The Anthropocene: Politik—Economics—Society—Science

Sabit Erşahin · Selim Kapur
Erhan Akça · Ayten Namlı
Hakkı Emrah Erdoğan *Editors*

Carbon Management, Technologies, and Trends in Mediterranean Ecosystems

TÜRKİYE TOPRAK BİLİMİ DERNEĞİ
1964
SOIL SCIENCE SOCIETY OF TURKEY

Springer

The Anthropocene: Politik—Economics—Society—Science

Volume 15

Series editor

Hans Günter Brauch, Mosbach, Germany

More information about this series at http://www.springer.com/series/15232
http://www.afes-press-books.de/html/APESS.htm
http://www.afes-press-books.de/html/APESS_15.htm

Sabit Erşahin · Selim Kapur
Erhan Akça · Ayten Namlı
Hakkı Emrah Erdoğan
Editors

Carbon Management, Technologies, and Trends in Mediterranean Ecosystems

TÜRKİYE TOPRAK BİLİMİ DERNEĞİ
SOIL SCIENCE SOCIETY OF TURKEY
1964

Springer

Editors
Sabit Erşahin
Department of Forestry Engineering
Çankırı Karatekin
Çankırı
Turkey

Selim Kapur
Department of Soil Science and Plant Nutrition
Çukurova University
Adana
Turkey

Erhan Akça
School of Technical Sciences
Adıyaman University
Adıyaman
Turkey

Ayten Namlı
Department of Soil Science and Plant Nutrition
Ankara University
Ankara
Turkey

Hakkı Emrah Erdoğan
Agro-Environment and Protection of Natural Resources
Ministry of Food, Agriculture and Livestock
Ankara
Turkey

ISSN 2367-4024 ISSN 2367-4032 (electronic)
The Anthropocene: Politik—Economics—Society—Science
ISBN 978-3-319-45034-6 ISBN 978-3-319-45035-3 (eBook)
DOI 10.1007/978-3-319-45035-3

Library of Congress Control Number: 2016951651

Cover page photo: Replica of ceramics of Iznik from the 12th century with carnations. Photo by N Özçelik and S Sabancılar who granted permission.
Internal title page photo: Red poppy (Papaver rhoeas) and pistachio nut tree (Pistacia vera) grafted to terebinth (Pistacia terebinthus). The cover photo was taken from the Mediterranean Highlands, Southern Turkey by Erhan Akça who granted permission for its use.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Mediterranean Soil Ecosystems: Publication of the Soil Science Society of Turkey

Publication of the Soil Science Society of Turkey (SSST)

International Advisory Board

- Luca Montanarella, Joint Institute of Environment and Sustainability, Milan, Italy
- Marcello Pagliai, Centro di recerca per l’agrobiologia e la pedologia, Firenze, Italy
- Marie-Agnes Courty, French National Centre for Scientific Research (CNRS), Paris, France.
- Michael Cherlet, Joint Institute of Environment and Sustainability, Milan, Italy
- Michael A. Wilson, USDA-NRCS, Soil Survey Division, World Soils, Washington DC, USA
- Nicola Senesi, University of Bari, Bari Italy
- Pandi Zdruli, Mediterranean Institute of Bari (MAI-B), Bari, Italy
- Rana Özbal, Koç University, Istanbul, Turkey
- Rattan Lal, The Ohio State University, Ohio, Columbus, USA
- Rivka Amit, Geological Survey of Israel, Jerusalem, Israel
- Salah Tahoun, El Zagazig University, Cairo, Egypt
- Sideris Theocharopoulos, Nagref Soil Institute, Athens, Greece
- Steven Nortcliff, University of Reading, Reading, UK
- Takanori Nagano, Kobe University, Kobe, Japan
- Tallal Darwish, National Center for Scientific Research, Beirut, Lebanon
- Tony Koppi, University of New South Wales, New South Wales, Australia
- Tsuhigiro Watanabe, Research Institute of Humanity and Nature, Kyoto, Japan
- Uriel Safriel, Hebrew University of Jerusalem, Jerusalem, Israel
- Winfried E. H. Blum, University of Natural Resources and Applied Life Sciences, Vienna, Austria

Editorial Office: University of Ankara, Department of Soil Science and Plant Nutrition, 06110 Dışkapı, Ankara, Turkey

Preface

Mediterranean Soil Ecosystems (MSE) is a series of formal scientific publications of the Soil Science Society of Turkey (SSST). Established in 1964, the SSST supports wide range of research in soil science and related disciplines. Mediterranean Soil Ecosystems invites contributions on topics in soil ecosystems, soil and land degradation and desertification, agroecosystem management, carbon dynamics and management systems and ancient land use in the Mediterranean environment and context, palaeopedology and geopedology, and the changing soils and soils of tomorrow and their likely use under climate change scenarios.

Mediterranean Soil Ecosystems also aims to improve communication and develop holistic integrated approaches for achieving a sustainable management of the environment. The MSE welcomes all aspects of soil science and its interrelations to soil and earth sciences, agriculture, forestry, biology, botany, climatology, ecology, ecological economics, environmental sciences and engineering, environmental law, carbon policies, and information sciences related to environmental integrity. Mediterranean Soil Ecosystems welcomes readers, authors, and research results from academia, business, government, research institutes, and public interest groups.

This book covers ecologic and socio-economic aspects of carbon management in Mediterranean ecosystems. The chapters were selected among those presented at the 1st Istanbul Carbon Summit, held at Istanbul Technical University, 2–4 April, 2014 and subsequently peer reviewed by the members of editorial committee.

Discussion on multiple interactions between soil carbon and environment were covered in first three chapters. Carbon treading issues in different Mediterranean nations and related policies, application, and implementations are covered in Chap. 4. Chapter 5 covers a unique discussion on how recent developments and related ecological disturbance affected life of Nubians, one of the most ancient peoples in the world, their civilization started more than 8,000 years ago in Egypt. Chapter 6 discusses the results of a study on relationships between carbon dioxide emissions and exports in terms of carbon dioxide emissions, total exports, agricultural exports, industrial exports, and service exports in 23 countries from different income levels and different regions. Chapter 7 introduces a functional ‘energy–economy–ecology–engineering’ integrated model that calculates final energy consumption from primary energy supply and discusses its application in Turkey and Chap. 8 covers discussion on the cost/benefit assessment of implementing Land Use, Land Use Change and Forestry (LULUCF) accounting the regulations in Turkey in the future. Chapter 9 discusses carbon certification applications in Turkey and finally, Chap. 10 discusses results of a long term study on carbon sequestration and mycorrhizae in two soil series located in the eastern Mediterranean region of Turkey (Adana). The editors of this book profoundly express their gratitude to the series editor Hans G Brauch for his everlasting and sincere efforts which led us to made this book a worthwhile achievement. We also thank N Özçelik and S Sabancılar who designed the İznik tile pattern on the front cover.

Çankırı, Turkey	Sabit Erşahin
Adana, Turkey	Selim Kapur
Adıyaman, Turkey	Erhan Akça
Ankara, Turkey	Ayten Namlı
Ankara, Turkey	Hakkı Emrah Erdoğan
June 2016	

Contents

Chapter 1
Soil Carbon Impacts on Functionality and Environmental Sustainability

Rattan Lal

Abstract The term soil functionality implies utilization of soil for specific purposes so that ecosystem functions and services are sustained. Soil functionality strongly impacts environmental sustainability in relation to climate change, water quality and renewability, biodiversity, elemental cycling and transformations. There is a wide range of soil parameters which impact soil functionality. These include physical (texture, structure, pore size distribution, continuity), chemical (pH, E_h, charge density, nutrient reserves, elemental toxicology), biological (microbial biomass carbon, soil respiration, biodiversity) and ecological (soil organic carbon concentration and quality, elemental transformation). The choice of specific indicator depends on specific functions. These parameters can be combined into a soil functionality index. Soil functionality can be measured indirectly be assessing soil quality. Soil functionality also depends on the parent material, land use and management, climate and CO_2 enrichment. Soil functionality can be restored by creating a positive soil/ecosystem carbon budget, carbon sequestration in soil and terrestrial biosphere, enhancement of biodiversity and control of soil erosion. The concept of soil functionality can be used to address global issues such as climate change, food and nutritional security water quality and renewability and biodiversity.

Keywords Soil quality · Ecosystem services · Soil functionality index · CO_2 enrichment · Soil structure and porosity

1.1 Introduction

The term ‘sustainability’ implies: (1) longtime period, and (2) the need for a steady growth. However, Bartlett (1997) opined that the term “sustainable growth” is an ‘oxymoron’ (Daly 1990). Among the list of seventeen laws proposed by Bartlett,

---

Prof. Rattan Lal, Carbon Management and Sequestration Center, The Ohio State University, Columbus, OH 43210, USA, E-mail: lal.1@osu.edu.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_1

law #13 states “Humans will always be dependent on agriculture, and the central task in sustainable agriculture is to preserve agricultural land.” The law #12 states that, “The chief cause of problems is solutions.” When asked if, after independence, India would attain British standards of living, Mahatma Gandhi replied, “It took Britain half the resources of the planet to achieve its prosperity, how many planets would a country like India require…?” (Goodland 1992). Gandhi’s response is even more relevant in 2016 than it was in 1940s. Therefore, the issue of environmental sustainability is on the forefront of any global agenda. Soil degradation plagued several ancient civilizations (e.g., Mesopotamia in the Tigris-Euphrates Valley, and Mayan in Central America). However, it is the mushrooming of the scale at which it is happening in the 21st Century, which is a major concern and an urgent issue to be addressed.

The emphasis on environmental sustainability during 2010s is attributed to the: (i) high rates of exploitation of renewable resources, (ii) continuous increase in generation of pollutants (pesticides, chemicals, gaseous emissions), (iii) a rapid depletion of non-renewable resources, (iv) extinction of biodiversity, and (v) severe degradation (and even extinction) of soils. Therefore, environmental sustainability involves a strategy of making prudent decisions on natural resources (soil, water, vegetation, etc.) management to reduce the human footprint encompassing indicators such as soil degradation, eutrophication of water and non-point source pollution, emission of greenhouse gases (GHGs), drainage of wetlands, cultivation of peat soils etc.

Judicious management of soils is integral to environmental sustainability (Kerzhentsev 2010). Ignoring the soil-environmental nexus and its ramifications can endanger some fragile resources by accelerated erosion (Tennesen 2014) along with severe adverse impacts on soil biodiversity (Tsiafouli et al. 2015). Soil structure, strongly affected by mycorrhizae (Rilling/Mummey 2006) and other biota, is prone to degradation through management-induced perturbations of the surface layer leading to strong adverse impacts on soil functionality.

Therefore, the objective of this article is to describe soil functionality, and discuss the impact of soil organic carbon (SOC) concentration and other properties on soil functionality and the environmental sustainability.

1.2 Soil Functionality

Soil is a dynamic entity, and its properties are strongly influenced by natural and anthropogenic factors. Thus, it is important to understand how and which soil properties change because of biotic and abiotic stresses, on short and long-term, and in the surface and sub-surface horizons. Thus, soil use and management can be chosen to advance the goals of environmental sustainability. It is in this context that soil functionality is multi-dimensional characteristics with ecological, economic, social and political ramifications.

Table 1.1 Principal functions of soils

	Function	Example
1	Food production	Medium for plant growth, Reservoir of water and nutrients, Support for root growth, Resistance against diseases and pathogens, Elemental transformation and reducing phytotoxicity
2	Agronomic	Sustaining productivity, Moderating use efficiency of inputs, Strengthening resilience against climate change
3	Gene pool	Habitat for biota, Reservoir for seed, Preserving germplasm over millennial time scale
4	Environmental/Ecologic	Recycling and retention of nutrients, filtrating and purifying water, Storing C and moderating atmospheric chemistry, Regulating gaseous exchange between pedosphere and the atmosphere, Resisting soil erosion, Buffering against perturbations
5	Industrial	Raw materials, Minerals, Pharmaceutical, Antibiotics
6	Anthropogenic	Physical and cultural heritage, Aesthetic and artistic values, Spiritual, Therapeutic, Human and planetary history, Evolutionary archive
7	Foundation	Platform for man-made structures, Foundation for dams, buildings, etc.

Source The author

The term soil functionality means utilization of soils for specific purposes at an optimal level so that the ecosystem functions and services are sustained. In other words, “it is the capacity of a specific soil to function under designed circumstances to meet its planned intentions or requirements without any loss of original functional capability” (Yong et al. 2012). The soil functionality concept addresses the performance aspects of a specific soil according to the specific goals or functions.

There are numerous soil functions (Table 1.1), including plant growth, and the food production through agronomic management. A German saying in the context of food production states, “Es ist die Erde, die gibt uns das Brot” or it is the soil, which gives us the bread. Food being essential to human survival, it is pertinent to state that we are soil. Thus, Gandhi stated that, “To forget how to dig the Earth and tend the soil is to forget ourselves.” Important among ecologic functions of soils are: recycling and retention of nutrients, filtration and purification of water, storing of carbon (C) and moderating atmospheric chemistry, moderating gaseous exchange between the pedosphere and the biosphere, resisting soil erosion, buffering against natural and anthropogenic perturbations, and providing habitat and energy for soil biota. There are also anthropologic and industrial functions. Therefore, protection of soil resources and their functionality is of a paramount importance (Blum et al. 1993).

Through its critical role in numerous functions (Table 1.1), soil functionality impacts water resources (renewability and quality), climate change (mitigation, adaptation and stabilization), food and nutritional security (quality and quantity), and biodiversity (above and belowground). Soil functionality is the engine of economic development.

1.3 Indicators of Soil Functionality

There is a strong interaction between environmental sustainability and soil functionality (Fig. 1.1). Principal indicators of soil functionality which impact environmental sustainability are physical, chemical, biological, and ecological (Table 1.2). There is a strong relationship between the functionality of physical and chemical attributes and the parent material of soil (Jenny 1941). An example of the effects of parent material on soil functionality is documented in a study from Brazil de Arúgo Filho et al. (2013) observed that in the Itapric region of Brazil, soils derived from the sandy parent material contained low nutrient reserves and high permeability. In contrast, soils derived from the fine sediments contained higher nutrient reserves and low permeability. These indicators are important soil properties, and the specific set of properties varies among functions (agronomic,

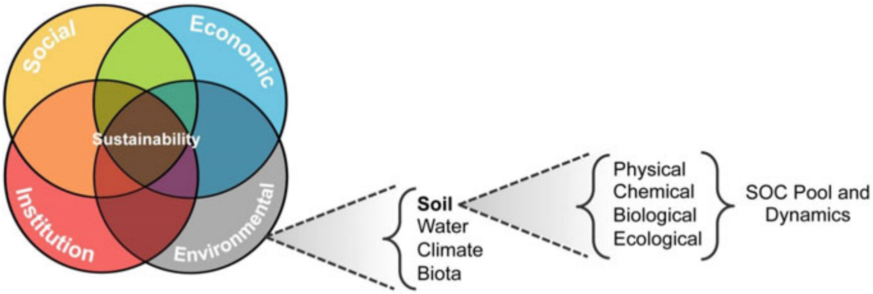


Fig. 1.1 Environmental sustainability in relation to soil functionality and soil organic carbon (SOC) pool and its dynamics. *Source* The author

Table 1.2 Important indicators of soil functionality

Indicator	Parameter
Physical	Texture, structure, bulk density, pore size distribution and continuity, water retention and transmission, thermal capacity and conductivity
Chemical	pH, E_h, charge density, nutrient reserves, elemental transformation, nitrification, denitrification
Biological	Microbial biomass carbon (MBC), biodiversity (macrofauna), soil respiration, potentially mineralizable N
Ecological	Soil organic carbon (SOC), biogeochemical transformations, methanogenesis, gaseous exchange and diffusivity, erosion, soil formation

Source The author

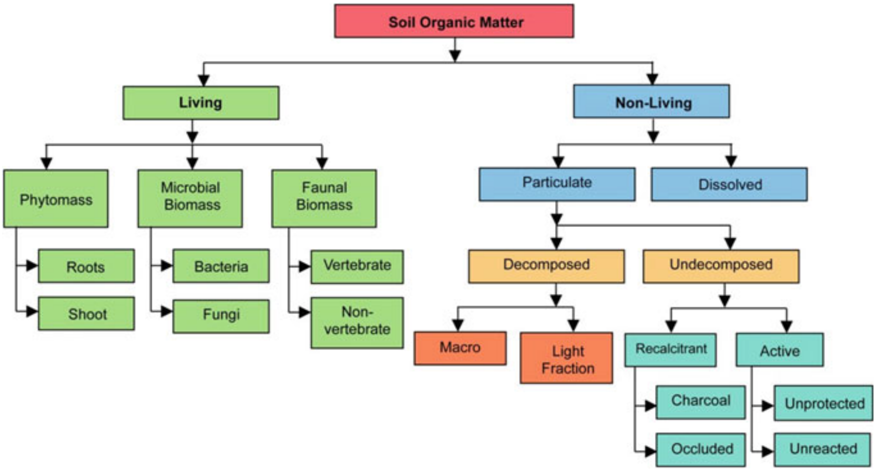


Fig. 1.2 Living and non-living components of soil organic matter content which impact soil functionality. *Source* The author

environmental, food production). Both soil organic C (SOC) concentration and pool are important determinants of soil functionality and environmental sustainability. In addition to the amount, composition of SOC also affects numerous properties and processes. It cuts across a range of soil functions of relevance to human wellbeing and nature conservancy. The SOC pool, as the principal component of soil organic matter (SOM), comprises of living and non-living organisms in soil (Fig. 1.2). It is the amount, quality and dynamics of SOC pool that governs soil functionality (Fig. 1.3) through changes in physio-chemical, biochemical, eco-biological processes and transformations are over time. These transformations are influenced by natural and anthropogenic factors, and biotic and abiotic stresses. Thus, judicious management of SOC pool is essential to sustainability of soil functionality. Indeed, the critical levels of SOC concentration in the root zone may be ∼2 % for soils of the temperate regions (Kemper/Koch 1966; Greenland et al. 1975; Loveland/Webb 2003), and ∼1.1 % for those of the tropics (Aune/Lal 1997).

It is not easy to measure soil functionality. Indeed, “most important things cannot be measured and still must be managed” (Edward Demmings 1900–1993). In other words, “manage what you can’t measure.” Thus, the question with regard to soil functionality is: what is there in the soil that can be measured in terms of what it does. What is does is soil functionality.

Because soil functionality is difficult to measure directly, it is measured indirectly by measuring soil quality index (Mukherjee/Lal 2014) or soil functionality index (SFI). Yong et al. (2012) defined SFI as a ratio of the value x_n of a soil parameter at time t_n to a reference base soil functionality value (x_{base}) for each specific indicator. If SOC concentration is selected as an indicator of soil functionality, then SFI of SOC is:

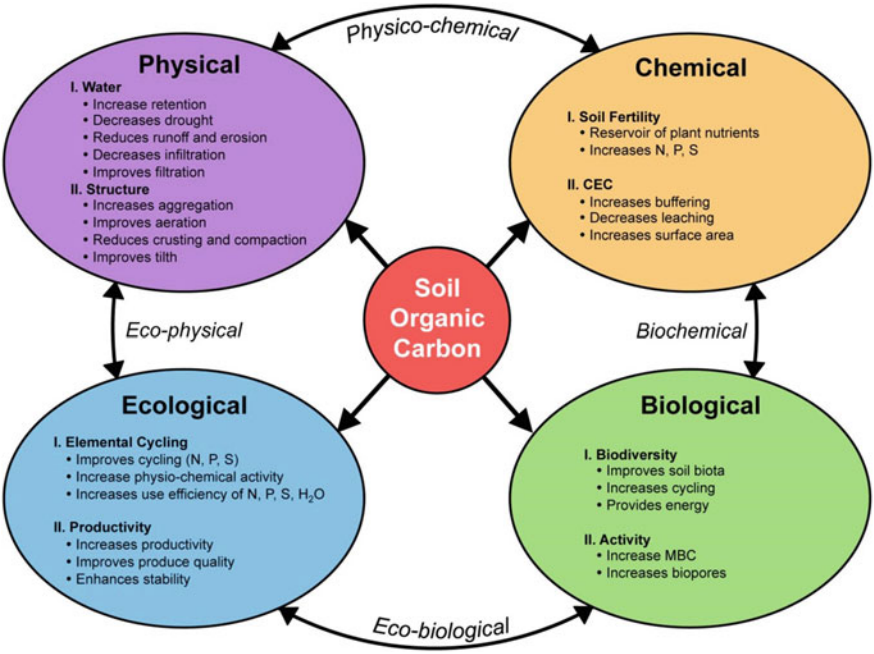


Fig. 1.3 Impacts of soil organic carbon pool on soil properties and processes which impact soil functionality. *Source* The Author

$$\mathrm{SFI}_{(\mathrm{SOC})} = \mathrm{SOC}_{\mathrm{n}} : \mathrm{SOC}_{\mathrm{base}}$$

Therefore, SOC depletion occur for SFI < 1 and sequestration for SFI > 1. Similar to SQI, SFI must also be the one that soil scientist can quantify and farmers can understand and relate to.

1.4 Management of Soil Functionality

The Law of Return by Sir Albert Howard states that, “the nutrients harvested from soil must be returned. Harvesting without returning is a robbery of the soil and banditry; a particularly mean form of banditry, because it involves robbing of future generations, which are not there to defend themselves” (Howard 1931). Lal (2009a) proposed ten tenants (laws) of sustainable management (Table 1.3), which also indicate that soil is like a bank account and maintaining a positive balance of key indicators of soil functionality is essential to its sustainable use over time of the finite but an essential resource.

Whereas, the vulnerability of a soil to degradation increase with increase in mean annual temperature (Law 4, Table 1.3), the SOC pool increase with decreases

Table 1.3 Laws of sustainable soil management

	Theme	Law	
I.	Soil and Its Degradation	1.	Soil resources are finite and unequally distributed geographically, and are non-renewable over the human timeframe
		2.	Soils are prone to land misuse and soil mismanagement
		3.	Accelerated erosion is caused more by "how" rather than "what" crops are grown
		4.	Vulnerability to soil degradation increases with increase in mean annual temperature and decrease in mean annual precipitation
II.	Soil and Climate	5.	Soil can be a source or sink of greenhouse gases depending on land use and management (i.e., soil, water, crops, animals)
		6.	Soil carbon sequestration implies creating a positive C budget through retention of plant-biomass or animal produce grown on the same land unit
		7.	Soil resilience to climate change depends on optimal level of physical, chemical, biological and ecological properties
III.	Soil Restoration	8.	Soil restoration is a slower process than degradation. Restoration of SOC pool may occur at a decadal or centennial scale
		9.	Soil structure and its functionality depend on stability and continuity of macro, meso and mircopores or voids
		10.	Sustainable management of soil implies an increasing trend over time in key indicators of soil functionality (e.g., SOC pool, aggregate stability, available water capacity or supply of green water)

Source Adapted from Lal (2009b)

in mean annual temperature and increases with increase in mean annual precipitation (Jenny 1941). For example, Scheer et al. (2011) observed that the environmental functionality of upper montane soils in southern Brazil depended on SOC pools, which are two-to-threefold higher than those in soils of low altitudes at the same latitude. Functionality of soil pores (Law 9, Table 1.3) depends on the stability and continuity of pore system. It is the formation of a stable and continuous pore system that governs aeration (gases diffusion), and water transmission (Dörner et al. 2010).

Input of biomass-C, to offset the losses caused by decomposition and erosion or leaching, is essential to enhancing soil functionality. Municipal sewage sludge and compost from crop residues etc. can enhance soil functionality for agricultural/agronomic purposes (Sciubba et al. 2013). Similarly, soil functionality for agriculture (Lal 2015) involving retention of crop residues mulch, cover cropping, integrated nutrient management, and elimination of plowing and other mechanical soil disturbances. Rather than a panacea or a silver bullet, there is a wide range of appropriate soil management practices depending on site-specific conditions.

1.5 Soil Functionality and Environmental Sustainability

Soil functionality strongly impacts environmental sustainability (Fig. 1.4). Principal among environmental issues are eutrophication (algal bloom) and filtration, gaseous emissions (CH_4, N_2O) and C sequestration, biodiversity (species enrichment or extinction and ecosystem disservices (erosion, salinization) and services (restoration) and net primary productivity, Soil degradation and loss of functionality can cause eutrophication of water resources. Functionality of soil physical and chemical attributes, as influenced by the parent material can also impact eutrophication of natural waters (de Araújo Filho et al. 2013). Soil memory, records of historical events, also depends on functionality of soil attributes. Targulian/Goryachkin (2004) observed that soil systems have a capacity for storing information about environmental factors and pedogenic processes which have affected soil functionality over the period of soil formation or pedogenesis. While interpreting the

Fig. 1.4 Environmental sustainability impacts of soil functionality. *Source* The author

historic records in soil systems within a specific climactic regime, it is important to account for the effects of lithodiversity, topodiversity, biodiversity, and chronodiversity (Targulian/Goryachkin 2004).

