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Warming accelerates the decomposition of root-derived hydrolysable lipids in a temperate forest and is depth- and compound class-dependent

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Table S1: Concentration (Conc mg g^{-1}organic carbon) of the aliphatic monomers present in the hydrolysable lipids of leaves, and roots of incense cedar (*Calocedrus decurrens*), sugar pine (*Pinus lambertiana*), mix of grass aboveground parts around the plots and stone oak (*Lithocarpus*).

	Calocedrus decurrens		*Pinus lambertiana*		Mix of Grass		*Lithocarpus*	
	Leaves	Roots	Needles	Roots	Leaves	Roots	Leaves	Roots
	Conc (mg g^{-1} OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)
n-Carboxylic acids								
Tetradecanoic acid (*n*-$C_{14:0}$)	0.12	0.02	0.39	0.02	0.17	0.01	0.22	0.03
Hexadecanoic acid (*n*-$C_{16:0}$)	0.98	0.52	1.43	0.56	2.17	0.82	2.06	0.75
Octadecanoic acid (*n*-$C_{18:0}$)	0.09	0.14	0.16	0.15	0.33	0.44	0.31	0.12
Eicosanoic acid (*n*-$C_{20:0}$)	0.09	1.02	0.09	1.25	0.04	0.10	0.44	0.05
Docosanoic acid (*n*-$C_{22:0}$)	0.08	0.14	0.02	0.12	0.29	0.11	1.53	0.19
Tetracosanoic acid (*n*-$C_{24:0}$)	0.13	0.49	0.11	0.61	0.09	0.17	1.28	0.07
ω-Hydroxy carboxylic acids								
16-Hydroxy hexadecanoic acid ($\omega C_{16:0}$)	5.44	3.51	2.51	2.99	0.69	0.60	1.30	1.71
18-Hydroxy Octadecanoic acid ($\omega C_{18:0}$)	0.19	3.84	0.12	2.52	0.05	0.06	0.20	0.37
20-Hydroxy eicosanoic acid ($\omega C_{20:0}$)	0.16	4.11	0.06	3.76	0.10	0.17	0.09	0.79
22-Hydroxy docosanoic acid ($\omega C_{22:0}$)	0.13	2.73	0.11	3.98	0.25	0.40	0.33	0.70

	Calocedrus decurrens		*Pinus lambertiana*		Mix of Grass		*Lithocarpus*	
	Leaves	Roots	Needles	Roots	Leaves	Roots	Leaves	Roots
	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)	Conc (mg g^{-1}OC)
24-Hydroxy tetracosanoic acid ($\omega C_{24:0}$)	0.02	0.48	0.03	0.57	0.16	0.35	0.06	0.04
α,ω-Alkanedioic acids								
1,16-Hexadecanedioic acid ($C_{16:0}$ diacid)	0.52	1.58	0.07	1.64	0.04	0.16	0.29	0.73
1,18-Octadecanedioic acid ($C_{18:0}$ diacid)	0.19	2.17	–	1.47	0.02	0.07	0.20	0.48
1,20-Eicosanedioic acid ($C_{20:0}$ diacid)	0.07	1.77	0.07	1.40	0.02	0.04	0.20	0.27
1,22-Docosanedioic acid ($C_{22:0}$ diacid)	0.07	1.20	0.14	1.35	0.13	0.11	0.12	0.21
Mid-chain acids								
Mix of *x*,ω-Dihydroxyhexadecanoic acid (*x* = 9 and 10) (*x*,ω-diOH $C_{16:0}$) and 18-Hydroxy octadecenoic acid ($\omega C_{18:1}$)	45.48	12.87	4.02	12.89	0.09	1.38	23.09	19.79
x-Hydroxy hexadecanedioic acid (*x*-OH $C_{16:0}$ diacid)	3.59	9.47	0.24	9.16	0.51	1.41	0.54	1.66
11,18-Dihydroxyoctadecenoic acid (11, 18-diOH $C_{18:1}$)	0.11	0.12	–	0.10	–	0.08	2.68	0.57
x,18-Dihydroxyoctadecenoic acids (*x* = 9 and 10) (*x*, 18 diOH $C_{18:1}$)	0.31	0.22	0.03	0.23	0.10	0.07	1.74	0.74
9,10,18-Trihydroxyoctadecanoic acid (9, 10,18-triOH $C_{18:0}$)	–	–	–	–	0.11	0.03	1.34	0.44

Table S2: Normalized concentration (conc; mg g^{-1}organic carbon) of each monomer in the hydrolysable lipids in the added ^{13}C-labelled roots and mass change of the aliphatic monomers present in added ^{13}C labelled roots (*Avena fatua*) after three years of incubation (%, mean ± SE; n = 3).

	Avena fatua	Ambient plots			Warmed plots		
		10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	Conc (mg g^{-1}OC)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)
n-Carboxylic acids							
Tetradecanoic acid (*n*-$C_{14:0}$)	66.56	61.14 ± 9.65	92.95 ± 10.77	89.96 ± 7.84	46.48 ± 10.32	76.33 ± 18.39	56.82 ± 13.49
Hexadecenoic acid (*n*-$C_{16:1}$)	289.78	12.56 ± 5.61	23.43 ± 7.74	35.00 ± 6.93	13.31 ± 1.94	20.21 ± 4.71	24.86 ± 5.78
Hexadecanoic acid (*n*-$C_{16:0}$)	1071.63	46.91 ± 8.81	116.43 ± 24.02	131.68 ± 6.35	32.49 ± 2.22	90.63 ± 31.91	68.22 ± 12.60
Octadecadienoic acid (*n*-$C_{18:2}$)	362.21	31.10 ± 16.02	53.78 ± 17.80	43.36 ± 1.09	28.76 ± 10.29	39.49 ± 12.98	31.58 ± 7.41
Octadecenoic acid (*n*-$C_{18:1}$)	265.80	78.31 ± 38.27	174.32 ± 73.59	228.19 ± 26.84	54.50 ± 6.40	124.83 ± 36.44	124.30 ± 29.97
Octadecanoic acid (*n*-$C_{18:0}$)	93.59	116.15 ± 29.93	311.09 ± 81.51	347.68 ± 48.88	74.67 ± 6.65	243.47 ± 96.22	180.93 ± 24.26
Eicosanoic acid (*n*-$C_{20:0}$)	163.75	44.28 ± 4.59	56.75 ± 12.12	82.83 ± 7.27	28.61 ± 7.11	65.36 ± 21.93	50.10 ± 6.03
Tetracosanoic acid (*n*-$C_{24:0}$)	1313.88	26.21 ± 1.82	23.64 ± 3.47	34.63 ± 7.32	17.71 ± 2.60	29.74 ± 5.35	29.26 ± 5.00
Hexacosanoic acid (*n*-$C_{26:0}$)	666.71	52.40 ± 5.25	41.51 ± 7.87	54.02 ± 10.71	33.65 ± 5.68	52.66 ± 12.29	51.33 ± 18.15

