1 Comparison report

1.1 General information

This is a comparison report that can include information from several countries and several data sources.

1.2 Processing

- This report and all the analysis was generated using the `forest_puller` python pipeline.
- Documentation and source code is available at:

  https://github.com/xapple/forest_puller

- Version `1.4.2` of the pipeline was used.
- This document was generated at `2020-12-07 00:31:15 CET+0100` on `macOS`.
- The exact git hash of the latest commit was: `85a8e78a1df05eb61b6b9f1b8bc0d41c40fd7617`
- Also referred to by its shortened tag `1.4.2`.

1.3 Scope and extent of data sources

In the following visualizations, we cover 27 of the 28 (past and present) EU member states. The list is the following and excludes Malta:

- Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom.

The plots usually run from the earliest official statistics around the year 1990 (depending on the country at hand) to the latest estimates in 2018.

Several data sources are also represented. Currently `forest_puller` provides programmatic access (via cached web-scraping) to the forest measurements from these data sources:

- IPCC.
- SOEF.
- FAOSTAT-GF.
- HPFFRE.
- FRA.

1.4 Comparison of total forest area

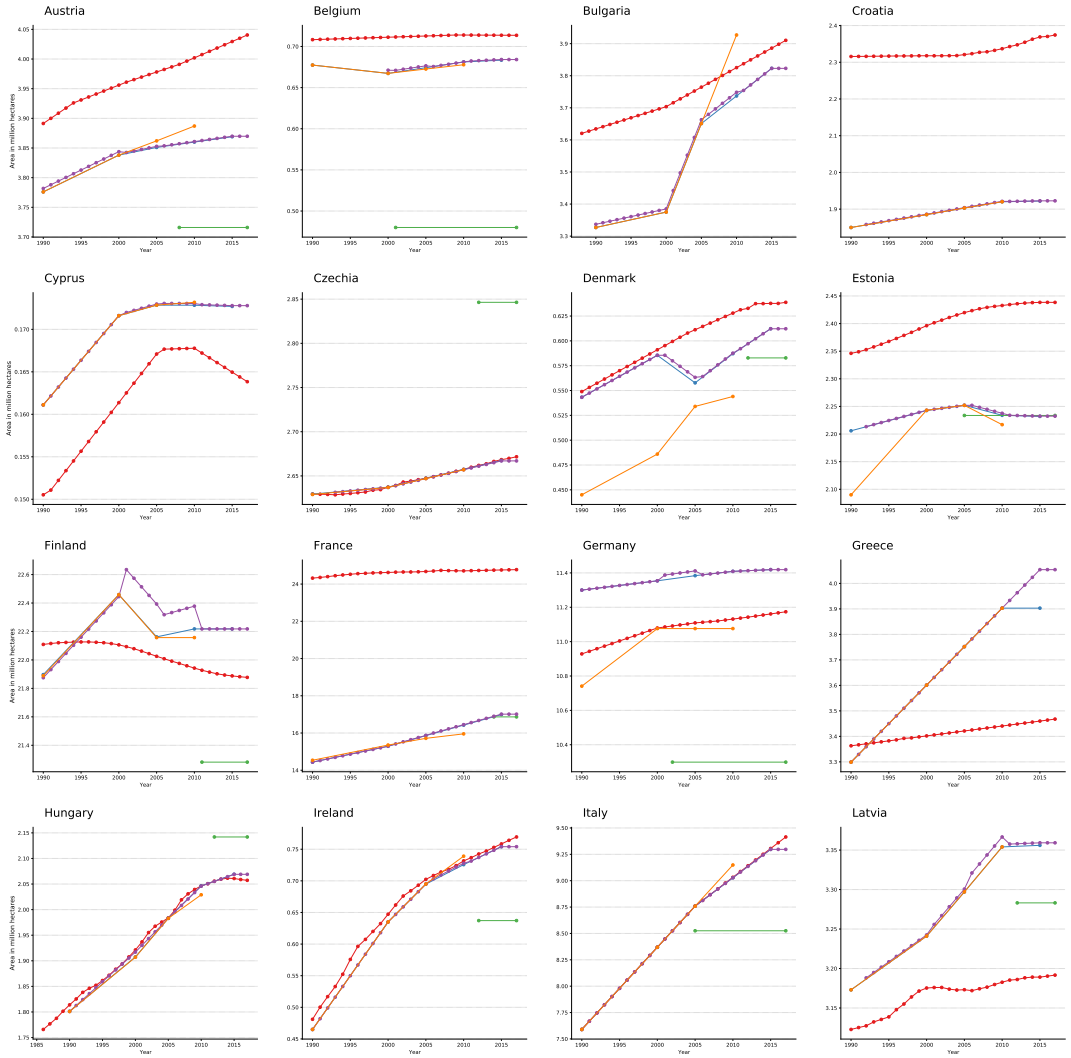
Below we compare the total forest area as it is reported in five different data sources.

The Y-axis represents area in million of hectares. To provide better insight, the scale is not aligned between countries nor does it start at 0.

The HPFFRE dataset is post-processed before being graphed as we do not wish to show future predictions in this visualization. Instead we show the earliest year of that dataset for each country and extend it to the current year.

If the SOEF dataset is not visible for some countries, it is because the FAOSTAT source precisely matches it and covers the line of the other dataset.

Also, not all datasets are available for all countries, unfortunately.



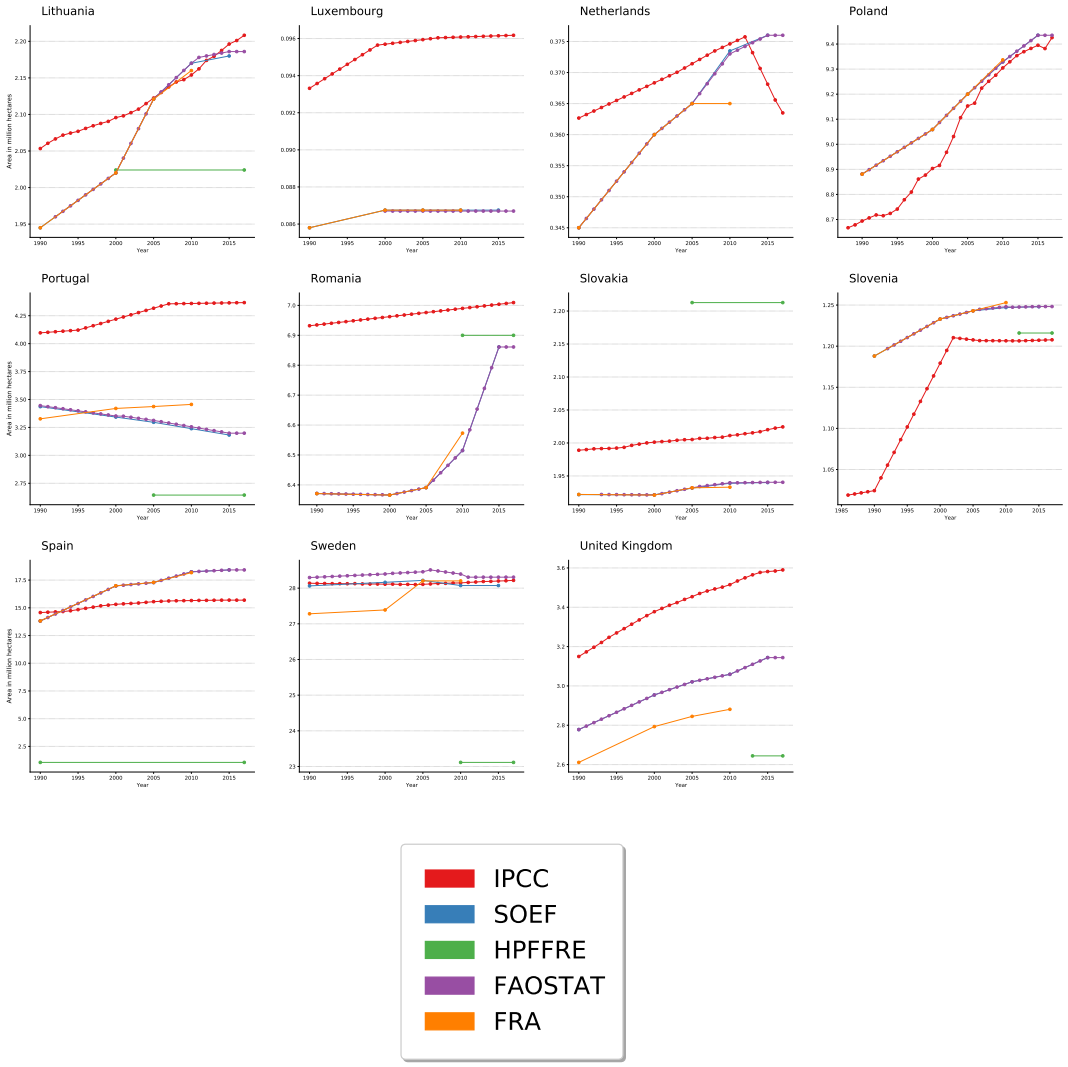


Figure 1. Comparison of total forest area reported in 27 countries and 5 data sources.

1.5 Comparison of gain and losses

Below we compare the total losses, gains and net changes in forest biomass for each country.

