Environmental Science

Riccardo Valentini
Franco Miglietta *Editors*

The Greenhouse Gas Balance of Italy

An Insight on Managed and Natural Terrestrial Ecosystems

Springer

Environmental Science and Engineering

Environmental Science

More information about this series at http://www.springer.com/series/3234

Riccardo Valentini · Franco Miglietta
Editors

The Greenhouse Gas Balance of Italy

An Insight on Managed and Natural Terrestrial Ecosystems

Springer

Editors
Riccardo Valentini
Department for Innovation in Biological, Agro-Food and Forest System (DIBAF)
University of Tuscia
Viterbo
Italy

and

Impacts on Agriculture, Forest and Natural Ecosystem Division (IAFENT)
Euro-Mediterranean Center on Climate Changes (CMCC)
Viterbo
Italy

Franco Miglietta
FoxLab Institute of Biometeorology
National Research Council of Italy (CNR) and Edmund Mach Foundation
San Michele all'Adige
Italy

ISSN 1431-6250
Environmental Science and Engineering
ISBN 978-3-642-32423-9 ISBN 978-3-642-32424-6 (eBook)
DOI 10.1007/978-3-642-32424-6

Library of Congress Control Number: 2014957323

Springer Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer-Verlag GmbH Berlin Heidelberg is part of Springer Science+Business Media
(www.springer.com)

Contents

Acronyms

AF/R/D	Afforestation/reforestation/deforestation
AIC	Akaike's information criterion
ANN	Artificial Neural Network
BEF	Biomass expansion factor
BVOC	Biogenic volatile organic compounds
BWD	Basic wood density
CAI	Current annual increment
CC	Combustion completeness
CE	Combustion efficiency
CLC	Corine land cover
CO_2 eq	Amount of CO_2 that would have the same global warming potential (GWP) for a given amount of greenhouse gas
CRO	Cropland
CUP	Carbon uptake period
DBF	Deciduous broadleaf forest
DBH	Diameter at breast height
EBF	Evergreen broadleaf forest
EF	Emission factor
ENF	Evergreen needleleaf forest
FE	Fire emissions
FIE	Fertilizer-induced emission
FM	Forest management
GHG	Greenhouse gas
GIS	Geographic information system
GPG-LULUCF	Good practice guidance for land use, land-use change and forestry. It refers to IPCC (2003) Penman J., Gytarsky M., Hiraishi T., Krug, T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., Tanabe K., Wagner F., Good Practice Guidance for Land Use, land-Use Change and Forestry IPCC/IGES, Hayama, Japan
GPP	Gross primary production

GRA	Grassland
IAV	Interannual variability
INFC	National inventory of forests and forest carbon pools
IPCC	Intergovernmental panel on climate change
ISCI	Carbon stock inventory
ISTAT	National statistics agency
IUTI	Land use inventory
LAI	Leaf area index
LUC	Land use change
LULUCF	Land use, land-use change and forestry
MBE	Mean bias error
NEE	Net ecosystem exchange
NEP	Net ecosystem production
NPP	Net primary production
Nr	Reactive nitrogen
PAR	Photosynthetically active radiation
PBMs	Process-based models
PFT	Plant functional types
QA/QC	Quality assurance/quality control
RMSE	Root mean square error
SHB	Shrubland
SLA	Specific leaf area
SOA	Secondary organic aerosols
SOC	Soil organic carbon
SOM	Soil organic matter
SVAT	Soil-vegetation-atmosphere transport
TER	Total ecosystem respiration
UNFCCC	United nations framework convention on climate change
VOC	Volatile organic compounds
VPD	Vapor pressure deficit

Part I
The Overview

Chapter 1
The Greenhouse Gas Balance of Italy: A Synthesis

Maria Vincenza Chiriacò and Riccardo Valentini

Abstract In this chapter a comprehensive assessment of the greenhouse gases budget of the Italian terrestrial ecosystems is provided, with particular attention to forest, cropland and grassland ecosystems and some case studies focusing on Italian shrublands and lands naturally or artificially converted to forests. Different methods have been applied and compared, such as regional measurements, use of flux networks and data-driven models within specific sectoral approaches in order to characterize the greenhouse gases budget of terrestrial ecosystems. The results presented respond also to the growing interest of the recent years in the role of the carbon cycle of terrestrial ecosystems and its relevance for national policies on mitigation and adaptation to climate changes.

