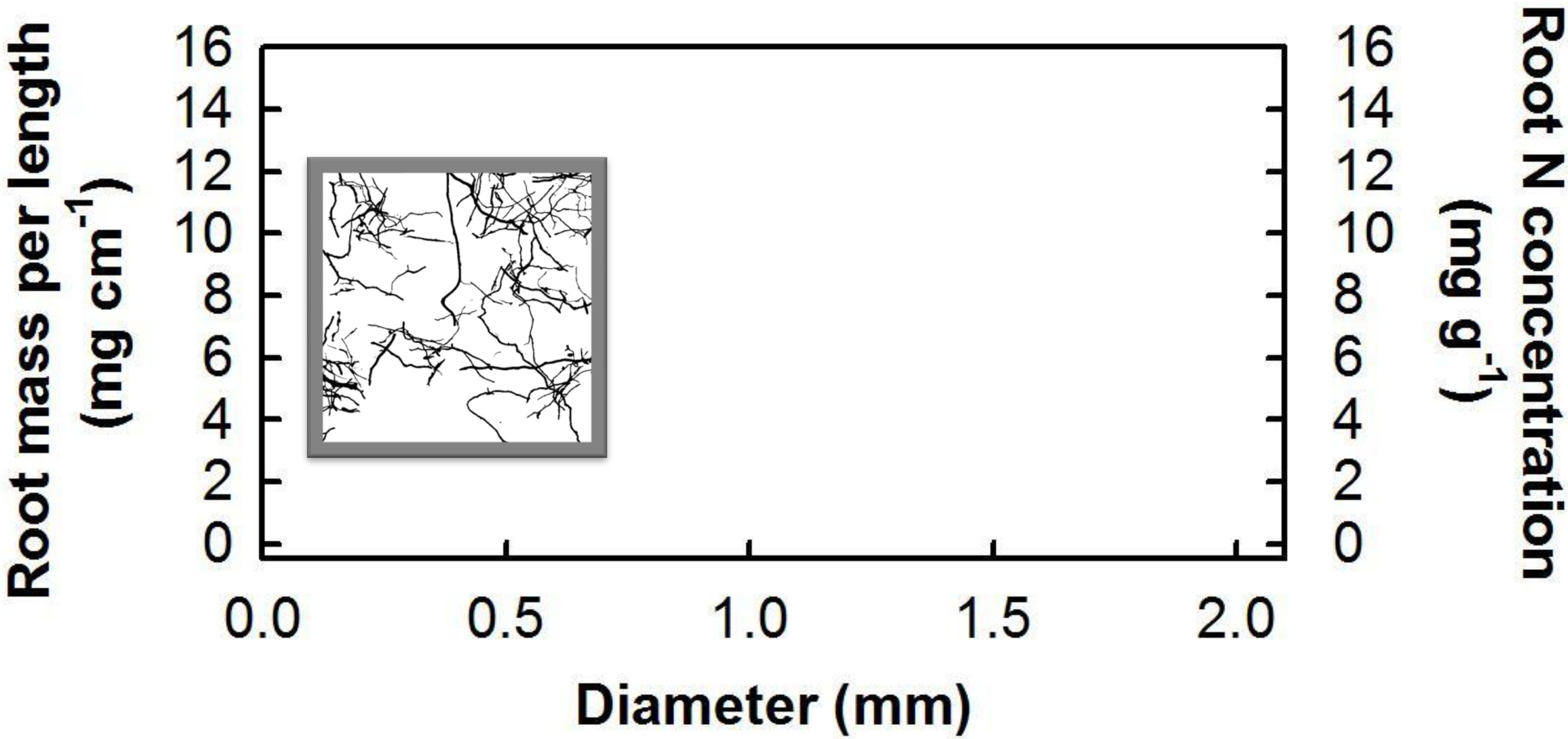
Does increased biomass allocation to fine roots lead to greater inputs of carbon and nitrogen to the soil?

Fine-root production and mortality from mini-rhizotron images

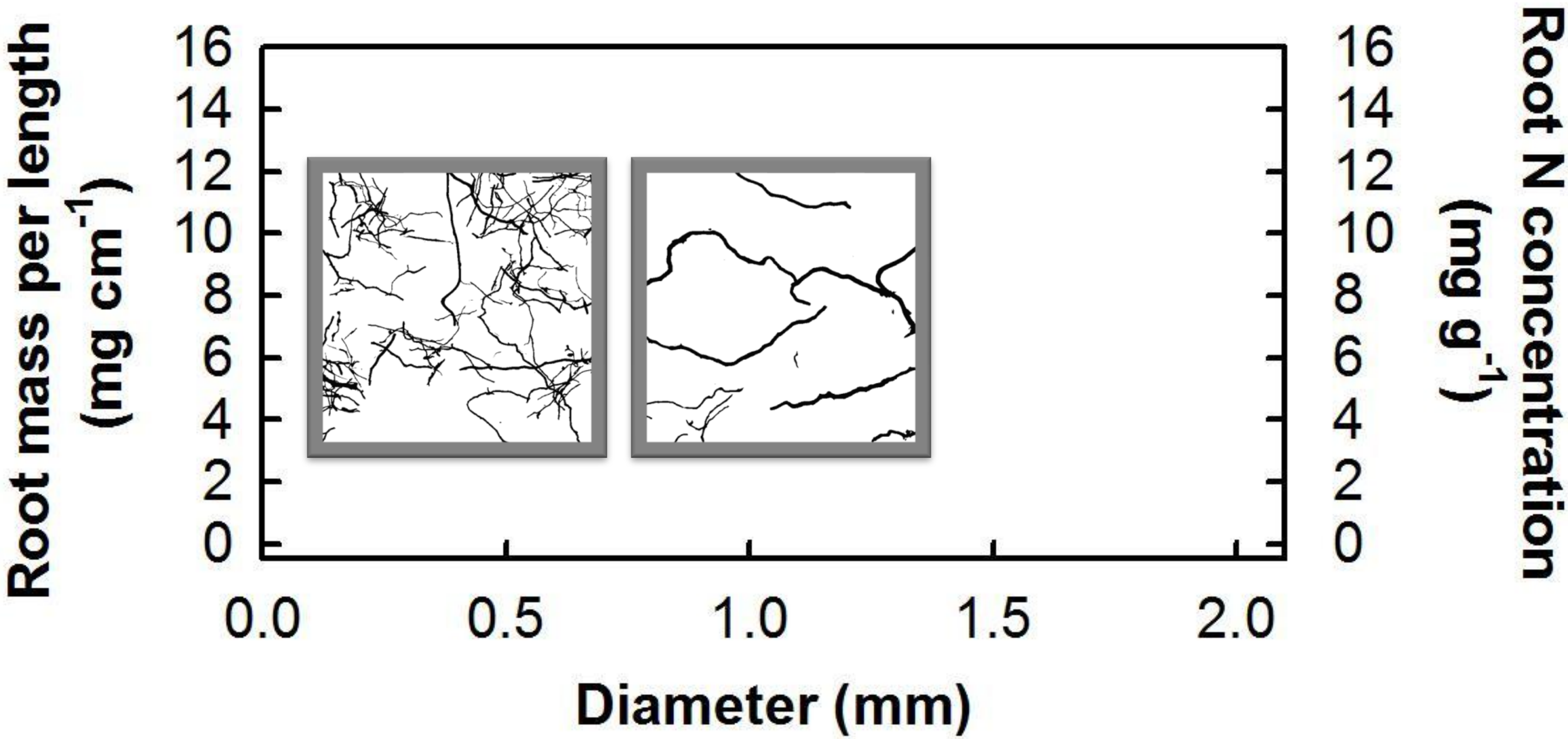


Fine root populations are extremely heterogeneous

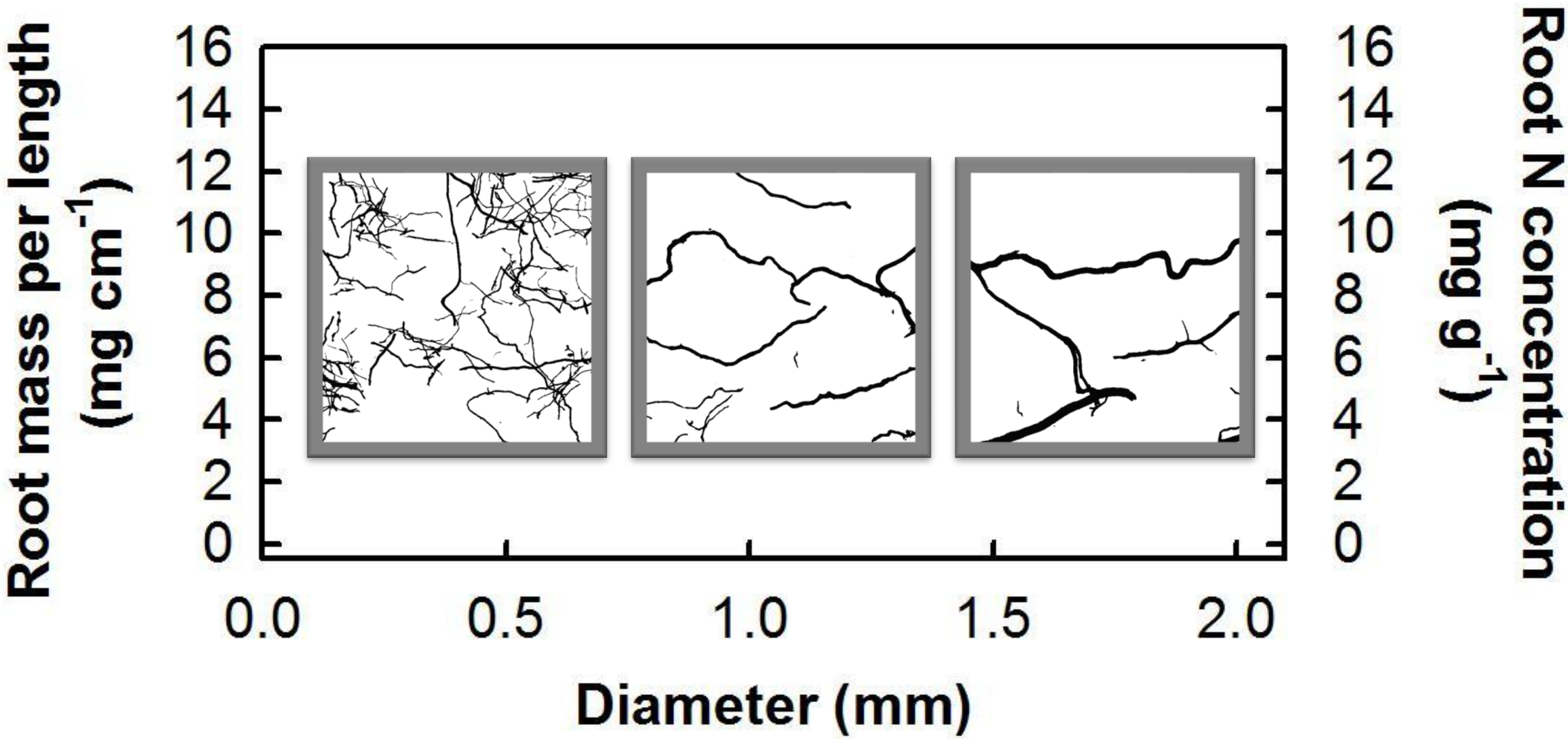

Root mass per length
(mg cm-1)
16
14
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
Diameter (mm)
Root N concentration
(mg g-1)



Root mass per length (mg cm-1)
16
14
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
Diameter (mm)
Root N concentration (mg g-1)

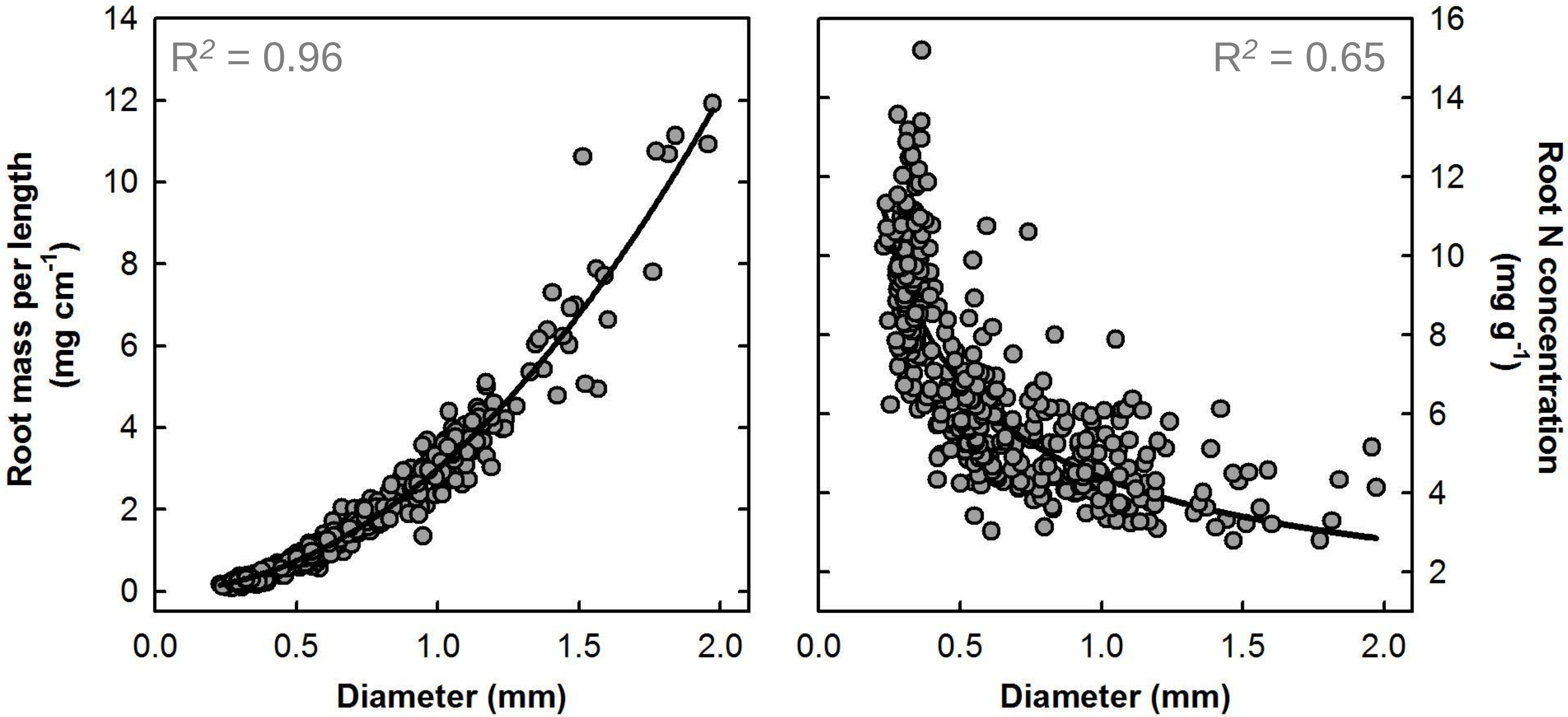


Root mass per length
(mg cm-1)
Root N concentration
(mg g-1)
16
14
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
Diameter (mm)