In addition to the impact on functionality of physical and chemical attributes, belowground biodiversity also moderates structure and functions of terrestrial ecosystems (Bardgett/van der Putten 2014). More specifically, soil biodiversity strongly impacts both ecological and evolutionary responses of terrestrial ecosystems to present and future climate/environmental change (Bardgett/van der Putten 2014). The ecological impact of climate change is intricately linked with that of the CO_2 fertilization effect. For example, Niklaus et al. (2003) observed, from a 6-years of in-situ CO_2 enrichment experiment, that elevated CO_2 increased micro-aggregates probably because of a higher soil moisture content (because of an increase in net primary productivity and the canopy cover). The elevated CO_2 decreased soil aggregation at the scale from μm to mm, which can affect soil micro faunal population (Niklaus et al. 2003). Since the Climate Summit (COP21) in Paris in December 2015, there is a lot of interest in storage of SOC in the top 40-cm layer. Any strategy to enhance SOC pool would have a strong impact on soil functionality and the provisioning of numerous ecosystem functions. Thus, it is important to develop a standardized protocol to measure changes in SOC pool through addition of biomass-C produced by plants grown on the same landscape unit (Olson et al. 2014).

1.6 Conclusions

Functionality of soil attributes (physical, chemical, biological and ecological) strongly impacts environmental sustainability. The SOC concentration and quality are key indicators of soil functionality because of their impacts on soil ecosystem services which moderate nature conservancy. In addition to the impacts on hydro-thermal regimes and biodiversity, SOC pool also impacts pore continuity and stability. The latter are also impacted by soil aggregation, which in turn may be altered by CO_2 enrichment and belowground biodiversity. Soil memory of historic processes depends on specific pedogenic processes which have been in operation over the pedogenic processes.

Degradation of soil functionality can lead to numerous ecosystem disservices including eutrophication, gaseous emissions, accelerated erosion, secondary salinization, loss of biodiversity, decline in net biome/ecosystem productivity, and decline in quantity and quality of food and feed. The health of soil (ie. functionality), plant, animal, human and ecosystems is one and indivisible. Therefore, restoration and sustainable management of soil functionality are important to human wellbeing, nature conservancy and environmental sustainability.

Soil functionality of agroecosystems can be enhanced by adoption of conservation agriculture, and by those landuse and management practices which create a positive soil/ecosystem C budget, enhance soil biodiversity, and strengthen mechanisms of nutrient cycling.

Soil functionality index (SFI), similar to that of soil quality index, can be used as a surrogate of soil functionality. However, the choice of sol parameters (indicators) depends on specific landuse and the desired soil/ecosystem services. In addition to SFI, additional research is needed towards (Kerzentsev 2010):

i. Developing mathematical models of soil functionality,
ii. Strengthening of scientific, methodological and technological principles of soil functionality,
iii. Identifying soil-specific landuse and management systems to restore soil functionality,
iv. Using soil functionality to address global issues of the 21st century, and
v. Relating soil functionality to climate change adaptation and mitigation.

References

Aune, J.; Lal, R., 1997: “Agricultural Productivity in the Tropics and Critical Limits of Properties of Oxisols, Ultisols, and Alfisols”, in: *Tropical Agriculture,* 74: 96–103.

Bardgett, R.; van der Putten, W., 2014: “Belowground Biodiversity and Ecosystem Functioning”, in: *Nature*, 515: 505–511.

Bartlett, A., 1997: “Environmental Sustainability”, Presented at the Annual Meeting of the American Association of Physic Teachers, Denver, Colorado, 16 August.

Blum, W.E.H.; Eijsakers, H.J.P.; Hammers, T., 1993: *Soil Protection Concept of the Council of Europe and Integrated Soil Research. Soil and Environment. Vol. 1* (Dordrecht: Kluwer Academic Publishers): 37–47.

Daly, H.E., 1990: “Towards Some Operational Principles of Sustainable Development”, in: *Ecology and Economy,* 2: 1–6.

Dörner, J.; Sandoval, P.; Dec, D., 2010: “Role of Soil Structure on the Pore Functionality of Autisol”, in: *Journal of Soil Science and Plant Nutrition,* 10: 495–508.

De Araújo Filho, J.C.; Gunke, G.; Sobral, M.C.M.; et al., 2013: “Soil Attributes Functionality and Water Eutrophication in the Surrounding Area of Itaparica Reservoir, Brazil”, in: *Revista Brasileira de Engenharia Agrícola e Ambiental,* 17: 1005–1013.

Goodland, R., 1992: “The Case that the World has Reached Limits—More Precisely that Current Throughput Growth in the Global Economy Cannot Be Sustained”, in: *Population and Environment,* 13: 167–182.

Greenland, D.; Rimmer, D.; Payne, D., 1975: “Determination of Structural Stability Class of English and Welsh Soils, Using a Water Coherence Test”, in: *Journal of Soil Science,* 26: 294–303.

Isbell, F.; Calcagno, V.; Hector, A.; et al., 2011: “High Plant Diversity is Needed to Maintain Ecosystem Services”, in: *Nature,* 477: 199–196.

Jenny, H., 1941: *Factors of Soil Formation* (New York: Dover Publications, Inc.).

Kemper, W.D.; Koch, E.J., 1966: *Agricultural Stability of Soils from Western U.S. and Canada* (Washington, D.C: USDA Technical Report).

Kerzhentsev, A.S., 2010: “Soil Functionality and Ecosystem Sustainability”, in: *Herald of the Russian Academy of Science,* 80: 360–364.

Lal, R., 2009a: “Ten Tenets of Sustainable Soil Management”, in: *Journal of Soil and Water Conservation,* 64: 20A–21A.

Lal, R., 2009b: “Laws of Sustainable Soil Management”, in: *Agronomy and Sustainable Development,* 29: 7–9.

Lal, R., 2015: “Sequestering Carbon and Increasing Productivity by Conservation Agriculture”, in: *Journal of Soil and Water Conservation,* 70: 55A–62A.

Loveland, P.; Webb, J., 2003: “Is There a Critical Level of Organic Matter in the Agricultural Soils of Temperate Regions: A Review”, in: *Soil & Tillage Research,* 70: 1–18.

Mukherjee, A.; Lal, R., 2014: “Comparison of Soil Quality Index Using Three Methods”, in: *Plos One*, 9: 1–15.

Niklaus, P.; Alphei, D.; Ebersberger, D.; et al., 2003: “Six Years of in-situ CO_2 Enrichment Evoke Changes in Soil Structure and Soil Biota of Nutrient-Poor Grassland”, in: *Global Change Biology,* 9: 585–600.

Olson, K.; Al-Kaisi, M.; Lal, R.; et al., 2014: Experimental Consideration, Treatments, and Methods in Determining Soil Organic Carbon Sequestration Rates”, in: *Soil Science Society of America Journal,* 78: 348–360.

Pimental, D.; Sparks, D., 2000: “Soil as an Endangered Ecosystem”, in: *Bioscience,* 50: 947–947.

Rillig, M.; Mummey, D., 2006: “Mycorrhizas and Soil Structure”, in: *New Phytologist*, 171: 41–53.

Scheer, M.B.; Curcio, G.R.; Roderjan, C.V., 2011: “Functional Idades Ambientais de solos altomontanos ne serra da Igreja, Paraná”, in: *Rev. Bras. Ciênc. Solo*, 35,4 (Viçosa July/Aug.).

Sciubba, L.; Cavani, L.; Marzadori, C.; et al., 2013: “Effect of Biosolids from Municipal Sewage Sludge Composted with Rice Husk on Soil Functionality”, in: *Biology and Fertilizer in Soils,* 49: 597–608.

Targulian, V.O.; Goryachkin, S.V., 2004: “Soil Memory: Types of Record, Carriers, Hierarchy and Diversity”, in: *Revista Mexicana de Ciencias Geológicas,* 21: 1–8.

Tennesen, M., 2014: “Rare Earth”, in: *Science,* 346: 692–695.

Tsiafouli, M.; Thebault, E.; Sgardelis, S.; et al., 2015: “Intensive Agriculture Reduces Soil Biodiversity Across Europe”, in: *Global Change Biology,* 21: 973–985.

Yong, R.N.; Nakano, M.; Pusch, R., 2012: *Environmental Soil Properties and Behaviors* (Boca Raton, FL: CRC Press).

Chapter 2
New World Atlas of Desertification and Issues of Carbon Sequestration, Organic Carbon Stocks, Nutrient Depletion and Implications for Food Security

Pandi Zdruli, Rattan Lal, Michael Cherlet and Selim Kapur

Abstract Soils are both sinks and sources of C with great potential to mitigate climate change. Global estimates indicate that they contain between 1,206 Pg of soil organic carbon (SOC) to 1-m depth to more than 1,550 Pg C, which is twice the amount of C present in the atmosphere. Nevertheless the overall the C stocks could reach as much as five times that of the atmosphere considering that many soils are much deeper than 1 m. Instead, emissions from land use change are estimated to make up to 20 % of atmospheric CO_2 through loss of biomass and SOM. Notwithstanding these critical outcomes, soil's impact in climate change scenarios is generally not well understood and the UNFCCC after CoP 21 in Paris started to increase attention to the potential for soil C sequestration thanks to the French "4 pour 1000" initiative. We argue that SLM can increase productivity particularly by improving water use efficiency, optimizing nutrient cycles and their supply for crop production, enhancing vegetation cover, and improving food security level. Healthy soils produce healthy food, support healthy living, and promote a healthy environment.

Keywords Desertification · Atlas · Carbon sequestration · Global carbon · Sustainable land management

---

P. Zdruli, Prof. Dr., International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), Mediterranean Agronomic Institute of Bari Land and Water Resources Management Department, Via Ceglie 9, 70010 Valenzano Bari, Italy; E-mail: pandi@iamb.it.

R. Lal, Prof. Dr., The Ohio State University, Carbon Management Sequestration Center, 2021 Coffey Rd., Columbus, OH 43210, USA; E-mail: Lal.1@osu.edu.

M. Cherlet, European Commission, Joint Research Centre, Institute for Environment and Sustainability, Land Resource Management Unit Via Enrico Fermi 2749 TP280, I-21027 Ispra (VA), Italy; E-mail: michael.cherlet@jrc.ec.europa.eu.

S. Kapur, Prof. Dr., University of Çukurova, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Balcalı, 01330 Adana, Turkey; E-mail: kapurs@cu.edu.tr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_2

2.1 Overview of the World Atlas of Desertification

A novel *World Atlas of Desertification* (WAD) is being compiled under the coordination of the Joint Research Centre (JRC) of the European Commission in partnership with the United Nations Environment Program (UNEP). The novel WAD will be available as both a published reference atlas and an online digital information portal. It builds upon recent scientific progress by taking a pragmatic and robust approach to the use of current concepts to assess and map land degradation and desertification. The updated WAD provides a foundation for improved mitigation strategies regarding global issues of food security, resource base efficiency, climate change, sustainable development and poverty reduction.

An entire chapter within the novel WAD is devoted to soil issues. Issues are organized in an ecosystem-based approach that identifies soil function and provides a detailed background. Additional attention is devoted to global soil resource availability and its capacity to feed a growing population that is expected to reach over 9 billion by 2050. The global average of per capita agricultural land decreased from 0.39 ha per person in 1960 to 0.21 ha in 2007 and continues to decline. Worldwide crop cultivation is practiced on 1.6 billion ha, but the distribution of arable land is extremely uneven. China and India account for more than 35 % of the total global population, and both have exploited most of their available land and water resources for agriculture. Similar situations exist throughout the Mediterranean and particularly in North Africa and the Middle East where only 5 % of the land is suitable for agriculture (Zdruli 2012).

2.2 Importance of Soils for Carbon Sequestration

Soils are both carbon sinks and sources. Global estimates indicate that soil up to 1 m depth contains between 1,206 Pg of soil organic carbon (SOC) (Hiederer/Köchy 2011) and more than 1,550 Pg C (Lal 2004; Baveye/Jacobson 2007), which is about twice the amount of atmospheric carbon (800 Pg). The total carbon soil stock could actually be up to five times that of the atmosphere because many soils are present at depths greater than 1 m. In particular, soils such as Mollisols (Soil Taxonomy) or Chernozems (WRB) are extremely important for storing organic carbon and providing food and fiber. Although soils cover only 3 % of global land area, they produce more than 40 % of the global food and over 90 % of these soils are used for cereal production (Eswaran et al. 2003). Soils must be considered as both national and international assets and be protected from any form of degradation.

The annual flux of carbon dioxide (CO_2) between the soil and atmosphere is estimated to be six times the amount derived from fossil fuels (GSP 2011). The amount of carbon stored in soil is about 300 times the amount released annually from burning fossil fuels. Emissions from land-use changes are estimated to contribute 20 % of atmospheric CO_2 as a result the loss of biomass and SOM (Smith et al. 2007). Land use intensification has significant effects on the stability of soil ecosystems. These effects may assist in the prediction and modelling of climate change responses, especially when the peculiar effects of soil biota are also considered (de Vries et al. 2013).

Although drylands store much less SOC per hectare than humid regions, the vast surface area they cover globally (nearly 40 % of land cover) makes them an important global carbon sink (Lal 2009). The potential for SOC storage per hectare in dryland soils may be comparable to that in soils of the humid areas. Large dryland soil ‘sink capacity’ is created when high amounts of SOC are lost through degradation, which soils in humid regions may not experience (Farage et al. 2007).

Large quantities of carbon are stored in waterlogged and permafrost soils. Permafrost soils could potentially emit potent greenhouse gases (GHGs) such as methane (CH_4) and nitrous oxide (N_2O) if the permafrost layer is affected by thawing or if wetlands are desiccated. These worst case scenarios could cause climate change to increase rapidly because the GHG CH_4 is 18–25 times more potent than CO_2. Despite these critical outcomes, the impact of soil in various climate change scenarios is generally not well understood. The United Nations Framework Convention on Climate Change process has paid little attention to the potential for soil C sequestration.

2.3 Soil Organic Matter and Soil Quality

Soil quality is the capacity of a soil to perform ecosystem functions and provide ecosystem services. Soil quality depends on key determinants (Lal 2012). SOM is a key constituent in this context that heavily impacts soil quality through positive effects on physical, chemical, and biological properties of the soil. Depletion of SOM initiates a downward spiral of cascading adverse effects. Conversion from a natural to an agroecosystem (cropland and grazing land) and the attendant changes in water and energy budgets at the ecosystem level cause severe and rapid SOM depletion and negative impacts on physical soil quality. SOM depletion reduces aggregation and has adverse effects on soil structure and tilth in addition to GHG emissions into the atmosphere (Fig. 2.2).

Decreased soil structure leads to densification, water infiltrability reduction, increased erosion susceptibility and decreased availability of green water for plant growth. Disrupted elemental cycling and reduced availability of plant nutrients decrease the efficiency of inherent and applied resources as well as agronomic productivity. The downward spiral initiated by SOM depletion adversely affects farm income. Similarly, SOM decline below the threshold level adversely impacts soil chemical, biological and ecological processes that lead to a range of degradation processes. These processes include alteration of soil reactions; elemental imbalances of deficiency and toxicity, salinization and sodication; and reduction in activity and species diversity of soil fauna, flora and microbial biomass carbon (MBC). Severe SOM depletion causes impacts such as the breakdown of

Fig. 2.1 A fertile Chernozem from Hungary. *Source* E. Micheli who granted permission to use this photo

community wellbeing, civil structure and political instability that ultimately lead to societal collapse (Diamond 2006) (Fig. 2.1).

SOC comprises 50–60 % (average 58 %) of the global SOM stock in addition to providing a source of nutrients (macro and micro) and other elements. Thus, the SOC stock is among the principal terrestrial carbon stocks. These stocks vary among biomes or eco-regions because of differences in climate, soil type, physiography, vegetation, and land use (Fig. 2.3). The pedologic (soil originated) soil carbon pool comprises the two distinct, yet related, components of soil inorganic carbon (SIC) and SOC stocks. The pedologic pool to 3 m depth is estimated at 4,000 Pg, i.e. ~5 times the atmospheric pool (800 Pg) and 6.45 times the biotic stock (620 Pg). The pedologic carbon stock influences carbon cycling and heavily impacts radiative forcing and soil albedo through close interaction with biotic and climatic stocks and changes in the soil-related flux of GHGs (Rubio 2007). The magnitude of the flux of GHGs from soil to atmosphere depends on land use, soil/animals/vegetation management and the antecedent SOC pool.

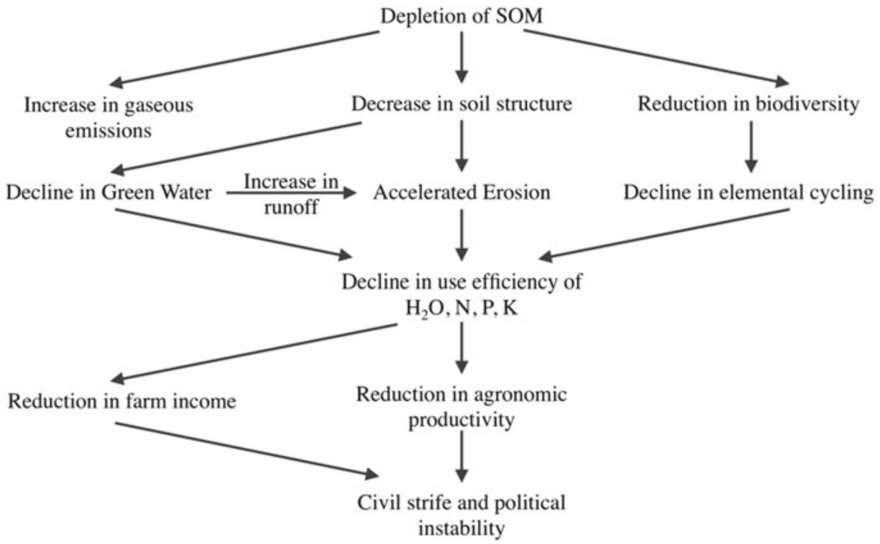


Fig. 2.2 Impact of the soil organic matter depletion on ecosystem functions and services. *Source* The authors

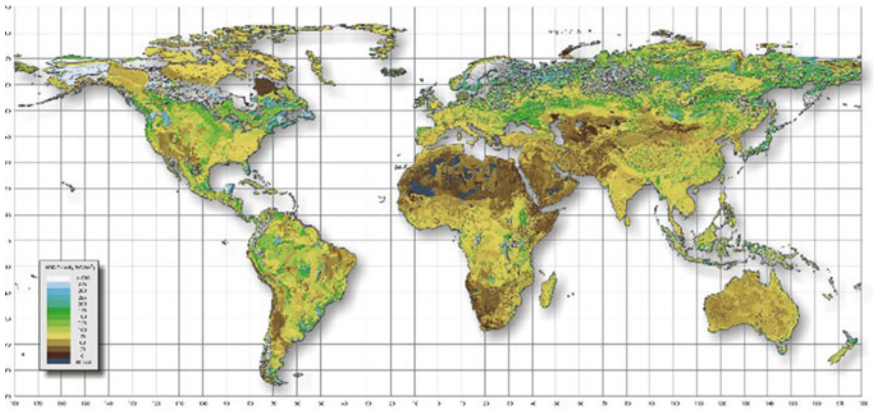


Fig. 2.3 Estimates of global soil organic carbon density from amended harmonized world soil database (Mg C ha^{-1}). *Source* Hiederer/Köchy (2011)

2.4 Land-Use/Cover Change and the Impact on SOC Stocks

Conversion from natural ecosystems to agroecosystems leads to decreased SOC stock (Lal 2004; Zdruli et al. 2014). The magnitude and rate of decline are generally higher in tropical soils than in temperate regions. Drastic perturbations caused by land-use conversion and soil/crop/animal management heavily impact soil physical, chemical, biological and ecological properties and processes (Fig. 2.2). Pedological and ecological processes impacted include alterations in hydrothermal regime, energy budget, biochemical transportation, rhizospheric processes, microclimate and the rate of SOM decomposition and turnover. The overall impact is decreased net primary productivity (NPP), net ecosystem productivity (NEP) and net biome productivity (NBP). The threshold level of SOC concentration in the root zone is 1.1–2.0 % (temperate soils higher than tropical soils). Drastic reduction in the SOC concentration magnitude has a negative feedback which exacerbates the rate and magnitude of SOC stock depletion.

A wide range of factors determine the SOC stock depletion. There are economic, political, societal, cultural and human dimensions in addition to the biophysical factors. Reduced input of biomass carbon causes decreased SOC stock in agroecosystem soils. A negative ecosystem carbon budget reduces soil biodiversity, disrupts aggregation, degrades soil structure, exacerbates soil erosion hazards, decreases green water supply, increases risk of drought stress, disrupts elemental cycling and reduces soil fertility (Fig. 2.4).

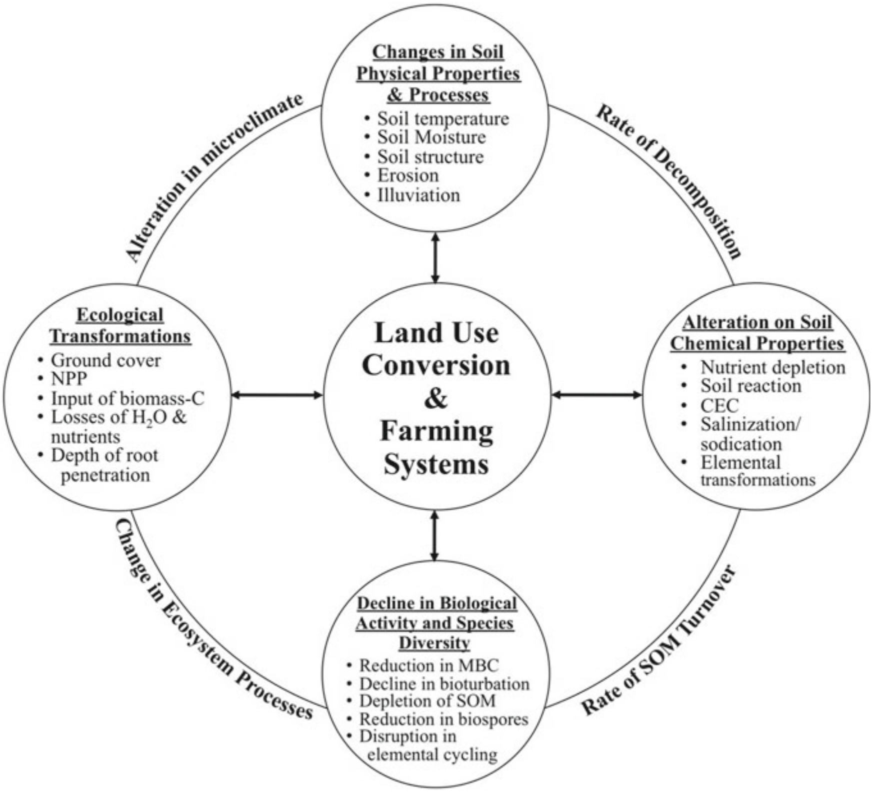


Fig. 2.4 Effects of land use conversion and farming systems on soil properties, processes, and ecosystem functions. *Source* The authors

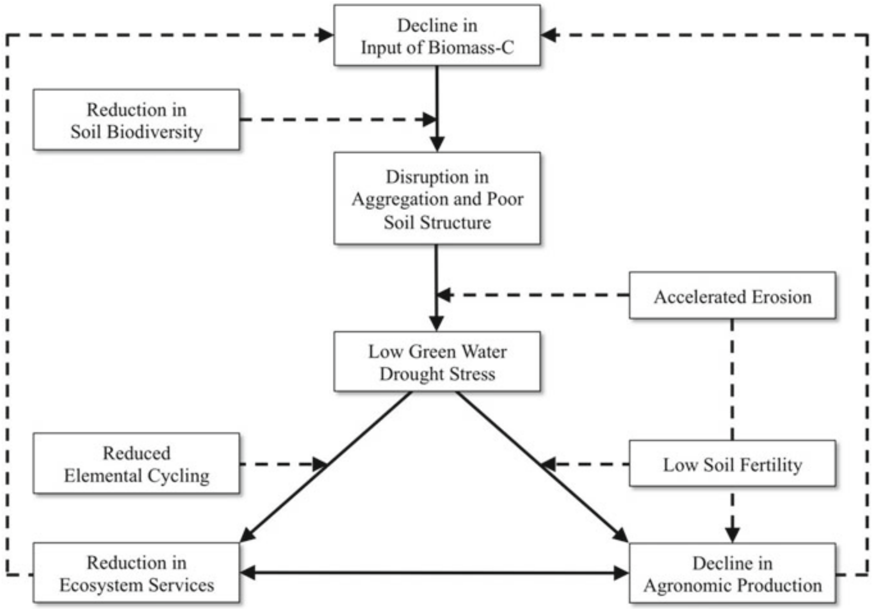


Fig. 2.5 Factors affecting soil organic carbon pool depletion in agroecosystems. *Source* The authors

Negative feedback to the SOC pool is the net effect of decreased agronomic production and reduced ecosystem services (Fig. 2.5). Accelerated soil erosion adversely affects the on-site SOC stock. Despite the limited amount of research on the fate of carbon transported by erosional processes on a watershed scale, erosion has been found to severely deplete the soil SOC stock of erosion-prone ecosystems (Lal 2003, 2004; Lal et al. 2004). Decreasing trends in SOC stock can be reversed by adopting best management practices (BMPs) that also have a low carbon footprint. The most important among a wide range of generic BMPs are no-till farming, cover cropping, integrated nutrient management, agroforestry systems and complex/diverse farming systems.

