1 EUROFLUX : An Integrated Network for Studying the Long-Term Responses of Biospheric Exchanges of Carbon, Water, and Energy of European Forests

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1.1 The Background

Much of what we know about the contemporary global carbon budget has been learned from careful observations of the atmospheric CO_2 mixing ratio and $^{13}C/^{12}C$ isotope ratio ($d^{13}C$), interpreted with global circulation models. From these studies we have learned important facts such as that about one third of the annual input of CO_2 to the atmosphere from fossil fuel combustion and deforestation is taken up by the terrestrial biosphere (Keeling et al. 1996), that a significant portion of the net uptake of CO_2 occurs at mid-latitudes of the Northern Hemisphere, and, in particular, north temperate terrestrial ecosystems are implicated as a large sink (Tans et al. 1990). The methods used have provided the necessary global and continental scale perspective for carbon balance calculations, but their value in addressing small temporal and spatial changes in the carbon balance is rather limited.

The net carbon exchange of terrestrial ecosystems is the result of a delicate balance between uptake (photosynthesis) and losses (respiration), and shows a strong diurnal, seasonal, and interannual variability. Under favorable conditions, during daytime the net ecosystem flux is dominated by photosynthesis, while at night, and for deciduous ecosystems in leafless periods, the system loses carbon by respiration. The influence of climate and phenology can in some cases shift a terrestrial ecosystem from a sink to a source of carbon.

Furthermore, the global and continental scale techniques are of limited use in addressing one of the key questions raised by the Kyoto protocol, namely, how to calculate the changes in "carbon stocks" associated with land-use changes and forestry activities during the commitment period. Indeed, one of the major effects of land-use changes, including the afforestation, reforestation, and deforestation of land, is changes in soil organic matter, both as

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buildup and decomposition. The changes in stocks of soil carbon in a 4–5 year period are unfortunately within the errors of the survey techniques used for most ecosystems. Remote sensing techniques also appear inadequate for such purposes, since they have limited capability of estimating below-canopy processes such as soil respiration.

In this context, the direct, long-term measurement of carbon fluxes by the eddy covariance technique, particularly if applied in conjunction with other ecosystem level studies, offers a distinct possibility of assessing the carbon sequestration rates of forests and of land-use changes activities at the local scale (Valentini et al. 2000). The technique can also provide a better understanding of the vulnerability of the carbon balance of ecosystems to climate variability and at the same time can be used to validate ecosystem models and provide parameterization data for land surface exchange schemes in global models. The correct application of the technique, however, depends on particular requirements which will be discussed later in Chapter 2.

Under the IVth Framework program Environment and Climate, the European Commission funded a consortium of European institutions (EUROFLUX, ENV4-CT95–0078) to investigate the long-term biospheric exchanges of carbon, water, and energy of European forests. Since 1996 automated eddy covariance measurements of CO_2 fluxes have now been made routinely over 15 forests in Europe.

1.2 The Network of Sites

The sites of investigation represent a range of forest ecosystems in Europe, which differ for species composition, type of management, climate, age, and geographical location. The map of the sites is presented in Fig. 1.1, while their main features are listed in Table 1.1.

The sites are distributed along a north–south transect, going from 38° to 60°N latitude and from about 8°W to 27°E longitude. The selected sites fall into four main climate classes: Mediterranean, Temperate, Temperate-Oceanic, Temperate-Continental and Boreal. The major forest biomes are constituted by deciduous (beech), coniferous (pine, spruce), and broad-leaved evergreen (oak) forests. In particular, *Fagus sylvatica* L. and *Pinus* spp. extend from the Mediterranean up to the Nordic region. *Spruce* spp. sites are also distributed along an ecoclimatic gradient, in this case lying mostly in an east–west direction, from the United Kingdom to North Sweden, crossing Germany. In the Mediterranean region the site of evergreen oak is located in Italy (*Quercus ilex* L.).

In Fig. 1.2, the representativeness of the EUROFLUX sites is displayed in a climate diagram showing how the sites cover a wide range of temperature and precipitation.

