

Supplementary Material

Carbon uptake by European agricultural land is variable, and in many regions could be increased: evidence from remote sensing, yield statistics and models of potential productivity

Science of the Total Environment

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The following Supporting Information is available for this article:

Fig. S1 Distribution of grasslands based on the MOD12Q1 product in Europe

Fig. S2 Comparison of Net Primary Production (NPP) from 12 EUROSTAT estimates using conversion factors of multiple literature references with output of MOD17 algorithm

Fig. S3 Comparison of potential Net Primary Production (NPP) based on fully irrigated yield from three global crop models (GEPIC, LPJmL, PEPIC) from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP).

Fig. S4 Potential Net Primary Production (NPP) comparison on country level of four crop models (GEPIC, LPJmL, PEPIC, EarthStat) with Miami output.

Fig. S5 Potential Net Primary Production (NPP) comparison on country level of four crop models (GEPIC, LPJmL, PEPIC, EarthStat) with EUROSTAT NPP.

Table S1 Example of estimating crop NPP from EUROSTAT data for entire Europe and year 2000

Table S2 Country comparison of all used NPP estimates

Table S3 EUROSTAT average NPP by country (ensemble mean)

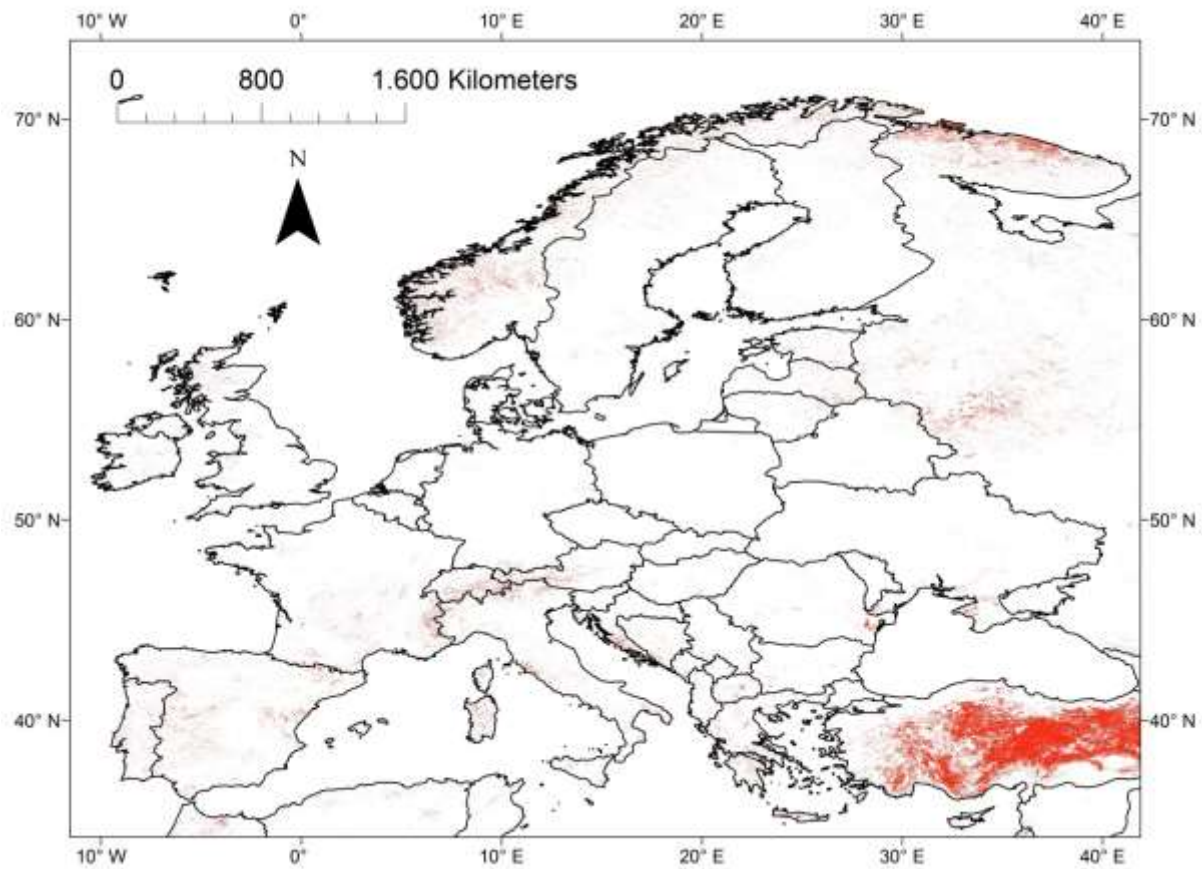


Fig. S1 Distribution of grasslands (code 10) in Europe available from the MOD12Q1 product in year 2000 classified by UMD classification system (Friedl et al., 2010)

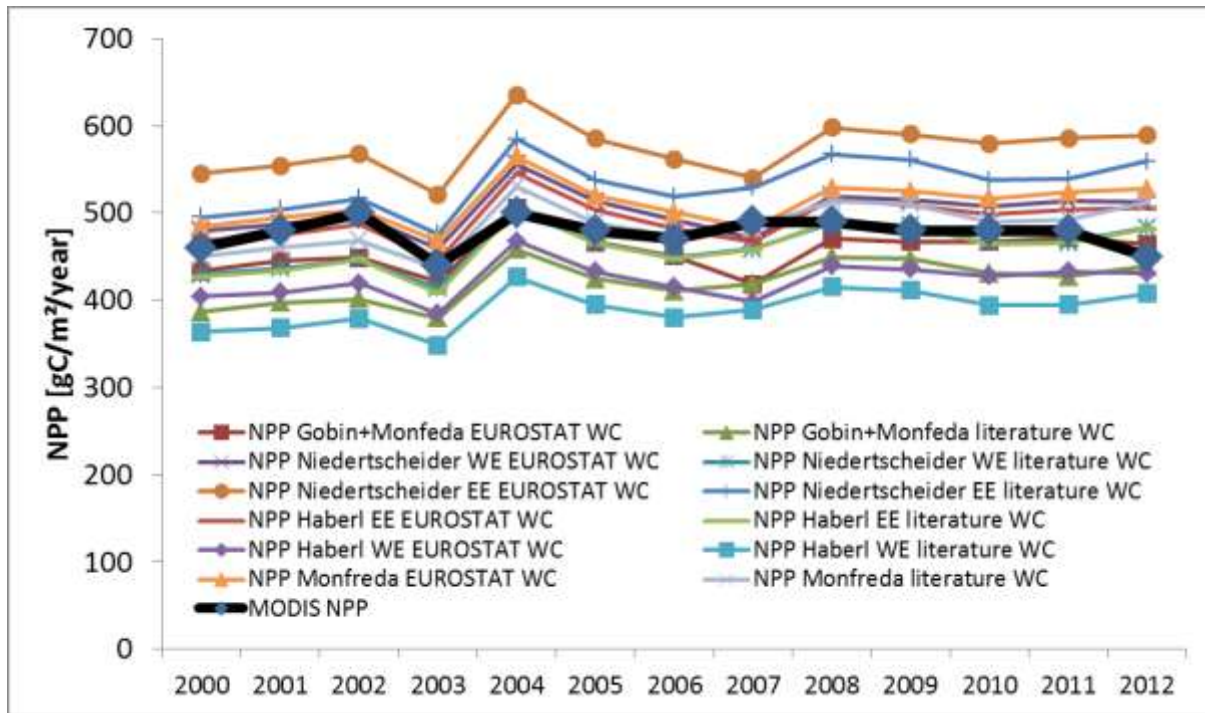


Fig. S2 Comparison of crop Net Primary Production (NPP) from 12 EUROSTAT estimates using conversion factors of multiple literature references (thin lines) with output of MOD17 algorithm (thick black line). Results represent European mean for 2000 to 2012.