1.1 Introduction

This chapter perceives the challenge to address in a comprehensive way the full greenhouse gases budget of the Italian terrestrial ecosystems, with particular attention to forest ecosystems, cropland and grassland ecosystems with some case studies focusing on Italian shrublands and lands naturally or artificially converted to forests.

The wealth of research information presented is mainly referred to the results of a national project, CarboItaly, which involved a number of Italian research institutions and several researchers with the aim to produce data and information useful to characterize different compartments of the greenhouse gases budget of the Italian terrestrial ecosystems, with a special emphasis on forest, croplands, grasslands and natural ecosystems.

M.V. Chiriacò (✉) · R. Valentini
Department for Innovation in Biological, Agro-Food and Forest System (DIBAF),
University of Tuscia, Via San C. de Lellis s.n.c., 01100 Viterbo, Italy
e-mail: chiriaco@unitus.it

M.V. Chiriacò · R. Valentini
Impacts on Agriculture, Forest and Natural Ecosystem Division (IAFENT),
Euro-Mediterranean Center on Climate Changes (CMCC), Viterbo, Italy

R. Valentini and F. Miglietta (eds.), *The Greenhouse Gas Balance of Italy*,
Environmental Science and Engineering, DOI 10.1007/978-3-642-32424-6_1

The results provided in this book respond to the growing interest of the recent years in the role of the carbon cycle of terrestrial ecosystems and its relevance for national policies on mitigation and adaptation to climate changes.

There is also a growing need on the part of institutions, agencies and policy stakeholders for new data and analysis in relation to the United Nations Framework Convention on Climate Change (UNFCCC) process. In particular, the data presented in this book contribute to build a basis for a full carbon accountability of the land sector.

1.2 Methods for the assessments of the greenhouse gases budget

Different methods have been applied and compared, such as regional measurements, use of flux networks and data-driven models within specific sectoral approaches in order to characterize the greenhouse gases budget of terrestrial ecosystems. The Eddy Covariance technique has been applied to a range of Italian sites representative of the main plant functional types (PFT) and of the main Italian macro-regions, to provide data and measures of carbon dioxide, water and energy flow for the whole period of the project. This has made Italy the country with the most dense network of production and eddy covariance Europe. The CarboItaly sites also contributed to the activities in the global network FLUXNET (www.fluxdata.org). Measures of the NEE and its partitioning into the Gross Primary Production (GPP) and ecosystem respiration have been performed with the Eddy Covariance technique in order to analyse the role of the Carbon Uptake Period in the total Net Ecosystem Exchange (NEE) and define the effect of temperature and precipitation, disturbances and management practices on the interannual variability of NEE, aiming at a better understanding of the role and response of ecosystems to climate change.

The role of the Italian managed forest ecosystems in national greenhouse gases budget has been widely discussed and investigated in this book. Integration of land use and forest inventory approaches as well as modeling based approaches have been applied for the assessment of the national forest Gross and net primary productivity (GPP and NPP) and the carbon, water, and elemental cycles. In forest ecosystems firewood and forest harvesting represent a net carbon loss but the use of wood, carbon-neutral renewable resource, for generating energy has also a strong substitution effect as it avoids the use of fossil fuels which are highly CO_2 emitting. The use of wood for construction purposes, substituting traditional materials, tends to increase carbon sequestration and to contribute to climate change mitigation. The great potential of the increasing use of forest wood products for energy, building and furniture purposes in contributing to the reduction of GHG emissions and to a more sustainable development have also been investigated. Another important aspect in the terrestrial carbon budget is represented by the emissions from forest fires. Several experimental and modelling studies have been conducted and presented in this book to improve knowledge of the atmospheric impact of vegetation fires. Biogenic Volatile Organic Compounds (BVOCs) fluxes have been measured in forest CarboItaly sites and a GIS-based model has been developed for predicting BVOCs emissions from the Italian forest ecosystems in order to estimate the fraction of the Net Ecosystem Production lost as reduced carbon and to assess the impact of BVOCs in the formation of ozone and secondary organic aerosols.

