Summary Report

GHG Inventory for Forests and Trees Outside Forests, 2008 to 2016
Boulder County, Colorado

Summary

Forests and trees play a key role in mitigating climate change, yet they are often not included in local greenhouse gas (GHG) inventories or climate action plans. Boulder County, Colorado has taken the first step towards understanding how local changes in land use and tree canopy have contributed to the county's net greenhouse gas profile. Unlike other sectors, land use (in this case, forests and trees) not only emit GHGs, they also remove CO2 from the atmosphere through photosynthesis, and play a critical role in regulating the planet's climate. The information contained in this summary report can be useful when designing climate actions that reduce GHG emissions and/or increase removals of GHGs from the atmosphere.

Key findings:

- Over the period 2008 to 2016, emissions from forests and trees were 96,095 t CO2e per year.

- Over the period 2008 to 2016, the Net GHG balance of forests and trees was -10,245 t CO2e per year.

- Roughly 44% of Boulder County's total land base of 191,798 hectares (473,942 acres) is forest. Many areas outside of forests are also covered by trees, including an average of nearly 4.1 percent tree canopy on lands outside of forest areas

- Over the same period, annual CO2 removals from forests and trees were -106,340 t CO2e per year. (Carbon removals are represented by negative values.)

- Total GHG emissions for Boulder County across all sectors could be reduced if additional forests/trees were added to its land base, and/or if losses of trees were reduced further.

Table 1. Boulder county's GHG fluxes from forests and trees for inventory period 2008 – 2016, all values reported in t CO2e per year

	Removals(t CO2e/yr)	Emissions(t CO2e/yr)
Undisturbed Forest	-71,749	
Forest Disturbances		66,886
Non-Forest to Forest	-260	
Forest to Settlement		89
Forest to Grassland		28,341
Forest to other non-forest lands		606
Trees outside of forests	-34,332	173
Harvested Wood Products	0	
TOTAL	-106,340	96,095
Net GHG balance	-10,245	

Data Inputs

Data used as inputs into the GHG emission and removal calculations are described below.

Land and Forest Cover

GHG inventories for lands are reported in six “land use” categories which were defined by data on land cover—forest land, grassland, cropland, wetland, settlement and other land (barren, snow, ice). Boulder County’s total land base is approximately 191,798 hectares (473,942 acres), with nearly 11.5% Settlement (i.e. developed areas of varying intensity), around 44.5% forest, 32.1% Grassland (which includes hay/pasture, shrub/scrub and other herbaceous cover), 6% cropland, 3.5% wetland and 2.4% other land.