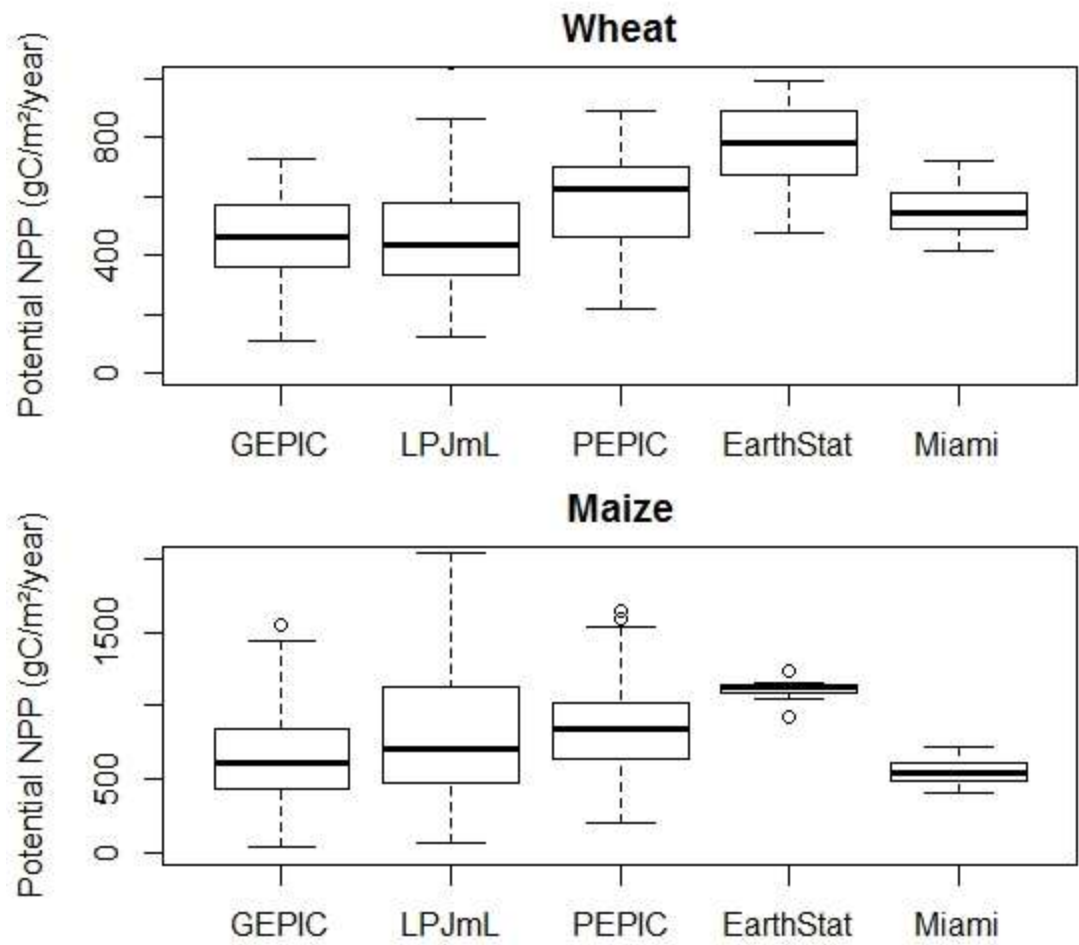


Fig. S3 Comparison of potential Net Primary Production (NPP) based on fully irrigated yield from three global crop models (GEPIC, LPJmL, PEPIC) from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) (Elliot et al., 2015) using HadGEM2-ES climate input and available on <https://esg.pik-potsdam.de/search/isimip/>, potential yield derived from climate-binned FAO statistics (EarthStat) available on <http://www.earthstat.org/data-download/> (Mueller et al., 2012) and the Miami model (Lieth, 1975). The first four models provide yield, which was converted into NPP using average European conversion factors. The boxplots represent the average NPP of all European countries for wheat (top) and maize (bottom) for the year 2000. The box represents the median and the 25th and 75th percentile, the whiskers extend to 1.5 of the interquartile range, values outside this range are indicated by circles.

