U.S. Forest Service
Briefing Paper
Research and Development

Topic: Improvements to the Land Use, Land Use Change, and Forestry chapter of the 2017 National Inventory Report (NIR) of greenhouse gas (GHG) emissions and removals.

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Issue: The 2017 National Inventory Report of greenhouse gas emissions and removals will be published and submitted to the UN on Friday, April 14 2017. A number of planned improvements for the forest land category within the 2017 NIR were made following the public review in response to public review comments and ongoing quality control procedures by EPA and the Forest Service. In particular, quality control procedures consistent with IPCC (2006) by EPA and the Forest Service during the 2017 public review phase resulted in refined analysis and interpretation of the land use dynamics and carbon losses associated with conversions from forest land to other land uses.

Summary/Key Points: In reviewing estimates that followed Tier 1 IPCC methodologies, the team determined that the public review version of the Inventory, based on Tier 1 methods, did not accurately characterize carbon losses. This was due to broad aggregation of FIA plots to determine pre-conversion carbon stock density as a result of forest land conversion to grassland, cropland and settlements, as well as the use of IPCC defaults for determining carbon stock changes after conversion in the case of forest land conversion to grassland in the Great Plains and Western United States. These quality control findings were further supported by peer review comments received during the public review. To remedy the peer review comments the following improvements where incorporated in the 2017 NIR.

1. *Forest Land Remaining Forest Land* (*FLRFL*) and *Land Converted to Forest Land* (*LCFL*) were separated, as was done for the 2016 submission, but in addition to the mineral soil pool that was included for LCFL in the previous submission, the *aboveground/belowground biomass, dead wood, and litter* pools were included in the 2017 submission for reporting carbon stock changes for LCFL. These estimates were developed using an estimation system based on annual FIA data and supplemented with periodic FIA and NRI data. Total estimated net carbon sequestration for *FLRFL* (-156 MMT C yr^{-1}, -571 MMT CO_2 eq. yr^{-1}), *LCFL* (-21 MMT C yr^{-1}, -75 MMT CO_2 eq. yr^{-1}), and Harvested Wood Products (-26 MMT C yr^{-1}, -96 MMT CO_2 eq. yr^{-1}) for the year 2015 in the 2017 NIR was -202 MMT C yr^{-1} (742 MMT CO_2 eq. yr^{-1}). In the 2017 NIR the inclusion of all IPCC pools in the *LCFL* category consistently contributed more than -21 MMT C yr^{-1} (-75 MMT CO_2 eq. yr^{-1}) over the recent time series.
2. Estimated carbon stock changes from *Forest Land Converted to Grasslands*, *Forest Land Converted to Cropland*, and *Forest Land Converted to Settlement (FLCL)* were expanded from the aboveground biomass, mineral and organic soils that were included in the 2016 submission for these conversions to now include *all* IPCC pools in the 2017 NIR. Total

estimated net carbon emissions from FLCL for the year 2015 in the final 2017 NIR was 22 MMT C (79 MMT CO2 eq. yr^{-1}) and those annual losses were consistently 22 MMT C yr^{-1} over the recent time series. Note that these estimates differ from the estimates included in the public review of the 2017 NIR. The carbon emissions in the FLCL categories in the public review draft of the 2017 NIR were biased high on the basis of a first-order analysis where IPCC Tier 1 methods were used. Quality control procedures indicated a need to examine more closely the land use dynamics and carbon losses associated with conversions from forest land to other land uses. In response, an additional analysis was implemented as part of finalizing the NIR to minimize the potential bias introduced during the IPCC Tier 1 assessment. The refined carbon density estimates on Forest Land prior to conversion were substantially lower than those obtained from the IPCC Tier 1 methods used in the draft 2017 Inventory. It was also determined that using an IPCC Tier I approach that assumes all woody biomass carbon is lost in the year of conversion for Forest Land Converted to Grasslands in the West and Great Plains states did not accurately characterize the transfer of carbon in woody biomass during abrupt or gradual land use change. To estimate this transfer of carbon in woody biomass, state-specific carbon densities for woody biomass remaining on these former forest lands following conversion to grasslands were developed and included in the estimation of carbon stock changes from Forest Land Converted to Grasslands in the West and Great Plains states. For all conversion in other states, the IPCC default values for herbaceous aboveground biomass and belowground biomass growth on Grasslands in the year after conversion were used and all woody biomass was assumed to be lost to the atmosphere in the year of the conversion.

