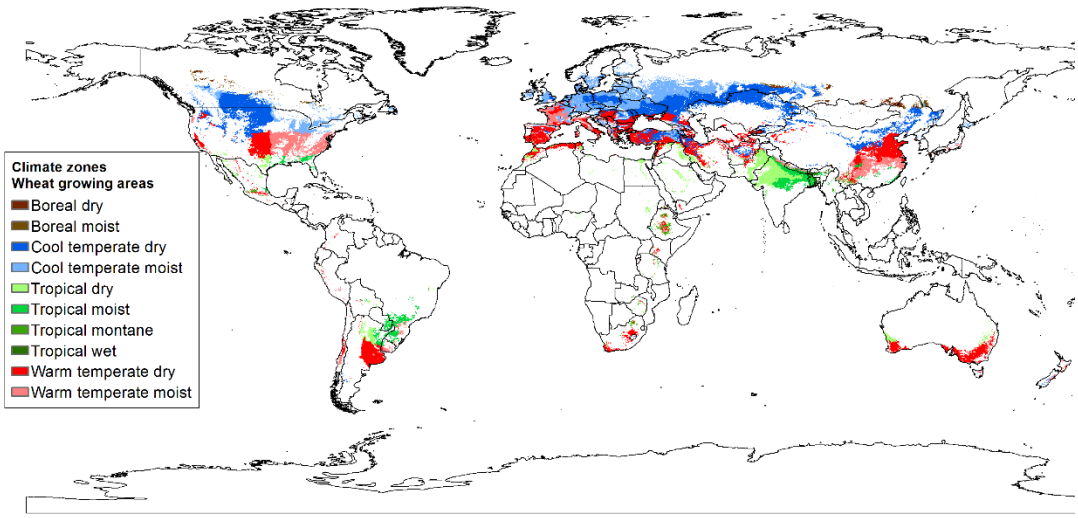
Figure S-1: Climatic zones in the (a) wheat and (b) rice growing areas of the world. Grid squares are included where the rice or wheat production >0.099 thousand t year^{-1} per 5 by 5 arc minute cell. Data source: GAEZ.

(a)



(b)

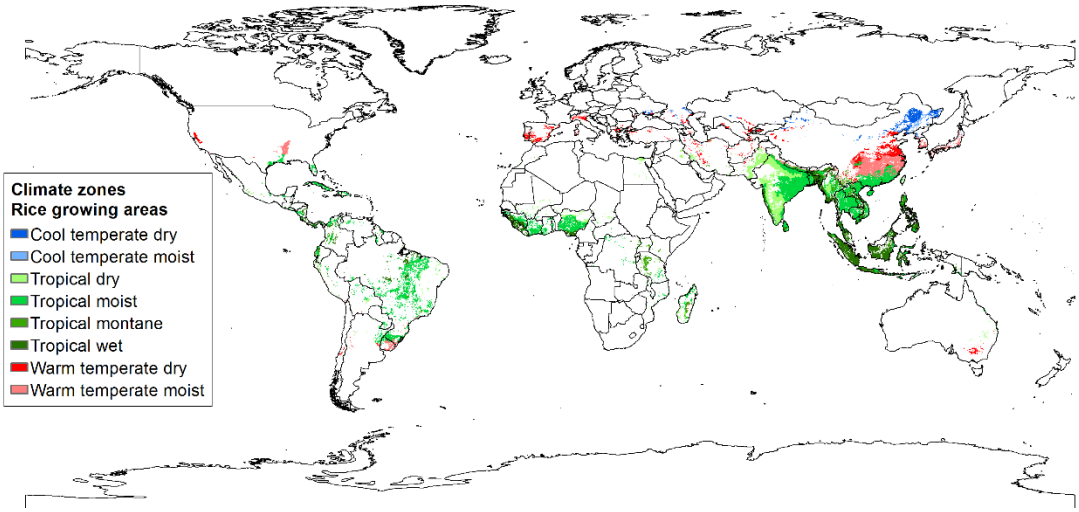
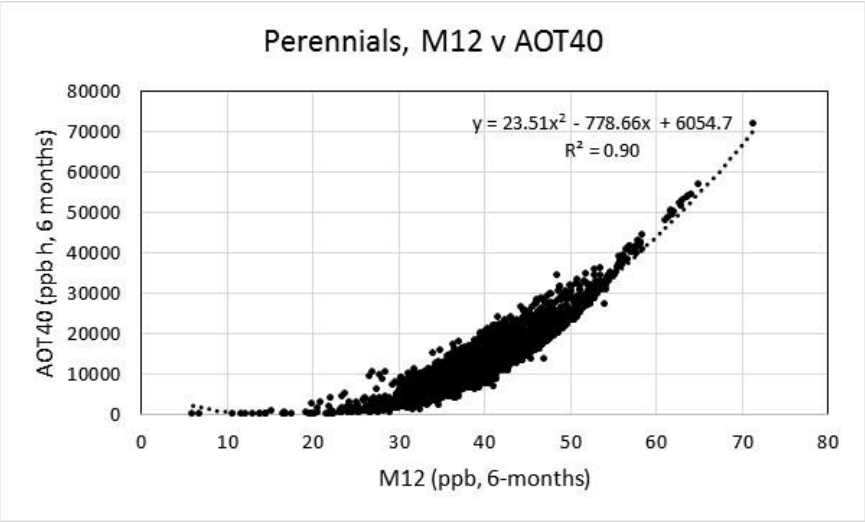
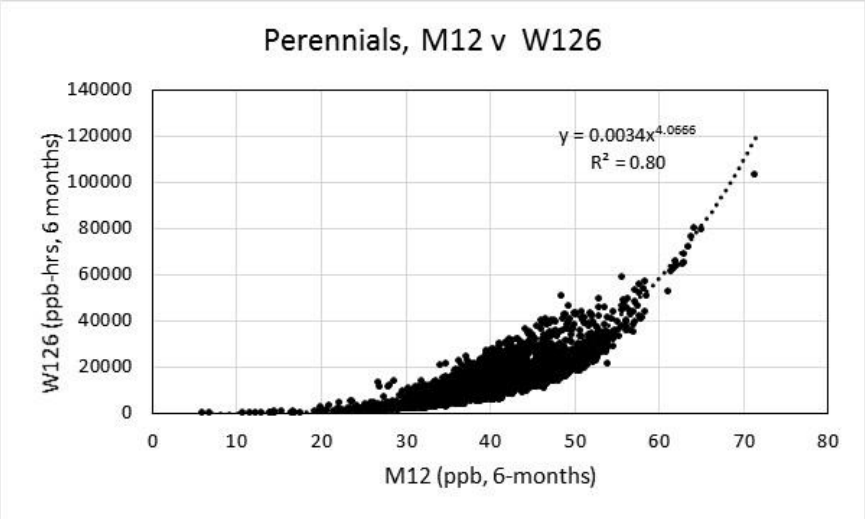


Figure S-2. Correlations between metrics for perennial vegetation. Analysis is provided for all sites classed as non-urban.