2.5 Global SOC Estimates

Although the issue of soil carbon sequestration is still a highly debated and complex topic, the general consensus is that increasing soil carbon stocks could be a highly cost effective (Grace et al. 2011) and environmentally suitable mitigation technique (Mermut 2010). Global and continental estimates of SOC stocks were made (Batjes 1996) and a close link between these stocks and potential CO_2 emissions from soil under different scenarios of land-use/cover and climatic change conditions were developed (IPCC 2006). A few global estimates are presented as spatial data. Based on the complete dataset derived from the Harmonized World Soil Database (HWSD) version 1.2, Hiederer/Köchy (2011) estimated global SOC stocks separately for depths 0–30 cm (topsoil) and 30–100 cm (subsoil) or shallower depending on effective soil depth. The study found that the Earth's topsoil contains 574 Pg C and the subsoil 632 Pg C, which totals 1,206 Pg C for 1 m depth. These estimates largely depend on availability and quality of soil data and especially bulk density values that are often missing. Other uncertainties are derived from the various relationships between SOC and bulk density in mineral and organic soils and numerous other factors (Schrumpf et al. 2011).

2.6 Soil Nutrient Mining

The cycling of nutrients in ecosystems is closely related to the flow of energy (Gliessman 2007) and biomass transformation from biotic to abiotic components and vice versa via processes referred to as the *biogeochemical* cycles. The main cycles recognized are carbon, oxygen and nitrogen, while the atmosphere serves as the primary abiotic reservoir (Pidwirny 2006). Less mobile elements such as phosphorus, sulfur, potassium, calcium and most trace elements have local cycles and the soil remains their main abiotic reservoir. These nutrients are taken up by plant roots, stored for a period of time in biomass and eventually returned to the soil by soil decomposers within the same ecosystem. The soil ecosystem may collapse with severe consequences to food security and other ecosystem services when the nutrient balance in the soil is disturbed by high losses from harvest, land-use changes, leaching and erosion (Jones et al. 2013).

Soil nutrient depletion has severe economic impacts at the global scale; however, in Sub-Saharan Africa (SSA), they are more pronounced than anywhere else. Studies conducted since the mid-1980s (Stoorvogel et al. 1993) calculated nutrient balances for 38 countries in SSA and estimated annual soil fertility depletion rates of 22 kg N, 3 kg P and 15 kg K ha^{-1} or the annual equivalent of 4 billion USD worth of fertilizer (Gilbert 2012). In Zimbabwe, soil erosion resulted in an annual loss of nitrogen and phosphorus totaling 1.5 billion USD (Eswaran et al. 2001) and 17.8 million tons of soil nutrients were lost from arable land annually due to land degradation. In South Asia, annual economic losses were estimated at 600 million USD for nutrient losses caused by erosion and 1,200 million USD due to soil fertility depletion (Stocking 1986; UNEP 1994). Furthermore, the Costa Rican Ministry of Environment showed that reduced soil fertility and soil erosion caused a 7.7 % drop in national agricultural Gross Domestic Product from 1970 to 1989 (Thatcher 2012). Additionally, the US annual harvest of major crops removes about 7.8 Tg of nitrogen (excluding the N_2–fixing crops alfalfa [*Medicago sativa* L.], soybean [*Glycine max* (L.) Merr.] and peanut [*Arachis hypogaea* L.]); 2.3 Tg of phosphorus; and 6.7 Tg of potassium with removals increasing by roughly 1 % $year^{-1}$ (IPNI 2010).

Nutrient depletion of soils combined with accelerated erosion and reduced fallow periods have direct consequences on crop productivity, food production, food security and human livelihood. Options for remediation and mitigation of soil nutrient mining include both the use of chemical fertilizers (IFPRI 2011) and green manure application through the expansion of nitrogen-fixing crops and trees or mixing organic waste with the soil. Organic farming has additional benefits. For example, the use of manures supports the development of microbial communities that are more complex than those from the use of synthetic fertilizers (Sradnick et al. 2013). However, these methods are complementary because neither of them alone solves the problem of soil fertility depletion. Many farmers in inland regions of Africa pay twice as much for fertilizers compared with European or US farmers due to high transportation costs. Data show that 40–60 % of the food produced in the US and UK is a result of fertilizer use (Stewart et al. 2005). One of the reasons for low yields recorded across SSA is that fertilizer use amount has remained constant at around 9 kg ha^{-1} of cultivated land over the past 40 years. In comparison, the use of inorganic fertilizers in Asia has increased to 96 kg ha^{-1} (Gilbert 2012). Increased population pressure in SSA and throughout Africa stresses the importance of the population–agriculture–environment nexus that remains severely unsustainable for much of the continent (Drechsel et al. 2001).

2.7 Sustainable Land Management Is the Answer for Carbon Sequestration and Food Security

Sustainable land management (SLM) can increase productivity by improving water use efficiency, optimizing nutrient cycling and supply for crop production, enhancing vegetation cover and improving food security. Healthy soils produce healthy food, support healthy living and promote a healthy environment.

Despite the possibility that economic benefits of some agricultural practices by carbon sequestration potential may be questionable in the long run, the World Overview of Conservation Approaches and Technologies (WOCAT) initiative has shown (WOCAT 2007) that SLM has the potential to increase yields by 30–170 %, increase water use efficiency by up to 100 % and increase SOC concentration by 1 % in degraded and up to 2–3 % in non-degraded soils (Lam et al. 2013). The most common SLM techniques include soil and water management (terracing, contour planting, living barriers, low tillage, mulches, cover crops including biological N-fixing (BNF) legumes that add a large quantity of N in just one season, grazing corridors and water harvesting) and soil fertility management (manure, compost, biochar,[1] biomass transfer, agro- forestry, N-fixing trees like [*Faidherbia albida* L.] and integrated overall soil management). Furthermore, approaches like EverGreen agriculture as a form of more intensive farming that integrates trees with

---

[1] See at: http://www.biochar-international.org.

annual crops to sustain green cover on the land throughout the year and 'climate-smart agriculture' that includes techniques such as mulching, inter-cropping, no-till farming, improved grazing and better water management demonstrate their efficiency through increased income and environmental benefits that reduce greenhouse gas emissions and enhance food security (WBI 2012).

Additionally, conservation agriculture (no-till, bed-and-furrow technologies, residue management, cover cropping, rotations, etc.), especially in the drylands, shows promise because it provides a low-cost entry point for long-term sustainability. Conservation agriculture is based on the 'no-till' approach that aims to reduce the impact of farming on the environment and on the farmland itself. It is characterized by three principles: (i) minimum mechanical soil disturbance, (ii) permanent organic soil cover and (iii) diversification of crop species grown in sequences and/or associations and rotations.

The worldwide conservation farming area was estimated to be around 105 million ha in 2008 (FAO 2009) and increased to about 125 million in 2012; however, almost half the increase occurred in Latin America (Friedrich et al. 2012). No-till is practiced on about 70 % of arable cropland in countries like Brazil, Argentina, Paraguay, Uruguay, Australia and New Zealand, while in the US that figure is only 25 % of the cropland (Kruger 2012). The next most promising result of conservation agriculture is erosion control in addition to increasing and sustaining yields.

Conservation tillage (Amato et al. 2013) also requires less energy and labor. Thus, it reduces costs and environmental impacts, increases SOC concentration and improves soil tilth and fertility. Overall SOM content increase is important because it is considered the 'elixir of life' for soil. However, this technique relies heavily on herbicide use for weed control and may cause resistant weeds to develop, as in the case of cotton [*Gossipium hirsutum* L.] Fertilizers will continue to play an important role in increasing crop production, especially in less developed countries, but they must be carefully applied on the basis of soil characteristics and crop nutrient requirements.

2.8 Conclusion

The SLM strategies offer tremendous opportunities and benefits, especially for drylands:

- Reverse negative trends in resource-based degradation and declining agricultural productivity,
- Contribute to mitigation and adaptation to climate change and other environmental threats,
- Improve local livelihoods by reducing poverty and improving food security,
- Preserve and enhance ecosystem services and functionality, and
- Provide important environmental benefits at local, regional and global levels.

However, issues of SLM, soil quality (Bone et al. 2012) and holistic adaptive land management (Herrick et al. 2012) require a profound recognition of local conditions as there are no universal 'ready-to-use recipes' for every location on earth. Each approach must be tailored and adopted locally.

The UNCCD also promotes the *zero-net land degradation* by 2030 initiative (UNCCD 2012) based on the principle that for each degraded hectare of land, another one must be restored or rehabilitated to build a land-degradation neutral world (Stringer 2012). Another example is the African great green wall for the Sahara and the Sahel; this represents a concrete example of Africa's contribution to the achievement of neutral land degradation.

Is it possible to defeat soil degradation and increase the capacity of soils to sequester carbon? Despite numerous positive and well documented examples worldwide this question remains critical unless immediate action is taken and the necessary policy and implementation frameworks for SLM are enacted through a holistic approach. Societies may need to prepare for the possibility that this conquest might take quite a long time to fully accomplish unless these requirements are met.

References

Amato, G.; Ruisi, P.; Frenda, A.S.; et al., 2013: "Long-Term Tillage and Crop Sequence Effects on Wheat Yield and Quality", in: *Agronomy Journal,* 105: 1317–1327.

Baveye, P.C.; Jacobson, A.R., 2007: "Soil Science Education and the 'Age of Money': Reflections and Concerns for the Near Future", in: *Water, Air, and Soil Pollution,* 187: 1–4.

Batjes, N.H., 1996: "Total Carbon and Nitrogen in the Soils of the World", in: *European Journal of Soil Science*, 47,2: 151–163; at: doi:10.1111/j.1365-2389.1996.tb01386.x.

Bone, J.; Barraclough, D.; Eggleton; et al., 2012: "Prioritising Soil Quality Assessment Through the Screening of Sites: The Use of Publicly Collected Data", in: *Land Degradation and Development,* 23,3: 252–266.

de Vries, F.T.; Thébault, E.; Liiri, M., 2013: "Soil Food Web Properties Explain Ecosystem Services Across European Land Use Systems", in: *Proceedings of the National Academy of Sciences*; at: doi:10.1073/pnas.1305198110.

Diamond, J., 2006: *Collapse: How Societies Chose to Fail or Succeed* (New York: Viking Press).

Drechsel, P.; Kunze, D.; de Vries, F.P., 2001: "Soil Nutrient Depletion and Population Growth in Sub Saharan Africa: A Malthusian Nexus. Population and Environment", in: *A Journal of Interdisciplinary Studies,* 22,4: 411–423.

Eswaran, H.; Lal, R.; Reich, P.F., 2001: "Land Degradation: An Overview", in: Bridges, E.M.; Hannam, I.D.; Oldeman, L.R.; Pening de Vries, F.W.T.; Scherr, S.J.; Sompatpanit, S. (Eds.): *Responses to Land Degradation.* Proceedings of the 2nd International Conference on Land Degradation and Desertification, Khon Kaen, Thailand (New Delhi: Oxford University Press).

Eswaran, H.; Beinroth, F.H.; Reich, P.F., 2003: "A Global Assessment of Land Quality", in: Wiebe K. (Ed.): *Land Quality, Agricultural Productivity, and Food Security: Biophysical Processes and Economic Choices at Local, Regional, and Global Levels* (Cheltenham: Edward Elgar Publishing): 111–132.

FAO, 2009: *Agriculture: Achieving Sustainable Gains in Agriculture*. Fact Sheet of FAO Programme (Rome: FAO); at: http://www.fao.org/about/en/.

Farage, P.K.; Ardo, J.; Olsson, L.; et al., 2007: "The Potential for Soil Carbon Sequestration in Three Tropical Dryland Farming Systems of Africa and Latin America: A Modelling Approach", in: *Soil & Tillage Research,* 94: 457–472.

Friedrich, T.; Derpsch, R.; Kassam, A., 2012: "Overview of the Global Spread of Conservation Agriculture", in: *Field Action Science*, 6: 1–17.

Gilbert, N., 2012: "Dirt Poor: The Key to Tackling Hunger in Africa is Enriching Its Soil", in: *Nature*, 483: 525–527.

Gliessman, S.R., 2007: *Agroecology: The Ecology of Sustainable Food Systems*, 2nd ed. (London: CRC).

GSP, 2011: *Towards the Establishment of the Global Soil Partnership—Terms of Reference Working Document* (Rome: FAO).

Grace, P.R.; Antle, J.; Aggarwal, P.K.; et al., 2011: "Soil Carbon Sequestration and Associated Economic Costs for Farming Systems of the Indo-Gangetic Plain: A Meta-Analysis", in: *Agriculture, Ecosystems and Environment*, 146: 137–146.

Herrick, J.E.; Duniway, M.C.; Pyke, D.A.; et al., 2012: "A Holistic Strategy for Adaptive Land Management", in: *Journal of Soil and Water Conservation,* 67,4: 105A–113A.

Hiederer, R.; Köchy, K., 2011: *Global Soil Organic Carbon Estimates and the Harmonized World Soil Database*. EUR 25225 (Luxembourg: Publications Office of the European Union).

IFPRI, 2011: *Global Food Policy Report* (Washington DC: International Food Policy Research Institute); at: doi:10.2499/9780896295476.

IPCC [Eggelstone, S.; Buemdia, L.; Miwa, K.; Ngara, T.; Tanabe. K. (Eds.)], 2006: *Guidelines for National Greenhouse Gas Inventories* (Hayama, Japan: IPCC/OECD/IEA/IGES).

IPNI, 2010: *A Preliminary Nutrient Use Geographic Information System (NuGIS) for the US.* Publ. 30-3270 (Norcross, GA: International Plant Nutrition Institute).

Kruger, S.H., 2012: "Conservation Crusader: Paraguayan Rolf Derpsch Helped Expand No-till Across Globe", in: *Corn and Soybean Digest*; at: http://cornandsoybeandigest.com/conservation/conservation-crusader-paraguayan-rolf-derpsch-helped-expand-no-till-across-globe (20 January 2014).

Jones, D.L.; Cross, P.; Withers, P.J.A.; et al., 2013: "Nutrient Stripping: The Global Disparity Between Food Security and Soil Nutrient Stocks", in: *Journal of Applied Ecology*; at: doi:10.1111/1365-2664.12089.

Lal, R., 2003: "Soil Erosion and the Global Carbon Budget", in: *Environment International,* 29: 437–450.

Lal, R., 2004: "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security", in: *Science*, 304: 1623–1627.

Lal, R.; Griffin, M.; Apt, J.; et al., 2004: "Managing Soil Carbon", in: *Science,* 304: 393.

Lal, R., 2009: "Sequestering Carbon in the Soils of Arid Ecosystems", in: *Land Degradation & Development,* 20: 441–454.

Lal, R., 2012: "Soils and Ecosystem Services", in: Lal, R.; Lorenz, K.; Huttle, R.F.; Schneider, B. U.; Von Braun, J. (Eds.): *Ecosystem Services and Carbon Sequestration in the Biosphere* (Dordrecht: Springer): 11–38.

Lam, S.K.; Chen, D.; Mosier, A.R.; et al., 2013: "The Potential for Carbon Sequestration in Australian Agricultural Soils is Technically and Economically Limited", in: *Nature Science Report*, 3: 2179.

Mermut, A.R., 2010: "Global Warming, Carbon Balance and Land and Water Management", in: Zdruli, P.; Pagliai, M.; Kapur, S.; Faz Cano, A. (Eds.): *Land Degradation and Desertification: Assessment, Mitigation and Remediation* (Berlin: Springer): 67–77.

Pidwirny, M., 2006: *Introduction to the Ecosystem Concept. Fundamentals of Physical Geography*; at: http://www.physicalgeography.net/fundamentals/9j.html.

Rubio, J.L., 2007: "Desertificacion y Cambio Climatico" [Desertification and Climate Change], in: *Ambienta*, 70: 26–27.

Schrumpf, M.; Schulze, E.D.; Kaiser, K.; et al., 2011: "How Accurately Can Soil Organic Carbon Stock Changes Be Quantified by Soil Inventories?", in: *Biogeosciences*, 8: 1193–1212.

Smith, P.; Martino, D.; Cai, Z.; et al., 2007: “Agriculture”, in: Metz, B.; Davidson, O.R.; Bosch, P. R.; Dave, R.; Meyer, L.A. (Eds.): *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press).

Sradnick, A.; Murugan, R.; Oltmanns, M.; et al., 2013: “Changes in Functional Diversity of the Soil Microbial Community in a Heterogeneous Sandy Soil After Long-Term Fertilization with Cattle Manure and Mineral Fertilizer”, in: *Applied Soil Ecology,* 63: 23–28.

Stewart, W.M.; Dibb, D.W.; Johnston, A.E.; et al., 2005: “The Contribution of Commercial Fertiliser Nutrients to Food Production”, in: *Agronomy Journal*, 97: 1–6.

Stocking, M., 1986: *The Cost of Soil Erosion in Zimbabwe in Terms of the Loss of Three Major Nutrients*. Consultant’s Working Paper No. 3 (Rome: FAO Land and Water Division, Soil Conservation Programme).

Stoorvogel, J.J.; Smaling, E.M.A.; Jansen, B.J., 1993: “Calculating Soil Nutrient Balances in Africa at Different Scales. I. Supra-national Scale”, in: *Fertilizer Research,* 35: 227–235.

Stringer, L., 2012: *Global Land and Soil Degradation: Challenges to Soil*. Technical Paper. *Global Soil Week, Berlin 19–22 November 2012. University of Leeds, UK.*

Thatcher, M., 2012: “Costa Rican Farmers Beat Climate Change by Protecting Soil”, at: http://www.insidecostarica.com/dailynews/2012/april/09/costarica12040904.htm.

UNCCD, 2012: “Zero Net Land Degradation”. UNCCD Secretariat Policy Brief May 2012. Bonn, Germany; at: http://www.unccd.int/en/resources/publication/Pages/default.aspx.

UNEP, 1994: “Land Degradation in South Asia: Its Severity, Causes and Effects upon the People”, INDP/UNEP/FAO. World Soil Resources Report 78 (Rome: FAO).

WBI, 2012: *Climate-Smart Agriculture: Helping the World Produce More Food* (Washington, DC: World Bank); at: http://lnkd.in/9JcyfC.

WOCAT, 2007: “Where the Land Is Greener: Case Studies and Analysis of SWC Worldwide”, in: Liniger, H.P.; Critchley. W. (Eds.) (Berne: CTA—University of Berne).

Zdruli, P., 2012: “Land Resources of the Mediterranean: Status, Pressures, Trends and Impacts on Regional Future Development”, in: *Land Degradation & Development*, 25,4: 373–384.

Zdruli, P.; Calabrese, J.; Ladisa, G.; et al., 2014: “Impacts of Land Cover Change on Soil Quality of Manmade Soils Cultivated with Table Grapes in the Apulia Region of South-Eastern Italy”, in: *Catena,* 121: 13–21.

Chapter 3
Terrestrial Ecosystem Carbon Dynamics as Influenced by Land Use and Climate

Sabit Erşahin, Selim Kapur, Gönül Aydın, Erhan Akça, Doğanay Tolunay, Özden Görücü, Gülay Karahan and Bayram C. Bilgili

Abstract Recent increases in atmospheric CO_2 concentration and increased climate variations enforced us to improve our understanding of the terrestrial biosphere to improve human-ecosystem harmony in regard with processes and feedbacks that have functions in the earth system as a whole. Terrestrial ecosystems are principal components of the main carbon pools and land use has a decisive impact on these pools. Studies showed that converting forest and grasslands to farmlands and urban areas can result in considerable amount of carbon losses to atmosphere. However, emitted amounts may depend on the geographical region as well as type of vegetation cover of the converted areas. Recent studies showed that feedbacks between climate change and vegetation is more complicated than it was thought. Combined with these feedbacks, the land use changes may have an intricate impact on carbon exchange between atmosphere and biosphere. Studies showed that the consequences of changes in land use are beyond the expected in terms of ecosystem functioning and environmental quality. Complex interactions among climate, soil, plant productivity, and land management should be understood

---

S. Erşahin, Prof. Dr., Department of Forest Engineering, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey; E-mail: acapsu@gmail.com.

S. Kapur, Retired. Department of Soil Sciences and Plant Nutrition, Faculty of Agriculture, Çukurova University, 01711 Balcalı, Adana, Turkey; E-mail: kapurs@cu.edu.tr.

G. Aydın, Prof. Dr., Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Adnan Menderes University, Çakmar, Aydın, Turkey; E-mail: gonaydin@gmail.com.

E. Akça, Assoc. Prof. Dr., School of Technical Sciences, Adıyaman University, Adıyaman, Turkey; E-mail: eakca@adiyaman.edu.tr.

D. Tolunay, Prof. Dr., Department of Forest Engineering, Faculty of Forestry, İstanbul University, İstanbul, Turkey; E-mail: dtolunayistanbul.edu.tr.

Ö. Görücü, Prof. Dr., Department of Forest Engineering, Faculty of Forestry, Kahramanmaraş Sütçü İmam University, Kahramanmaraş, Turkey; E-mail: ogorucu@ksu.edu.tr.

G. Karahan, Assist. Prof. Dr., Department of Landscape Architecture, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey; E-mail: gkarahan03@gmail.com.

B.C. Bilgili, Assoc. Prof. Dr., Department of Landscape Architecture, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey; E-mail: cemilbilgili@gmail.com.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_3

well to balance ecosystem functions and human welfare. In this literature review, we discussed interactions and feedbacks among terrestrial ecosystems and global carbon balance in regard with global climate change.

Keywords Carbon sequestration · Ecosystem functioning · Land use · Global carbon balance · Atmospheric carbon dioxide

3.1 Introduction

The elevated CO_2 concentrations in the atmosphere and its effects on abrupt climate change augmented a considerable interest in the global CO_2 emissions (McKitrick/Strazicich 2005; Lal 2014). Since 1850, approximately 500 Pg carbon is emitted from fossil fuel combustion and land-use changes (Lal 2014). Greenhouse gas emissions have risen to 70 % for the last 30 years, and in spite of 1997 Kyoto Protocol are expected to double or triple in the 21st century. Global surface temperatures have increased by 0.8 °C since the late nineteenth century. In addition, 11 of 12 warmest years on record have occurred since 1995 (IPCC 2007). It is predicted that the temperature of earth will increase by 1.5–5.8 °C during the twenty-first century, and the global temperature has increased by 0.15 °C per decade since 1975 (IPCC 2007).

Atmospheric CO_2 has been increasing since industrial revolution. Concentration of CO_2 increased from 280 ppm in pre-industrial revolution to 390 ppm in 2010 (Lal 2014). Data on atmospheric CO_2 concentration show that rate of increase is not linear. Deforestation, consumption of fossil fuels, and land use changes are the main causes of the elevated atmospheric CO_2 (Vesterdal/Feifeld 2010). Intensified land use and degraded landscapes generally support concentration of the atmospheric CO_2 (Lal 2014). It is very difficult to foresee the causes of the elevated atmospheric CO_2 due to that the earth system dynamics are very complex. For example, it's unknown how the elevated atmospheric CO_2 will alter the net primary product (NPP) of different vegetation across time and ecoregions (Vesterdal/Feifeld 2010).

The principal causes of atmospheric CO_2 increase may be classified in two main groups as human related factors and climate related factors. The harmony between human and landscape is very important in CO_2 sequestration, which mainly determines the amount of carbon emitted to the atmosphere. Sustainability of land use as affected by cultural, social, and economical aspects of the land dwellers is critical in building resilient landscapes to climate changes.

Climate change has a direct impact on ecosystem dynamics (Hudiburg et al. 2009). The feedbacks between atmospheric CO_2 concentrations and ecosystem dynamics are highly unpredictable due to the nonlinearity of the controlling processes (Vesterdal/Feifeld 2010). It's difficult to generalize the feedbacks of terrestrial ecosystems to climate and land use changes across soil types, landscapes, and vegetation. Different soil types respond differently to similar management practices in different climates. Forest management differences may result in huge differences in carbon sequestration in mineral soils, forest stands, and forest floor (Ordóñez et al. 2008). Combined with climate changes, human interventions can further complicate these feedbacks (Heimann/Reichstein 2008).

Understating the terrestrial ecosystem feedbacks to climate change needs conducting long term controlled studies to measure/predict temporal and spatial variation of carbon fluxes and sizes across different soil, vegetation, climate, and land uses. The measurements may be supported with integrated process ecosystem models such as Dynamic Land Ecosystem Model (DLEM) to address responses of terrestrial ecosystems to multiple stressor including land use change, climate change, and ecosystem disturbances (Zhang et al. 2007). The aim of this review is to discuss terrestrial ecosystem carbon dynamics in regard with land use and climate aspects.

