The Impact of Land Use Change for Greenhouse Gas Inventories and State-level Climate Mediation Policy:

A GIS methodology applied to Connecticut

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ALM Thesis, Sustainability and Environmental Management Program, Harvard University

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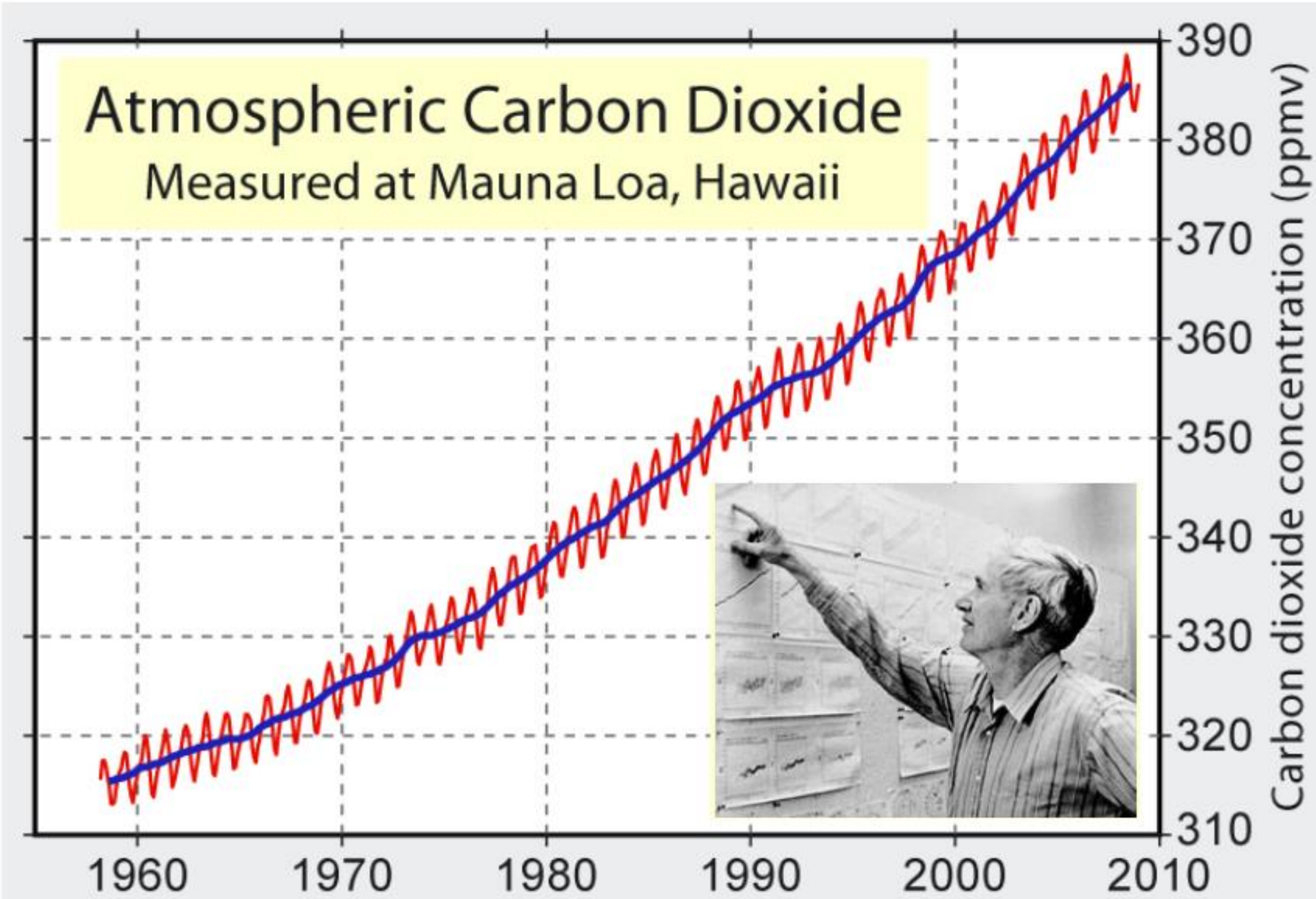
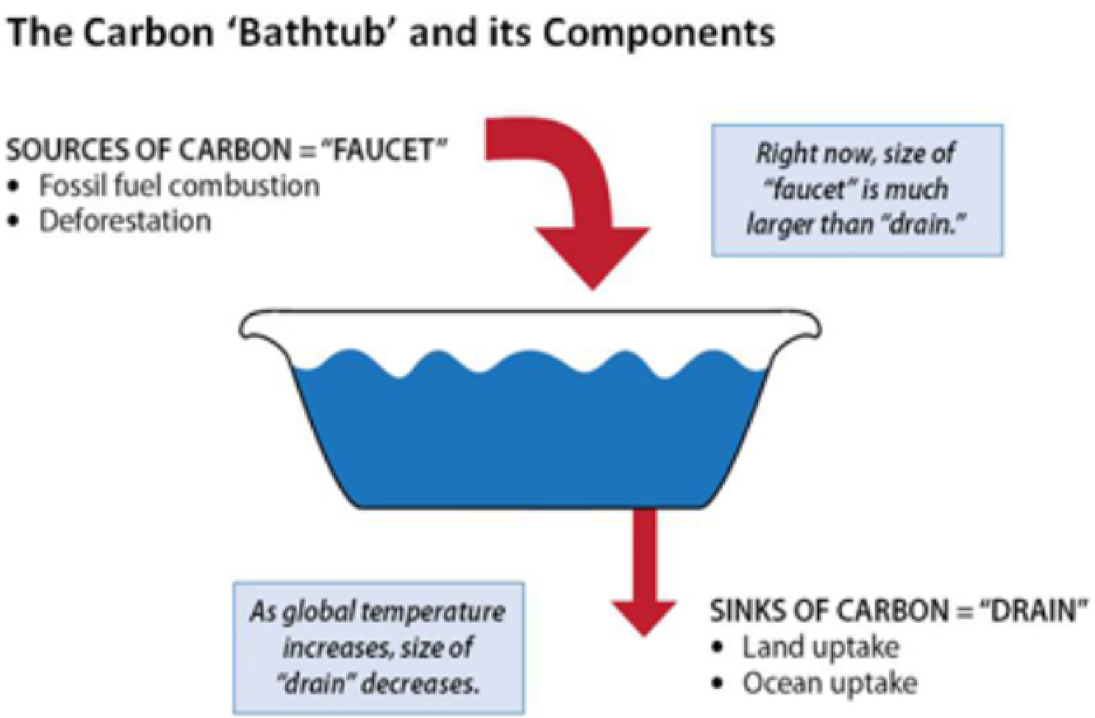
HARVARD SCHOOL OF PUBLIC HEALTH

Measured Rise of CO_2: now 397 ppm



Charles David Keeling

Sources and Sinks



↑CO_2
when we

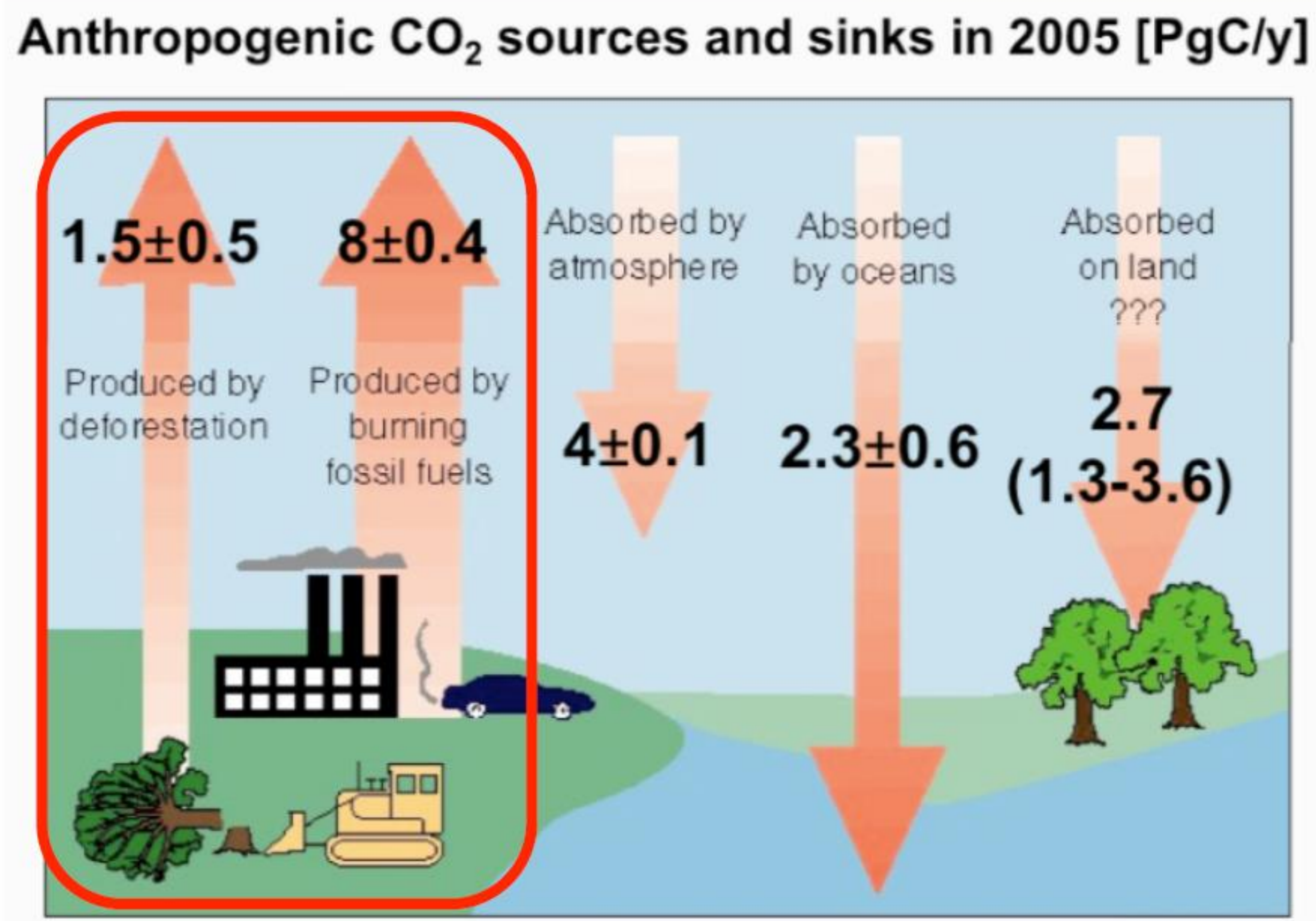
ADD SOURCES

or

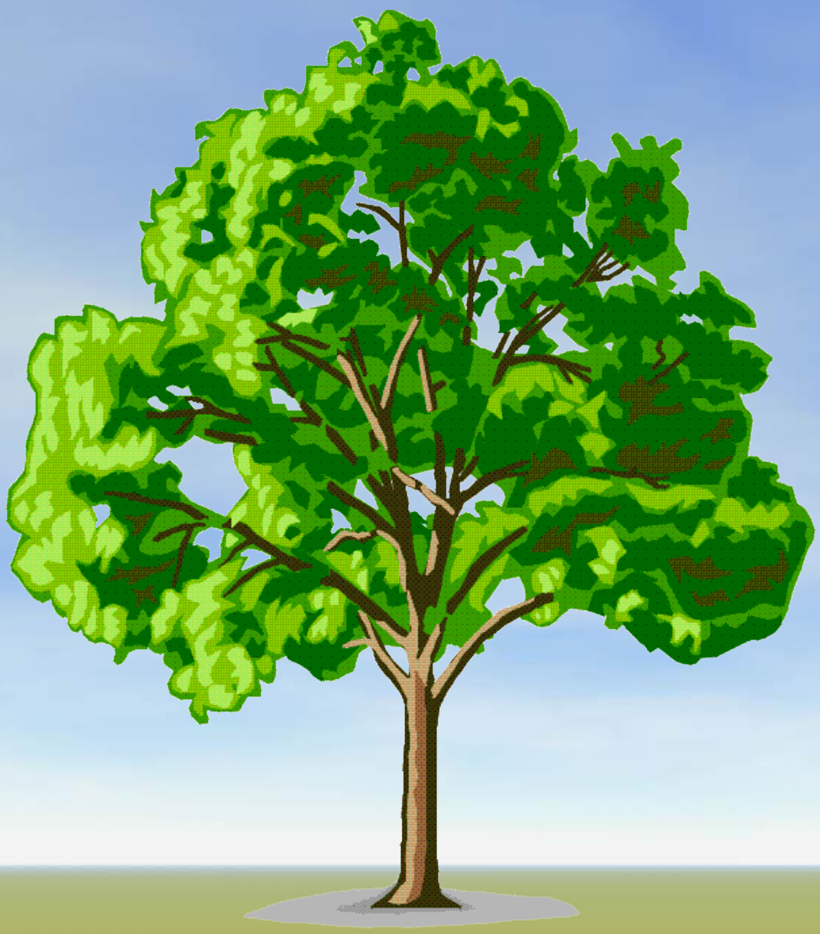
REMOVE SINKS

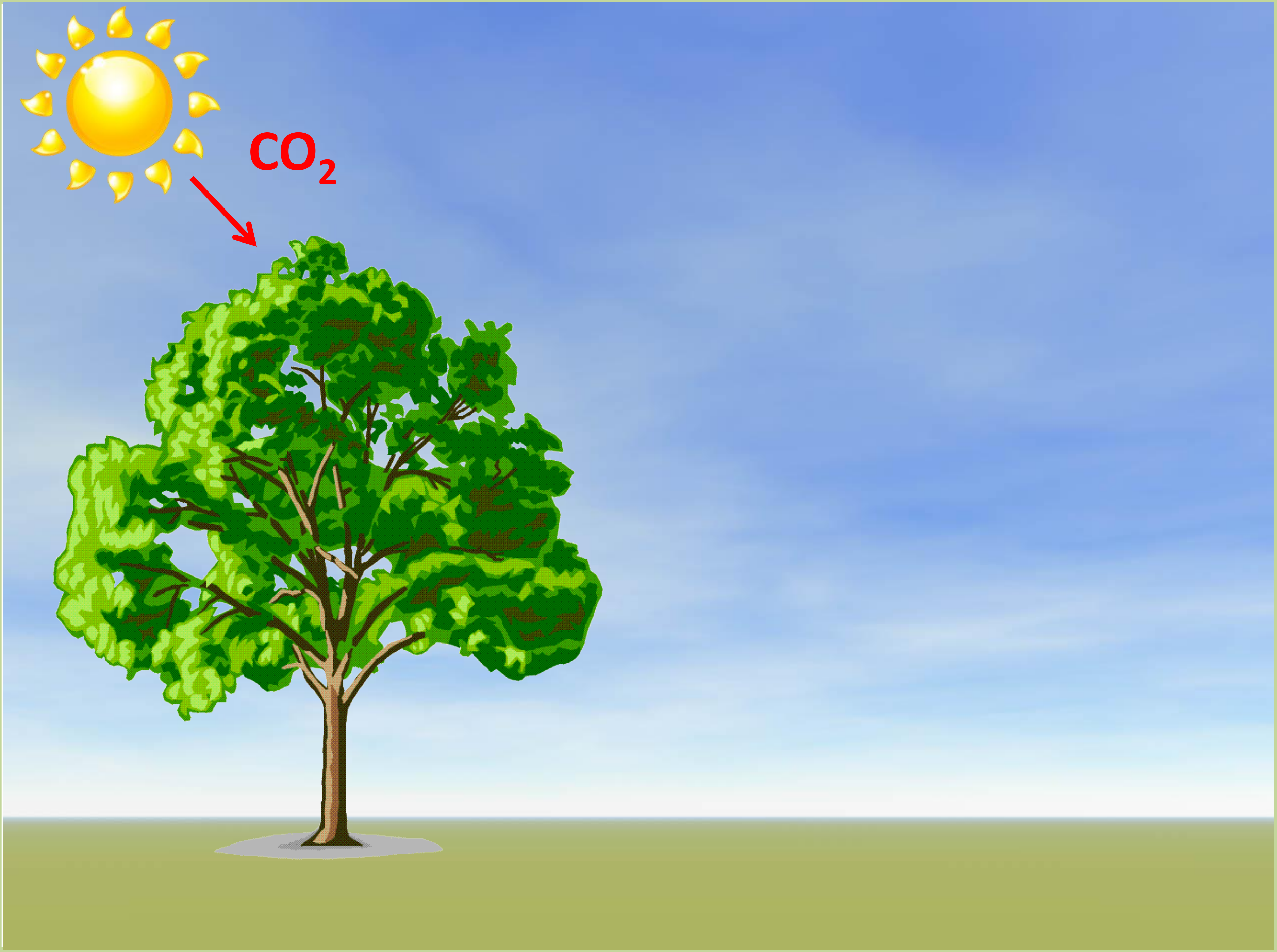
(http://www.epa.gov/climatechange/science/causes.html)