	Avena fatua	Ambient plots			Warmed plots		
		10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	Conc (mg g^{-1}OC)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)
n-Alcohols							
Docosanol (Alcohol $C_{20:0}$)	415.08	39.59 ± 4.47	36.30 ± 7.14	28.96 ± 10.51	29.42 ± 6.99	44.40 ± 8.16	47.68 ± 9.10
Mid-chain acids							
11,18-Dihydroxyoctadecenoic acid (11,18-diOH $C_{18:1}$)	114.61	25.40 ± 3.42	21.33 ± 5.05	15.34 ± 7.65	16.33 ± 4.09	28.69 ± 5.02	29.93 ± 4.10
x,18-Dihydroxyoctadecenoic acids (*x* = 9 and 10) (*x*, 18 diOH $C_{18:1}$)	72.16	106.09 ± 23.77	91.86 ± 11.74	96.84 ± 23.52	53.99 ± 10.07	117.53 ± 7.24	108.16 ± 17.08
ω-Hydroxy carboxylic acids							
16-Hydroxy hexadecanoic acid ($\omega C_{16:0}$)	970.04	34.80 ± 4.63	44.40 ± 8.24	43.07 ± 6.48	22.31 ± 4.53	42.26 ± 7.91	42.18 ± 8.44
18-Hydroxy Octadecanoic acid ($\omega C_{18:0}$)	37.49	42.99 ± 13.50	59.92 ± 16.95	56.84 ± 8.99	29.62 ± 16.23	72.28 ± 7.23	64.36 ± 7.57
20-Hydroxy eicosanoic acid ($\omega C_{20:0}$)	101.06	53.59 ± 10.81	58.67 ± 11.88	63.54 ± 20.88	48.01 ± 10.90	90.15 ± 3.23	79.50 ± 17.33
22-Hydroxy docosanoic acid ($\omega C_{22:0}$)	719.54	82.44 ± 4.89	78.99 ± 12.42	72.57 ± 12.05	61.26 ± 8.53	104.36 ± 11.25	91.15 ± 16.75

	Avena fatua	Ambient plots			Warmed plots		
		10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	Conc (mg g^{-1}OC)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)	Mass change (%)
24-Hydroxy tetracosanoic acid ($\omega C_{24:0}$)	1450.37	67.85 ± 6.34	57.60 ± 10.25	56.94 ± 11.52	50.68 ± 7.89	80.87 ± 2.88	72.77 ± 10.57
α,ω-Alkanedioic acids							
1,16-Hexadecanedioic acid ($C_{16:0}$ diacid)	189.44	40.78 ± 1.95	40.92 ± 7.39	39.58 ± 9.13	28.31 ± 7.24	50.22 ± 7.05	48.66 ± 13.89
1,18-Octadecanedioic acid ($C_{18:0}$ diacid)	51.04	53.88 ± 9.95	45.18 ± 7.08	50.11 ± 15.04	34.36 ± 12.30	74.48 ± 4.63	76.77 ± 28.33
1,22-Docosanedioic acid ($C_{22:0}$ diacid)	93.02	92.06 ± 6.80	84.19 ± 15.10	76.84 ± 14.22	73.03 ± 20.04	133.65 ± 9.49	126.00 ± 35.18
1,24-Tetracosanedioic acid ($C_{24:0}$ diacid)	199.81	71.19 ± 7.49	53.24 ± 9.93	58.63 ± 16.85	52.74 ± 8.89	81.37 ± 9.36	89.04 ± 24.11

Table S3: Weighted mean residence time (MRT) in years of each compound class (with a chain length ≥ 20 in *n*-Carboxylic acids) in hydrolysable lipids that originally derived from added ^{13}C-labelled roots (mean; n = 3).

	Ambient plots			Warmed plots		
	10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	MRT (y)	MRT (y)	MRT (y)	MRT (y)	MRT (y)	MRT (y)
n-Carboxylic acids	3.00	3.37	5.88	2.15	4.78	3.41
n-Alcohols	3.29	3.09	2.60	2.52	3.90	4.39
ω-Hydroxy carboxylic acids	5.77	6.82	7.00	3.39	11.87	10.18
α,*ω*-Alkanedioic acids	5.62	5.35	5.66	3.61	15.02	6.31*

* There are only two replicates because for one sample, there is accumulation of diacids.

Mid-chain fatty acids are not included because there are also several samples from deep soil have accumulation of mid-chain fatty acids.

Figure. S1: Weighted mass change of all the compound classes (with a carbon chain length ≥ 20 for fatty acids) present in added ^{13}C labelled roots (*Avena fatua*) after three years of incubation (mean in %, error bars denotes standard error; n = 3)