3.2 Factors Affecting the Global Carbon Cycle

A significant increase has occurred in the global atmospheric CO_2 concentration in the 21st century which is even accelerated recently (Lal 2014). The atmospheric CO_2 concentration was 280 ppm (parts per million) before industrial epoch and rose to 390 ppm by 21st century (Tans/Keeling 2013). Approximately 500 billion Mg of carbon has been stored in terrestrial vegetation (Janzen 2004). The amount of carbon stored in underground of the ecosystems is predicted approximately 2000 billion Mg (in 1-m deep soils). It was predicted that 1.6 Gt carbon is released into atmosphere per year during the 1990s due to deforestation. On the other hand, terrestrial vegetation is believed to offset this release by absorbing between 2 and 3 Gt C per year at the same time (Broadmeadow/Matthews 2003).

Land carbon sinks have decreased on a global scale. Since 1959, approximately 350 billion tons of carbon has been emitted to the atmosphere, and 55 % of this has moved into the land and oceans. The mechanisms and locations responsible for elevated global carbon uptake are important for balancing the global carbon budget and predicting future carbon-climate interactions (Ballantyne et al. 2012). The average annual global carbon budgets for 1980–1989 and 1989–1998 are shown in Table 3.1. This table shows that the rates and trends of carbon uptake in terrestrial ecosystems are quite uncertain. However, during these two decades, terrestrial ecosystems may have served as a small net sink for carbon dioxide. This terrestrial sink seems to have occurred in spite of net emissions into the atmosphere from land-use change, primarily in the tropics, having been 1.7 ± 0.8 Gt C year^{-1} and 1.6 ± 0.8 Gt C year^{-1} during these two decades, respectively (IPCC 2000).

The oceans contain 50 times as much carbon as the atmosphere, mostly in the deep ocean. Over the time scale of 1000–2000 years, natural uptake of CO_2 by the ocean, combined with dissolution of marine carbonate, will absorb 90 % of the carbon released by human activities (Schrag 2007). An understanding of the degree and timing of the response of this carbon reservoir to perturbations associated with climate or land use changes requires knowledge of both the inventory of carbon in

Table 3.1 Average annual budget of CO_2 for 1980–1989 and for 1989–1998, expressed in Gt C year^{-1} (error limits correspond to an estimated 90 % confidence interval)

	1980–1989	1989–1998
Emissions from fossil fuel combustion and cement production	5.5 ± 0.5	6.3 ± 0.6[a]
Storage in the atmosphere	3.3 ± 0.2	3.3 ± 0.2
Ocean uptake	2.0 ± 0.8	2.3 ± 0.8
Net terrestrial uptake = (1) − [(2) + (3)]	0.2 ± 1.0	0.7 ± 1.0
Emissions from land-use change	1.7 ± 0.8	1.6 ± 0.8[b]
Residual terrestrial uptake = (4) + (5)	1.9 ± 1.3	2.3 ± 1.3

Source IPCC (2000: 10)

[a] Note that there is a 1-year overlap (1989) between the two decadal time periods

[b] This number is the average annual emissions for 1989–1995, for which data are available

soils and the turnover rate of carbon in soil organic matter (Trumbore 1993; Vesterdal/Feifeld 2010). Land use changes mainly disturb the ecosystems dynamics (Vesterdal/Feifeld 2010).

3.3 Land Use and Management

The land-use and land-cover change sector is the second most important source of terrestrial carbon emissions after fossil fuel burning (Lal 2014). Accelerated carbon emission from biosphere contributes significantly to atmospheric change, particularly atmospheric CO_2 concentration (Lal 2014). Estimates of carbon stocks within different land management and cropping systems are an important element in planning sustainable land use that protects carbon (Table 3.2). Tropical countries have a large potential of carbon sequestration through reforestation and restoration of degraded agro-ecosystems (Dixon et al. 1994).

Table 3.2 Global carbon stocks in vegetation and top 1-m of soils

Biome	Area (106 km^2)	Vegetation	Soils	Total
Tropical forests	17.6	212	216	428
Temperate forests	10.4	59	100	159
Boreal forests	13.7	88	471	559
Tropical Savannas	22.5	66	264	330
Temperate Grasslands	12.5	9	295	304
Deserts and semi-deserts	45.5	8	191	199
Tundra	9.5	6	121	127
Wetlands	3.5	15	225	240
Croplands	16.0	3	128	131
Total	151.2	466	2011	2477

Source IPCC (2000: 10)

Conversion of arable lands to forests generally result in carbon sequestration (Lal 2005). However, it's questionable whether legacy of intensive agriculture will be recovered or not (Vesterdal/Feifeld 2010). Chuluun/Ojima (2002) reported that a 30 yearlong study showed that cultivation of Chernozem soils in Northern Kazakhstan caused %25–30 reduction in soil organic matter.

The rate of greenhouse gases being released into the atmosphere has increased mainly by burning of fossil fuels, land clearance, and deforestation (Broadmeadow/Matthews 2003). Forests and forest soils have large capacities to store carbon as compared with other land uses (Dixon et al. 1994). Therefore, researchers and policy makers are interested in forest ecosystem carbon sequestration as forests account for 80–90 % of terrestrial plant carbon and 30–40 % of soil carbon at global scale (Harvey 2000). Since Forests and forest soils have large capacities to both store and release carbon (Dixon et al. 1994), detailed forest ecosystem carbon budgets are helpful for improving our understanding of the terrestrial carbon cycle and for supporting the decision-making processes in forest management (Liu et al. 2006).

Forest management strategies can affect carbon sequestration substantially. However, relation between forest management and carbon sequestration is generally not well known (Vesterdal/Feifeld 2010). As most of the studies focused on the type-effect of the tree species on forest floor carbon sequestration, only little is known on the effect of the forest ecosystem on the carbon sequestration of soils. (Vesterdal/Feifeld 2010). Forest age, forest management, forest type, and disturbance history considerably affect the carbon uptake from atmosphere (Hudiburg et al. 2009). Hudiburg et al. (2009) reported that climate had a most important influence on maximum NPP (net primary product) and dead biomass while forest type had the most important effect on live biomass in the forest of Oregon and Northern California. These researchers also reported that it was possible to increase carbon stocks by 46 % if the forests are managed for maximum carbon storage.

Afforestation may result in highly different carbon sequestration chronosequences across different topographies, soils, forest types, and climate zones. Vesterdal/Feifeld (2010) reported from their afforestation study conducted on former croplands in Denmark, Sweden, and The Netherlands that carbon sequestration rates ranged from approximately zero in two Danish chronosequences to 1.3 Mg ha^{-1} $year^{-1}$ in two Dutch chronosequences and that almost entire of the carbon sequestration took place through forest floor development. They further reported that in contrast to forest floor, mineral soil carbon sequestration showed no obvious patterns. Afforestation in nutrient poor sandy soils had lower carbon sequestration compared to nutrient rich soils, and in short term (30 years) oak and spruce showed a little difference in their effects on carbon sequestration.

Thinning can have considerable influence on the carbon dynamics of forest soils. In general, carbon stocks are largest in weakly thinned stands, while thinning intensity may be offset by site-related differences (Vesterdal/Feifeld 2010). Increased thinning generally results in faster decomposition of litter that causes carbon losses. Organic matter input in thinned forest soils is more continuous compared to traditional clear-cut forest soils. In addition, since better climate is maintained under thinning, litter decomposition will be slower compared to clear-cut system, which will result in a lower carbon emission rates from the system (Vesterdal/Feifeld 2010).

Soils and terrestrial vegetation are vast reservoirs of carbon (Table 3.2). Therefore, the best way to prevent elevated CO_2 concentration in the atmosphere is to increase the amount of CO_2 stored in terrestrial ecosystems (Lal 2014). Improper land-use and land-use changes have been predicted to cause a loss of 1.7 ± 0.8 Gt carbon/year and 1.6 Gt carbon/year during the 1980s and 1990s, respectively (Houghton et al. 2000; Upadhyay et al. 2005). The evolution of the terrestrial carbon sink is largely the result of changes in land use over time (Schimel et al. 2001). Compared to arable lands, forests are greater carbon sequesters (Lettens et al. 2005). On the other hand, Jiao et al. (2010) reported greater soil carbon stocks (0–40 cm) in arable soils than forest and grassland soils. In Southwest Goias of Brazil, some cultivated areas appeared to have greater C stocks than native vegetation (Balieiro et al. 2010). In overall, conversion of native vegetation results in loss of original carbon stocks.

Converting forests and grasslands to arable lands result in decreased carbon sequestration (Ordóñez et al. 2008). However, it is difficult to generalize the rate of change in soil carbon stocks across diverse climate and soil conditions (Vesterdal/Feifeld 2010). Zhang et al. (2007) reported that greater precipitation and lower temperature in higher elevation forests resulted in greater amount of carbon to store in soils compared to those in lower elevation forests in Great Smoky Mountains National Park.

Figure 3.1 shows MODIS-predicted net primary products (NPPs) for different land uses in Turkey in 2006. The NPP of mixed forests is far greater than other land uses. However, the amount of carbon sequestered in soils and vegetation (net biome production: NBP) is critical in evaluating the feedbacks of these ecosystems to abrupt climate change. The NBP may be highly variable across forest types, soil types, and climate as well as across different land uses. Lal (2014) stated that The NBB can be increased to about 10 Pg/year globally through the land use and management.

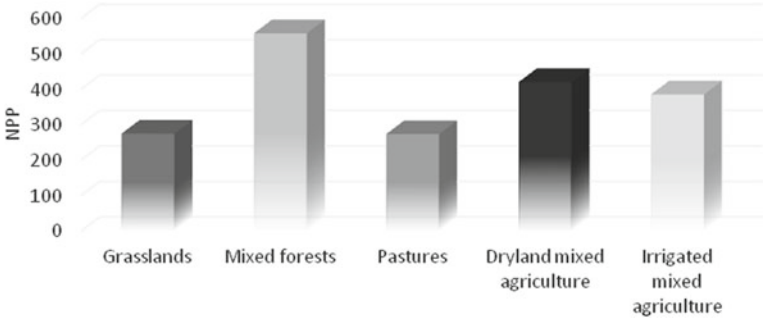


Fig. 3.1 MOD17A3 (Annual MODIS GPP/NPP data sets)-obtained net primary product (NPP; g m^{-2} $year^{-1}$)-values for some principal land uses in Turkey. *Source* Bilgili et al. (2014: 268)

Prediction of large-scale forest ecosystem carbon budget is complicated due to the difficulty of quantifying the impacts of both natural environmental variability and human disturbances. Different management regimes affect the forests to sequester carbon. Succession; direct human activities such as silviculture, harvesting, and clearing for conversion to non-forest use; natural disturbances caused by wildfire or pest outbreaks; and changes in climate and atmospheric pollutants have decisive effects on soil biomass changes (Sivrikaya et al. 2007). The accumulation of carbon by forest stands is often referred to as carbon sequestration. According to Thompson/Matthews (1989), time for soil carbon to reach equilibrium is much longer than that for forest biomass in newly planted forests.

3.4 Soil as a Carbon Sink or Source

The soils are the third largest carbon sink after oceans and calcareous rocks. Approximately 4000 Pg of carbon is stored in world soils to 3-m depth (Lal 2014). Soil texture, depth, and soil organic matter have a significant effect on the amount of soil organic carbon (SOC). The importance of soil texture for the SOC contents was stressed repeatedly as clays are an important component that directly stabilizes organic molecules against degradation (Bationo/Buerkert 2001). It was reported that independent of climatic variations such as precipitation, temperature, and duration of the dry season, SOC increased with the soil clay and silt contents (Six et al. 2002).

Amount of carbon stored in soil ecosystems vary spatially and temporally. The organic carbon content of surface soils directly affect nutrient cycle and the gas exchange with the atmosphere. Little information is available on residence time of carbon in the soil organic matter reservoir, especially regarding its variation with soil forming factors such as climate, topography, time, parent material, and land use. In order to understand the role of the soil carbon pool in the global carbon cycle, it is necessary to quantify the accumulation, transformation, translocation, and decomposition of soil organic matter on different time scales ranging from seasonal to millennial (Trumbore et al. 1996). Models of soil carbon turnover at the ecosystem level differentiate soil organic carbon into fast (annual turnover), slow (decadal to centennial turnover) and passive (millennial and longer turnover) pools.

Similar management practices may have very different impacts on soil carbon stock across different soil, climate, and crop types. Srinivasarao et al. (2009) reported a significant positive correlation ($r = 0.59$, $P < 0.01$) between annual rainfall and soil carbon stocks and that the organic carbon stocks changed between 26.7 and 57.7 Mg ha^{-1} for Inceptisols, between 23.3 and 49.8 Mg ha^{-1} for Alfisols, between 28.6 and 95.9 for Vertisols, and between 20.1 and 27.4 Mg ha^{-1} for Aridisols in a range of cropping systems and climate conditions in dryland farming regions of India.

Prediction of the short-term effects of climate or land use change on soil carbon storage requires determination of soil carbon turnover rates in regard with the feedbacks between SOC and factors such as temperature, precipitation, and soil properties (Trumbore et al. 1996). Changes of SOM is generally reported from long-term studies and is chosen as the most important indicator of soil quality and agronomic sustainability because of its impact on other physical, chemical, and biological indicators of soil quality (Lal 2014).

3.4.1 Agricultural Ecosystems

Carbon dioxide emissions from agriculture are originated from machinery used for cultivating the land, production and application of fertilizers and pesticides, and the SOC oxidized due to soil disturbance such as tillage. Energy and CO_2 emissions associated to different tillage practices are resulted from the fuel used by farm machines and the energy consumed in manufacturing, transportation, and repair of the machines (Bowers 1992). Kern/Johnson (1993) calculated average carbon emissions associated to crop production, based on an energy analysis by Frye (1984), and they predicted that carbon emissions under conventional, reduced, and no-tillage (NT) were 52.8, 41.0, and 29.0 kg C ha^{-1} per year, respectively.

Sequestration of carbon in terrestrial ecosystems, including in agricultural soils, might be used to offset some of the emissions of CO_2 from burning fossil fuels (IPCC 2000). This may be achieved by adaptation of reduced or no-tillage that can lead to sequestration of more carbon in agricultural soils.

Differences among tillage practices in carbon loss depend on crop grown, soil type, and climate. Adaptation of conservation tillage (reduced and no-tillage) practices can reduce the organic carbon loss from soils (Dick 1983; Kern/Johnson 1993). However, results of some studies showed that no till only changed the distribution of carbon in topsoil (in the top 0–5 cm) while it unaffected the amount of total carbon stored in the soil profile. Therefore, greater soil depths than currently applied (20–30 cm) should be sampled to capture the tillage effect on soil carbon sequestration (Baker et al. 2007). The other topics of soil tillage such as erosion control, weed effect, energy consumptions, nitrous oxides emissions, and so on should also be considered besides carbon sequestration in evaluation tillage effects on climate change (Vesterdal/Feifeld 2010).

Crop rotation and application of green manure including winter cover crops and farmyard manure are important factors that should be considered in regard with carbon sequestration of arable soils. Increased soil carbon stocks, resulted from rotations included winter cover crops that provided additional residue input while protecting the soils against erosion, have been reported (Lal et al. 1999). In spite of common belief that manure application enhances soil organic carbon stock, some argued that it results no net sequestration effect in soil carbon stocks since application of manures is simply redistribution of resources (Vesterdal/Feifeld 2010). Besides the crop rotation, crop residue management is an important factor affecting carbon sequestration and organic carbon turnover in arable soils (Vesterdal/Feifeld 2010).

In continuous no-tillage (NT) systems, plant residues accumulate on the soil surface. The lack of tillage, results in less redistribution and greater accumulation of carbon in NT soils. Soil organic matter increases when previously cultivated soils are converted to NT. Reduced tillage and NT affect C/N cycling. This is due primarily to decreased mixing of residues in the plow layer and a decrease in aeration plus an increase in soil water content. Soil organic carbon is significantly greater under NT, especially in topsoil (Donigian et al. 1994). However, in reduced tillage, soil carbon and N, microbial activity, and nutrient dynamics are altered somehow (Salinas-Garcia et al. 1997). The changes in carbon and N are partly attributed to the changes in the microbial environment. Conservation tillage, along with efficient management of irrigation, fertilizer, and pesticides may increase soil organic carbon (SOC) due to increased yields and decreased loss of SOC (Lal 2008).

Evaluation of cropping effects on carbon stocks in arable soils needs evaluating the data across different soil, crop and climate types. Follett et al. (2005) concluded from their five-year study conducted on an irrigated Vertisol (clayey, smectitic, isotermic, Udic Pellustert) that in a wheat-Been cropping system, N-rate and tillage had no effect on soil's carbon sequestration, while a considerable carbon sequestration occurred under wheat-corn cropping system with no-till. Srinivasarao et al. (2009) studied carbon stocks for last 25 years at 21 sites under rainfed production system and management regimes on principal soil types and climatic conditions in India. Their findings showed that the soils considerably varied in their carbon stocks and that the carbon stocks were Vertisols > Inceptisols > Alfisols > Aridisols. They further reported that soybean-maize- and groundnut-based systems exhibited greater soil organic carbon stocks.

3.4.2 Urban Ecosystems

Urban ecosystems are expanding globally. Assessment of the ecological consequences of urbanization is critical to understanding the biology of local and global changes related to land use. Urbanization of arid and semiarid ecosystems leads to enhanced C-cycling rates that alter regional carbon budgets (Kaye et al. 2005). Urban ecosystems are the home to more than half of the world's population, and are responsible for >70 % of anthropogenic release of carbon dioxide and 76 % of wood used for industrial purposes. The proportion of the urban population is expected to increase to 70 % worldwide by 2050.

The organic carbon change and storage in human settlements have not been well quantified. Human settlements can store as much carbon per unit area (23–42 kg C m^{-2} urban areas and 7–16 kg C m^{-2} exurban areas) as tropical forests, which have the greatest carbon density of natural ecosystems (4–25 kg C m^{-2}). To counterbalance rising urban carbon emissions, regional and national governments should act to protect or even to increase carbon stored in human-dominated landscapes. Rigorous studies addressing carbon budgets of human settlements and vulnerability of their carbon storage are needed (Churkina et al. 2010). For example; China is the world's most crowded country and the largest emitter of fossil-fuel CO_2 into the atmosphere. However, its experience on regionally distinct land-use histories and climate trends may help control the carbon budget of its ecosystems (Piao et al. 2009).

3.4.3 Grasslands

Grasslands have taken considerable attention as they behave as carbon sink (Soussana et al. 2004). Most grasslands behave as carbon sink when they are managed properly. However, when improperly managed, the grasslands become carbon source (He et al. 2012).

Grazing may reduce carbon sequestration in some grassland ecosystems, while contribute it in other ecosystems depending on climate, vegetation characteristics and grazing management. He et al. (2012) concluded that grazing exclusion resulted in 15.5 Mg C ha^{-1} carbon sequestration in 0–50 cm soil depth in Inner Mongolian grasslands. However, Chuluun/Ojima (2002) reported that yearlong or summer heavy grazing for 50 years affected soil carbon stocks differently in Mongolian grasslands from grasslands in Xilingole (China). They further reported that while a 25 % decrease occurred in Chinese sites, no decrease was observed in Mongolian sites. On the other hand, Schuman et al. (2002) reported that grazing (either light stocks or heavy) Northern mixed prairie for 12 years resulted in increased carbon stocks in the 0–30 cm surface soils compared to ungrazed areas. Derner et al. (1997) and Henderson (2000) observed greater carbon stocks in grazed soils than ungrazed soils.

Greater soil carbon stocks in grazed grasslands may be attributed to greater return of ingested nutrients to the soil as excreta (Schnabel et al. 2000). In addition, the foot traffic of grazing animals may trigger the litter breakdown resulting in faster decomposition (Schuman et al. 2002). Distribution of grasses through undigested seeds by grazing animals may contribute maintenance of heterogeneity of vegetation over the grasslands that result in greater carbon sequestration. Heavy grazing is expected to damage the grasslands (both soil and vegetation cover) due to nutrient loss by soil erosion. The studies showed that the correlation between grazing and soil carbon stocks is not consistent across different climate, soil, and socio-ecological conditions (Vesterdal/Feifeld 2010).

Carbon sequestration can be enhanced through fertilization of grasslands due to increased net primary product that results in greater residue inputs (Lal 2005). Greater NPP was reported for nitrogen and sulfur fertilized grasslands compared to unfertilized ones (Vesterdal/Feifeld 2010). Land use history, soil texture, and hydrology are important drivers in evaluation influence of management on carbon sequestration (Mestdagh et al. 2006).

3.5 Climate Change

Biological systems can control the Earth System in a large scale. Terrestrial ecosystems control exchanges of CO_2, nitrous oxides, water vapor, energy, and momentum between atmosphere and earth surface. Climate-ecosystem feedbacks may amplify or dampen regional and global climate change. Feedbacks between the carbon cycle and climate change have recently taken considerable attention. Studies show that the increased CO_2 can provide a negative feedback by enhancing plant growth through (Vesterdal/Feifeld 2010) the damaging effects of other air pollutants such as tropospheric ozone. Altitude has a dramatic control on the ecosystem C storage and its responses to global change. The protected areas in the high altitudes may provide a unique opportunity to study ecosystem response to climate change since these ecosystems are highly sensitive to climate change (Zhang et al. 2007).

Ecosystem-climate feedback has been operated for thousands of years as correlations between climate change and atmospheric concentrations of CO_2, nitrous oxides, and methane during the last glacial time (Petit et al. 1999). Studies show that the terrestrial component of carbon cycle is responding to climate change on a global scale (Matthews et al. 2009) as strong correlation between inter-annual CO_2 and El-Nino-Southern oscillation climate variations. “Uncertainty in the response of the global carbon cycle to anthropogenic emissions plays a key role in assessments of potential future climate change and response strategies” (O’neil/Melnikov 2008). Climate–carbon modeling experiments have shown that: (1) the warming per unit CO_2 emitted does not depend on the background CO_2 concentration; (2) the total allowable emissions for climate stabilization do not depend on the timing of those emissions; and (3) the temperature response to a pulse of CO_2 is approximately constant on timescales of decades to centuries (Matthews et al. 2009).

Positive feedbacks between climate change and carbon cycle may amplify the global warming due to increased atmospheric CO_2. Matthews et al. (2009) studied response of vegetation photosynthesis to climate change using a coupled climate-carbon model. Their results showed that large feedbacks were associated to climatic suppressions of terrestrial primary productivity, which caused a reduction in terrestrial carbon uptake. Figure 3.2 depicts variations of NPP of broadleaf and needle leaf forests in four different climate zones in Turkey between 2000 and 2010. Two most drastic decreases occurred for both broad and needle leaf forests in Aydın (W Turkey) and Bolu (NW Turkey). These two regions were strongly affected by 2003 and 2007 heat waves. However, NPP of needle leaf forests in Çankırı (N-central Turkey) and Erzurum (NE Turkey) were not affected much as the heat waves were slightly felt in these provinces. This showed that climate extremes could be considerably important for carbon sequestration of forest ecosystems.

Hudiburg et al. (2009) reported mean NPP of 1.9 $g\ m^{-2}\ year^{-1}$ to 44.2 $g\ m^{-2}\ year^{-1}$ for different forest age groups in six ecoregions located in Oregon and Northern California and that climate was the most important factor, followed by forest type and age group, determining the maximum NPP in these ecoregions. Clark et al. (2003)

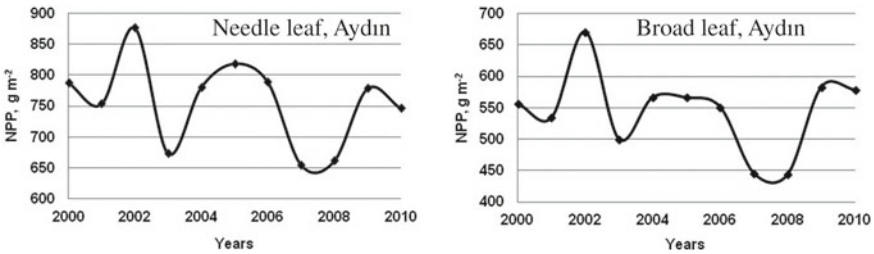


Fig. 3.2 Fluctuation of MODIS-predicted (MOD17A3 (Annual MODIS GPP/NPP data sets)) net primary products (NPP) of needle leaf and broad leaf forests between 2000 and 2010 in four different provinces of Turkey. *Source* Erşahin and Bilgili, Unpublished data

reported that the NPP of tropical forests were considerably affected by inter-annual climate and decreased NPP values in warmer years.