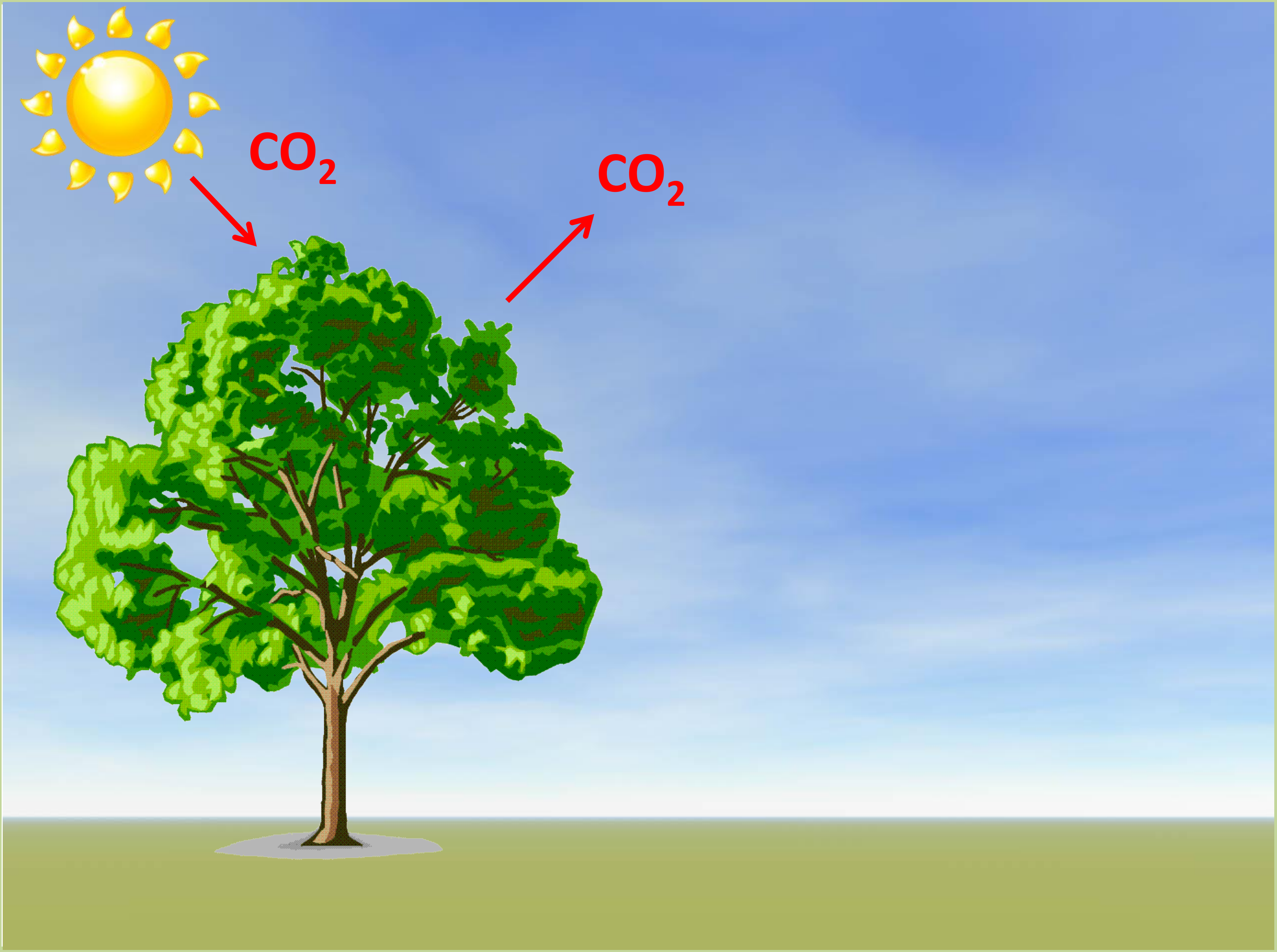
Sources and Sinks

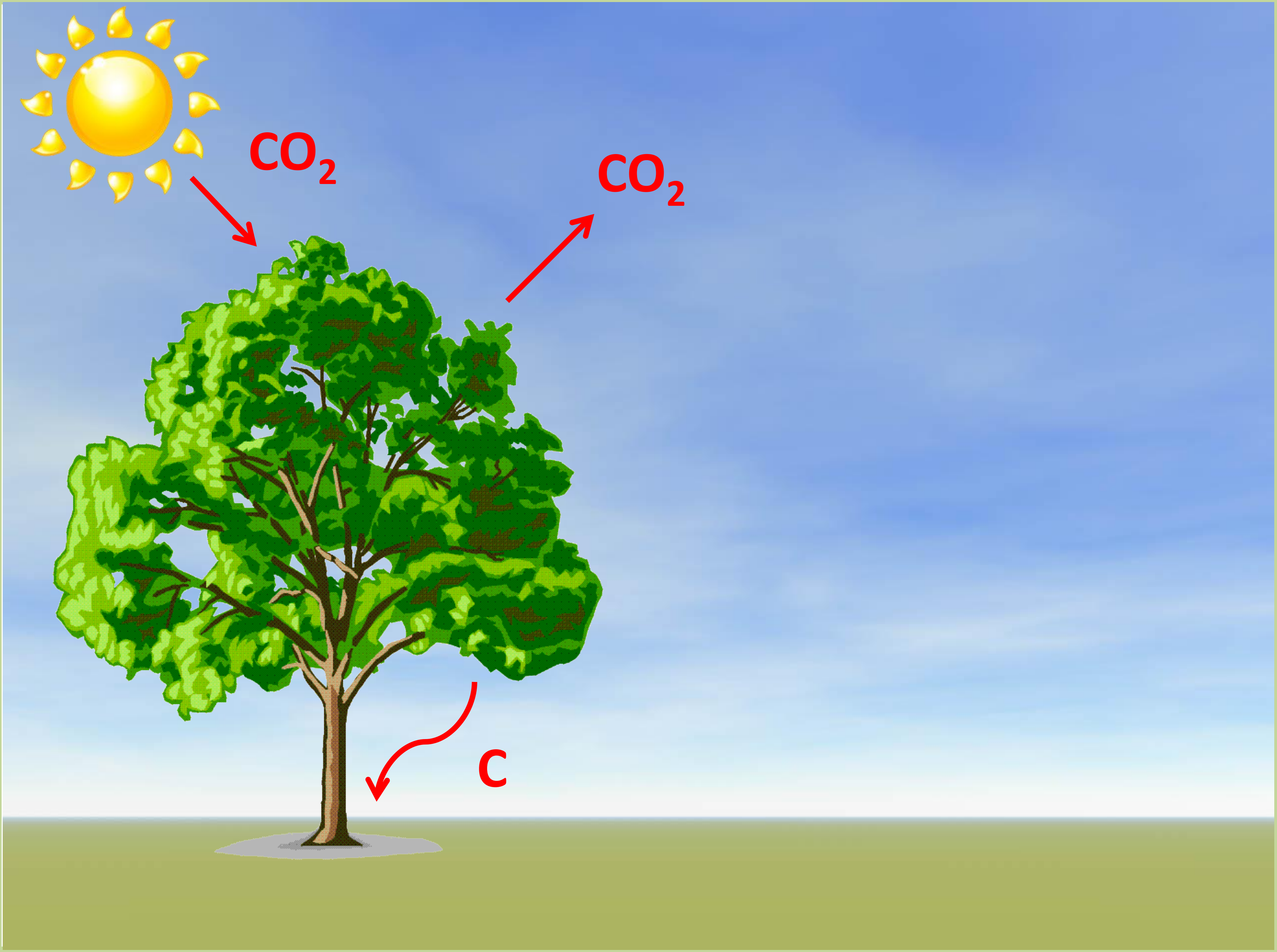


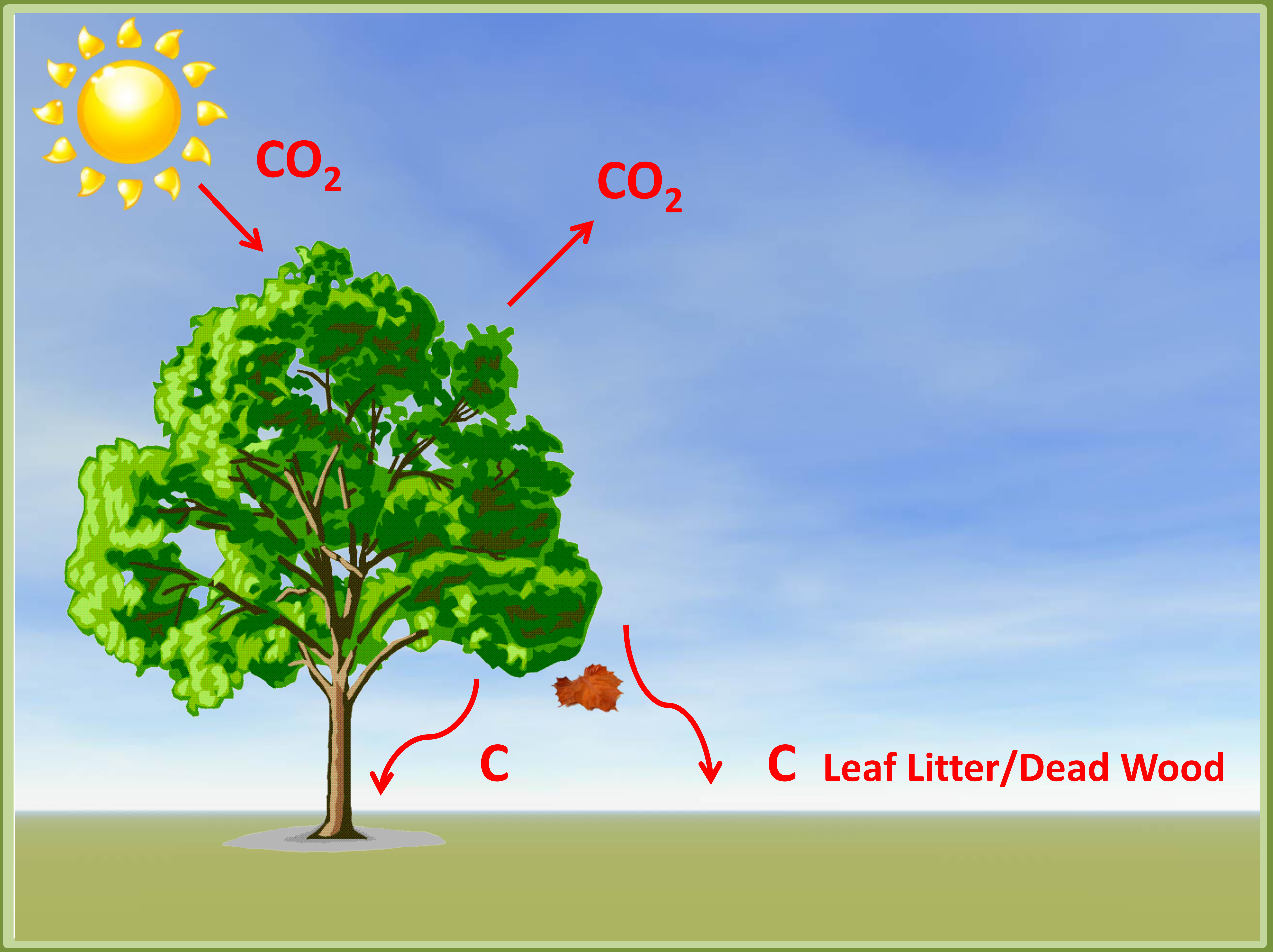
Goddard Institute for Space Studies.NASA.gov