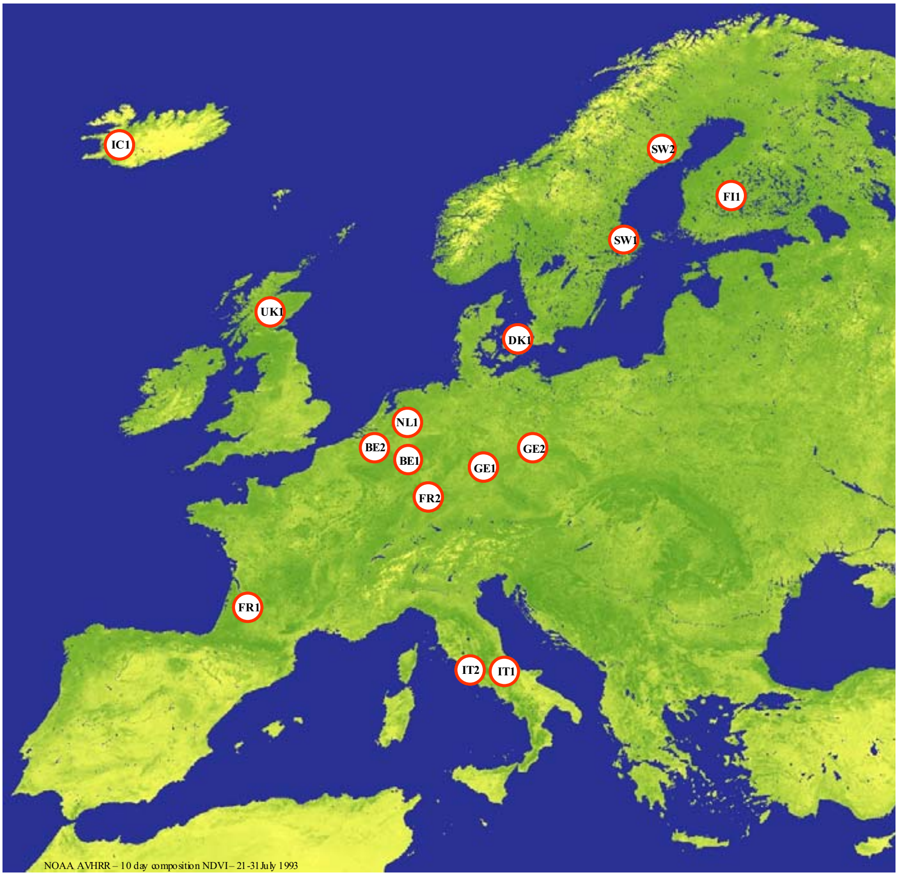

Fig. 1.1. Euroflux network sites distribution in Europe (see Table 1 for details)

After the example of EUROFLUX, the first network of this kind to be initiated, and the development of methodological standards, new networks appeared in various regions of the world. In 1998, the network approach was expanded in the US (AMERIFLUX) and plans are being developed to implement similar networks in Brazil (the Large-Scale Biosphere Atmosphere Experiment in Amazonia), Southeast Asia (the GEWEX Asian Monsoon Experiment), Japan, and Siberia. These major sites are now forming a global network, FLUXNET, with standard measurement protocols and data quality and storage systems.

Table 1.1. Main characteristics of Euroflux sites

Site	Position	Elevation (m)	Species overst.	Species underst.	T (°C)	P (mm)	LAI	H (m)	Age	Density (No./ha)	Soil type	Soil depth	Forest type[a]	Structure
IT1	41°52′N 13°38′E	1550	*Fagus sylvatica*	Herbs *Gallium*	7	1100	4	25	90	1200	Brown earth	80	NM	Uneven aged (irregular)
IT2	41°45′N 12°22′E	3	*Quercus ilex*	Evergreen shrubs	16	500	3.5	10-15	30	1500	Sandy	45	NM	Uneven aged
FR1	44°05′N 0°05′E	60	*Pinus pinaster*	*Molinia coerulea*	13.5	900	5.5	15	25	600	Podzolic	70	P	Even aged
FR2	48°40′N 7°05′E	300	*Fagus sylvatica*	*Carpinus betulus*	9.2	820	6 (?)	12	30	4000	Sandy luvisol	100	NM	Even aged
DK1	56°00′N 12°20′E	40	*Fagus sylvatica*	Anemones	8	600	5.4	27	100	215	Cambisol	50-250	NM	Even aged
SW1	60°05′N 17°28′E	45	*Pinus sylvestris* *Picea abies*	–	5.5	527	5	25	100	600	Till	>100	NM	Even aged
SW2	64°07′N 19°27′E	225	Picea abies	–	1	567	2	8	31	2100	Till	<50	P	Even aged
GE1	50°09′N 11°52′E	780	*Picea abies*	*Deschampia flexuasa*	5.8	885	5	18	40	1000	Brown earth	100	NM	Even aged
NL1	52°10′N 5°45′E	25	*Pinus sylvestris*	*Deschampia flexuasa*	12	800	3	14	80	500	Sandy	50	NM	Even aged
UK1	56°37′N 3°48′E	340	*Picea sitchensis*	Mosses	8	1400	8	7	14	2500	Stony podsolized brown earth	70	P	Even aged
GE2	50°58′N 13°38′E	380	*Picea abies*	*Deschampia flexuasa*	7.5	824	6	28	104	550	Brown earth	150	NM	even aged
BE1	50°18′N 6°00′E	450	*Picea abies* *Pseudotesuga menziesii*, *Fagus sylvatica*	Mosses	7	1000	3.7	27-35	60-90	230	Dystric cambisol	50–100	NM	Uneven aged
BE2	51°18′N 4°31′E	10	*Pinus sylvestris*	Herbs	10	750	3	20	60	672	Silty clay Loam	180–230	P	Even aged
IC1	63°50′N 20°13′W	78	*Populus trichocarpa*	grass and mosses	3.6	1117	1.4	0.6	5	10,000	Andisol	80	P	Even aged
FI1	61°51′N 24°17′E	170	*Pinus sylvestris*	*Vaccinium* spp.	3.5	640	3	11	30	2500	Till	40	NM	Even aged