The terrestrial ecosystems respond to concrete time series of actual weather conditions, but not the mean climate (Matthews et al. 2009). Therefore, variability and extremes such as heat waves should be considered too in assessing climate-ecosystem feedbacks. Changes in frequency and timing of rainfall and temperature extremes without changing in annual total or average may impact water-carbon cycle interactions. For example, the warmer winter and early spring may result in earlier leafing and flowering causing vulnerability of plants to late frosts. In addition, temporal changes in water deficit, wind speed, air temperature, and humidity may trigger forest fires that result in rapid emission of carbon (Matthews et al. 2009). On the other hand, feedbacks in the atmosphere may offset the warming effect of greenhouse gasses. For example, Auffhammer et al. (2006) showed that atmospheric brown clouds, formed from the burning of fossil fuels, reduced rice harvest in India due to that these clouds absorb solar radiation in the lower atmosphere and scatter it back to the atmosphere, reducing photosynthetically active radiation at the earth surface.

In carbon cycle-climate models, fundamental paradigm was that increased atmospheric CO_2 and grater temperature stimulates the photosynthetic uptake of CO_2 by plants. However, recent studies showed that the process is much more complicated than previously thought due to the complex dynamics via interactions between chemical, physical, and biological processes within the ecosystem including soil (Matthews et al. 2009). This indicates that climatic and environmental factors may modify the carbon balance of the world's ecosystem (Matthews et al. 2009). Availability of water, vertical distribution of carbon and roots in soil, and drought sensitivity of vegetation will control net primary product (NPP). Different vegetation covers may respond differently to the same drought conditions, while the same vegetation cover may respond differently in similar drought conditions due to changes in soil, microclimate, and topographic conditions.

The aboveground and belowground processes such as photosynthesis and respiration principally determine the net effect of environmental change on carbon balance in an ecosystem. The interaction carbon-nitrogen cycles may alter ecosystem carbon responses to climate change. Carbon dioxide fertilization effect on canopy assimilation may be offset by nitrogen deficiency in nitrogen limited ecosystems. In addition, nitrogen availability affects the decomposition of soil organic matter. A strong integrative consideration of complex integrations between ecosystem processes at different level of organization is necessary to understand feedbacks among ecosystem, carbon, and climate change (Matthews et al. 2009).

3.6 Mitigating the Atmospheric CO_2 Increase

According to many commentators, climate change and the global carbon budget will chiefly affect the future of the global environment and its potential impact on mankind. The world's forests have an important function in offsetting the climate change. The carbon that they contain would be enough to raise atmospheric CO_2 concentration to well over 1000 ppm that it may potentially lead to a catastrophic rise in temperature of 5–8 °C. Maintaining and rehabilitating global forests is essential to mitigate climate change (Broadmeadow/Matthews 2003). In mitigating CO_2 emissions following restored hydrology, quantification of net greenhouse gas emissions should be balanced since carbon stocks can be enhanced in wet conditions through decreased decomposition of organic matter while emission of other greenhouse gases can be enhanced (Vesterdal/Feifeld 2010).

Emphasis has been focused on decreasing the rate of CO_2 emissions from fossil-fuel use. There is an increasing recognition that the rate of emissions can be mitigated by transferring CO_2 from the atmosphere to the terrestrial biosphere (Lal 2014). Elevated CO_2 concentrations in the atmosphere may enhance plant growth due to that the increased CO_2 may result in increased photosynthesis, especially in newly foretasted areas. Therefore, reforestation and afforestation can make a significant contribution to the mitigation of climate change (Broadmeadow/Matthews 2003).

The potential use of forests to mitigate carbon has long been discussed. Some of the carbon emitted by fossil fuel burning may be converted to vegetation and this help offset CO_2 buildup in the atmosphere. Some commentators suggest storing industrially emitted carbon in underground storage tanks. Nevertheless, society should consider the costs and side effects of different options in mitigating CO_2 emissions. Tropical deforestation accounts for one-quarter of anthropogenic carbon emission and avoiding deforestation activities are one of the most efficient and cost effective measures to reduce carbon emissions (Kindermann et al. 2008). They showed that a 10 % decrease in deforestation globally from 2005 to 2030 could result in 0.3–0.6 Gt CO_2 per year reduction in emission and would require $0.4 billion to $17 billion per year for 30 years. According to Soares-Filho et al. (2006) saving approximately 130 M ha of tropical forest in Amazon can result in a reduction of 62 Gt CO_2 emissions over the next 50 years. In addition, loss of biodiversity and other environmental services can be avoided through a well-adapted deforestation program. As some nations have already advocated (Kindermann et al. 2008) carbon credits should be provided to save these native forests.

A sustainable land management has been defined as the system that allows an adequate production, while maintaining quality of soil and water (Lal 2014). Soil tillage systems are important factors of sustainable land management. Conventional tillage decrease soil carbon storage significantly and influence the soil environment of a crop (Basso et al. 2006). Cultured soils, converted from grasslands, generally show a slower decline in soil organic matter with no-tillage (NT) compared to conventional tillage. Conservation management systems, such as NT, also increase the active fractions of soil organic matter (Salinas-Garcia et al. 1997).

All plant material contain carbon (normally around 50 % of dry weight), and burning or decomposition of cleared vegetation releases it to the atmosphere, mainly in the form of CO_2. Plants and particularly trees continue to make an important contribution to the global carbon cycle (Broadmeadow/Matthews 2003). Retention of carbon in terrestrial ecosystems is one of the most effective ways in the prevention of global warming and decreasing greenhouse gases. A significant portion of the carbon is retained in the rizosphere. Therefore, knowledge on carbon dynamics in different plant's rizosphere may help mitigate carbon losses from the soils. Long term studies have consistently showed benefit of increasing carbon input into the soil. However, even in sustainable cropping systems, continuous cropping results in a decline of soil organic carbon (Roose/Barthes 2001).

Plant residue, and thus soil carbon inputs are mainly affected by the (1) type of plants being grown, (2) amount of dry matter the plants accumulate over the growing season, and (3) environmental factors which govern plant production. The rate of carbon loss is determined by (1) type of plant and animal matter entering the soil, (2) climate conditions (rainfall, temperature, sunlight), and (3) soil clay content (Baldock 2011). Mulching decreases soil temperature, maintains favorable soil structure and infiltration rate, and enhance microbial and mesofaunal activities (Roose/Barthes 2001). Mulches also contribute the soil carbon stock by reducing mineralization and protecting soil against erosion (Nandwa 2001).

Nations should take necessary measures to control C emissions and to avoid further atmospheric CO_2-related global warming. Different policy options should be considered to develop sustainable landscapes resilient to global warming and to desertification. Social, ecological, cultural, economic, and environmental factors should be balanced well to avoid land degradation and desertification that may impact future of natural resources and societies' well-being (Soytas/Sari 2006). Hence, the economic and ecologic aspects of the emissions–energy–income nexus needs to be studied carefully and in detail. Carbon sequestration from fossil fuel combustion, particularly coal, is an essential component of a planning targeted to avoiding impacts of human-induced climate change. Unfortunately, the present scientific and economic challenges are not adequate to capture and store carbon at the required scale (Schrag 2007).

"Terrestrial ecosystem carbon sequestration can reduce the rate of buildup of greenhouse gases in the atmosphere and therefore can contribute to a better human adaptation to current and future environmental changes" (Sivrikaya et al. 2007). In soil carbon sequestration, every aspect of the inputs and outputs should be considered (IPCC 2007). There are three strategies of reducing CO_2 emissions to mitigate climate change (Schrag 2007) (1) reducing the global energy use, (2) developing low or no-carbon fuels, and (3) sequestering CO_2 from point sources or atmosphere by natural and engineering techniques.

In addition to economics, the human dimension issues need to be addressed objectively and critically for both biotic and abiotic CO_2 sequestration options. "Appropriate policy and regulatory measures need to be developed, especially with regards to measurement, monitoring, residence time, and trading" (Lal 2014). The harmony between society and nature should be set well to ensure an adequate carbon sequestration for balancing atmospheric CO_2 budget.

3.7 Conclusions

Recently it has been recognized that biological systems can control and steer the global carbon cycle, and terrestrial ecosystems are an integral part of these systems as they feedback to the changes in atmospheric CO_2 concentration. Even in hyper-arid regions, there are keystone plants with tremendous ecological value. In these ecosystems, significant amount of carbon is stored as they occupy large areas worldwide. Recent advances showed that the interactions between terrestrial ecosystems and atmosphere are far more complicated than it was thought. It has been recognized that quantifying the carbon cycle-climate feedbacks on a global scale is highly difficult since factors such as availability of nutrients, water, and pests add additional uncertainty to the direction and magnitude of these feedbacks. Besides burning of fossil fuels, human induced land degradation and urbanization is responsible for significant amount of carbon emitted from landscapes to atmosphere.

Drivers of carbon loss from terrestrial ecosystems should be identified well to mitigate the atmospheric CO_2 increase. Extreme events such as heat waves should be considered besides gradual mean changes in atmospheric components as well as changes in seasonal distributions in climate factors in modeling ecosystem-climate interactions. Factors affecting forest fires should be identified to avoid rapid loss of carbon from fire-vulnerable forests. Changes in seasonality and long extreme droughts can also have a harmful effect on ecosystems. The carbon emitted by fossil fuel use, industry, and agriculture may be offset by improved carbon sequestration by reforestation and afforestation, decreased use of fossil fuel burning, developing green urbanization, and sustainable agricultural practices.

Climate and socio-economic changes can amplify each other's effect and trigger landscape degradation. There is plenty of evidence on local or regional disappearance of forest ecosystems worldwide that associated to climate change combined with rapid anthropogenic changes in land cover and land use. Overcome of interacting thresholds in the ecological, socio-economic and cultural systems together with climate change impacts that may lead to cascade effects with irreversible changes (regime shifts) should be avoided. The adaptive knowledge and skills of historically developed social systems can be used to cope with the current and future climate changes and to improve livelihood and increase the landscape resilience to global changes. Effective institutional frameworks are needed to resolve conflicts between offsetting and supporting sectors of atmospheric carbon buildup. These systems work well if strong social control is ensured over land use from local to global scale.

References

Auffhammer, M.; Ramanathan, V.; Vincent, J.R., 2006: "Integrated Model Shows that Atmospheric Brown Clouds and Greenhouse Gases have Reduced Rice Harvests in India", in: *Proceedings of the National Academy of Sciences*, 103: 19668–19672.

Baker, J.M.; Ochsner, T.E.; Venterea, R.T.; et al., 2007: "Tillage and Soil Carbon Sequestration—What Do We Really Know?", in: *Agriculture, Ecosystems & Environment*, 118: 1–5.

Baldock, J., 2011: "Factors Which Influence Soil Carbon Levels", in: *CSIRO*.

Balieiro, F.D.C.; Prado, R.B.; Coutinho; et al., 2010: "Soil Carbon Stocks in Southwest Goiás, Brazilian Cerrado: Land Use Impact and Spatial Distribution", in: Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia, 1–6 August 2010. Symposium 3.1.2 Farm System and Environment Impacts: 221–224. International Union of Soil Sciences (IUSS), c/o Institut für Bodenforschung, Universität für Bodenkultur.

Ballantyne, A.P.; Alden, C.B.; Miller, J.B.; et al., 2012: "Increase in Observed Net Carbon Dioxide Uptake by Land and Oceans During the Past 50 Years", in: *Nature*, 488: 70–73.

Basso, B.; Ritchie, J.T.; Grace, P.R.; et al., 2006: "Simulation of Tillage Systems Impact on Soil Biophysical Properties Using the SALUS Model. Italy", in: *L.Agron,/Riv.Agrron*, 4: 677–688.

Bationo, A.; Buerkert, A., 2001: "Soil Organic Carbon Management for Sustainable Land Use in Sudano-Sahelian West Africa", in: *Nutrient Cycling in Agroecosystems*, 61: 131–142.

Bilgili, B.C.; Erşahin, S.; Dikmen, Ü., 2014: "The Geostatistical NPP Analysis of the Closed Konya Basin", in: I. First National Basin Management Symposium, 10–12 Sep. 2014, Çankırı [in Turkish] (unpublished data).

Bowers, W., 1992: "Agricultural Field Equipment", in: Fluck, R.C. (Ed.): *Energy in Farm Production* (Amsterdam: Elsevier), 10: 117–129.

Chuluun, T.; Ojima, D., 2002: "Land Use Change and Carbon Cycle in Arid and Semi-arid Lands of East and Central Asia", in: *Science in China Series C Life Sciences-English Edition*, 45: 48–54.

Churkina, G.; Brown, D.; Keoleian, G., 2010: "Carbon Stored in Human Settlements: The Conterminous United States", in: *Global Change Biology*, 16: 135–143.

Clark, D.; Piper, S.; Keeling, C.; et al., 2003: "Tropical Rain Forest Tree Growth and Atmospheric Carbon Dynamics Linked to Interannual Temperature Variation During 1984–2000", in: *National Academy of Sciences*, 100: 5852–5857.

Derner, J.; Briske, D.; Boutton, T., 1997: "Does Grazing Mediate Soil Carbon and Nitrogen Accumulation Beneath C4, Perennial Grasses Along an Environmental Gradient?", in: *Plant and Soil*, 191: 147–156.

Dick, W., 1983: "Organic Carbon, Nitrogen, and Phosphorus Concentrations and pH in Soil Profiles as Affected by Tillage Intensity", in: *Soil Science Society of America Journal*, 47: 102–107.

Dixon, R.; Brown, S.; Houghton, R.; et al., 1994: "Carbon Pool and Flux of Global Forest Ecosystems", in: *Science*, 263.

Donigian, A.; Barnwell, T.; Jackson, R.; et al., 1994: "Assessment of Alternative Management Practices and Policies Affecting Soil Carbon in Agroecosystems of the Central United States", in: "EPA/600/R-94/067", vol. 2014. EPA.

Follett, R.; Castellanos, J.; Buenger, E., 2005: "Carbon Dynamics and Sequestration in an Irrigated Vertisol in Central Mexico", in: *Soil and Tillage Research*, 83: 148–158.

Frye, W.W., 1984: “Energy Requirement in No-Tillage”, in: Phillips, R.; Phillips, S. (Eds): *No-Tillage Agriculture* (New York: Springer): 127–151.

Harvey, D., 2000: “Global Warming”, in: *The Hard Science* (Harlow, UK: Prentice Hall).

He, N.; Zhang, Y.; Dai, J.; et al., 2012: “Land-Use Impact on Soil Carbon and Nitrogen Sequestration in Typical Steppe Ecosystems”, in: *Inner Mongolia Journal of Geographical Sciences*, 22: 859–873.

Henderson, D.C., 2000: *Carbon Storage in Grazed Prairie Grasslands of Alberta* (Edmonton, Alberta: University of Alberta).

Houghton, R.; Skole, D.; Nobre, C.A.; et al., 2000: “Annual Fluxes of Carbon from Deforestation and Regrowth in the Brazilian Amazon”, in: *Nature*, 403: 301–304.

Hudiburg, T.; Law, B.; Turner, D.P.; et al., 2009: “Carbon Dynamics of Oregon and Northern California Forests and Potential Land-Based Carbon Storage”, in: *Ecological Applications*, 19: 163–180.

IPCC, 2000: “Land Use, Land-Use Change, and Forestry”, in: *Special Report of the Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press).

IPCC, 2007: *Climate Change Impacts, Adaptation and Vulnerability* (Geneva: IPCC).

Janzen, H.H., 2004: “Carbon Cycling in Earth Systems—A Soil Science Perspective”, in: *Agriculture, Ecosystems & Environment*, 104: 399–417.

Jiao, J.G.; Yang, L.Z.; Wu, J.X.; et al., 2010: “Land Use and Soil Organic Carbon in China’s Village Landscapes”, in: *Pedosphere*, 20: 1–14.

Kaye, J.P.; McCulley, R.L.; Burke, I.C., 2005: “Carbon Fluxes, Nitrogen Cycling, and Soil Microbial Communities in Adjacent Urban, Native and Agricultural Ecosystems”, in: *Global Change Biology*, 11: 575–587.

Kindermann, G.; Obersteiner, M.; Sohngen, B.; et al., 2008: “Global Cost Estimates of Reducing Carbon Emissions Through Avoided Deforestation”, in: *Proceedings of the National Academy of Sciences*, 105: 10302–10307.

Lal, R., 2005: “Forest Soils and Carbon Sequestration”, in: *Forest Ecology and Management*, 220: 242–258.

Lal, R., 2008: “Carbon Sequestrian”, in: *Philosophical Transactions of the Royal Society*, 363: 815–830.

Lal, R., 2014: “Managing Terrestrial Carbon in a Changing Climate”, in: Kapur, S.; Erşahin, S. (Eds.): *Soil Security for Ecosystem Management* (Cham: Springer International Publishing): 1–18.

Lettens, S.; Van Orshoven, J.; Van Wesemael, B.; et al., 2005: “Stocks and Fluxes of Soil Organic Carbon for Landscape Units in Belgium Derived from Heterogeneous Data Sets for 1990 and 2000”, in: *Geoderma*, 127: 11–23.

Liu, J.; Liu, S.; Loveland, T.R., 2006: “Temporal Evolution of Carbon Budgets of the Appalachian Forests in the US from 1972 to 2000”, in: *Forest Ecology and Management*, 222: 191–201.

Matthews, R.; Broadmeadow, M., 2003: “Forests, Carbon and Climate Change the UK Contribution”, in: *Forestry Commission* (Farnham, UK): 231.

Matthews, H.D.; Gillett, N.P.; Stott, A.P.; et al., 2009: “The Proportionality of Global Warming to Cumulative Carbon Emissions”, in: *Nature*, 459: 829–832.

McKitrick, R.; Strazicich, M., 2005: “Stationarity of Global per Capita Carbon Dioxide Emissions: Implications for Global Warming Scenarios”, in: *Working Papers 0503* (University of Guelph, Department of Economics and Finance).

Mestdagh, I.; Lootens, P.; Van Cleemput, O.; et al., 2006: “Variation in Organic-Carbon Concentration and Bulk Density in Flemish Grassland Soils”, in: *Journal of Plant Nutrition and Soil Science*, 169: 616–622.

Nandwa, S.M., 2001: “Soil Organic Carbon (SOC) Management for Sustainable Productivity of Cropping and Agro-Forestry Systems in Eastern and Southern Africa”, in: *Nutrient Cycling in Agroecosystems*, 61: 143–158.

O’neil, B.C.; Melnikov, N.B., 2008: “Learning About Parameter and Structural Uncertainty in Carbon Cycle Models”, in: *Climatic Change*, 89: 23–24.

Ordóñez, J.A.B.; de Jong, B.H.J.; García-Oliva, F.; et al., 2008: "Carbon Content in Vegetation, Litter, and Soil Under 10 Different Land-Use and Land-Cover Classes in the Central Highlands of Michoacan, Mexico", in: *Forest Ecology and Management*, 255: 2074–2084.

Petit, J.; Jouzel, J.; Raynaud, D.; et al., 1999: "Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica", in: *Nature*, 399: 429–436.

Piao, S.; Fang, J.; Ciais, P.; Peylin, P.; Huang, Y.; Sitch, S.; Wang, T., 2009: "The Carbon Balance of Terrestrial Ecosystems in China", in: *Nature*, 458: 1009–1013.

Roose, E.; Barthes, B., 2001: "Organic Matter Management for Soil Conservation and Productivity Restoration in Africa: A Contribution from Francophone Research", in: *Nutrient Cycling in Agroecosystems*, 61: 159–170.

Salinas-Garcia, J.R.; Hons, F.M.; Motocha, J.E., 1997: "Long-Term Effects of Tillage and Fertilization on Soil Organic Matter Dynamics", in: *Soil Science Society of America Journal*, 61: 152–159.

Schimel, D.S.; House, J.I.; Hibbard, K.A.; et al., 2001: "Recent Patterns and Mechanisms of Carbon Exchange by Terrestrial Ecosystems", in: *Nature*, 414: 169–172.

Schnabel, R.R.; Franzluebbers, A.J.; Stout, W.L.; et al., 2000: "The Effects of Pasture Management Practices", in: Kimble, J.M.; Lal, R.; Follett, R.F. (Eds.): *The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect* (Boca Raton, FL: CRC Press).

Schrag, D.P., 2007: "Preparing to Capture Carbon", in: *Science*, 315: 812–813.

Schuman, G.E.; Janzen, H.H.; Herrick, J.E., 2002: "Soil Carbon Dynamics and Potential Carbon Sequestration by Rangelands", in: *Environmental Pollution*, 116: 391–396.

Sivrikaya, F.; Keleş, S.; Çakır, G., 2007: "Spatial Distribution and Temporal Change of Carbon Storage in Timber Biomass of Two Different Forest Management Units", in: *Environmental Monitoring and Assessment*, 132.

Six, J.; Feller, C.; Denef., K.; et al., 2002: "Soil Organic Matter, Biota and Aggregation in Temperate and Tropical Soils-Effects of No-Tillage", in: *Agronomie*, 22: 755–775.

Soares-Filho, B.S.; Nepstad, D.C.; Curran, L.M.; et al., 2006: "Modelling Conservation in the Amazon Basin", in: *Nature*, 440, 520–523.

Soussana, J.F.; Loiseau, P.; Vuichard, N.; et al., 2004: "Carbon Cycling and Sequestration Opportunities in Temperate Grasslands", in: *Soil Use and Management*, 20,2: 219–230.

Soytas, U.; Sari, R., 2006: "Can China Contribute More to the Fight Against Global Warming?", in: *Policy Modeling*, 28: 837–846.

Srinivasarao, C.; Vittal, K.P.R.; Venkateswarlu, B.; et al., 2009: "Carbon Stocks in Different Soil Types Under Diverse Rainfed Production Systems in Tropical India", in: *Communications in Soil Science and Plant Analysis*, 40,15–16: 2338–2356.

Tans, P.; Keeling, R., 2013: "Trends in Atmospheric Carbon Dioxide", in: *NOAA/ESRL*.

Thompson, D.; Matthews, R.W., 1989: "The Storage of Carbon in Trees and Timber", in: (R. i. n. 160, ed.), 4: June 2014.

Trumbore, S.E.; Chadwick, O.A.; Amundson, R., 1996: "Rapid Exchange Between Soil Carbon and Atmospheric Carbon Dioxide Driven by Temperature Change", in: *Science*, 272: 393–396.

Upadhyay, T.P.; Sankhayan, P.L.; Solberg, B., 2005: "A Review of Carbon Sequestration Dynamics in the Himalayan Region as a Function of Land-Use Change and Forest/Soil Degradation with Special Reference to Nepal", in: *Agriculture, Ecosystems and Environment*, 105: 449–465.

Vesterdal, L.; Feifeld, J., 2010: "Land-Use Change and Management Effects on Soil Carbon Sequestration", in: Forestry and Agriculture, Austrian Research Centre for Forests.

Zhang, C.; Tian, H.; Chappelka, A.H.; et al., 2007: "Impacts of Climatic and Atmospheric Changes on Carbon Dynamics in the Great Smoky Mountains National Park", in: *Environmental Pollution*, 149: 336–347.

Chapter 4
EU Emissions Trading Scheme Application in Bulgaria, Greece and Romania from 2008 to 2012

Christina-Stavrula Hatzilau, Dionysios Giannakopoulos, Sotirios Karellas and Emmanuel Kakaras

Abstract Emission trading in three European Union (EU) member states in the Balkans during the second phase (2008–2012) of the EU emissions trading scheme (EU ETS) is investigated in terms of allocation submission of emission credits (assigned amount units (AAU), certified emission reductions (CER), emission reduction units (ERU) and potential trading activities). Greece, Bulgaria and Romania are analyzed as three individual cases under the scope of the EU Directive 2003/87/EC with the aim to identify the adequacy of emission allowances in individual sectors and their resulting utilization. The aforementioned Balkan countries produced over 750 Mt of verified emissions in the first commitment period of 2008–2012, of which approximately 70 % correspond to combustion installations. A deficit emerged for individual installations; although at the sector level, deficits appeared only in the aviation sector for all countries. Greece also experienced a deficit in the emissions trading scheme (ETS) combustion sector prior to the use of CER or ERU under the clean development mechanism (CDM) and the joint implementation (JI) mechanism. This study mainly focuses on the combustion sector while attempting to identify differences in use of international emission credits among the three Balkan countries and sectors therein.

Keywords EU-ETS · Flexible mechanisms · CO_2 · Bulgaria · Greece · Romania

---

C.S. Hatzilau, Ph.D., School of Mechanical Engineering. Thermal Engineering Section, National Technical University of Athens, 9. Heroon Polytechniou Str. 15780 Athens, Greece; E-mail: hatzilau@central.ntua.gr.

D. Giannakopoulos, Ph.D., Centre for Research and Technology Hellas, Chemical Process & Energy Resources Institute 4th km, Ptolemais-Mpodosakeio-P.O. box 95, GR 502 00 Ptolemais, Greece; E-mail: dgia@central.ntua.gr.

S. Karellas, Assoc. Prof. Dr., Laboratory of Steam Boilers and Thermal Plants. School of Mechanical Engineering. Thermal Engineering Section, National Technical University of Athens, 9, Heroon Polytechniou Str. 15780 Athens, Greece; E-mail: sotokar@mail.ntua.gr.