3. A unit conversion error was discovered dating back to the 2016 NIR between FIA data files for litter and soil carbon and the estimation system was identified, corrected, and described in the 2017 NIR.
4. New harvested wood products data from 2006 to 2016 were included and only the WoodCarb II model was used to compile HWP estimates. In the 2016 NIR, WoodCarb II and the U.S. forest products module were used.
5. Emissions from drained organic soils on *FLRFL* and *LCFL* were included for the first time using the latest guidance in the 2013 IPCC Wetlands Supplement.

Planned Next Steps: Planned improvements for the next few years can be broadly assigned to the following categories: continued improvement of a robust estimation system, including individual carbon pool estimation, coordination with other land-use categories, and continued incorporation of FIA annual inventory data.

1. Improvement will provide more spatially and temporally resolved estimates of carbon stocks and stock changes in the forest land category. The initial phase of work is being piloted in 6 states in 2017 and will be expanded based on results and resources.
2. In situ observations from the inventory along with auxiliary information are being used to improve models to predict carbon in below-ground biomass, understory vegetation, foliage, and downed dead wood will be explored for implementation in the forest land category in the 2019 NIR.
3. A Tier 1 approach was used to estimate uncertainty associated with carbon stock changes in the FLRFL, LCFL, FLCL categories in the 2017 submission. More robust approaches for characterizing total uncertainty are underway.
4. Research on carbon dynamics within the LCFL and the FLCL categories is underway following IPCC guidelines.

5. Data from the Interior AK are being used to parameterize carbon pool models for use in future reporting (Domke et al. In prep).
6. All forest land category estimates and text will be reviewed internally within EPA and the Forest Service prior to submission for expert and public review to ensure that results and changes made in the forest land category are understood within these agencies prior to release. There will also be a brief prepared prior to expert submission documenting substantial changes in the forest land category.

U.S. Forest Service
Research & Development
Summary

Date: 11 April 2017

Topic: Summary of improvements and changes in the forest land category within the Land Use, Land Use Change, and Forestry chapter of the 2017 National Inventory Report (NIR) of greenhouse gas (GHG) emissions and removals.

Outcomes: Interested parties will gain an understanding of the changes and improvements made in the forest land category within the 2017 NIR and particularly those improvements that were made following the public review in response to public review comments and ongoing quality control procedures by EPA and the Forest Service.

Background: In response to comments from the UN Framework Convention on Climate Change (UNFCCC) Expert Review Team (ERT) and as part of USDA Forest Service's continuing work to improve the Land Use, Land Use Change, and Forestry chapter of the GHG Inventory, a range of technical changes and improvements were implemented that altered the 2017 NIR estimates from previous Inventory reports. In particular, quality control procedures consistent with IPCC (2006) by EPA and the Forest Service during the 2017 public review phase indicated a need to examine more closely the land use dynamics and carbon losses associated with conversions from forest land to other land uses. In reviewing estimates that followed Tier 1 IPCC methodologies, the team determined that the public review version of the Inventory, based on Tier 1 methods, did not accurately characterize carbon losses. This was due to broad aggregation of FIA plots to determine pre-conversion carbon stock density as a result of forest land conversion to grassland, cropland and settlements, as well as the use of IPCC defaults for determining carbon stock changes after conversion in the case of forest land conversion to grassland in the Great Plains and Western United States. These quality control findings were further supported by comments received during the public review. This document describes recent improvements and changes related to Forest Land carbon estimation in the 2017 NIR and describes improvements made during the 2017 public review period in response to internal OA/QC procedures and public review comments.