The Y-axis represents different units depending on the data source considered. Therefor, vertical scales are not directly comparable in the plots. Each source provides a different measure and a slightly different definition for losses and gains.

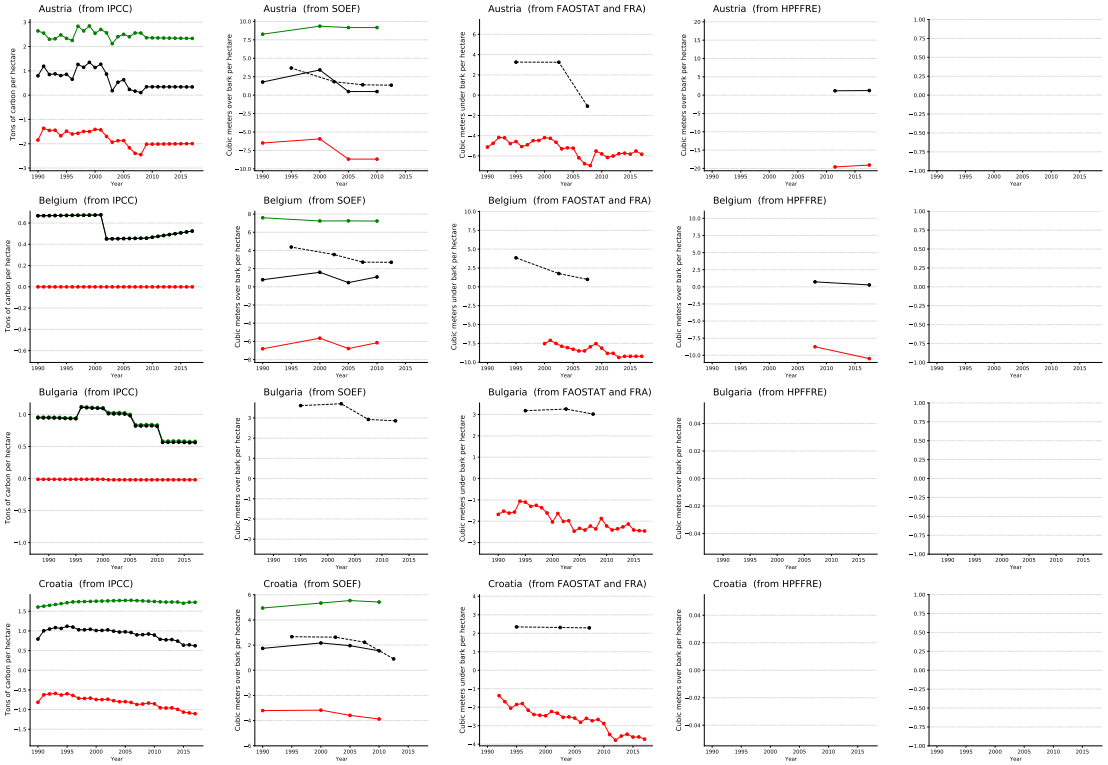
- IPCC indicates "tons of carbon per hectare (over bark)".
- SOEF indicates "cubic meters over bark per hectare".
- FAOSTAT writes: "Removals of roundwood comprise all quantities of wood felled and removed from the forest and other wooded land or other felling sites. They are measured in cubic meters under bark (without bark)".
- HPFFRE writes: "Stemwood volume measured over bark expressed as unit area volume". It further specifies: "Total stemwood volume measured over bark. Part of tree stem from the felling cut to the tree top with the branches removed, including bark".

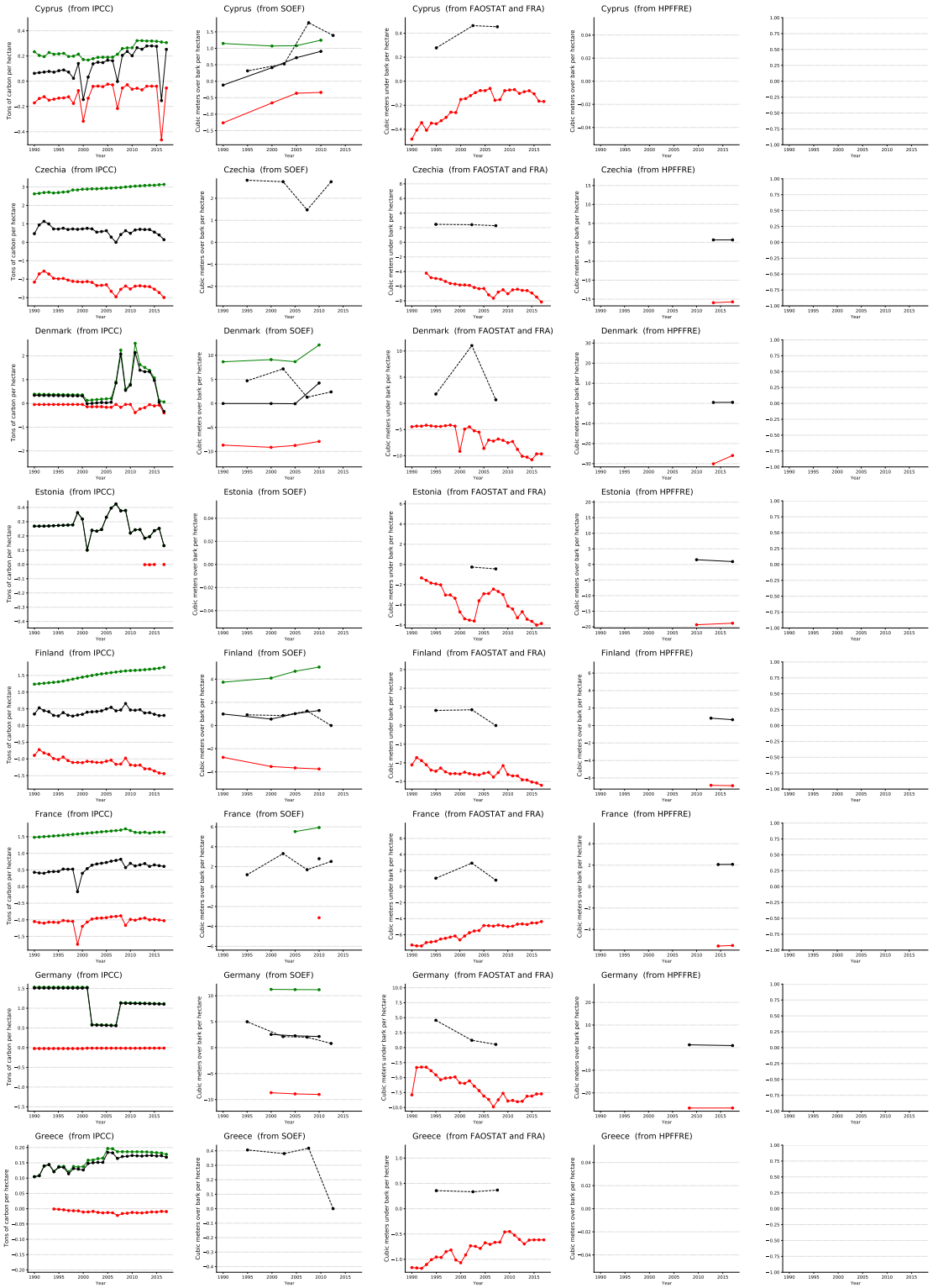
Also of note is that the X-axis is not aligned between the different subplots.