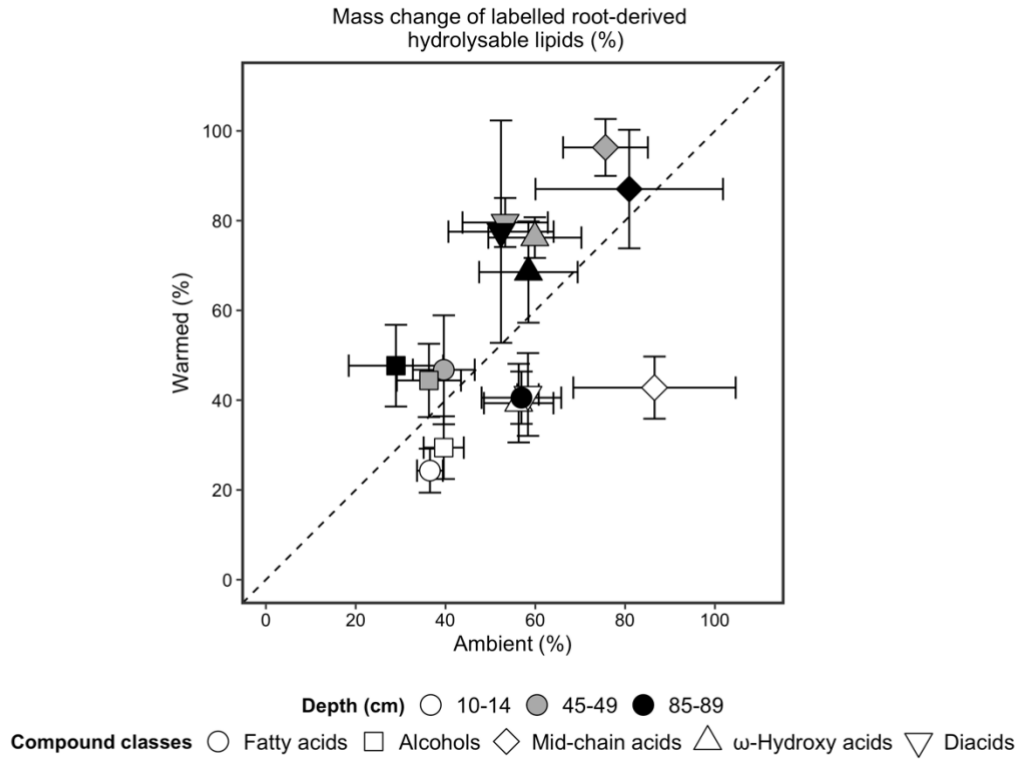

***Figure. S2*:** (a) Concentration of long-chain hydrolysable lipids (with carbon chain lengths ≥ 20 for fatty acids, alcohols, *ω*-Hydroxy acids, and diacids) in disturbance control plots (mean ± SE, n = 3). (b) Relative contribution of each long-chain compound class (mean; n = 3).

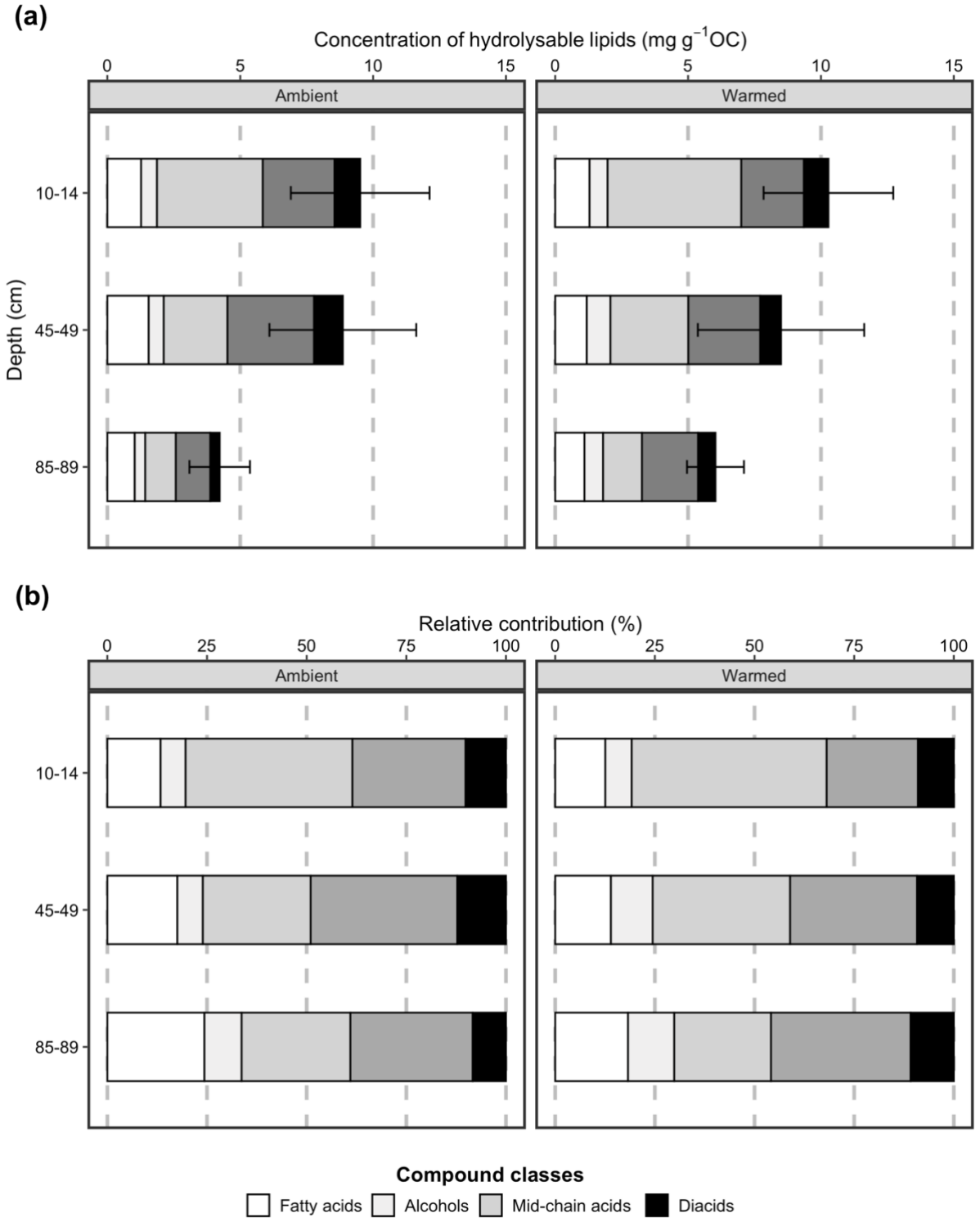

Table S4: $\delta^{13}C$ of each aliphatic monomers in hydrolysable lipids in disturbance control plots (mean ± SE; n = 3).