[a] NM, Natural managed; N, natural; P, plantation.

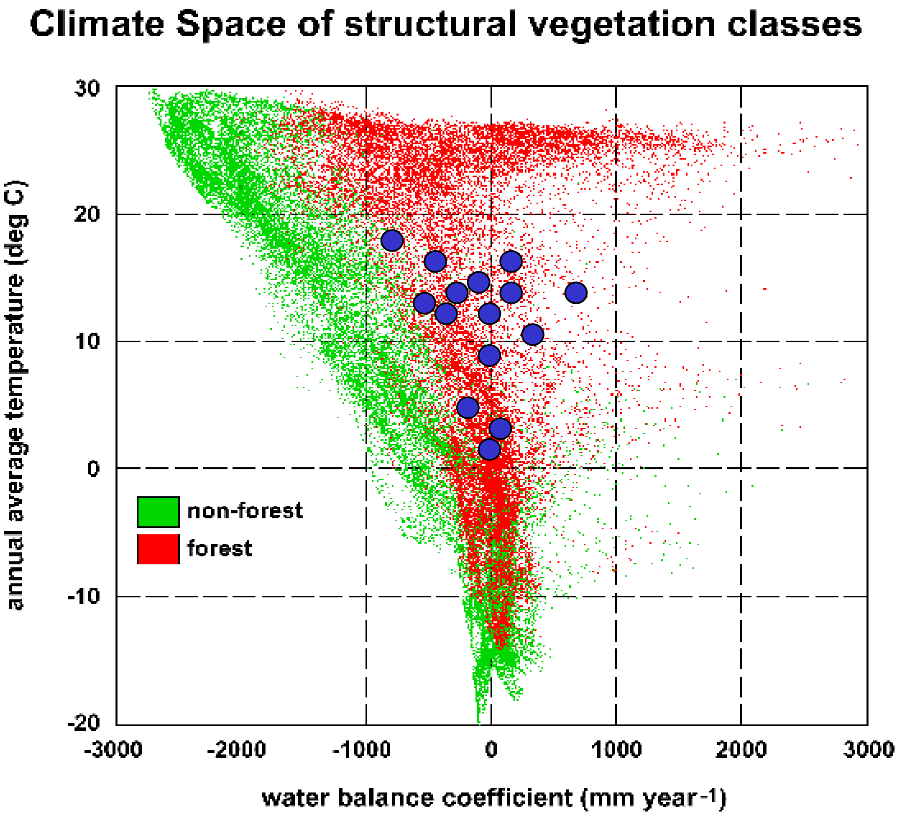

Fig. 1.2. Distribution of Euroflux sites in a climate-space diagram

1.3 The Methodology

The flux stations measure the net flux of carbon entering or leaving the ecosystem. This is the flux which, if summed annually, provides the estimate of Net Ecosystem Exchange (NEE), and thus provides a direct measurement of the annual ecosystem carbon balance, excluding disturbances by harvest and fire (Net Biome Productivity).

The innovation in the technique is that:

- it is possible to measure carbon and energy fluxes directly, without destructive sampling, using a highly standardized technology, allowing comparison across ecosystems on the same basis;
- the measurements integrate over an area of approximately 1 km^2 which is the typical scale of vegetation stands, and where land management also usually occurs;