Figure 1. Land cover in Boulder from the National Land Cover Database, 2016

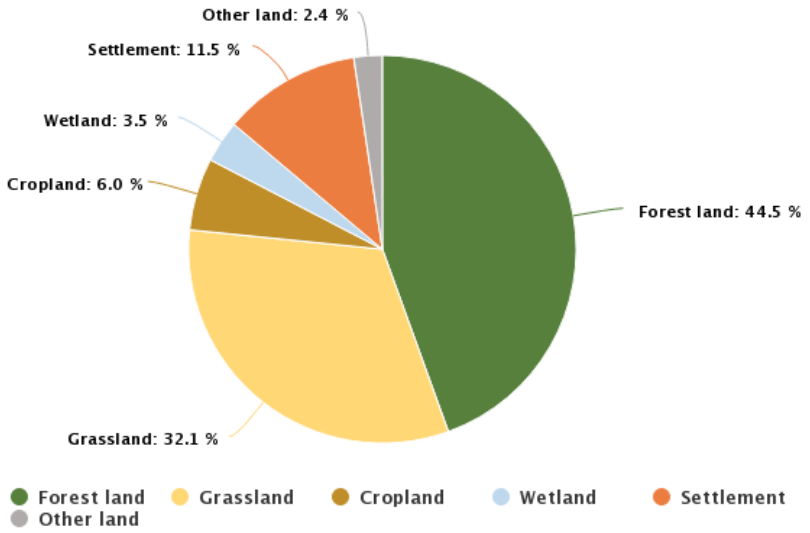
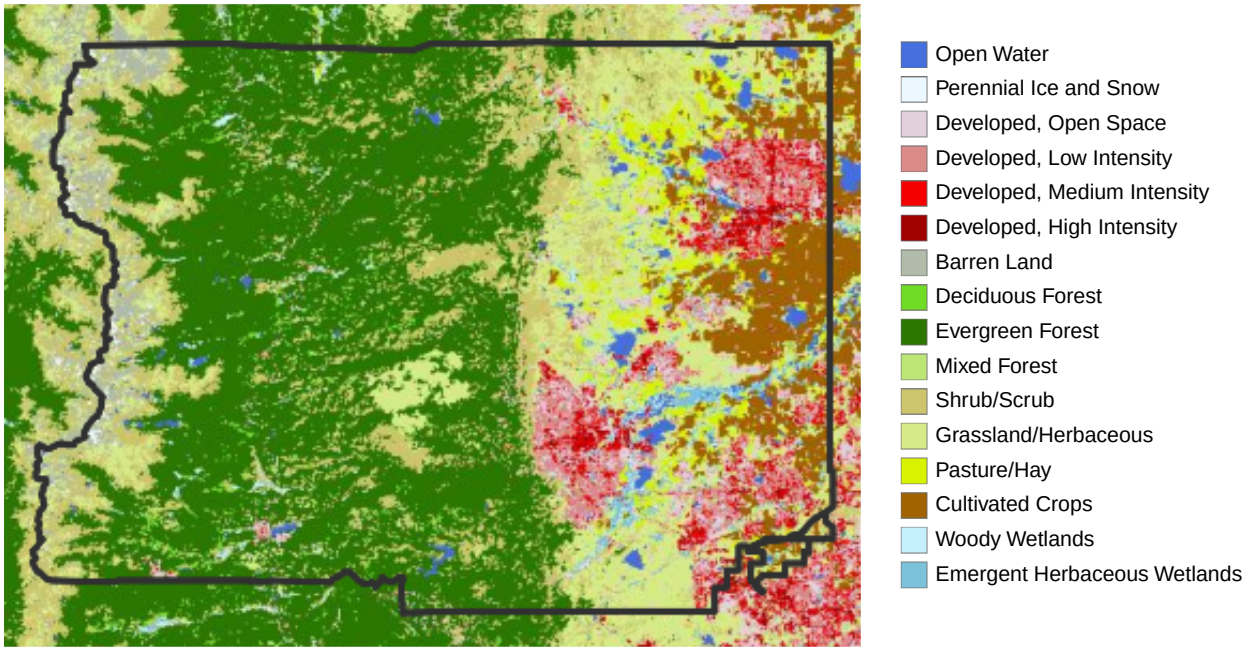