The cropland ecosystems with the organic carbon stock in mineral soils and in permanent woody structure of perennial tree crops also play a key role in the terrestrial carbon budget. In this book an assessment of the total soil organic carbon (SOC) stock in the top 30 cm of mineral soil for the whole Italian territory, according to the different land use types of the Intergovernmental Panel on Climate Change (IPCC) cropland category (arable land, agroforestry, vineyards, olive groves, orchards and rice fields), has been performed as a basis for future land use scenarios and to address mitigation policy at country level.

Also nitrous oxide (N_2O) emissions from several Italian croplands along a latitudinal gradient as well as the relationship between N_2O production and applied N fertilization rate were analyzed and empirically derived from experimental sites in order to assess the effect of climate variability on N_2O emissions for Italian crops and to verify the reliability of internationally applied emission factors for temperate crops.

The effects of climate and management practices on the carbon balance in the soil and in the perennial woody biomass have been particularly investigated for Italian vineyard ecosystems. Moreover, regional case studies have been focused of different managements in cropland and grassland ecosystems and on the consequence on the effect on the soil organic carbon of the abandonment of agricultural land and the natural or artificial afforestation.

1.3 Results

The main results presented in the next chapters have been grouped and further elaborated in order to provide a comprehensive assessment of the whole national greenhouse gases budget of terrestrial ecosystems. The values of Gross Primary Production (GPP) and Net Ecosystems Production (NEP) referred to the total Italian surface as well as the main national emissions of BVOCs and N_2O and CH_4 have been assessed and are reported in the Tables 1.1, 1.2 and 1.3.

Table 1.1 Carbon fixed in Italian natural ecosystems

Parameter	Unit value (g C m^2 y^{-1})	Total carbon uptake from natural ecosystems (Mt C y^{-1})	Comments
NEE	−227 (25 %: −264; 75 %: −191)	62.3	Median and interquartile range of empirical upscaling using artificial neural network (ANN) trained with eddy covariance data (Luyssaert et al. 2012) (Chap. 2). The national area of natural ecosystems includes forestland, cropland and grassland, and has been derived from Corine Land Cover 2006 (CLC 2006)
GPP	849 (25 %: 811; 75 %: 891)	233	

Table 1.2 Total Net Primary Production (NPP) of Italian forest ecosystems

Parameter	Unit value (g C m^2 y^{-1})	Total carbon fixed in Italian forest ecosystems (Mt C y^{-1})	Comments
NPP (only aboveground biomass, 2005)	135–145	11.82–12.70	Inventory approach (Chap. 4) Italian forest area from INFC (2005)
NPP (only below ground biomass, 2005)	40.5435	3.55–3.81	Based on inventory approach (Chap. 4) and elaborated considering a mean value of the root/shoot ratio (R) of the main Italian forest types equal to 0.30 (Federici et al. 2008) Italian forest area from INFC (2005)
NPP forest tree biomass (below + above ground) in 2005	176–189	15.37–16.51	
Simulated NPP (all forest carbon pools) total	300–450	26.72–40.08	Modeling approach (Chap. 5) The national area of Italian forest types has been derived from Corine Land Cover 2006 (CLC 2006)
• Mediterranean shrub land	317	6.67	
• Holm oak and evergreen woods	420	3.02	
• Woods mainly planted with Mediterranean pine trees and/or cypresses	368	0.73	
• Hygrophilous forests	320	0.23	
• Broad-leaved woods and plantations with non native species	302	3.17	
• Deciduous mixed oaks woods	402	7.98	
• Chestnut woods	467	3.54	
• Beech forests	381	3.5	
• Woods mainly planted with pine-trees in the sub-alpine and alpine areas (Silver fir and red fir woods)	407	3.52	
• Black pine and mountain pine woods	372	0.81	
• Conifers woods and plantations of non native species	392	0.09	