	Ambient plots			Warmed plots		
	10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)
n-Carboxylic acids						
Tetradecanoic acid (*n*-$C_{14:0}$)	-35.9 ± 1.9	-34.5 ± 2.2	-30.6 ± 1.2	-37.9 ± 2.7	-39.1 ± 2.5	-37.1 ± 2.7
Hexadecenoic acid (*n*-$C_{16:1}$)	-27.7 ± 1.6	-25.3 ± 1.0	-27.6 ± 0.4	-28.7 ± 3.9	-32.1 ± 0.5	-30.2 ± 3.3
Hexadecanoic acid (*n*-$C_{16:0}$)	-27.8 ± 0.1	-28.9 ± 1.4	-27.6 ± 0.4	-28.4 ± 1.2	-30.4 ±2.1	-28.4 ± 1.8
Octadecadienoic acid (*n*-$C_{18:2}$)	-30.1 ± 1.2	-25.1 ± 2.3	-29.0 ± 1.7	-26.0 ± 1.6	-29.8 ± 1.9	-29.1 ± 0.8
Octadecenoic acid (*n*-$C_{18:1}$)	-26.8 ± 0.3	-28.1 ± 1.0	-28.1 ± 0.2	-26.7 ± 1.1	-30.6 ± 0.7	-29.5 ± 0.1
Octadecanoic acid (*n*-$C_{18:0}$)	-28.1 ± 1.4	-29.8 ± 1.7	-28.3 ± 0.4	-28.5 ± 0.8	-31.6 ± 1.0	-29.4 ± 1.4
Eicosanoic acid (*n*-$C_{20:0}$)	-27.9 ± 2.1	-27.8 ± 1.3	-28.0 ± 1.3	-29.7 ± 1.8	-32.2 ± 0.8	-29.2 ± 0.0
Docosenoic acid (*n*-$C_{22:1}$)	-28.8 ± 0.7	-28.5 ± 1.0	-27.9 ± 0.2	-28.9 ± 0.8	-29.2 ± 0.3	-28.2 ± 1.0
Tetracosanoic acid (*n*-$C_{24:0}$)	-26.3 ± 0.6	-26.5 ± 1.0	-25.0 ± 1.4	-27.5 ± 2.4	-27.3 ± 1.7	-28.8 ± 3.2
Hexacosanoic acid (*n*-$C_{26:0}$)	-28.3 ± 0.9	-28.3 ± 0.8	-26.5 ± 0.6	-27.7 ± 2.8	-28.9 ± 1.8	–
n-Alcohols						
Octadecanol (Alcohol $C_{18:0}$)	-29.9 ± 0.4	-29.4 ± 1.2	-29.9 ± 1.0	-29.5 ± 0.9	-32.5 ± 2.4	-31.4 ± 0.6
Docosanol (Alcohol $C_{20:0}$)	-28.9 ± 3.5	-29.7 ± 0.5	-25.7 ± 1.6	-32.5 ± 4.2	-31.5 ± 4.6	-30.0 ± 5.4

	Ambient plots			Warmed plots		
	10-14 cm	45-49 cm	85-89 cm	10-14 cm	45-49 cm	85-89 cm
	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)	$\delta^{13}C$ (‰)
Mid-chain acids						
11,18-Dihydroxyoctadecenoic acid (11,18-diOH $C_{18:1}$)	-21.7 ± 0*	-21.9 ± 1.2	–	-24.9 ± 1.1	-23.3 ± 1.5	-20.3 ± 0*
x,18-Dihydroxyoctadecenoic acids (*x* = 9 and 10) (*x*, 18 diOH $C_{18:1}$)	-22.7 ± 0.5	-20.9 ± 0.5	-18.2 ± 2.3	-21.0 ± 2.1	-22.9 ± 1.8	-22.0 ± 0.1
ω-Hydroxy carboxylic acids						
16-Hydroxy hexadecanoic acid ($\omega C_{16:0}$)	-25.5 ± 0.8	-24.1 ± 0.5	-24.9 ± 0.9	-24.7 ± 2.2	-25.7 ± 3.1	-26.1 ± 1.1
18-Hydroxy Octadecanoic acid ($\omega C_{18:0}$)	-25.6 ± 1.0	-24.2 ± 0.5	-23.3 ± 0.5	-26.5 ± 2.6	-27.8 ± 1.4	-26.0 ± 2.3
20-Hydroxy eicosanoic acid ($\omega C_{20:0}$)	-24.8 ± 0.4	-24.4 ± 0.6	-23.0 ± 2.3	-25.4 ± 1.8	-26.7 ± 1.6	-25.3 ± 2.1
22-Hydroxy docosanoic acid ($\omega C_{22:0}$)	-26.1 ± 1.2	-26.0 ± 0.3	-25.7 ± 1.4	-28.8 ± 3.2	-26.7 ± 1.9	-24.9 ± 2.2
24-Hydroxy tetracosanoic acid ($\omega C_{24:0}$)	-23.3 ± 2.3	-24.0 ± 3.4	-22.6 ± 3.0	-25.0 ± 3.0	-22.6 ± 1.5	-27.4 ± 2.6
α,*ω*-Alkanedioic acids						
1,16-Hexadecanedioic acid ($C_{16:0}$ diacid)	-24.5 ± 0.4	-23.8 ± 0.2	-24.6 ± 1.2	-24.8 ± 2.0	-25.6 ± 1.8	-27.3 ± 0.6
1,18-Octadecanedioic acid ($C_{18:0}$ diacid)	-25.2 ± 1.8	-28.0 ± 1.2	-28.3 ± 1.1	-25.3 ± 2.7	-30.4 ± 0.3	-29.7 ± 2.1
1,22-Docosanedioic acid ($C_{22:0}$ diacid)	-24.6 ± 1.7	-24.5 ± 1.8	-26.8 ± 1.4	-27.2 ± 3.2	-26.4 ± 1.3	-26.1 ± 1.4
1,24-Tetracosanedioic acid ($C_{24:0}$ diacid)	-21.7 ± 0.6	-25.0 ± 0.4	-24.4 ± 1.2	-27.0 ± 1.9	–	-23.2 ± 0*

* Monomers are only detected in one of all the three plots.

Octadecanol (Alcohol $C_{18:0}$) and Docosenoic acid (*n*-$C_{22:1}$) are not detected in added ^{13}C-labelled roots but exist in disturbance control plots.