Summary of Technical changes and improvements

Several methodological changes and improvements were applied in the 2017 submission of the *Inventory of US GHG Emissions and Sinks: 1990-2015* report (referred to as NIR), to fully comply with methodological approaches based on the 2006 IPCC Guidelines and 2013 IPCC Wetlands Supplement and adhered to IPCC Good Practice Guidance and UNFCCC Reporting requirements. The results from implementation of these improvements, as compared to previous inventory reports are summarized below, including details for the most significant results:

1. *Forest Land Remaining Forest Land* (*FLRFL*) and *Land Converted to Forest Land* (*LCFL*) were separated, as was done for the 2016 submission, but in addition to the mineral soil pool that was included for LCFL in the previous submission, the *aboveground/belowground biomass, dead wood, and litter* pools were included in the 2017 NIR for reporting carbon stock changes for LCFL. These estimates were developed using an estimation system based almost entirely on annual FIA data.
2. Estimated carbon stock changes from *Forest Land Converted to Grasslands, Forest Land Converted to Cropland,* and *Forest Land Converted to Settlement (FLCL)* were expanded

from the aboveground biomass, mineral and organic soils that were included in the 2016 NIR for these conversions to now include *all* IPCC pools in the 2017 NIR.

3. A new model for estimating soil organic carbon (SOC) was fully implemented for *FLRFL* category based on an extensive network of field measurements (Domke et al. 2017) and mineral and organic soil carbon were separated for the first time in the *FLRFL* category.
4. A unit conversion error was discovered dating back to the 2015 submission between FIA data files for litter and soil carbon and the estimation system was identified, corrected, and described in the 2017 NIR.
5. Woodland area was compiled using the latest annual inventory data which led to minor changes in forest land area in the *FLRFL* category.
6. Conversion areas (*FLRFL* and *LCFL*) were updated based on the latest FIA and NRI data which led to minor changes in forest land area.
7. New harvested wood products (HWPs) data from 2006 to 2016 was included and only the WoodCarb II model was used to compile HWP estimates. In the 2016 NIR, WoodCarb II and the U.S. forest products module were used.
8. Downed dead wood carbon estimates were updated using adjustment factors based on annual FIA observations (Domke et al. 2013)
9. Emissions from drained organic soils on *FLRFL* and *LCFL* were included for the first time using the latest guidance in the 2013 IPCC Wetlands Supplement.
10. Several states updated their annual forest inventories which were included in the draft 2017 NIR.

Forest Land Category Results

These are the improvements that had the most substantial impact on estimates for the Forest Land and Forest Land conversion categories

1. Total estimated net carbon sequestration for *FLRFL* (-156 MMT C yr^{-1}, -571 MMT CO_2 eq. yr^{-1}), *LCFL* (-21 MMT C yr^{-1}, -75 MMT CO_2 eq. yr^{-1}), and Harvested Wood Products (-26 MMT C yr^{-1}, -96 MMT CO_2 eq. yr^{-1}) for the year 2015 in the 2017 NIR was -202 MMT C yr^{-1} (742 MMT CO_2 eq. yr^{-1}). In the 2017 NIR the inclusion of all IPCC pools in the *LCFL* category consistently contributed more than -21 MMT C yr^{-1} (-75 MMT CO_2 eq. yr^{-1}) over the recent time series (Table 1, Figure 1).
2. The most recent total estimated annual carbon sequestration from forest ecosystem pools and HWP in the *FLRFL* category increased by 5 percent between the 2016 and 2017 NIRs and those increases were consistent over the recent time series (Table 1). The comparisons are based on corrected estimates from the 2016 NIR for litter and soil carbon. Full implementation of the soil carbon model in the *FLRFL* category resulted in substantial increases in net annual sequestration which was offset, in part, by decreases in HWPs sequestration based on updated data from 2006 to 2015.
3. The managed forest land area over the recent time series changed by less than a fraction of 1 percent (Table 2) between the draft 2017 NIR and the 2016 NIR. The changes that occurred were due to updated woodland area estimates (Coulston et al. 2016) which are included in the Grassland land use category and updated NRI and FIA data for the conversion categories associated with forest land area gains or losses. The reclassification of woodland areas from the Forest Land category to the Grassland category are the result of the land use definitions used in the NIR Land Representation (i.e., the woodland areas do not meet the forest land definition).
4. The total carbon stocks in the *FLRFL* category between the 2017 NIR and the published 2016 NIR changed by less than 0.5 percent over the recent time series (Table 2). The comparisons are based on corrected estimates from the 2016 NIR for litter and soil carbon. The largest differences by IPCC pool were for dead wood (6 percent) and are based on the

inclusion of adjustment factors for downed dead wood pieces and residue piles based on FIA observations (Domke et al. 2013). HWP stock estimates decreased by approximately 3 percent over the recent time series and those changes can be attributed to updated HWPs data from 2006 to 2015.