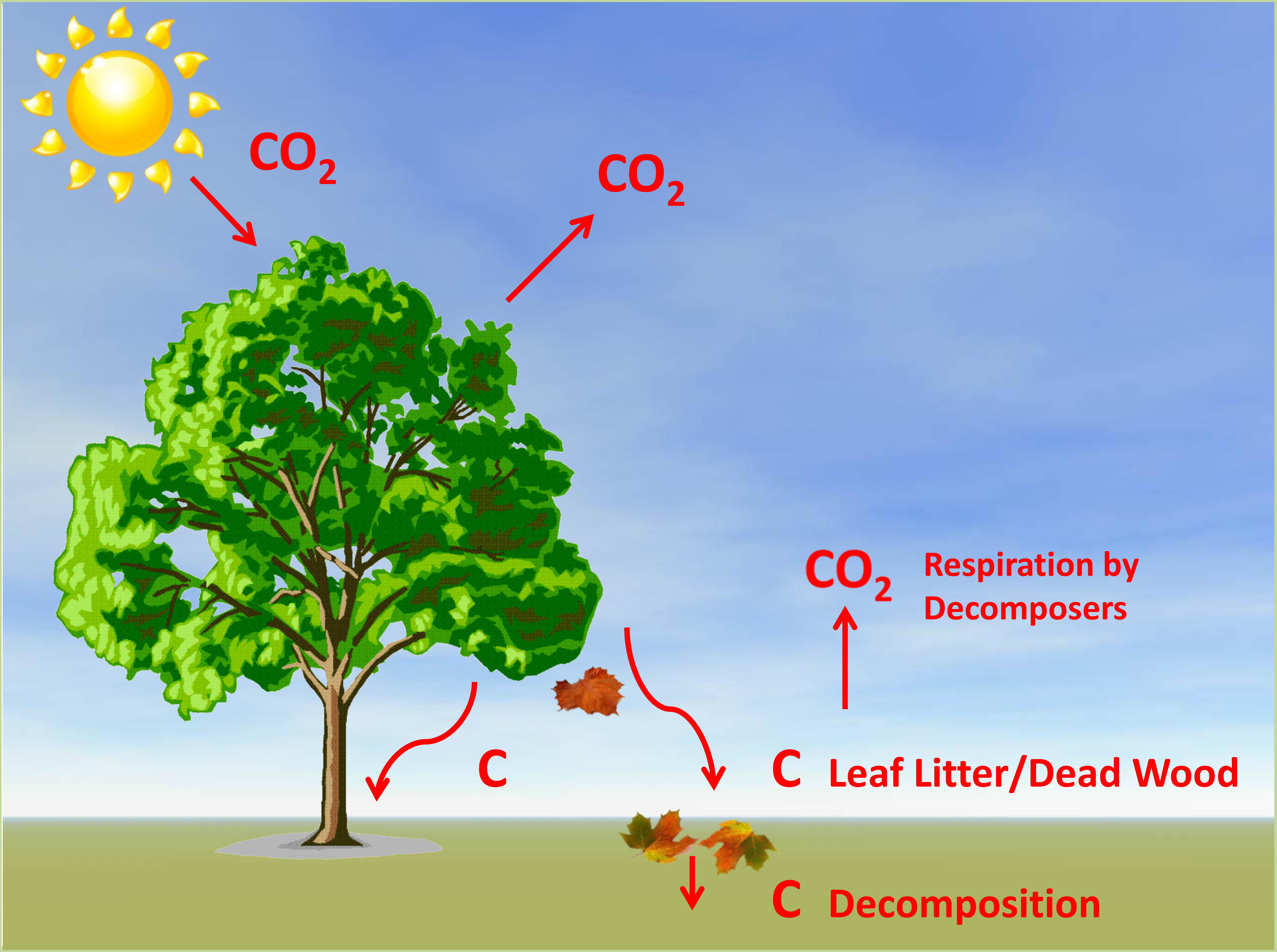



CO_2

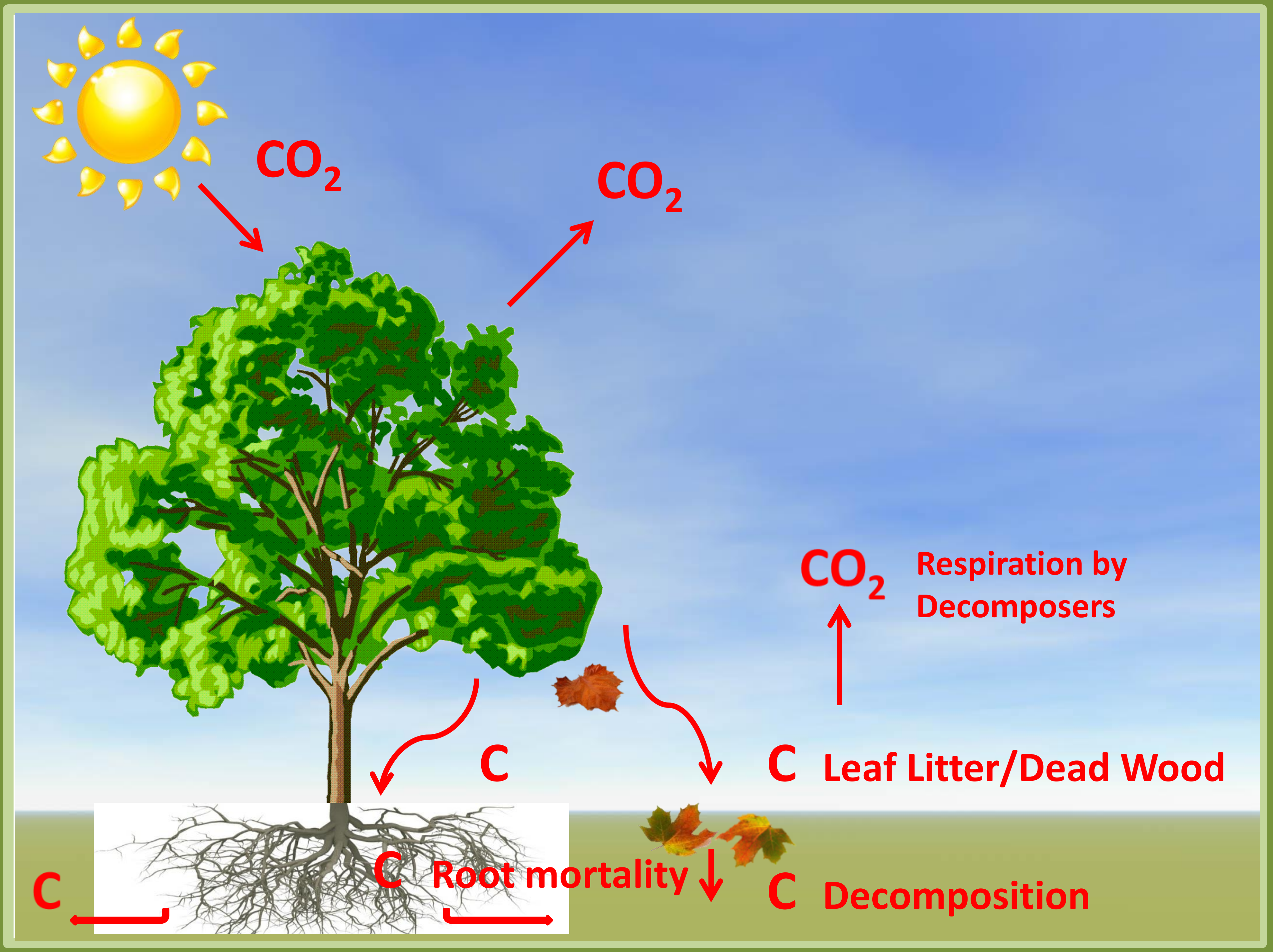

CO_2
CO_2


CO_2
CO_2
C

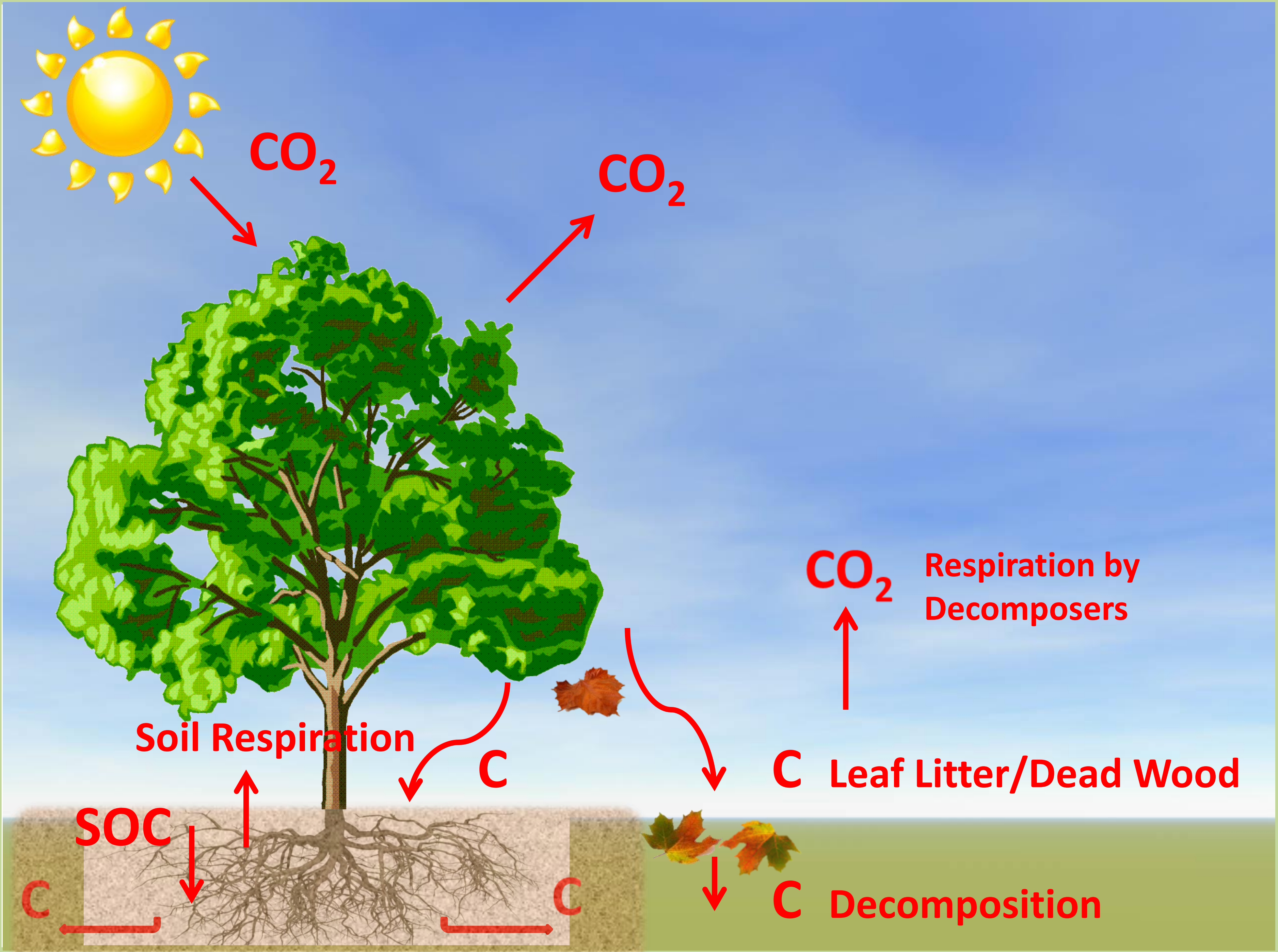

CO_2
CO_2
C
C Leaf Litter/Dead Wood



CO_2
CO_2
CO_2
Respiration by Decomposers
C
C Leaf Litter/Dead Wood
C Decomposition



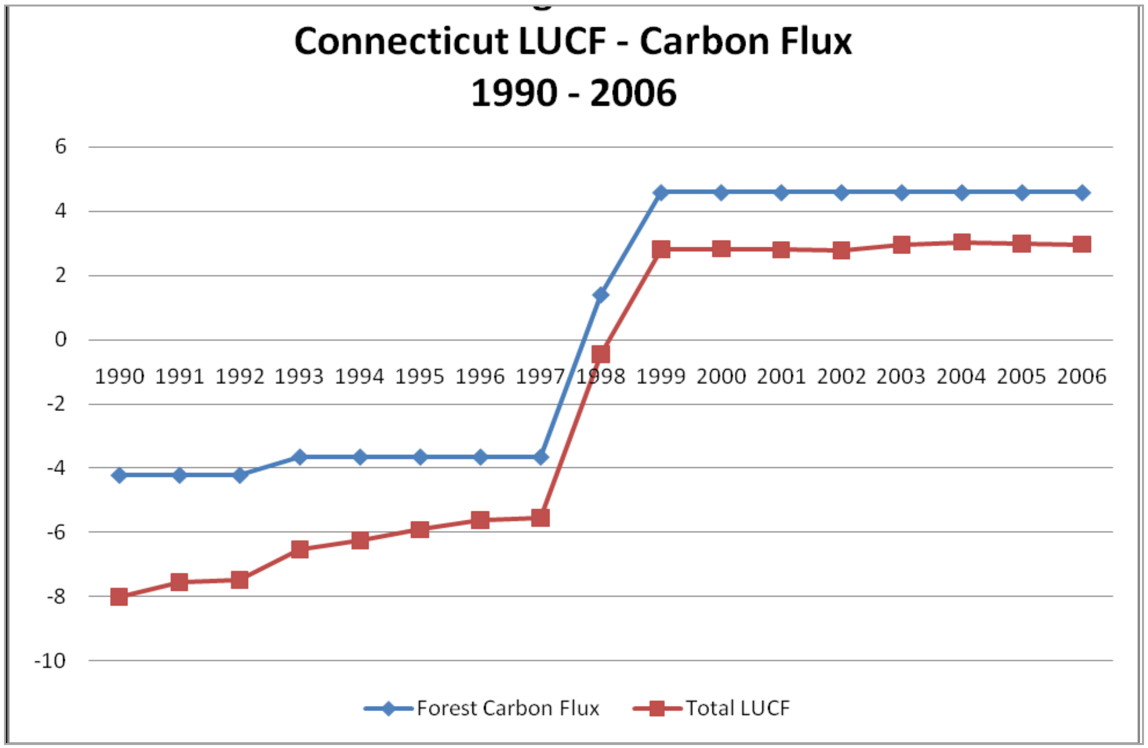
CO_2
CO_2
CO_2
Respiration by Decomposers
C
C Leaf Litter/Dead Wood
C Root mortality
C Decomposition
C



CO_2
CO_2
CO_2
Respiration by
Decomposers
Soil Respiration
C
C
Leaf Litter/Dead Wood
SOC
C
C
C
Decomposition

Problem: Inconsistent carbon sink accounting for CT's land use & forestry

Using EPA State Inventory Tool, CT's LUCF sector moved from **(-) 4.2** MMTCO$_2$e in 1990 → **(+) 4.5** MMTCO$_2$e by 2006



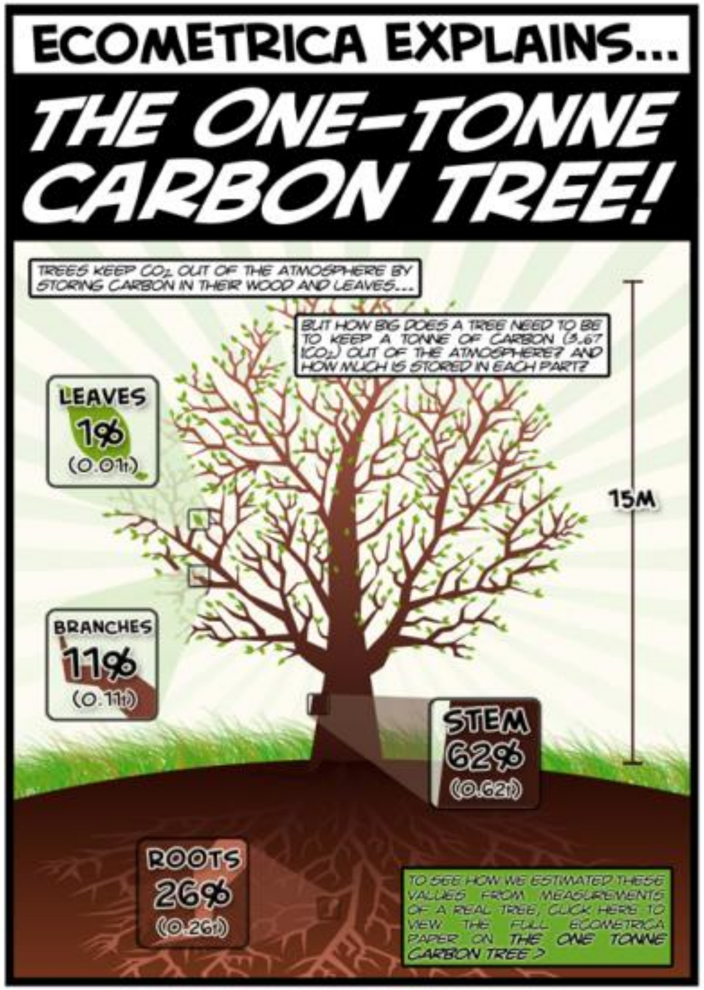
CT Department of Energy and Environmental Protection, *Climate Change*, 2010a

My Research Question:

If terrestrial C sequestration were evaluated from a two-step methodology:

Scientific + Financial

Could land conservation and strategic land use planning prove more cost-effective public policy instruments, on a $ per $ basis, for states to reduce C emissions?



Thesis Conclusions:

Fact: Ratio of forest loss to C sequestration = **1: 4.62** due to land conversion from high → low C densities.

Cost: $ invested in C reduction through land conservation offer a greater yield than many policies currently being pursued by state/regional govts.

Opportunity: Demographic shift of retiring baby boomers south + small forest tracts they own presents a one-time window to preserve natural C sinks.

Connecticut's forest loss (green line) is the steepest in New England

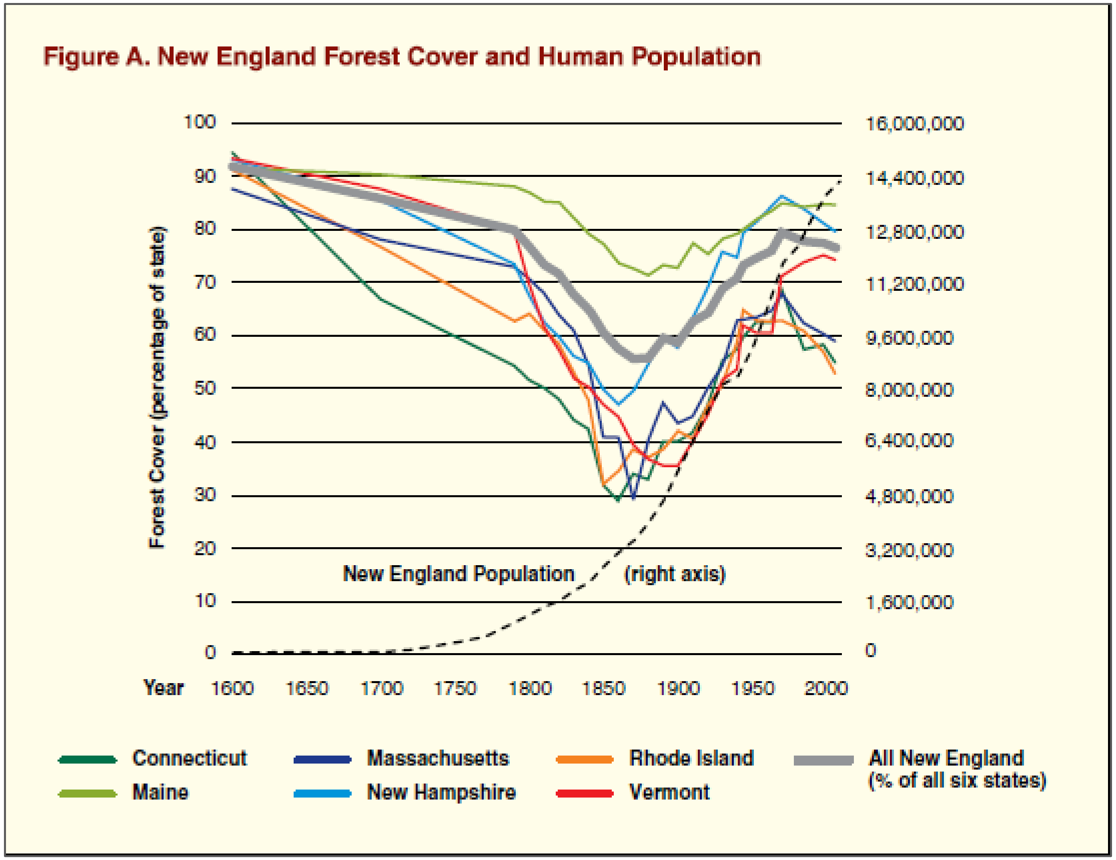


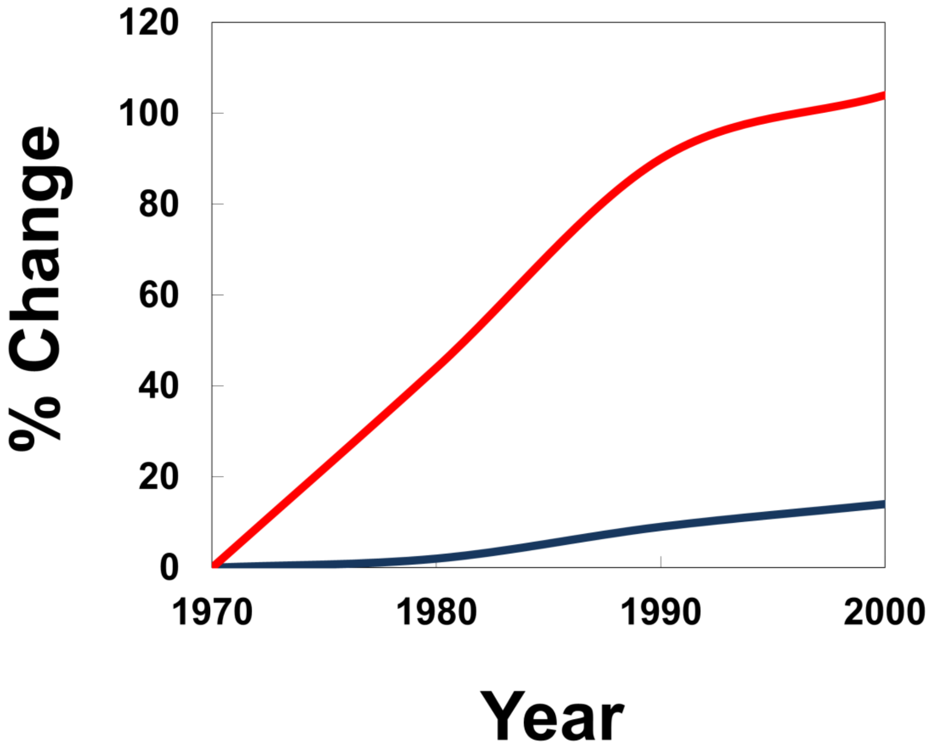
Figure A. New England Forest Cover and Human Population

Stein, et al. (2005) *Wildlands and Woodlands*, Harvard Forest.

