

Albedo-Induced Global Warming Impact at Multiple Temporal Scales within an Upper Midwest USA Watershed

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Table S1. Summary table for the overall linear downscaling models (Equation (1) in the main text) for the estimated $\hat{\alpha}_{gs}$ and $\hat{\alpha}_{mo}$ (dependent variables) across the entire Kalamazoo River Watershed.

	Variable	Estimates	SE	t	p	DF	adj. R ²
α_{gs}	barren	0.152	0.000	1340.300	***		
	*cropland	0.174	0.000	26281.727	***		
	*forest	0.145	0.000	13171.109	***		
	grassland	0.129	0.000	1347.355	***		
	*pasture	0.165	0.000	5715.941	***	9	0.995
	shrubland	0.138	0.000	653.438	***		
	*urban	0.145	0.000	10926.929	***		
	water	0.091	0.000	2815.767	***		
	wetland	0.154	0.000	12248.465	***		
α_{mo}	barren	0.237	0.003	93.220	***		
	*cropland	0.283	0.000	1904.740	***		
	*forest	0.185	0.000	745.962	***		
	grassland	0.171	0.002	76.378	***		
	*pasture	0.260	0.001	398.528	***	9	0.745
	shrubland	0.149	0.005	32.996	***		
	*urban	0.215	0.000	715.211	***		
	water	0.183	0.001	251.948	***		
	wetland	0.215	0.000	766.229	***		

Signif. codes: *** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05, · p-value < 0.1, " " p-value > 0.1.

$\hat{\alpha}_{gs}$ and $\hat{\alpha}_{mo}$: estimated whites-sky shortwave albedo for growing season and monthly periods, respectively.

"*": cover types considered in this study.

Table S2. Mean (\pm standard deviation) for $\hat{\alpha}_{gs}$ and $\hat{\alpha}_{mo}$ 2001–2019 for the four cover types. Average values (\bar{X}) across the four cover types ($\bar{X}_{cover\ type}$) and for the 19-years growing season (\bar{X}_{gs}) and the 11-month (\bar{X}_{mo}) periods are also shown.

Time-period		Cover type				
		Cropland	Forest	Pasture	Urban	$\bar{X}_{cover\ type}$
$\hat{\alpha}_{gs}$	2001	0.171(±0.002)	0.143(±0.001)	0.163(±0.001)	0.145(±0.001)	0.156(±0.013)
	2002	0.174(±0.001)	0.152(±0.001)	0.166(±0.001)	0.149(±0.002)	0.160(±0.011)
	2003	0.169(±0.001)	0.146(±0.001)	0.162(±0.001)	0.145(±0.001)	0.155(±0.012)
	2004	0.172(±0.002)	0.144(±0.001)	0.161(±0.001)	0.143(±0.002)	0.155(±0.014)
	2005	0.171(±0.002)	0.145(±0.001)	0.162(±0.001)	0.144(±0.002)	0.156(±0.013)
	2006	0.172(±0.002)	0.146(±0.001)	0.165(±0.001)	0.145(±0.002)	0.157(±0.014)
	2007	0.170(±0.001)	0.148(±0.001)	0.160(±0.001)	0.146(±0.001)	0.156(±0.011)
	2008	0.171(±0.001)	0.147(±0.001)	0.163(±0.001)	0.146(±0.001)	0.157(±0.012)
	2009	0.174(±0.002)	0.146(±0.002)	0.166(±0.001)	0.148(±0.002)	0.158(±0.014)
	2010	0.172(±0.002)	0.141(±0.002)	0.161(±0.001)	0.145(±0.002)	0.155(±0.014)
	2011	0.175(±0.002)	0.149(±0.001)	0.166(±0.001)	0.147(±0.002)	0.159(±0.013)
	2012	0.170(±0.001)	0.150(±0.001)	0.161(±0.001)	0.147(±0.001)	0.157(±0.010)
	2013	0.168(±0.001)	0.145(±0.001)	0.160(±0.001)	0.144(±0.001)	0.154(±0.012)
	2014	0.172(±0.002)	0.147(±0.001)	0.167(±0.001)	0.147(±0.002)	0.158(±0.013)
	2015	0.169(±0.002)	0.134(±0.002)	0.156(±0.001)	0.142(±0.002)	0.150(±0.015)
	2016	0.171(±0.001)	0.147(±0.001)	0.163(±0.001)	0.147(±0.002)	0.157(±0.012)
	2017	0.170(±0.002)	0.141(±0.001)	0.159(±0.001)	0.142(±0.002)	0.153(±0.014)
	2018	0.168(±0.002)	0.141(±0.001)	0.156(±0.001)	0.143(±0.001)	0.152(±0.013)
	2019	0.173(±0.001)	0.151(±0.001)	0.164(±0.001)	0.148(±0.001)	0.159(±0.012)
	\bar{X}_{gs}	0.171(±0.002)	0.145(±0.004)	0.162(±0.003)	0.146(±0.002)	0.156(±0.013)
$\hat{\alpha}_{mo}$	Jan	0.575(±0.013)	0.320(±0.012)	0.504(±0.013)	0.413(±0.008)	0.453(±0.111)
	Feb	0.579(±0.013)	0.333(±0.012)	0.516(±0.013)	0.408(±0.008)	0.459(±0.109)
	Apr	0.162(±0.002)	0.129(±0.002)	0.155(±0.002)	0.139(±0.002)	0.147(±0.015)
	May	0.175(±0.002)	0.146(±0.002)	0.169(±0.002)	0.150(±0.001)	0.160(±0.014)
	Jun	0.178(±0.001)	0.163(±0.001)	0.177(±0.001)	0.158(±0.001)	0.169(±0.010)
	Jul	0.179(±0.001)	0.160(±0.001)	0.173(±0.001)	0.155(±0.001)	0.167(±0.011)
	Aug	0.177(±0.002)	0.153(±0.001)	0.166(±0.001)	0.149(±0.002)	0.161(±0.013)
	Sep	0.170(±0.002)	0.145(±0.001)	0.160(±0.001)	0.144(±0.001)	0.155(±0.012)
	Oct	0.156(±0.001)	0.136(±0.001)	0.151(±0.001)	0.138(±0.001)	0.145(±0.010)
	Nov	0.158(±0.002)	0.119(±0.002)	0.147(±0.002)	0.134(±0.002)	0.140(±0.017)
	Dec	0.530(±0.013)	0.277(±0.012)	0.463(±0.014)	0.374(±0.008)	0.411(±0.110)
	\bar{X}_{mo}	0.276(±0.183)	0.189(±0.080)	0.253(±0.156)	0.215(±0.119)	0.233(±0.134)