5. Total estimated net carbon emissions from *FLCL* for the year 2015 in the final 2017 NIR was 22 MMT C (79 MMT CO_2 eq. yr^{-1}) and those annual losses were consistently 22 MMT C yr^{-1} over the recent time series (Table 1, Fig 1).
    a. These differ from the estimates included in the public review draft of the 2017 NIR (see Table 1 and Table 3 for comparisons). The carbon emissions in the Forest Land Converted to Lands (i.e., Cropland, Grassland, Settlement) categories in the public review draft of the 2017 NIR were biased high on the basis of a first-order analysis where only entire FIA plots defined as Forest Land during the initial measurement and non-Forest Land at the subsequent measurement were used. Since this data query resulted in a relatively small sample in most states, particularly Western states with limited remeasurement, as a second step, adjacent Forest Land plots with non-Forest Land conditions (e.g., a plot with forest land and non-forest land uses) were also included to develop the first-order carbon density estimates used as initial conditions on Forest Land prior to conversion in the public review Inventory. The effect of including these adjacent lands was that the initial forest carbon density estimates were biased high and resulted in an overestimate of the carbon losses associated with conversions from forest land to other land uses.
    b. Quality control procedures consistent with IPCC (2006) by EPA and the Forest Service during the 2017 public review, as well as comments received on the public review draft version of the 2017 NIR, indicated a need to examine more closely the land use dynamics and carbon losses associated with conversions from forest land to other land uses. In response, an additional analysis was implemented as part of finalizing the NIR to minimize the potential bias introduced during the first-order assessment. This analysis only included FIA plots and portions of plots defined as Forest Land during the initial measurement and non-Forest Land at the subsequent measurement (i.e., no plots or portions of plots that were forest land at the initial measurement and the remeasurement were included) and further disaggregated by the present land use (i.e., conversion category) – Cropland, Grasslands, or Settlement. Including all plots and portions of plots which had a land use change from Forest Land markedly increased the sample size in each state thus eliminating the need to include Forest Land plots adjacent to non-Forest Land and allowed for estimation of initial carbon densities on Forest Land which are specific to each land use conversion (e.g., Forest Land Converted to Cropland, Forest Land Converted Grasslands, Forest Land Converted to Settlements). The refined carbon density estimates on Forest Land prior to conversion were substantially lower than those obtained from the first-order analysis used in the public review draft 2017 Inventory.
    c. It was also determined that using an IPCC Tier I approach that assumes all carbon is lost in the year of conversion for Forest Land Converted to Grasslands in the West and Great Plains states did not accurately characterize the transfer of carbon in woody biomass during abrupt or gradual land use change. To estimate this transfer of carbon in woody biomass, state-specific carbon densities for woody biomass remaining on these former forest lands following conversion to grasslands were developed and included in the estimation of carbon stock changes from Forest Land Converted to Grasslands in the West and Great Plains states. A review of the literature in grassland and rangeland ecosystems (Asner et al. 2003, Huang et al. 2009, Tarhouni et al. 2016), as well as an analysis of FIA data, suggests that a conservative estimate of 50 percent of the woody biomass carbon density was lost during conversion from Forest

Land to Grasslands. This estimate was used to develop state-specific carbon density estimates for biomass, dead wood, and litter for Grasslands in the West and Great Plains states and these state-specific carbon densities were applied to each state-specific forest land carbon density estimate to compile the carbon losses associated with conversion from forest land to grassland in the West and Great Plains states.

d. For all conversion in other states, the IPCC default values for herbaceous aboveground biomass and belowground biomass growth on Grasslands in the year after conversion were used and all woody biomass was assumed to be lost to the atmosphere in the year of the conversion. Further, IPCC defaults values for aboveground biomass growth from annual crops were used in the year after conversion in all states in the Forest Land Converted to Cropland category and all woody biomass was assumed to be lost to the atmosphere in the year of the conversion. In Forest Land converted to Settlements all woody biomass was assumed to be lost to the atmosphere in the year of the conversion and no re-growth was assumed.