Figure 2. Land cover in Boulder from the National Land Cover Database, 2016

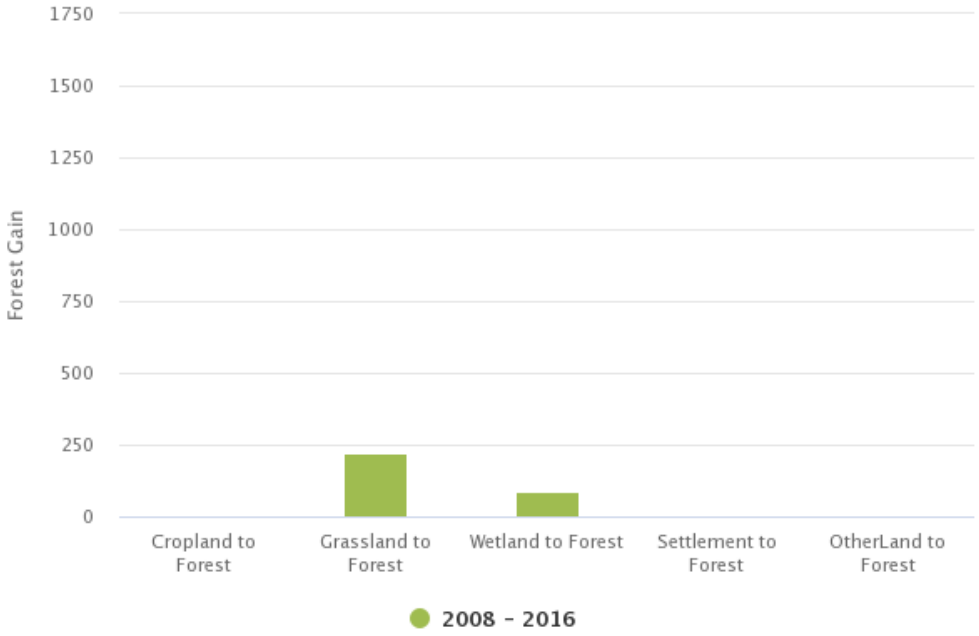


Forest Cover Change

Generating GHG estimates requires data not just on areas of land use, but also data on how land use has changed over time. Between 2008 and 2016, the county lost around 1,731 hectares (4,276 acres) of forest land, largely conversion to Grassland. Over the same period, the county gained around 308 hectares (762 acres) of forest land, largely from Grassland.

Figure 3. Loss of forest to other land use types between 2008 and 2016 (ha)

Figure 4. Gain of forest from other land use types between 2008 and 2016 (ha)



Forest Disturbances

Over the inventory period 2008 to 2016, forest disturbance from insects was the most significant in Boulder County, affecting 49016.4 hectares (121,122 acres), followed by harvests, which affected 293.9 hectares (726 acres) and fires, which affected 47.2 hectares (117 acres).

Trees Outside Forests

Figure 5 shows tree canopy captured by the NLCD tree canopy data. (Note that some areas with high tree canopy in Figure 5 overlap with the NLCD forest class shown in Figure 2.)

This data are available only for the years 2011 and 2016. Over this time period, Boulder County had an average of 4,331 hectares (10,701 acres) of tree canopy outside forests. Between 2011 and 2016, 1 hectares per year of tree canopy were lost, for a total of 6 hectares (16 acres) of tree canopy loss over the 5 year period. Most of this loss occurred within the Grassland class.

Figure 5. Tree canopy 2016 (Source: National Land Cover Database)