(a)



(b)



(c)

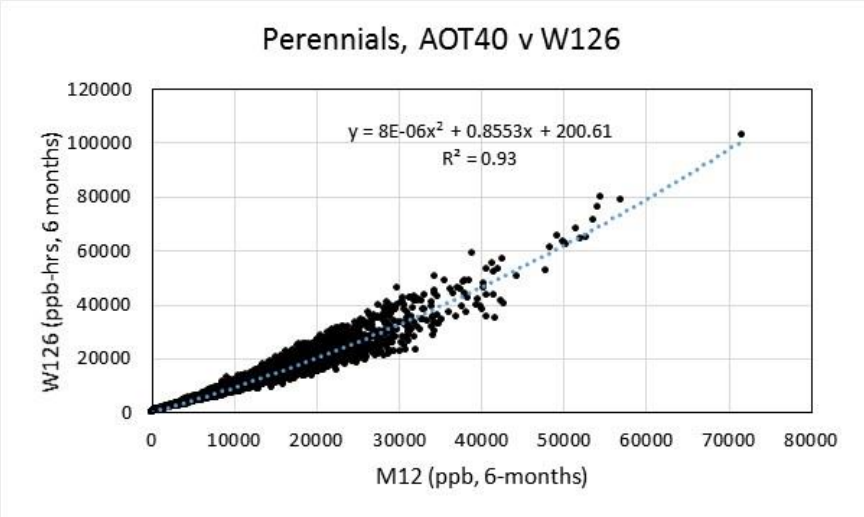


Figure S-3. Stylised 24 h mean ozone profile to illustrate the effect of measurement height on ozone value. The consequences of these changes for 3-month and 6-month M12 and AOT40 are provided in Table S4.

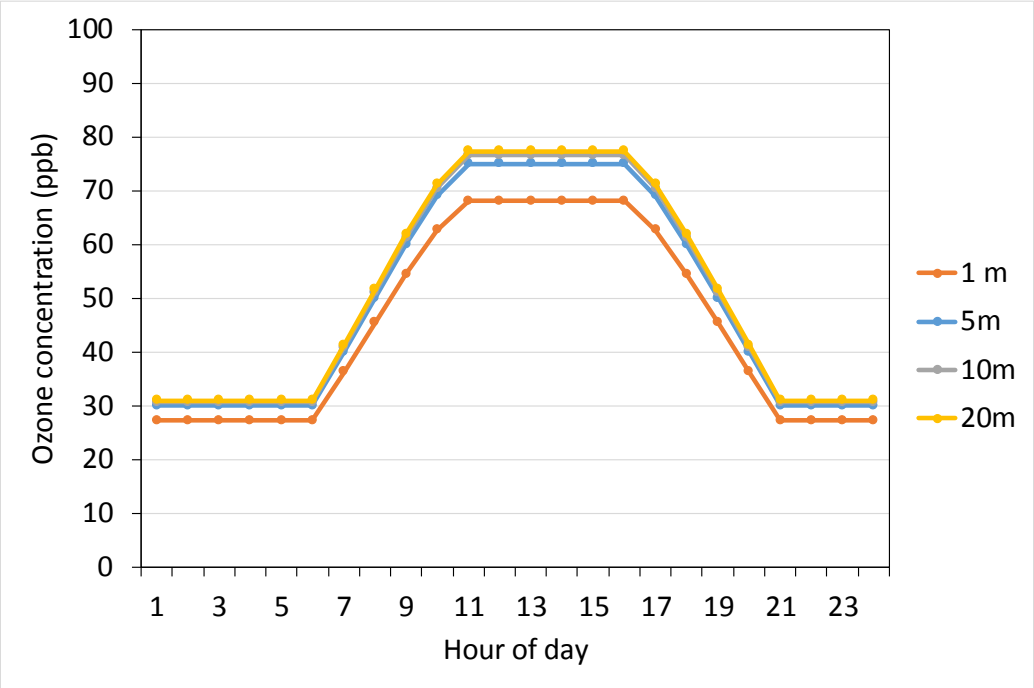
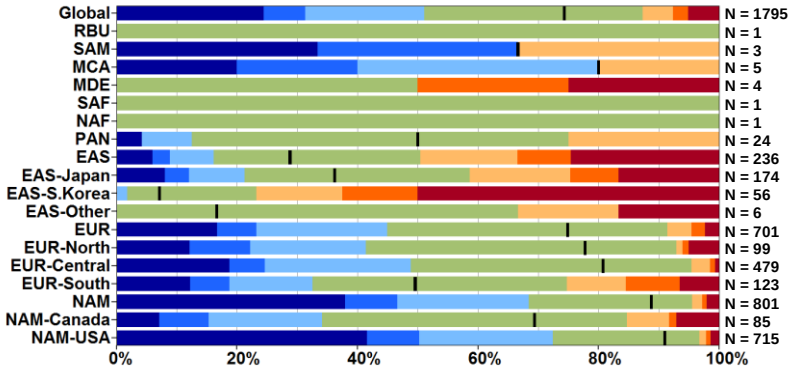
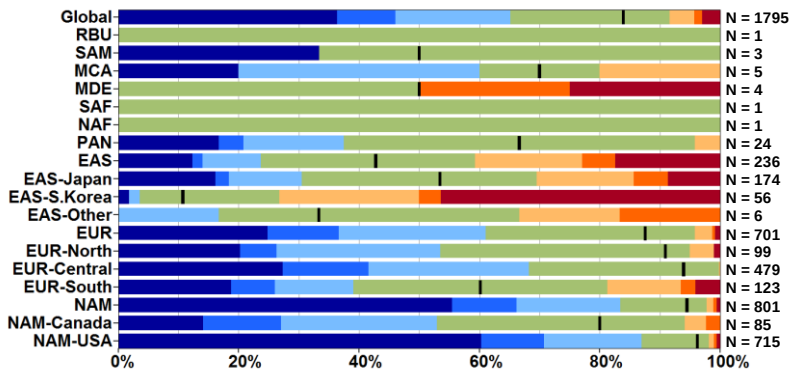


Figure S-4. Trends in (a) M12, (b) AOT40 and (c) W126 over a 6-month growing season for perennials at all non-urban sites for the period 2000 - 2014. Data are presented as the proportion of monitoring sites in different regions and countries with trends that: are significantly increasing or decreasing ($p \leq 0.05$); show an indication of an increase/decrease ($0.05 < p \leq 0.1$); have a weak indication of an increase/decrease ($0.1 < p \leq 0.34$), or no change ($p > 0.34$). Blue colours indicate decreasing trends, green colours no trend and red colours indicate decreasing trends. Note: Maps are not presented for 2000 – 2014 trends.