Table S5: Mean ± SE (n = 3) bulk soil carbon, $\delta^{13}C$, and hydrolysable lipids for each depth (10-14, 45-49, and 85-89 cm) in ambient and warmed, without root-litter addition (Disturbance control), and with root-litter addition (labelled) plots.

Depth (cm)	Warming treatment	Root treatment	Carbon (%)	Std Error Carbon (%)	$\delta^{13}C$ (‰)	Std Error $\delta^{13}C$ (‰)	Total hydrolysable lipids (mg $g^{-1}OC$)	Std Error Hydrolysable lipids
10-14	Ambient	Disturbance control	1.95	0.55	-25.8	0.3	18.40	4.19
45-49	Ambient	Disturbance control	0.74	0.48	-25.5	0.1	17.84	5.40
85-89	Ambient	Disturbance control	0.40	0.21	-25.8	0.5	10.96	1.90
10-14	Warmed	Disturbance control	4.38	0.88	-26.3	0-4	18.58	3.11
45-49	Warmed	Disturbance control	1.54	0.61	-25.7	0.5	16.83	3.84
85-89	Warmed	Disturbance control	0.68	0.23	-25.7	0.5	12.49	0.41
10-14	Ambient	Labelled	2.26	0.34	26.3	8.2	11.54	5.44

45-49	Ambient	Labelled	1.53	0.86	65.5	27.5	12.29	1.94
85-89	Ambient	Labelled	0.33	0.07	202.1	46.3	12.37	4.38
10-14	Warmed	Labelled	3.65	0.90	-0.5	6.3	14.82	4.53
45-49	Warmed	Labelled	1.11	0.54	90.9	36.0	12.21	1.94
85-89	Warmed	Labelled	0.47	0.25	247.7	122.7	14.98	4.52

***Table S6*:** Anova table for linear mixed effects model (LMEs) to test soil organic carbon (SOC) concentration by warming, root litter treatment, and depth and their interactions. SOC concentration was log-transformed due to heteroscedasticity. numDF denotes numerator degrees of freedom and denDF denotes denominator degrees of freedom, respectively. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).
Full model: log(SOC concentration) ~ warming × root treatment × depth, random = ~1|Block.
Final model: log(SOC concentration) ~ warming + root treatment + depth, random = ~1|Block.

Fixed effects	numDF	denDF	F-value	*p*-value
Intercept (Ambient, 10-20 cm)	1	29	0.01	0.935
Warming	1	29	4.16	0.051
Root litter	1	29	0.25	0.622
Depth	2	29	41.67	**< 0.001**

***Table S7*:** Summary of log-transformed SOC concentration by warming, root litter treatment, and depth. Log-transformed values and exponentiated values are reported. Exponentiated values represent the relative change in the original scale of the response variable compared to the reference group (intercept). *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Fixed effects	Estimated values	Exponentiated values	Sdt.Error	DF	t-value	*p*-value
Intercept (Ambient, 10-14 cm)	0.89	2.45	0.279	29	3.21	**0.003**
Warming	0.36	1.43	0.175	29	2.04	0.051
Root treatment	-0.09	0.92	0.175	29	-0.50	0.622
Depth 45-49 cm	-1.08	0.34	0.214	29	-5.04	**< 0.001**
Depth 85-89 cm	-1.95	0.14	0.214	29	-9.11	**< 0.001**

***Table S8*:** Anova table for linear mixed effects model (LMEs) to test ^{13}C-excess of bulk soil organic carbon (SOC; %) by warming, depth and their interactions. ^{13}C-excess was log-transformed due to heteroscedasticity. numDF denotes numerator degrees of freedom and denDF denotes denominator degrees of freedom, respectively. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Full model: log(^{13}C-excess) ~ warming × depth, random = ~1|Block.

Final model: log(^{13}C-excess) ~ warming + depth, random = ~1|Block.

Fixed effects	numDF	denDF	F-value	*p*-value
Intercept (Ambient, 10-20 cm)	1	12	126.98	**< 0.001**
Warming	1	12	0.42	0.527
Depth	2	12	12.35	**0.001**

***Table S9*:** Summary of log-transformed bulk soil organic carbon (SOC) ^{13}C-excess (%) by warming, and depth. Log-transformed values and exponentiated values are reported. Exponentiated values represent the relative change in the original scale of the response variable compared to the reference group (intercept). *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Fixed effects	Estimated values	Exponentiated values	Sdt.Error	DF	t-value	*p*-value
Intercept (Ambient, 10-14 cm)	1.35	3.87	0.32	12	4.25	**0.001**
Warming	-0.19	0.83	0.29	12	-0.65	0.527
Depth 45-49 cm	0.99	2.70	0.36	12	2.78	**0.016**
Depth 85-89 cm	1.77	5.89	0.36	12	4.96	**< 0.001**

***Table S10*:** Anova table for linear mixed effects model (LMEs) to test hydrolysable lipids normalized to soil organic carbon (SOC) concentration (mg g^{-1} SOC) by warming, root litter treatment, depth and their interactions. Normalized hydrolysable lipids concentration was log-transformed due to heteroscedasticity. numDF denotes numerator degrees of freedom and denDF denotes denominator degrees of freedom, respectively. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Full model: log(normalized concentration of hydrolysable lipids) ~ warming × root treatment × depth, random = ~1|Block.

Final model: log(normalized concentration of hydrolysable lipids) ~ warming + root treatment + depth, random = ~1|Block.

Fixed effects	numDF	denDF	F-value	*p*-value
Intercept (Ambient, 10-20 cm)	1	29	1758.12	**0**
Warming	1	29	0.53	0.472
Root treatment	1	29	2.21	0.148
Depth	2	29	0.80	0.460

***Table S11*:** Summary of log-transformed normalized concentration of hydrolysable lipids (mg g^{-1} SOC) by warming, root treatment, and depth. Log-transformed values and exponentiated values are reported. Exponentiated values represent the relative change in the original scale of the response variable compared to the reference group (intercept). *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Fixed effects	Estimated values	Exponentiated values	Sdt.Error	DF	t-value	*p*-value
Intercept (Ambient, 10-14 cm)	2.73	15.30	0.14	29	19.67	**< 0.001**
Warming	0.09	1.09	0.12	29	0.73	0.472
Root treatment	-0.18	0.83	0.12	29	-1.49	0.148
Depth 45-49 cm	-0.05	0.95	0.15	29	-0.35	0.731
Depth 85-89 cm	-0.19	0.83	0.15	29	-1.23	0.228

***Table S12*:** Anova table for linear mixed effects model (LMEs) to test ^{13}C-excess of each compound class in hydrolysable lipids by warming, , depth and their interactions. ^{13}C-excess of each compound class was log-transformed due to heteroscedasticity. denDF denotes denominator degrees of freedom. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Final model: log(^{13}C-excess of each compound class, e.g. fatty acids) ~ warming × depth, random = ~1|Block.