$\hat{\alpha}_{gs}$ and $\hat{\alpha}_{mo}$: estimated whites-sky shortwave albedo for growing season and monthly periods, respectively.

Table S3.1. Growing season albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha_{\text{GS}}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ gs}^{-1}$) 2001–2019 for Ecoregion 56b. Cumulative $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ value for the entire ecoregion over the 19-year period is underlined. Major deviations (i.e., peaks (\uparrow) and decreases (\downarrow)) from the $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ mean are also shown. Positive and negative values of $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ indicate growing season warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, 2001–2019.

Ecoregion	GS	$\text{GWI}_{\Delta\alpha_{\text{GS}}} (\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ gs}^{-1})$			
		Cropland	Pasture	Urban	Tot.cover type
56b	2001	-0.37	-0.29 \downarrow	-0.03	-0.69
	2002	-0.29 \uparrow	-0.20 \uparrow^{**}	0.04 \uparrow^{**}	-0.45
	2003	-0.32 \uparrow^{**}	-0.23	0.01	-0.54
	2004	-0.39	-0.25	0.00	-0.64
	2005	-0.35	-0.24	0.01	-0.58
	2006	-0.36	-0.27 \downarrow^*	0.01	-0.63
	2007	-0.30 \uparrow	-0.18 \uparrow	0.03 \uparrow	-0.46
	2008	-0.34	-0.24	0.00	-0.58
	2009	-0.39	-0.28 \downarrow	-0.02	-0.68
	2010	-0.42 \downarrow	-0.29 \downarrow	-0.06	-0.77
	2011	-0.35	-0.24	0.02 \uparrow^*	-0.57
	2012	-0.27 \uparrow^*	-0.16 \uparrow^*	0.04 \uparrow^{**}	-0.39
	2013	-0.33	-0.22	0.01	-0.55
	2014	-0.35	-0.28 \downarrow	0.00	-0.64
	2015	-0.47 \downarrow^{**}	-0.31 \downarrow^{**}	-0.10	-0.89
	2016	-0.33	-0.23	0.00	-0.56
	2017	-0.40 \downarrow^*	-0.25	-0.01	-0.67
	2018	-0.37	-0.22	-0.03	-0.62
	2019	-0.31 \uparrow	-0.20 \uparrow^{**}	0.03 \uparrow	-0.48
	Tot.2001–2019	-6.73	-4.60	-0.03	<u>-11.36</u>
	$\bar{X}_{2001-2019}$	-0.35	-0.24	0.00	

GS: growing season.

"*" and "**": min and max decrease/peak, respectively.

"-": no data available.

Table S3.2. Growing season albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha_{\text{GS}}}$, $\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1}$) 2001–2019 for Ecoregion 56d. Cumulative $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ value for the entire ecoregion over the 19-year period is underlined. Major deviations (i.e., peaks (\uparrow) and decreases (\downarrow)) from the $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ mean are also shown. Positive and negative values of $\text{GWI}_{\Delta\alpha_{\text{GS}}}$ indicate growing season warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, 2001–2019.

Ecoregion	GS	$\text{GWI}_{\Delta\alpha_{\text{GS}}} (\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1})$			
		Cropland	Pasture	Urban	Tot.cover type
56d	2001	-0.37	–	-0.04 \downarrow^*	-0.41
	2002	-0.29 \uparrow	–	0.04 \uparrow^{**}	-0.25
	2003	-0.32 \uparrow^{**}	–	0.01	-0.31
	2004	-0.39 \downarrow^*	–	0.00	-0.39
	2005	-0.35	–	0.01	-0.34
	2006	-0.36	–	0.00	-0.36
	2007	-0.30 \uparrow	–	0.02 \uparrow^*	-0.28
	2008	-0.34	–	0.00	-0.34
	2009	-0.39	–	-0.03	-0.42
	2010	-0.43 \downarrow	–	-0.06 \downarrow	-0.49
	2011	-0.36	–	0.02	-0.34
	2012	-0.27 \uparrow^*	–	0.04 \uparrow^{**}	-0.23
	2013	-0.33	–	0.00	-0.33
	2014	-0.35	–	-0.01	-0.36
	2015	-0.47 \downarrow^{**}	–	-0.11 \downarrow^{**}	-0.58
	2016	-0.34	–	0.00	-0.34
	2017	-0.40 \downarrow	–	-0.02	-0.42
	2018	-0.38	–	-0.03	-0.40
	2019	-0.31 \uparrow	–	0.03	-0.28
	Tot.2001–2019	-6.76		-0.13	<u>-6.89</u>
	$\bar{X}_{2001-2019}$	-0.36		-0.01	

GS: growing season.

"*" and "**": min and max decrease/peak, respectively.

"–": no data available.

Table S3.3. Growing season albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha_{\text{gs}}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ gs}^{-1}$) 2001–2019 for Ecoregion 56f. Cumulative $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ value for the entire ecoregion over the 19-year period is underlined. Major deviations (i.e., peaks (\uparrow) and decreases (\downarrow)) from the $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ mean are also shown. Positive and negative values of $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ indicate growing season warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, 2001–2019.