Table 1.3 Soil organic carbon (SOC) stock in Italian cropland ecosystems

Parameter	Unit value (g C m^2)	Total SOC stock in Italian croplands (Mt C)	Comments
SOC stock in the upper 30 cm	–	489 ± 148.2	Data referred to 2007 (Chap. 8)
SOC stock in the upper 30 cm	–	470.5	Projected for 2020, with no mitigation options (Chap. 8)
Arable land and Agroforestry	4.010 ± 230 to 6.980 ± 2530	285–497	SOC stock in Italian cropland sub-categories, depending on climate types (Chiti et al. 2010) Data referred to 2000 (Chap. 8)
Vineyards	3.920 ± 1.000 to 8.220 ± 5.490	281–590	
Olive groves	4.210 ± 1.330 5.600 ± 3.500	45.5–60.5	
Orchards	3.810 ± 990 to 5.780 ± 1.640	240–365	
Rice fields	6.010 ± 1.110 to 23.440 ± 8.030	12.8–19.9	

Table 1.4 Carbon stock and fluxes measured in local case studies in Italy

Parameter	Total value	Comments
Annual NEE Vineyards	89–145–814	Measured on sites of Serdiana (CA), Valle dell'Adige (TN) and Negrisia (TV) respectively, in 2009 NEE expressed in g C m^2 y^{-1} It includes all carbon pools: soil, grass cover, vine canopy and woody biomass (Chap. 11)
SOC stock permanent irrigated and irrigated arable lands	3.160	SOC Stock expressed in g C m^2 Measured in Sardinia croplands in 2008 (Chap. 8)
SOC stock vineyard	3.380	
SOC stock olive groves	3.220	
Aboveground carbon stock on afforested croplands	2530–4.030	SOC stock measured in g C m^2 on afforested cropland due to land use change after abandonment in Friuli Venezia Giulia (Chap. 13)
Belowground carbon stock on afforested croplands	660–1.050	
SOC stock on afforested croplands	5.430–7.700	
Aboveground NPP on afforested croplands	240–940	
Belowground NPP on afforested croplands	60–240	
Soil carbon sequestration on afforested croplands	40–110	

The total carbon fixed in the Italian natural ecosystems through the process of photosynthesis, expressed as GPP, can be assumed of 233 millions of tons of Carbon (Mt C), of which 62.3 Mt C represents the total Italian net carbon sink, expressed as NEE (Table 1.1).

A considerable amount of national carbon budget of natural ecosystems is represented by the Net Primary Production (NPP) of Italian forests, with a total of 15.37–16.51 millions of tons of Carbon per year (Mt C y^{-1}) fixed in the above and below ground biomass of forest trees and 26.72 (±5.34)–40.08 (±8.02) Mt C y^{-1}) if considering all carbon pools including litter, dead wood and forest soils (Table 1.2).

Another considerable amount of carbon contained in natural ecosystems is represented by the soil carbon (SOC) stock of Italian croplands. The SOC stock in the upper 30 cm of Italian agricultural soils has been assessed of about 489 (±148.2) Mt C in 2007 and is projected for 2020 = 470.5 Mt C, with no mitigation options (Table 1.3).

Others values of carbon stock and fluxes are reported in the Table 1.4 related to specific local case studies of the Italian territory.

As reported in Table 1.5, a fraction of the total Net Ecosystem Production (NEP) of the Italian forest ecosystems is lost as reduced carbon and transformed to BVOCs emissions assessed for 2006 = 41.2 Gg y^{-1} of Monoterpene emissions and to 31.7 Gg y^{-1} of Isoprene emissions. The BVOCs emissions from the Italian forest ecosystems in 2006. The loss of NEP from the Italian forest ecosystems as Biogenic Volatile Organic Compound emissions is estimated of about 3–4 %.