Root mass per length
(mg cm-1)
Root N concentration
(mg g-1)
16
14
12
10
8
6
4
2
0
0.0
0.5
1.0
1.5
2.0
Diameter (mm)

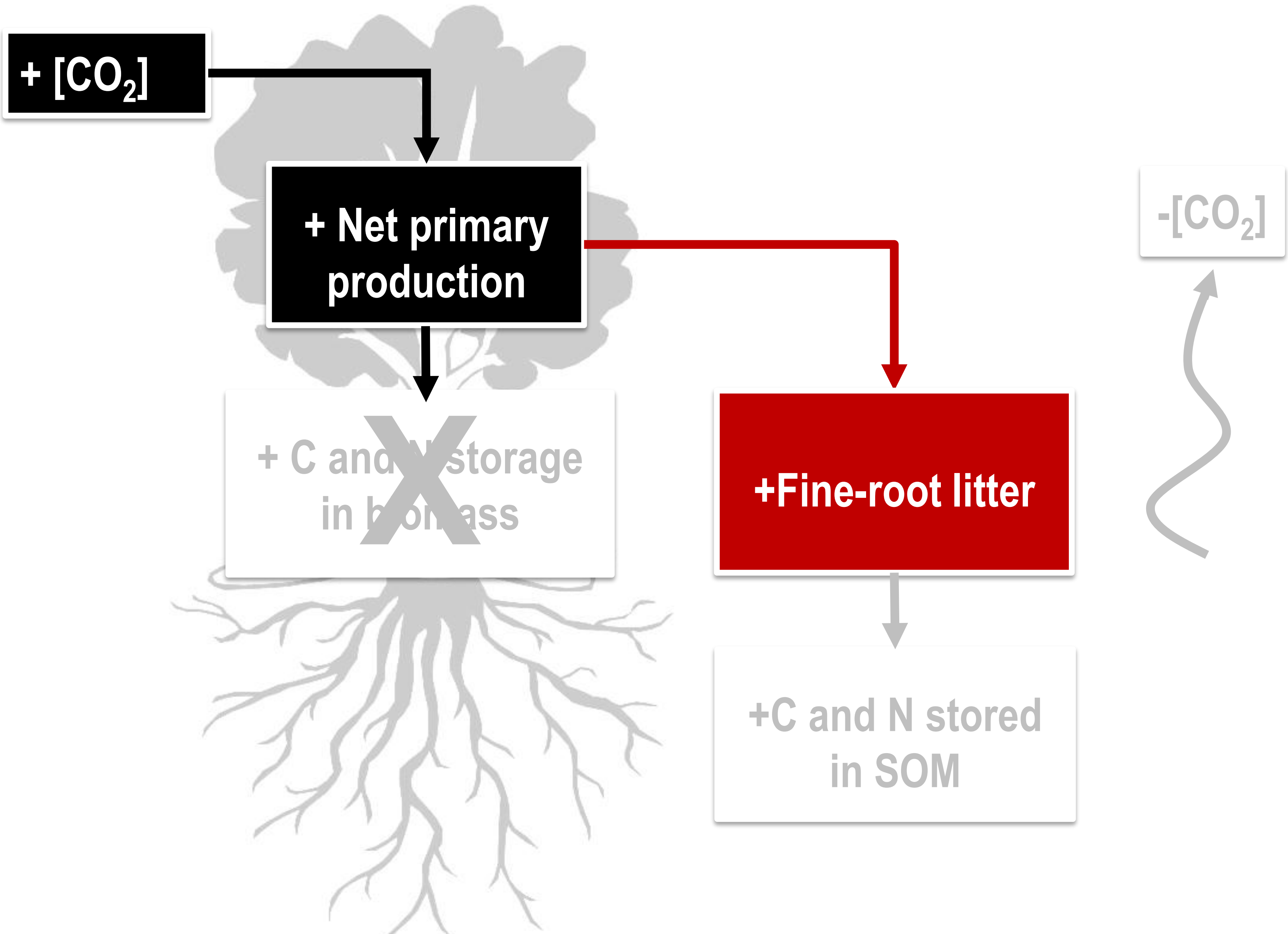
Power functions nicely describe the variation in root mass and N



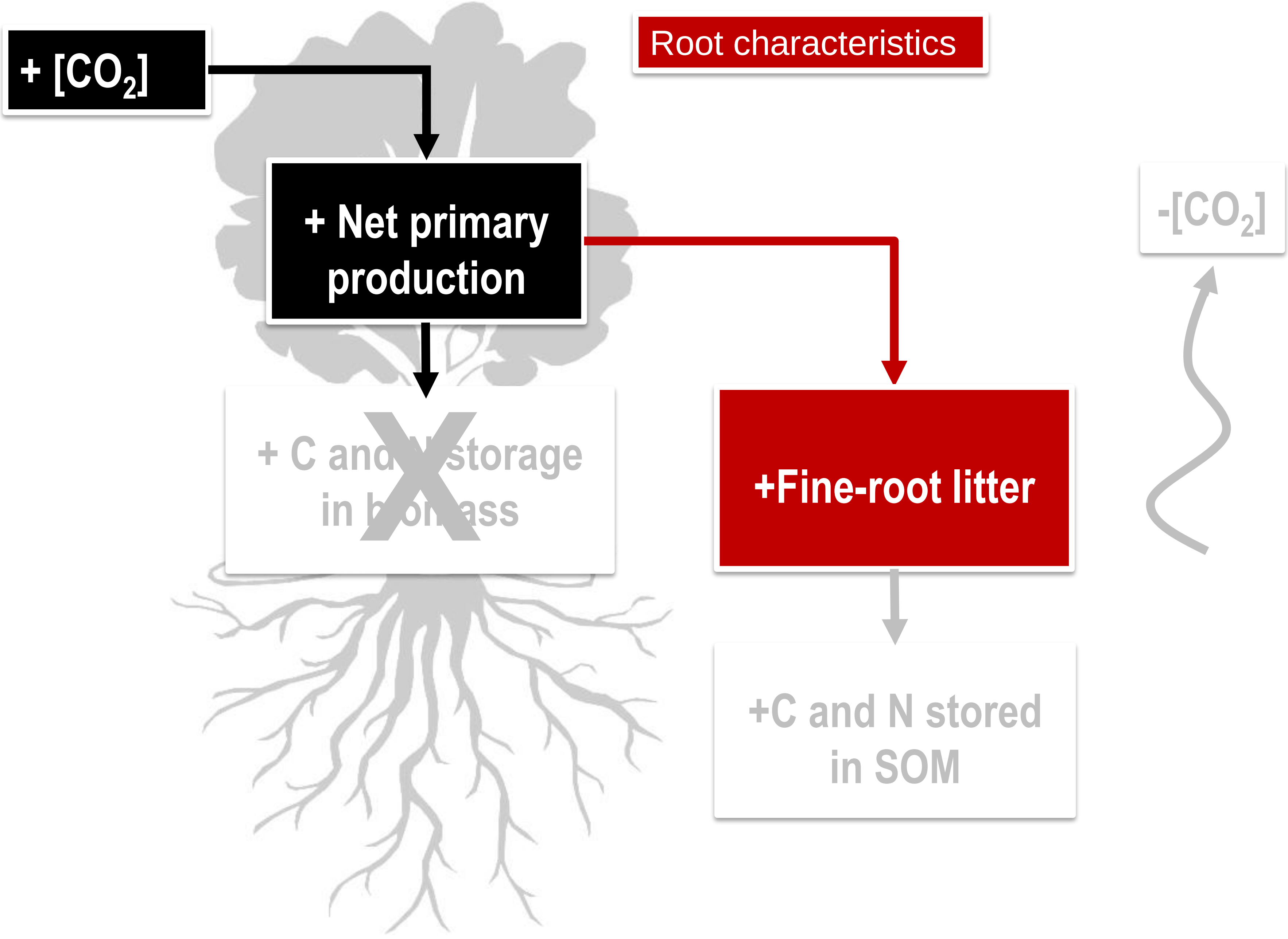
RML = 3.00 × Diameter $^{2.01}$

[N] = 4.40 × Diameter $^{-0.63}$

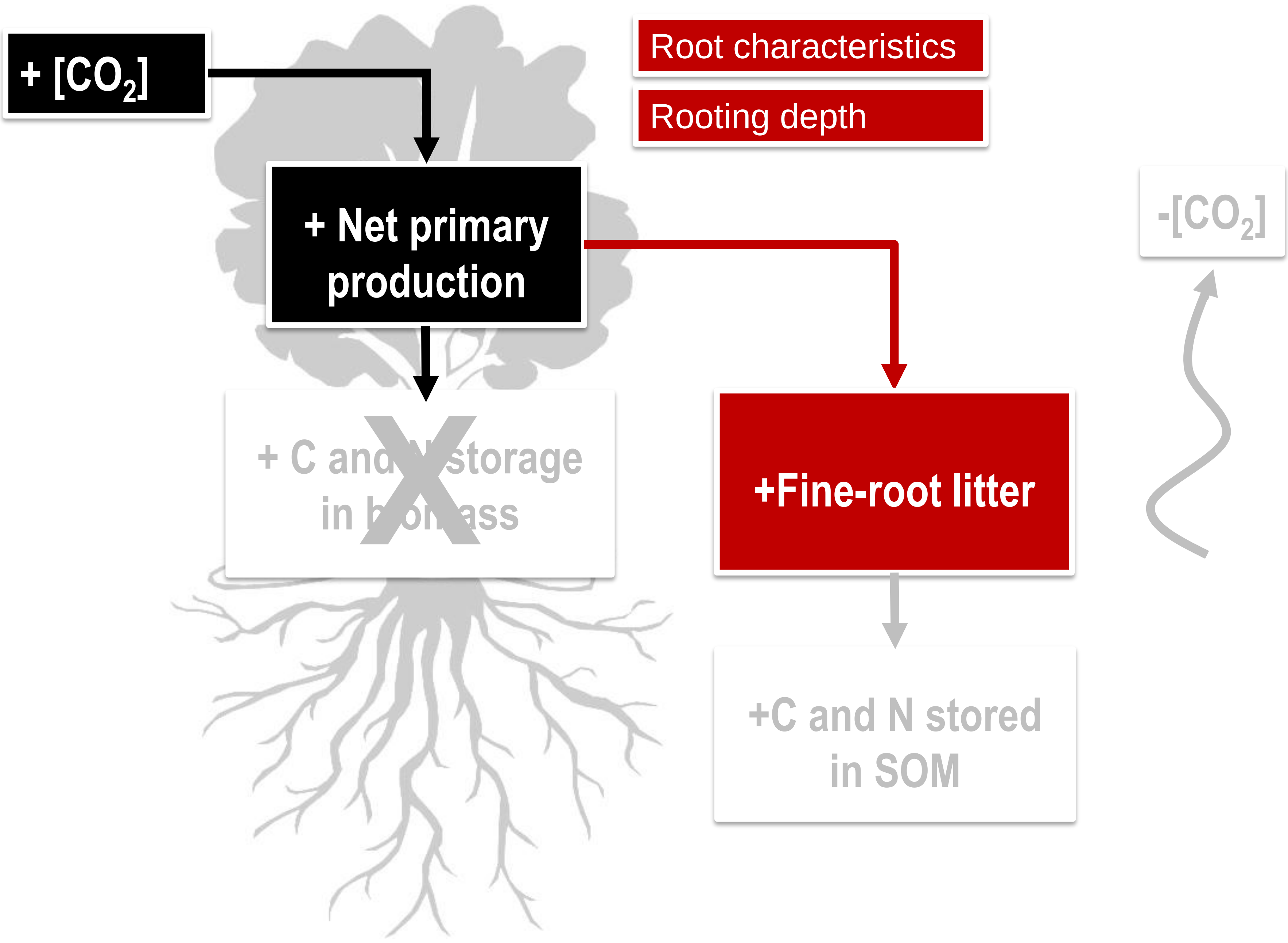
Iversen CM, Ledford L, Norby RJ (2008) *New Phytologist*