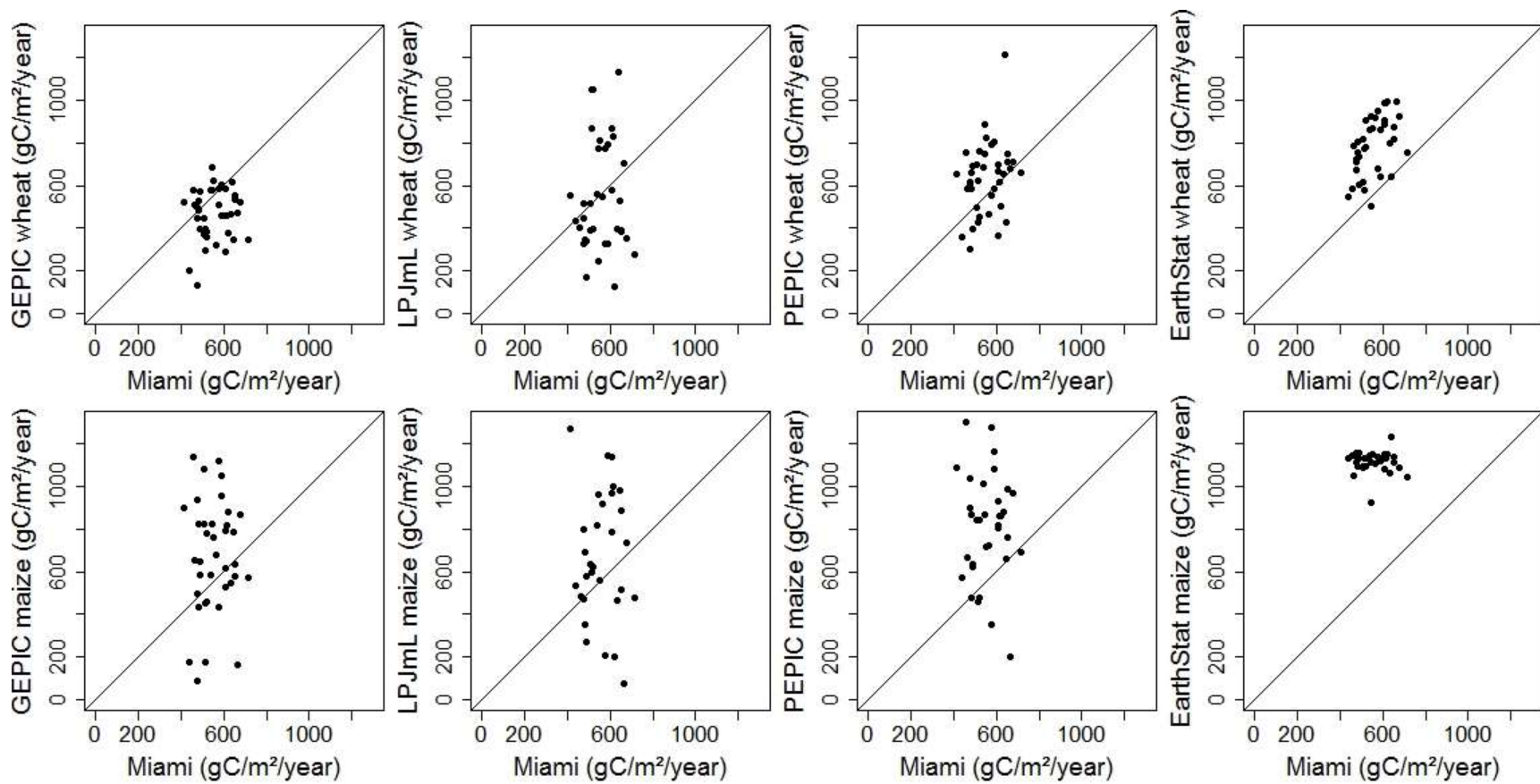


Fig. S4 Potential Net Primary Production (NPP) comparison on country level of four crop models (GEPIC, LPJmL, PEPIC, EarthStat) with Miami output. We show results for wheat (top) and maize (bottom), the only two crops provided by all models.