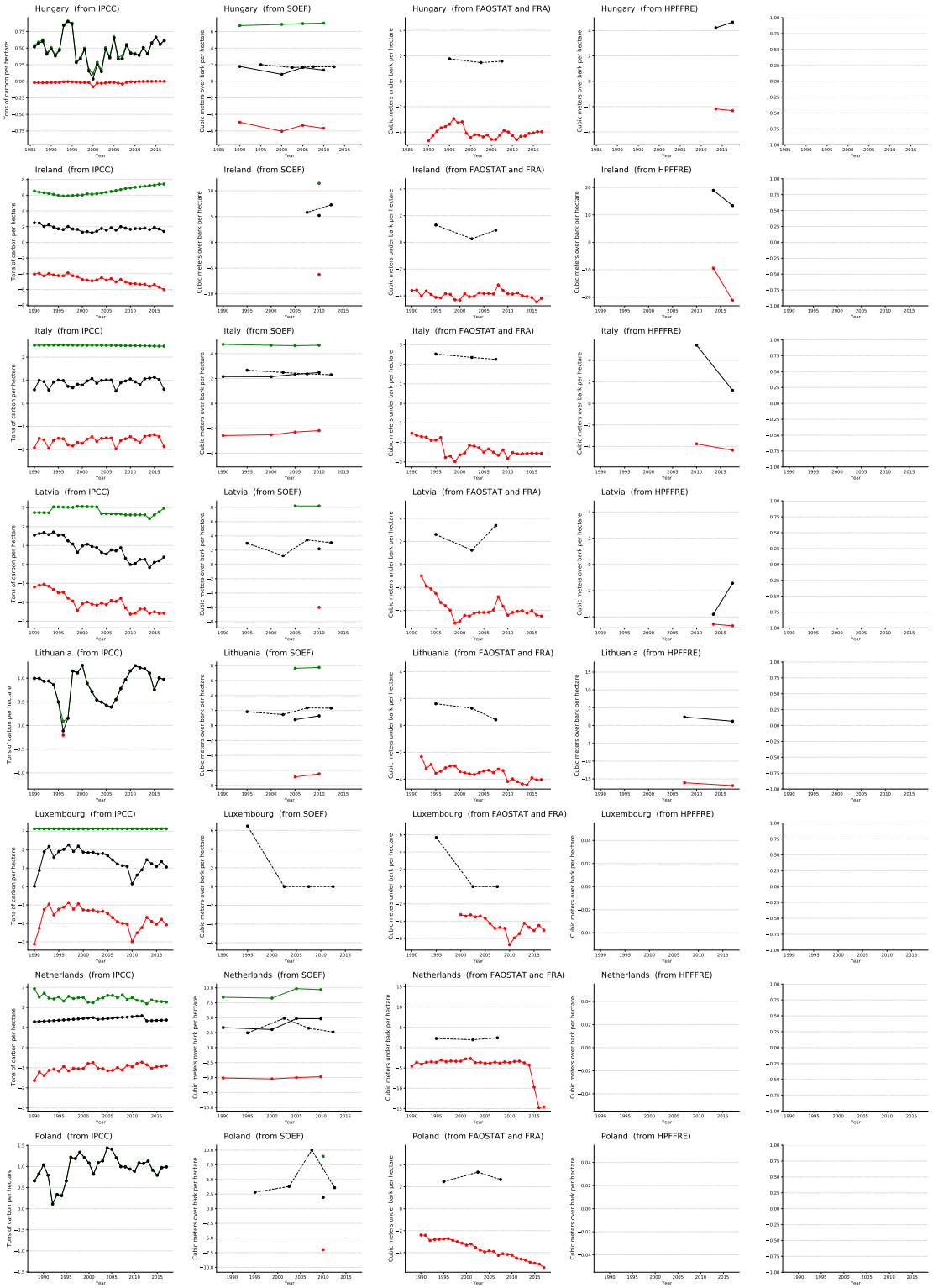
Again, not all datasets are available for all countries.

The extra net estimations in dotted lines shown in SOEF and FAOSTAT are acquired by taking the total growing stock in each country and subtracting by the total growing stock of the previous time point. In effect, yielding the growing stock difference along time. Finally we divide by the number of years elapsed and the average area in that time period to obtain the net stock change estimation.

All values are per annum.




Cyprus (from IPCC)
Cyprus (from SOEF)
Cyprus (from FAOSTAT and FRA)
Cyprus (from HPFFRE)
Czechia (from IPCC)
Czechia (from SOEF)
Czechia (from FAOSTAT and FRA)
Czechia (from HPFFRE)
Denmark (from IPCC)
Denmark (from SOEF)
Denmark (from FAOSTAT and FRA)
Denmark (from HPFFRE)
Estonia (from IPCC)
Estonia (from SOEF)
Estonia (from FAOSTAT and FRA)
Estonia (from HPFFRE)
Finland (from IPCC)
Finland (from SOEF)
Finland (from FAOSTAT and FRA)
Finland (from HPFFRE)
France (from IPCC)
France (from SOEF)
France (from FAOSTAT and FRA)
France (from HPFFRE)
Germany (from IPCC)
Germany (from SOEF)
Germany (from FAOSTAT and FRA)
Germany (from HPFFRE)
Greece (from IPCC)
Greece (from SOEF)
Greece (from FAOSTAT and FRA)
Greece (from HPFFRE)
Tons of carbon per hectare
Cubic meters over bark per hectare
Cubic meters under bark per hectare
Year


Hungary (from IPCC)
Hungary (from SOEF)
Hungary (from FAOSTAT and FRA)
Hungary (from HPFFRE)
Ireland (from IPCC)
Ireland (from SOEF)
Ireland (from FAOSTAT and FRA)
Ireland (from HPFFRE)
Italy (from IPCC)
Italy (from SOEF)
Italy (from FAOSTAT and FRA)
Italy (from HPFFRE)
Latvia (from IPCC)
Latvia (from SOEF)
Latvia (from FAOSTAT and FRA)
Latvia (from HPFFRE)
Lithuania (from IPCC)
Lithuania (from SOEF)
Lithuania (from FAOSTAT and FRA)
Lithuania (from HPFFRE)
Luxembourg (from IPCC)
Luxembourg (from SOEF)
Luxembourg (from FAOSTAT and FRA)
Luxembourg (from HPFFRE)
Netherlands (from IPCC)
Netherlands (from SOEF)
Netherlands (from FAOSTAT and FRA)
Netherlands (from HPFFRE)
Poland (from IPCC)
Poland (from SOEF)
Poland (from FAOSTAT and FRA)
Poland (from HPFFRE)
Tons of carbon per hectare
Cubic meters over bark per hectare
Cubic meters under bark per hectare
Year

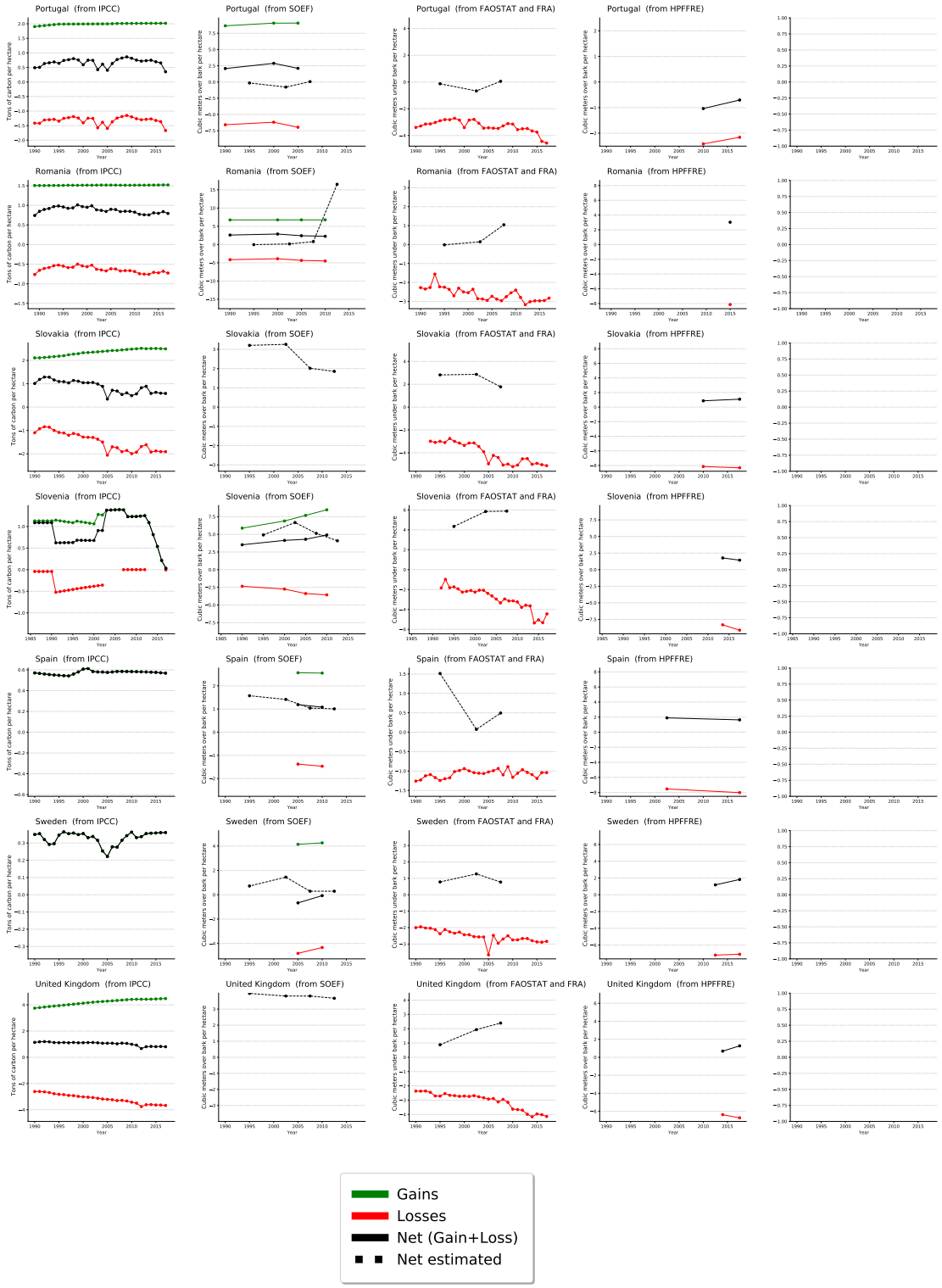


Figure 2. Comparison of gains, losses, and totals reported in 27 countries and 5 data sources.

1.6 Conversion to tons of carbon

Below we compare once again the total losses, gains and net changes in forest biomass for each country.

This results in a series of graphs that are almost identical to the ones above.

The difference is that we harmonize the Y axis units and convert all measures into mass for sources which were providing volumes. These were SOEF, FAOSTAT, HPFFRE. In effect, all graphs will now share the IPCC measurements units.