Ecoregion	GS	$\text{GWI}_{\Delta\alpha_{\text{gs}}} (\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ gs}^{-1})$			
		Cropland	Pasture	Urban	Tot.cover type
56f	2001	-0.37	-0.27 \downarrow	-0.03 \downarrow	-0.67
	2002	-0.28 \uparrow	-0.19 \uparrow^{**}	0.04 \uparrow^{**}	-0.43
	2003	-0.31 \uparrow^{**}	-0.22	0.01	-0.52
	2004	-0.38	-0.24	0.01	-0.61
	2005	-0.35	-0.23	0.02	-0.56
	2006	-0.35	-0.26 \downarrow^*	0.01	-0.60
	2007	-0.30 \uparrow	-0.17 \uparrow	0.03 \uparrow	-0.44
	2008	-0.33	-0.22	0.00	-0.55
	2009	-0.38	-0.26 \downarrow^*	-0.02 \downarrow^*	-0.66
	2010	-0.42 \downarrow	-0.27 \downarrow	-0.05 \downarrow	-0.75
	2011	-0.35	-0.23	0.03 \uparrow^*	-0.55
	2012	-0.27 \uparrow^*	-0.14 \uparrow^*	0.04 \uparrow^{**}	-0.37
	2013	-0.32	-0.21	0.01	-0.52
	2014	-0.34	-0.27 \downarrow	0.00	-0.62
	2015	-0.47 \downarrow^{**}	-0.29 \downarrow^{**}	-0.10 \downarrow^{**}	-0.86
	2016	-0.33	-0.22	0.01	-0.54
	2017	-0.40 \downarrow^*	-0.24	-0.01	-0.64
	2018	-0.37	-0.21	-0.02 \downarrow^*	-0.60
	2019	-0.31 \uparrow^{**}	-0.18 \uparrow	0.04 \uparrow^{**}	-0.46
	Tot.2001–2019	-6.63	-4.31	0.00	<u>-10.94</u>
	$\bar{X}_{2001-2019}$	-0.35	-0.23	0.00	

GS: growing season.

"*" and "**": min and max decrease/peak, respectively.

"-": no data available.

Table S3.4. Growing season albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha_{\text{gs}}}$, $\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1}$) 2001–2019 for Ecoregion 56g. Cumulative $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ value for the entire ecoregion over the 19-year period is underlined. Major deviations (i.e., peaks (\uparrow) and decreases (\downarrow)) from the $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ mean are also shown. Positive and negative values of $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ indicate growing season warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, 2001–2019.

Ecoregion	GS	$\text{GWI}_{\Delta\alpha_{\text{gs}}} (\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1})$			
		Cropland	Pasture	Urban	Tot.cover type
56g	2001	-0.36	-0.26 \downarrow	-0.02 \downarrow^*	-0.65
	2002	-0.28 \uparrow	-0.18 \uparrow^{**}	0.05 \uparrow^*	-0.41
	2003	-0.31 \uparrow^{**}	-0.21	0.02	-0.50
	2004	-0.37	-0.23	0.01	-0.59
	2005	-0.34	-0.22	0.02	-0.54
	2006	-0.35	-0.25 \downarrow	0.02	-0.58
	2007	-0.29 \uparrow	-0.16 \uparrow	0.04 \uparrow^*	-0.42
	2008	-0.33	-0.22	0.01	-0.53
	2009	-0.37	-0.25 \downarrow^*	-0.01	-0.64
	2010	-0.41 \downarrow	-0.27 \downarrow	-0.05 \downarrow	-0.73
	2011	-0.34	-0.22	0.03	-0.52
	2012	-0.26 \uparrow^*	-0.14 \uparrow^*	0.05 \uparrow^{**}	-0.35
	2013	-0.32	-0.20	0.02	-0.51
	2014	-0.34	-0.26 \downarrow	0.01	-0.59
	2015	-0.46 \downarrow^{**}	-0.29 \downarrow^{**}	-0.09 \downarrow^{**}	-0.84
	2016	-0.32	-0.21	0.01	-0.52
	2017	-0.39 \downarrow^*	-0.23	0.00	-0.62
	2018	-0.36	-0.20	-0.02	-0.58
	2019	-0.30 \uparrow	-0.18 \uparrow^{**}	0.04 \uparrow^*	-0.44
	Tot.2001–2019	-6.50	-4.19	0.14	<u>-10.54</u>
	$\bar{X}_{2001-2019}$	-0.34	-0.22	0.01	

GS: growing season.

"*" and "***": min and max decrease/peak, respectively.

"-": no data available.

Table S3.5. Growing season albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha_{\text{gs}}}$, $\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1}$) 2001–2019 for Ecoregion 56h. Cumulative $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ value for the entire ecoregion over the 19-year period is underlined. Major deviations (i.e., peaks (\uparrow) and decreases (\downarrow)) from the $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ mean are also shown. Positive and negative values of $\text{GWI}_{\Delta\alpha_{\text{gs}}}$ indicate growing season warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, 2001–2019.