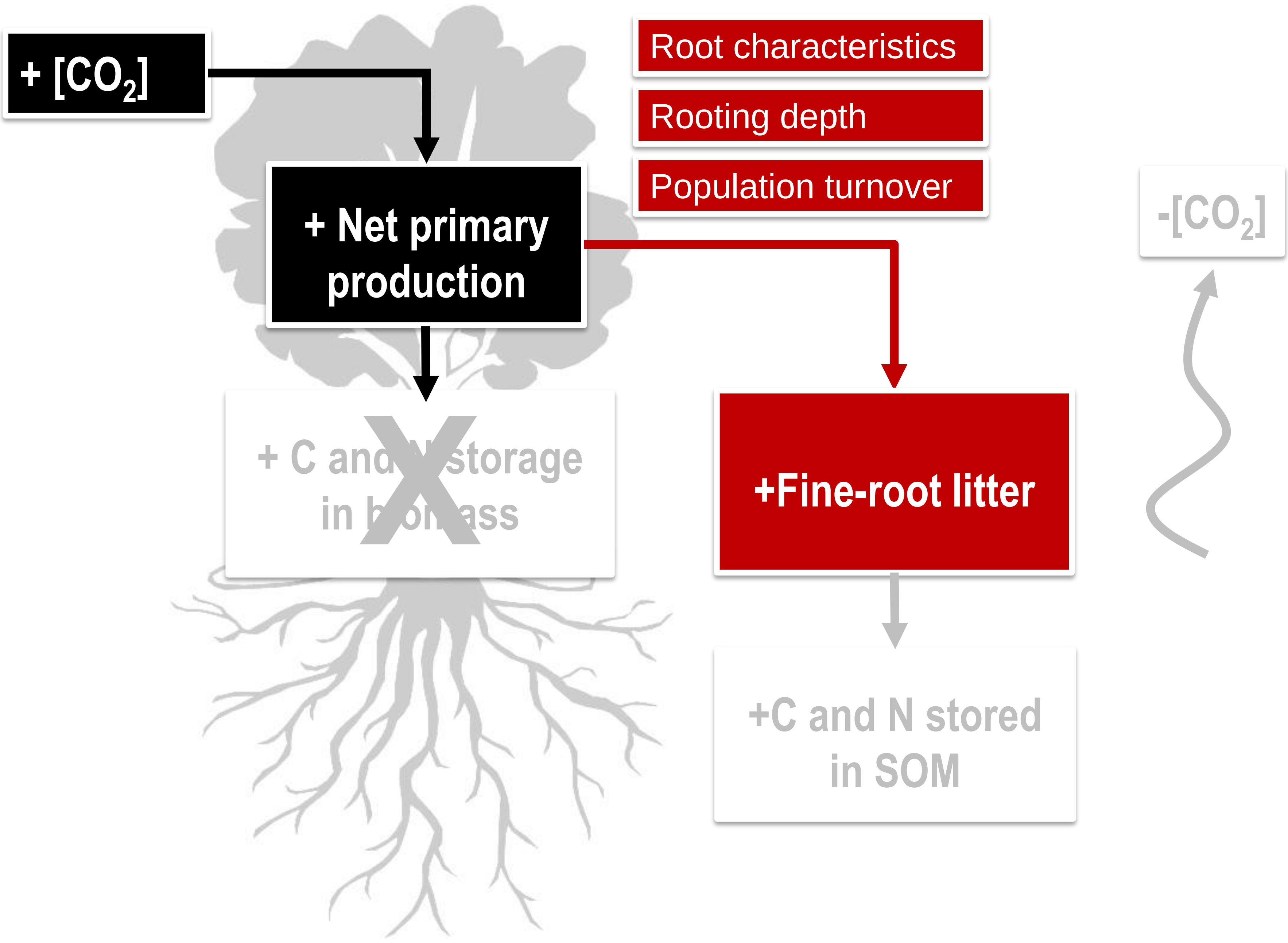


+ $[CO_2]$
+ Net primary production
+ C and N storage in biomass
X
+Fine-root litter
+C and N stored in SOM
-$[CO_2]$



+ [CO_2]
Root characteristics
+ Net primary production
-[CO_2]
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM


+ $[CO_2]$
Root characteristics
Rooting depth
+ Net primary production
-$[CO_2]$
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM


+ $[CO_2]$
+ Net primary production
Root characteristics
Rooting depth
Population turnover
$-[CO_2]$
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM

Has elevated [CO_2] affected root mass or [N]?

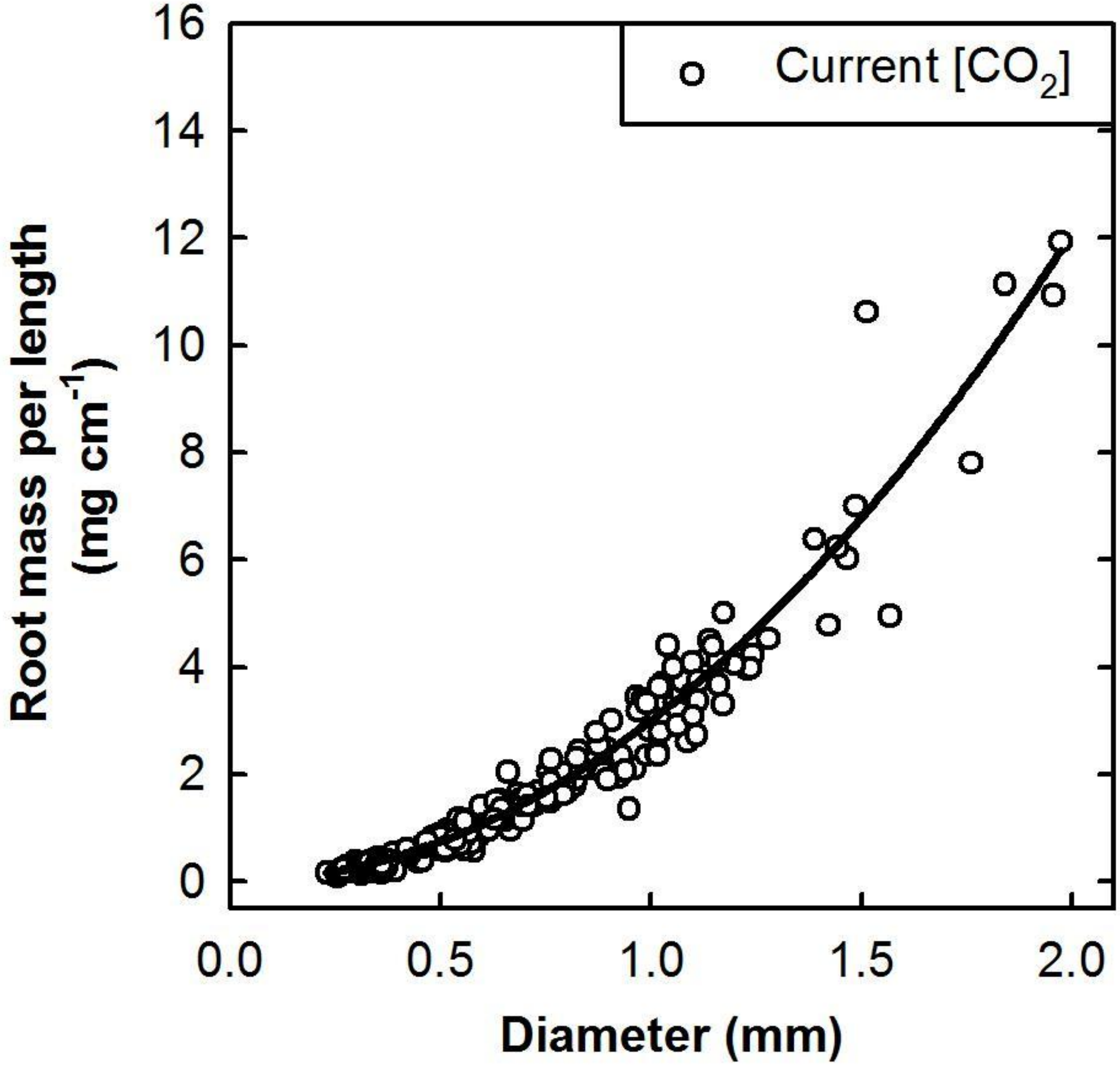
Has elevated [CO_2] affected root proliferation throughout the soil?

Has elevated [CO_2] affected the turnover rate of the fine root population?

Has elevated [CO_2] affected root mass or [N]?

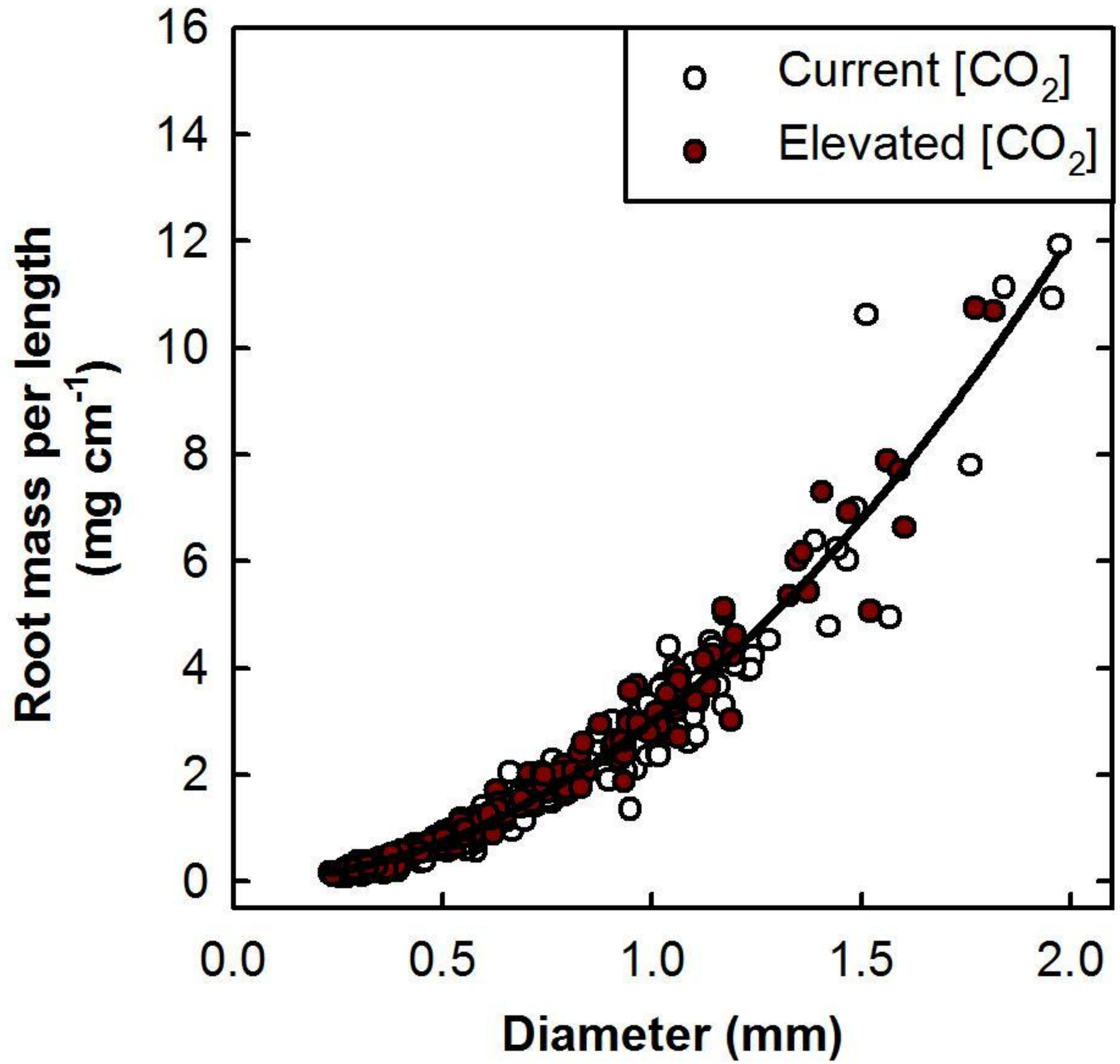
Has elevated [CO_2] affected root proliferation throughout the soil?

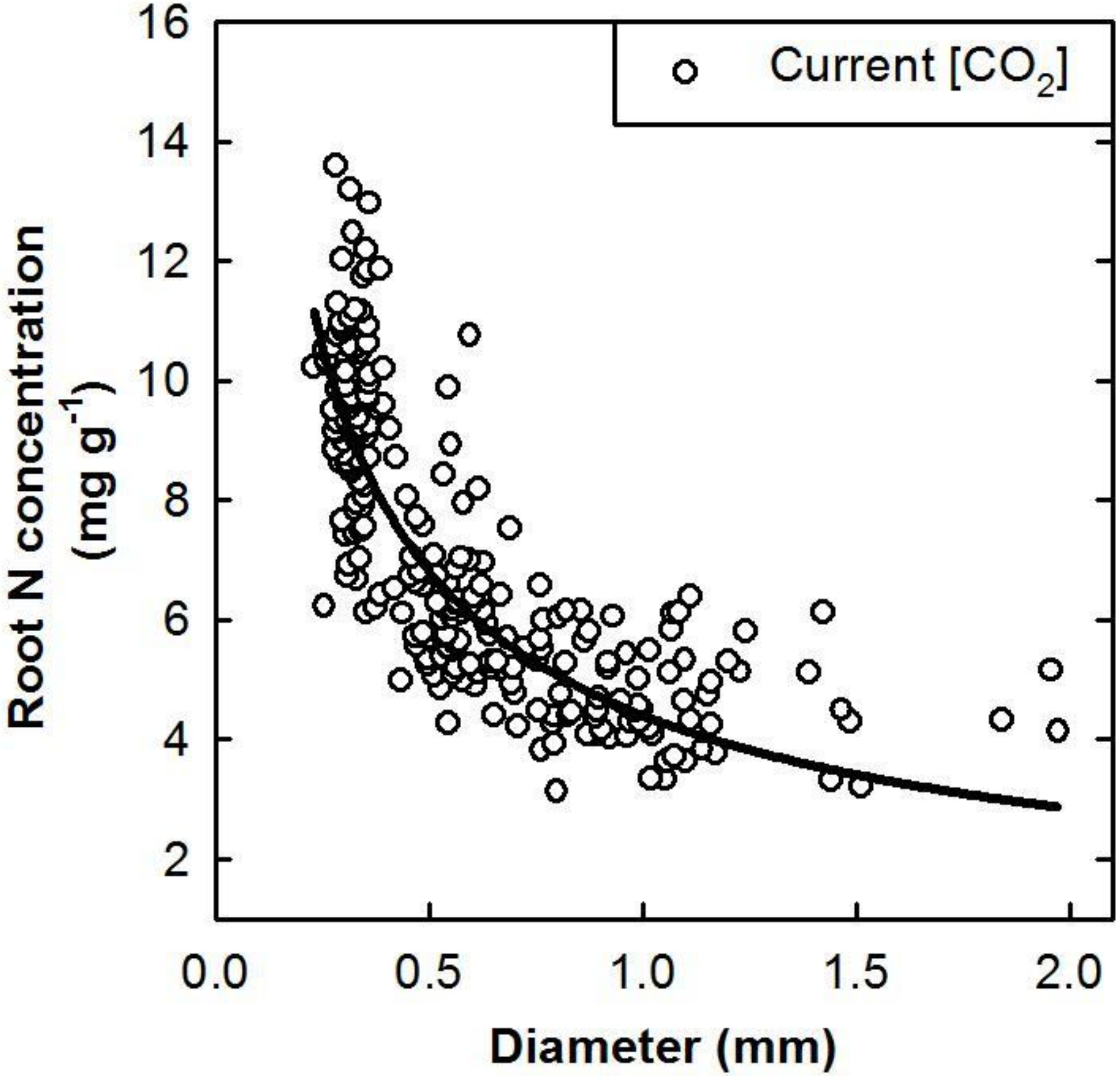
Has elevated [CO_2] affected the turnover rate of the fine root population?