CT Forest Loss and Conversion

- CT experienced the **steepest rate of forest** loss vis-à-vis neighboring states since 1970
- 20% classified as **urban forests**
- 49% **< 100 yards** of hard devt or agriculture (Butler/2011)
- New London County may **lose btw 40-63%** to land conversion & devt by 2031 (Stein, 2005)
- **Low-density housing** (6-25 homes/km^2) is fastest growing driver of NE's land change

Connecticut's Land Development is far outpacing Population Growth, 1970-2000



Data Sources:
Blue line: U.S. Bureau of the Census, 2011
Red line: Orfield & Luce, Metropatterns, 2003

"Development outside Hartford, CT."
Woodlands & Wildlands, Harvard Forest

Research objectives in proposing a new land use change and forest methodology

1. **Assign a C sink value to CT’s biomass.**
2. **Determine rates of C sink loss.**
3. **Quantify a long-term ratio of C capture to total GHG emissions.**
4. **Monetize the resulting sink valuation as $/tonCO_2$.**
5. **Specify conditions for replicating this methodology elsewhere.**
6. **Consider environmental and policy applications for my conclusions.**

Research Methods and Designs

InVEST *Carbon Storage and Sequestration* computer model provided simulation software to quantify and track terrestrial C storage

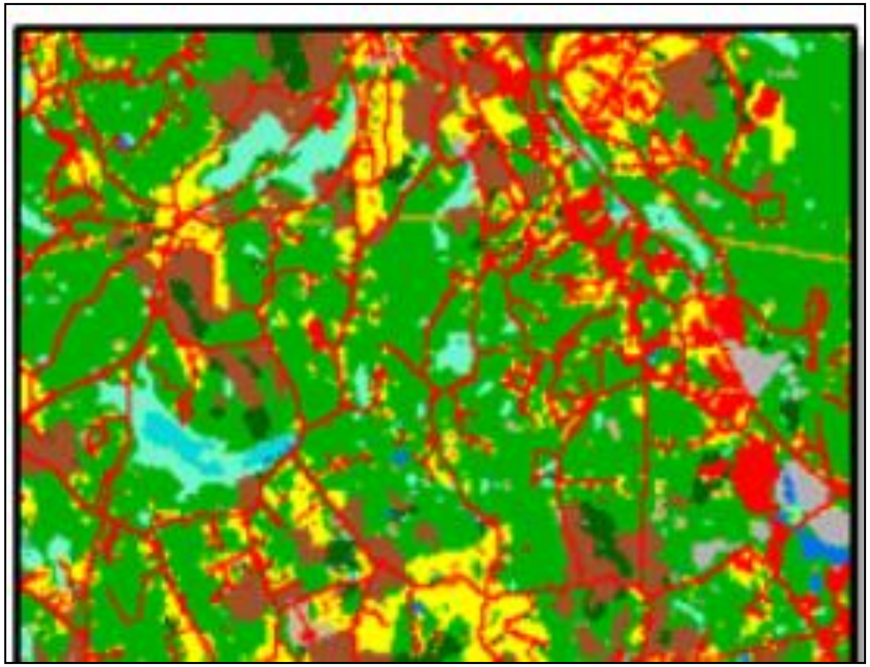
2 sets input data:

1. **Current Land use/land cover (LUCF) maps** sensed by CLEAR
2. **Carbon pool valuations**: above-ground, below-ground biomass, soil, dead organic matter

Research Methods: Input Data

1. 25 years of CLEAR raster data sets capturing land cover change for CT, 1985-2010

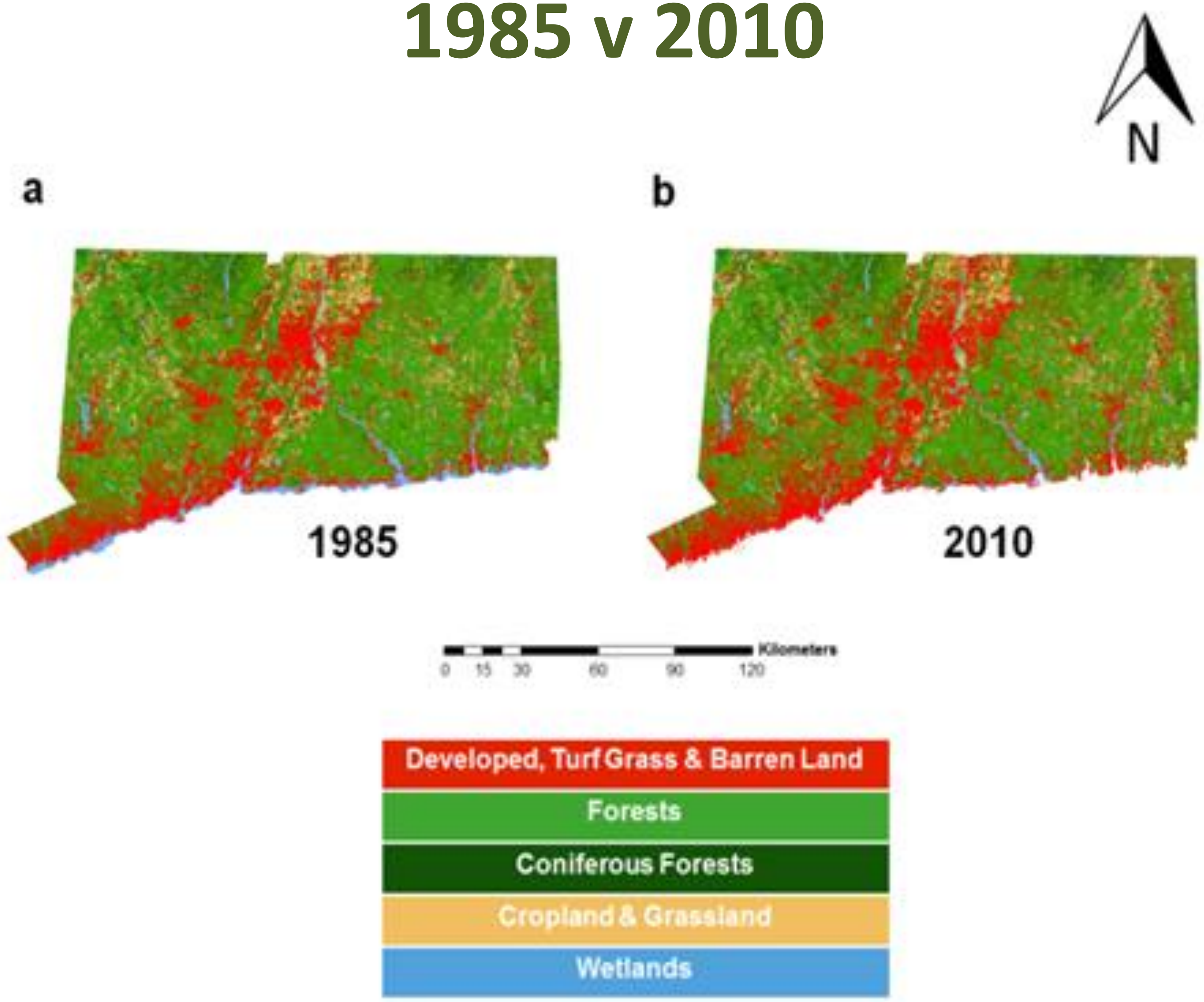
	1985		2010		Change	
-	sq. miles	% of state	sq miles	% of state	sq. miles	% of state
Developed	796.6	16.04%	945.5	19.04%	148.9	3.00%
Turf & Grass	308.7	6.22%	383.6	7.72%	74.8	1.51%
Other Grasses	65.2	1.31%	95.7	1.93%	30.5	0.61%
Agricultural Field	425.0	8.56%	362.1	7.29%	-62.9	-1.27%
Deciduous Forest	2466.0	49.66%	2301.9	46.35%	-164.1	-3.30%
Coniferous Forest	455.7	9.18%	439.8	8.86%	-15.9	-0.32%
Water	172.5	3.47%	160.8	3.24%	-11.7	-0.24%
Non-forested Wetland	20.2	0.41%	20.6	0.42%	0.5	0.01%
Forested Wetland	183.7	3.70%	174.2	3.51%	-9.5	-0.19%
Tidal Wetland	22.5	0.45%	22.8	0.46%	0.3	0.01%
Barren	32.1	0.65%	41.8	0.84%	9.7	0.19%
Utility (Forest)	17.6	0.35%	17.1	0.34%	-0.5	-0.01%
Totals	4966.0	100.00%	4966.0	100.00%	0.0	-5.12%
Forest Cover Δ					-190.058	-3.83%



Center for Land Use Education and Research, UConn

Land Cover Change by Vegetation Category

1985 v 2010



2. Carbon stock values in MgC/ha^2

LUCF	LUCF_name	C_above	C_Below	C_Soil	C_dead
1	Developed	0.20	0.59	33.00	0.00
2	Turf & Grass	0.90	9.11	110.00	0.00
3	Other Grasses	0.33	0.89	80.52	0.20
4	Agricultural Field	5.20	0.89	60.00	1.70
5	Deciduous Forest*	109.80	50.50	78.50	31.40
6	Coniferous Forest*	95.40	43.90	52.60	31.10
7	Water	0.00	0.00	0.00	0.00
8	Non-forested Wetland	35.24	9.18	99.91	0.00
9	Forested Wetland	49.28	12.83	99.91	20.05
10	Tidal Wetland	1.30	1.30	240.00	0.70
11	Barren	0.00	0.33	0.33	0.00
12	Utility (Forest)	71.80	47.20	65.50	21.90

Foundation of thesis research was to assign values derived from 80-100 published scientific articles.

Exchange of Carbon Dioxide by a Deciduous Forest: Response to Interannual Climate Variability

J. William Munger; Song-Miao Fan; Bruce C. Daube; Steven

Equilibrium Responses of Soil Carbon

Process-Based Estimates

growth eastern hemlock

Local-Scale Carbon Budgets and Mitigation Opportunities for the Northeast

The influence of land use and climate change on forest biomass and composition in Massachusetts, USA

Jonathan R. Thompson,[1,2,5] David R. Foster,[2] Robert Scheller,[3] and David Kittredge[2,4]

Forests

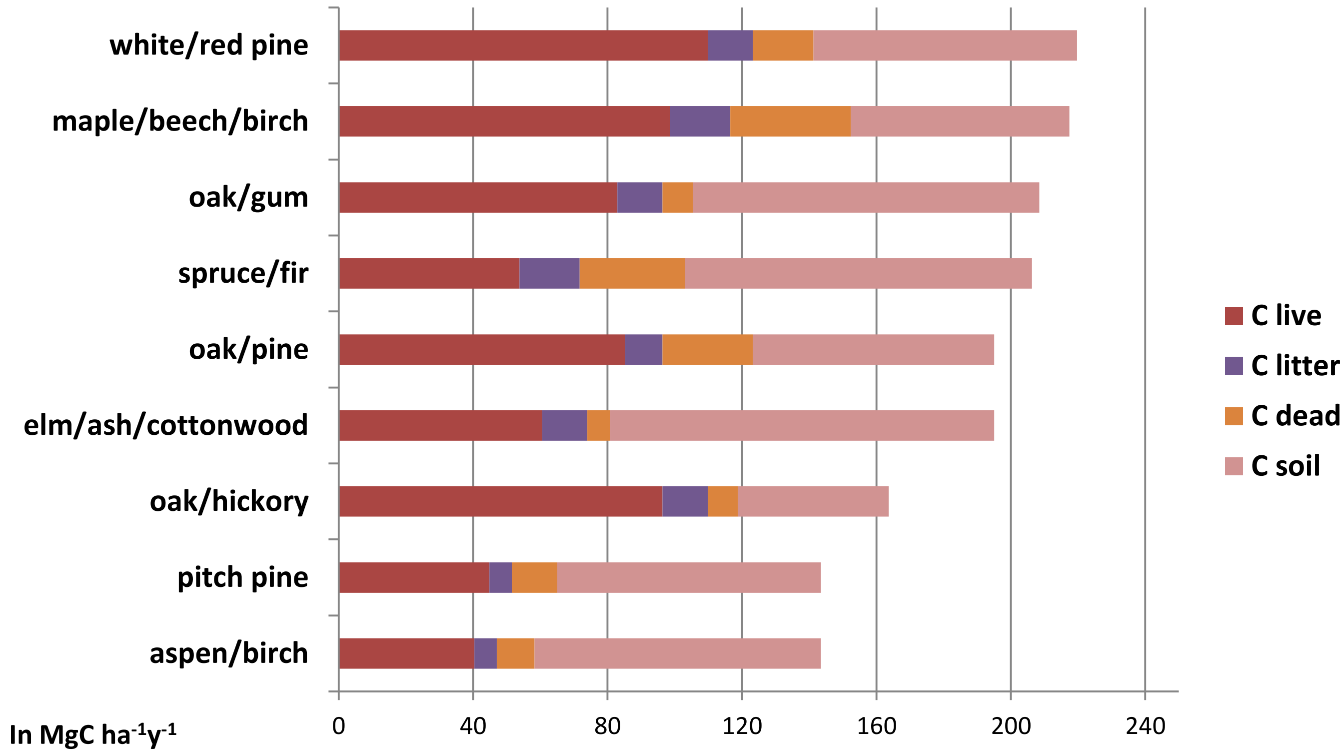
Position

Klighter; Linda A. Joyce

carbon allocation in forests from and IRGA-based soil respiration measurements

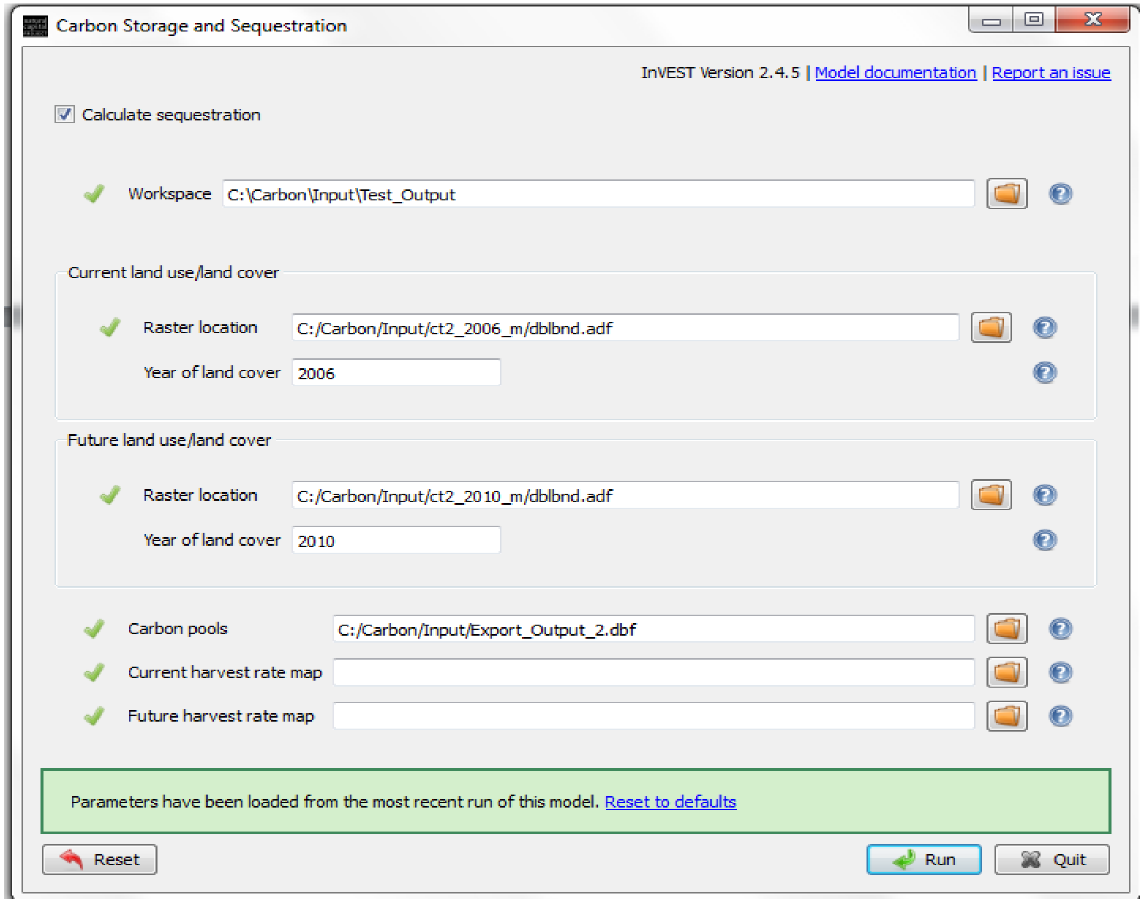
E.A. Davidson[a,*], K. Savage[a], P. Bolstad[b], D.A. Clark[c], P.S. Curtis[d]