Moreover, another relevant annual loss of NEP of the Italian forest ecosystems is represented by the carbon emissions due to wood removals (Table 1.6).

The two most important non CO_2 greenhouse gases (GHG) exchanged with the atmosphere in Italian agricultural soils are the nitrous oxides (N_2O) and methane (CH_4).

Table 1.5 Total Italian Biogenic Volatile Organic Compounds (BVOCs) emissions from the Italian forest ecosystems in 2006

Parameters	Total emissions of BVOCs (Gg y^{-1})	Comments
Monoterpene emissions	41.2	of which: α-pinene (9.10 Gg y^{-1}), sabinene (4.34 Gg y^{-1}) and β-pinene (3.37 Gg y^{-1}) Limonene, myrcene, *trans*- and *cis*-beta ocimene, linalool, 1-8 cineol, camphene, β-phellandrene and terpinolene contributed for the rest of the emission (Chap. 3)
Isoprene emissions	31.7	

Table 1.6 Annual loss of NEP as carbon emissions due to wood removal from Italian forests

Parameters	Total emissions (Mt CO_2)	Comments
Annual carbon loss due to wood removal in Italy	6	Statistical data approach (Chap. 7)
Annual emission of hwp	0.92	Production approach (Chap. 7)

An emission of N_2O of 1.52 (± 0.04) Mt CO_2 eq yr^{-1} and a slight sink of CH_4 (−0.08 ± 0.001 Mt CO_2 eq yr^{-1}) has been assessed for the five main crops which represented 54% of the total harvested land in 2009, excluding rice paddies (Lugato et al., 2010). Applying the emission factor (EF, kg N_2O-N/kg extra N) of 0.8% (derived from the range 0.4 to 0.8% provided by Chapter 9 and 10) to the total amount of fertilizer N consumed in Italy in 2009 (514.480 tons of N) (FAOSTAT 2014) and considering a similar flux strength for the remaining Italian harvested land, the total amount of N_2O emissions in CO_2 equivalent is 1.93 (± 0.09) Mt CO_2 eq yr^{-1} for 2009 while the total sink of CH_4 (excluding rice cultivation) is −0.148 (± 0.002) Mt CO_2 eq yr^{-1} (Table 1.7).

Table 1.8 shows SOC stock variations related to different management practices, ranging from a carbon sequestration potential of 26–67 g C m^2 y^{-1} when

Table 1.7 Fluxes of N_2O and CH_4, expressed as CO_2 equivalents, in soils of Italian croplands and woodland crops for year 2009 (rice paddies excluded)

Parameters	Total fluxes of GHG (Mt CO_2 eq)	Comments
N_2O	1.93 (± 0.09)	Estimated applying an EF of 0.8 % to total N fertilizer consumption in 2009 (Chapter 9 and 10) Sum of −0.08 Mt CO_2 eq from modeling simulation applied to 54 % of national harvested land, and −0.068 Mt CO_2 eq extrapolated applying a similar GHG source strength (tons CO_2 eq/ha) to the remaining harvested land (excluding ricepaddies) (Lugato et al 2010).
CH_4	-0.148 (± 0.002)	

Table 1.8 SOC stock variations related to different management practices (the negative sign indicates a sequestration potential)

Parameters	Total carbon (g C m^2 y^{-1})	Comments
SOC—Average annual carbon loss (with no mitigation options)	20–50	SOC loss in Italian croplands Gardi and Sconosciuto (2007), Janssens et al. (2005), Lugato et al. (2010), Morari et al. (2006) (Chap. 8)
SOC—Annual carbon loss (with no mitigation options)	16	Calculated as difference between 1990 and 2000 (Chap. 8)
Permanent set a side or zero tillage	−40	Carbon sequestration potential in soils of mitigation options in Italian croplands. Freibauer et al. (2004), Smith et al. (2000a, b) (Chap. 8)
Perennial crops or deep rooting crops	−60	
Change from conventional to organic farming	−50	
Best management practice: change from cropland to grassland; no-till; farm yard manure	−26 to −67	Field experiments (Morari et al. 2006; Lugato et al. 2006; Triberti et al. 2008; Mazzoncini et al. 2011) (Chap. 10)
Abandonment of a vineyard	+27 %	SOC stock variation in Sicilian vineyards (Chap. 11)
Re-planting	−43 % initially	

best management practices like permanent set a side or zero tillage, perennial crops or deep rooting crops, change from conventional to organic farming change and from cropland to grassland, no-till and use of farm yard manure are applied.