These IPCC measurements are in:

1. Dry carbon content (in the atomic sense).
2. Including both the above ground and below ground parts of the trees (all living biomass).
3. Including both the trunk and leaves (all above ground).
4. Mass (in tons).
5. The tree trunk includes the bark.
6. Per hectare.
7. Per year.

The process we want to accomplish is the following:

```
Start --> FAOSTAT (wet, vol, under bark, without branches, etc.)
End   --> IPCC (dry, mass, over bark, with branches, etc.)
```

The "BCEF" factor includes both the expansion factor E and the wood density D (see further down) and is found at:

Chapter 4: Forest Land 2006 IPCC Guidelines for National Greenhouse Gas Inventories Table 4.5 Basic Wood Density (d) Of Selected Temperate And Boreal Tree Taxa https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf See page 51.

To harmonize we use the following factors:

1. "CF" is the carbon fraction of dry biomass. This is constant per country (at 0.47). Taken from Table 4.3.

2. "R" is the root to shoot ratio. This is variable per country. Taken from Table 4.4. It is based on the result of B*E*D. As it depends on the climate and the level of above-ground biomass in tonnes per hectare.

3. "E" the expansion factor from trunk to trunk+branches. This is variable per country. Taken from Table 4.5. It depends on (i) the climatic zone (ii) the forest type and (iii) the growing stock level in cubic meters.

4. "D" the wood density (dry volumic mass). This is variable per country (around 0.25). Taken from Table 4.5.

5. "B" is the bark correction factor of 0.88. This is constant per country. This measures volume. This value comes from: https://www.unece.org/fileadmin/DAM/timber/publications/DP-49.pdf

The equation in the case of FAOSTAT losses is thus:

$$L_{IPCC} = L_{FAO} * B * BCEF_R * (1 + R) * CF$$

The equation to convert SOEF losses (m3/ha) to IPCC losses (1000 kg of carbon/ha):

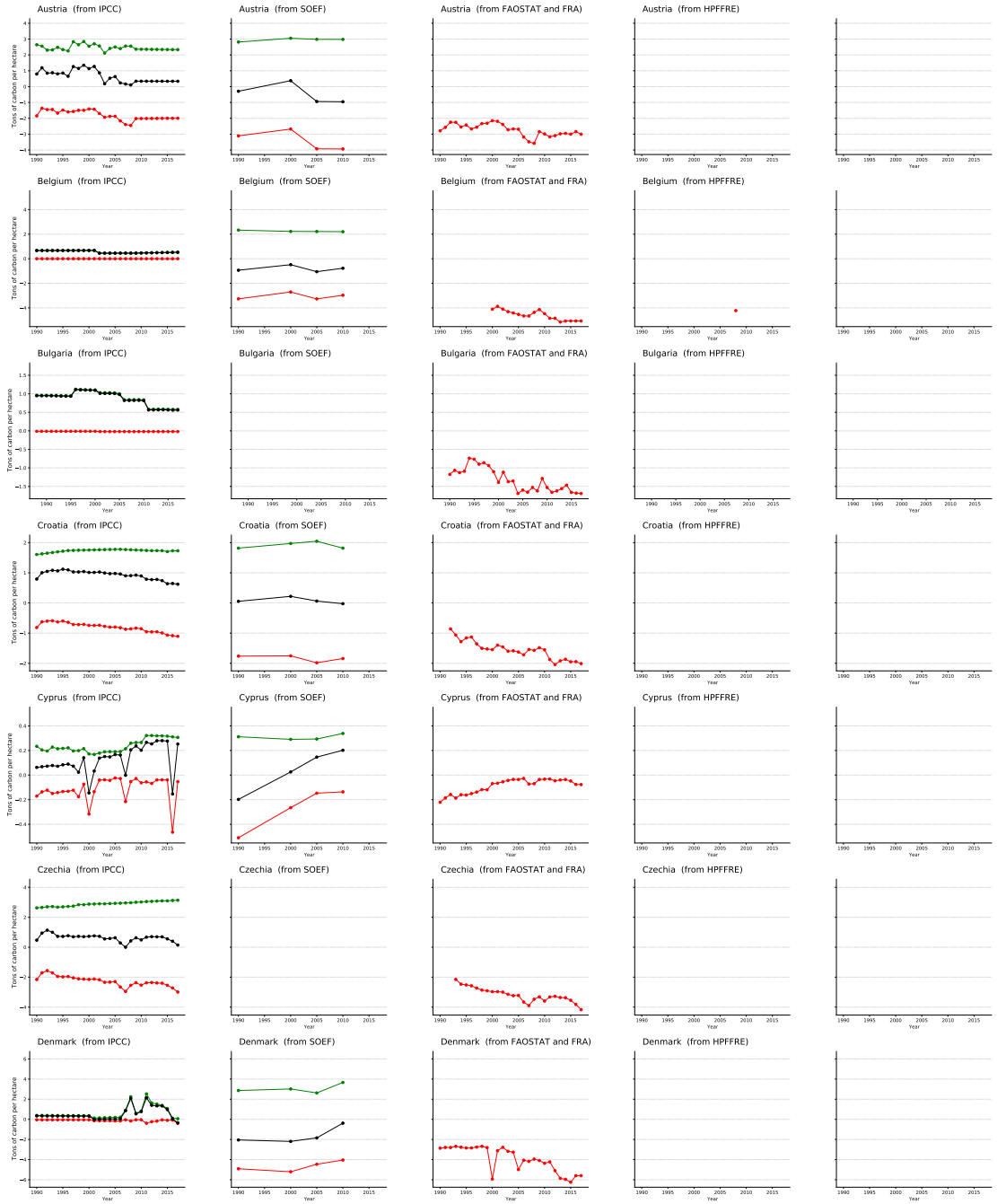
$$L_{IPCC} = L_{SOEF} * BCEF_R * (1 + R) * CF$$

The equation to convert SOEF increments (m3/ha) to IPCC gains (1000 kg of carbon/ha):

$$I_{IPCC} = I_{SOEF} * BCEF_I * (1 + R) * CF$$

Only the rows "firs and spruces" and "hardwoods" are considered when picking BCEF.

The bark correction factor is applied only to the FAOSTAT data source, which provided values in cubic meters under bark instead of over bark.




Estonia (from IPCC)
Estonia (from SOEF)
Estonia (from FAOSTAT and FRA)
Estonia (from HPFFRE)
Finland (from IPCC)
Finland (from SOEF)
Finland (from FAOSTAT and FRA)
Finland (from HPFFRE)
France (from IPCC)
France (from SOEF)
France (from FAOSTAT and FRA)
France (from HPFFRE)
Germany (from IPCC)
Germany (from SOEF)
Germany (from FAOSTAT and FRA)
Germany (from HPFFRE)
Greece (from IPCC)
Greece (from SOEF)
Greece (from FAOSTAT and FRA)
Greece (from HPFFRE)
Hungary (from IPCC)
Hungary (from SOEF)
Hungary (from FAOSTAT and FRA)
Hungary (from HPFFRE)
Ireland (from IPCC)
Ireland (from SOEF)
Ireland (from FAOSTAT and FRA)
Ireland (from HPFFRE)
Italy (from IPCC)
Italy (from SOEF)
Italy (from FAOSTAT and FRA)
Italy (from HPFFRE)
Tons of carbon per hectare
Year


Latvia (from IPCC)
Latvia (from SOEF)
Latvia (from FAOSTAT and FRA)
Latvia (from HPFFRE)
Lithuania (from IPCC)
Lithuania (from SOEF)
Lithuania (from FAOSTAT and FRA)
Lithuania (from HPFFRE)
Luxembourg (from IPCC)
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Netherlands (from FAOSTAT and FRA)
Netherlands (from HPFFRE)
Poland (from IPCC)
Poland (from SOEF)
Poland (from FAOSTAT and FRA)
Poland (from HPFFRE)
Portugal (from IPCC)
Portugal (from SOEF)
Portugal (from FAOSTAT and FRA)
Portugal (from HPFFRE)
Romania (from IPCC)
Romania (from SOEF)
Romania (from FAOSTAT and FRA)
Romania (from HPFFRE)
Slovakia (from IPCC)
Slovakia (from SOEF)
Slovakia (from FAOSTAT and FRA)
Slovakia (from HPFFRE)
Tons of carbon per hectare
Year