Annual carbon uptake for the most abundant CT forest species



Data Source: Forests of Southern New England (Butler et al., 2011)

Sample input window from InVEST Carbon Sequestration Model



Methods: Output from InVEST *Carbon Storage & Sequestration* model

Arguments:
carbon_pools_uri C:/Carbon/Input/Export_Output_2.dbf
lulc_cur_uri C:/Carbon/Input/ct2_2006_m/dblbnd.adf
lulc_cur_year 2006
lulc_fut_uri C:/Carbon/Input/ct2_2010_m/dblbnd.adf
lulc_fut_year 2010
workspace_dir C:\Carbon\Input\Test_Output
04/02/2013 11:03:31 root INFO Logging will be saved to carbon_biophysical-log-2013-04-02--11_03_31.txt
04/02/2013 11:03:31 root DEBUG Loaded the model from invest_natcap.carbon.carbon_biophysical
04/02/2013 11:03:31 root INFO Executing the loaded model
04/02/2013 11:03:31 root INFO Running InVEST version 2.4.5
04/02/2013 11:03:31 root INFO Disk space remaining for workspace: 364.03 GB
04/02/2013 11:03:31 carbon_biophysical DEBUG loading C:/Carbon/Input/ct2_2006_m/dblbnd.adf
04/02/2013 11:03:31 carbon_biophysical DEBUG loading C:/Carbon/Input/ct2_2010_m/dblbnd.adf
04/02/2013 11:03:31 carbon_biophysical DEBUG loading C:/Carbon/Input/Export_Output_2.dbf
04/02/2013 11:03:31 carbon_biophysical DEBUG creating output raster C:\Carbon\Input\Test_Output\Output\tot_C_cur.tif
04/02/2013 11:03:32 carbon_biophysical DEBUG creating output raster C:\Carbon\Input\Test_Output\Output\sequest.tif
04/02/2013 11:03:32 carbon_biophysical DEBUG creating output raster C:\Carbon\Input\Test_Output\Output\tot_C_fut.tif
04/02/2013 11:03:32 carbon_biophysical INFO starting carbon biophysical model
04/02/2013 11:03:32 carbon_core DEBUG building carbon pools
04/02/2013 11:03:32 carbon_core DEBUG built carbon pools
04/02/2013 11:03:32 carbon_core INFO calculating carbon storage for the current landscape
04/02/2013 11:03:38 carbon_core INFO finished calculating carbon storage for the current landscape
04/02/2013 11:03:38 carbon_core INFO calculating raster stats for tot_C_cur
04/02/2013 11:03:38 carbon_core INFO calculating carbon storage for future landscape
04/02/2013 11:03:44 carbon_core INFO finished calculating carbon storage for future landscape
04/02/2013 11:03:44 carbon_core INFO calculating raster stats for tot_C_fut
04/02/2013 11:03:45 carbon_core INFO calculating carbon sequestration
04/02/2013 11:03:53 carbon_core INFO calculating raster stats for sequest
04/02/2013 11:03:53 carbon_core INFO finished calculating carbon sequestration
04/02/2013 11:03:53 carbon_biophysical INFO finished carbon biophysical model
04/02/2013 11:03:53 carbon_core DEBUG calculate summary
04/02/2013 11:03:54 carbon_core INFO Total current carbon: 275251250.233 Mg
04/02/2013 11:03:55 carbon_core INFO Total scenario carbon: 274916743.698 Mg
04/02/2013 11:03:57 carbon_core INFO Total sequestered carbon: -334506.873549 Mg
04/02/2013 11:03:57 root INFO Opening file explorer to workspace directory
04/02/2013 11:03:57 root INFO Using windows explorer to view files
04/02/2013 11:03:57 root INFO Disk space free: 364.03 GB
04/02/2013 11:03:57 root INFO Finished.

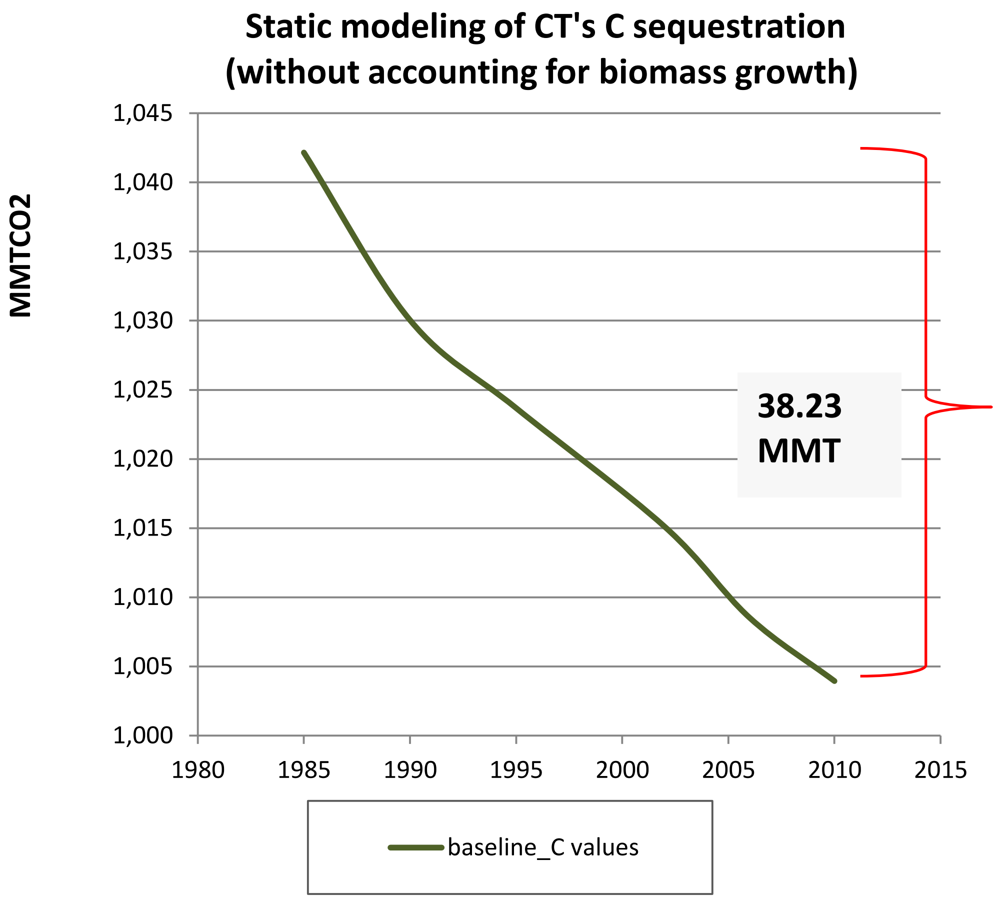
Stanford Woods Institute for the Environment

Natural Capital Project, Stanford University

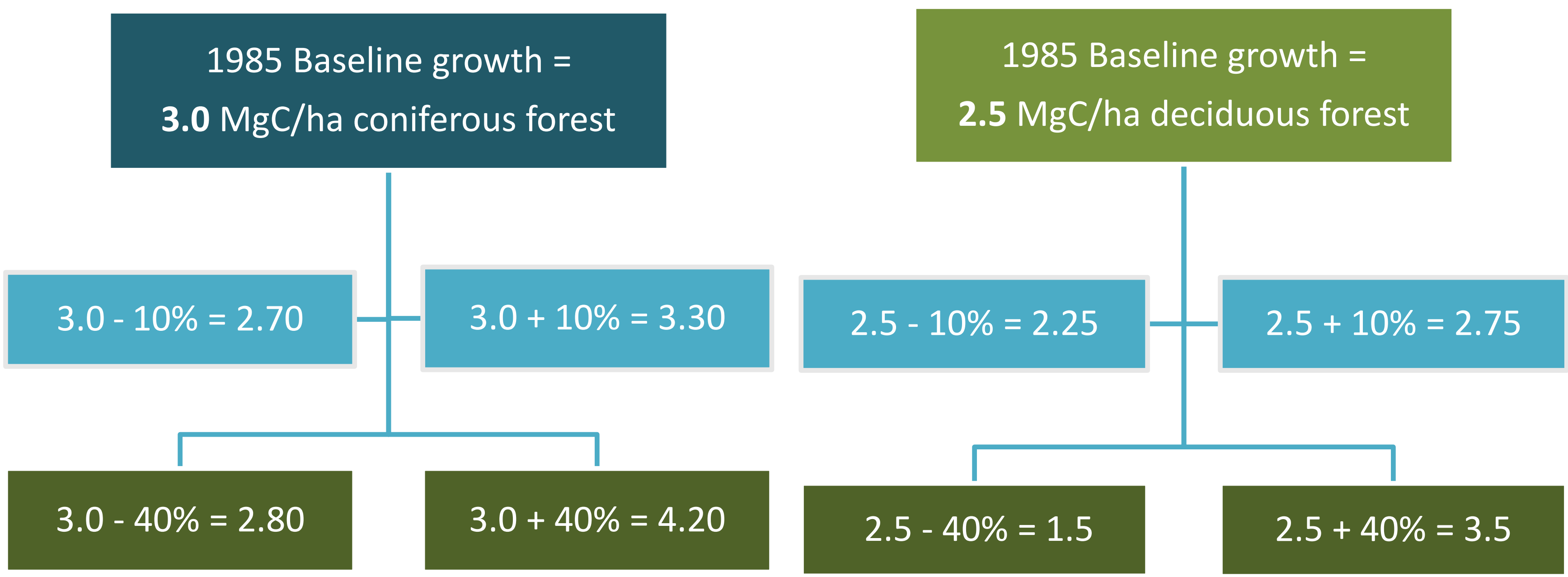
Results: loss of sequestered C from land conversion, 1985-2010; no biomass growth

	MMTCO2
1985	1,042.16
1990	1,030.04
1995	1,023.68
2002	1,015.10
2006	1,008.52
2010	1,003.94

25-year loss: 38.23
(without biomass growth)

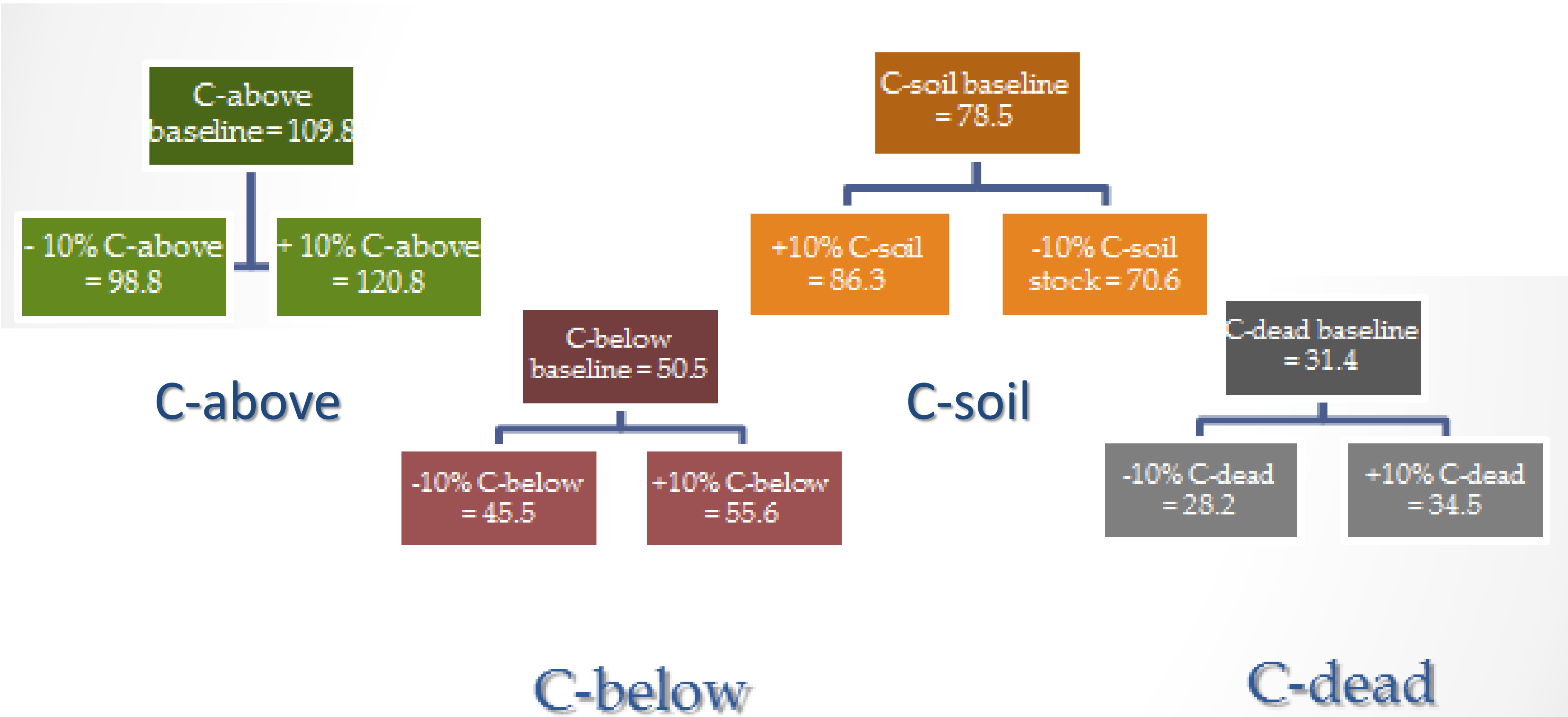


Sensitivity analyses model variations from baseline values of C-above sequestration due to biomass growth

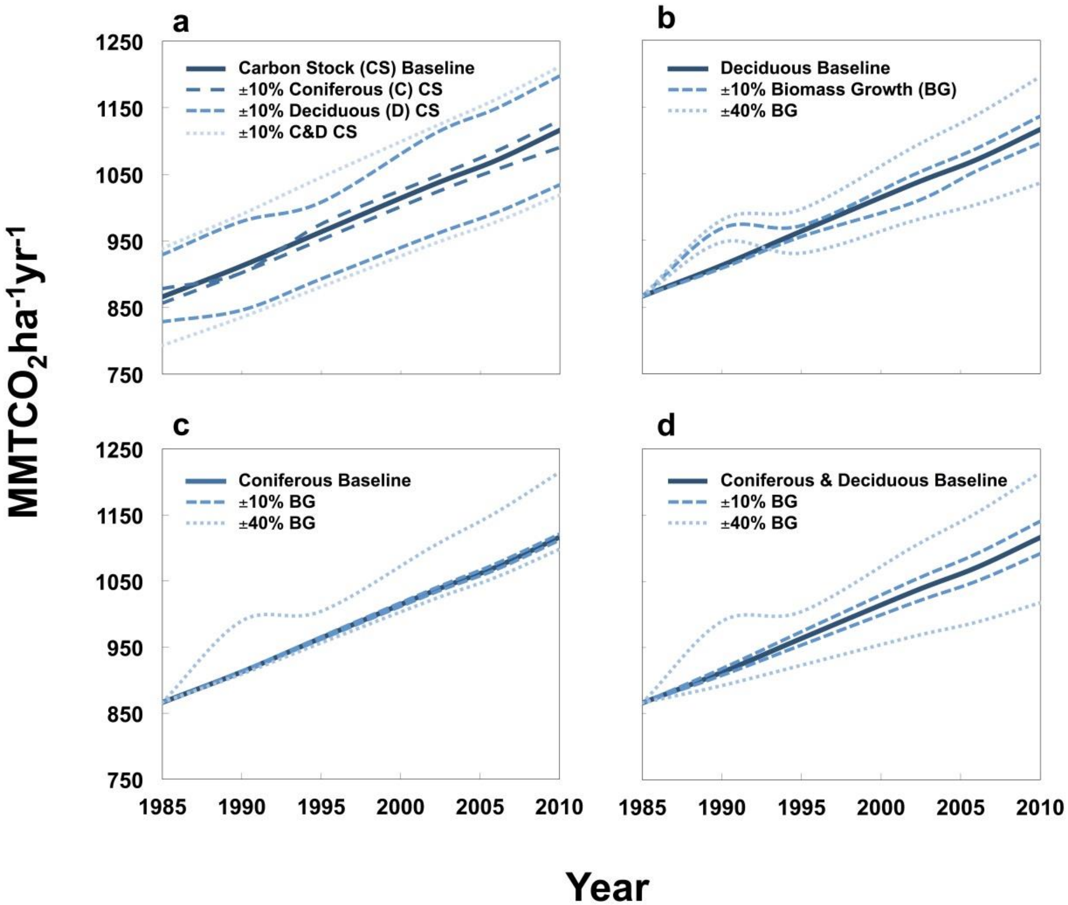


Modeling of sequestration levels using mean biomass growth rates of 2.5 MgC $ha^{-1}y^{-1}$ for deciduous & 3.0 MgC $ha^{-1}y^{-1}$ for coniferous forests (Thompson 2011).