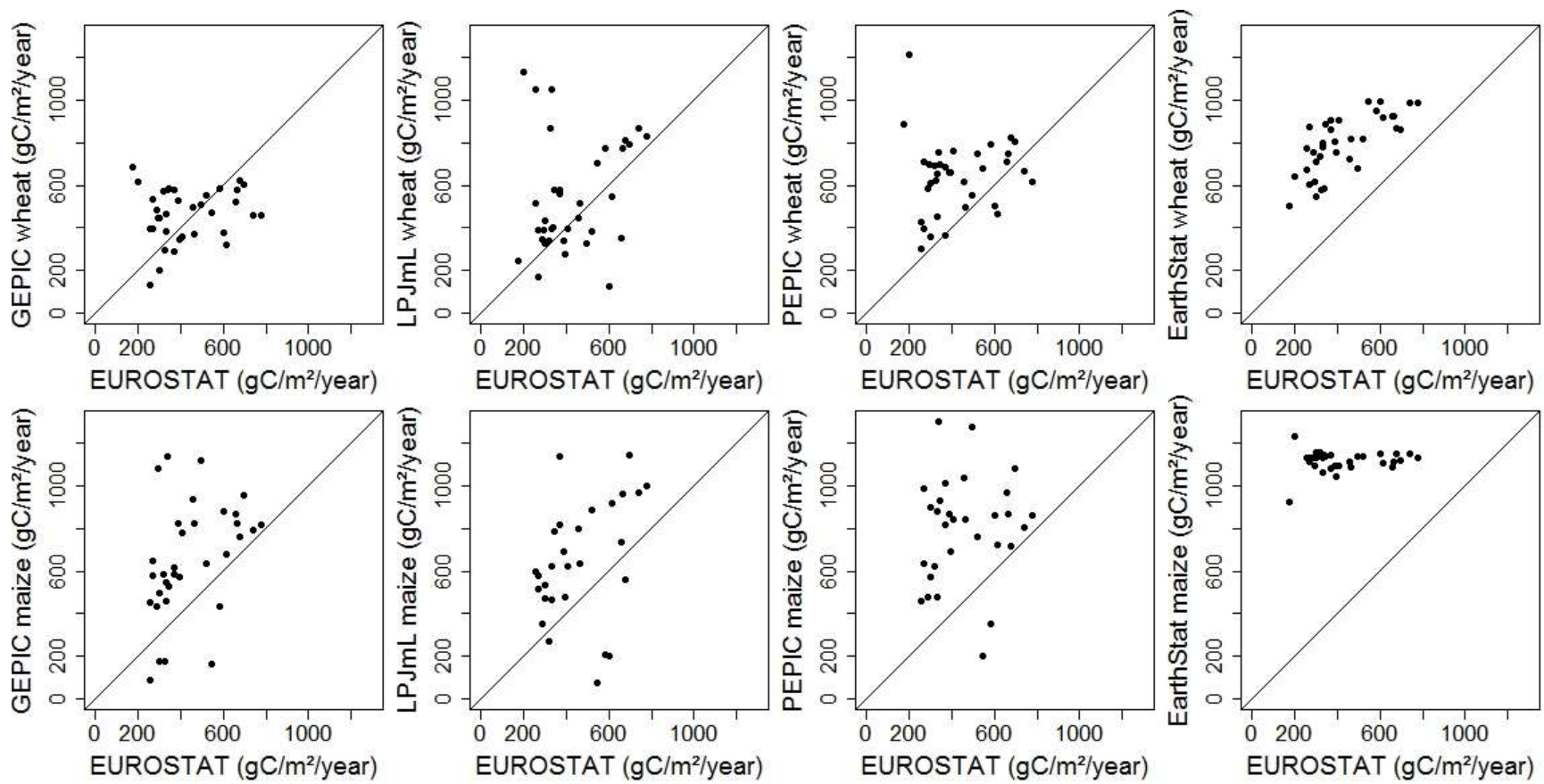


Fig. S5 Potential Net Primary Production (NPP) comparison on country level of four crop models (GEPIC, LPJmL, PEPIC, EarthStat) with EUROSTAT NPP. We show results for wheat (top) and maize (bottom), the only two crops provided by all models.