Current [CO_2]
Root mass per length (mg cm^{-1})
Diameter (mm)
0
2
4
6
8
10
12
14
16
0.0
0.5
1.0
1.5
2.0

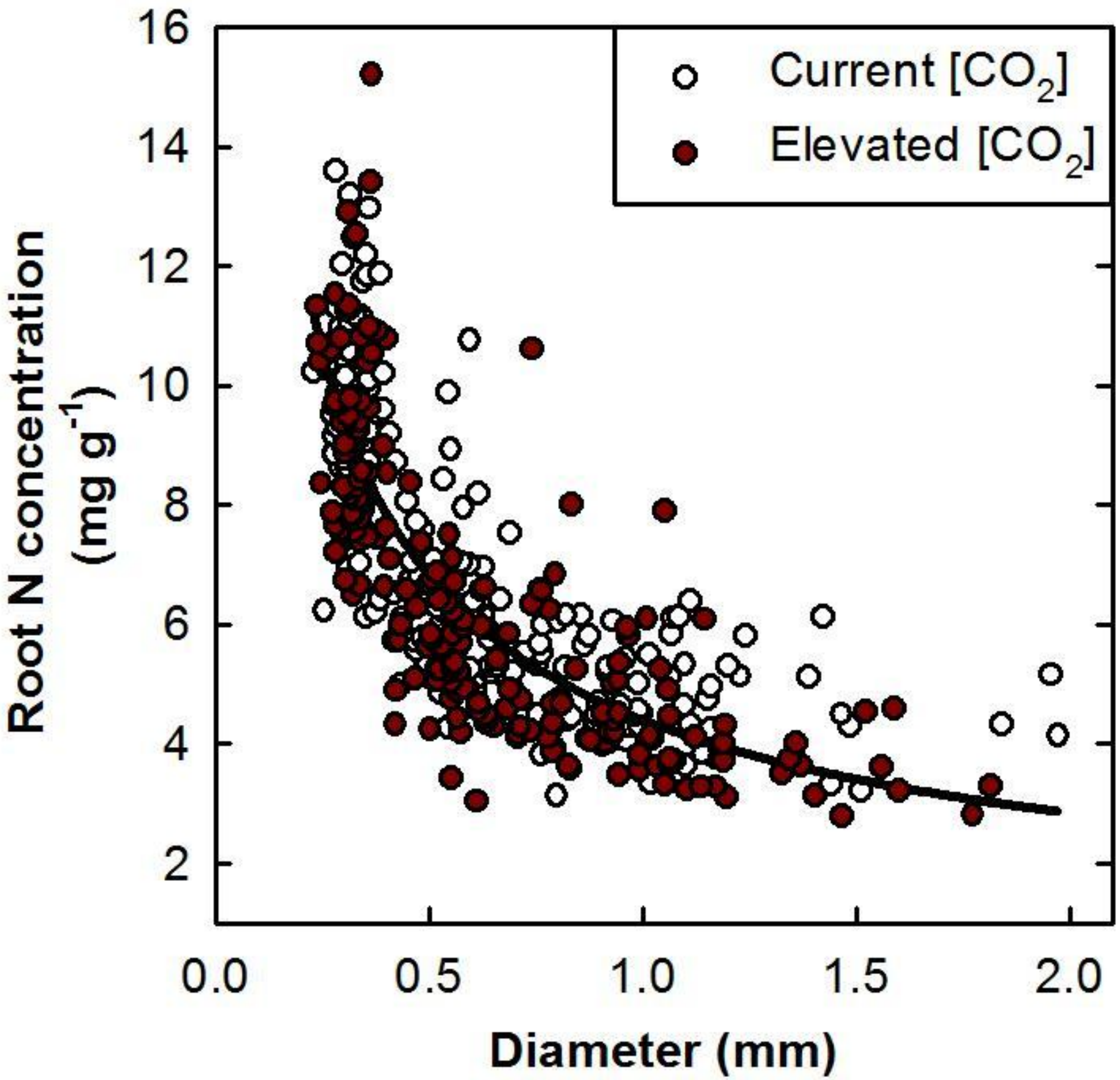
Elevated [CO_2] had no effect on diameter-RML relationship





Root N concentration (mg g-1)
16
14
12
10
8
6
4
2
0.0
0.5
1.0
1.5
2.0
Diameter (mm)
Current [CO2]

Elevated [CO_2] had no effect on diameter-N relationship



Has elevated [CO_2] affected root mass or [N]?

Has elevated [CO_2] affected root proliferation throughout the soil?

Has elevated [CO_2] affected the turnover rate of the fine root population?

Elevated [CO_2] has not affected root mass or [N].

Has elevated [CO_2] affected root proliferation throughout the soil?

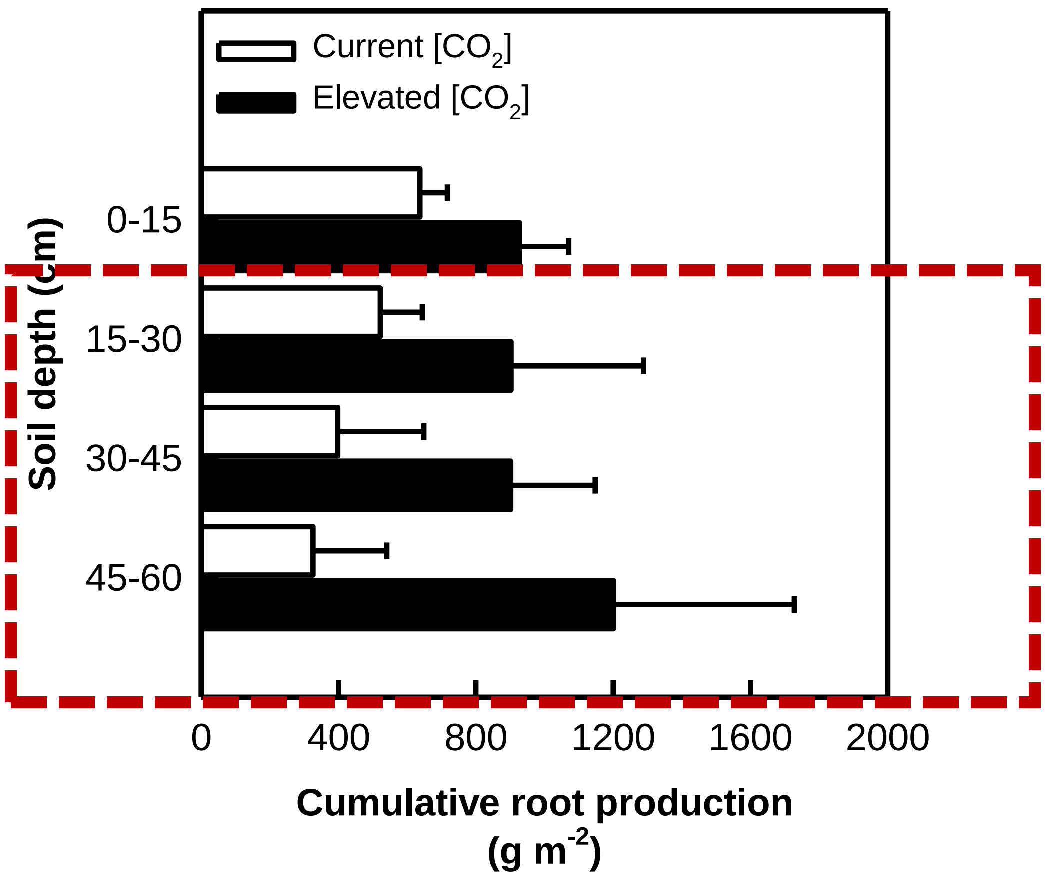
Has elevated [CO_2] affected the turnover rate of the fine root population?

Elevated [CO_2] has not affected root mass or [N].

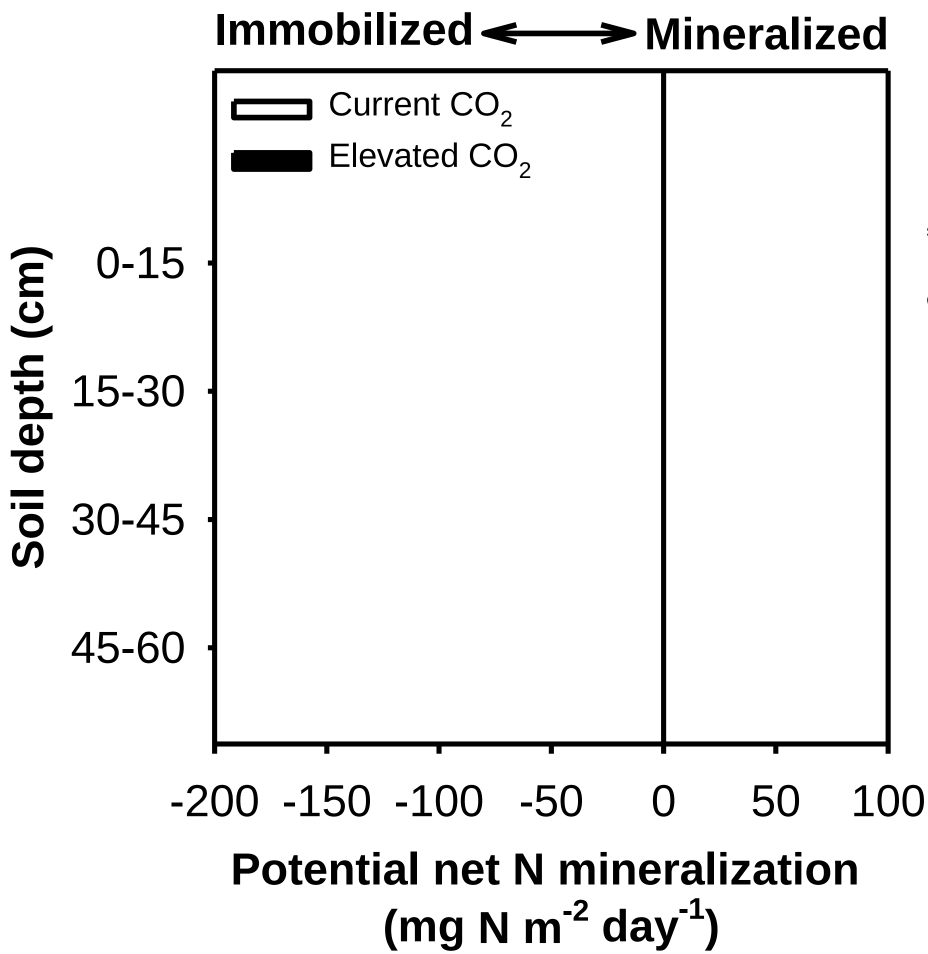
Has elevated [CO_2] affected root proliferation throughout the soil?

Has elevated [CO_2] affected the turnover rate of the fine root population?