Variations from baseline values for C stocks of Southern New England deciduous and coniferous forests



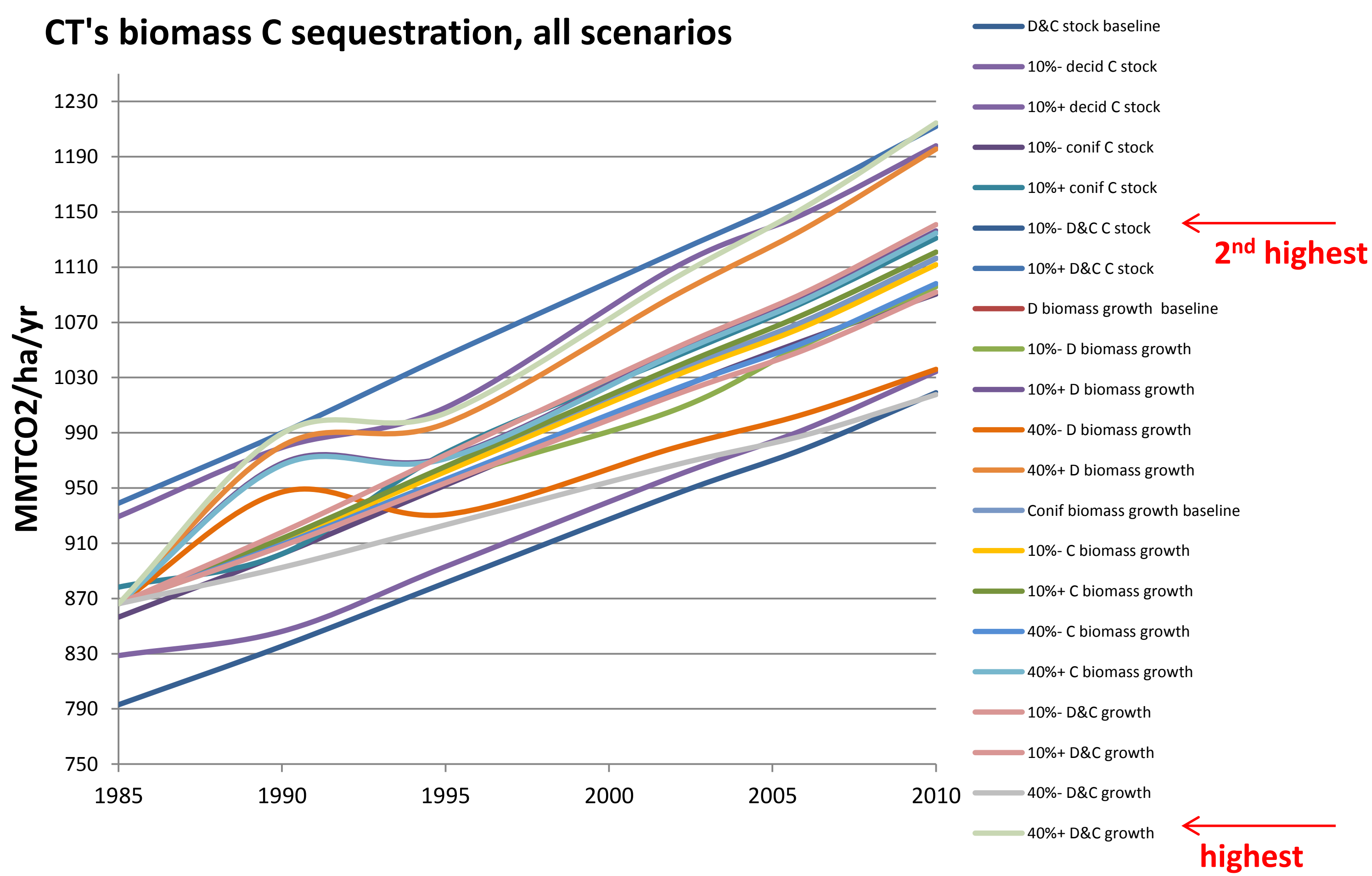
Sensitivity Analyses run on Sequestration Modeling by Connecticut's forests



a. +/- 10% of baseline value of Carbon Stocks (tree biomass).

b. +/10% and +/- 40% of baseline value for annual biomass growth, deciduous forests, c. coniferous forests, and d. combined deciduous and coniferous forests .

Results: Sequestration output from sensitivity analyses, with biogrowth



Sequestration level output from sensitivity analyses graphed above

	Sequestered MMCO2/ha/yr					
Scenario	**1985**	**1990**	**1995**	**2002**	**2006**	**2010**
D&C stock baseline	866.11	912.50	963.76	1,034.20	1,071.03	1,116.37
10%- decid C stock	828.64	846.16	893.04	958.53	992.61	1,034.38
10%+ decid C stock	929.35	979.35	1008.26	1,109.68	1,149.02	1,197.91
10%- conif C stock	856.50	902.29	952.06	1,021.09	1,057.13	1,090.51
10%+ conif C stock	878.23	902.29	975.45	1,044.94	1,084.90	1,131.03
10%- D&C C stock	793.03	835.46	881.35	945.39	978.71	1,019.05
10%+ D&C C stock	939.00	990.01	1045.72	1,120.45	1,162.88	1,211.99
D biomass growth baseline	866.20	912.50	963.76	1,034.20	1,071.03	1,116.37
10%- D biomass growth	866.20	908.20	955.62	1,006.45	1,054.17	1,095.88
10%+ D biomass growth	866.20	967.94	972.12	1,047.96	1,087.90	1,136.26
40%- D biomass growth	866.20	947.11	930.77	979.15	1,003.79	1,035.98
40%+ D biomass growth	866.20	980.53	996.74	1,089.29	1,138.06	1,195.58
Conif biomass growth baseline	866.20	912.50	963.76	1,034.20	1,071.03	1,116.37
10%- C biomass growth	866.20	912.04	961.87	1,031.10	1,067.18	1,111.77
10%+ C biomass growth	866.20	913.46	965.63	1,037.40	1,076.14	1,120.92
40%- C biomass growth	866.20	909.21	956.29	1,021.64	1,055.62	1,098.07
40%+ C biomass growth	866.20	966.69	971.23	1,046.80	1,086.45	1,134.66
10%- D&C growth	866.20	907.92	953.74	1,017.30	1,050.31	1,091.87
10%+ D&C growth	866.20	918.05	973.99	1,051.13	1,091.75	1,140.81
40%- D&C growth	866.20	892.49	923.30	966.59	988.37	1,017.68
40%+ D&C growth	866.20	989.51	1004.21	1,101.85	1,153.48	1,214.46

2nd highest

highest

Differentials in levels of sequestered C generated by sensitivity analyses

in MMTCO2	C sequestered	foregone seq	Seq Difference	C seq	foregone C gain	C seq difference	25 yr % C loss
baseline	1,116.37	1,170.10	-53.74	250.16	303.90	-53.74	17.68%
A_-10% D	1,095.88	1,148.18	-52.30	229.68	281.98	-52.30	18.55%
B_+10% D	1,136.26	1,190.81	-54.55	270.06	324.61	-54.55	16.81%
C_-40% D	1,035.98	1,084.01	-48.03	169.78	217.80	-48.03	22.05%
D_+40% D	1,195.58	1,254.99	-59.41	329.37	388.79	-59.41	15.28%
E_-10% C	1,111.77	1,164.73	-52.97	245.56	298.53	-52.97	17.74%
F_+10% C	1,120.92	1,174.22	-53.30	254.72	308.01	-53.30	17.30%
G_-40% C	1,098.07	1,150.54	-52.47	231.86	284.33	-52.47	18.45%
H_+40% C	1,134.66	1,188.46	-53.80	268.46	322.26	-53.80	16.69%
I_both -10	1,091.87	1,143.42	-51.55	225.67	277.21	-51.55	18.59%
J_both +10	1,140.81	1,195.53	-54.72	274.61	329.33	-54.72	16.61%
K_both -40	1,017.68	1,065.05	-47.36	151.48	198.84	-47.36	23.82%
L_both +40	1,214.46	1,273.95	-59.49	348.26	407.75	-59.49	14.59%
M_-10% D stock	1,034.38	1,081.67	-47.28	231.27	278.55	-47.28	16.97%
N_+10% D stock	1,197.91	1,256.86	-58.95	268.13	327.09	-58.95	18.02%
O_-10% C stock	1,090.51	1,142.70	-52.20	186.49	238.68	-52.20	21.87%
P_+10% C stock	1,131.03	1,184.69	-53.66	255.33	309.00	-53.66	17.37%
Q_-10% D&C stock	1,019.05	1,066.38	-47.34	178.59	225.93	-47.34	20.95%
R_+10% D&C_stock	1,211.99	1,272.06	-60.07	225.55	285.62	-60.07	21.03%

If 250 $MMTCO_2$ was sequestered *with* forest loss, how much would have been captured *without* ?

Foregone C sequestration in CT owing to land use change, 1985-2010

	in MMTCO2	Foregone C sequestration, Deciduous Forests				Foregone C sequestration, Conifers			
Note: C seq denominated in CO2 equivalents	baseline_C values	A_-10% D	B_+10% D	C_-40% D	D_+40% D	E_-10% C	F_+10% C	G_-40% C	H_+40% C
Foregone C seq									
1985	866.20	866.20	866.20	866.20	866.20	866.20	866.20	866.20	866.20
2010	1,170.10	1,148.18	1,190.81	1,084.01	1,254.99	1,164.73	1,174.22	1,150.54	1,188.46
Foregone seq for 25 yr	303.90	281.98	324.61	217.80	388.79	298.53	308.01	284.33	322.26
Variation from baseline									
(in MMTCO2)	0	-21.92	20.71	-86.10	84.89	-5.37	4.11	-19.57	18.36
2010 seq	1,116.37	1,095.88	1,136.26	1,035.98	1,195.58	1,111.77	1,120.92	1,098.07	1,134.66
2010 foregone seq	53.74	52.30	54.55	48.03	59.41	52.97	53.30	52.47	53.80
2010 foregone seq as % of 25-yr foregone seq	17.68%	18.55%	16.81%	22.05%	15.28%	17.74%	17.30%	18.45%	16.69%

Method to calculate foregone C sequestration as a % of realized 25-year sequestered C, including forest biomass growth:

$$\frac{25\ yr\ Foregone\ Sequestration - 25\ yr\ C\ Sequestration\ Gain}{25\ yr\ Foregone\ Sequestration}$$

$$All\ Values\ cover\ 1985 - 2010$$

Foregone C sequestration in CT owing to land use change, 1985-2010

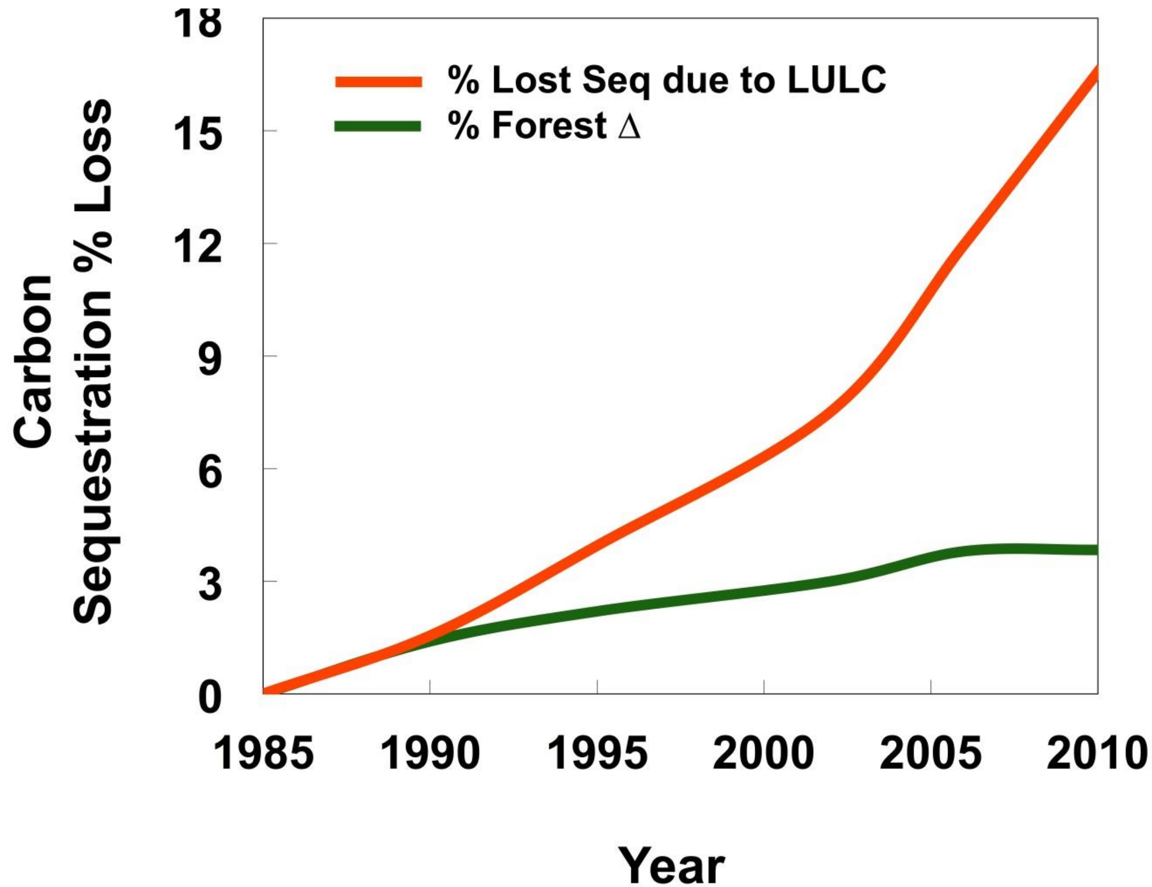
	in MMTCO2	Foregone C sequestration, Deciduous Forests				Foregone C sequestration, Conifers			
Note: C seq denominated in CO2 equivalents	baseline_C values	A_-10% D	B_+10% D	C_-40% D	D_+40% D	E_-10% C	F_+10% C	G_-40% C	H_+40% C
Foregone C seq									
1985	866.20	866.20	866.20	866.20	866.20	866.20	866.20	866.20	866.20
2010	1,170.10	1,148.18	1,190.81	1,084.01	1,254.99	1,164.73	1,174.22	1,150.54	1,188.46
Foregone seq for 25 yr	303.90	281.98	324.61	217.80	388.79	298.53	308.01	284.33	322.26
Variation from baseline									
(in MMTCO2)	0	-21.92	20.71	-86.10	84.89	-5.37	4.11	-19.57	18.36
2010 seq	1,116.37	1,095.88	1,136.26	1,035.98	1,195.58	1,111.77	1,120.92	1,098.07	1,134.66
2010 foregone seq	53.74	52.30	54.55	48.03	59.41	52.97	53.30	52.47	53.80
2010 foregone seq as % of 25-yr foregone seq	17.68%	18.55%	16.81%	22.05%	15.28%	17.74%	17.30%	18.45%	16.69%