Ecoregion	GS	$\text{GWI}_{\Delta\alpha_{\text{gs}}} (\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1})$			
		Cropland	Pasture	Urban	Tot.cover type
56h	2001	-0.37	-0.26	-0.03 \downarrow	-0.65
	2002	-0.28 \uparrow	-0.17 \uparrow^{**}	0.04 \uparrow	-0.42
	2003	-0.31 \uparrow^{**}	-0.20	0.01	-0.51
	2004	-0.38	-0.22	0.00	-0.60
	2005	-0.35	-0.21	0.01 \uparrow^*	-0.55
	2006	-0.35	-0.24 \downarrow^*	0.01	-0.59
	2007	-0.30 \uparrow	-0.16 \uparrow	0.03 \uparrow	-0.43
	2008	-0.33	-0.21	0.00	-0.54
	2009	-0.38	-0.25 \downarrow	-0.02 \downarrow^*	-0.65
	2010	-0.42 \downarrow	-0.26 \downarrow	-0.06 \downarrow	-0.73
	2011	-0.35	-0.21	0.02 \uparrow	-0.53
	2012	-0.27 \uparrow^*	-0.13 \uparrow^*	0.04 \uparrow^{**}	-0.36
	2013	-0.33	-0.20	0.01	-0.51
	2014	-0.34	-0.25 \downarrow	0.00	-0.60
	2015	-0.47 \downarrow^{**}	-0.28 \downarrow^{**}	-0.10 \downarrow^{**}	-0.85
	2016	-0.33	-0.20	0.01	-0.53
	2017	-0.40 \downarrow^*	-0.22	-0.01 \downarrow	-0.63
	2018	-0.37	-0.19	-0.02 \downarrow^*	-0.59
	2019	-0.31 \uparrow^{**}	-0.17 \uparrow^{**}	0.03 \uparrow	-0.44
	Tot.2001–2019	-6.64	-4.04	-0.02	<u>-10.71</u>
	$\bar{X}_{2001-2019}$	-0.35	-0.21	0.00	

GS: growing season.

"*" and "***": min and max decrease/peak, respectively.

"-": no data available.

Table S4.1. Monthly albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha\text{mo}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$) January–December for Ecoregion 56b. Cumulative $\text{GWI}_{\Delta\alpha\text{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{GWI}_{\Delta\alpha\text{mo}}$ indicate monthly warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, during the 19-year period.

Ecoregion	Month	$\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$)			
		Cropland	Pasture	Urban	Tot.cover type
56b	Jan	-1.50	-1.11	-0.54	-3.16
	Feb	-2.15	-1.64	-0.64	-4.43
	Apr	-0.50	-0.41	-0.15	-1.06
	May	-0.50	-0.40	-0.08	-0.98
	Jun	-0.28	-0.26	0.09	-0.45
	Jul	-0.32	-0.22	0.09	-0.45
	Aug	-0.35	-0.19	0.05	-0.49
	Sep	-0.29	-0.18	0.01	-0.46
	Oct	-0.18	-0.14	-0.02	-0.34
	Nov	-0.23	-0.17	-0.09	-0.48
	Dec	-1.21	-0.91	-0.46	-2.58
	Tot.Jan–Dec	-7.52	-5.63	-1.75	<u>-14.89</u>
	$\bar{X}_{\text{Jan–Dec}}$	-0.68	-0.51	-0.16	

“–”: no data available.

Table S4.2. Monthly albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha\text{mo}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$) January–December for Ecoregion 56d. Cumulative $\text{GWI}_{\Delta\alpha\text{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{GWI}_{\Delta\alpha\text{mo}}$ indicate monthly warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, during the 19-year period.

Ecoregion	Month	$\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$)			
		Cropland	Pasture	Urban	Tot.cover type
56d	Jan	-1.49	–	-0.58	-2.07
	Feb	-2.11	–	-0.70	-2.82
	Apr	-0.51	–	-0.16	-0.67
	May	-0.51	–	-0.09	-0.60

Jun	-0.28	–	0.08	-0.20
Jul	-0.32	–	0.08	-0.25
Aug	-0.35	–	0.04	-0.31
Sep	-0.29	–	0.01	-0.28
Oct	-0.18	–	-0.02	-0.21
Nov	-0.23	–	-0.09	-0.32
Dec	-1.21	–	-0.48	-1.70
Tot, Jan–Dec	-7.50		-1.92	-9.42
$\bar{X}_{\text{Jan–Dec}}$	-0.68		-0.17	

“–”: no data available.

Table S4.3. Monthly albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha\text{mo}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$) January–December for Ecoregion 56f. Cumulative $\text{GWI}_{\Delta\alpha\text{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{GWI}_{\Delta\alpha\text{mo}}$ indicate monthly warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, during the 19-year period.

Ecoregion	Month	$\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$)			
		Cropland	Pasture	Urban	Tot., cover type
56f	Jan	-1.48	-1.04	-0.53	-3.05
	Feb	-2.11	-1.53	-0.64	-4.27
	Apr	-0.50	-0.38	-0.15	-1.03
	May	-0.49	-0.37	-0.08	-0.94
	Jun	-0.27	-0.24	0.09	-0.42
	Jul	-0.32	-0.20	0.09	-0.42
	Aug	-0.34	-0.17	0.06	-0.46
	Sep	-0.29	-0.16	0.02	-0.43
	Oct	-0.18	-0.13	-0.02	-0.33
	Nov	-0.23	-0.16	-0.09	-0.47
	Dec	-1.19	-0.85	-0.45	-2.49
	Tot, Jan–Dec	-7.39	-5.23	-1.70	<u>-14.32</u>

$\bar{X}_{\text{Jan-Dec}}$ -0.67 -0.48 -0.15

“–”: no data available.

Table S4.4. Monthly albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha\text{gs}}$, $\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$) January–December for Ecoregion 56g. Cumulative $\text{GWI}_{\Delta\alpha\text{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{GWI}_{\Delta\alpha\text{mo}}$ indicate monthly warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, during the 19-year period.

Ecoregion	Month	$\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ ha}^{-1} \text{ mo}^{-1}$)			
		Cropland	Pasture	Urban	Tot.cover type
56g	Jan	-1.47	-1.05	-0.53	-3.05
	Feb	-2.10	-1.54	-0.62	-4.26
	Apr	-0.49	-0.38	-0.14	-1.01
	May	-0.48	-0.37	-0.07	-0.92
	Jun	-0.26	-0.23	0.10	-0.40
	Jul	-0.31	-0.20	0.10	-0.40
	Aug	-0.34	-0.17	0.06	-0.44
	Sep	-0.28	-0.16	0.02	-0.42
	Oct	-0.18	-0.13	-0.02	-0.32
	Nov	-0.22	-0.16	-0.09	-0.47
	Dec	-1.19	-0.86	-0.45	-2.49
	Tot.Jan-Dec	-7.31	-5.26	-1.62	<u>-14.19</u>
	$\bar{X}_{\text{Jan-Dec}}$	-0.66	-0.48	-0.15	

“–”: no data available.