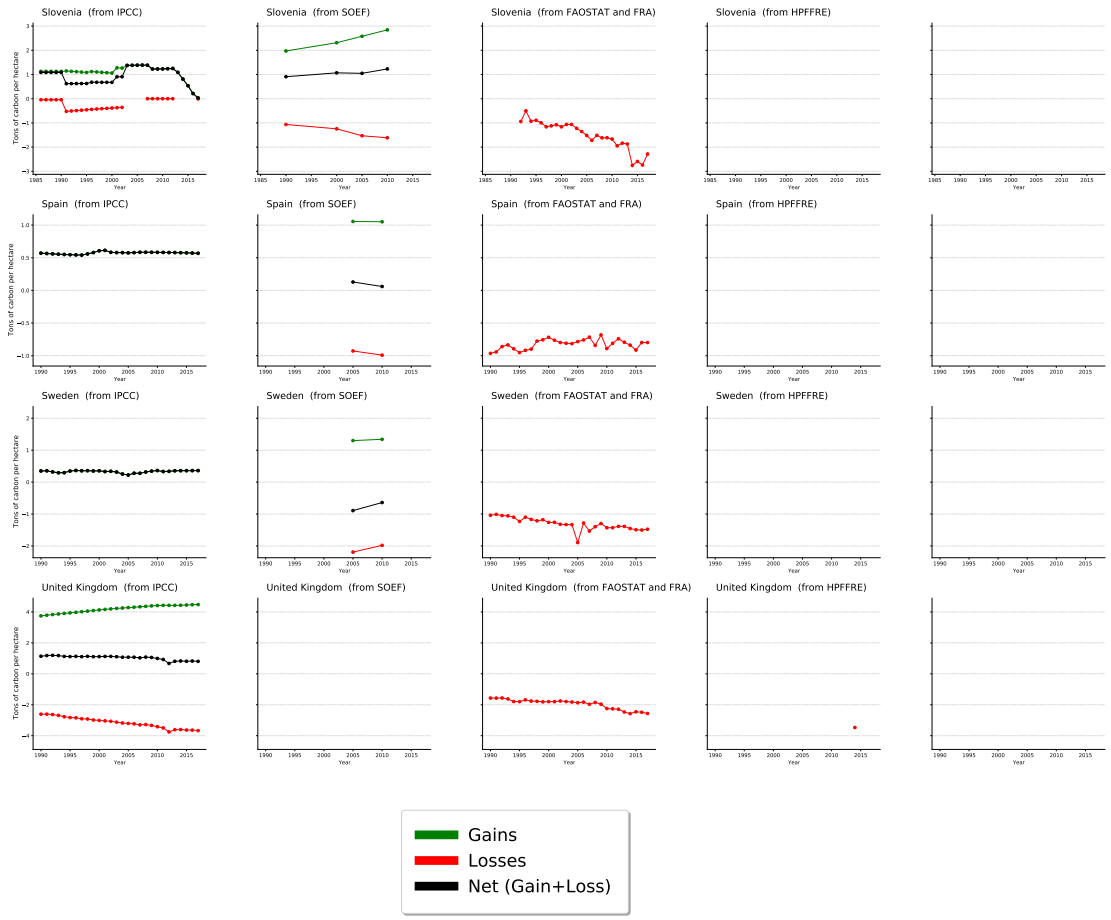
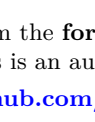


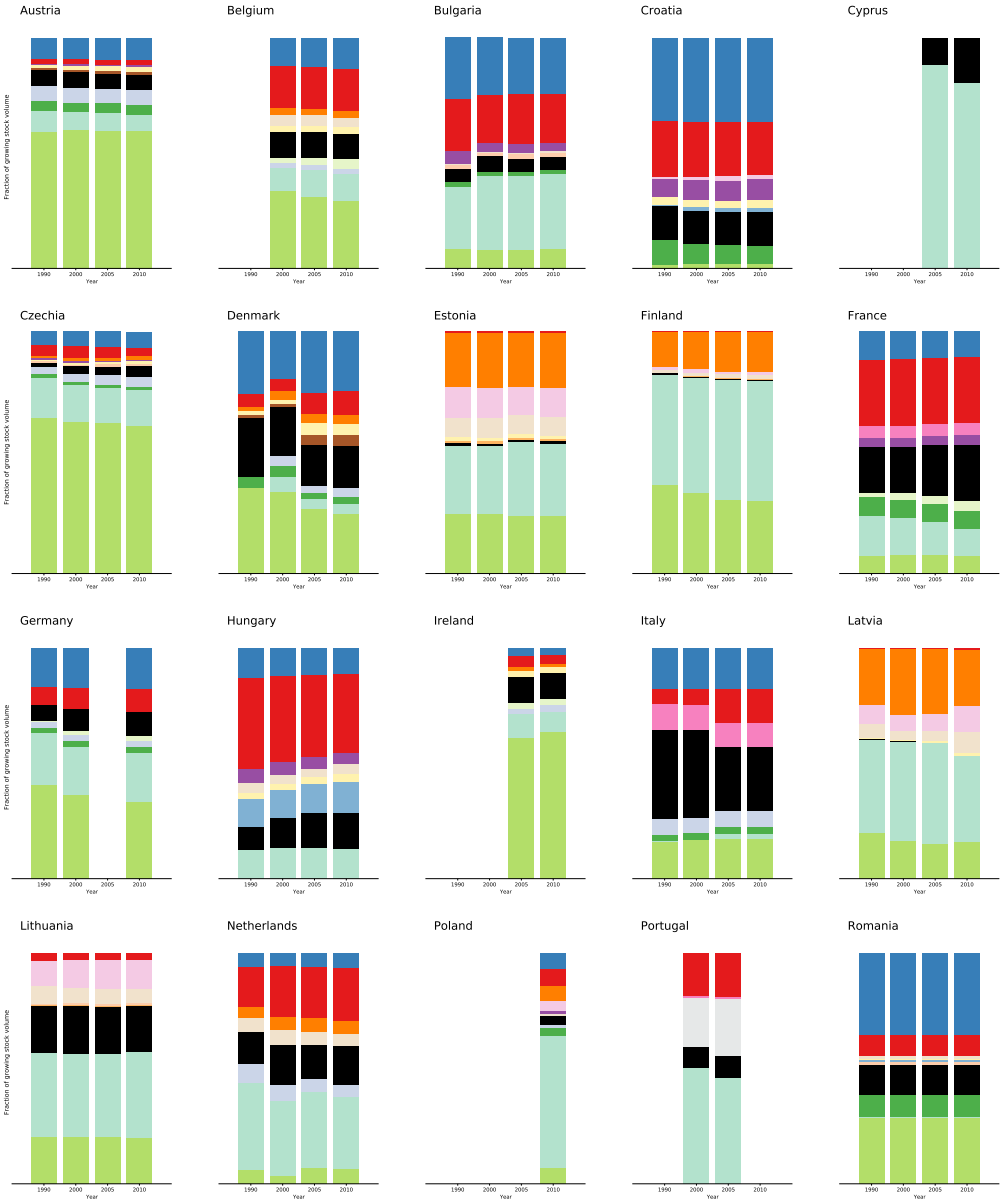
Figure 3. Comparison of gains, losses, and totals converted to tons of carbon reported in 27 countries and 5 data sources.



1.7 Comparison of the growing stock genera composition

Below we compare the breakdown of a country's growing stock in terms of the tree species that compose it. Namely, we plot the fraction of each genus that the country reported at four different years in the SOEF dataset.

The growing stock here is reported as volumes in cubic meters and converted to a fraction of total volume.



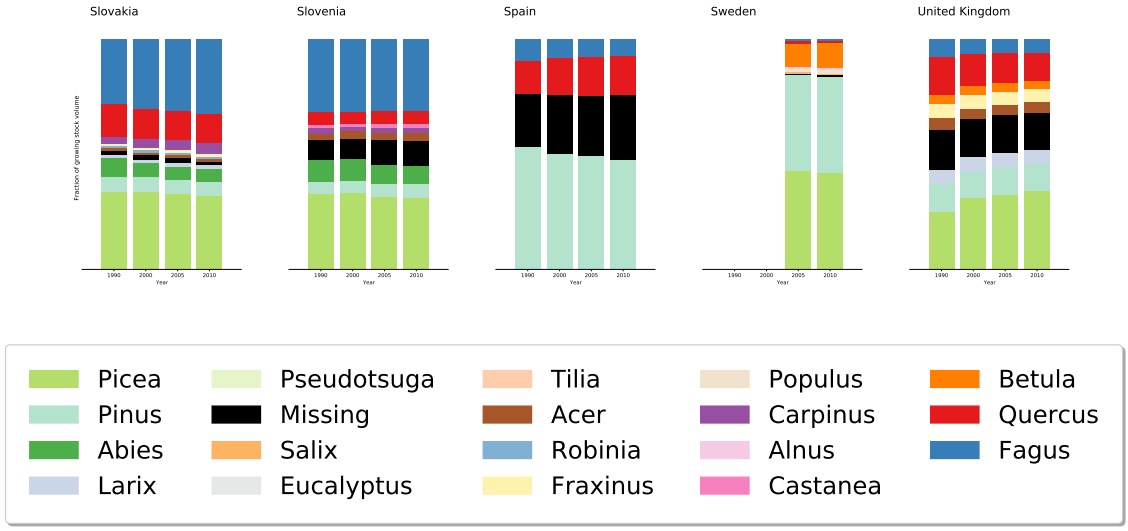


Figure 4. Comparison of genus composition in the growing stock at 4 different time points in 27 countries.

1.8 Aggregation of all countries together

In the following graphs, we do not separate the results by country, but instead aggregate countries together by either summing or performing an average.

To aggregate a particular statistic and display its evolution along time, the statistic at hand must be available for every single country for each time point. This means that if a single country out of the 27 is missing a value on a particular year, say 2004, we cannot display a point for that year at all in the final graph. Displaying a statistic for the year 2004 for only 26 countries while other points concern 27 countries would break the comparability between each point. Missing values therefor have a disproportionate effect on the following visualizations.

The first graph represents a summation of the area for every country.