Results: Difference in rate of forest loss vs C capture by same land coverage

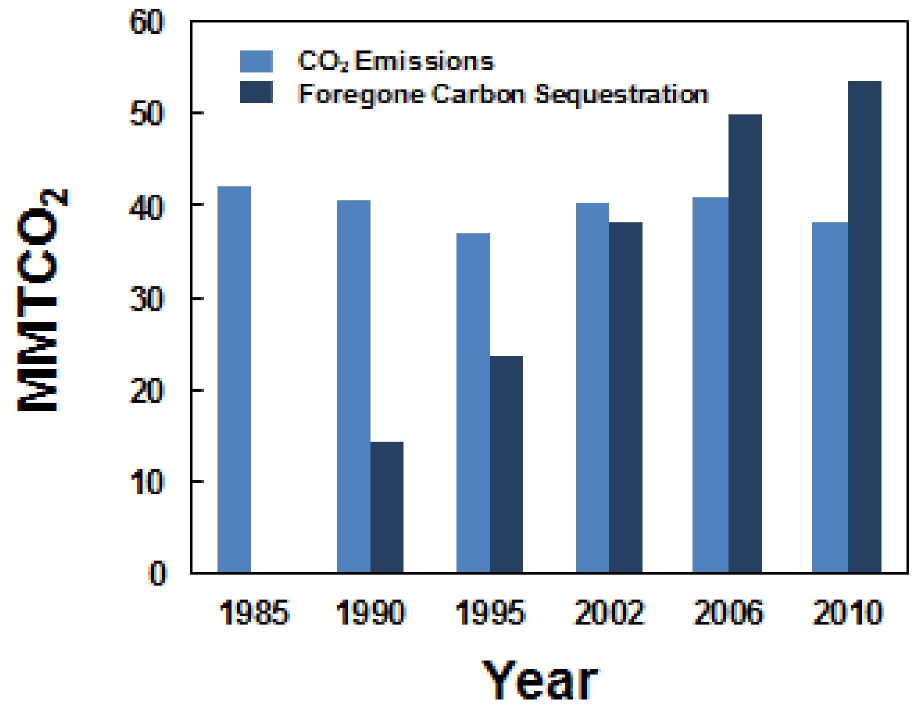
	1985		1990		1995		2002		2006		2010		Change	
	sq. miles	% of state	sq. miles	% of state	sq. miles	% of state	sq. miles	% of state	sq. miles	% of state	sq miles	% of state	sq. miles	% of state
Forest Cover Δ	3123.08		3056.9	0.0	3020.2	0.01	2973.3	0.94%	2938.10	0.0	2933	0.10%	-190.1	-3.83%
Forest Coverage		62.89%		61.56%		60.82%		59.87%		59.16%		59.06%		

	actual C seq	lost C scenario	C seq Difference	actual	lost scenario		25 yr Percentage lost
baseline	1,116.37	1,170.10	-53.74	250.16	303.90	-53.74	17.68%
A_-10% D	1,095.88	1,148.18	-52.30	229.68	281.98	-52.30	18.55%

Modeling of LUCF shows that 3.83% loss of forests => 17.68% sequestration loss, 1985-2010



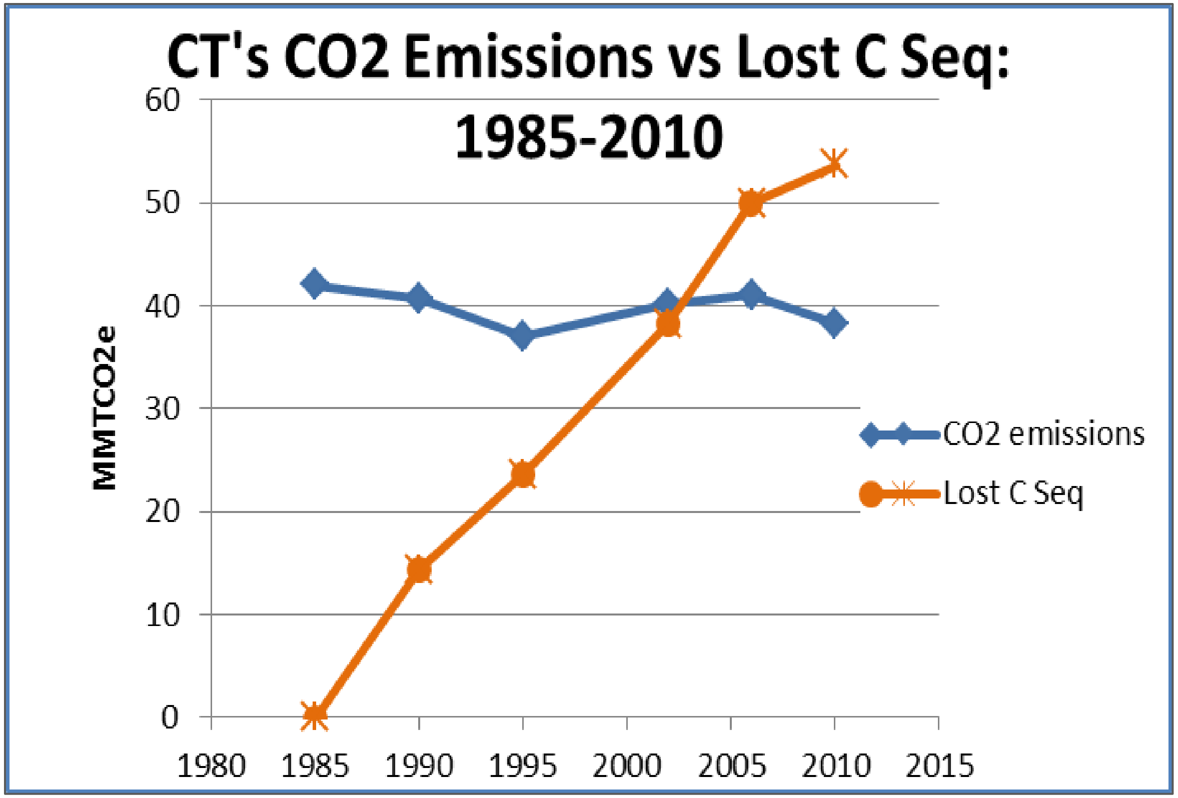
Results: Baseline C sequestration loss is 4.62 times > baseline forest conversion

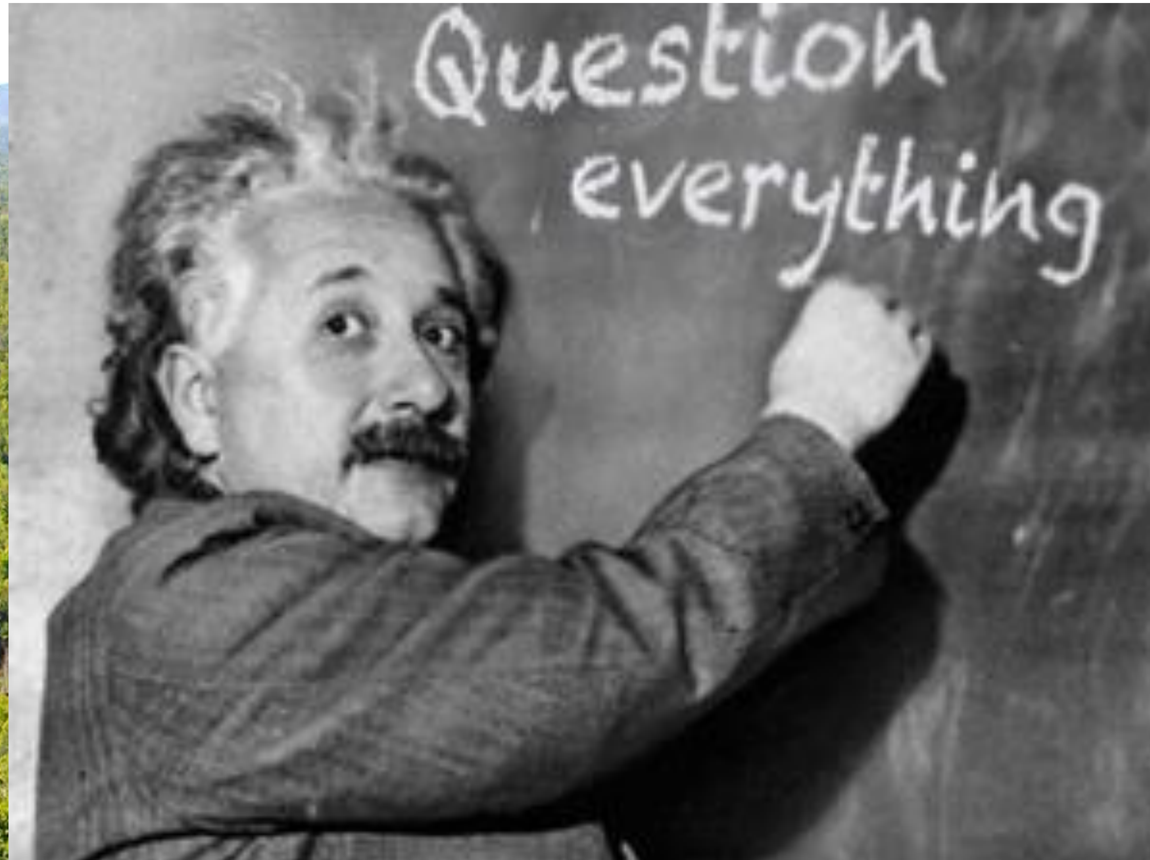


42.00	40.72	37.07	40.15	41.04	38.19
0	14.39	23.65	38.29	49.97	53.74

Results: CT's annual CO_2 emissions exceed foregone C sequestration due to LUCF

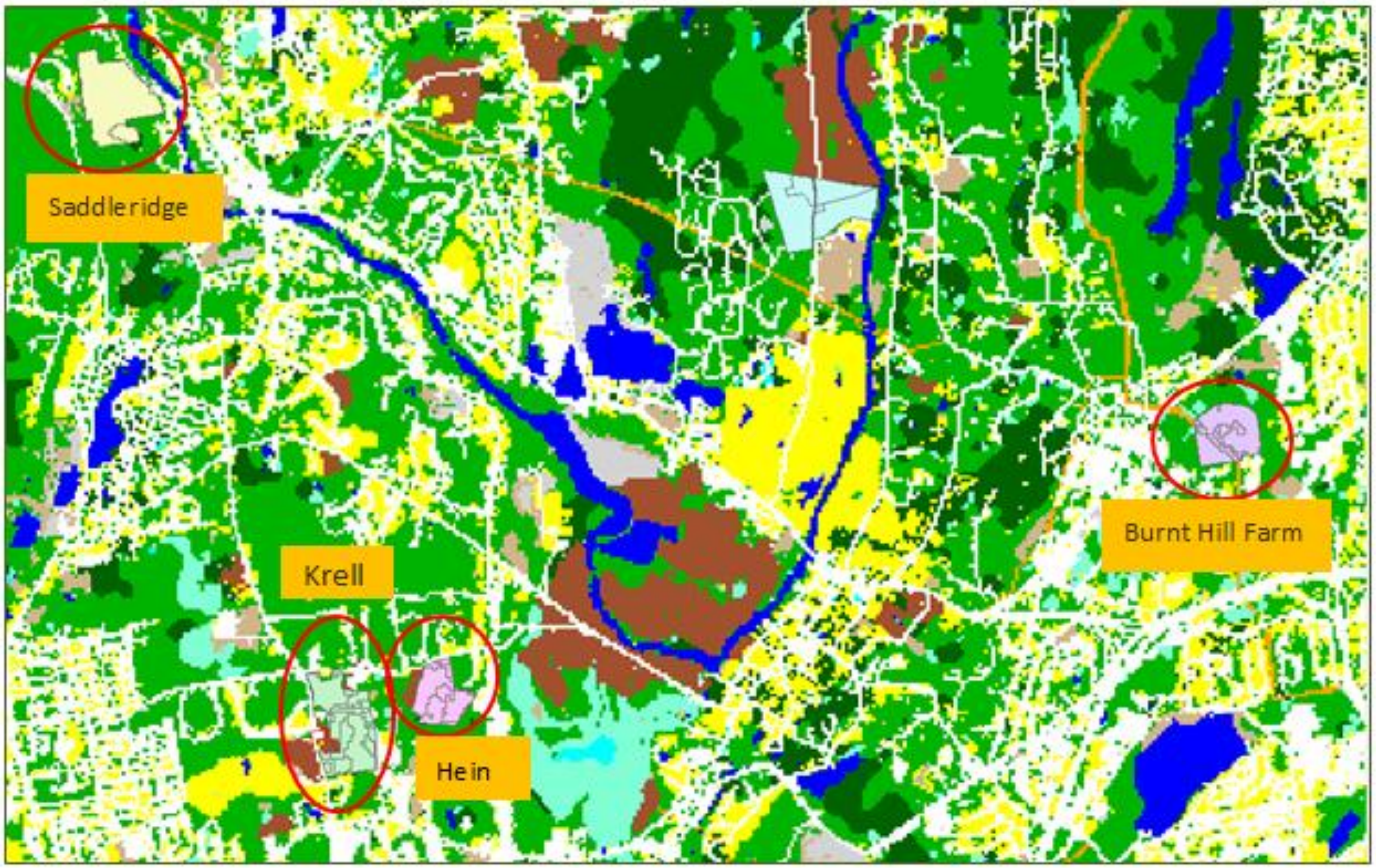
CT forest loss + 25 years biomass growth → Foregone C sequestration > annual CO_2





Questions at this point?

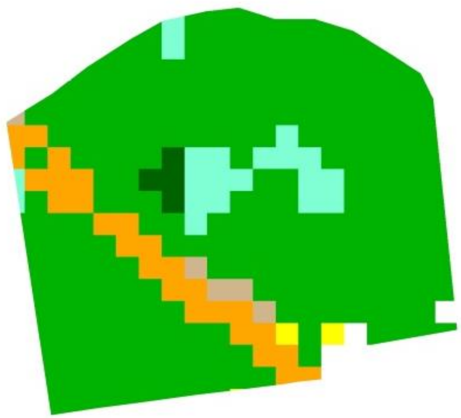
Research applied to open parcels in Farmington, CT



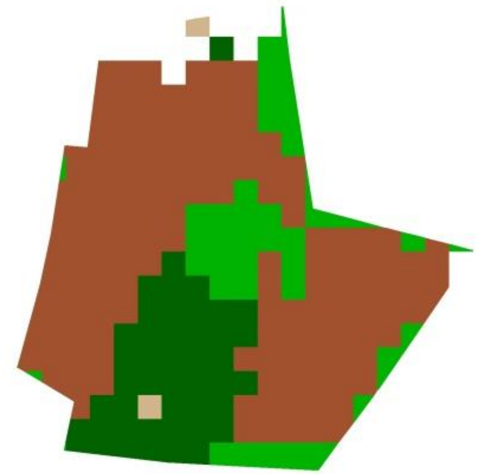
Source: Esri 10.1 ArcGIS

ArcGIS land cover maps of open space parcels

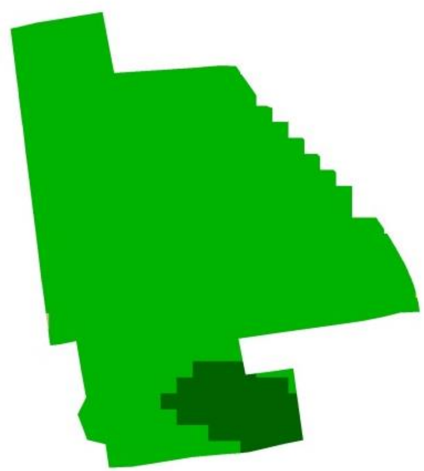
Burnt Hill Farm



Hein Farm



Krell Farm



Saddleridge Farm

Results: Price differentials in $\$/tCO_2$ are a function of C densities

Farm		acres	ha	Total MgC	MgC/ha sequestered	MgC>MgCO2 sequestered	MgCO2 > MtCO2	$/acre	$/ha	$/MgC	$/MTonsC	$/MTCO2	$/MMTCO2
Burnt Hill													
	1985	64.9	26.264	6,625.02	252.25	924.23	924.23	25,000.00	61,776.35	244.90	244.90	66.84	66,840,652
	2010	64.9	26.264	8,903.19	338.99	1,242.05	1,242.05	25,000.00	61,776.35	182.24	182.24	49.74	49,737,286
Hein													
	1985	53.5	21.651	2,668.99	123.27	451.67	451.67	25,000.00	61,776.35	501.13	501.13	136.77	136,772,110
	2010	53.5	21.651	3,521.73	162.66	595.98	595.98	25,000.00	61,776.35	379.79	379.79	103.65	103,654,695
Krell													
	1985	90	36.422	6,890.12	189.17	693.14	693.14	25,000.00	61,776.35	326.56	326.56	89.13	89,125,898
	2010	90	36.422	9,642.90	264.75	970.06	970.06	25,000.00	61,776.35	233.33	233.33	63.68	63,682,880
Saddleridge													
	1985	103.5	41.885	10,743.50	256.50	939.82	939.82	25,000.00	61,776.35	240.84	240.84	65.73	65,732,428
	2010	103.5	41.885	15,004.19	358.22	1,312.53	1,312.53	25,000.00	61,776.35	172.45	172.45	47.07	47,066,579

1 acre = 0.404685642 ha

1 ha = 2.471054 acre

Comparison of CO_2 abatement strategies shows forest preservation as cost-competitive

- Transit modification strategies
  - Reason Foundation
  - Moore, Staley & Poole
  - Victoria Policy Institute
- Bus rapid transit systems
  - Los Angeles
  - Vancouver (Millard-Ball)
- Major road improvements
  - (Reason Foundation)
- Concentrated solar in select sun-rich locations (CT State DEEP)
- Current nuclear competitive with coal/NG (MIT)
- RGGI auction 25 clearing price
- **Forest preservation**

- \$ 4,257/tCO_2
- \$ 833/tCO_2
- \$ 1,000/tCO_2
- \$ 117/tCO_2
- \$ 3,238/tCO_2
- \$ 3,995/tCO_2
- \$ 52/tCO_2
- \$ 27/tCO_2
- \$ 4.88/tCO_2
- **\$ 47-137/tCO_2**

Policy implications for CT forestlands

- **Public Act 490** provides tax incentives for CT's forest landholders only with ≥ **25**-acres.