Table S4.5. Monthly albedo-induced global warming impact ($\text{GWI}_{\Delta\alpha\text{mo}}$, $\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{mo}^{-1}$) January–December for Ecoregion 56h. Cumulative $\text{GWI}_{\Delta\alpha\text{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{GWI}_{\Delta\alpha\text{mo}}$ indicate monthly warming and cooling effects, respectively, equivalent to Carbon (C_{eq}) emission and mitigation, respectively, during the 19-year period.

Ecoregion	Month	$\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{mo}^{-1}$)			
		Cropland	Pasture	Urban	Tot.cover type
56h	Jan	-1.48	–	-0.54	-2.02
	Feb	-2.12	–	-0.64	-2.76
	Apr	-0.50	–	-0.15	-0.65
	May	-0.49	–	-0.08	-0.57
	Jun	-0.27	–	0.09	-0.19
	Jul	-0.32	–	0.09	-0.23
	Aug	-0.35	–	0.05	-0.29
	Sep	-0.29	–	0.01	-0.27
	Oct	-0.18	–	-0.02	-0.20
	Nov	-0.23	–	-0.09	-0.31
	Dec	-1.20	–	-0.46	-1.65
	Tot.Jan–Dec	-7.41		-1.73	<u>-9.14</u>
	$\bar{X}_{\text{Jan–Dec}}$	-0.67		-0.16	

“–”: no data available.

Table S5. Nested analysis of variance (ANOVA with repeated measurements), among and within ecoregions, based on the linear models (see Equations (5) and (6) in the main text). Dependent variables: $\text{GWI}_{\Delta\alpha\text{gs}}$ ($\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1}$) and $\text{GWI}_{\Delta\alpha\text{mo}}$ ($\text{Mg C}_{\text{eq}} \text{ha}^{-1} \text{gs}^{-1}$).

	Variable	DF	SS	MS	F	p	η^2 (%)
Among Ecoregion	Ecoregions	4	0.00	0.00	860.57	***	32.04 ^a
	Cover type	1	5.80	5.80	4786.41	***	94.81
	Ecoregions × cover type	4	0.00	0.00	182.84	***	51.83 ^a
	Residuals	162	0.02	0.00			
	Ecoregions	4	0.01	0.00	24.17		28.53 ^a
	Cover type	1	7.34	7.34	19.05	***	23.52
	Ecoregions × cover type	4	0.00	0.00	3.61		25.61 ^a
	Residuals	90	3.86	0.39			
With in	$\text{GWI}_{\Delta\alpha\text{gs}}$						
	Cover type	2	5.94	2.97	12185	***	99.00

	Residuals	245	0.06	0.00		
GWI _{Δamo}	Cover type	2	7.47	2.67	122.80	*** 65.40
	Residuals	130	3.95	0.03		

GWI_{Δags} and GWI_{Δamo}: albedo-induced global warming impact (GWI_{Δa}) at growing season and monthly periods, respectively.

Signif. codes: *** p-value < 0.001, ** p-value < 0.01, * p-value < 0.05, · p-value < 0.1, p-value > 0.1.

η²: generalized eta squares indicating the variance in the dependent variable (i.e., GWI_{Δa}) accounted for by the independent variables (i.e., ecoregion, cover type, and their interactions).

“a”: η² values obtained from the Mauchly’s test of sphericity by applying the Greenhouse-Geisser correction.

Table S6. Overall percent contribution and percent contribution higher than the average (>8%; i.e., 1/12th of the total, i.e., equal contribution across the 12-month period) of albedo-induced global warming impact (GWI_{Δa}) by season and month in the five Level IV ecoregions. Cooling effects showing the contributions higher than the average are underlined.

Overall contribution (%)						Contribution higher than the average (%)				
Level IV ecoregions										
months	56b	56d	56f	56g	56h	56b	56d	56f	56g	56h
NGS	73	75	73	73	74	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>
GS	27	25	27	27	26	0	0	0	0	0

NGS: non-growing season months (January, February, March, and December).

GS: growing season months (April–November).

Table S7. Percent contribution higher than the average (>8%; i.e., 1/12th of the total, i.e., equal contribution across the 12-month period) of albedo-induced global warming impact (GWI_{Δa}) by season and month for cropland, pasture, and urban in the five Level IV ecoregions.

Contribution higher than the average (%)				
Cover type				
Ecoregion	Months	Cropland	Pasture	Urban
56b	NGS	100	100	100
	GS	0	0	0
56d	NGS	100	–	100
	GS	0	–	0
56f	NGS	100	100	100
	GS	0	0	0
56g	NGS	100	100	100
	GS	0	0	0
56h	NGS	100	–	100
	GS	0	–	0

NGS: non-growing season months (January, February, March, and December).

GS: growing season months (April–November).

“–”: no data available.

Table S8.1. Growing season albedo-induced radiative forcing ($RF_{\Delta\alpha_{gs}}$, $W\ m^{-2}$) 2001–2019 for Ecoregion 56b. Cumulative $RF_{\Delta\alpha_{gs}}$ value for the entire ecoregion over the 19-year period is underlined. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ indicate growing season warming and cooling effects, respectively.