(a)



(b)



(c)

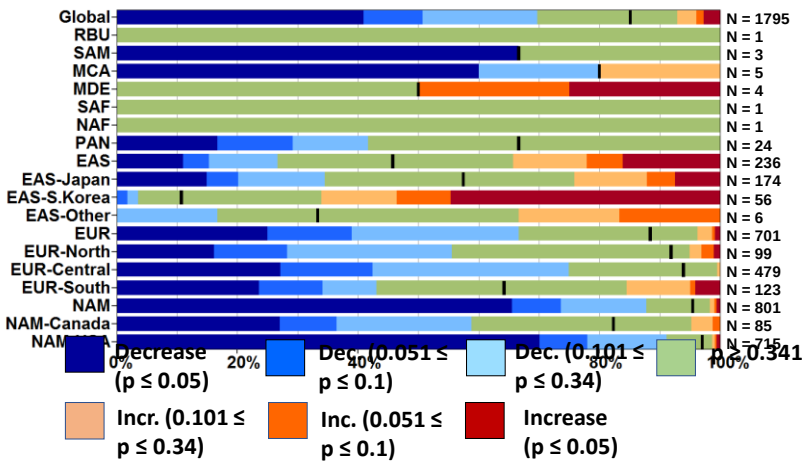


Figure S-5. **Trends in (a) M12 (b) AOT40 and (c) W126 over a 3 month wheat growing season at wheat growing sites for the period 2000 - 2014**. Data are presented as the proportion of monitoring sites in different regions and countries with trends that: are significantly increasing or decreasing ($p \leq 0.05$); show an indication of an increase/decrease ($0.05 < p \leq 0.1$); have a weak indication of an increase/decrease ($0.1 < p \leq 0.34$), or no change ($p > 0.34$). Blue colours indicate decreasing trends, green colours no trend and red colours indicate decreasing trends. Note: Maps are not presented for 2000 – 2014 trends.

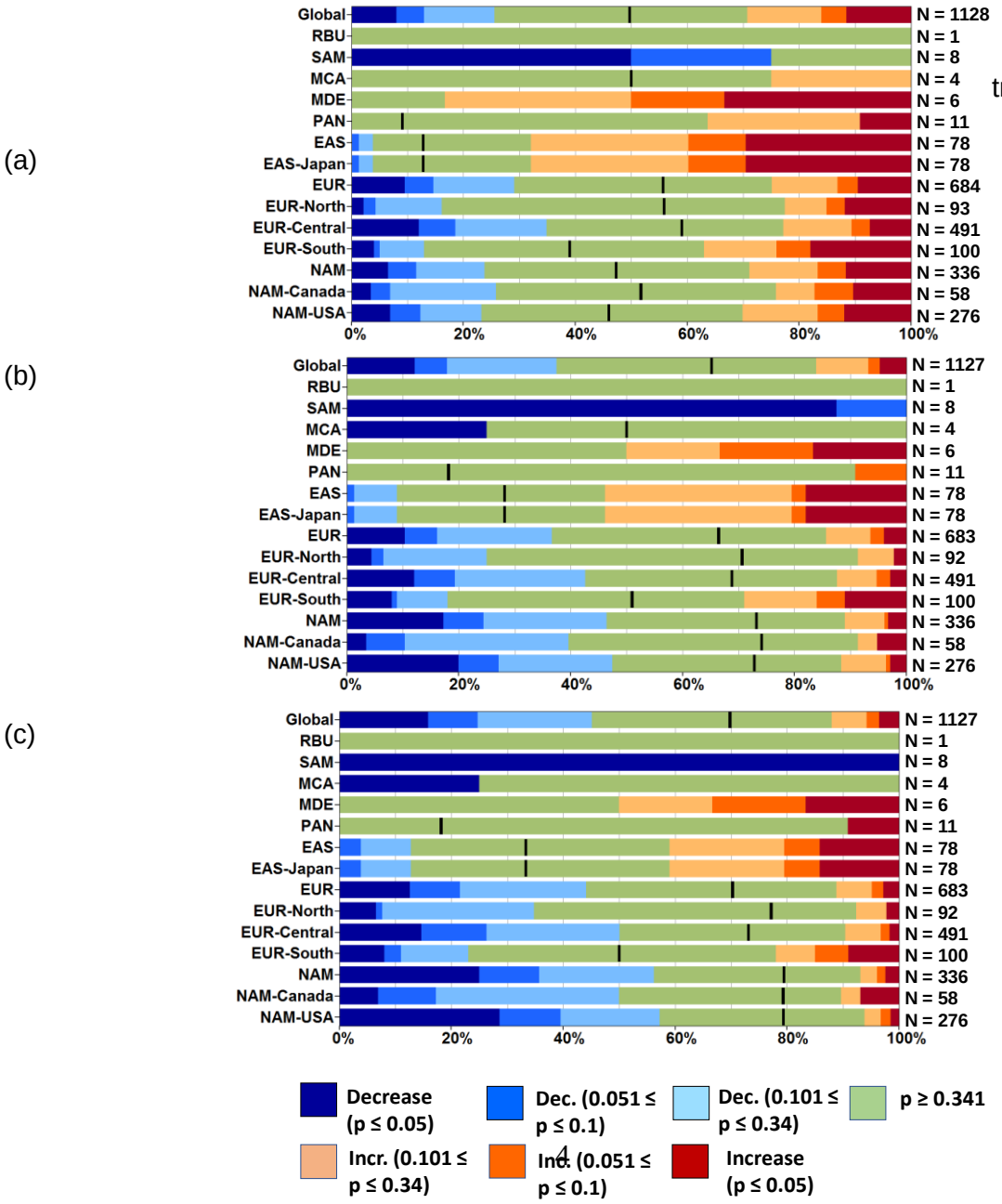
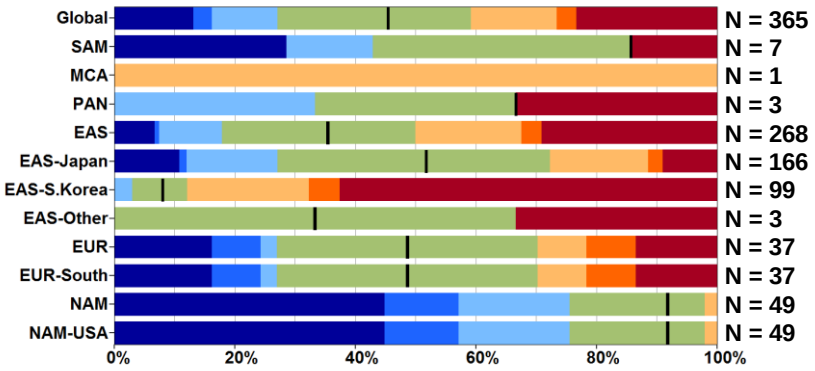
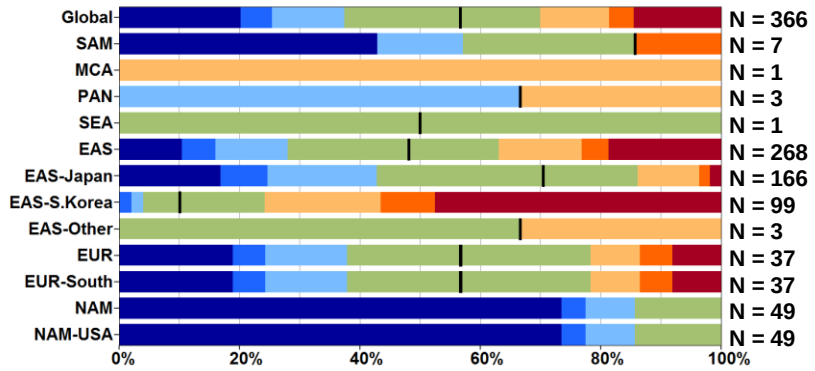