- On half of CT's total privately-owned forests, **70% of owners are age 50+**, spelling large generational change in long-term land ownership.

- **3/4** of Southern New England's forestlands are large stands of **80-100 yr-old** tree specimens.

Policy recommendations of research

- Broaden criteria for public land acquisition: environmental aims → climate reduction goals.
- Expand RGGI's offset allowances to include forest preservation; raise cap on compliance obligations (CT 3% v CA's 8%) thru sale of offset permits
- Fiscal policies need to engage private landholders & land preservation NGOs toward climate goals.
- Compact re/development & revised zoning before current wave of deforestation becomes permanent.

Conclusions for CT's climate policy

- Estimates of C sequestration from now-developed forests would have yielded **53.74** $MMTCO_2$ additional sequestration, 1985-2010, an amount exceeding ***total annual fossil fuel emissions in CT***.
- Preservation of forest C stocks over time becomes the determinant factor for influencing biomass C sequestration levels.
- Results indicate avoided deforestation through land preservation, compact development/ redevelopment can reduce C levels more cost effectively than many current emissions reduction strategies.

Forthcoming Article:

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Scientific Research

The Impact of Land Use Change for Greenhouse Gas Inventories and State-level Climate Mediation Policy: A GIS Methodology Applied to Connecticut

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Abstract

Greenhouse gas (GHG) inventories conducted at state and regional levels serve to quantify long-term emissions trends and set benchmarks against which to evaluate the effectiveness of state government-mandated emissions reductions. GHG inventories which incompletely account for land use, land change, and forestry (LUCF) due to insufficient measurement tools discount the value of terrestrial carbon (C) sinks. In consequence, sink preservation is often omitted from regional land use planning. This paper proposes an accounting methodology which estimates foregone C sequestration derived LUCF change in the southern New England state of Connecticut (CT). The Natural Capital Project's InVEST program provided a template for modeling C storage and sequestration for CT's land class categories. LandSat mapping of long-term land cover patterns in CT conducted by CLEAR at the University of CT served as input data for InVEST computer modeling of C sequestration, both realized and foregone due to LUCF. The results showed that: 1) Land converted from high C density forestland to low density C land cover classes reduced the rate of C sequestration loss at 4.62 times the rate of forest reduction. Forest loss of 3.83% over twenty-five years was responsible for foregone C sequestration equivalent to 17.68% of total 2010 sequestration. 2) Accumulating C stocks pushed total annual sequestration from a 1985 baseline level of 866 $MMTCO_2$ to 1,116 $MMTCO_2$ by 2010 –a 250 $MMTCO_2$ increment. 3) C sequestration from forest loss since 1985 would have yielded additional sequestration of 53.74 $MMTCO_2$ by 2010. By 2002, foregone yield surpassed CT's annual fossil fuel emissions, currently at 40 $MMTCO_2$. 4) Preservation of forest C stocks over time becomes the determining factor for influencing biomass C sequestration levels. Deciduous forests have a preponderant influence on CO2 budgets. The ground-up methodology to quantify land-based C sequestration presented

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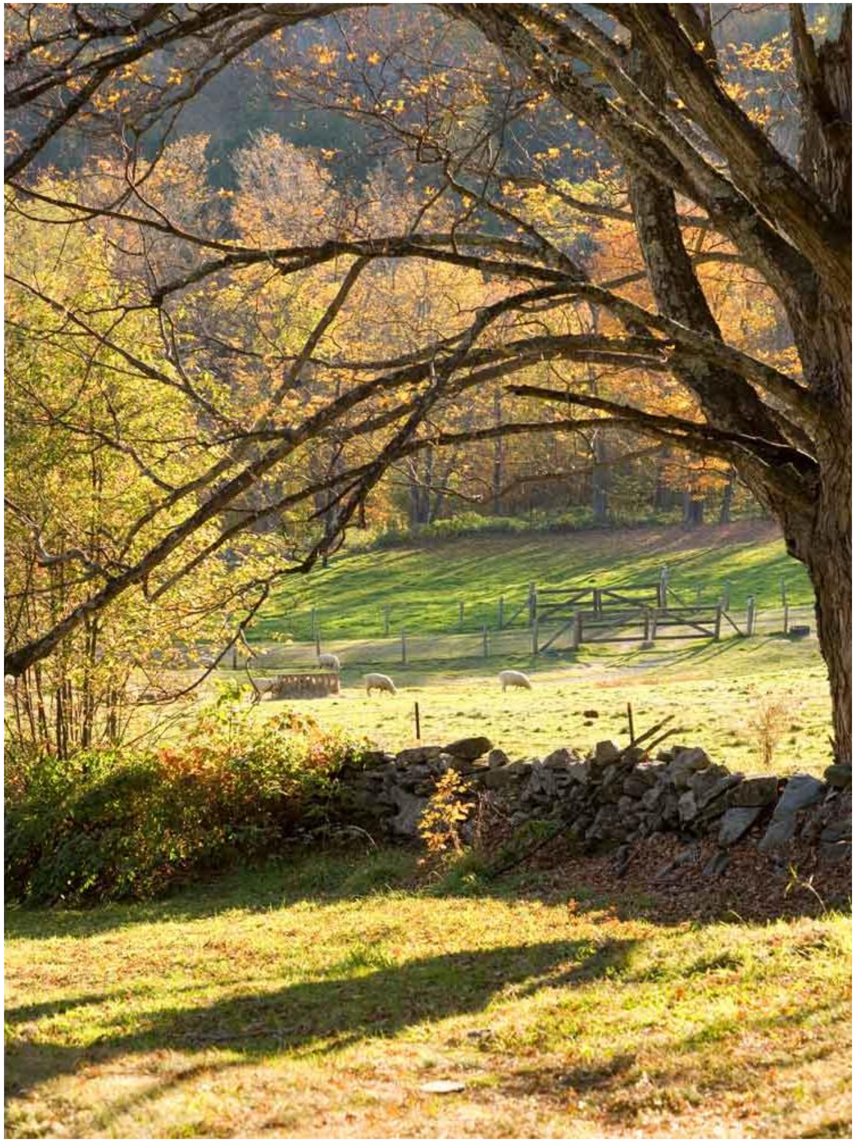
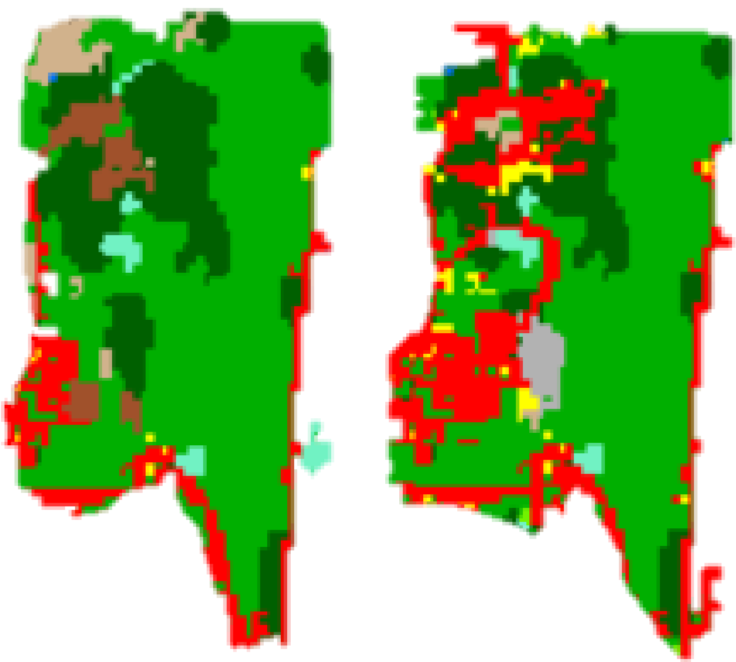
- Harvard Forest

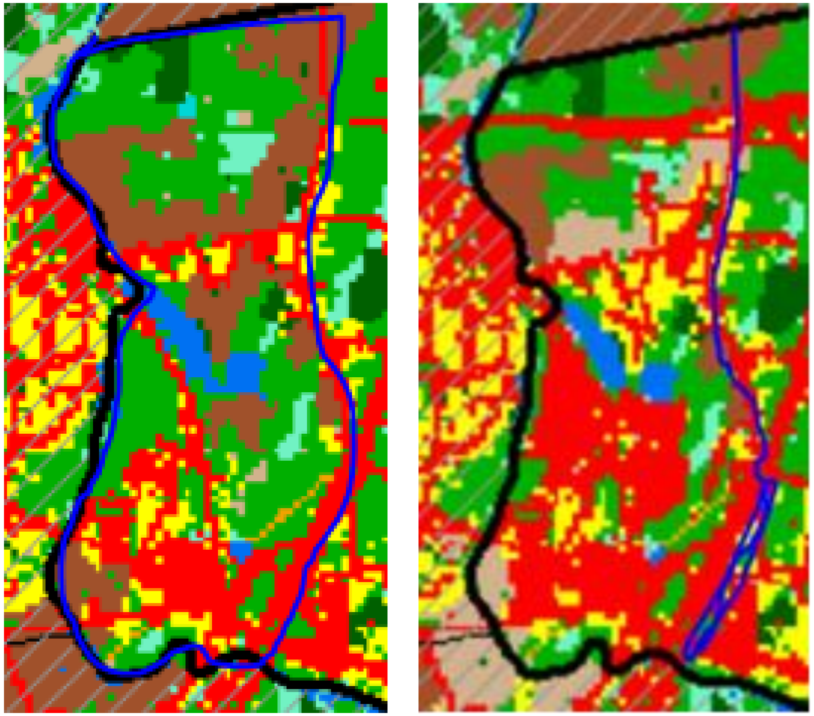


Follow-up research on CT land conversion from forest to development

Avon: 1985 v 2010
Residential: Hunters Run



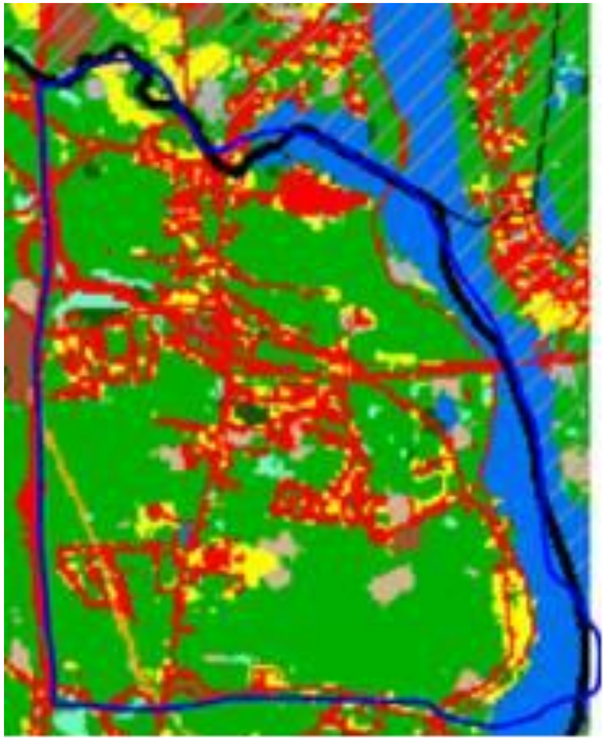
Cromwell: 1985 v 2010
Transportation: Rt 9 connector



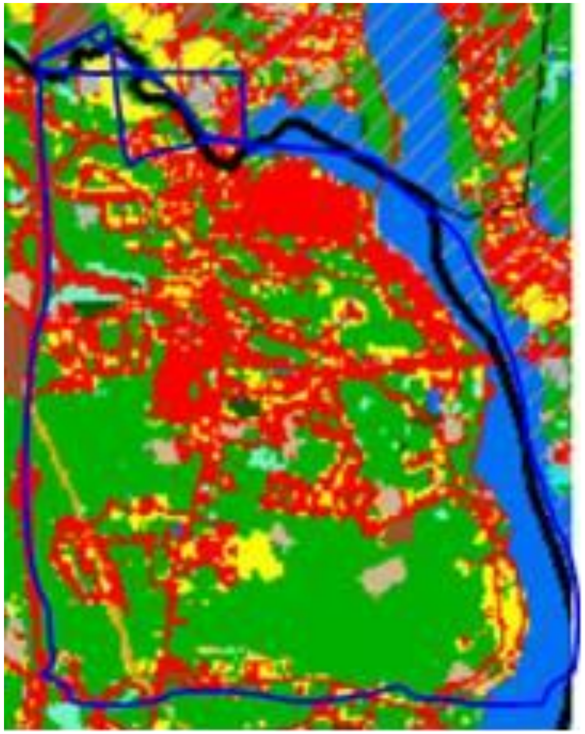
Foregone C sequestration = 0.16 MMTCO_2 left; 0.16 MMTCO_2 right.

Follow-up research on CT land conversion from forest to development

Montville 1985
Pre-casino development



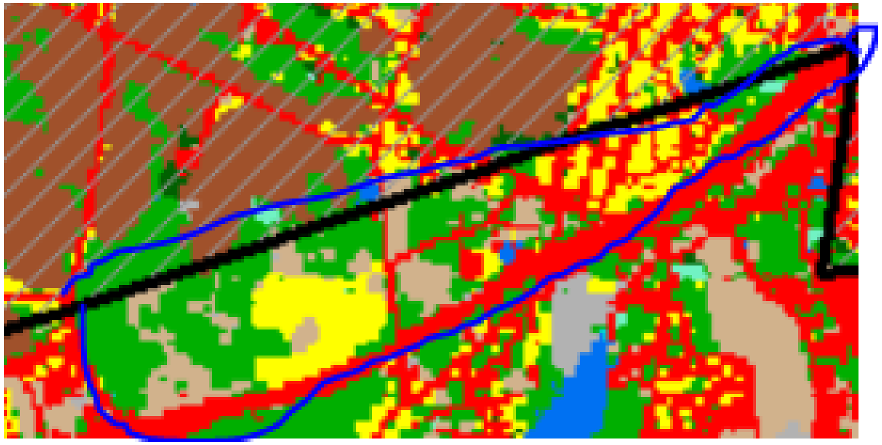
Montville 2010
Post-Mohegan Sun



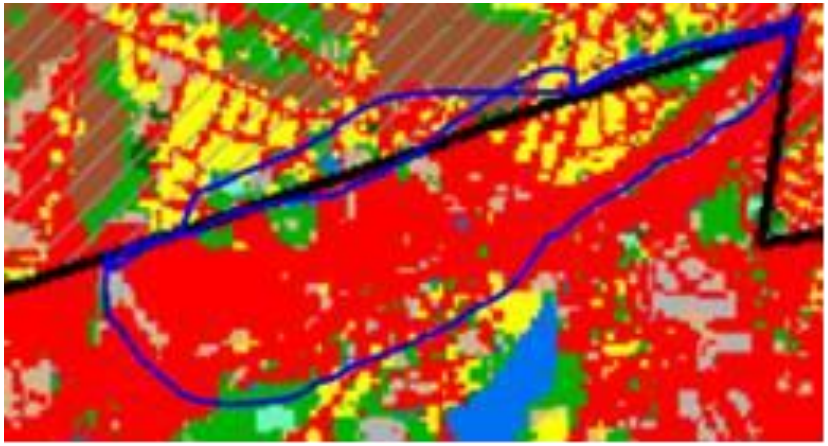
Foregone C sequestration = 0.357 MMTCO_2 / 0.92% of CT's annual emissions

Follow-up research on CT land conversion from forest to development

Manchester 1985, I-84
Pre-commercial development



Manchester 2010
Post-Buckland Hills Mall



Should future development projects require a GHG assessment as part of Environmental Impact Assessments?