Ecoregion	GS	$RF_{\Delta\alpha_{gs}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56b	2001	-5.08	-3.91	-0.44	-9.43
	2002	-3.93	-2.73	0.57	-6.10
	2003	-4.35	-3.12	0.12	-7.35
	2004	-5.28	-3.44	0.04	-8.67
	2005	-4.83	-3.33	0.19	-7.97
	2006	-4.91	-3.74	0.10	-8.55
	2007	-4.13	-2.48	0.38	-6.22
	2008	-4.63	-3.27	0.03	-7.87
	2009	-5.27	-3.79	-0.28	-9.34
	2010	-5.79	-3.96	-0.78	-10.53
	2011	-4.83	-3.29	0.33	-7.79
	2012	-3.71	-2.14	0.56	-5.28
	2013	-4.50	-3.05	0.10	-7.45
	2014	-4.76	-3.89	-0.05	-8.70
	2015	-6.46	-4.27	-1.37	-12.10
	2016	-4.55	-3.15	0.06	-7.64
	2017	-5.52	-3.44	-0.18	-9.14
	2018	-5.11	-3.03	-0.35	-8.49
	2019	-4.26	-2.71	0.47	-6.49
	Tot.2001–2019	-91.90	-62.73	-0.48	<u>-155.11</u>
	$\bar{X}_{2001-2019}$	-4.84	-3.30	-0.025	

GS: growing season.

“–”: no data available.

Table S8.2. Growing season albedo-induced radiative forcing ($RF_{\Delta\alpha_{gs}}$, $W\ m^{-2}$) 2001–2019 for Ecoregion 56d. Cumulative $RF_{\Delta\alpha_{gs}}$ value for the entire ecoregion over the 19-year period is underlined. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ indicate growing season warming and cooling effects, respectively.

Ecoregion	GS	$RF_{\Delta\alpha_{gs}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56d	2001	-5.11	–	-0.52	-5.64
	2002	-3.96	–	0.50	-3.46
	2003	-4.36	–	0.08	-4.28
	2004	-5.32	–	-0.04	-5.36
	2005	-4.83	–	0.13	-4.69
	2006	-4.94	–	0.00	-4.94
	2007	-4.13	–	0.32	-3.81
	2008	-4.65	–	-0.04	-4.69
	2009	-5.31	–	-0.37	-5.68
	2010	-5.80	–	-0.84	-6.64
	2011	-4.86	–	0.23	-4.62
	2012	-3.70	–	0.52	-3.18
	2013	-4.50	–	0.05	-4.45
	2014	-4.79	–	-0.14	-4.92
	2015	-6.47	–	-1.44	-7.90
	2016	-4.58	–	-0.01	-4.59
	2017	-5.52	–	-0.24	-5.76
	2018	-5.12	–	-0.39	-5.51
	2019	-4.27	–	0.39	-3.88
	Tot.2001–2019	-92.21		-1.80	<u>-94.00</u>
	$\bar{X}_{2001-2019}$	-4.85		-0.095	

GS: growing season.

“–”: no data available.

Table S8.3. Growing season albedo-induced radiative forcing ($RF_{\Delta\alpha_{gs}}$, $W\ m^{-2}$) 2001–2019 for Ecoregion 56f. Cumulative $RF_{\Delta\alpha_{gs}}$ value for the entire ecoregion over the 19-year period is underlined. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ indicate growing season warming and cooling effects, respectively.

Ecoregion	GS	$RF_{\Delta\alpha_{gs}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56f	2001	-5.00	-3.69	-0.41	-9.10
	2002	-3.87	-2.56	0.59	-5.84
	2003	-4.28	-2.94	0.15	-7.08
	2004	-5.21	-3.23	0.07	-8.36
	2005	-4.75	-3.12	0.22	-7.65
	2006	-4.84	-3.53	0.12	-8.25
	2007	-4.05	-2.30	0.41	-5.94
	2008	-4.55	-3.07	0.05	-7.57
	2009	-5.19	-3.56	-0.26	-9.01
	2010	-5.71	-3.73	-0.74	-10.18
	2011	-4.76	-3.09	0.35	-7.50
	2012	-3.64	-1.97	0.59	-5.03
	2013	-4.43	-2.86	0.13	-7.15
	2014	-4.69	-3.68	-0.03	-8.41
	2015	-6.37	-4.02	-1.32	-11.70
	2016	-4.47	-2.95	0.09	-7.34
	2017	-5.44	-3.22	-0.14	-8.80
	2018	-5.04	-2.83	-0.31	-8.18
	2019	-4.18	-2.52	0.49	-6.21
	Tot.2001–2019	-90.48	-58.87	0.04	<u>-149.31</u>
	$\bar{X}_{2001-2019}$	-4.76	-3.10	0.002	

GS: growing season.

“–”: no data available.

Table S8.4. Growing season albedo-induced radiative forcing ($RF_{\Delta\alpha_{gs}}$, $W\ m^{-2}$) 2001–2019 for Ecoregion 56g. Cumulative $RF_{\Delta\alpha_{gs}}$ value for the entire ecoregion over the 19-year period is underlined. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ indicate growing season warming and cooling effects, respectively.

Ecoregion	GS	$RF_{\Delta\alpha_{gs}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56g	2001	-4.90	-3.61	-0.31	-8.81
	2002	-3.78	-2.46	0.69	-5.55
	2003	-4.19	-2.84	0.23	-6.81
	2004	-5.10	-3.12	0.17	-8.05
	2005	-4.68	-3.03	0.31	-7.40
	2006	-4.73	-3.43	0.24	-7.92
	2007	-3.98	-2.21	0.50	-5.69
	2008	-4.46	-2.98	0.16	-7.29
	2009	-5.08	-3.47	-0.14	-8.70
	2010	-5.61	-3.65	-0.65	-9.90
	2011	-4.66	-2.97	0.47	-7.16
	2012	-3.57	-1.88	0.67	-4.79
	2013	-4.35	-2.77	0.22	-6.90
	2014	-4.58	-3.58	0.09	-8.07
	2015	-6.26	-3.95	-1.23	-11.44
	2016	-4.38	-2.86	0.19	-7.05
	2017	-5.34	-3.13	-0.05	-8.53
	2018	-4.95	-2.75	-0.24	-7.94
	2019	-4.11	-2.42	0.59	-5.94
	Tot.2001–2019	-88.70	-57.13	1.91	<u>-143.92</u>
	$\bar{X}_{2001-2019}$	-4.67	-3.01	0.100	

GS: growing season.