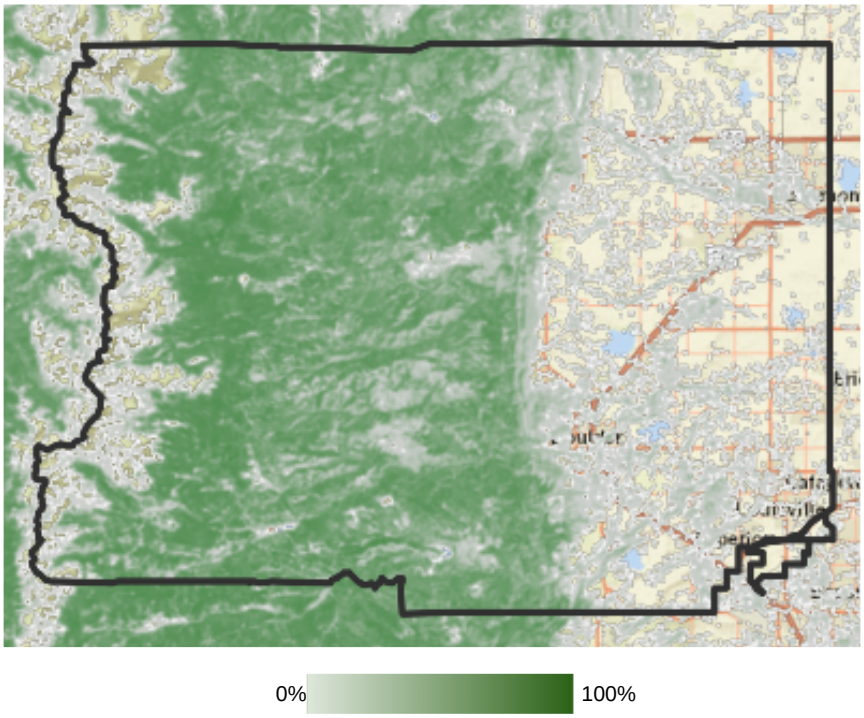


Figure 6: Average tree canopy (in hectares) and % tree canopy in different non-forest land use categories in Boulder County for the period 2011-2016. Note: bars relate to tree canopy area (left vertical-axis, hectares) and dots are the % tree cover per land use category (right vertical-axis). “Other” category not shown due to very low area.

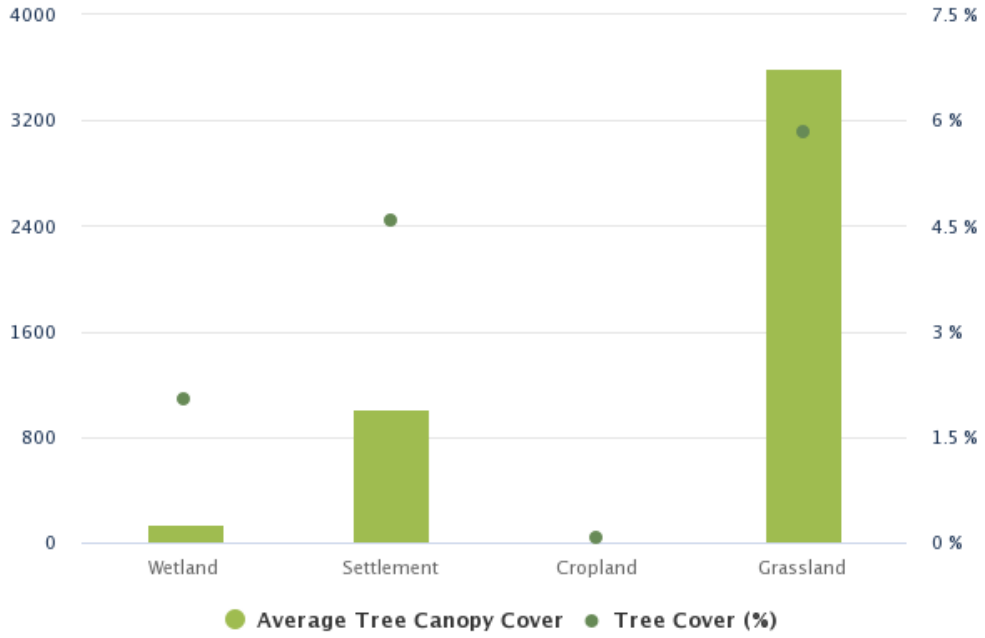
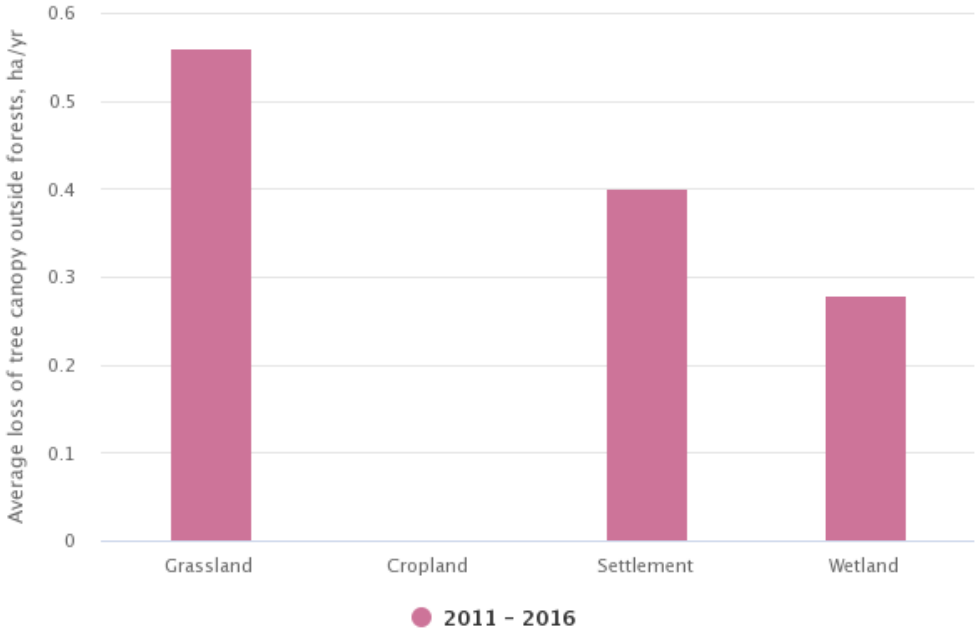