References

Chiti T, Papale D, Smith P, Dalmonech D, Matteucci G, Yeluripati J, Rodeghiero M, Valentini R (2010) Predicting changes in soil organic carbon in mediterranean and alpine forests during the Kyoto Protocol commitment periods using the century model. Soil Use Manag 26:475–484. doi: 10.1111/j.1475-2743.2010.00300.x, ISSN: 0266-0032

CLC (2006) Corine Land Cover 2006 technical guidelines: European environment agency, EEA technical report No 17/2007, p 66

FAOSTAT (2014) Consumption of fertilizer N in Italy. http://faostat3.fao.org/home/index.html

Federici S, Vitullo M, Tulipano S, De Lauretis R, Seufert G (2008) An approach to estimate carbon stocks change in forest carbon pools under the UNFCCC: the Italian case. IForest 1:86–95

Freibauer A, Rounsevell MDA, Smith P, Verhagen J (2004) Carbon sequestration in the agricultural soils of Europe. Geoderma 122:1–23

Gardi C, Sconosciuto F (2007) Evaluation of carbon stock variation in Northern Italian soils over the last 70 years. Sustain Sci 2:237–243

INFC (2005) Inventario nazionale delle foreste e dei serbatoi forestali di carbonio: estensione e composizione dei boschi (http://www.sian.it/inventarioforestale/jsp/dati_introa.jsp)

Janssens IA, Freibauer A, Schlamadinger B, Ceulemans R, Ciais P, Dolman AJ, Heimann M, Nabuurs GJ, Smith P, Valentini R, Schulze ED (2005) The carbon budget of terrestrial ecosystems at country-scale-a European case study. Biogeosciences 2:15–26

Lugato E, Berti A, Giardini L (2006) Soil organic carbon (SOC) dynamics with and without residue incorporation in relation to different nitrogen fertilisation rates. Geoderma 135:315–321. doi:10.1016/j.geoderma.2006.01.012

Lugato E, Zuliani M, Alberti G, Delle Vedove G, Gioli B, Miglietta F, Peressotti A (2010) Application of DNDC biogeochemistry model to estimate greenhouse gas emission from Italian agricultural areas at high spatial resolution. Agr Ecosyst Environ 139:546–556

Luyssaert S, Abril G, Andres R, Bastviken D, Bellassen V, Bergamaschi P, Bousquet P, Chevallier F, Ciais P, Corazza M, Dechow R, Erb K-H, Etiope G, Fortems-Cheiney A, Grassi G, Hartmann J, Jung M, Lathiere J, Lohila A, Mayorga E, Moosdorf N, Njakou DS, Otto J, Papale D, Peters W, Peylin P, Raymond P, Odenbeck CR, Saarnio S, Schulze E-D, Szopa S, Thompson R, Verkerk PJ, Vuichard N, Wang R, Wattenbach M, Zaehle S (2012) The European land and inland water CO_2, CO, CH_4 and N_2O balance between 2001 and 2005. Biogeosciences 9(8):3357–3380. doi: 10.5194/bg-9-3357-2012, ISSN: 1726-4170

Mazzoncini M, Bahadur Sapkota T, Barberi P, Antichi D, Risaliti R (2011) Long-term effect of tillage, nitrogen fertilization and cover crops on soil organic carbon and total nitrogen content. Soil Tillage Res 114:165–174. doi:10.1016/j.still.2011.05.001

Morari F, Lugato E, Berti A, Giardini L (2006) Long term effects of recommended management practices on soil carbon changes and sequestration in north-eastern Italy. Soil Use Manag 22:71–81