Figure S-6. **Trends in (a) M12 (b) AOT40 and (c) W126 over a 3-month rice growing season at rice growing sites for the period 2000 – 2014.** Data are presented as the proportion of monitoring sites in different regions and countries with trends that: are significantly increasing or decreasing ($p \leq 0.05$); show an indication of an increase/decrease ($0.05 < p \leq 0.1$); have a weak indication of an increase/decrease ($0.1 < p \leq 0.34$), or a weak or no change ($p > 0.34$). Blue colours indicate decreasing trends, green colours no trend and red colours indicate decreasing trends. Note: Maps are not presented for 2000 – 2014 trends.

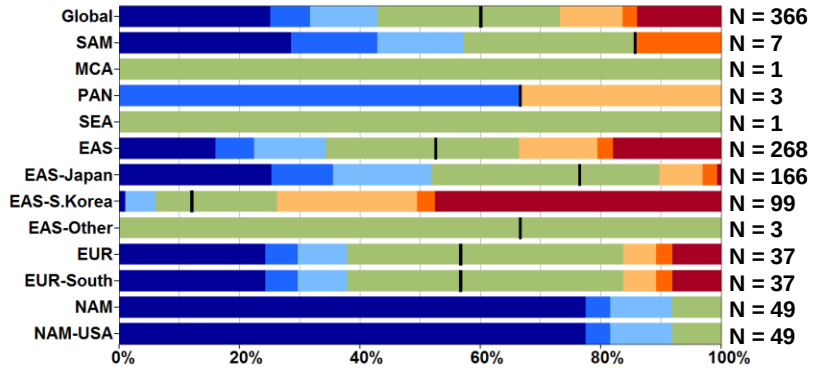
(a)



(b)



(c)



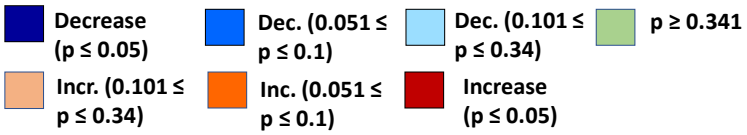


Table S-1. Mean and standard deviation (SD) for M12, AOT40 and W126 for the 6-month summer period (2010 – 2014), by country.

Country	N	M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
		Mean	SD	Mean	SD	Mean	SD
Algeria	1	41.2		6943		5613	
Argentina	1	17.6		0		118	
Armenia	1	53.8		31231		26270	
Australia	34	25.0	3.2	1761	1185	2020	1277
Austria	96	40.4	4.4	14052	4769	12531	3861
Barbados	1	22.5		330		1005	
Belgium	27	34.8	3.1	7451	2296	8002	2225
Bermuda	1	22.3		897		903	
Brazil	2	8.4	3.3	54	75	77	70
Bulgaria	18	40.4	6.7	13367	8582	12232	9008
Canada	146	32.2	4.7	4566	3538	4155	3402
Cape Verde	1	29.0		526		1023	
Chile	3	33.7	1.8	5553	4069	5322	3735
China	9	44.8	11.5	24432	16574	31850	24430
Croatia	2	45.4	3.2	21558	2360	19840	252
Cyprus	1	54.6		34193		28499	
Czech Republic	49	40.3	2.8	12384	2935	11024	2560
Denmark	6	35.4	2.4	4932	2171	4429	1643
Estonia	5	34.9	2.6	4904	1421	3867	869
Finland	13	31.8	3.6	3239	1693	2779	1232
France	238	40.9	4.5	12665	5947	11967	6018
Germany	231	36.8	3.6	9551	3373	9413	3082
Gibraltar	1	39.2		10173		8514	
Greece	7	51.1	10.0	30154	17101	31609	21430
Guadeloupe	2	14.9	2.7	189	267	247	251
Hungary	15	42.6	3.0	15715	4530	14739	4463
India	3	38.9	16.1	18718	19009	26751	29366
Indonesia	1	12.3		60		107	
Ireland	6	30.6	4.1	2194	1369	2058	892
Israel	7	54.0	5.2	32644	10822	32937	16058
Italy	228	45.2	5.4	20044	8109	21250	10513
Japan	476	39.2	4.4	15281	4928	17195	6772
Latvia	5	35.2	3.8	5509	3992	4676	3129
Lithuania	11	32.6	3.6	4562	2620	4086	2310
Luxembourg	5	37.8	4.2	10138	3685	10501	3955
Macedonia	6	45.7	13.3	17569	24367	25056	38535
Malta	2	51.3	3.6	25873	7628	22544	9634
Martinique	2	9.3	3.4	0	0	31	21
Mexico	3	33.8	6.6	5194	4179	4854	3708
Nepal	1	47.2		25494		29086	
Netherlands	26	33.8	2.2	5963	1516	6525	1748
New Zealand	2	19.9	0.2	2	3	173	6
Norway	10	32.5	4.5	3297	1487	2784	1071
Poland	38	38.8	2.7	10455	3504	9220	3172
Portugal	24	38.2	5.8	10324	5762	9775	5735
Réunion	4	14.8	1.3	0	0	87	25
Republic of Korea	122	40.3	4.6	18274	6035	22880	8672
Romania	35	34.6	6.6	7373	7411	7292	8893
Russia	1	43.9		12868		8575	
Serbia	1	26.0		3333		3234	
Slovakia	13	43.4	3.6	16207	5593	13570	4635
Slovenia	13	44.9	5.4	20664	6924	19954	7344
Somalia	2	41.8	2.0	19160	2479	22454	3663
South Africa	9	34.3	6.4	8940	6081	9996	7279
Spain	255	41.9	6.6	13329	7359	11577	6942
Sweden	12	35.0	2.4	4618	2015	3897	1456
Switzerland	19	43.4	4.9	17821	7551	18614	8486
Taiwan	5	38.4	4.4	16663	5191	20645	6859
Thailand	1	28.2		8697		11426	
United Kingdom	42	31.7	2.8	2796	1372	2755	1066
United States of America	1023	42.5	6.3	15580	8137	15238	9587