Figure 7: Average area of tree canopy loss in different non-forest land use categories in Boulder County over the period 2011 to 2016 (hectares per year). Note: other category not shown due to very low area.



Land Cover Change Matrix

Table 2. Full NLCD land cover change matrix for 2008 to 2016. All areas are in hectares.

2016: Top 2008: Left	Deciduous Forest	Evergreen Forest	Mixed Forest	Woody Wetlands	Cultivated Crops	Pasture/Hay	Grassland/Herbaceous	Shrub/Scrub	Open Water	Emergent Herbaceous Wetlands	Developed, Open Space	Developed, Low Intensity	Developed, Medium Intensity	Developed, High Intensity	Barren Land	Perennial Ice/Snow	Total
Deciduous Forest	1,829	3	2	0.3	0.1	0.8	22	5	1	1	2	1	0.4	0	0	0	1,868
Evergreen Forest	0.4	80,333	0.8	0	0	0	1,273	261	15	0.2	4	0.3	0.1	0	0.1	0	81,888
Mixed Forest	0.1	0	170	0.1	0	0	2	0	0	0	0.3	0	0	0	0	0	172
Woody Wetlands	0.4	0.1	1	2,665	2	27	11	4	15	63	7	6	5	1	0.1	0	2,807
Cultivated Crops	0	0.1	0	1	11,282	39	13	0	26	10	79	57	66	21	5	0	11,599
Pasture/Hay	0.9	0	0.2	5	52	5,995	5	0.6	2	25	18	13	14	7	0	0	6,138
Grassland/Herbaceous	0	51	0.4	22	217	425	25,794	938	77	106	145	82	93	40	5	0	27,995
Shrub/Scrub	5	128	2	8	1	10	727	25,868	4	16	18	5	1	0.1	0	0	26,792
Open Water	1	2	0.4	16	9	1	30	0.5	3,058	77	0.6	0.4	0.4	0.7	12	0	3,209
Emergent Herbaceous Wetlands	2	0.5	0.5	63	18	112	24	11	96	3,096	15	6	2	1	0	0	3,445
Developed, Open Space	0	0	0	0	0	0	0	0	0	0	6,750	31	103	27	0	0	6,911
Developed, Low Intensity	0	0	0	0	0	0	0	0	0	0	0	9,166	22	29	0	0	9,217
Developed, Medium Intensity	0	0	0	0	0	0	0	0	0	0	0	0	4,167	5	0	0	4,171
Developed, High Intensity	0	0	0	0	0	0	0	0	0	0	0	0	0	1,067	0	0	1,067
Barren Land	0	0	0	0	0	0	1	0	20	0.1	0	0	0.6	1	3,808	0	3,831
Perennial Ice/Snow	0	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0	690	690
Total	**1,839**	**80,518**	**177**	**2,779**	**11,580**	**6,608**	**27,901**	**27,088**	**3,314**	**3,393**	**7,039**	**9,366**	**4,474**	**1,202**	**3,831**	**690**	**0**

Table 3. Simplified land cover change matrix for 2008 to 2016.All areas are in hectares.