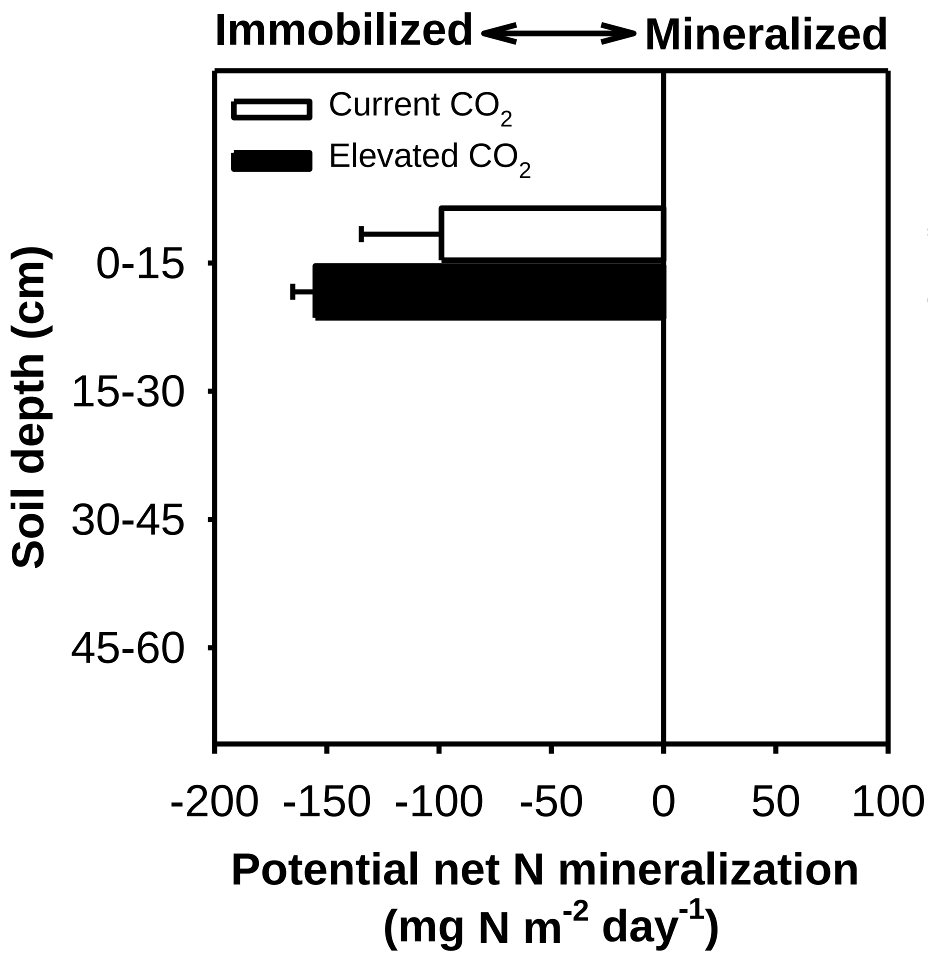
Elevated [CO_2] has increased fine-root proliferation at depth

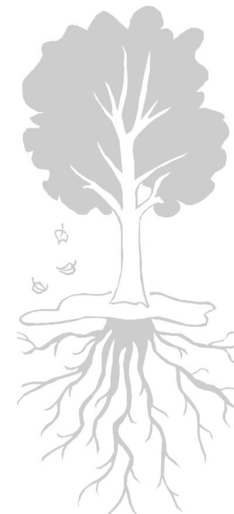


Soil N availability changes with soil depth

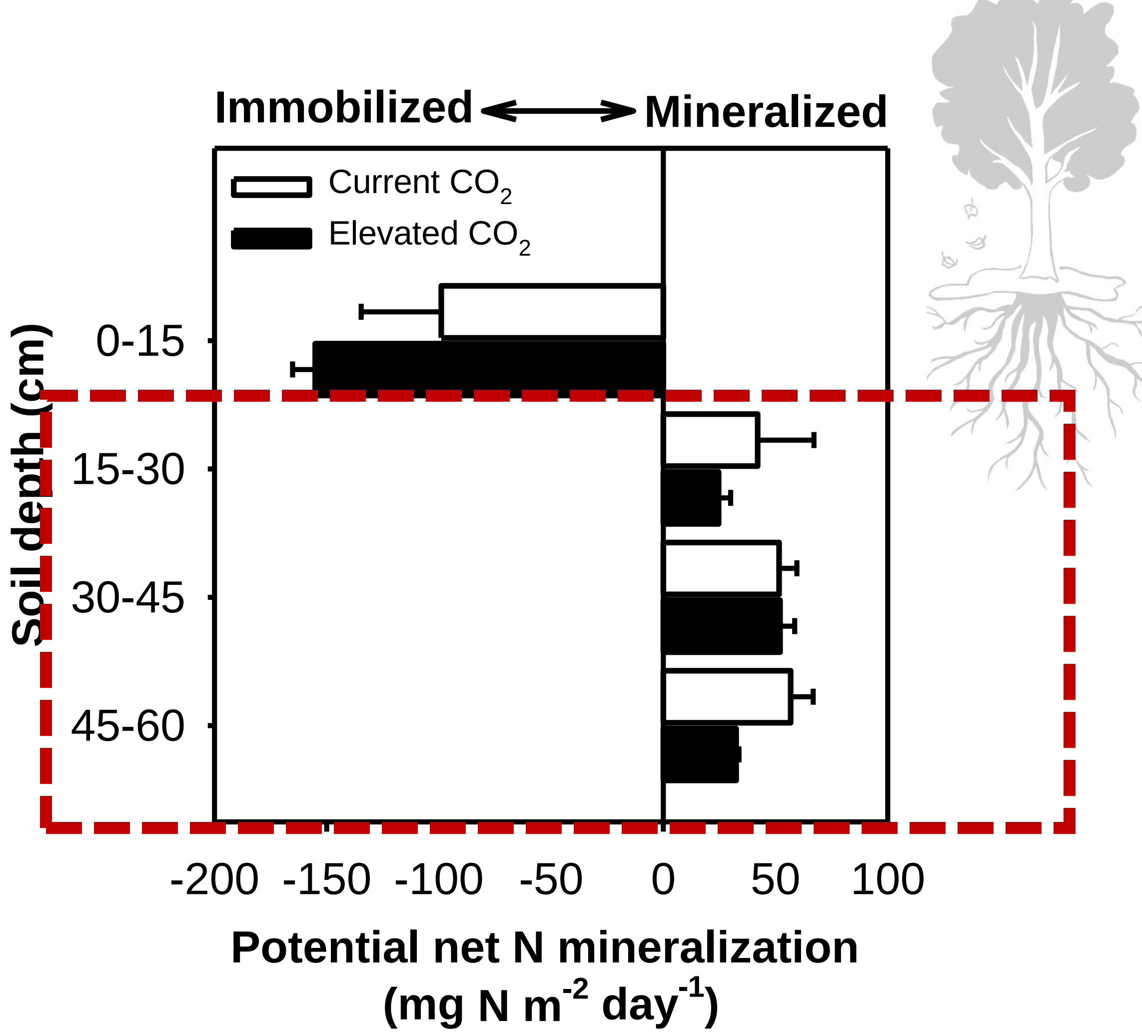


Less N available for plant uptake near the soil surface





More N may be accessed by deeper roots under elevated [CO_2]



Elevated [CO_2] has not affected root mass or [N].

Has elevated [CO_2] affected root proliferation throughout the soil?

Has elevated [CO_2] affected the turnover rate of the fine root population?

Elevated [CO_2] has not affected root mass or [N].

Biomass production doubled under elevated CO_2; response at depth to alleviate N limitation.

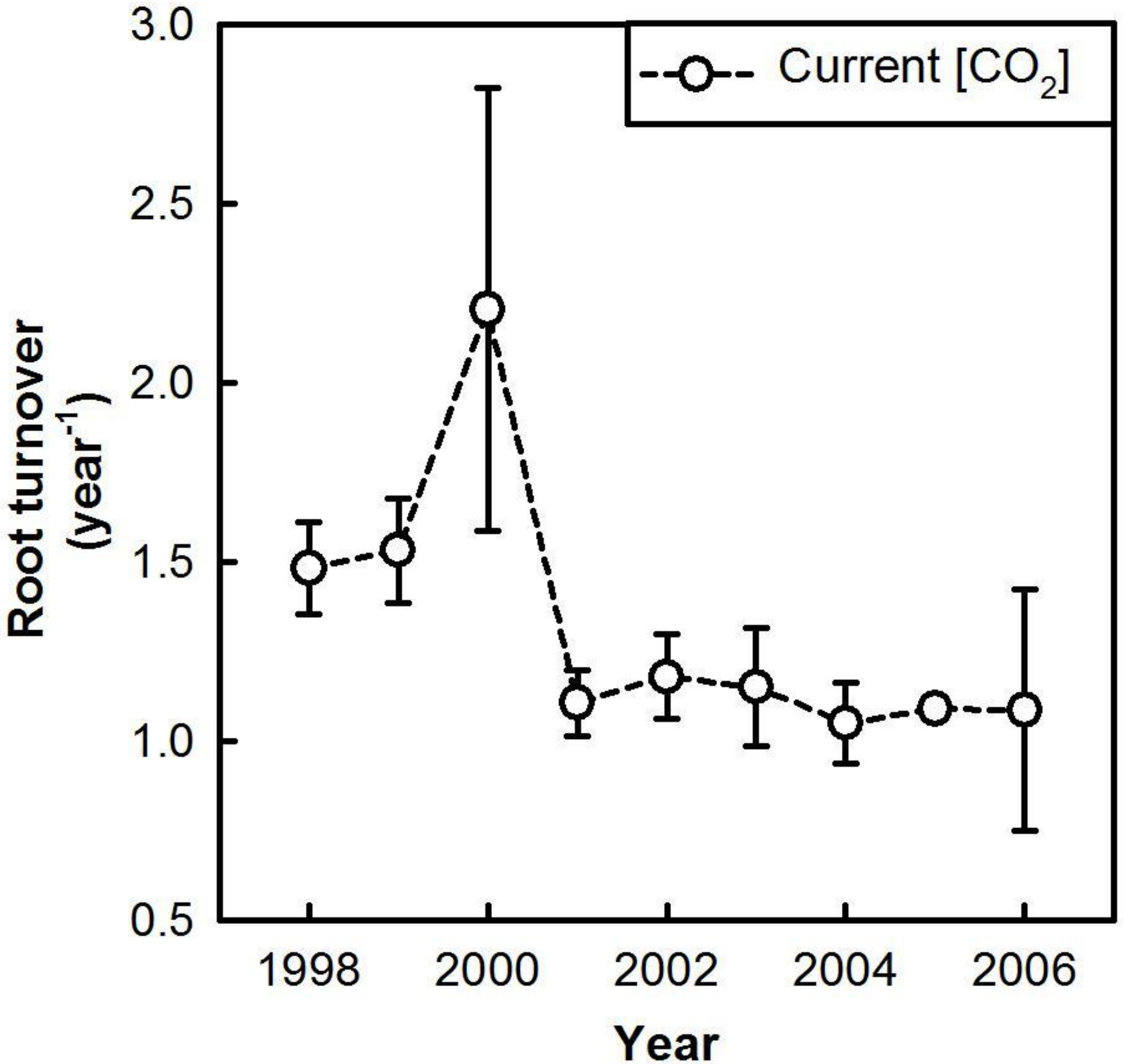
Has elevated [CO_2] affected the turnover rate of the fine root population?

Elevated [CO_2] has not affected root mass or [N].

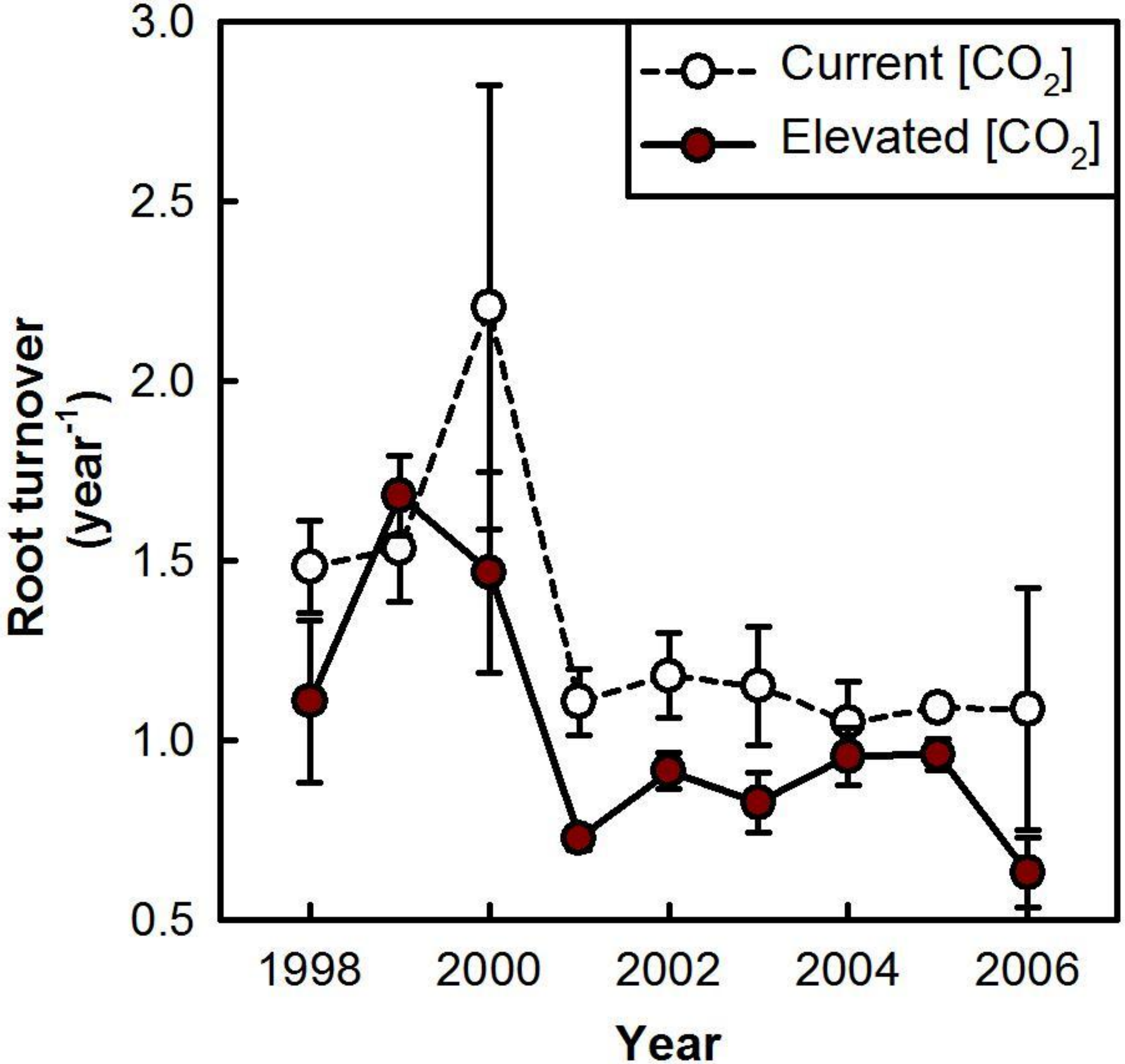
Biomass production doubled under elevated CO_2; response at depth to alleviate N limitation.