E. Kakaras, Prof. Dr., Centre for Research and Technology Hellas/Chemical Process & Energy Resources Institute 4th km, Ptolemais-Mpodosakeio, P.O. box 95, GR 502 00 Ptolemais, Greece; E-mail: ekak@central.ntua.gr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_4

4.1 Introduction

This study examines the application of the European Union emissions trading scheme (EU ETS) in Bulgaria, Greece and Romania in an effort to identify the absolute as well as comparative patterns of trading emissions, which are then compared on both country and overall basis. This study ultimately aims to demonstrate the outcomes from the EU ETS implementation in these three Balkan countries and highlight the main findings regarding market activities. All installations with allocated allowances and/or verified emissions between the years 2008 and 2012 were examined in terms of allocation and surrender of allowances concerning not only assigned amount units (AAU) but also certified emission reductions (CER) and emission reduction units (ERU) as well as potential trading activities. Installations falling under the scope of the EU Directive 2003/87/EC, for which no allowances were issued during the 2008–2012 period and that declared no verified emissions according to the EU transaction log (EUTL) were, characterized as 'inactive' and therefore were not considered in the current analysis.

This study focuses on surpluses and deficits that appeared on country and sector levels as well as deficits that appeared in absolute terms for specific installations. In addition, the extent of 'Market Activity' has been investigated based on maximum potential and final utilization of international credits (CER and ERU). ETS installations were divided into 3 categories according to emissions over the 5-year period, namely, (a) large-sized emitters with verified emissions totaling over 2.5 Mt, (b) medium-sized emitters with total verified emissions between 0.25 and 2.5 Mt and (c) small-sized emitters with emissions less than 0.25 Mt. Patterns of market activity regarding the use of international credits have been mapped for each category of the selected industrial sectors to highlight the prospects for the next commitment period of 2013–2020.

4.2 ETS Sectors' Allowances and Emissions During Phase II (2008–2012)

The total greenhouse gas (GHG) emissions in Bulgaria, Greece and Romania, which account for approximately 6.6 % of EU28 emissions, totaled 62.4, 115.2 and 120.6 Mt, respectively, in 2012. The respective GHG per capita ratios were 8.5, 10.2 and 5.6 t CO_{2eq}/capita in 2012, whereas their respective GHG per GDP ratios were 2.3, 0.7 and 1.3 kgCO_{2eq}/EUR (EEA 2013).

According to the EU Directive 2003/87/EC and in light of the Kyoto Protocol's target, National Allocation Plans (NAP) had to be designed at the member-state (MS) level for the period 2008–2012. Initially, Bulgaria, Greece and Romania proposed annual allocations of 67.6, 75.5 and 95.7 million allowances, respectively (EC 2012). After considering GDP increases as well as carbon-intensity reduction measures, the European commission (EC) set the final maximum annual allowance allocations as 42.4, 69.1 and 76.0 million, respectively (European Commission 2006, 2007, 2008).

The final total allowance allocations based on data from the EUTL were 39.8, 64.7 and 73.1 million, respectively, resulting in total allowances of 888 million for the period 2008–2012.

4.3 Country Surpluses and Installation Deficits

Considering the allocated and verified emissions, all three countries presented a surplus during the specified time period. The total verified emissions in the three countries were only 755 million tons CO_{2eq}. Bulgaria had a surplus of over 18 million tons CO_{2eq}, corresponding to 9 % over-allocation during the period, Greece had a surplus of almost 10 million tons CO_{2eq}, a 3 % of over-allocation, and Romania had a surplus of more than 100 million tons CO_{2eq}, i.e. a 29 % over-allocation. These surpluses correspond to a minimum MS level prior to the use of international credits. Bulgaria and Romania did not experience a deficit in any of the studied years, but Greece had deficits in 2008 and 2009, although the latter was marginal. However since the intra period-borrowing was valid according to the Greek NAP, the individual year deficit did not necessarily have an actual impact on ETS operators. Considering the performance of each sector's installations, an overall sectional minimum surplus is calculated assuming that all CERs and ERUs surrendered were gained by swapping the same amount of allocated European Emission Allowances (EUAs). Using the assumption that all CERs and ERUs surrendered have been acquired from the market without EUA swapping, the maximum surplus is defined in Table 4.1. Each country's surplus changed substantially after considering the use of international credits. Since

Surrendered Units = X + Y + Z

where X = the amount of AAU surrendered; Y = the amount of CER surrendered and Z = the amount of ERU surrendered.

Depending on the option for acquiring surrendered CERs and ERUs, i.e. whether all CERs and ERUs have been acquired through swapping or whether all CERs and ERUs have been acquired on the Market, the minimum and maximum surplus' are derived.

Table 4.1 Minimum and maximum surplus prior and after the use of international credits (millions emission allowances)

	Bulgaria	Greece	Romania
Minimum surplus	18.3	9.9	104.4
CER & ERU used	23.3	28.0	33.7
CER & ERU max use	24.8	29.1	36.6
Maximum Surplus	41.6	37.9	138.1

Source The authors

Prior to the use of CERs and ERUs on the sector level, approximate deficits of 49, 73 and 131 kt existed for Bulgaria, Greece and Romania, respectively, in the airlines sector, while Greece had a 20.6 million emission allowances deficit in the combustion sector. Surpluses were observed in all other sectors. On the installation level, however, 102 out of 560 active installations in Bulgaria, Greece and Romania appeared to have an 'initial' deficit prior to the use of international credits, as illustrated in Table 4.2.

Depending on the option of acquiring surrendered CERs and ERUs, the minimum and maximum surplus per sector on an installation level is derived as presented in Table 4.3.

Table 4.2 Installations with a deficit by sector

	Bulgaria	Greece	Romania
Installations No with deficit out of total No of installations in a sector	[Comb.: 9 of 29] [Refineries: 1 of 4] [Glass: 2 of 6] [Tile: 3 of 26] [Airlines: 3 of 4] [Opt-in: 8 of 72]	[Comb.: 22 of 50] [Refineries: 1 of 4] [Paper: 3 of 16] [Airlines: 7 of 9]	[Comb.: 29 of 143] [Ferrous: 4 of 25] [Lime: 1 of 7] [Tile: 1 of 32] [Airlines: 6 of 6] [Other: 2 of 6]
Deficit [kt] during 2008–2012	[Comb.: 2079.1] [Refineries: 0.6] [Glass: 3.6] [Tile: 6.6] [Airlines: 65.9] [Opt-in: 8756.8]	[Comb.: 31704.7] [Refineries: 310.0] [Paper: 43.4] [Airlines: 167.6]	[Comb.: 15940.7] [Ferrous: 112.8] [Lime: 2.7] [Tile: 2.7] [Airlines: 130.9] [Other: 710.2]

Source The authors

Table 4.3 Market potential based on max/min surplus per sector [Mt]

Market potential	Bulgaria	Greece	Romania
Combustion	3.94–12.18	**[−20.57]**–0.17	71.22–97.72
Refineries	0.07–0.08	0.71–2.55	6.96–7.87
Coke Ovens	0.01	na	na
Ferrous & Sintering	na	2.48–3.01	3.48–3.95
Cement & Lime	6.74–8.32	23.50–28.01	23.19–28.03
Glass	1.60–2.34	0.06–0.09	0.53–0.57
Tile & Ceramics	0.63–0.78	3.34–3.54	1.33–1.53
Paper & Pulp	0.58–0.67	0.19–0.23	1.74–1.85
Other	na	na	0.99–1.47
Opt in	6.05–18.56	na	0.16–0.19
Air	[−0.05]–[−0.01]	[−0.07]–0.04	[−0.13]–[−0.05]

Source The authors

4.4 Use of International Credits

International credits derived from projects based on clean development mechanism (CDM) and joint implementation (JI) mechanism had a mean lower price than that of EUAs in the period 2008–2012. Specifically, as the EUA price ranged from almost 30 Euro per ton at the beginning of the period to less than 5 Euro per ton at its end, the respective price range for CERs was approximately 15 Euro to less than 0.5 Euro over the same period, resulting in a lower average price for CERs. In addition, the ERU had a mean lower price than the CER, meaning that ETS operators found it more profitable to surrender CERs and ERUs instead of EUAs. The allowed use of international credits varied across the three examined countries. According to the National Allocation Plans and respective EC Decisions, during the second trading period, the maximum shares of ERU and CER that could be used to fulfil the operators' obligations were limited as follows:

- 12.507 % of allocated allowances for Bulgaria;
- 9 % of allocated allowances for Greece and
- 10 % of allocated allowances for Romania.

In absolute terms, more than 90 million international credits could potentially be used by the three countries for submission instead of EUAs, of which over 5.5 million remained unexploited (Table 4.2). Close to half of all international credits were surrendered in compliance with the final year of the investigated time period.

In absolute terms, Greece exploited its potential more efficiently, leaving only 4 % of its international credits' potential surrender unexploited, followed by Bulgaria at 6 % and Romania at 8 %. This can be mainly attributed to the fact that Greece had the lowest surplus, followed by Bulgaria then Romania.

CER and ERU exploitation by each EU ETS sector (except the airline sector) is depicted in Figs. 4.1, 4.2, and 4.3. The more a sector's verified/allocated emissions

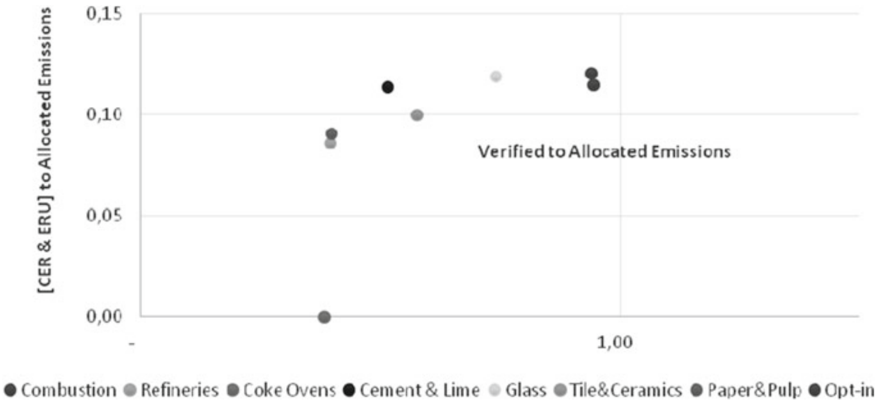


Fig. 4.1 Sector level 'Market Activity' in Bulgaria. *Source* The authors

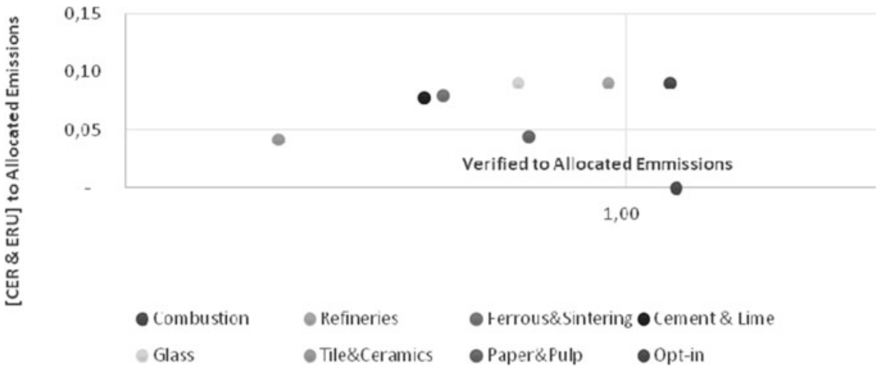


Fig. 4.2 Sector level "Market Activity" in Greece. *Source* The authors

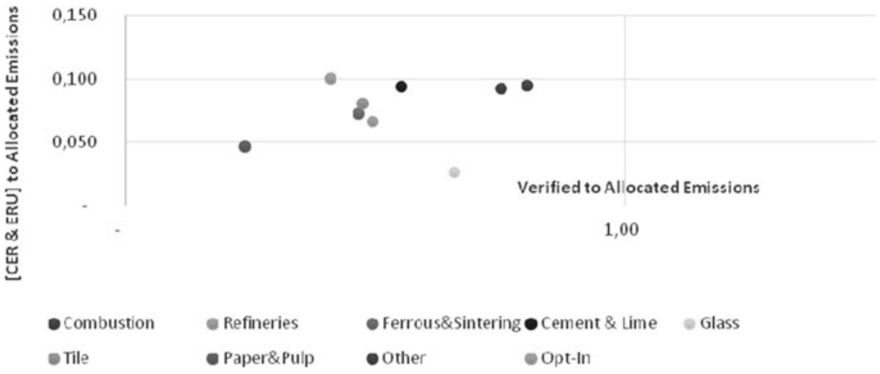


Fig. 4.3 Sector level 'Market Activity' in Romania. *Source* The authors

ratio exceeds a value of 1, the more action it needed to take to achieve compliance. In cases of a lower ratio, the sector's market orientation is revealed.

In Bulgaria, where the maximum potential for CER and ERU surrender was 12,507 % of the allocated allowances, sectors that exploited their potential to a significant extent i.e. in the range of 91–96 %) were the cement and lime sector, the glass industry, the combustion sector, and the opt-in sector.

In Greece, where the maximum potential for CER and ERU surrender was 9.0 % of the allocated allowances, the combustion sector, the glass industry and the refineries sector exploited almost all of their full potential.

In Romania, where the maximum potential for CER and ERU surrender was 10.0 % of the allocated allowances, the most active sector was 'opt-in' installations, followed by the combustion, cement and lime and the 'Others' sectors, which were 92–94 % active.

The distribution of CER and ERU international credits varied across countries and sectors, as illustrated in Figs. 4.4, 4.5, and 4.6 at the country level, Bulgaria, Greece, and Romania surrendered more ERUs than CERs (EC 2012, 2013). Few sectors used only ERU credits, as illustrated in Figs. 4.7, 4.8, and 4.9.

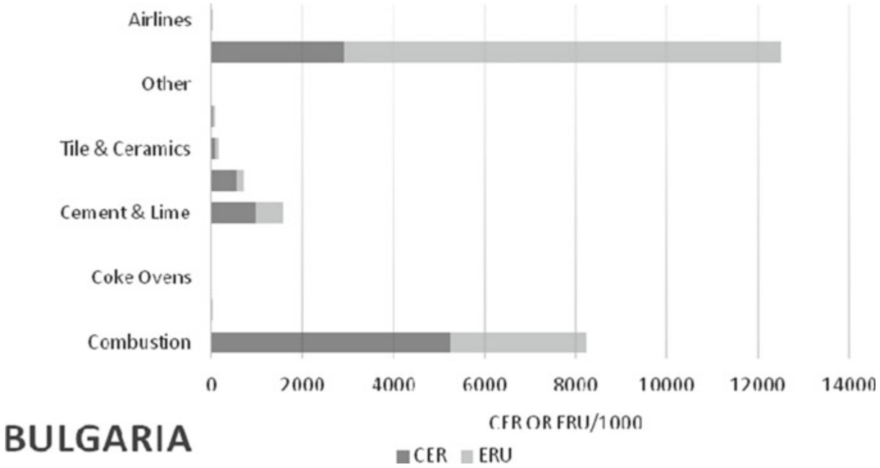


Fig. 4.4 Use of international credits per sector by Bulgaria. *Source* The authors

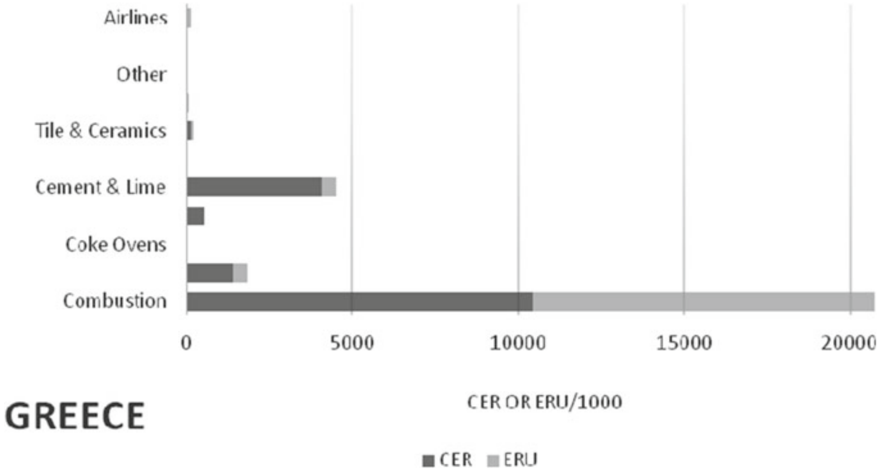


Fig. 4.5 Use of international credits per sector by Greece. *Source* The authors

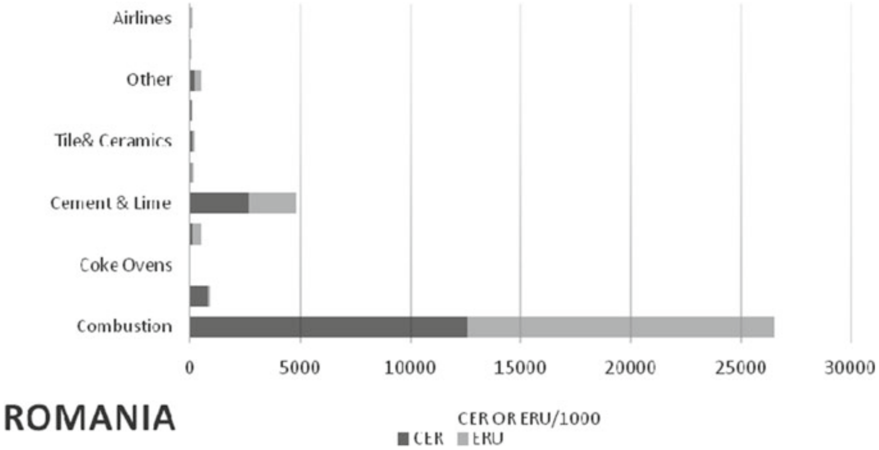


Fig. 4.6 Use of international credits per sector by Romania. *Source* The authors

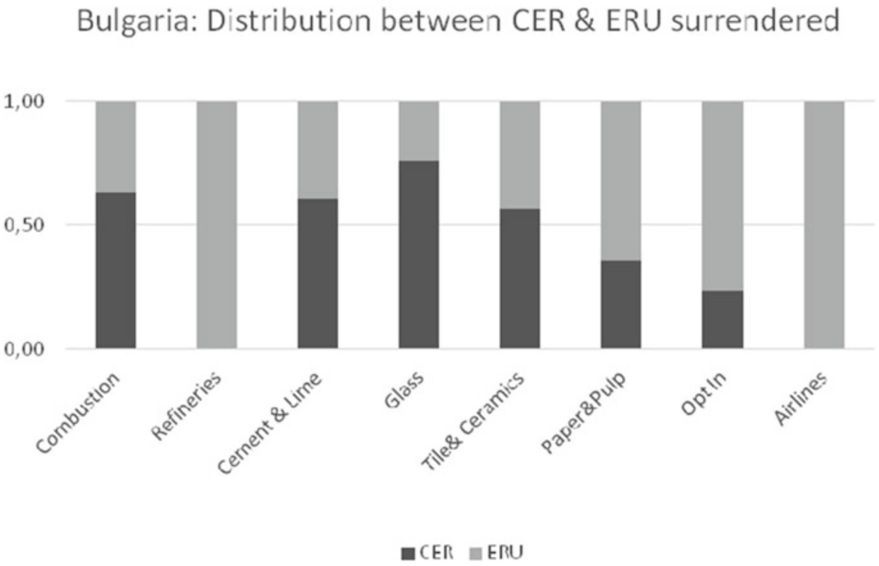


Fig. 4.7 Relative use of CER and ERU per sector by Bulgaria. *Source* The authors

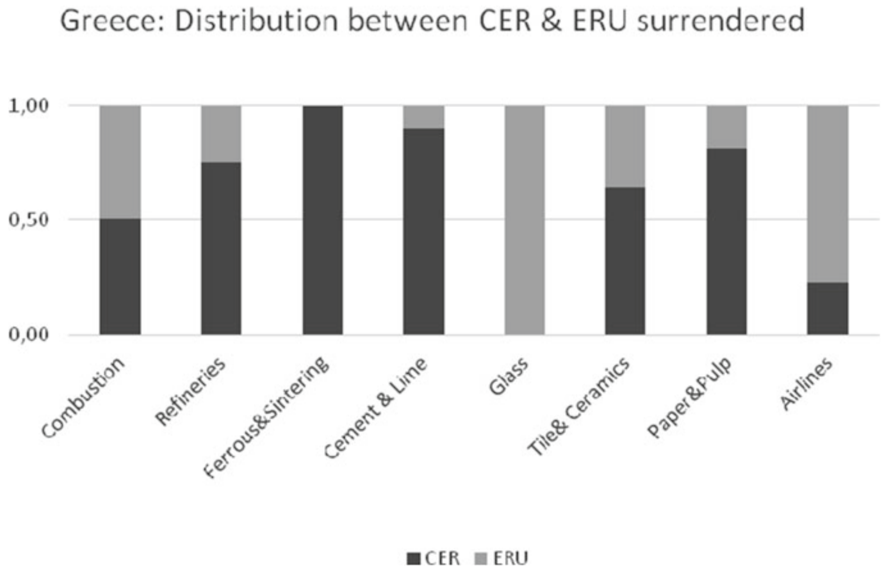


Fig. 4.8 Relative uses of CER and ERU per sector by Greece. *Source* The authors

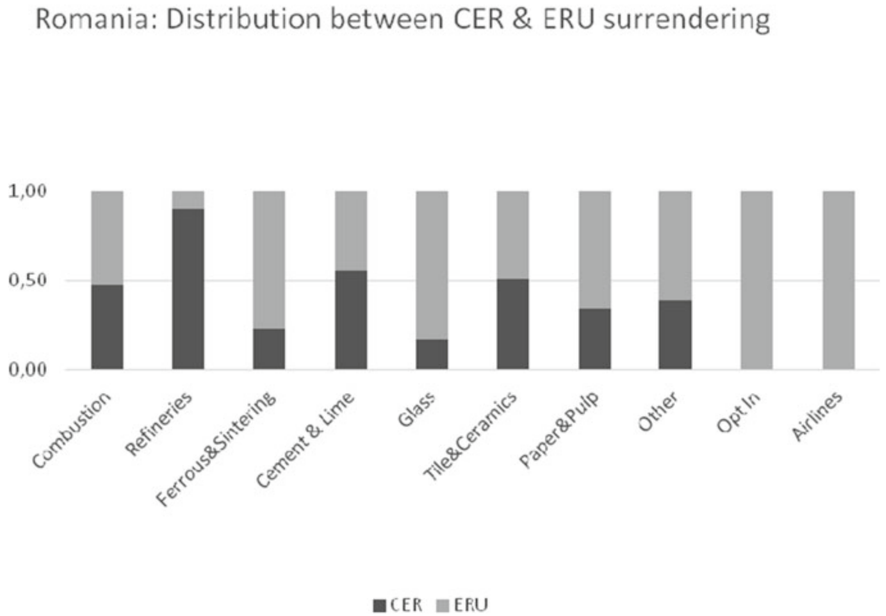


Fig. 4.9 Relative uses of CER and ERU per sector by Romania. *Source* The authors

4.5 'Market Activity' at the Installation Level

Bulgaria is home to 13 large-sized emitters comprising 83 % of the country's verified ETS emissions. Out of these, five were combustion installations, six were opt-in installations, one was a cement plant and one was a glass production plant, covering 86, 87, 55, and 56 % of each sector's verified ETS emissions, respectively (Fig. 4.10).

A 9.7 Mt deficit appeared for the large-sized emitters in three combustion installations and one installation from the opt-in sector, producing verified emissions totaling 42.6 % of the country's verified ETS emissions. However, their deficit was 5.4 % compared with the country's total verified emissions. The two combustion installations having a deficit appeared inactive and surrendered 40 and 67 % of their maximum international credits' surrender potential. The one opt-in and one remaining combustion installation with deficits were active to a very high extent, i.e. 99 %.

The nine large-sized emitters having a surplus were mostly active. Their total verified emissions represented 40.4 % of the country's ETS emissions. However, their surplus was 12.3 % of the country's total verified emissions. In particular, only one opt-in emitter with a surplus surrendered about 50 % of its allowed maximum international credits' surrender potential. The cement operator was very active (96 % exploitation) and the large glass plant exploited its potential to the full extent. The two additional combustion installations and the four additional opt-in installations surrendered at least 99 % of their maximum international credit surrender potential.