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value
Intercept (Ambient, 10-20 cm)	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**
Warming	10	0.328	10	0.871	10	0.956	10	0.857	10	0.790
Depth	10	**0.001**	10	**0.016**	10	**0.016**	10	**0.010**	10	**0.003**
Warming: Depth	10	0.824	10	0.508	10	0.510	10	0.412	10	0.429

***Table S13*:** Summary of linear mixed effects model (LMEs) to evaluate the effects of warming, depth and their interaction on the ^{13}C-excess of each compound class. The intercept represents the estimated mean for the reference group (each compound class at 10-14 cm depth in ambient plots). Coefficients represent the estimated differences from this reference level. Negative values indicate a lower response relative to the reference. Interaction terms represent deviations from the additive effects of the main fixed effects. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept (Ambient, 10-14 cm)	11.39	**< 0.001**	23.36	**< 0.001**	10.85	**< 0.001**	13.11	**< 0.001**	6.64	**0.002**
Warming	-3.37	0.494	-8.49	0.503	-4.25	0.473	-6.40	0.369	-3.23	0.327
Depth 45-49 cm	25.53	**0.039**	2.48	0.880	2.70	0.746	2.57	0.807	3.19	0.558
Depth 85-89 cm	62.15	**0.004**	73.31	0.054	36.66	0.051	62.92	**0.033**	38.10	**0.015**
Warming: Depth 45-49 cm	1.54	0.677	32.07	0.259	16.01	0.261	22.18	0.205	10.66	0.209

Warming: Depth 85-89 cm	-24.6	0.859	7.59	0.641	1.29	0.656	-10.69	0.689	-5.00	0.624

***Table S14*:** Pairwise post hoc comparisons of ^{13}C-excess of each compound class hydrolysable lipids (%) at three depths (10-14, 45-49, and 85-89 cm) in ambient and warmed plots (n = 3) based on estimated marginal means (EMMs) from linear mixed-effects models. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**) after back transformed (exponentiated). Positive values indicate warming increased the ^{13}C-excess of the evaluated compound class hydrolysable lipids, whereas negative values indicate warming decreased the mass change. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Depth [cm]	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*
10-14	-3.37	0.494	-8.49	0.503	-4.25	0.473	-6.40	0.369	-3.23	0.327
45-49	-1.83	0.920	23.58	0.342	11.77	0.370	15.78	0.351	7.43	0.404
85-89	-27.97	0.356	-0.90	0.989	-2.95	0.925	-17.09	0.728	-8.23	0.760

***Table S15*:** Anova table for linear mixed effects model (LMEs) to test mass change of each compound class in labelled root-derived hydrolysable lipids (%) by warming, depth, and their interactions. denDF denotes denominator degrees of freedom. Due to heteroscedasticity, data for diacids was log-transformed. The results presenting here are back-transformed (exponentiated). *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Final model: mass change of each compound class (e.g. fatty acids) ~ warming × depth, random = ~1|Block.

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value
Intercept (Ambient, 10-20 cm)	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**
Warming	10	**0.035**	10	0.413	10	0.583	10	0.685	10	0.518
Depth	10	**0.008**	10	0.763	10	0.204	10	0.120	10	0.406
Warming: Depth	10	0.409	10	0.234	10	0.057	10	0.210	10	0.158

***Table S16*:** Summary of linear mixed effects model (LMEs) to evaluate the effects of warming, depth and their interaction on the mass change of each compound class derived from labelled root litter (%). The intercept represents the estimated mean for the reference group (each compound class at 10-14 cm depth in ambient plots). Coefficients represent the estimated differences from this reference level. Negative values indicate a lower response relative to the reference. Interaction terms represent deviations from the additive effects of the main fixed effects. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept (Ambient, 10-14 cm)	0.64	**0.019**	0.40	**< 0.001**	0.87	**< 0.001**	0.56	**< 0.001**	0.58	**0.031**
Warming	-0.24	0.435	-0.10	0.387	-0.44	**0.029**	-0.17	0.224	-0.19	0.214
Depth 45-49 cm	0.67	**0.044**	-0.03	0.776	-0.11	0.540	0.04	0.789	-0.07	0.694
Depth 85-89 cm	1.02	**0.006**	-0.11	0.367	-0.06	0.750	0.02	0.871	-0.08	0.617
Warming: Depth 45-49 cm	-0.01	0.973	0.18	0.278	0.64	**0.024**	0.33	0.102	0.47	0.082

Warming: Depth 85-89 cm	-0.51	0.248	0.29	0.099	0.50	0.068	0.27	0.174	0.39	0.119

***Table S17*:** Pairwise post hoc comparisons of mass change of each compound class in labelled root derived hydrolysable lipids (%) at three depths (10-14, 45-49, and 85-89 cm) in ambient and warmed plots (n = 3) based on estimated marginal means (EMMs) from linear mixed-effects models. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**). Positive values indicate warming increased the mass change of the evaluated compound class in labelled root-derived hydrolysable lipids, whereas negative values indicate warming decreased the mass change. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Depth [cm]	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*
10-14	-0.24	0.435	-0.10	0.387	-0.44	**0.029**	-0.17	0.224	-0.19	0.214
45-49	-0.25	0.409	0.08	0.488	0.21	0.257	0.16	0.240	0.28	0.189
85-89	-0.74	**0.029**	0.19	0.127	0.17	0.729	0.10	0.458	0.19	0.305

***Table S18*:** Anova table for linear mixed effects model (LMEs) to test mass change of each compound class (carbon number ≥ 20 for fatty acids, *ω*-hydroxy acids, and diacids) in labelled root-derived hydrolysable lipids (%) by warming, depth, and their interactions. denDF denotes denominator degrees of freedom. Due to heteroscedasticity, data for diacids was log-transformed. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Final model: mass change of each compound class (e.g. fatty acids) ~ warming × depth, random = ~1|Block.