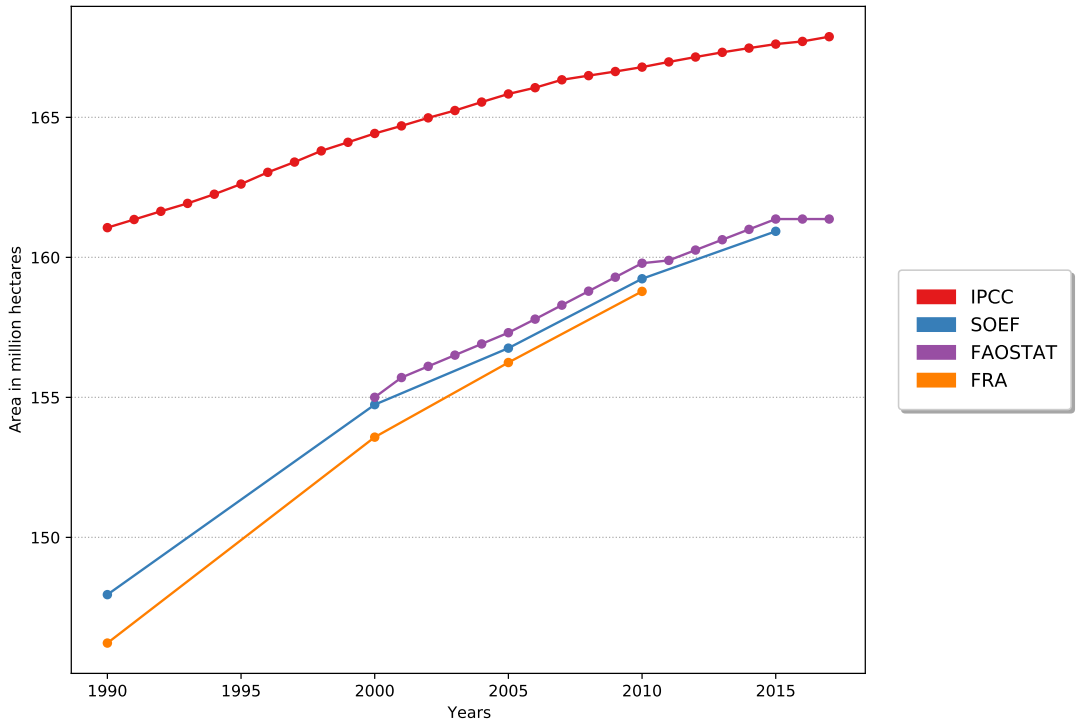


Figure 5. Sum of total forest area for 27 different countries in four data sources.

The second graph represents an average of the net change (gains - losses) for every country from the IPCC data source.

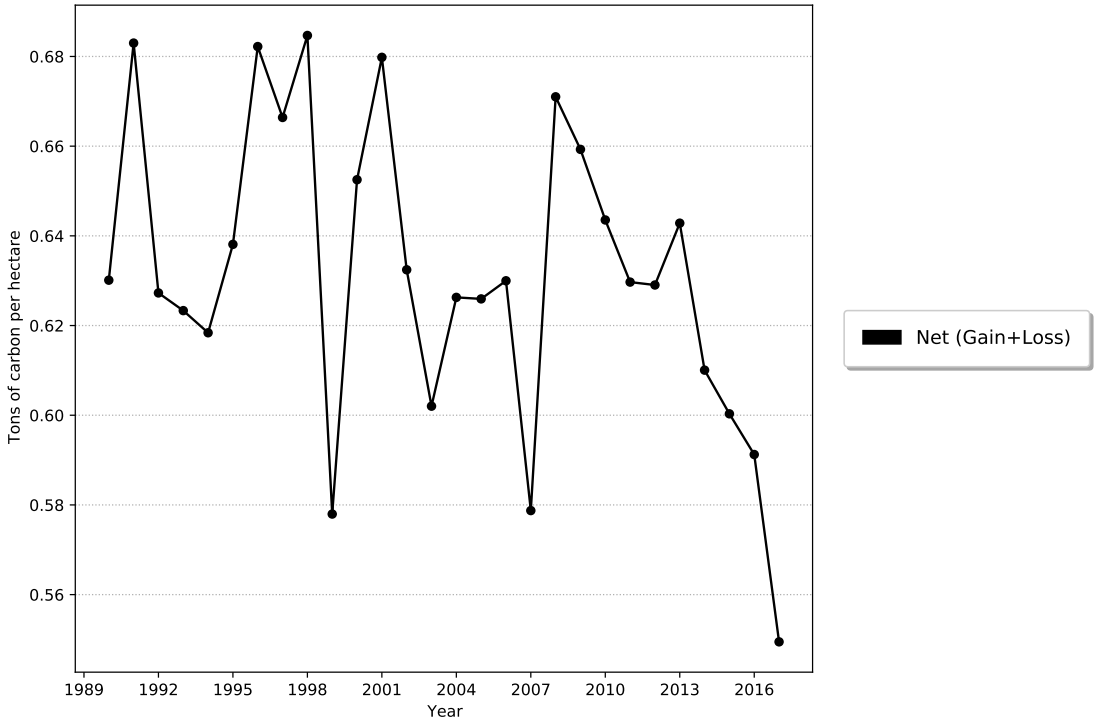


Figure 6. Average of net change per hectare for 27 different countries together from the IPCC data source.

The third graph represents an average of the losses, gains and net changes, but only for a subset of 11 countries which provided that info to the SOEF source. The list of countries included is the following: 'AT', 'BE', 'HR', 'CY', 'DK', 'FI', 'HU', 'IT', 'NL', 'RO', 'SI'.

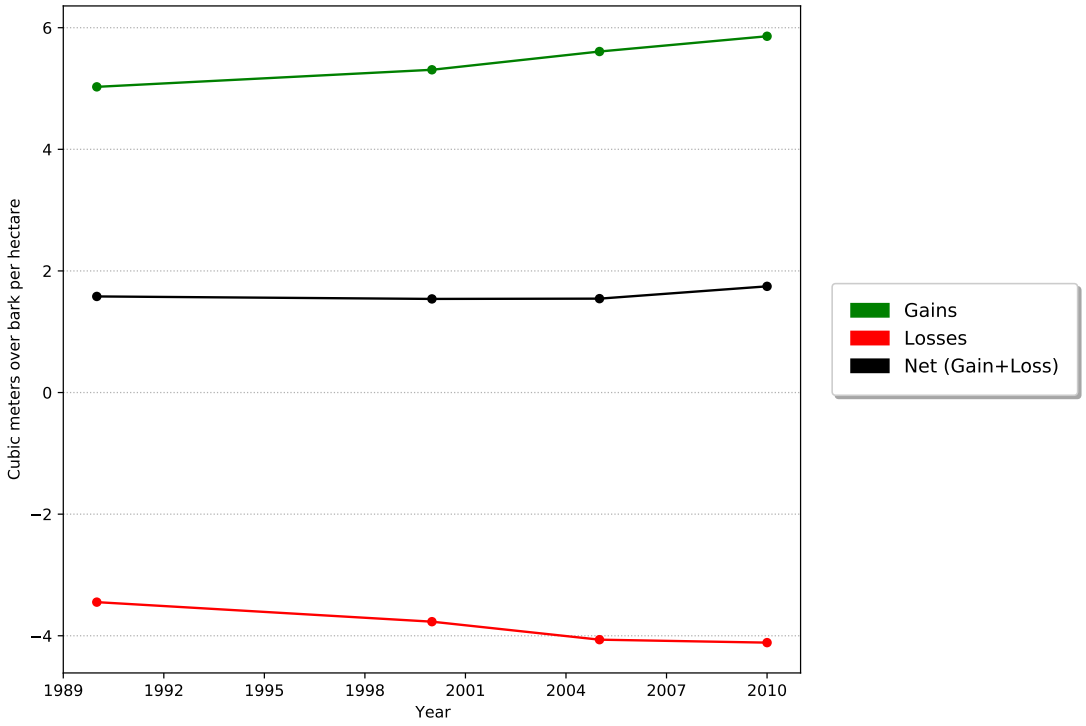


Figure 7. Average of increments per hectare for 11 different countries from the SOEF data source.

The fourth graph represents an average of the losses (reported production) for every country from the FAOSTAT data source starting in 2000.