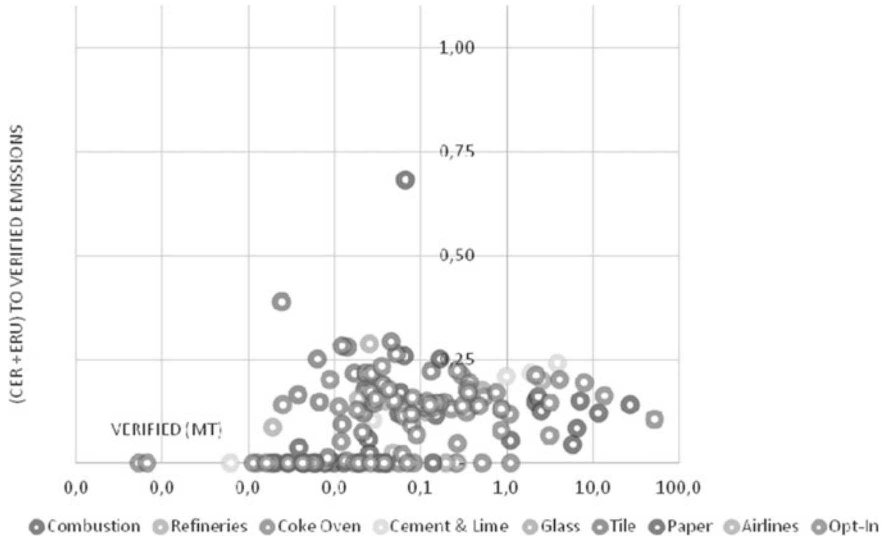


Fig. 4.10 International credits use at the installation level in Bulgaria. *Source* The authors

Furthermore, Bulgaria has 29 medium-sized emitters comprising 14 % of the country's verified ETS emissions. Six combustion installations, 17 opt-in installations, three cement plants and three glass production plants, respectively, cover 13, 12, 45, and 37 % of each sector's verified ETS emissions. A 1.1 Mt deficit for medium-sized emitters appeared for two combustion and three opt-in installations, whose total verified emissions represented 1.8 % of the country's ETS emissions. However, their deficit was 0.6 % of the country's total verified emissions. Out of these five installations with a deficit, all—apart from one combustion installation that had no allowances but only verified emissions—exploited their maximum potential. The 24 medium-sized emitters with a surplus were also mostly active. Their total verified emissions amounted to 12 % of the country's ETS emissions. The four combustion installations, nine out of 14 opt-in installations, two of the three cement plants and two out of three glass production plants exploited their potential to at least a 99 % of their maximum international credits' surrender potential. Only two opt-in plants, one cement plant and one glass plant did not surrender any international credits. Three opt-in installations with a surplus surrendered 26, 60, and 90 % of their potential.

Small-sized Bulgarian installations comprise 3 % of the country's total verified emissions. A deficit of approximately 0.1 Mt appeared at small-sized installations, representing 1 % of the country's ETS verified emissions. Bulgaria's sum of absolute deficits at the installation level is illustrated in Table 4.2.

Ten small ETS operators in Bulgaria surrendered an amount of more than 25 % of CERs and ERUs compared to their verified emissions. These were six tile operators, two paper production companies, one refinery and one combustion installation. The maximum deficit was observed at a large opt-in installation and totaled 8.6 million allowances i.e. 19 % of its allocated allowances. This ETS operator surrendered its maximum number of allowed international credits. The minimum deficit appeared in a small combustion plant, which surrendered only 33 % of its maximum international credit surrender potential. Its deficit was 402 allowances, i.e. 12 % of its allocated allowances.

Among Bulgaria's large and medium ETS installations with deficits, only two large combustion emitters were not active. In every emitter category, 2–3 ETS operators surrendered international credits in the range of 17–90 % of their maximum potential. Large and medium ETS operators that had a surplus were mostly active, but some small plants did not surrender any international credits.

Greece is home to 21 large-sized emitters covering 90 % of the country's verified ETS emissions during the investigated period. Of these, 13 combustion installations, five cement plants and two refineries cover 93, 86, and 87 %, respectively, of each sector's ETS verified emissions, and 1 sintering plant covers all sectors' ETS emissions. Large-sized emitters in Greece had a 31 Mt deficit, distributed among 11 combustion installations and one refinery. The verified emissions of the large-sized emitters represented 72 % of the country's ETS emissions. However, their deficit was only 10 % compared with the country's total verified emissions. These 12 installations all exploited their maximum potential for the surrender of international credits (Fig. 4.11).

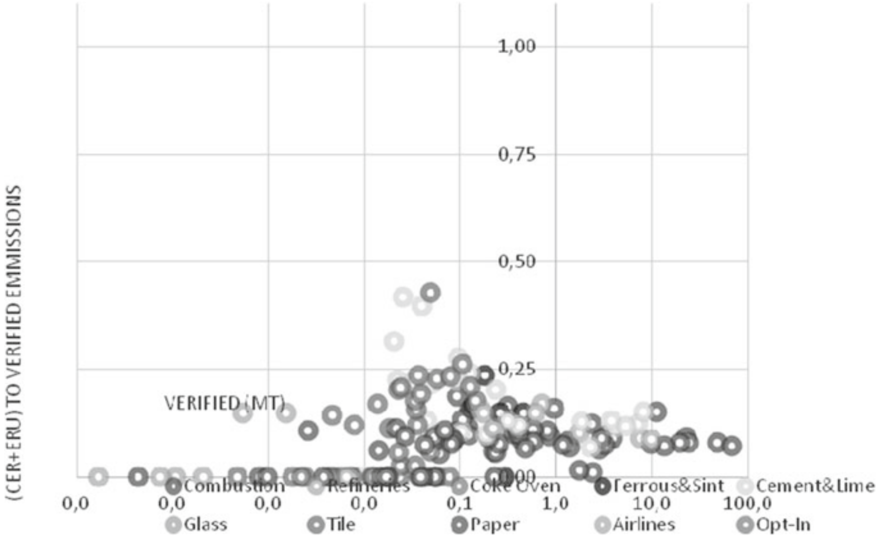


Fig. 4.11 International credit uses at the installation level in Greece. *Source* The authors

Out of the 21 large-sized emitters, nine had a surplus during the period. Their total verified emissions represented 17 % of the country's ETS emissions. However, their surplus was 5.8 % compared with the country's total verified emissions. The two combustion installations, four cement plants, one sintering plant and one refinery surrendered at least 99 % of their maximum potential. Only a single cement operator surrendered 98 % of its potential. Greece is also home to 29 medium-sized emitters under the scope of the EU ETS, covering 8 % of the country's verified emissions. These involved 19 combustion installations, two refineries, three ferrous plants, three cement production plants and one lime plant covering 7, 13, 76, 14, 16, and 77 % of the respective sector's ETS emissions. A 1 Mt deficit appeared for medium-sized emitters in seven combustion installations and one airline, whose total verified emissions represent 2 % of the country's ETS emissions. However, their deficit was 0.3 % of the country's total verified emissions. These eight installations each surrendered at least 99 % of their maximum international credits potential. The total verified emissions of the 21 medium-sized emitters with a surplus, comprised 6 % of Greece's total ETS emissions. Of those ETS operating plants, 11 combustion installations, two refineries, two ferrous plants and one lime plant fully utilized their potential. The additional ferrous plant surrendered 98 % of its potential, three cement factories surrendered 21, 76, and 99 % of their respective potential, while one combustion installation was very inactive and surrendered around 7 % of its international credits potential in 2012. A deficit of approximately 0.2 Mt existed for installations representing 0.003 % of the country's ETS verified emissions. Table 4.2 illustrates the sum of absolute deficits at the installation level in Greece. The largest proportion of CERs and ERUs compared to verified emissions, a greater than 25 % proportion when compared to their verified emissions, was surrendered by four small lime and two small tile ETS operators. The maximum deficit in Greece was observed at a large combustion installation and totaled 12.7 million allowances, for example, 23 % of its allocated allowances. This plant surrendered the maximum allowed amount of international credits. The minimum deficit, i.e. 180 emission allowances, appeared in a small airliner that did not surrender any international credits.

Concerning Greek ETS installations with a deficit, all emitters utilized at least 99 % of their potential surrender of international credits. In the medium- and small-sized emitters' category, some ETS operators surrendered 7–87 % of their international credits potential. Large and medium ETS operators with surplus were mostly active, whereas very few small installations with a very low potential did not surrender any international credits.

In Romania, 27 large-sized emitters represented 81 % of the country's verified ETS emissions during the investigated period. These comprised 17 combustion installations, two refineries, seven cement plants and one ammonia production plant, covering 80, 97, 99.5, and 62 % of each respective sector's verified ETS emissions (Fig. 4.12).

A 13 Mt deficit appeared for large-sized emitters in Romania, comprising six combustion installations corresponding to 37 % of the country's verified ETS emissions. However, their deficit was only 5 % of the country's total verified emissions. These installations all exploited their maximum potential for international credits' surrender. Out of the 27 large-sized emitters, 21 presented a surplus during the examined period. Their total verified emissions represented 44 % of the country's ETS emissions. However, their surplus was 33 % of the country's total verified emissions. Of these 21 installations, nine combustion, four cement plants,

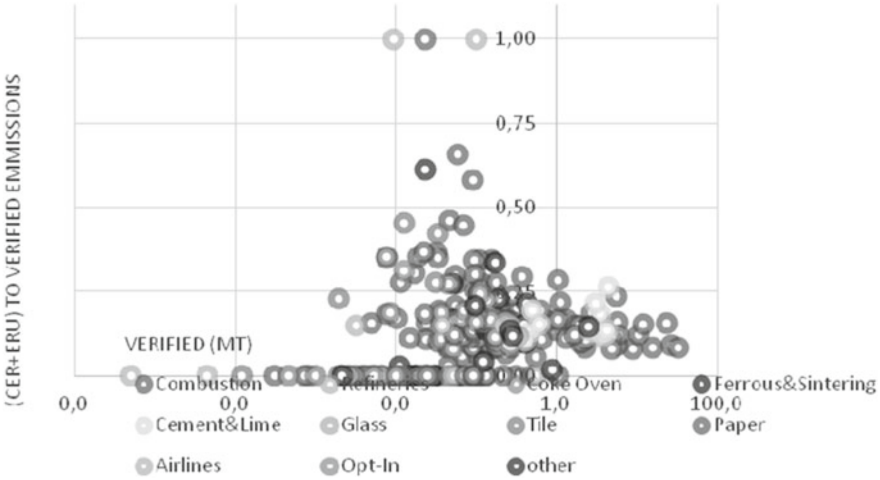


Fig. 4.12 International credit uses at the installation level in Romania. *Source* The authors

two refineries and one ammonia plant surrendered at least 99 % of their potential allowances. The cement plants surrendered 82, 82, and 96 % of their potential, while the two combustion installations surrendered 44 and 66 % of their potential. In Romania, 45 medium-sized emitters according to the scope of the EU ETS represented 13 % of the country's verified emissions. These comprised 28 combustion installations, four ferrous plants, two glass production plants, three plants from the 'other' sector and one airline, comprising 10, 50, 88, 35, and 50 %, respectively, of each sector's verified ETS emissions. This included all 7 lime plants as well. A 2.7 Mt deficit was found for the medium-sized emitters, in five combustion installations, two ferrous plants, one ammonia plant, one lime and one airline; the verified emissions of these emitters amounts to 2.5 % of the country's ETS emissions. However, their deficit was 0.5 % compared to the country's total verified emissions. Of these 10 deficit-containing plants, four combustion plants, two ferrous production plants, one lime industry and the single airline, all surrendered at least 99 % of their potential allocation of international credits (EC 2014a). The ammonia plant surrendered 88 % of its potential and the one combustion plant that had no allowances allocated during the period did not surrender any international credits.

The total verified emissions of the 36 medium-sized emitters with a surplus comprised 11 % of Romania's ETS emissions. Of those plants, 15 combustion plants, four lime industries, the two ferrous production industries, the aluminum production plant, one chemical plant, one glass production plant and the airline surrendered at least 99 % of their international credits surrender potential. One glass company and two combustion plants stayed totally inactive, two lime plants surrendered 64 and 89 % of their potential and seven combustion plants surrendered 55–90 % of their potential, whereas one combustion company with no allocated allowances surrendered no international credits. A deficit of approximately 1.2 Mt appeared at installations representing 1.8 % of the country's verified ETS emissions. The sum of absolute deficits at the installation level in Romania is illustrated in Table 4.2.

The largest proportion of CERs and ERUs in Romania when compared to verified emissions, at a greater than 25 % proportion was surrendered by one large cement industry, two medium-sized combustion plants, 19 small combustion installations, two small refineries, one small sintering plant, three small ferrous plants, four small tile industries and two small paper industries. Romania's maximum deficit was observed at a large combustion installation, totaling 4.8 million allowances, i.e. 17 % of its allocation. This plant surrendered its maximum allowed amount of international credits. The minimum deficit, i.e. five allowances, appeared in a small airliner that did not surrender any international credits.

Romania's large and medium ETS installations where a deficit appeared were mostly active to their maximum potential. Overall, approximately 10 ETS operators surrendered international credits in the 55–88 % range; however, only one of them had a deficit. Large and medium ETS operators with surplus were mostly active.

4.6 Conclusions

Examining the experience gained from the application of the EU ETS in the three Balkan countries in the EU ETS phase II leads to the conclusion that ETS operators became active at some point during this trading period, mostly towards its end. The reasons behind ETS operators large utilization of the potential to surrender international CER and ERU credits instead of EU emission allowances (EUAs) appears, on the one hand, due to the deficit of the allowances and the applicable fine of 100 per ton of CO_2 emissions in case there were no emission allowances to be surrendered in due time. On the other hand, the high extent of utilization reflects the opportunity to gain monetary profit due to the price spread between EUA versus the CER and the ERU. Large-sized emitters in Bulgaria, Greece and Romania, respectively, comprised 83, 90, and 81 % of their country's total verified ETS emissions. The absolute deficit found among large-sized emitters, covering 20 combustion installations, one refinery and one opt-in plant, amounted to 54 million emission allowances overall. Only two combustion plants were not particularly active and surrendered less than 70 % of their maximum potential. Medium-sized emitters, respectively, covered 14, 8, and 13 % of the total ETS verified emissions in each individual MS. The absolute deficit found among medium-sized emitters amounted to almost 5 million emission allowances overall and relates to 14 combustion installations, two ferrous plants, two airlines, three opt-ins, one lime plant and one ammonia production plant. Small-sized emitters in Bulgaria, Greece and Romania, respectively, covered 1, 2 % and 2 % of total ETS verified emissions and had an overall deficit of 1.5 million emission allowances (EC 2014b).

Overall, it can be concluded that in the examined countries, several EU ETS operators that had no deficit have been very active. In addition, some EU ETS operators that had a surplus remained inactive. However, few ETS operators had a deficit that remained inactive. These trends related to the ETS operators' size, with larger emitters were more active than smaller emitters. It is estimated that the low amount of unexploited international credits, i.e. 5.5 million overall, was due to exemptions relating to very small operators, probable unexpected occurrences (e.g. closure of installations) or other issues involving common management of credits among ETS operators (the so-called 'pooling' option).

On the installation level, large-sized emitters, i.e. plants with a total amount of verified emissions of over 2.5 Mt during the 2008–2012 period, produced 83 % of the total verified ETS emissions in Bulgaria (13 large-sized emitters, of which, five combustion installations alone covered 86 % of the sector's verified ETS emissions), 90 % of the verified ETS emissions in Greece (21 large-sized emitters, of which 13 combustion installations produced 93 % of the sector's ETS verified emissions) and 81 % of the verified ETS emissions in Romania (27-sized large emitters, of which 17 combustion installations produced 80 % of the sector's ETS verified emissions).

In the three countries examined in this study, the combustion sector as a whole exhibited a deficit in Greece but a surplus in both Bulgaria and Romania—prior to the use of international credits. Both Bulgaria's and Romania's combustion sectors have exploited their potential for CER and ERU surrender to a significant extent (more than 90 %). However, in Greece, this sector exploited most of its total potential (close to 100 %). Greece and Romania utilized almost as much ERUs as CERs while Bulgaria's combustion sector utilized more CERs than ERUs.

Acknowledgments This study was conducted as part of the 'CO_2-Glass' project and in the frame of the Sustainable Industry Low Carbon Scheme—Short term innovation measures—SILC I programme under the Competitiveness & Innovation Framework Programme (CIP) for 2007–2013 of the European Commission, DG Enterprise & Industry.

References

EC, 2006: "European Commission Decision of 29th November 2006 Concerning the National Allocation Plan for the Allocation of GHG Emission Allowances Notified by Greece in Accordance with Directive 2003/87/EC of the European Parliament and of the Council".

EC, 2007: "European Commission Decision of 26th October 2007 Concerning the National Allocation Plan for the Allocation of GHG Emission Allowances Notified by Romania in Accordance with Directive 2003/87/EC of the European Parliament and of the Council".

EC, 2008: Corrigendum to the Commission Decision C(2007)5256 of 26 October 2007; at: http://ec.europa.eu/clima/policies/ets/pre2013/nap/docs/bg07_en.pdf.

EC, 2012: "State Aid SA.34753 (2012/N)—Romania Transitional Free Allocation of Greenhouse Gas Certificates for Electricity Producers Under Article 10c of the ETS Directive", Document C (2012) 8776 final; at: http://gov.ro/en/government/cabinet-meeting/measures-to-implement-the-mechanism-of-transitional-allowance-for-free-of-greenhouse-gas-emission-certificates-for-electricity-producers.

EC, 2013: "Press Release 4/12/2013, State Aid: Commission Authorizes €945 Million Worth Allocation of Free Greenhouse Gas Emission Allowances for Modernization of Bulgarian Electricity Sector"; at: http://europa.eu/rapid/press-release_IP-13-1202_en.htm.

EC, 2014a: "Status Table on Free Allocation to Industry and Heat Production for Phase 3, Updated on 14/3/2014"; at: http://ec.europa.eu/clima/policies/ets/cap/allocation/faq_en.htm.

EC, 2014b: DG Climate Action; at: http://ec.europa.eu/clima/index_en.htm.

EEA, 2013: "EEA Climate and Energy Country Profiles—Key Facts and Figures for EEA Member Countries", Technical Report 17/2013 (Luxembourg: European Commission): 178.

Chapter 5
Indigenous Egyptian Nubians and Climate Change Mitigation

Essam Hassan Mohamed Ahmed

Abstract Egypt and Sudan are the most populous countries in Africa and the Middle East. The Nile is considered as a very important artery that joins Sudan and Egypt and was an important part of ancient Egyptian spiritual life. Nubian peoples are an ethnic group and considered as one of the most ancient peoples in the world, their civilization started more than 8,000 years ago. Lake Nasser is the second largest man-made lake in the world; among the impacts that were anticipated were the resettlement of the Nubian population in the area inundated by the reservoir, saving of historic monuments, health impacts and coastal erosion. The climate models all estimate a steady increase in temperatures for Egypt, with little intermeddle variance. Somewhat more warming is estimated for summer than for winter. However, since Egypt is mainly a desert and relies primarily on irrigated agriculture, precipitation over the country itself matters very little. Much more important are precipitation changes at the water sources of the Nile, which affect the vulnerability of the water resources. The potential impacts of climate change on coastal resources are ranked as most serious and climate change induced sea level rise reinforces this trend. In addition to this high biophysical exposure to the risk of sea level rise, Egypt's social sensitivity to sea level rise is particularly high. In general, although the models on average show an increase in precipitation, inter-model variation is so high that it is uncertain as to predict whether annual average precipitation will increase or decrease.

Keywords Indigenous · Egypt · Nubian · Climate change · Nile

E.H.M. Ahmed, Ph.D., Climate Change and Sustainable Development Consultant, El Haram, Giza, Egypt; E-mail: esamhasan62@yahoo.com.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_5

5.1 Introduction

Egypt is one of the most populous countries in Africa and the Middle East with the majority of the estimated 89.5 million people (Oct. 2015), living in about 40,000 km^2 (15,000 $mile^2$) near the banks of the Nile River, the only arable land available in the country (World Bank 2013). Large areas of the Sahara Desert, however, are sparsely inhabited. About half of Egypt's residents live in urban areas, mostly spread across the densely populated centres of greater Cairo, Alexandria and other major cities on the Nile delta (Yael 2007).

Sudan, a country in North Africa and politically in the Middle East, is bordered by Egypt to the north, the Red Sea to the northeast, Eritrea and Ethiopia to the east, South Sudan to the south, the Central African Republic to the southwest, Chad to the west and Libya to the northwest (Yael 2007). Most of Sudan's population, estimated at 38.5 million people (July 2015), follows Islam and is a combination of indigenous Saharan Africans and descendants of Arabian Peninsula migrants. The Nile divides the country into the east and the west (WB 2008). The Nile River is the major north-flowing river in North Africa and is generally regarded as the longest river in the world (6,650 km). It was an important part of ancient Egyptian spiritual life and has been a very important artery between Sudan and Egypt. The Nile runs through ten countries, namely of Burundi, Rwanda, Democratic Republic of the Congo, Tanzania, Kenya, Ethiopia, Uganda and South Sudan, before finally flowing through Sudan and Egypt to the sea. The Greek historian Herodotus wrote that 'Egypt was the gift of the Nile'. An unending source of sustenance, the Nile was crucial to the development of the Egyptian civilization. As the river annually overflows, the remaining silt deposits have made the surrounding land fertile since thousands of years.

5.2 Indigenous Nubians in Egypt

Nubians, an ethnic group who lived and continue to live in north Sudan and southern Egypt are considered one of the most ancient peoples in the world, with evidence that their civilization started more than 8,000 years ago. They have their own culture, and it is believed that the Egyptian civilization arose from the Nubian lands (Macchi et al. 2008).

Nubians used to live around the stretch of the Nile about 350 km upstream of the Old Aswan Dam in the reservoir area, though they led a very hard life in small communities. The construction of the Old Aswan Dam and its subsequent height twice led them to change their location or migrate to cities in Lower Egypt.

Furthermore, the influx of Arabs to Egypt and Sudan contributed to the suppression of the Nubian identity following the collapse of the last Nubian kingdom in 1900. However, after 30 years, the social impact of the Nubian immigrants was considered more positively by the indigenous population. The unique characteristics of the Nubians are their culture (dress, dances, traditions and music) and their indigenous language (UNESCO 2009).

5.3 Environmental Setting

Lake Nasser is the second largest man-made lake in the world; it was created by the construction of the Aswan High Dam. After the construction of the Dam, a little less than a million metric tons of water was available in the new lake. The lake was named after the deceased President Nasser, who was the president of Egypt (1954–1970) during the High Dam construction period, when the Nubians had to leave their motherland in south Egypt because of the altered geography caused by this development. Since then, the Nubians have searched their roots in their ancestral mother lands.

Lake Nasser lies behind the Aswan High Dam; it is 480 km long and covers an area of 5,250 km^2 (Fig. 5.1). The dam and the consequent development of Lake Nasser displaced more than 100,000 people, resulting in significant environmental and societal impacts, many of which had not been anticipated. These impacts have been mitigated to varying degrees since then.

Among the anticipated impacts were the resettlement of the Nubian population from the areas inundated by the building of the reservoir, the saving of historic monuments, the loss in soil fertility, health impacts and coastal erosion. However, other impacts such as the water logging and salinization of the soil came to light only gradually where highly expensive mitigation efforts were only instigated after

Fig. 5.1 Lake Nasser in Egypt. *Source* Türk (2011)

long delays. However, other anticipated impacts such as reservoir evaporation and increasing sedimentation could not be mitigated. On the other hand, anticipated impacts such as seepage from the reservoir did not materialize and others such as river-bed erosion were less severe than expected (Türk 2011).

The climate of the Nubian lands at South Egypt is continental with marked variations between summer and winter temperatures and daytime and night time temperatures. July and August are the hottest months with average temperatures between 24 and 39.7 °C. In the coolest months of December and January, temperatures fall to between 10 and 21.7 °C. The average humidity varies from 13 % in the summer to 34 % in the winter. The rainfall is rare, although rain in the eastern desert occasionally causes flash flooding in the valleys on the eastern banks of Lake Nasser and the Nile River.

5.4 Nubian Resettlement

The motherland of the Egyptian Nubians was the south of Egypt since a long time. The establishments of the Aswan High Dam caused the distribution of the Nubians to the north and re-locate them at various and different Governorates after leaving their homes and cultivated lands. Egyptian Nubians lived in a starkly beautiful environment where on both sides of their lands were desert sands interspersed with rocky hills and extending down to the water's edge.

There were 553 sparsely populated communities in this area, which belonged to three distinct ethnic groups, two of which spoke Nubian dialects. After the construction of the reservoir, all date palms were destroyed, and most of the year, all cultivated land was left inundated. Cultivation was restricted to only a few months each year when the reservoir water was drawn down.

Nubians were consequently resettled southwards between Egypt and the Sudan with the majority of those who had lived in Egypt being resettled 3–10 km from the Nile near Kom-Ombo, 45 km downstream from Aswan. Population planners wished to establish a New Nubba in a crescent 60 km long and on average 3 km wide; hence, 47 village unit housings and facilities were built which approximated those in Old Nubba (Zaghloul et al. 2011).

To support the population, reclamation began on 21,000 feddans (equivalent to 8,820 ha or 21,798 acres) and out of this 18,000 feddans were eventually reclaimed. This land was to be irrigated by three main canals into which water was to be pumped from the Nile. Sixty percent of the land was dedicated to sugar cane, the harvest of which was expected to double the capacity at the nearby sugar refinery.