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value
Intercept (Ambient, 10-20 cm)	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	0.104
Warming	10	0.255	10	0.413	10	0.583	10	0.327	10	0.223
Depth	10	0.076	10	0.763	10	0.204	10	0.257	10	0.483
Warming: Depth	10	0.269	10	0.234	10	0.057	10	0.183	10	0.136

***Table S19*:** Summary of linear mixed effects model (LMEs) to evaluate the effects of warming, depth and their interaction on the mass change of each compound class (carbon number ≥ 20 for fatty acids, *ω*-hydroxy acids, and diacids) derived from labelled root litter (%). The intercept represents the estimated mean for the reference group (each compound class at 10-14 cm depth in ambient plots). Coefficients represent the estimated differences from this reference level. Negative values indicate a lower response relative to the reference. Interaction terms represent deviations from the additive effects of the main fixed effects. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept (Ambient, 10-14 cm)	0.36	**< 0.001**	0.40	**< 0.001**	0.87	**< 0.001**	0.71	**< 0.001**	0.88	**0.031**
Warming	-0.12	0.260	-0.10	0.387	-0.44	**0.029**	-0.16	0.334	-0.22	0.214
Depth 45-49 cm	0.03	0.769	-0.03	0.776	-0.11	0.540	-0.02	0.915	-0.12	0.694
Depth 85-89 cm	0.20	0.075	-0.11	0.367	-0.06	0.750	-0.05	0.762	-0.18	0.617
Warming: Depth 45-49 cm	0.19	0.210	0.18	0.278	0.64	**0.024**	0.43	0.085	0.69	0.082
Warming: Depth 85-89 cm	-0.04	0.781	0.29	0.099	0.50	0.068	0.34	0.163	0.60	0.119

***Table S20*:** Pairwise post hoc comparisons of mass change of each compound class (carbon number ≥ 20 for fatty acids, *ω*-hydroxy acids, and diacids) in labelled root derived hydrolysable lipids (%) at three depths (10-14, 45-49, and 85-89 cm) in ambient and warmed plots (n = 3) based on estimated marginal means (EMMs) from linear mixed-effects models. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**). Positive values indicate warming increased the mass change of the evaluated compound class in labelled root-derived hydrolysable lipids, whereas negative values indicate warming decreased the mass change. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Depth [cm]	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*
10-14	-0.12	0.260	-0.10	0.387	-0.10	0.387	-0.16	0.334	-0.22	0.316
45-49	-0.07	0.501	0.08	0.488	0.08	0.488	0.26	0.123	0.47	0.112
85-89	-0.16	0.141	0.19	0.127	0.19	0.127	0.18	0.292	0.38	0.150

***Table S21*:** Anova table for linear mixed effects model (LMEs) to test relative contribution (%) of each compound class to total hydrolysable lipids by warming, depth and their interactions in disturbance control plots. denDF (denotes denominator degrees of freedom). The relative contribution for mid-chain acids was log-transformed due to heteroscedasticity. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$). **Final model: relative contribution of each compound class (e.g. fatty acids) ~ warming × depth, random = ~1|Block.**

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value	denDF	*p*-value
Intercept (Ambient, 10-14 cm)	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**	10	**< 0.001**
Warming	10	0.168	10	0.914	10	0.286	10	0.496	10	0.380
Depth	10	0.134	10	0.332	10	**0.003**	10	0.760	10	0.451
Warming: Depth	10	0.440	10	0.289	10	0.883	10	0.550	10	0.191

***Table S22*:** Summary of linear mixed effects model (LMEs) to evaluate the effects of warming, depth and their interaction on the relative contribution of each compound class to total hydrolysable lipids (%) in disturbance control plots. The intercept represents the estimated mean for the reference group (each compound class at 10-14 cm depth in ambient plots). Coefficients represent the estimated differences from this reference level. Negative values indicate a lower response relative to the reference. Interaction terms represent deviations from the additive effects of the main fixed effects. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Fixed effects	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Intercept (Ambient, 10-14 cm)	0.27	**0.001**	0.09	**< 0.001**	0.21	**< 0.001**	0.31	**< 0.001**	0.13	**< 0.001**
Warming	-0.05	0.587	-0.03	0.251	0.03	0.481	0.03	0.747	0.00	0.883
Depth 45-49 cm	0.01	0.938	0.01	0.750	-0.07	0.072	0.06	0.472	0.01	0.724
Depth 85-89 cm	0.18	0.055	-0.01	0.686	-0.10	**0.011**	-0.04	0.597	-0.03	0.105
Warming: Depth 45-49 cm	0.04	0.751	0.03	0.310	-0.00	0.877	-0.05	0.641	-0.01	0.588

Warming: Depth 85-89 cm	-0.11	0.360	0.05	0.129	-0.03	0.747	0.07	0.535	0.03	0.202

***Table S23*:** Pairwise post hoc comparisons of relative contribution of each compound class to total hydrolysable lipids (%) at three depths (10-14, 45-49, and 85-89 cm) in ambient and warmed plots (n = 3) based on estimated marginal means (EMMs) from linear mixed-effects models. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**). Positive values indicate warming increased the relative contribution of the evaluated compound class to total hydrolysable lipids, whereas negative values indicate warming decreased the relative contribution. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Compound classes									
	Fatty acids		Alcohols		Mid-chain acids		*ω*-hydroxy acids		Diacids	
Depth [cm]	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*	Estimate	*p-value*
10-14	-0.05	0.587	-0.03	0.251	0.03	0.481	0.03	0.747	0.00	0.883
45-49	-0.01	0.923	0.01	0.775	0.03	0.361	-0.03	0.736	-0.01	0.535
85-89	-0.16	0.084	0.02	0.289	0.01	0.798	0.09	0.243	0.03	0.064

***Table S24*:** Anova table for linear mixed effects model (LMEs) to test mass difference of native bulk and hydrolysable lipids (defined as the pre-existing SOC and hydrolysable lipids before ^{13}C-labeled root litter was added) by warming, depth, and their interactions. denDF denotes denominator degrees of freedom. Due to heteroscedasticity, data for diacids was log-transformed. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Final model: mass difference of pre-existing SOC or hydrolysable lipids ~ warming × depth, random = ~1|Block.