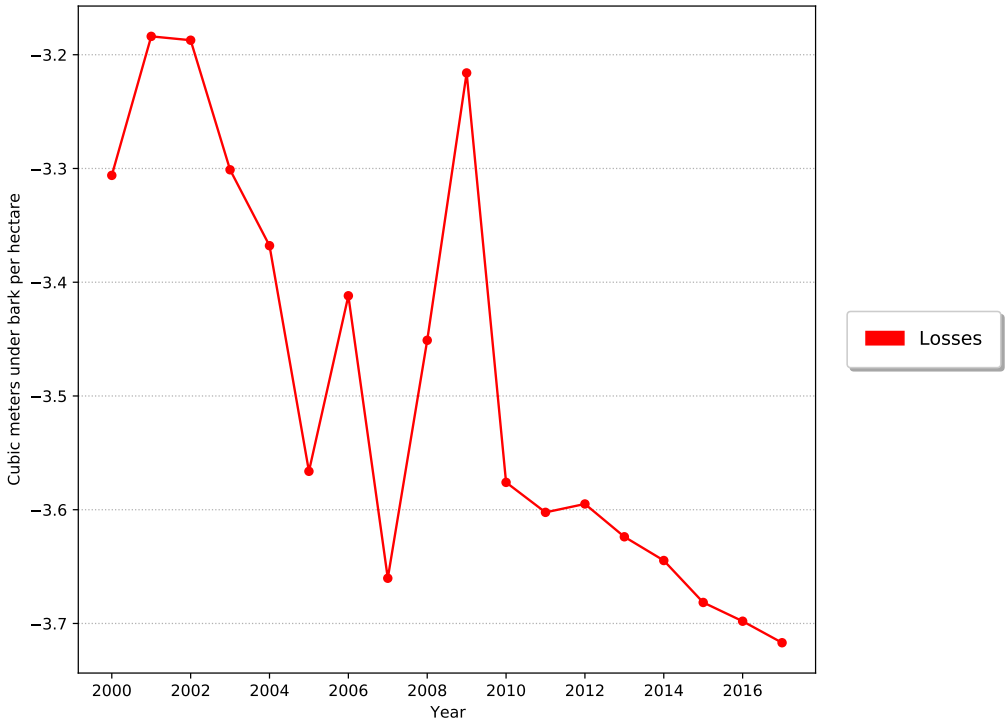


Figure 8. Average of losses per hectare for 27 different countries from the FAOSTAT data source.

The fifth graph represents a summation of the growing stock per genus statistic from the SOEF data source, but only for a subset of 24 countries which provided that info for the year 2010. The list of countries included is the following: 'AT', 'BE', 'BG', 'CY', 'CZ', 'DE', 'DK', 'EE', 'ES', 'FI', 'FR', 'GB', 'HR', 'HU', 'IE', 'IT', 'LT', 'LV', 'NL', 'PL', 'RO', 'SE', 'SI', 'SK'.

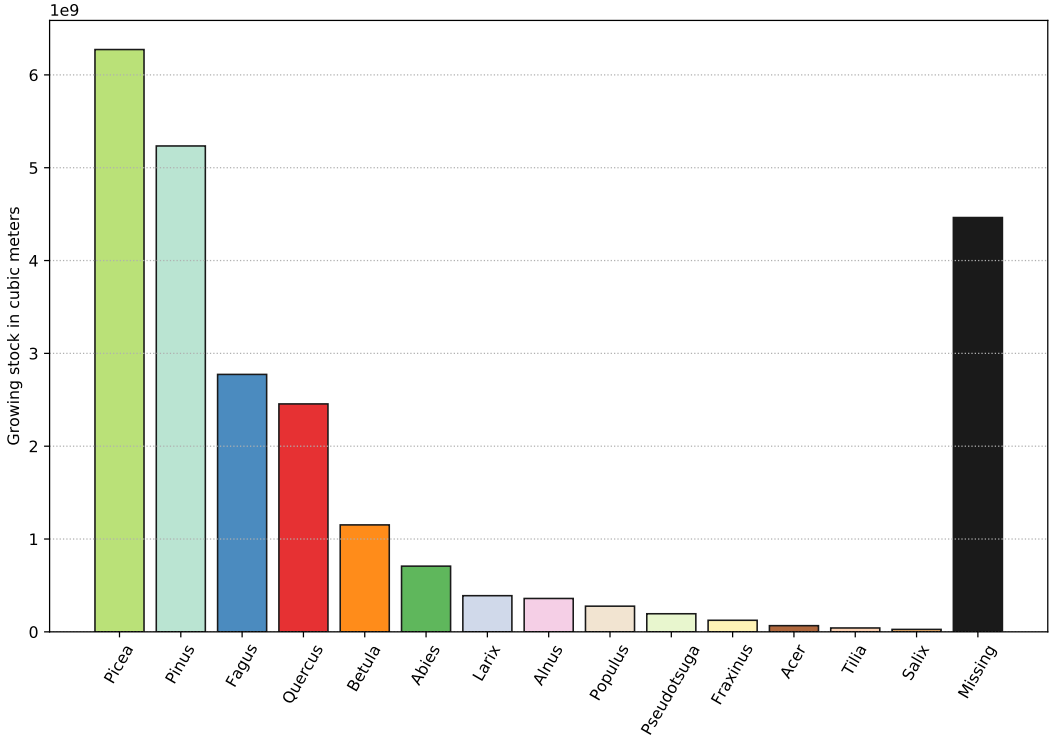


Figure 9. Sum of the growing stock genus breakdown for 24 different countries for the year 2010 in the SOEF data source.

1.9 Tables

Here figures several tables containing raw values for comparison purposes.

The first table details the maximum forest area over time for each country. Usually, the last year of the time series has the largest area, but this is not the case for every country. Values are in hectares.

Country	IPCC	SOEF	FAOSTAT	HPFFRE	FRA
AT	4'040'500	3'869'000	3'869'800	3'716'000	3'887'000
BE	713'948	683'400	684'120	480'000	677'800
BG	3'910'384	3'823'000	3'823'000	-	3'927'000
HR	2'374'262	1'922'000	1'922'600	-	1'920'000
CY	167'776	172'851	173'049	-	173'182
CZ	2'671'658	2'667'412	2'667'000	2'846'400	2'657'000
DK	638'816	612'225	612'200	582'847	544'000
EE	2'438'484	2'252'090	2'252'000	2'233'650	2'252'000
FI	22'126'760	22'458'554	22'634'637	21'281'685	22'459'000
FR	24'775'015	16'989'000	17'012'800	16'866'120	15'954'000
DE	11'173'782	11'419'000	11'419'000	10'298'810	11'076'000
GR	3'467'785	3'903'000	4'054'000	-	3'903'000
HU	2'061'432	2'069'130	2'069'000	2'142'000	2'029'000
IE	769'395	754'016	754'016	637'130	739'000
IT	9'414'636	9'297'000	9'297'000	8'525'300	9'149'000
LV	3'191'625	3'356'000	3'366'600	3'283'130	3'354'000
LT	2'208'296	2'180'000	2'186'000	2'024'023	2'160'000
LU	96'176	86'750	86'700	-	86'750
NL	375'744	376'000	376'000	-	365'000
PL	9'425'730	9'435'000	9'435'000	-	9'337'000
PT	4'367'228	3'436'192	3'445'300	2'644'620	3'456'000
RO	7'009'356	6'861'000	6'861'000	6'900'000	6'573'000
SK	2'024'374	1'940'000	1'940'400	2'212'800	1'933'000
SI	1'210'350	1'248'000	1'248'200	1'216'000	1'253'000
ES	15'694'285	18'417'874	18'417'870	1'057'417	18'173'280
SE	28'218'481	28'218'000	28'511'000	23'114'900	28'203'000
GB	3'589'932	3'144'000	3'144'000	2'644'200	2'881'000

Table 1. Maximum forest area over time for 27 different countries in five data sources.

The second table is similar to the one above, except that only two sources are shown, IPCC and SOEF. In addition, the divergence between the respective maximum forest area is calculated in the form of a percentage. Values are in hectares.

Country	IPCC	SOEF	difference
FR	24'775'015	16'989'000	45.8%
PT	4'367'228	3'436'192	27.1%
HR	2'374'262	1'922'000	23.5%
GB	3'589'932	3'144'000	14.2%
LU	96'176	86'750	10.9%
EE	2'438'484	2'252'090	8.3%
BE	713'948	683'400	4.5%
AT	4'040'500	3'869'000	4.4%
SK	2'024'374	1'940'000	4.3%
DK	638'816	612'225	4.3%
BG	3'910'384	3'823'000	2.3%
RO	7'009'356	6'861'000	2.2%
IE	769'395	754'016	2.0%
LT	2'208'296	2'180'000	1.3%
IT	9'414'636	9'297'000	1.3%
CZ	2'671'658	2'667'412	0.2%
SE	28'218'481	28'218'000	0.0%
NL	375'744	376'000	-0.1%
PL	9'425'730	9'435'000	-0.1%
HU	2'061'432	2'069'130	-0.4%
FI	22'126'760	22'458'554	-1.5%
DE	11'173'782	11'419'000	-2.1%
CY	167'776	172'851	-2.9%
SI	1'210'350	1'248'000	-3.0%
LV	3'191'625	3'356'000	-4.9%
GR	3'467'785	3'903'000	-11.2%
ES	15'694'285	18'417'874	-14.8%

Table 2. Comparison of maximum areas between IPCC and SOEF for 27 different countries.

The third table shows the fraction of forest labeled as "available for wood supply". It is calculated by taking the AWS amount and dividing it by the total forest area reported. The only sources providing this information are SOEF and HPFFRE. All values are for the year 2015.