Planned Improvements

Planned improvements for the next few years can be broadly assigned to the following categories: development of a robust estimation system, individual carbon pool estimation, coordination with other land-use categories, and annual inventory data incorporation (see the Planned Improvements section within the Forest Land category of the 2017 NIR).

1. Research is underway to incorporate all FIA plot information (both annual and periodic data) and remotely sensed time series data for estimating GHG emissions and removals as well as change detection across the entire reporting period and all managed forest land in the United States (Domke et al. 2014, Deo et al. 2017). This improvement will provide more spatially and temporally resolved estimates of carbon stocks and stock changes in the forest land category. The initial phase of work is being piloted in 6 states in 2017 and will be expanded based on results and resources.
2. In situ observations from the NFI along with auxiliary information are being used to improve models to predict carbon in below-ground biomass (Russell et al. 2015), understory vegetation (Russell et al. 2014, Johnson et al. In prep)), foliage (Clough et al. 2016), and downed dead wood (Domke et al. In prep) and will be explored for implementation in the forest land category in the 2019 NIR.
3. A Tier 1 approach was used to estimate uncertainty associated with carbon stock changes in the FLRFL, LCFL, FLCL categories in the 2017 submission. More robust approaches for characterizing total uncertainty are underway (Clough et al. 2016, Clough et al. 2016).
4. Research on carbon dynamics within the LCFL and the FLCL categories is underway following IPCC guidelines.
5. Several FIA database processes will be institutionalized to increase efficiency and QA/QC in reporting and further improve transparency, consistency, and availability of data used in reporting.
6. Data from the Interior AK are being used to parameterize carbon pool models for use in future reporting (Domke et al. In prep).
7. Major methodological changes and improvements in the forest land category will continue to undergo peer review and will go through an application readiness protocol prior to adoption in future inventories. Furthermore, to maintain consistency and continuity in reporting, these changes and improvements will be adopted together in years when all components are compiled over the entire time series.
8. All forest land category estimates and text will be reviewed internally within EPA and the Forest Service prior to submission for expert and public review to ensure that results and

changes made in the forest land category are understood within these agencies prior to release. There will also be a brief prepared prior to expert submission documenting substantial changes in the forest land category.

Additional details: This document is a companion and expansion of the 2-page brief developed by the USDA Forest Service which describes the most substantial changes and improvements made throughout the 2017 NIR compilation process for the forest land category. You may also refer to the Land Use, Land Use Change, and Forestry chapter of the 2017 NIR which describes all changes and improvements and will be published on April 15, 2017.

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

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Table 1. Difference in forest carbon stock change by pool between the draft estimates in the 2017 NIR and the 2016 published NIR. Note that the units were corrected for litter and soil carbon estimates in the 2016 NIR to allow for comparison. Negative differences represent increases in carbon sequestration and positive differences represent decreases in sequestration. Also included are 2017 NIR Public Review estimates for FLCL for comparison to final estimates compiled during PR.