	Bulk SOC		Hydrolysable lipids	
Fixed effects	denDF	*p*-value	denDF	*p*-value
Intercept (Ambient, 10-20 cm)	9	0.965	9	0.468
Warming	9	0.558	9	0.987
Depth	9	0.422	9	0.310
Warming: Depth	9	0.943	9	0.824

***Table S25*:** Summary of linear mixed effects model (LMEs) to evaluate the effects of warming, depth and their interaction on the mass difference of pre-existing bulk SOC and hydrolysable lipids. The intercept represents the estimated mean for the reference group (each compound class at 10-14 cm depth in ambient plots). Coefficients represent the estimated differences from this reference level. Negative values indicate a lower response relative to the reference. Lower. CL and upper. CL represent the bound of the 95 % confidence interval for the estimated mass difference of bulk SOC or hydrolysable lipids at the corresponding fixed effects level. Interaction terms represent deviations from the additive effects of the main fixed effects. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Bulk SOC				Hydrolysable lipids			
Fixed effects	Coefficient	*p*-value	Lower. CL	Upper. CL	Coefficient	*p*-value	Lower. CL	Upper. CL
Intercept (Ambient, 10-14 cm)	0.28	0.273	-0.76	1.32	-0.19	0.596	-1.64	1.27
Warming	-0.17	0.629	-0.93	1.15	-0.04	0.941	-1.68	1.23
Depth 45-49 cm	-0.37	0.359	-1.36	1.18	-0.35	0.529	-2.32	1.25
Depth 85-89 cm	-0.32	0.375	-1.07	1.00	0.45	0.372	-1.19	1.72
Warming: Depth 45-49 cm	0.17	0.753	-1.13	0.95	0.34	0.649	-1.69	1.22

Warming: Depth 85-89 cm	0.03	0.957	-1.22	0.86	-0.10	0.887	-1.33	1.58

***Table S26*:** Pairwise post hoc comparisons of mass difference of pre-existing bulk SOC or hydrolysable lipids between ambient and warmed plots (n = 3) based on estimated marginal means (EMMs) from linear mixed-effects models. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**). Positive values indicate warming increased the mass difference, and negative values indicate warming decreased the mass difference. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Bulk SOC		Hydrolysable lipids	
Depth [cm]	Estimate	*p-value*	Estimate	*p-value*
10-14	-0.17	0.629	-0.04	0.941
45-49	-0.00	0.991	0.30	0.587
85-89	-0.14	0.684	-0.14	0.784

***Table S27*:** Anova table for linear mixed effects model (LMEs) to test the effects of carbon chain length (carbon number), compound class, depth, warming and their interactions on the mass change of *ω*-hydroxy acids and diacids. numDF denotes numerator degrees of freedom and denDF denotes denominator degrees of freedom. Since compound class has no significant impact and does not interact with other main fixed effects, it is dropped from the final model. Due to heteroscedasticity, data for diacids was square root transformed. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Full model: mass change of *ω*-hydroxy acids or diacids ~ Warming × depth × carbon number × compound class, random = ~1|Block.

Final model: mass difference of *ω*-hydroxy acids or diacids ~ warming × depth + carbon number, random = ~1|Block.

	Hydrolysable lipids mass change			
Fixed effects	numDF	denDF	F-value	*p*-value
Intercept (Ambient, 10-20 cm, carbon number 16)	1	153	4407.4	**0**
Warming	2	153	10.4	**< 0.001**
Depth	1	153	3.0	0.087
Carbon number	1	153	56.9	**< 0.001**
Warming: Depth	2	153	13.0	**< 0.001**

***Table S28*:** Summary of linear mixed effects model (LMEs) to test the effects of carbon chain length (carbon number), compound class, depth, warming and their interactions on the mass change of *ω*-hydroxy acids and diacids. Because compound class had no significant effect and did not interact with other factors, it was excluded from the final model. Therefore, results are aggregated across both compound classes. Intercept is the mass change of both compound classes at 10-14 cm in ambient plots with carbon number = 16. Root square values indicate absolute changes from the intercept on the transformed scale (root square), whereas "Difference" refers to the corresponding changes back-transformed to the original scale. Because carbon number is treated as a continuous variable (numeric) in our model, the coefficient represents the slope of its effect on the mass change of the two compound classes. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

Fixed effects	Root square values	Difference	Sdt.Error	DF	t-value	*p*-value
Intercept (Ambient, 10-14 cm, carbon number = 16)	0.64	-	0.03	153	20.02	**< 0.001**
Warming	-0.13	-0.15	0.04	153	-3.14	**0.002**
Depth 45-49 cm	-0.01	-0.01	0.04	153	-0.29	0.771
Depth 85-89 cm	-0.02	-0.02	0.04	153	-0.40	0.689
Carbon number	0.03	-	0.00	153	7.54	**< 0.001**
Warming:45-49 cm	0.26	0.34	0.06	153	4.66	**< 0.001**
Warming:85-89 cm	0.23	0.29	0.06	153	4.12	**< 0.001**

***Table S29*:** Pairwise post hoc comparison of mass change ω-hydroxy acids and diacids of pre-existing bulk SOC or hydrolysable lipids between ambient and warmed plots (n = 3) across soil depth based on estimated marginal means (EMMs) from linear mixed-effects models. Since only warming and depth interaction was significant, carbon number was aggregated for this post hoc comparison. The **Estimate** column shows the difference in values between treatments (**warmed – ambient**). Positive values indicate warming increased the mass difference, and negative values indicate warming decreased the mass difference. DF denotes the degree of freedom. *p*-values are presented in bold to indicate statistical significance ($\alpha < 0.05$).

	Bulk SOC		
Depth [cm]	Estimate	DF	*p-value*
10-14	-0.13	153	**0.002**
45-49	0.14	153	**< 0.001**
85-89	0.11	153	**0.008**