	SOEF	HPFFRE	
	AWS	AWS	AWS+FRAWS
Country			
AT	86.3%	85.4%	94.3%
BE	98.1%	100.0%	-
BG	57.9%	-	-
CY	23.8%	-	-
CZ	86.3%	95.0%	-
DE	95.3%	95.5%	99.2%
DK	93.5%	96.2%	-
EE	89.3%	77.3%	90.3%
ES	79.9%	94.7%	-
FI	87.6%	79.3%	89.9%
FR	94.3%	76.4%	94.7%
GB	100.0%	100.0%	-
GR	92.1%	-	-
HR	90.5%	-	-
HU	86.0%	96.8%	-
IE	83.8%	83.8%	99.4%
IT	88.4%	93.8%	-
LT	88.3%	87.1%	98.8%
LU	99.3%	-	-
LV	93.9%	97.1%	-
NL	80.1%	-	-
PL	87.3%	-	-
PT	65.6%	59.3%	-
RO	67.4%	-	-
SE	70.6%	96.2%	-
SI	91.3%	90.0%	-
SK	92.0%	94.9%	98.0%

Table 3. Comparison of area available for wood supply between two data sources for 27 different countries.

The fourth table shows the average loss and gains (over time) for each country, in each data source.

As every data source provides values at a different granularity and for a different historical time-span, all the average gains and losses displayed here are heterogeneous when it comes to their period covered and measurement count.

All values are converted to mass, using an estimation of the wood density parameter, as explained in figure 3 (see above). Values are in tons of carbon per hectare.

	Gains per hectare		Losses per hectare			
Source	IPCC	SOEF	FAO	HPFFRE	IPCC	SOEF
Country						
AT	2.45	2.96	-2.74	-	-1.81	-3.41
BE	0.56	2.24	-4.60	-4.23	-0.00	-3.05
BG	0.89	-	-1.33	-	-0.02	-
CY	0.24	0.31	-0.09	-	-0.11	-0.26
CZ	2.90	-	-3.18	-	-2.27	-
DE	1.18	-	-	-	-0.02	-
DK	0.64	3.04	-3.94	-	-0.11	-4.66
EE	0.27	-	-2.41	-10.85	-0.00	-
ES	0.57	1.05	-0.82	-	-	-0.96
FI	1.50	1.35	-1.18	-2.67	-1.10	-1.41
FR	1.61	1.95	-3.99	-	-1.04	-1.95
GB	4.19	-	-1.96	-3.47	-3.16	-
GR	0.16	-	-	-	-0.01	-
HR	1.73	1.91	-1.56	-	-0.81	-1.83
HU	0.49	2.39	-3.03	-	-0.02	-3.62
IE	6.52	4.16	-2.59	-	-4.76	-3.66
IT	2.51	1.88	-1.52	-2.01	-1.61	-1.40
LT	0.84	2.86	-2.47	-	-0.20	-4.04
LU	3.14	-	-	-	-1.69	-
LV	2.81	2.73	-2.47	-	-1.98	-3.40
NL	2.45	3.05	-2.97	-	-1.03	-2.87
PL	0.96	2.88	-1.93	-	-	-3.20
PT	1.99	-	-	-	-1.32	-
RO	1.51	2.35	-1.84	-5.03	-0.64	-2.61
SE	0.33	1.32	-1.31	-	-	-2.09
SI	1.09	2.43	-1.51	-	-0.23	-1.36
SK	2.35	-	-2.27	-3.97	-1.47	-

Table 4. Comparison of converted gains and losses for five data sources and for 27 different countries.

The fifth table shows the average wood density by country, as it was calculated by crossing the species growing stock breakdown provided by SOEF and the density per species table.

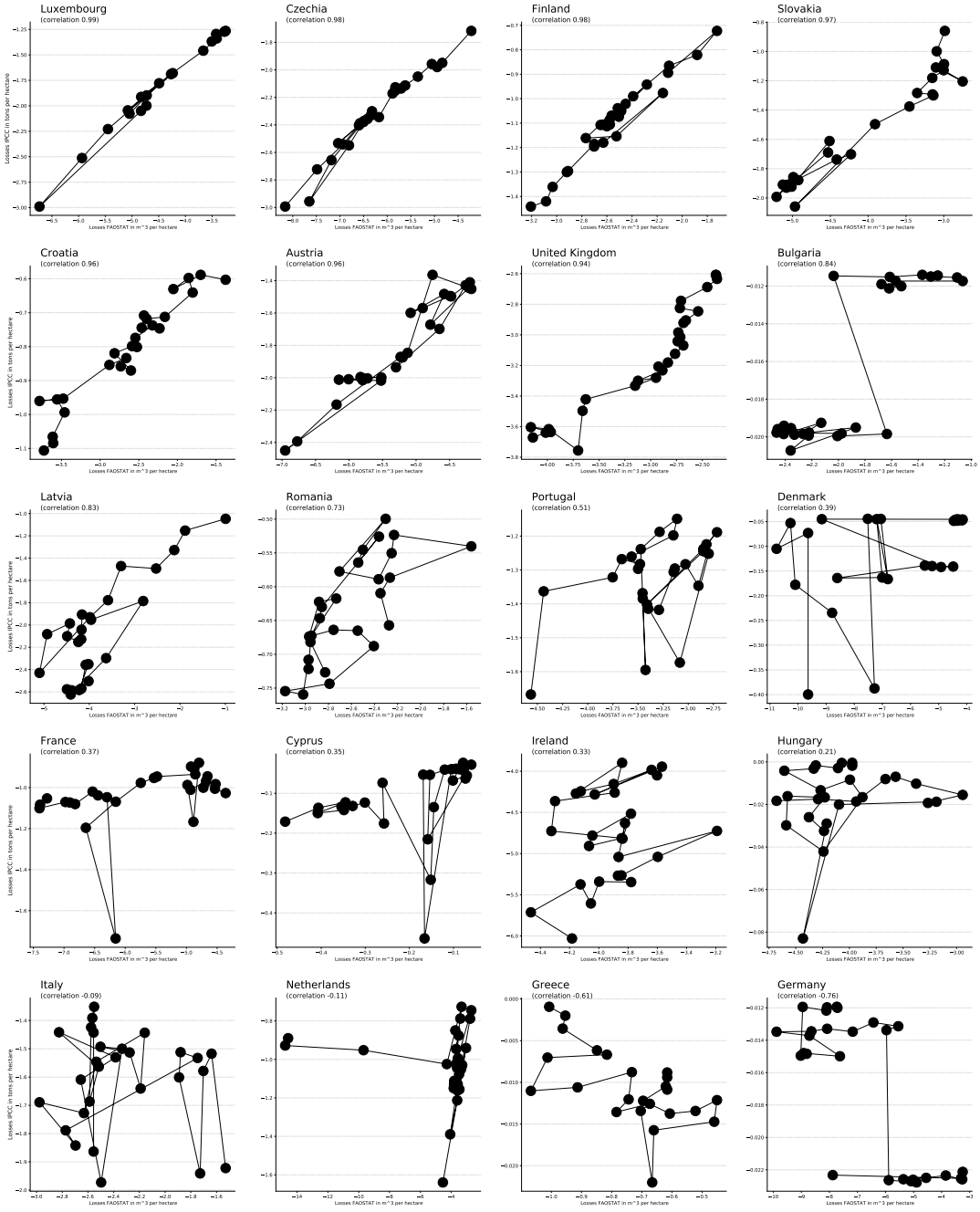
	Average density (kg/m^3)				Fraction missing			
Year	1990	2000	2005	2010	1990	2000	2005	2010
Country								
AT	431	432	433	434	8%	8%	7%	8%
BE	-	473	476	479	-	13%	14%	14%
BG	510	509	509	508	17%	20%	20%	20%
CZ	426	428	428	428	2%	3%	4%	5%
DE	464	471	-	476	29%	30%	-	31%
DK	481	470	497	499	24%	20%	16%	17%
EE	436	436	436	437	1%	1%	1%	1%
ES	483	487	489	489	37%	40%	41%	42%
FI	425	426	428	428	0%	0%	0%	0%
FR	505	505	505	507	27%	27%	29%	32%
GB	487	476	473	470	19%	19%	19%	19%
HR	548	551	552	551	23%	24%	24%	25%
HU	541	541	541	538	31%	33%	36%	37%
IE	-	-	429	426	-	-	22%	20%
IT	494	494	505	505	50%	48%	40%	40%
LT	417	418	420	419	56%	56%	56%	56%
LV	437	443	443	438	0%	0%	0%	0%
NL	469	479	478	483	19%	22%	20%	22%
PL	-	-	-	448	-	-	-	4%
PT	-	478	482	-	-	33%	37%	-
RO	493	493	493	493	13%	13%	13%	13%
SE	-	-	422	423	-	-	1%	1%
SI	481	481	484	485	12%	13%	15%	16%
SK	486	489	491	493	6%	7%	7%	6%

Table 5. Weighted average wood density for 27 different countries.

1.10 Correlations

Below we compute and visualize the correlation between the IPCC loss values (per hectare) and the FAOSTAT loss values (per hectare).

Countries are sorted in descending order based on their correlation coefficient (Pearson).



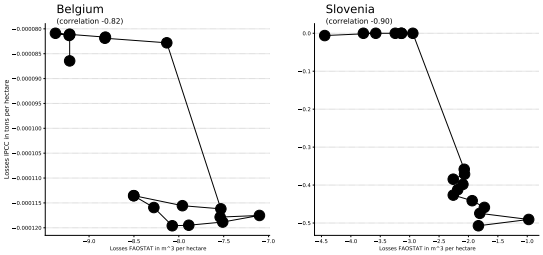


Figure 10. Correlation of loss values in 22 countries and 2 data sources.