Table S1 Example of estimating Net Primary Production (NPP) of croplands from EUROSTAT data (EUROSTAT, 2015) for Europe and the year 2000. We show area, harvested production, wet yield (production divided by area), dry yield (accounting for water content in harvested products) and finally NPP using literature conversion factors (Gobin et al., 2011; Monfreda et al., 2008) and water content from EUROSTAT. We show results for each crop type and at the end area-weighted average for all croplands. For fallow land and permanent grassland EUROSTAT only provides area. In the last column we show for comparison MOD17 NPP (Neumann et al., 2016b).

crop type	area (1000 ha)	production (1000 t)	wet yield (t ha ⁻¹)	dry yield (t ha ⁻¹)	NPP (gC m ⁻² year ⁻¹)	MOD17 (gC m ⁻² year ⁻¹)
cereals	62929	283576	4.5	3.9	441	
plants harvested green	19969	192258	9.6	5.8	522	
oil crops	9581	15167	1.6	1.4	291	
root crops	5615	232738	41.4	8.3	448	
vegetables, strawberries	2451	64759	26.4	3.4	405	
pulses	1942	4912	2.5	2.2	256	
all annual crops	102487	793409	7.7	4.2	439	
olives	4859	10200	2.1	1.7	540	
grapes	3935	29935	7.6	1.4	288	
fruits, berries, nuts	1835	21073	11.5	2.2	435	
citrus fruits	563	10080	17.9	2.3	698	
permanent grasslands	64123	-	-	-	-	
fallow land	11694	-	-	-	-	
all	189497				439	460

Table S2 Country comparison of NPP estimates in $\text{g C m}^{-2} \text{ year}^{-1}$ (mean 2000-2012). We show Miami NPP (Lieth, 1975) using WorldClim data (Hijmans et al., 2005) and MOD17 followed by 12 EUROSTAT estimates. MO indicates (Monfreda et al., 2008), HA (Haberl et al., 2007), GO (Gobin et al., 2011) and NI (Niedertscheider et al., 2016). HA and NI have west and east coefficients. Water content from literature reference is indicated by “lit” and reported water content by “Eurostat”. Countries with missing data were removed.

country name	Miami WC	MOD17	MO lit	HA east lit	HA west lit	GO lit	NI west lit	NI east lit	MO Eurostat	HA east Eurostat	HA west Eurostat	GO Eurostat	NI west Eurostat	NI east Eurostat
Albania	718	532	372	340	307	496	374	407	402	369	340	455	416	445
Austria	563	498	660	650	552	591	645	745	606	616	518	496	603	703
Belgium	615	566	896	860	771	805	890	981	735	725	641	503	729	816
Bosnia and Herz.	651	553	274	276	226	232	264	314	277	286	236	235	276	326
Bulgaria	488	471	327	333	279	291	315	371	326	340	285	294	322	379
Croatia	655	526	522	515	430	439	500	588	556	559	472	490	552	641
Cyprus	441	-	227	175	157	196	218	237	224	175	157	196	218	237
Czech Republic	509	473	460	463	390	392	444	518	492	502	429	442	493	567
Denmark	552	492	645	641	539	606	628	732	730	731	630	694	741	844
Estonia	491	410	256	253	220	294	256	290	276	275	242	285	283	317
Finland	440	312	341	337	285	349	335	388	268	280	227	212	263	316
France	588	569	639	633	538	579	623	721	770	763	670	750	787	883
Germany	546	500	689	688	582	579	665	774	684	699	593	574	679	788
Greece	506	435	352	241	210	314	291	323	355	250	217	322	300	334
Hungary	479	455	470	475	395	408	453	535	462	478	399	405	458	540
Ireland	667	546	591	602	479	467	560	685	541	569	453	442	530	648
Italy	579	527	539	447	391	539	501	559	540	457	400	511	512	570
Kosovo	606	-	355	358	293	294	342	409	350	362	297	294	347	414
Latvia	516	434	280	275	240	310	279	315	229	234	199	199	229	264
Lithuania	521	447	333	329	283	329	328	375	335	337	292	305	338	385
Luxembourg	623	577	466	460	391	486	459	530	717	694	625	799	750	821