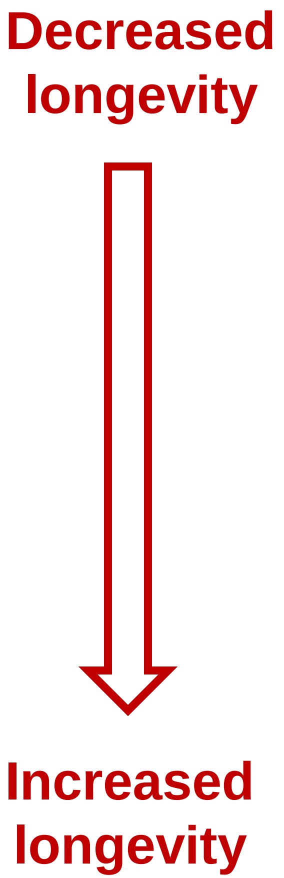
Has elevated [CO_2] affected the turnover rate of the fine root population?

Root turnover stabilized over time as minirhizotron tubes colonized



Root turnover was slightly less under elevated CO_2





Elevated [CO_2] has not affected root mass or [N].

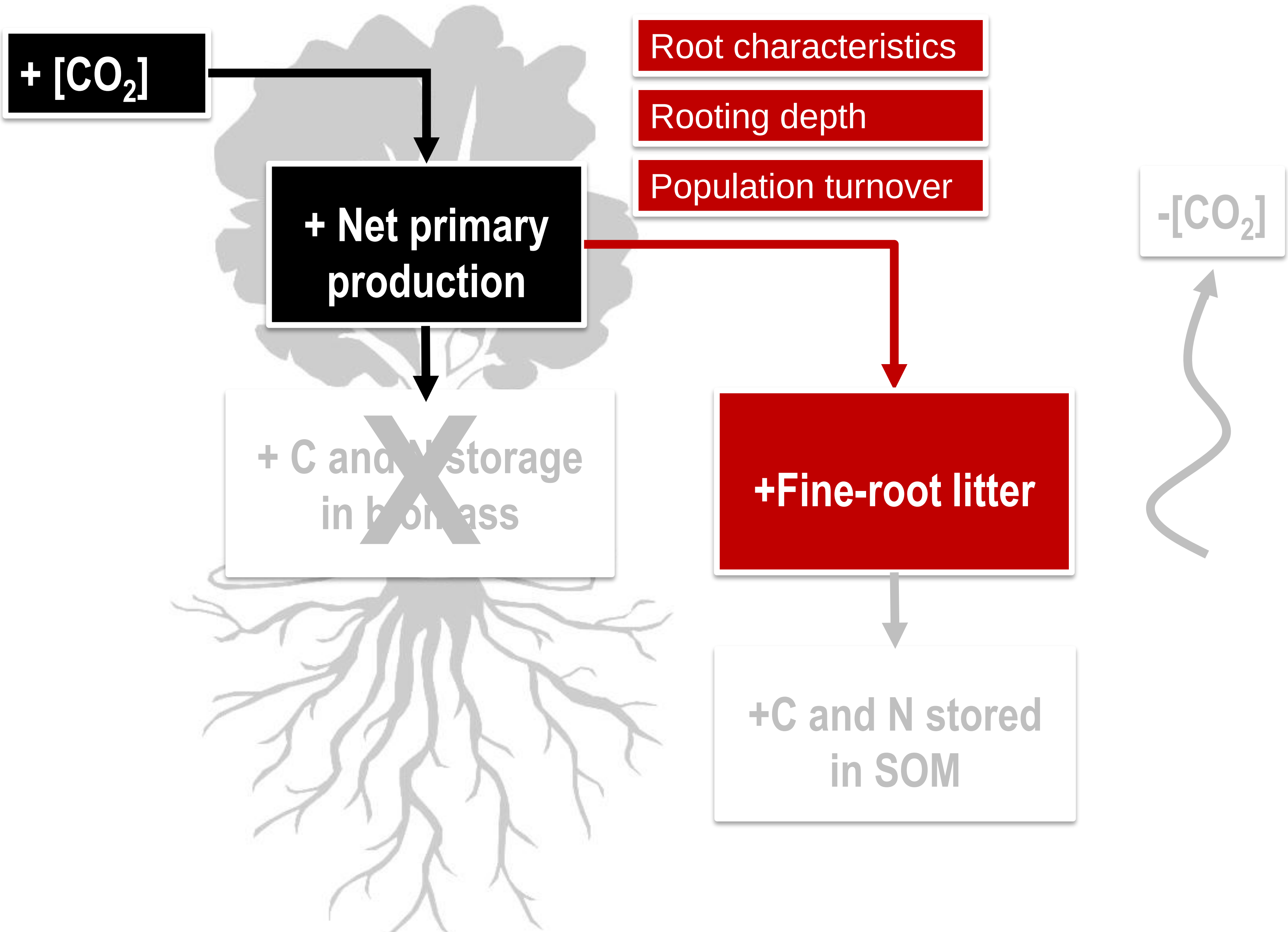
Biomass production doubled under elevated CO_2; response at depth to alleviate N limitation.

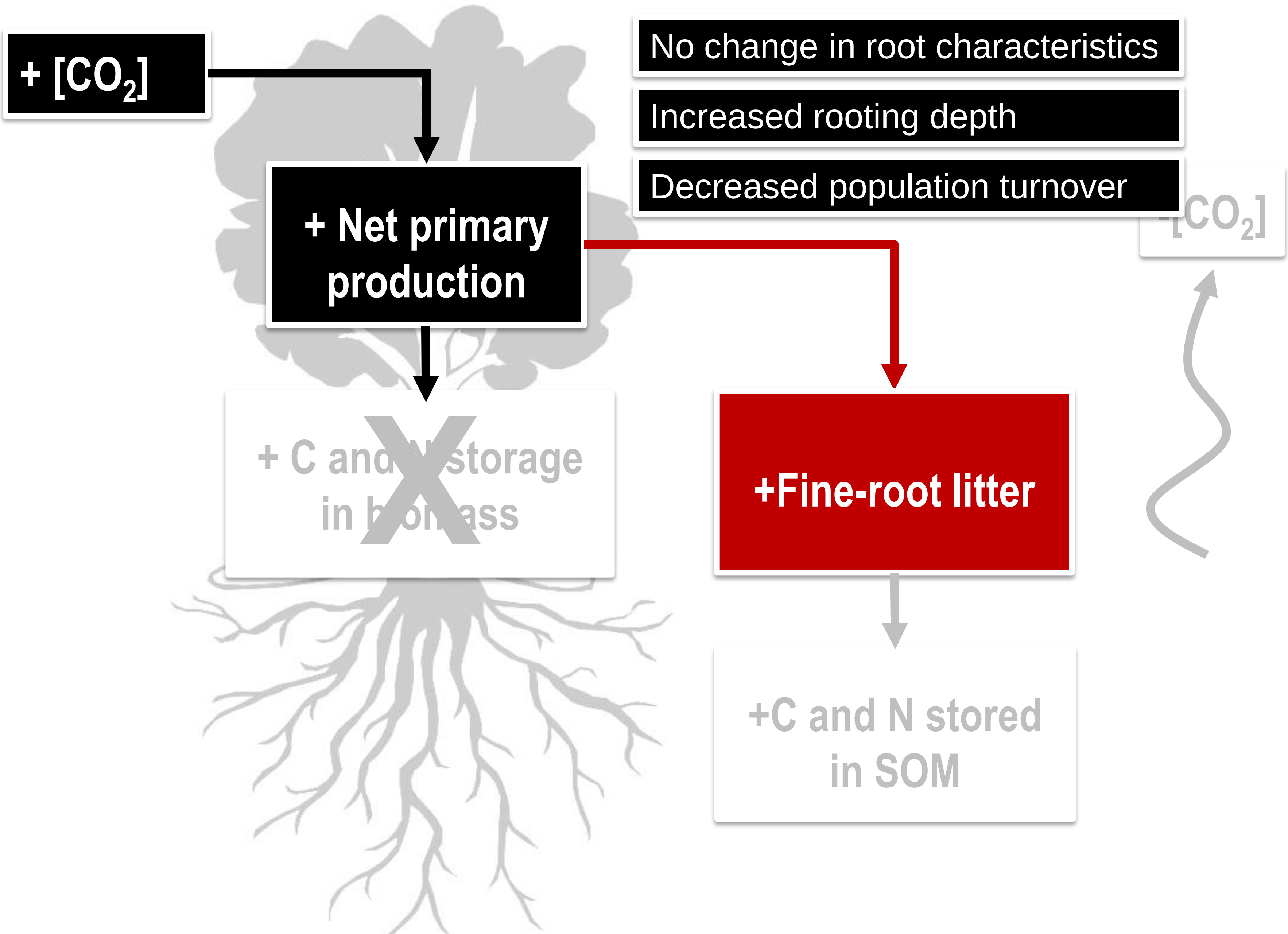
Has elevated [CO_2] affected the turnover rate of the fine root population?

Elevated [CO_2] has not affected root mass or [N].

Biomass production doubled under elevated CO_2; response at depth to alleviate N limitation.

Turnover declined slightly under elevated [CO_2]; roots living longer.

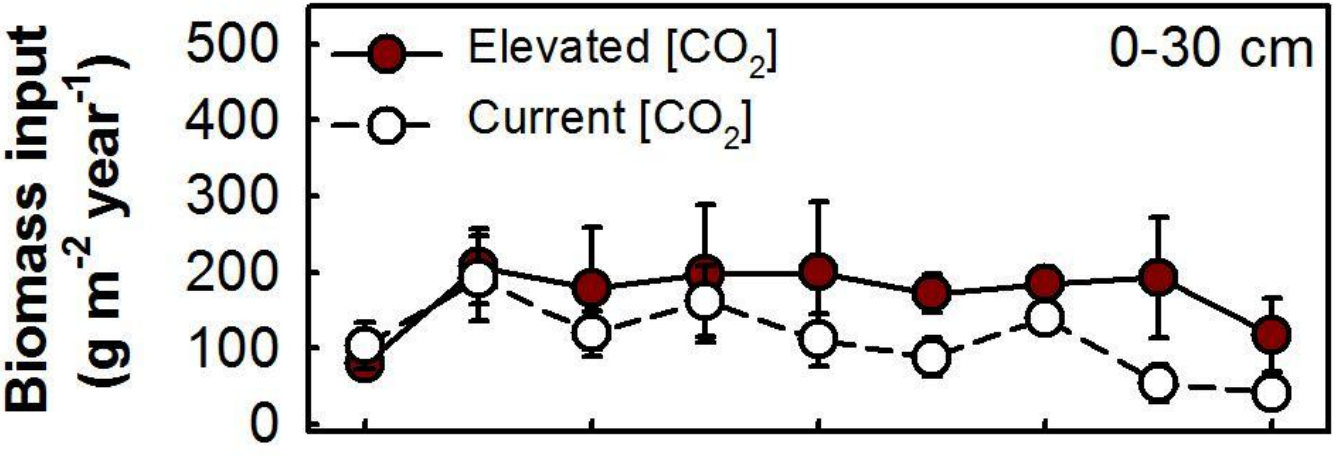

+ [CO_2]
Root characteristics
Rooting depth
Population turnover
+ Net primary production
-[CO_2]
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM



+ [CO_2]
+ Net primary production
No change in root characteristics
Increased rooting depth
Decreased population turnover
-[CO_2]
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM

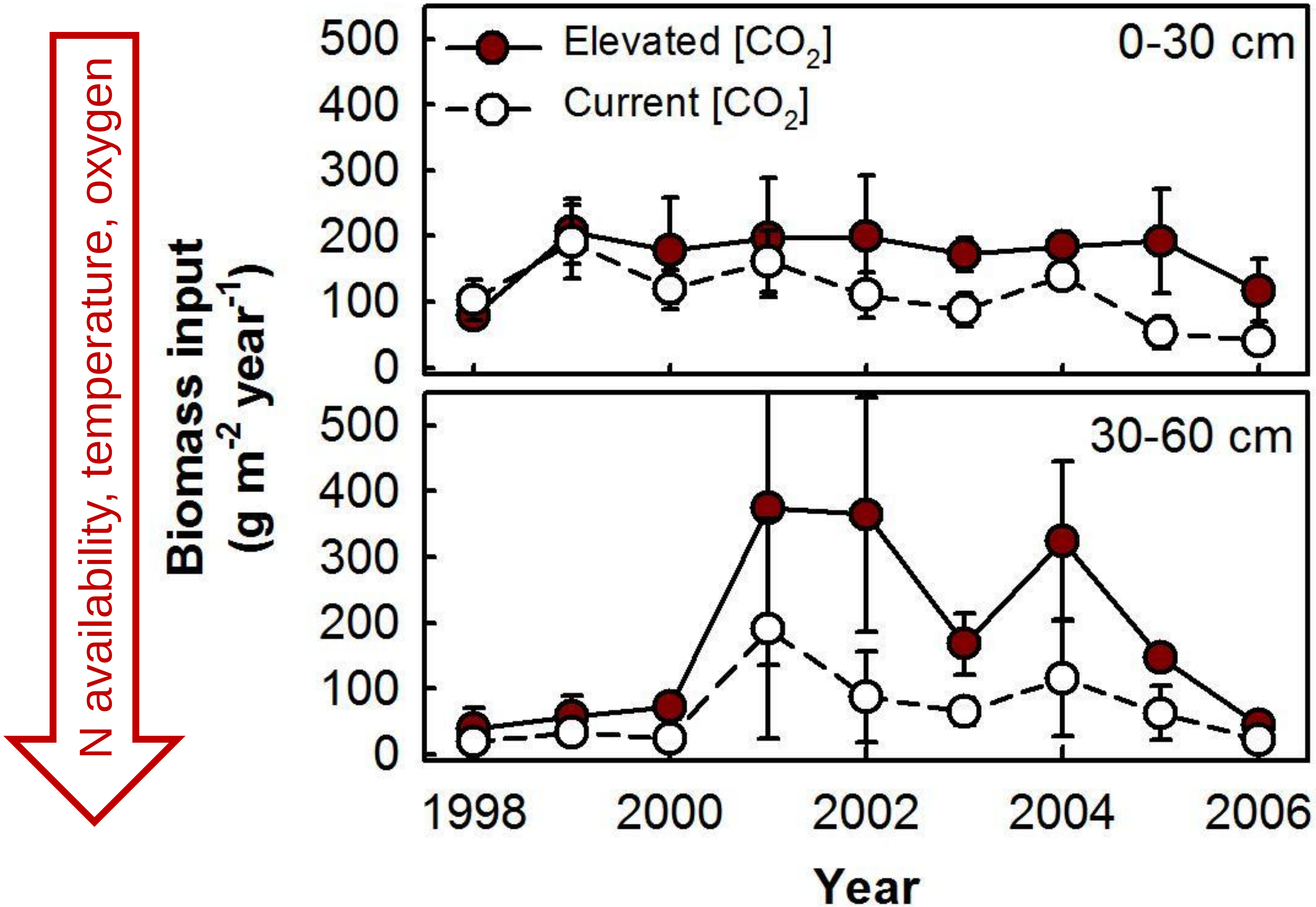
Does increased biomass allocation to fine roots lead to greater inputs of carbon and nitrogen to the soil?