“–”: no data available.

Table S8.5. Growing season albedo-induced radiative forcing ($RF_{\Delta\alpha_{gs}}$, $W\ m^{-2}$) 2001–2019 for Ecoregion 56h. Cumulative $RF_{\Delta\alpha_{gs}}$ value for the entire ecoregion over the 19-year period is underlined. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ indicate growing season warming and cooling effects, respectively.

Ecoregion	GS	$RF_{\Delta\alpha_{gs}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56h	2001	-5.00	-3.51	-0.43	-8.94
	2002	-3.88	-2.36	0.56	-5.67
	2003	-4.28	-2.74	0.12	-6.91
	2004	-5.20	-3.00	0.05	-8.16
	2005	-4.77	-2.91	0.19	-7.49
	2006	-4.84	-3.31	0.10	-8.06
	2007	-4.07	-2.12	0.38	-5.81
	2008	-4.56	-2.88	0.04	-7.41
	2009	-5.19	-3.37	-0.27	-8.83
	2010	-5.71	-3.55	-0.76	-10.01
	2011	-4.77	-2.86	0.34	-7.29
	2012	-3.66	-1.79	0.56	-4.89
	2013	-4.44	-2.67	0.11	-7.00
	2014	-4.69	-3.47	-0.04	-8.20
	2015	-6.36	-3.86	-1.33	-11.56
	2016	-4.48	-2.77	0.07	-7.18
	2017	-5.44	-3.02	-0.17	-8.63
	2018	-5.04	-2.66	-0.34	-8.03
	2019	-4.20	-2.32	0.47	-6.05
	Tot.2001–2019	-90.61	-55.17	-0.34	<u>-146.12</u>
	$\bar{X}_{2001-2019}$	-4.77	-2.90	-0.018	

GS: growing season.

“–”: no data available.

Table S9.1. Monthly albedo-induced radiative forcing ($RF_{\Delta\alpha_{mo}}$, $W\ m^{-2}$) January–December for Ecoregion 56b. Cumulative $RF_{\Delta\alpha_{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $RF_{\Delta\alpha_{mo}}$ indicate monthly warming and cooling effects, respectively.

Ecoregion	Month	$RF_{\Delta\alpha_{mo}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56b	Jan	-20.51	-15.17	-7.40	-43.08
	Feb	-29.29	-22.39	-8.80	-60.48
	Apr	-6.87	-5.55	-2.08	-14.51
	May	-6.80	-5.50	-1.07	-13.37
	Jun	-3.80	-3.49	1.21	-6.08
	Jul	-4.39	-3.01	1.21	-6.19
	Aug	-4.80	-2.63	0.73	-6.70
	Sep	-3.98	-2.46	0.19	-6.25
	Oct	-2.46	-1.88	-0.34	-4.69
	Nov	-3.12	-2.27	-1.21	-6.60
	Dec	-16.55	-12.44	-6.28	-35.27
	Tot.Jan–Dec	-102.58	-76.80	-23.84	<u>-203.22</u>
	$\bar{X}_{Jan-Dec}$	-9.33	-6.98	-2.17	

“–”: no data available.

Table S9.2. Monthly albedo-induced radiative forcing ($RF_{\Delta\alpha_{mo}}$, $W\ m^{-2}$) January–December for Ecoregion 56d. Cumulative $RF_{\Delta\alpha_{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $RF_{\Delta\alpha_{mo}}$ indicate monthly warming and cooling effects, respectively.

Ecoregion	Month	$RF_{\Delta\alpha_{mo}}$ ($W\ m^{-2}$)			
		Cropland	Pasture	Urban	Tot.cover type
56d	Jan	-20.35	–	-7.89	-28.24
	Feb	-28.84	–	-9.59	-38.43
	Apr	-6.95	–	-2.17	-9.11
	May	-6.95	–	-1.27	-8.22

Jun	-3.85	–	1.07	-2.78
Jul	-4.42	–	1.06	-3.35
Aug	-4.80	–	0.59	-4.21
Sep	-3.99	–	0.12	-3.87
Oct	-2.47	–	-0.33	-2.80
Nov	-3.15	–	-1.21	-4.36
Dec	-16.57	–	-6.61	-23.19
Tot, Jan–Dec	-102.34		-26.22	<u>-128.56</u>
$\bar{X}_{\text{Jan–Dec}}$	-9.30		-2.38	

“–”: no data available.

Table S9.3. Monthly albedo-induced radiative forcing ($\text{RF}_{\Delta\alpha_{\text{mo}}}$, W m^{-2}) January–December for Ecoregion 56f. Cumulative $\text{RF}_{\Delta\alpha_{\text{mo}}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{RF}_{\Delta\alpha_{\text{mo}}}$ indicate monthly warming and cooling effects, respectively.

Ecoregion	Month	$\text{RF}_{\Delta\alpha_{\text{mo}}} (\text{W m}^{-2})$			
		Cropland	Pasture	Urban	Tot.cover type
56f	Jan	-20.17	-14.16	-7.30	-41.63
	Feb	-28.77	-20.85	-8.72	-58.34
	Apr	-6.79	-5.21	-2.01	-14.01
	May	-6.73	-5.09	-1.02	-12.84
	Jun	-3.74	-3.21	1.22	-5.73
	Jul	-4.31	-2.73	1.23	-5.80
	Aug	-4.70	-2.36	0.76	-6.29
	Sep	-3.90	-2.24	0.23	-5.92
	Oct	-2.43	-1.76	-0.30	-4.49
	Nov	-3.08	-2.14	-1.16	-6.38
	Dec	-16.28	-11.62	-6.15	-34.04
	Tot, Jan–Dec	-100.89	-71.36	-23.22	<u>-195.46</u>

$\bar{X}_{\text{Jan-Dec}}$ -9.17 -6.49 -2.11

“–”: no data available.