2016: Top 2008: Left	Forest Land	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest Land	85,005	2	1,605	96	28	0.2	**86,735**
Cropland	1	11,282	52	36	223	5	**11,599**
Grassland	222	271	59,761	229	436	5	**60,925**
Wetland	85	26	178	6,326	26	12	**6,654**
Settlement	0	0	0	0	21,366	0	**21,366**
Other Land	0	0	1	20	2	4,498	**4,520**
Total	**85,313**	**11,580**	**61,597**	**6,707**	**22,081**	**4,521**	**0**

Emission and Removal Factors

A summary of the emission and removal factors used in the calculations is provided in Table 4.

	Emission Factor (t C/ha)	Removal Factor (t C/ha/yr)
Forest Change		
Deforestation		
To Cropland	0.12	
To Grassland	38.49	
To Settlement	7.08	
To Wetland	13.73	
To Other	46.02	
Reforestation (Non-Forest to Forest)		-0.23
Forest Remaining Forest		
Undisturbed		-0.55
Disturbed		
Fire	26.67	
Insect/Disease	2.65	
Harvest/Other	50.49	
Trees Outside Forest		
Tree canopy loss	58.82	
Canopy maintained/gained		-2.16

Harvested Wood Products

Harvested wood products (HWP) temporarily store carbon from the forest ecosystem as the wood goes through a series of production processes and end-uses, with eventual disposal (and emission to the atmosphere). The delay represents a net benefit to the atmosphere. The period of storage varies from long-lived solid wood products that remain in use for long periods of time to products that are quickly disposed of in landfills.

In the web tool, the HWP Calculator tracks carbon in harvested wood through four different “fates,” from harvest to timber products to primary wood products to end-use to disposal, applying best estimates for product ratios and half-lives at each stage. Based on user inputs entered about annual harvest volumes in Boulder County, the change in the harvested wood pool over the inventory period 2008 to 2016 is estimated as 0 t CO2e per year.

Caveats

Information presented here represents a snapshot in time of the net GHG balance and many of the factors contributing to that balance. The estimates can help identify where policies may be designed to reduce net GHG emissions. This inventory currently uses a simplifying assumption that a loss of forest or trees results in immediate emissions to the atmosphere (rather than delayed emissions in the case of various use cases from long-term storage to shorter decay timelines if sent to landfills). In general, it is important to consider that these estimates represent a relatively short period of time compared with the long-term consequences of policy decisions and land management actions. For example, a forest converted to settlement represents a permanent loss of removal capacity. Over the long term, maintaining forests will sustain a higher rate of carbon removal, depending on age-related growth rates and occurrence of disturbances.

There are significant uncertainties in the estimates. Although not quantified here, typical greenhouse gas inventories of forests using similar approaches, including the national GHG inventory, report uncertainties in the net GHG balance that can be as high as ±45% (with 95% confidence). In the results presented here, the most uncertain estimates involve emissions from land-use change which are based on well-documented remote-sensing products, but relatively few field observations from a statistical sampling of county forests. While uncertainties can be high, the estimates can still provide useful information on the relative magnitude and importance of such GHGs; subsequent analyses can also provide information on the directionality of emissions and removals from land management.

Finally, it is recommended that additional analyses be done using models that project impacts of alternatives over coming decades. Such models are available and have been used in other studies at county scale. The GHG inventory presented here is only the first step to providing science-based information to support policy decisions. To more fully explore the potential impacts of alternate policies, projection models can be used to compare long-term results among the alternatives which typically include a “business as usual” (i.e. no change in policy) alternative. This feature may be added into the web tool in the future.