	2010	2011	2012	2013	2014	2015
FLRFL flux 2017 Draft NIR	**-164**	**-165**	**-163**	**-163**	**-162**	**-156**
FLRFL flux 2016 NIR*	**-147**	**-146**	**-146**	**-144**	**-144**	
Difference b/t 2016 and Draft 2017	**-18**	**-19**	**-17**	**-19**	**-18**	
HWP flux 2017 Draft NIR	**-18**	**-18**	**-19**	**-21**	**-21**	**-26**
HWP flux 2016 NIR*	**-26**	**-27**	**-28**	**-29**	**-31**	
Difference b/t 2016 and Draft 2017	**8**	**9**	**9**	**8**	**10**	
Total 2017 Draft NIR	**-183**	**-183**	**-182**	**-183**	**-183**	**-182**
Total 2016 NIR*	**-173**	**-173**	**-174**	**-174**	**-174**	
Difference b/t 2016 and Draft 2017	**-10**	**-10**	**-8**	**-9**	**-8**	
LCFL flux Draft 2017 NIR	**-21**	**-21**	**-21**	**-21**	**-21**	**-21**
LCFL flux 2016 NIR*	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	
Difference b/t 2016 and Draft 2017	**-21**	**-21**	**-20**	**-20**	**-20**	
FLRFL and LCFL flux Draft 2017 NIR	**-203**	**-204**	**-203**	**-204**	**-203**	**-202**
FLRFL and LCFL flux 2016 NIR*	**-173**	**-173**	**-174**	**-174**	**-174**	
Difference b/t 2016 and Draft 2017	**-31**	**-31**	**-29**	**-30**	**-29**	
FLCL flux Final 2017 NIR	**22**	**22**	**22**	**22**	**22**	**22**
FLCL flux Draft 2017 NIR	**79**	**77**	**76**	**76**	**76**	**76**
Difference b/t Final 2017 and Draft 2017 NIR	**-57**	**-55**	**-54**	**-54**	**-54**	**-54**
FLCL flux Final 2017 NIR	**22**	**22**	**22**	**22**	**22**	**22**
FLCL flux 2016 NIR*	**9**	**9**	**10**	**10**	**10**	
Difference b/t 2016 and Final 2017 NIR	**13**	**13**	**12**	**12**	**12**	

* Note that the units were corrected for litter and soil carbon estimates in the 2016 NIR to allow for comparison.

Table 2. Difference in forest land area and carbon stocks (forest and harvested wood products) between the draft estimates in the 2017 NIR and the 2016 published NIR. Positive differences represent increases while negative values represent decreases.

	2010	2011	2012	2013	2014	2015	2016
Forest Area (1000 ha) Draft 2017 NIR	**270,258**	**270,654**	**271,064**	**271,512**	**271,812**	**272,113**	**272,260**
Forest Area (1000 ha) 2016 NIR*	**270,065**	**270,462**	**270,871**	**271,871**	**271,719**	**272,158**	
Difference b/t 2016 and 2017	**193**	**192**	**193**	**-359**	**93**	**-45**	
Forest stocks (MMT C) Draft 2017 NIR	**50,002**	**50,166**	**50,331**	**50,494**	**50,657**	**50,819**	**50,975**
Forest stocks (MMT C) 2016 NIR*	**49,782**	**49,928**	**50,074**	**50,220**	**50,364**	**50,508**	
Difference b/t 2016 and 2017	**220**	**238**	**257**	**275**	**293**	**311**	
HWP stocks (MMT C) Draft 2017 NIR	**2,462**	**2,481**	**2,498**	**2,517**	**2,538**	**2,559**	**2,585**
HWP stocks (MMT C) 2016 NIR*	**2,474**	**2,500**	**2,527**	**2,555**	**2,584**	**2,615**	
Difference b/t 2016 and 2017	**-12**	**-19**	**-29**	**-38**	**-46**	**-56**	
Total stocks (MMT C) Draft 2017 NIR	**52,464**	**52,647**	**52,830**	**53,012**	**53,195**	**53,378**	**53,560**
Total stocks (MMT C) 2016 NIR*	**52,256**	**52,428**	**52,601**	**52,775**	**52,949**	**53,123**	
Difference b/t 2016 and 2017	**209**	**218**	**229**	**237**	**246**	**255**	

* Note that the units were corrected for litter and soil carbon estimates in the 2016 NIR to allow for comparison.