Table S9.4. Monthly albedo-induced radiative forcing ($\text{RF}_{\Delta\text{amo}}$, W m^{-2}) January–December for Ecoregion 56g. Cumulative $\text{RF}_{\Delta\text{amo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $\text{RF}_{\Delta\text{amo}}$ indicate monthly warming and cooling effects, respectively.

Ecoregion	Month	$\text{RF}_{\Delta\text{amo}}$ (W m^{-2})			
		Cropland	Pasture	Urban	Tot.cover type
56g	Jan	-20.09	-14.34	-7.18	-41.60
	Feb	-28.63	-21.09	-8.42	-58.14
	Apr	-6.66	-5.22	-1.95	-13.83
	May	-6.55	-5.11	-0.89	-12.54
	Jun	-3.61	-3.16	1.37	-5.40
	Jul	-4.20	-2.67	1.38	-5.50
	Aug	-4.62	-2.32	0.88	-6.05
	Sep	-3.84	-2.21	0.30	-5.75
	Oct	-2.39	-1.74	-0.29	-4.42
	Nov	-3.05	-2.14	-1.17	-6.36
	Dec	-16.18	-11.77	-6.09	-34.04
	Tot.Jan-Dec	-99.83	-71.74	-22.06	<u>-193.64</u>
	$\bar{X}_{\text{Jan-Dec}}$	-9.08	-6.52	-2.01	

“–”: no data available.

Table S9.5. Monthly albedo-induced radiative forcing ($RF_{\Delta\alpha_{mo}}$, $W\ m^{-2}$) January–December for Ecoregion 56h. Cumulative $RF_{\Delta\alpha_{mo}}$ value for the entire ecoregion over the 11-month period is underlined. Positive and negative values of $RF_{\Delta\alpha_{mo}}$ indicate monthly warming and cooling effects, respectively.

Ecoregion	Month	$RF_{\Delta\alpha_{mo}}\ (W\ m^{-2})$			
		Cropland	Pasture	Urban	Tot.cover type
56h	Jan	-20.25	–	-7.33	-27.58
	Feb	-28.92	–	-8.72	-37.64
	Apr	-6.76	–	-2.05	-8.81
	May	-6.69	–	-1.04	-7.73
	Jun	-3.74	–	1.20	-2.54
	Jul	-4.34	–	1.20	-3.14
	Aug	-4.73	–	0.73	-4.01
	Sep	-3.92	–	0.19	-3.73
	Oct	-2.43	–	-0.33	-2.76
	Nov	-3.07	–	-1.19	-4.26
	Dec	-16.32	–	-6.21	-22.53
	Tot.Jan–Dec	-101.18		-23.55	<u>-124.73</u>
	$\bar{X}_{Jan-Dec}$	-9.20		-2.14	

“–”: no data available.

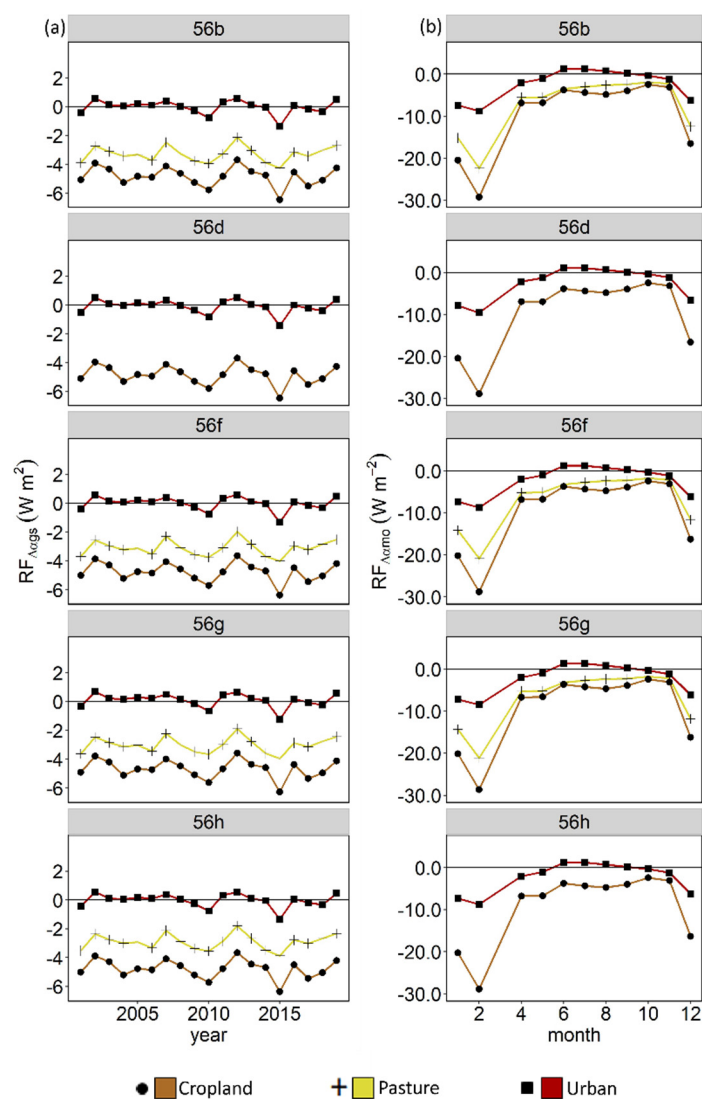


Figure S1. Albedo-induced radiative forcing ($RF_{\Delta\alpha}$) for the five Level IV ecoregions. Panels **a,b** represent the $RF_{\Delta\alpha}$ for the growing season ($RF_{\Delta\alpha_{gs}}$; 2001–2019) and monthly ($RF_{\Delta\alpha_{mo}}$; January–December, less March) periods, respectively. Positive and negative values of $RF_{\Delta\alpha_{gs}}$ and $RF_{\Delta\alpha_{mo}}$ indicate warming and cooling effects, respectively, during 19 growing seasons and 11 months over the 19-year period, respectively.