Table S-2. Present-day perennial vegetation metrics, by climatic zone for North America (NAM), Europe (EUR) and East Asia (EAS), presented as 6-month values, mean and standard deviation (SD) for 2010-2014).

HTAP			M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
Region	Climate zone	N	Mean	SD	Mean	SD	Mean	SD
NAM	Warm Temperate Moist	362	42.4	3.9	15169	4453	14859	5165
	Warm Temperate Dry	143	46.9	7.8	21470	12293	22987	16387
	Cool Temperate Moist	366	37.4	6.1	9529	6151	8900	5964
	Cool Temperate Dry	112	45.3	6.8	17699	8848	14965	8527
	Boreal Moist	8	40.2	9.5	12646	10566	9874	8396
	Boreal Dry	7	28.2	1.9	2341	1456	2179	1267
	Tropical Montane	1	48.5		21146		19133	
	Tropical Moist	104	35.7	3.1	8872	2833	8808	3380
	Tropical Dry	62	47.8	7.1	23073	9566	23952	12000
	All	**1165**	**41.3**	**7.0**	**14183**	**8518**	**13832**	**9755**
EUR	Warm Temperate Moist	275	40.2	6.3	13567	8520	14476	10833
	Warm Temperate Dry	437	43.5	6.1	15888	7972	14814	8699
	Cool Temperate Moist	605	37.9	5.3	10486	6578	9917	6952
	Cool Temperate Dry	121	38.4	3.7	10878	3847	10381	3800
	Tropical Dry	20	38.1	8.4	9385	9046	8078	8172
	All	**1458**	**40.1**	**6.2**	**12758**	**7731**	**12295**	**8552**
EAS	Warm Temperate Moist	572	39.6	4.1	16073	5051	18609	7316
	Warm Temperate Dry	2	45.3	4.6	25965	11764	34396	23078
	Cool Temperate Moist	22	39.3	5.7	14711	9071	16711	12406
	Cool Temperate Dry	3	54.3	12.3	34752	24434	42259	37263
	Tropical wet	11	28.7	7.4	9264	5867	10825	7687
	Tropical Moist	1	34.2		15127		20672	
	Tropical Dry	1	39.8		15822		18689	
	All	**612**	**39.5**	**4.7**	**16023**	**5688**	**18572**	**8153**

Table S-3. Mean and standard deviation (SD) for M12, AOT40 and W126 for the 3-month wheat period (2010 – 2014), by country.

Country	N	M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
		Mean	SD	Mean	SD	Mean	SD
Armenia	1	52.5		14344		10585	
Australia	15	26.8	2.6	341	359	549	346
Austria	48	42.8	3.2	7879	1916	6801	1522
Belgium	37	35.0	4.8	3579	1773	3677	1741
Bulgaria	17	35.3	6.5	3798	3994	3238	3582
Canada	83	37.3	5.0	3777	2209	3261	1986
Chile	11	22.1	1.7	1145	587	1090	648
China	6	43.9	12.5	12119	8893	17079	13566
Croatia	1	40.7		7810		7395	
Czech Republic	52	41.5	3.2	6449	1861	5485	1591
Denmark	5	35.5	5.7	2377	1256	1967	913
Finland	4	37.3	2.5	2696	1077	2115	702
France	297	39.8	3.9	5495	2288	4919	2219
Germany	230	37.8	3.7	4671	1599	4360	1462
Greece	4	46.8	8.8	10543	7135	10756	9975
Hungary	17	41.4	3.7	6835	2316	6028	2246
India	3	41.4	13.6	9057	6595	10582	8747
Ireland	5	33.3	3.2	1353	851	1285	539
Israel	7	41.2	8.2	6623	5940	6306	6820
Italy	192	39.7	5.0	6414	2787	6215	3124
Japan	269	45.8	3.9	10334	2924	11227	4052
Latvia	5	39.4	4.2	4559	2810	3661	2263
Lithuania	12	36.1	3.1	3101	1422	2563	1291
Luxembourg	5	40.6	4.7	6279	2359	6285	2443
Macedonia	9	33.7	15.8	5397	11519	6818	16159
Malta	3	32.5	5.2	1275	967	1240	698
Mexico	3	42.2	9.3	8827	9262	11179	14441
Netherlands	32	36.1	3.2	3395	1073	3451	1086
New Zealand	1	19.9		3		75	
Norway	4	39.0	1.9	3112	715	2422	422
Poland	53	40.5	3.1	5692	1837	4836	1644
Portugal	9	39.7	5.9	4775	2480	3675	1759
Romania	48	32.4	7.1	2750	3003	2622	3343
Russia	1	46.6		6905		4566	
Serbia	1	20.5		519		528	
Slovakia	12	43.6	3.0	7811	1960	6519	1835
Slovenia	7	45.3	7.2	10043	5038	8968	4345
Somalia	1	38.1		6899		7398	
South Africa	1	57.3		20934		30319	
Spain	232	40.7	6.0	5776	3122	4721	2636
Sweden	4	35.5	3.4	1895	948	1753	719
Switzerland	24	40.9	4.0	6698	2105	6486	2159
United Kingdom	48	33.1	3.9	1676	891	1624	712
United States of America	450	41.7	4.6	6415	2735	5789	2721

Table S-4. Present-day wheat metrics, by climatic zone for North America (NAM), Europe (EUR) and East Asia (EAS) (3-month values mean and standard deviation (SD) for 2010-2014).