Root biomass input to the soil was greater under elevated [CO_2]

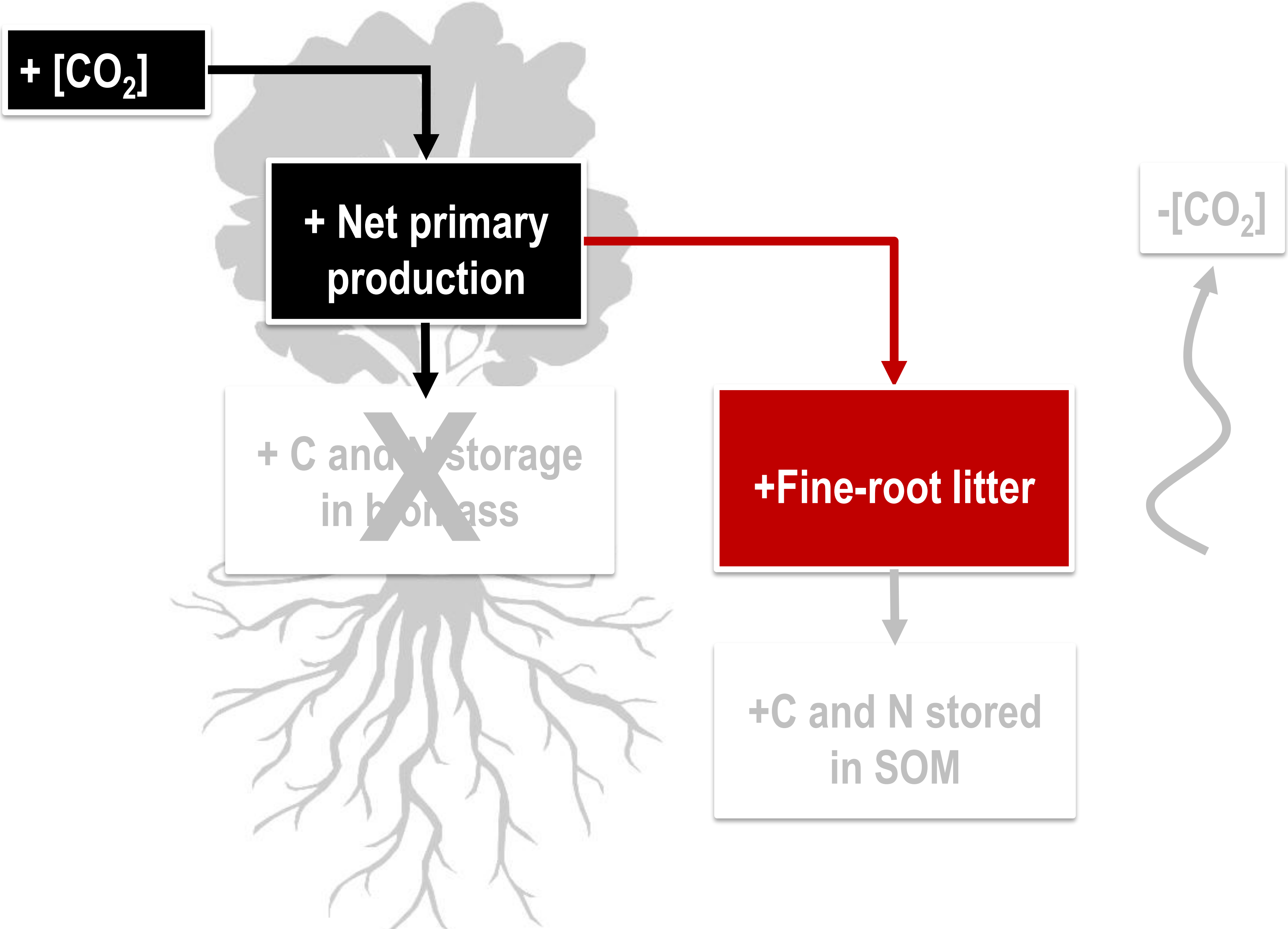


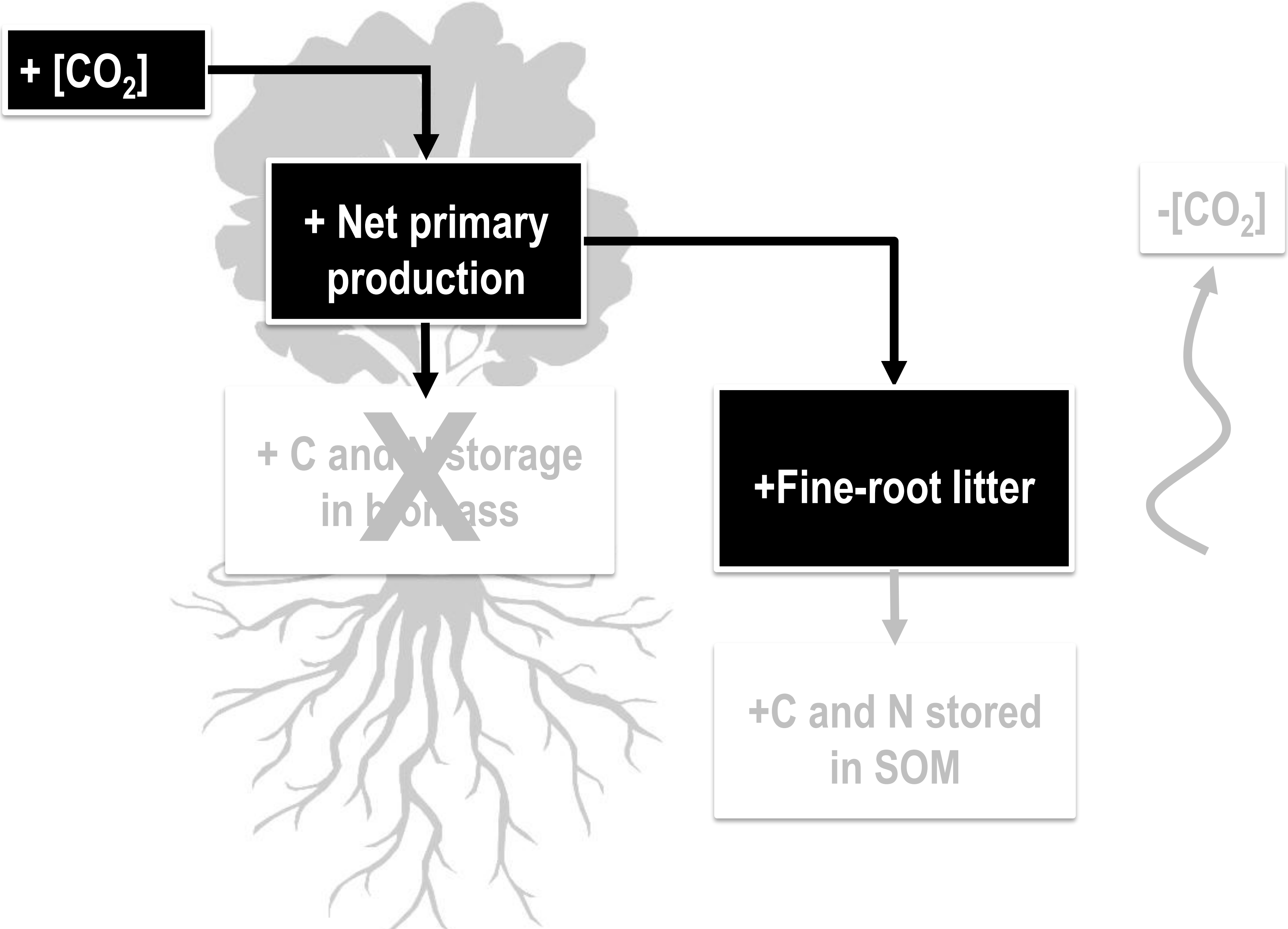
SOM dynamics in ecosystem models

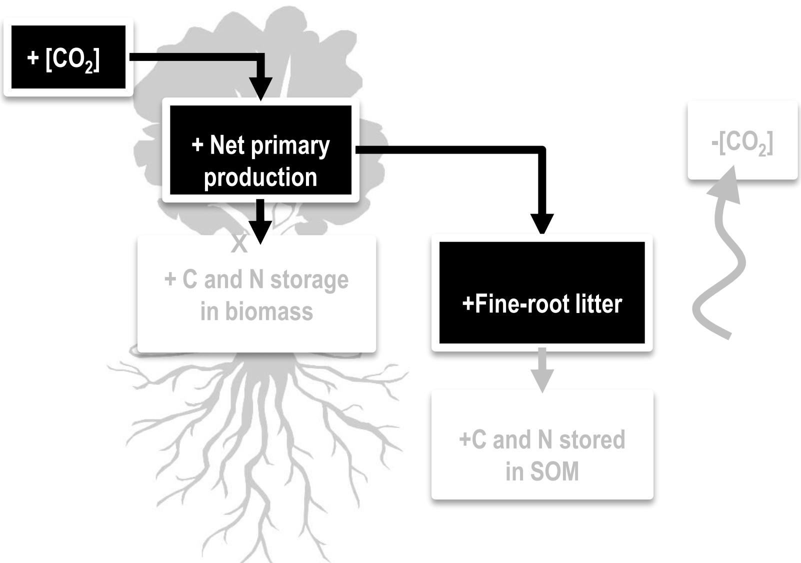
More than half of the inputs were below 30 cm depth



SOM dynamics in ecosystem models


+ [CO_2]
+ Net primary production
+ C and
storage
in b
ass
X
+Fine-root litter
+C and N stored in SOM
-[CO_2]

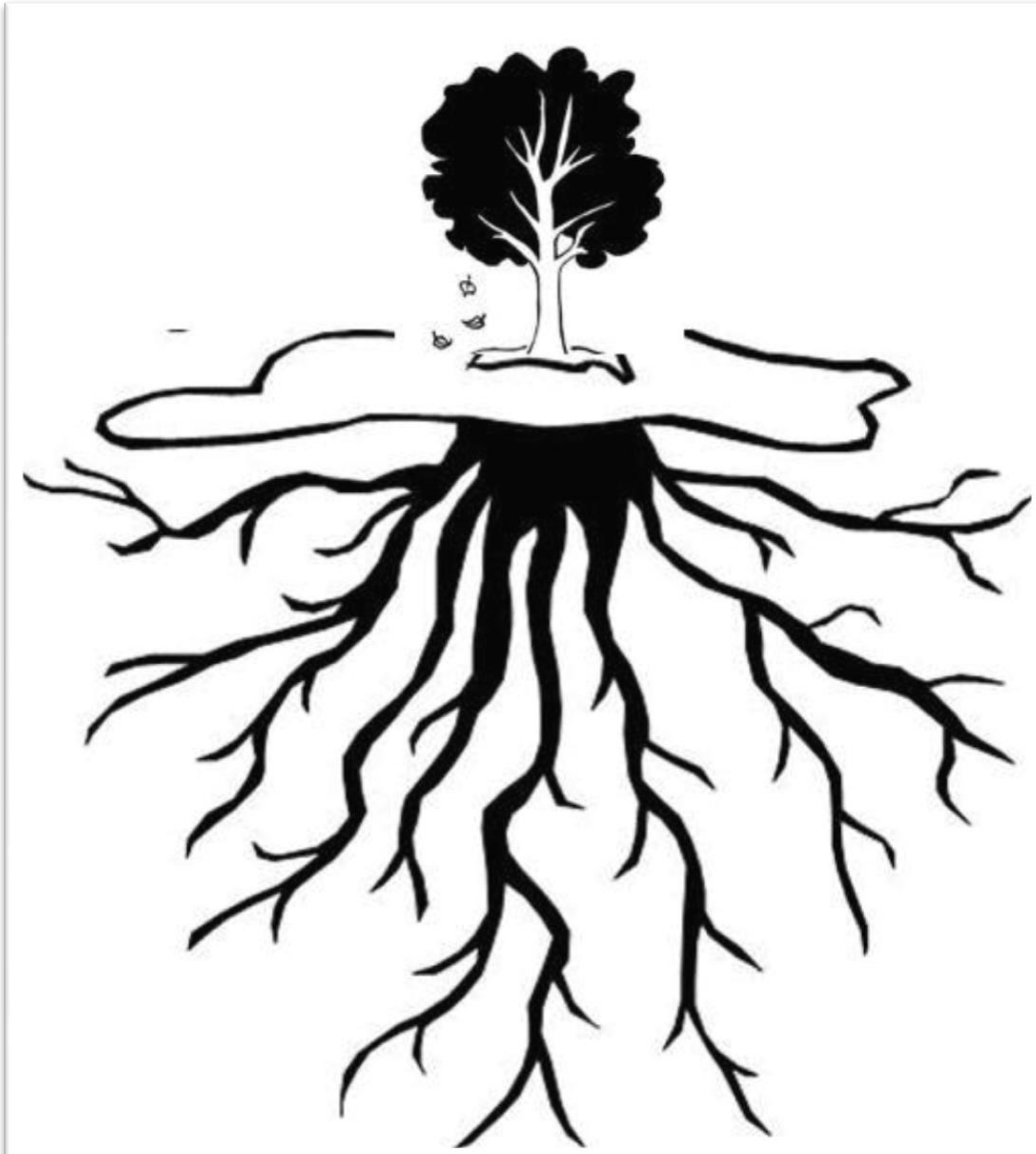

+ $[CO_2]$
+ Net primary production
+ C and storage
in b ass
X
+Fine-root litter
+C and N stored in SOM
$-[CO_2]$