Smith P, Powlson DS, Smith JU, Falloon P, Coleman K (2000a) Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture. Glob Change Biol 6:525–539

Smith WN, Desjardins RL, Patty E (2000b) The net flux of carbon from agricultural soils in Canada 1970–2010. Glob Change Biol 6:557–568

Triberti L, Nastri A, Giordani G, Comellini F, Baldoni G, Toderi G (2008) Can mineral and organic fertilization help sequestrate carbon dioxide in cropland? Eur J Agron 29:13–20

Chapter 2
Carbon, Water and Energy Fluxes of Terrestrial Ecosystems in Italy

Dario Papale, Mirco Migliavacca, Edoardo Cremonese, Alessandro Cescatti, Giorgio Alberti, Manuela Balzarolo, Luca Belelli Marchesini, Eleonora Canfora, Raffaele Casa, Pierpaolo Duce, Osvaldo Facini, Marta Galvagno, Lorenzo Genesio, Damiano Gianelle, Vincenzo Magliulo, Giorgio Matteucci, Leonardo Montagnani, Fabio Petrella, Andrea Pitacco, Guenther Seufert, Donatella Spano, Paolo Stefani, Francesco P. Vaccari and Riccardo Valentini

Abstract In this chapter the Eddy Covariance network of Italy is presented, with a short introduction to each of the 29 sites that were active during the CarboItaly project. These sites provided a unique dataset for a better study and understanding of the carbon cycle of terrestrial ecosystems and the links between carbon sink capacity and the main environmental factors. After a number of examples of Eddy Covariance time series where it is possible to see the effect of interannual climate variability and disturbances and managements practices, an analysis of the role of

D. Papale (✉) · M. Balzarolo · L. Belelli Marchesini · E. Canfora · P. Stefani · R. Valentini
Department for Innovation in Biological, Agro-Food and Forest System (DIBAF), University of Tuscia, Viterbo, Italy
e-mail: darpap@unitus.it

M. Migliavacca · A. Cescatti · G. Seufert
Joint Research Centre, Institute for Environment and Sustainability, European Commission, Ispra, Italy

E. Cremonese · M. Galvagno
ARPA Valle D'Aosta, Aosta, Italy

G. Alberti
Department of Agricultural and Environmental Sciences, University of Udine, Udine, Italy

R. Casa
DAFNE, University of Tuscia, Viterbo, Italy

O. Facini
IBIMET, CNR, Bologna, Italy

L. Genesio · F.P. Vaccari
IBIMET, CNR, Florence, Italy

D. Gianelle
Department of Sustainable Agro-Ecosystems and Bioresources, Research and Innovation Centre, Fondazione Edmund Mach, Michele All' Adige, Trento, Italy

R. Valentini and F. Miglietta (eds.), *The Greenhouse Gas Balance of Italy*, Environmental Science and Engineering, DOI 10.1007/978-3-642-32424-6_2

the Carbon Uptake Period in the total Net Ecosystem Exchange (NEE) definition and a study of the effect of temperature and precipitation on the interannual variability of NEE are presented in order to show the way these data can contribute to a better understanding of the role and response of ecosystems to climate change.

2.1 Introduction

Monitoring carbon, water and energy fluxes between terrestrial ecosystems and atmosphere is essential for a better understanding of the biological and ecological processes, also in relation to climate variability and climate change, and to assess the carbon balance of the different ecosystems and their ability to sequester CO_2 from the atmosphere.