HTAP Region	Climate zone	N	M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
			mean	SD	mean	SD	mean	SD
NAM	Warm Temperate Moist	180	41.6	3.0	6124	1757	5420	1674
	Warm Temperate Dry	81	42.9	3.8	6917	2904	6555	3300
	Cool Temperate Moist	156	40.8	4.8	5924	2543	5452	2492
	Cool Temperate Dry	60	44.3	6.0	7778	4286	6493	4142
	Tropical Moist	21	34.3	3.1	2693	834	2465	716
	Tropical Dry	34	33.3	2.5	2614	822	2229	639
	All	**532**	**41.0**	**4.9**	**6013**	**2821**	**5403**	**2772**
EUR	Warm Temperate Moist	276	37.7	4.5	4893	2406	4657	2613
	Warm Temperate Dry	477	39.9	6.0	5709	3025	4898	2828
	Cool Temperate Moist	514	39.3	4.9	5371	3063	4950	3232
	Cool Temperate Dry	132	39.0	4.7	5207	2162	4642	1956
	Tropical Dry	19	30.0	3.8	1496	674	1311	484
	All	**1418**	**39.0**	**5.4**	**5324**	**2884**	**4798**	**2886**
EAS	Warm Temperate Moist	255	46.0	3.6	10526	2493	11512	3512
	Warm Temperate Dry	3	34.8	1.5	7835	966	11224	1823
	Cool Temperate Moist	15	42.4	6.9	7434	6573	7241	9157
	Cool Temperate Dry	2	54.7	16.5	16819	16805	22349	26568
	All	**275**	**45.8**	**4.2**	**10373**	**3142**	**11355**	**4489**

Table S-5. Mean and standard deviation (SD) for M12, AOT40 and W126 for the 3-month rice period (2010 – 2014), by country.

Country	N	M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
		Mean	SD	Mean	SD	Mean	SD
Australia	3	23.3	3.4	705	467	787	512
Brazil	4	22.7	12.4	2871	2089	3297	2466
Chile	5	33.4	1.9	3746	856	3535	997
China	6	50.9	11.6	17095	11919	24082	18845
Greece	2	52.9	18.1	18465	16237	21714	23130
India	3	30.7	14.0	4920	6041	6772	8746
Indonesia	2	19.6	8.8	1041	1337	1427	1806
Italy	68	50.9	5.1	15342	4345	19403	6624
Japan	535	37.1	5.7	7252	3697	8687	5426
Macedonia	4	41.0	4.6	5426	3941	4854	3682
Portugal	9	38.8	6.4	6033	3167	6124	3136
Republic of Korea	190	35.8	5.6	7691	3106	9656	4465
Somalia	1	47.4		13355		16911	
Spain	94	43.7	5.6	7444	3836	6454	3678
Taiwan	3	39.9	3.2	9275	1905	11961	2875
Thailand	3	19.0	1.4	807	185	868	270
United States of America	59	39.3	9.3	7110	5902	8135	8066

Table S-6. Present-day rice metrics, by climatic zone for North America (NAM), Europe (EUR) and East Asia (EAS) (3-month values mean and standard deviation (SD) for 2010-2014).

HTAP Region	Climate zone	N	M12 (ppb)		AOT40 (ppb h)		W126 (ppb-hrs)	
			Mean	SD	Mean	SD	Mean	SD
NAM	Warm Temperate Moist	6	41.8	5.0	7508	2755	7926	3122
	Warm Temperate Dry	26	46.9	7.2	11386	6159	13340	9461
	Tropical Moist	25	31.1	3.8	2709	1608	2985	2048
	Tropical Dry	1	33.4		3688		3988	
	All	**58**	**39.3**	**9.4**	**7112**	**5954**	**8155**	**8135**
EUR	Warm Temperate Moist	44	51.0	5.1	15725	3903	20272	5972
	Warm Temperate Dry	121	45.5	6.2	9296	5204	9271	6931
	Tropical Dry	13	37.1	5.5	4049	2765	3622	2515
	All	**178**	**46.3**	**6.8**	**10502**	**5780**	**11578**	**8291**
EAS	Warm Temperate Moist	723	36.8	5.7	7381	3532	8958	5179
	Warm Temperate Dry	2	50.7	8.9	20168	9620	30353	15962
	Cool Temperate Moist	3	38.7	11.6	8696	7592	11406	11086
	Cool Temperate Dry	2	57.4	20.7	20339	22178	27634	34527
	Tropical Wet	3	29.5	14.8	5492	4672	6930	5917
	Tropical Moist	1	43.5		11455		15220	
	All	**734**	**36.9**	**5.9**	**7454**	**3774**	**9077**	**5578**

Table S-7. The effect of change in measurement height on 3-month and 6-month AOT40, calculated using the conversion factors in CLRTAP (2017) for a representative ozone gradient over a 1m high crop or 20m high tree. The calculations are for a 90d (3-months) or 180d (6-months) repetition of the diurnal ozone profile shown in Figure S1.

	Measurement height			
	1m	**5m**	**10m**	**20m**
Crops				
M12 (ppb)	50.0	55.1	56.3	56.8
90d AOT40 (ppb h)	10800	16323	17550	18164
90d W126 (ppb-hrs)	390	806	934	1003
Trees				
M12 (ppb)	50.0	52.7	53.8	54.3
180d AOT40 (ppb h)	21600	27470	29817	30991
180d W126 (ppb-hrs)	779	1162	1352	1456

Text S-1 **Analysis of the statistical differences between the NAM, EUR and EAS regions for perennial metrics.**

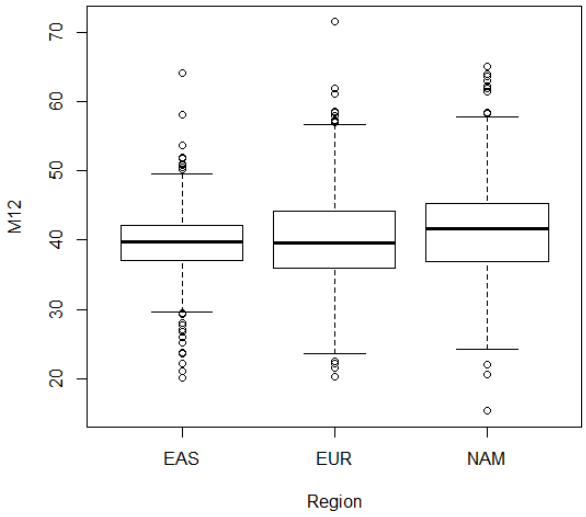
General linear mixed models were run using the R lme4 package. Where necessary, the dependent variable was transformed to meet model assumptions. The Likelihood ratio test determines if the 'Region' variable is required in the model. A p-value of <0.05 indicates that the model is better with 'Region' included, i.e. there is a difference between the regions. The post-hoc Tukey test then shows where the differences between regions lie. A p-value of < 0.05 indicates a significant difference between 2 regions. Box plots show the median of the data (middle line across the box) and the lower (25%) and upper (75%) quartiles (lower and upper edges of the box). The vertical size of the box is the interquartile range (IQR). The whiskers represent minimum and maximum values 1.5 * IQR from the middle 50% of the data. Points beyond these values are plotted as outliers.