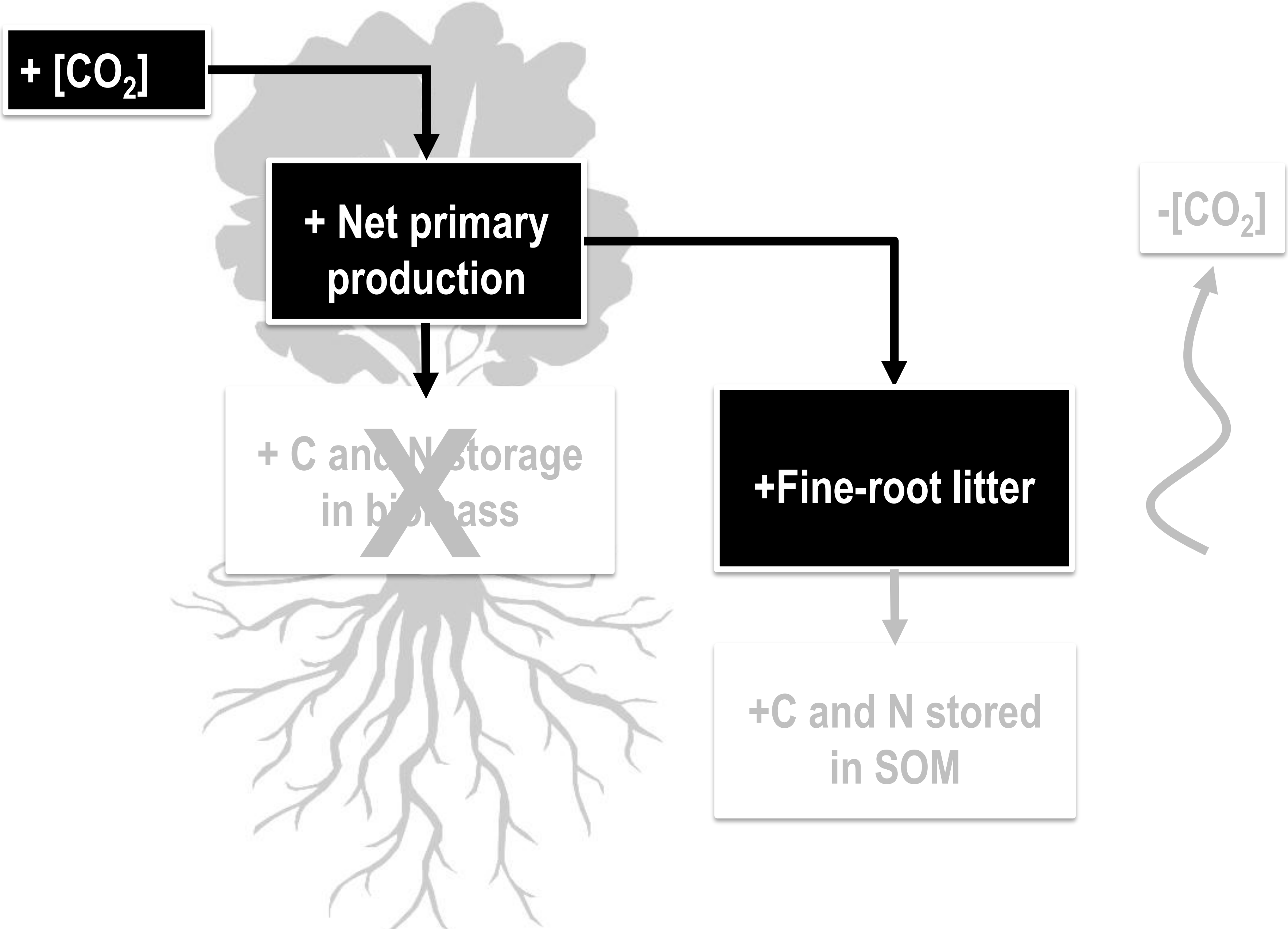


Root biomass and N content estimated from MR data with continuous functions based on root diameter

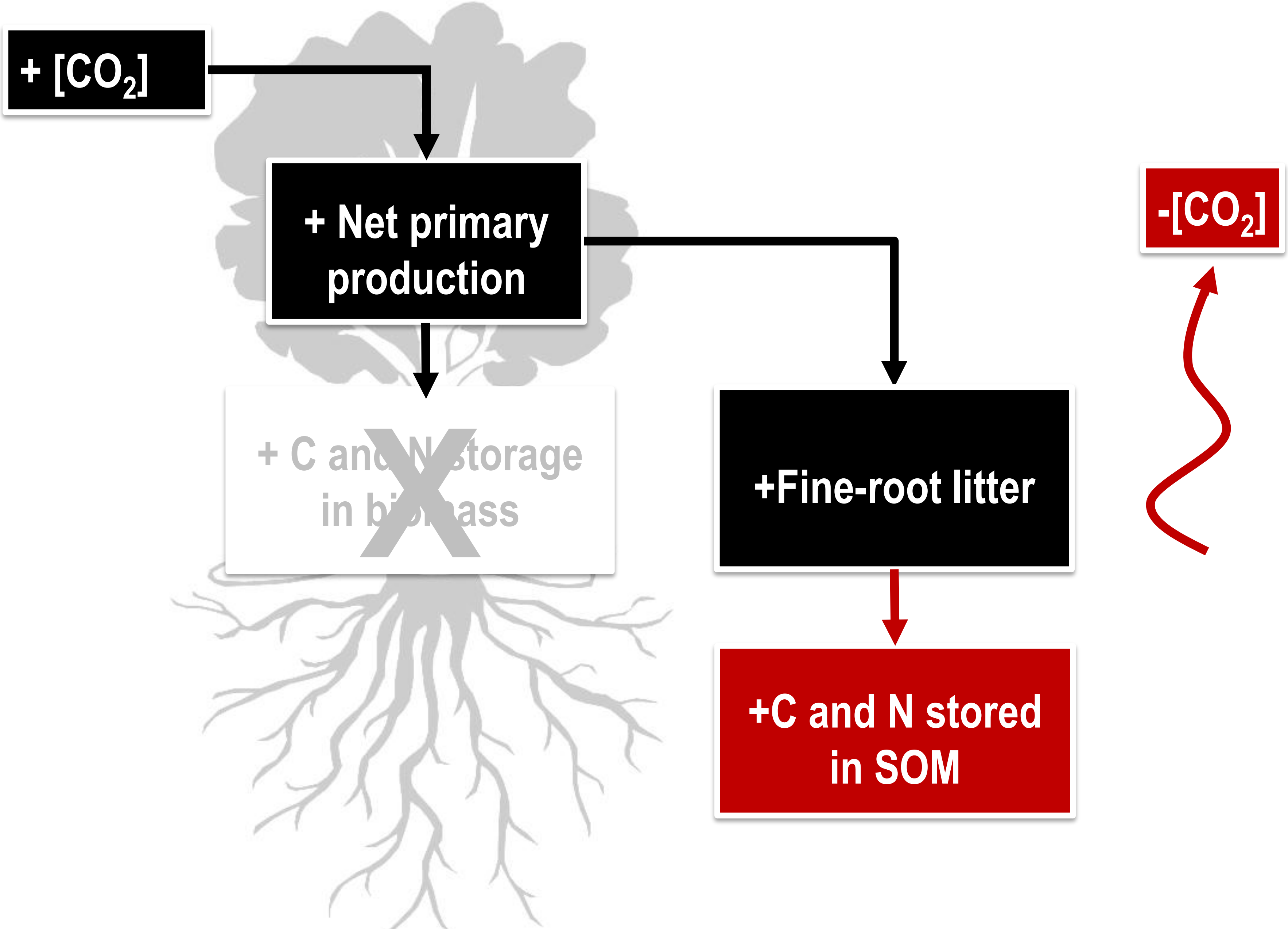
Though turnover was somewhat slower, C and N input from fine-root mortality doubled under elevated [CO_2]

Important to incorporate rooting depth and N feedbacks into ecosystem models



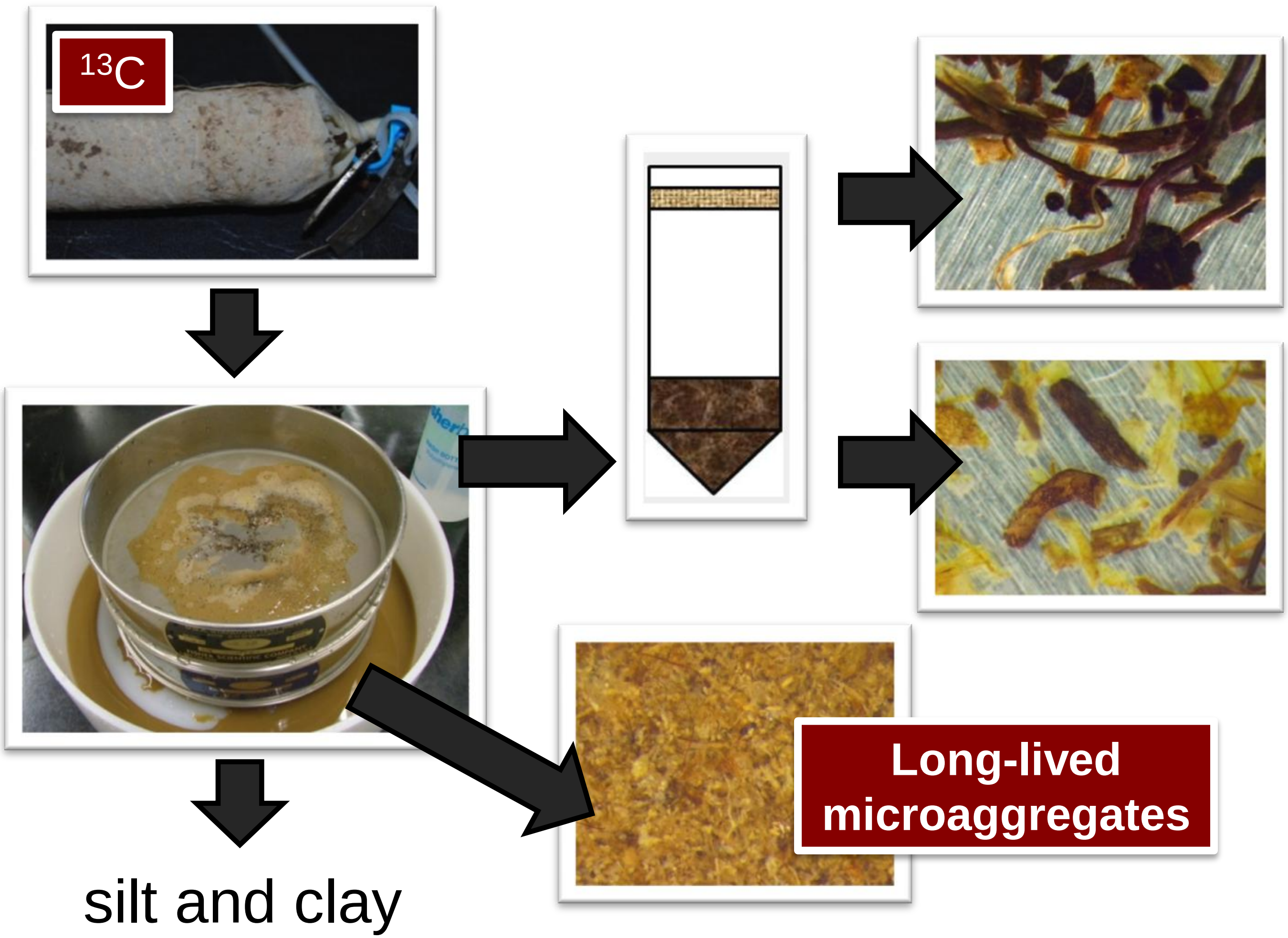


+ $[CO_2]$
+ Net primary production
+ C and N storage in biomass
X
+Fine-root litter
+C and N stored in SOM
-$[CO_2]$



+ [CO_2]
+ Net primary production
+ C and N storage in biomass
+Fine-root litter
+C and N stored in SOM
-[CO_2]

Our next step will be to link root decomposition with soil C storage



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For more information, see: Iversen CM, Ledford L, Norby RJ (2008) CO_2 enrichment increases carbon and nitrogen input from fine roots in a deciduous forest. *New Phytologist* ***179****: 837–847.*