In order to improve the understanding of the quantities involved in the carbon balance of terrestrial ecosystems, it is important to provide the following definitions: it is defined Gross Primary Production (GPP) of an ecosystem, the total amount of CO_2 that is fixed by the vegetation in photosynthesis. The synthesis of new plant tissues and the maintenance of the plants themselves require energy that is provided by the autotrophic respiration (Ra). The difference between the amount of carbon fixed by photosynthesis and respired by the vegetation is defined Net Primary Production (NPP):

$$NPP = GPP - Ra$$

V. Magliulo
ISAFOM, CNR, Ercolano, NA, Italy

G. Matteucci
ISAFOM, CNR, Rende, CS, Italy

G. Matteucci
IBAF, CNR, Monterotondo, RM, Italy

L. Montagnani
Forest Services and Agency for the Environment, Autonomous Province of Bolzano,
Faculty of Science and Technology, Free University of Bolzano, Bolzano, Italy

F. Petrella
Institute for Wood Plant and Environment (IPLA),
Environmental Disease and Soil Conservation Unit, Turin, Italy

A. Pitacco
DAFNAE, University of Padua, Padua, Italy

D. Spano
Department of Science for Nature and Environmental Resources (DIPNET),
University of Sassari, via E. de Nicola 9, 07100 Sassari, Italy

P. Duce
IBIMET, CNR, Sassari, Italy

D. Spano
Impacts on Agriculture, Forest and Natural Ecosystem Division (IAFENT),
Euro-Mediterranean Center on Climate Changes (CMCC), Sassari, Italy

The NPP is allocated to the production of biomass (wood, leaves, roots, fruits, seeds etc.) and respired back to the atmosphere mainly due to decomposition by microbial activities. The quantity of carbon lost by respiration for heterotrophic organisms is defined heterotrophic respiration (Rh) and the difference between NPP and Rh is the Net Ecosystem Production

$$\mathrm{NEP} = \mathrm{NPP} - \mathrm{Rh} = \mathrm{GPP} - \mathrm{TER}$$

The NEP represents the net ecosystem carbon sink or source due to physiological processes and it is also named Net Ecosystem Exchange (NEE) when it is quantified using measurements of CO_2 exchanges between ecosystem and atmosphere (while it is called NEP when measured using inventory approaches). The two terms are somehow interchangeable but in general with opposite signs: a flux of carbon from the atmosphere to the ecosystem is positive in NEP and negative in NEE. The sum of the two respiration components (Rh and Ra) represents the total ecosystem respiration (TER).

The NEP is however different from the long term carbon balance of the ecosystem because there can be changes in the carbon stocks due to episodic losses by natural or anthropogenic disturbances and management practices. For this reason the Net Biome Production (NBP) is defined as (Schulze et al. 2000):

$$\mathrm{NEP} = \mathrm{NPP} - \mathrm{CO_2}\ \text{losses due to disturbances}$$

There are different possible approaches and methods to measure the fluxes of energy and greenhouse gases (GHGs) in terrestrial ecosystems, ranging from inventory approaches to chambers measurements and ecosystem scale techniques such as the Eddy Covariance method (Aubinet et al. 2012).

The Eddy Covariance methodology has been developed in the early ’90s and has been widely applied at global level. It is based on high frequency (10 Hz) measurements of wind speed, temperature and gas concentration using a three-axis sonic anemometer (which measures the wind speed along the three axis) and a fast response gas analyzer, typically an Infra Red Gas Analyzer (IRGA) for CO_2 and H_2O, even if new systems have been recently developed and commercialized to measure high frequency concentrations of other gases such CH_4, N_2O and O_3.

With the Eddy Covariance technique it is possible to measure the Net Ecosystem Exchange (NEE) of a GHG of a given surface extended around the monitoring tower (the footprint). The extension and shape of the footprint is function of the wind speed, wind direction and the difference between the measurement and canopy heights and it has generally a radius between few hundred meters and one kilometer around the measurement point. The Eddy Covariance technique is the only method available today to continuously measure the net ecosystem exchanges at ecosystem level and in a not-destructive way.

In addition, for CO_2 NEE measurements, there is the possibility to statistically partition the net carbon fluxes measured into its major components as the gross primary production (GPP) and the ecosystem respiration (Reichstein et al. 2005; Lasslop et al. 2010) allowing a better interpretation of the fluxes in terms of ecosystem processes.

Nowadays, more than 500 sites exist globally, organized in regional networks contributing to the global network FLUXNET (http://fluxnet.ornl.gov/) with the