M12

Model:

Lmer (M12 ~ Region + (1 | Country), data = Perennial, REML=T)

Likelihood ratio test for Region variable: p = 0.76



Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	1
NAM	EAS	1
NAM	EUR	1

AOT40

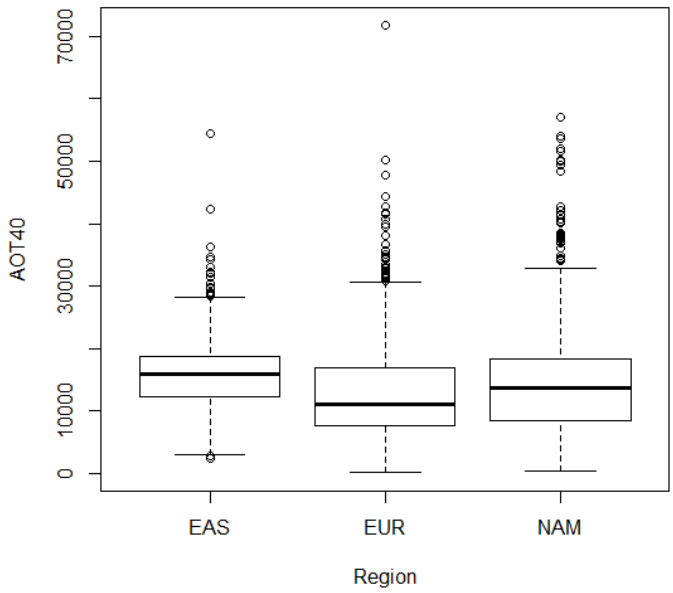
Model:

Lmer (LogAOT40 ~ Region + (1 | Country), data = Perennial, REML=T)

Likelihood ratio test for Region variable: p = 0.15

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.19
NAM	EAS	0.27
NAM	EUR	0.75



W126

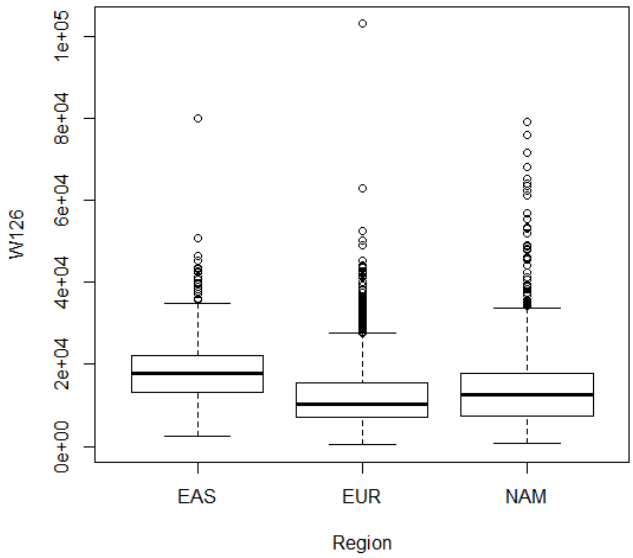
Model:

Lmer (LogW126 ~ Region + (1 | Country), data = Perennial, REML=T)

Likelihood ratio test for Region variable: p = 0.04

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.04
NAM	EAS	0.11
NAM	EUR	0.76



Text S-2 **Analysis of the statistical differences between the NAM, EUR and EAS regions for wheat metrics.**

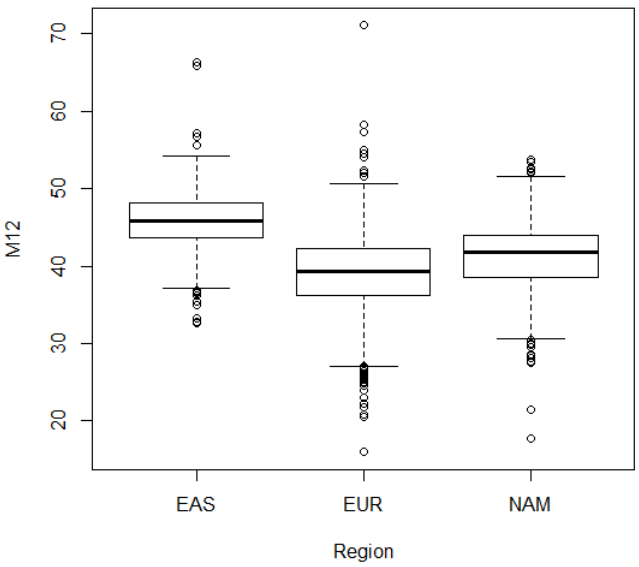
General linear mixed models were run using the R lme4 package. Where necessary, the dependent variable was transformed to meet model assumptions. The Likelihood ratio test determines if the 'Region' variable is required in the model. A p-value of <0.05 indicates that the model is better with 'Region' included, i.e. there is a difference between the regions. The post-hocTukey test then shows where the differences between regions lie. A p-value of < 0.05 indicates a significant difference between 2 regions. Box plots show the median of the data (middle line across the box) and the lower (25%) and upper (75%) quartiles (lower and upper edges of the box). The vertical size of the box is the interquartile range (IQR). The whiskers represent minimum and maximum values 1.5 * IQR from the middle 50% of the data. Points beyond these values are plotted as outliers.

M12

Model:

Lmer (M12 ~ Region + (1 | Country), data = Wheat, REML=T)

Likelihood ratio test for Region variable: p = 0.048



Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.04
NAM	EAS	0.17
NAM	EUR	0.75

AOT40

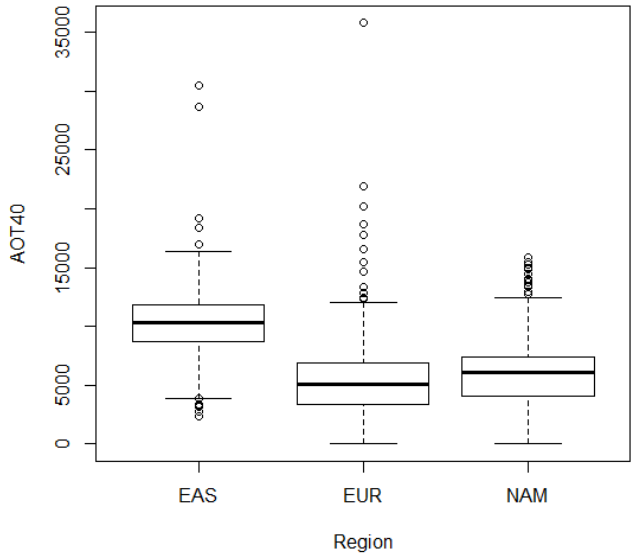
Model:

Lmer (SqrtAOT40 ~ Region + (1 | Country), data = Wheat, REML=T)

Likelihood ratio test for Region variable: p = 0.01

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.01
NAM	EAS	0.04
NAM	EUR	0.95



W126

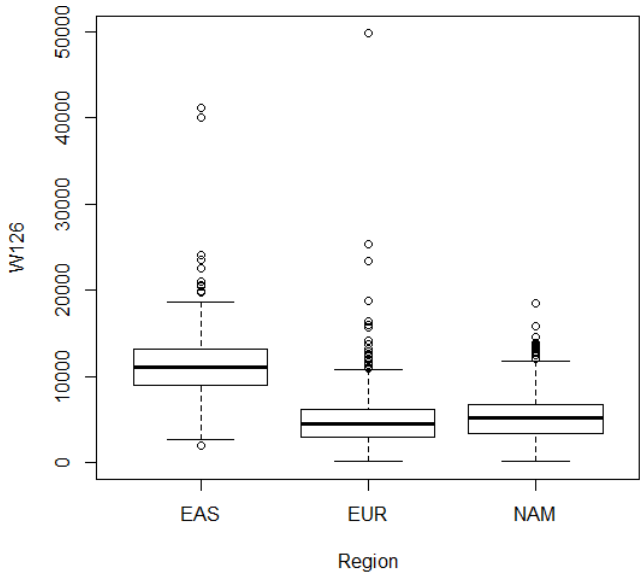
Model:

Lmer (LogW126 ~ Region + (1 | Country), data = Wheat, REML=T)

Likelihood ratio test for Region variable: p = 0.02

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.01
NAM	EAS	0.047
NAM	EUR	0.88



Text S-3 **Analysis of the statistical differences between the NAM, EUR and EAS regions for rice metrics.**

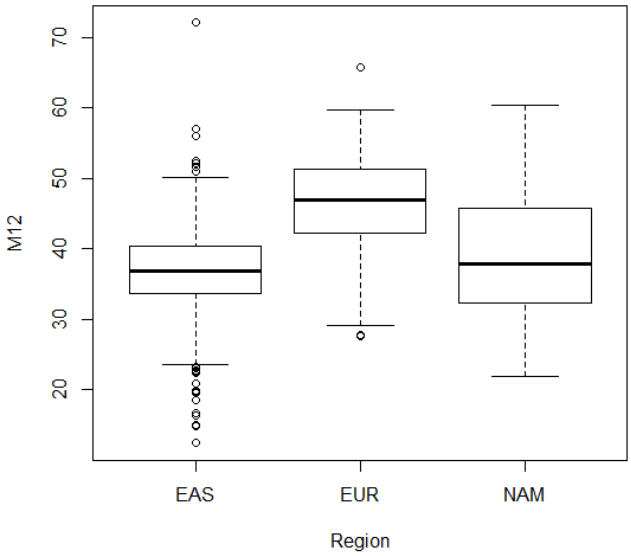
General linear mixed models were run using the R lme4 package. Where necessary, the dependent variable was transformed to meet model assumptions. The Likelihood ratio test determines if the 'Region' variable is required in the model. A p-value of <0.05 indicates that the model is better with 'Region' included, i.e. there is a difference between the regions. The post-hocTukey test then shows where the differences between regions lie. A p-value of < 0.05 indicates a significant difference between 2 regions. Box plots show the median of the data (middle line across the box) and the lower (25%) and upper (75%) quartiles (lower and upper edges of the box). The vertical size of the box is the interquartile range (IQR). The whiskers represent minimum and maximum values 1.5 * IQR from the middle 50% of the data. Points beyond these values are plotted as outliers.

M12

Model:

Lmer (M12 ~ Region + (1 | Country), data = Rice, REML=T)

Likelihood ratio test for Region variable: p = 0.29



Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.67
NAM	EAS	0.85
NAM	EUR	0.67

AOT40

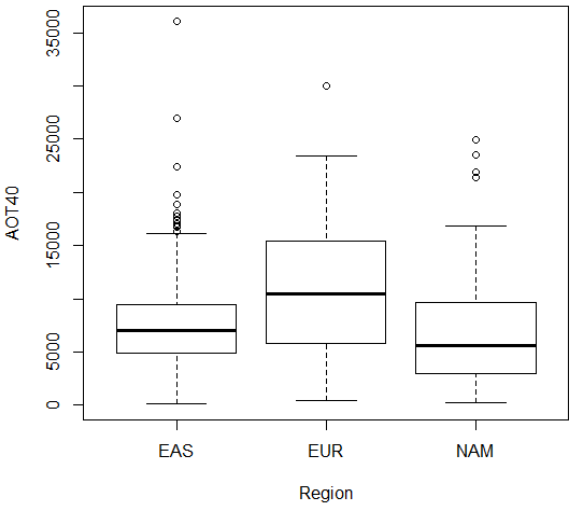
Model:

Lmer (SqrtAOT40 ~ Region + (1 | Country), data = Rice, REML=T)

Likelihood ratio test for Region variable: p = 0.63

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	1
NAM	EAS	1
NAM	EUR	1

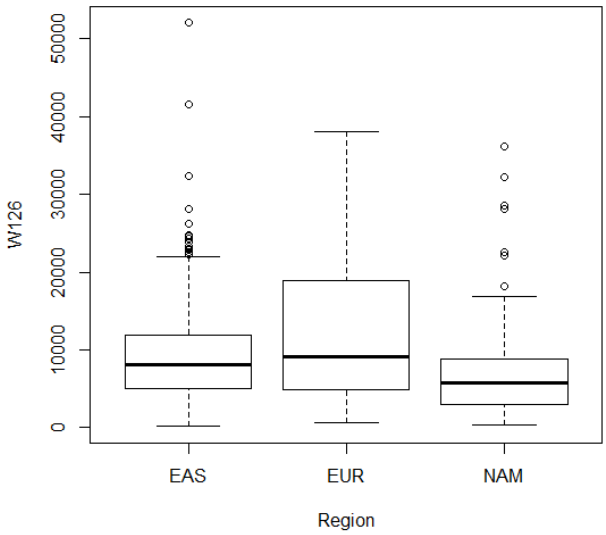


W126

Model:

Lmer (LogW126 ~ Region + (1 | Country), data = Rice, REML=T)

Likelihood ratio test for Region variable: p = 0.46

Post-hoc Tukey test

Pairwise comparison		p-value
EUR	EAS	0.90
NAM	EAS	0.83
NAM	EUR	0.90