Table 3. Carbon Stock Changes from Conversion of Forest Land to Grassland/Settlements/Croplands: 2017 Draft (i.e., Public Review) and Final Estimates

Conversion Category	Draft Estimate 2015 (MMT C)	Final Estimate 2015 (MMT C)	Average Change Over Time-Series (MMT C)	Area Conversion 2015 (ha)	Change Over Time-Series
Forest to Grassland	**83**	**8.8**	**-79.5**	**1,348,981**	**-90%**
Forest to Settlement	**34.6**	**12.2**	**-26.9**	**59,697**	**-70%**
Forest to Cropland	**4.6**	**1**	**-8.1**	**404,488**	**-75%**
TOTALS	**122.2**	**22**		**1,813,166**	

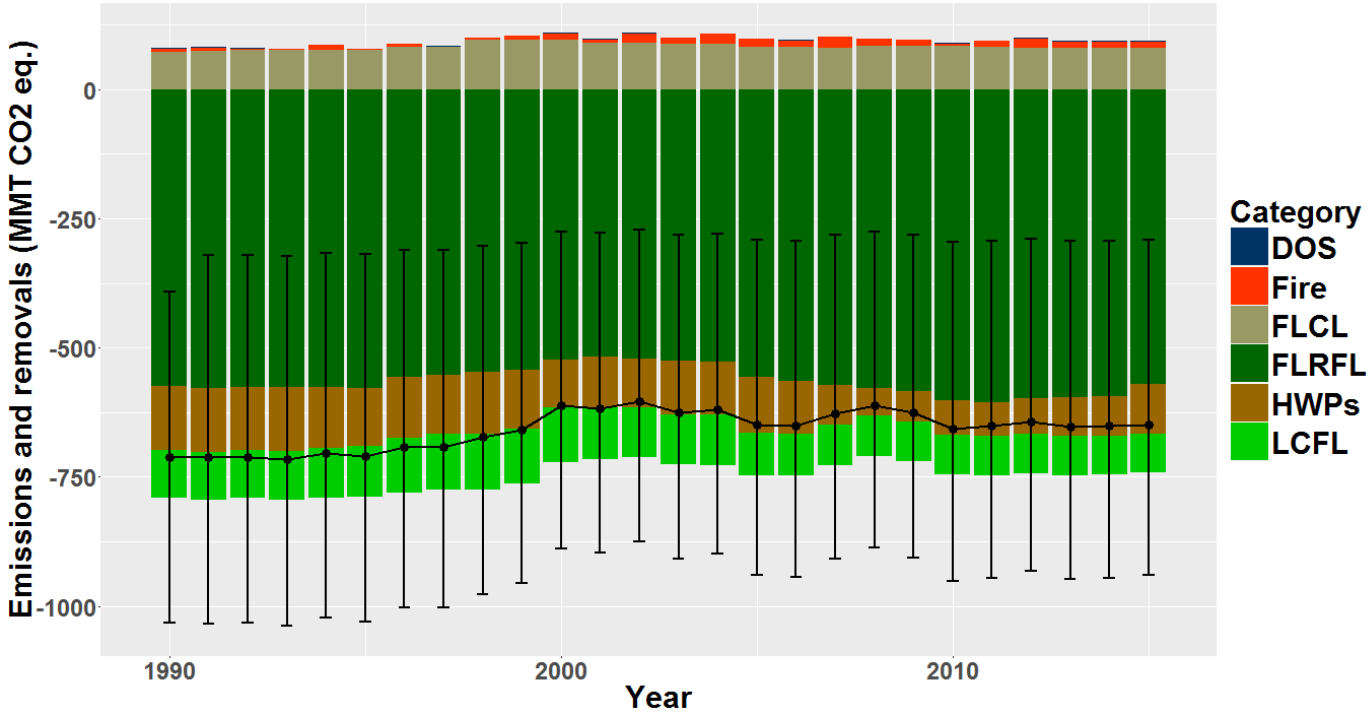

Figure 1. Estimated emissions and removals (MMT CO_2 eq.) from all sources and sinks associated with forest land in the final 2017 NIR. Note that the points represent the estimated net from all sources and sinks associated with forest land (with approximate 95 percent confidence intervals). DOS = Drained organic soils, Fire = Non-CO_2 emissions from wildland and prescribed fire (expressed as CO_2 eq.), FLCL = Forest Land Converted to Land, FLRFL = Forest Land Remaining Forest Land, Harvested Wood Products, Land Converted to Forest Land.

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