Macedonia	479	469	305	303	259	266	301	347	302	307	263	266	306	351
Montenegro	631	-	337	302	288	309	356	371	339	306	291	309	361	376
Netherlands	607	544	844	805	755	797	856	907	700	681	633	480	705	754
Norway	477	341	287	286	235	250	275	329	239	248	201	192	235	283
Poland	481	461	414	411	348	348	402	466	389	396	335	311	385	448
Portugal	543	458	201	157	139	179	182	201	199	158	140	180	183	202
Romania	482	450	299	300	251	258	289	339	296	304	255	258	294	344
Serbia	537	-	506	505	417	406	486	576	258	260	222	209	257	296
Slovakia	521	461	411	413	350	379	399	464	418	428	365	380	418	482
Slovenia	680	548	533	511	440	540	529	602	776	739	667	832	812	885
Spain	457	362	391	292	253	363	341	381	392	299	258	358	347	388
Sweden	513	435	349	349	290	289	335	396	322	334	275	254	316	377
Switzerland	605	559	482	476	408	333	462	532	311	308	272	196	305	342
United Kingdom	578	521	619	622	522	507	596	699	585	606	506	472	576	678

Table S3 EUROSTAT average NPP (ensemble mean) in g C m⁻² year⁻¹ by country for 2000 to 2012. Countries with missing data were removed.

country name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Albania	179	207	279	270	403	425	433	424	492	478	434	545	547
Austria	563	598	594	537	646	608	565	583	672	618	634	737	643
Belgium	769	724	817	812	825	844	804	817	847	819	982	517	555
Bosnia and Herz.	77	75	74	224	396	373	370	269	357	384	320	314	257
Bulgaria	248	282	311	226	381	312	331	200	382	347	397	407	361
Croatia	415	497	549	371	559	549	557	486	664	612	560	532	434
Cyprus	179	245	275	243	228	173	179	170	123	178	195	211	219
Czech Republic	391	440	431	372	533	476	429	464	524	510	466	551	473
Denmark	629	634	603	652	646	650	628	618	650	709	773	806	845
Estonia	251	252	241	246	259	283	236	313	302	301	259	283	293
Finland	315	293	308	294	280	318	298	311	305	320	275	293	291
France	783	743	808	674	810	746	704	551	681	695	633	632	591
Germany	642	688	620	569	720	655	626	603	673	687	713	712	755
Greece	310	280	290	266	311	306	282	285	311	313	298	280	269
Hungary	325	449	381	332	577	559	522	375	583	485	456	507	385
Ireland	544	528	464	503	584	498	567	539	589	530	570	664	537
Italy	483	483	491	443	548	539	480	548	565	559	446	465	413
Kosovo	-	-	-	-	-	-	-	274	377	342	367	368	330
Latvia	279	245	234	226	236	251	200	316	263	258	240	240	322
Lithuania	300	282	310	351	364	332	233	347	366	368	309	331	407
Luxembourg	648	703	574	539	633	585	581	588	635	650	563	517	584
Macedonia	261	236	286	256	338	315	313	275	330	330	325	328	282
Malta	208	189	225	226	200	205	188	181	197	183	183	206	188
Netherlands	766	740	750	689	700	684	664	818	883	860	708	673	722
Kosovo	-	-	-	-	-	-	-	290	349	367	368	317	282
Norway	205	194	184	204	227	207	191	195	273	168	453	393	420
Poland	323	362	394	350	421	378	325	406	400	431	428	401	422

Portugal	164	158	174	162	183	142	188	167	188	186	187	204	196
Romania	195	302	245	245	398	329	312	171	324	291	330	388	247
Serbia	276	276	276	276	276	276	276	387	501	520	533	523	367
Slovakia	279	395	409	325	475	455	400	368	509	426	364	476	436
Slovenia	640	577	735	513	724	751	619	649	654	645	672	706	634
Spain	345	320	319	351	359	264	331	385	355	322	346	373	332
Sweden	353	333	342	332	348	326	277	306	318	327	280	321	349
Switzerland	279	279	279	279	279	279	440	460	456	432	420	472	442
United Kingdom	608	528	610	593	589	596	593	544	633	602	565	584	525