Unlike the situation in Egypt, 50,000–70,000 Sudanese Nubians were moved approximately 700 km south to an area near the town of Khashm el-Gibran, several hundred kilometers up the Atbara River from its junction with the Nile. There, the resettled had to adapt to a climate which has a regular rainy season as opposed to their previous desert habitat, in which virtually no rain fell. They also had to deal with new diseases such as endemic malaria and a host population that included no Nubians. Similar to the action taken for the Egyptian Nubians, the government developed an even larger irrigation project, called the New Half Agricultural Development Scheme, which would draw water from a dam built on the Atbara River.

5.5 Climate Change Impacts on Upper Egypt

All climate models estimate a steady increase in temperature in Egypt, with little variance, and more warming estimated in summer than in winter. The changes in precipitation are not expected to be statistically significant for June, July and August or in terms of annual totals. However, for December, January and February, significant declines in precipitation are projected.

Since most of Egypt is mainly a desert and relies primarily on irrigated agriculture, precipitation over the country itself matters very little. However, the precipitation changes at the Nile's water sources are more important, enhancing vulnerability.

In general, although the models on average show an increase in precipitation, inter-model variation is so high that it is uncertain as to whether the annual average precipitation will increase or decrease. The models estimate an increased precipitation in the winter months and a slightly decreased precipitation in the summer months, but there is little confidence in these seasonal projections.

In a study on the effect of climate change on Egypt, scenarios were examined for changes of 0, +2 and +4 °C and for changes in rainfall of ±10 and ±20 %. The potential impact of climate change on coastal resources was found to be the most serious due to an induced sea level rise, which would bring high biophysical exposure and have a significant effect on local communities. Further, a substantial decrease in the flow of the Nile could have a very serious impact on Egypt's well-being as the Nile provides almost all of the water in the country for drinking, irrigation and hydroelectric generation (Agrawala et al. 2004).

While there are substantial uncertainties about how climate change might affect the Nile flow itself through changes in rainfall, there is much more certainty about how temperature increases will increase evaporative losses, during simultaneously increasing irrigation and other water demands.

The impact of climate change on the availability of water from the Nile for agriculture, which employs over 30 % of the labor force, is estimated to be dramatic. The key impact on agriculture would, however, be indirect and would be mediated by the loss or salinization of prime agricultural land in the coastal zone and/or reduced irrigation supplies from the Nile.

5.6 Climate Change and Indigenous People

Regional and global assessments confirm that the Earth’s climate is changing. Current and projected levels of exposure to climate-related sensitivities, as well as limits and restrictions to adaptive capacity mean that some environments and societies are more exposed to climate change and are significantly more vulnerable to the long-term consequences than others.

Indigenous people depend on natural resources for their livelihood and they often inhabit diverse but fragile ecosystems. At the same time, indigenous people are among the World’s most marginalized, impoverished and vulnerable. Hence, while indigenous peoples bear the brunt of the catastrophe of climate change, they have minimal access to resources to cope with such changes.

For indigenous people around the world, climate change brings different types of risks and opportunities, threatens cultural survival and undermines indigenous human rights. The consequences of ecosystem changes have implications for the use, protection and management of wildlife, fisheries and forests, affecting the customary uses of culturally and economically important species and resources (Nilsson 2008).

Despite the impact of climate change on indigenous people and their traditional knowledge, international experts most often overlook the rights of indigenous people as well as the potentially invaluable contributions the traditional knowledge, innovation and practices can bring to the global search for climate change solutions.

As the global discourse on climate change focuses on understanding how we can scientifically and technologically adapt to, as well as mitigate climate change, indigenous people are faced with the prospect of climate change, further challenging their abilities to adapt to and cope with environmental and social changes. Increasingly, international and national climate change mitigation strategies pose an additional threat to indigenous territories and coping strategies.

The most significant considerations for the climate change impacts from the settlements point of view are the adaptation and social impacts. These two factors are highly important for the indigenous people, for Nubians in particular. A number of international, national and regional institutions have initiated the awareness on the impacts of climate change concerning the indigenous people. This is attempted by enhancing the capacities of the indigenous societies in communication and participation through providing support and encouragement to their activities. Despite these positive attempts, the amendments concerning the indigenous societies are still not sufficiently incorporated to the future development strategies of the global agencies, namely to the climate change programs of the UNFCCC, IPCC (IPCC 2007) and UNCCD.

5.7 Forests and Indigenous Peoples

Degradation and deforestation of the world's tropical forests are cumulatively responsible for about 10 % of the net global carbon emissions. Therefore, tackling the destruction of tropical forests is core to any concerted effort to combat climate change. Traditional approaches to halting tropical forest loss have unfortunately been unsuccessful, as can be seen from the fact that deforestation and forest degradation continue unabated.

Reducing Emissions from Deforestation and Forest Degradation (REDD) incentivizes a break from historic trends of increasing deforestation rates and greenhouse gases emissions (UN-REDD 2012). It is a framework through which developing countries are rewarded financially for any emissions reductions achieved associated with a decrease in the conversion of forests to alternate land uses. Having identified current and/or projected rates of deforestation and forest degradation, a country taking remedial action to effectively reduce those rates will be financially rewarded relative to the extent of their achieved emissions reductions (Sam 2010).

REDD (2009) provides a unique opportunity to achieve large-scale emissions reductions at comparatively low abatement costs. By economically valuing the role forest ecosystems play in carbon capture and storage, it allows intact forests to compete with historically more lucrative, alternate land uses resulting in their destruction.

In its infancy, REDD (2009) was first and foremost focused on reducing emissions from deforestation and forest degradation. However, in 2007 the Bali Action Plan, formulated at the thirteenth session of the Conference of the Parties (COP-13) to the United Nations Framework Convention on Climate Change (UNFCCC), stated that a comprehensive approach to mitigating climate change should include policy approaches and positive incentives on issues related to reducing emissions from deforestation and forest degradation in developing countries. This initiative was also concerned with the role of conservation and, sustainable management of the forests and the enhancement of forest carbon stocks in the developing countries (IUCN 2009).

A year later, this was further elaborated on as the role of conservation, sustainable management of forests and enhancement of forest carbon stocks that was upgraded so as to include the same emphasis as avoided emissions from deforestation and forest degradation.

Finally, in 2010, at COP-16, as set out in the Cancun Agreements, REDD became REDD-plus (REDD+), to reflect the new components. REDD+ now includes:

(a) Reducing emissions from deforestation;
(b) Reducing emissions from forest degradation;
(c) Conservation of forest carbon stocks;

(d) Sustainable management of forests;
(e) Enhancement of forest carbon stocks.

Within its remit, REDD+ has the potential to simultaneously contribute to climate change mitigation and poverty alleviation, whilst also conserving biodiversity and sustaining vital ecosystem services (IUCN 2010).

This potential for multiple benefits raises the crucial question of to what extent the inclusion of development and conservation objectives may help or hinder the overall success of, and negotiations for, a future REDD+ framework (explicitly for climate change mitigation). Having said this, prospective co-benefits can easily transform into prospective co-detriments, making the earlier question arguably irrelevant. Aside from whether consideration of such factors will promote or hamper the success and negotiations of a REDD+ framework, they are unquestionably important for the creation of a sustainable and equitable REDD+ process.

The details of a REDD+ mechanism continue to be debated under the UNFCCC, and the considerable financial needs for full-scale implementation have not yet been met. A final mechanism is therefore not yet in place and operating at scale. At this extent, the UNFCC should bear in mind that the indigenous societies' contribution to carbon emissions remains among the lowest in the world. Within the deforestation context, this was mentioned directly through an acknowledgement and call to action within the REDD+ program, which has applied a rights-based approach and updated its mission to align more closely with the objectives of the UN Declaration on the Rights of the Indigenous Peoples.

An afforestation/reforestation carbon sequestration model has been developed to show the potential of community schools as instruments of environment conservation through their promotion of indigenous knowledge systems. The model reflects the strength of community schools and children as important components of forest carbon projects and how their involvement as active participant in such projects, could ensure effective implementation of afforestation/reforestation projects and reducing leakage of carbon emission in REDD+ (IUCN 2010).

The motherland of the Nubians located at southern Egypt is on fertile agricultural land and on the Nubian sandstone rich in water resources. Additionally, the water from the River Nile contains suspended clay to reclaim and enhance the quality of the prime soils. Consequently, the REDD and REDD+ programs could be successfully implemented on these sites, which will be useful to reduce the CO_2 emissions. Unfortunately, so far, the Egyptian Government did not undertake REDD-related programs in this area seeking alleviation of the people. However, the extensive orchards established by some communities have enhanced income-generation via fruit yields and in turn combat erosion by halting sand movement. Despite these unguided and individual efforts, these activities provide indirect impacts in climate change mitigation.

5.8 Mitigation Actions in the Egyptian Indigenous Communities

The Nubians are indigenous to the area around Lake Nasser and have their own language, customs, culture, and traditions (Fig. 5.2). To mitigate the effects of high temperatures which approach 50 °C in the summer in the Lake Nasser area and to reduce the use of electrical power to run air conditioning, the Nubians have developed special models and architectural settlement forms (Fig. 5.3). Houses have been built with domes to exploit air currents to reduce internal high temperatures so that air conditioning is not necessary, thereby reducing the electricity needs and greenhouse gas emissions. Further, many trees of different dimensions have been planted along the lakeside to increase respiration and reduce local temperatures.

Regardless of these attempts to combat the climate, similar to the Egyptians in other areas, the Nubians around Lake Nasser are suffering from the climate change impacts of high temperatures and humidity. The Nubian society is facing drought, lack of drinking water, rising water temperatures and the consequent impacts of these problems. Although Pollution does not affect the local environment as there is no industrial production near Lake Nasser; the Nubians are still suffering the impact of climate change on their crops and a quality loss in their overall health. REDD provides financial rewards for avoided deforestation and forest degradation. In doing so, it also provides incentive to manage forests sustainably and equitably for people who live in and around forested areas.

Fig. 5.2 A Nubian Family. *Source* The author

Fig. 5.3 A Nubian's House. *Source* The author

Carbon emissions could be reduced by reducing forest destruction and burning and pumping less carbon dioxide into the atmosphere. However, there is a second, equally important part of REDD which enhances forest protection and in turn the capture of carbon from the air storing it in trees and plants and sequester it in the soil. Ultimately, by keeping forests healthy and intact, GHG emissions are reduced and CO_2 is sequestered.

5.9 Conclusion

As in other areas in Egypt and especially the coastal areas, the ancient Nubian societies in Egypt and Sudan are suffering from significant climate change impacts. Some of this impact was caused by the construction of the Aswan High Dam, which forced the relocation of the Nubians, thereby causing them to lose their contact with their roots and their mother land.

Nubians have designed special architectural forms to exploit the air currents, thus alleviating the effect of the high temperatures and reducing the need for air conditioning, which consequently reduces electrical supply needs and greenhouse gas emissions. REDD is a mitigation response that could assist Nubian and other indigenous communities to mitigate the impact of climate change. So far, the indigenous societies' contribution to carbon emissions remains among the lowest in the world. This should encourage the positive climate change mitigation actions taken by the governmental agencies by enhancing the knowledge and awareness of indigenous people to reflect the benefit towards deforestation, reforestation, REDD and REDD+ projects.

The government and local authorities need to smooth the titling process to ensure the applicability of REDD projects, encourage more participation from indigenous areas and protect the common benefits for communities. Therefore, capacity building is necessary for the effective engagement of the relevant actors in the REDD process. Thus, it is crucial to ensure that communities and especially indigenous communities are aware of and involved in the implementation of REDD and its operational strategies.

References

Africa Water Atlas, 2008: "Summary for Decision Makers", International Report; at: http://na.unep.net/atlas/africaWater/downloads/Africa_Water_Atlas_Executive_Summary.pdf.

Agrawala, S.; Moehner, A.; El Raey, M.; et al., 2004: "Development and Climate Change in Egypt: Focus on Coastal Resources and the Nile"; at: http://www.oecd.org/env/cc/33330510.pdf.

Bhattarai, B., 2009: "FECOFUN: Stakeholder Engagement in REDD Process: Addressing Equity Issues", Presentation in Hanoi, Vietnam; at: https://www.iisd.org/pdf/2010/redd_hanoi_stakeholder_involvement.pdf.

IPCC, 2007: *Climate Change 2007. Synthesis Report* (Geneva: IPCC); at: https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

IUCN, 2009: "REDD-Plus and Benefit Sharing", Experiences in Forest Conservation and Other Resource Management Sectors. Forest Conservation Program; at: https://cmsdata.iucn.org/downloads/benefit_sharing_english.pdf.

IUCN, 2010: "Indigenous People and REDD Plus: Challenges and Opportunities for the Engagement of Indigenous Peoples and Local Communities in REDD Plus"; at: http://cmsdata.iucn.org/downloads/a4_iucn_indigenous_peoples_and_redd_.pdf.

Macchi, M.; Oviedo, G.; Gotheil, S.; et al., 2008: "Indigenous and Traditional Peoples and Climate Change", Issues Paper, International Union for Conservation of Nature (IUCN); at: https://cmsdata.iucn.org/downloads/indigenous_peoples_climate_change.pdf.

National Geographic Magazine (NGM.com), 2008: "The Black Pharaohs", Feb. 2008; at: http://ngm.nationalgeographic.com/print/2008/02/black-pharaohs/robert-draper-text.

Nilsson, C., 2008: "Climate Change from an Indigenous Perspective Key Issues and Challenges"; at: http://www.iwgia.org/iwgia_files_publications_files/IA%201-2_08_Climate_Change_from_ind_perspective.pdf.

Parker, C.; Mitchell, A.; Trivedi, M.; et al., 2009: "The Little REDD+ Book", Global Canopy Program (John Krebs Field Station, Oxford): 133.

Sam, C., 2010: "The Inclusion of Indigenous Peoples in REDD Project in Mundolkiri Province, Cambodia"; at: http://www.seachangecop.org/files/documents/TAI_REDD_Report.pdf.

Scudder, T., 2005: *The Future of Large Dams: Dealing with Social, Environmental, Institutional and Political Costs* (London: Earthscan): 389.

Türk, S.L., 2011: "Environmental Risks in Africa: The Case of Egypt"; at: http://www.oecd.org/mena/investment/BCR%20Egypt_April29_with_cover.pdf.

UNESCO [Bates, P.; Chiba, M.; Kube, S.; Nakashima, D. (Eds.)], 2009: *Learning and Knowing in Indigenous Societies Today* (Paris: UNESCO); at: http://unesdoc.unesco.org/images/0018/001807/180754e.pdf.

UN-REDD, 2012: “Guidelines on Stakeholder Engagement in REDD+ Readiness with a Focus on the Participation of Indigenous Peoples and Other Forest-Dependent Communities, UN-REDD Program”, UNEP, April 20, 2012.

World Bank, 2013: *Doing Business in Egypt 2014* (Washington, DC).

Yael, D., 2007: “The Environmental Effects of the High Dam at Aswan. June Talk at the California Institute of Technology”.

Zaghloul, S.S.; Pacini, N.; Schwaiger, K.; et al., 2011: “Towards a Lake Nasser Management Plan: Results of a Pilot Test on Integrated Water Resources Management”, in: *International Water Technology Journal (IWTJ),* 3: 249–258.

Chapter 6
Carbon Trading Via Exports: Comparison of the Emissions Embodied in Exports in China and Turkey

Nejat Erk and Ali Vural Cengiz

Abstract This study first takes a brief look at the relationship between countries' carbon dioxide emissions and their exports to determine if a relationship exists between carbon emissions and international trading, particularly exports. The analysis considered 23 countries from different income levels and different regions in terms of carbon dioxide emissions, total exports, agricultural exports, industrial exports and service exports. Econometric model 'Xtreg' was used to test if the statistical correlation between carbon dioxide emissions and three types of exports (agricultural, industrial and services) was significant or not. The findings were very interesting: carbon emissions were found to increase with the industrial and service exports; however, no meaningful relationship was found between carbon emissions and agricultural exports. The study argues that carbon trading puts a new crack in competition analysis in international economics.

Keywords Carbon trade · Econometry · Xtreg · Carbon emission

6.1 Preface

Climate change and its outcomes have been studied as a major subject by not only scientists but also environmentalists and even most of the population, particularly in terms of its causes and possible solutions. According to United Nations Framework Convention on Climate Change (UNFCCC), Turkey has been identified as the country with the highest percentage increase in emission between 2012 and 2014. New Zealand ranks second and Malta ranks third (UNFCCC Report 2014). Therefore, research on the development of carbon emissions over the last decade in Turkey is particularly important.

N. Erk, Prof. Dr., Çukurova University, School of Economics and Administrative Studies, Adana, Turkey; E-mail: erk@cu.edu.tr.

A.V. Cengiz, Ph.D., Çukurova University, Institute of Social Sciences, Adana, Turkey; E-mail: avurcengiz@gmail.com.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_6

On the other hand, current studies show that modern economies generate an important percentage of carbon emissions via the production of the goods to be exported—more than 50 % in most developed economies (Su et al. 2010). For example, 70 % of Norway's carbon emissions stem from exported goods (Peters/Hertwich 2008).

All studies on the subject agree upon the following two points:

(1) An important element of carbon emissions arises from international trade. In other words, carbon emissions are transferred from producing countries to importers via trade.
(2) Carbon emissions from trade have increased over time.

Thus, calculating the emissions embodied in exports (EEE) is important for the Turkish economy as well as others to enable them to decrease their total emissions.

6.2 History of Studies

Input–output analysis has been widely used to study production, relationships and interdependence of economic sectors. Quesnay (1759) published 'Tableau Economique' to explain the American economy from the viewpoint of sector-dependence. Later, Leontief (1936) developed an analytical framework of input–output analysis in the 1930s to show the interdependence among economic sectors, an achievement that won him the 1973 Nobel Prize. Even today, input–output analysis remains one of the most widely accepted methods of analysis in modern economics (Baumol 2000).

Skolka's input–output studies (Skolka 1976) in 1976 were followed by Stone's analysis in 1984 (Stone 1984) and Rose and Miernyk's 1989 study (Rose/Miernyk 1989). Leontief himself continued to develop input–output analysis, using it as part of social studies on empirical as well as theoretical analyses.

According to Miller/Blair (2009), an input–output analysis basically shows how one industry's production output is allocated among other sectors. Later, additional economical activities were added and input–output tables became employed in conjunction with other economic analysis tools.

Application of Leontief's input–output analysis approach widely at different levels (local, regional, national and international) became possible with the advent of high-speed computers and statistical programs. It has now been applied in studies to link not only sectors of a national economy but also various sectors from many countries in global input–output studies (Xu/Dietzenbacher 2014).

Input–output analysis has been used in social calculations for employment as well as for subjects as diverse as energy consumption, environmental pollution and industrial production as well as geographical analysis (Miller/Blair 2009). Since the 1960s, input–output analysis has been used for environmental pollution calculations stemming from transfers between sectors, with Leontief himself conducting one such analysis personally in 1970. Many studies followed in his footsteps over the past 45 years.

One accurate and simple method to calculate the level of pollution as a result of industrial production activity and product transfers between the sectors assumes that a matrix of the created emissions also exists. This approach has been widely used to calculate EEE and embodied emissions imports (EEI), thus enabling the study of EEE and EEI developments in several country groups.

6.3 Our Econometric Study

This study, presented at the Istanbul Carbon Summit in 2014, seeks to determine if a meaningful correlation exists between carbon emissions and exports at the global level. Our dependent variable is CO_2 emission values (metric tons per capita); total exports, industrial exports, agricultural exports, and service exports are the independent variables. The data cover the years 2000, 2005 and 2010.

The ‘Xtreg’ (Fixed-, between-, and random-effects and population-averaged linear models) statistical method was used to pinpoint the correlation between CO_2 and the three examined branches of exports. The data were taken in February 2014 from databases compiled by the United Nations Development Program (UNDP), World Bank and OECD from the following sources:

(1) UNDP 2013 Human Development Report, United Nations Development Program 1 UN Plaza, New York, NY 10017, USA
(2) The World Bank, 2002 World Development Indicators, Page 230.
(3) The World Bank, Indıcator Data 2010, 1818 H Street NW, Room MC2-812, Washington, D.C. 20433 USA
(4) The World Bank, Indıcator Data 2013, 1818 H Street NW, Room MC2-812, Washington, D.C. 20433 USA
(5) OECD. Stat Extracts, stats.oecd.org/index.aspx?queryid167#, 21 April 2016

As the calculations shown below indicate, we found significant ($R^2 = 0.5030$, $P < 0.03$) statistical relation between carbon emissions and two types of exports: industrial exports and service exports. On the other hand, no significant relation occurred between carbon emissions and agricultural exports.

Unfortunately, an item specifically detailing environmental cost is not included in the prices for industrial goods and services. Despite seeking low wages, high technology and effective managerial skills, neither developed nor underdeveloped countries pay attention to the ecosystem damage caused by exports. In addition to these pricing issues, countries may need to find their net exports after calculating all emission amounts and subtract these numbers from their total exports. For example, Turkish exports in 2013 have been declared as $151.7 billion but the real number after ecological damage is accounted for would probably run under $150 billion.

The people of Turkey, and not just the government, have the right to know the real numbers.

Determining CO_2 emissions and adjusting world export prices raises another question: Do the trading theories of Ricardo, Ehlin and Samuelson need to be reconsidered? Do all countries still benefit from international trade? Is the theory that claims each country shall specialize in the products using most common production factors still correct? The same uncertainty applies to the theory that the most common factor yields the highest income. All these theories may need to be adjusted.

A first step could be calculating the real emission cost per production unit together with the real cost for industrial products and exported services. Before we conclude this section, we would like to mention a study by Peters et al. (2011) that supports our findings. 'The increase in exports can explain the majority of CO_2 emissions in time even though different data sets show different values. In Norway, we found that 60.6 % of emission increases were created by industrial exports. This is followed by household consumption (17.9 %) and public expenditures (12.7 %).

6.4 Emissions Embodied in Exports in China and Turkey—2000 and 2009

Calculations are completed using input–output analysis for 34 sectors in each country. We used Matlab to perform the calculations. According to the Netherlands Environmental Assessments Agency, China, whose production output and exports soared have over the last 30 years, has created most of the world's emissions since 2006. Total carbon emissions created amounted to 6200 million tons in 2006 (IPCC 2011). Many studies show that trade in goods has been an important factor behind this substantial increase in total emissions (Pan et al. 2008a; Ma/Ying 2011). China's total international trade reached $2.5 trillion in 2008, and China became the second largest exporter in the world following Germany. However, most of the products sold to developed countries are labor- and energy-intensive goods, and emissions embodied in those products play an important role in China's total emission increases. EEE stem directly from not only production activities but also transport, energy used in production and other supporting activities (Peters/Hertwich 2008).

Calculations show us that both China's and Turkey's EEE numbers increased from 2000 to 2009. China's increase, in particular, showed substantial growth; its 541 % increase was the highest in the world. Our findings parallel to research with our results showing export increases leading to rising emissions and previous research stating "when a consumption-based system is adopted, China's emissions are lower than those reported by some international organizations. The rapid growth in China's exports is a key determinant of China's rising total emissions (Ma/Ying 2011).

One important issue in China's emission growth is the high discrepancy between EEE and EEI because of the country's very high trade surplus. In this regard, Turkey is in much better shape due to its foreign trade deficit.

6.5 Conclusions

In the first part of our two-part study, we found a correlation between total carbon emissions and two types of exports: industrial and service exports. We did not find a significant correlation between emissions and agricultural exports. We also demonstrated that the EEI increased to high levels as a result of the trade increases in all regions in the world between both developed and developing countries and between countries from different development levels.

In the second step of this study, we calculated EEE levels. We found increases between 2000 and 2009 of 541 % in China and 37 % in Turkey. These findings indicate how emissions from the productions for export are so hard to reduce in developing countries. Even Turkey's EEE levels showed a high percentage increase, whereas China's EEE increases by 15 times more than Turkey's EEE, growth that can be largely attributed to China's very high production levels.

Our study proved that both China and Turkey need to make greater strides in the fight against carbon emissions and need to replace their current production technologies with better and more efficient ones.

References

Baumol, W., 2000: "Leontief's Great Leap Forward. Economic", in: *Systems Research,* 12: 141–152.

IPCC, 2011: *"Climate Change 2011" Working Group I: Technical Summary. Intergovernmental Panel on Climate Change* (Cambridge: Cambridge University Press): 47.

Leontief, W., 1936: "Quantitative Input and Output Relations in the Economic System of the United States", in: *Review of Economics and Statistics*, 18: 105–125.

Ma, S.; Ying, C., 2011: "Estimation of China's Embodied CO_2 Emissions During 2000–2009", in: *China and World Economy*, 19,6: 109–126.

Miller, R.E.; Blair, P.D., 2009: *Input-Output Analysis: Foundations and Extensions* (Cambridge: Cambridge University Press).

Pan, J.H.; Phillips, J.; Chen, Y., 2008a: "China's Balance of Emissions Embodied in Trade: Approaches to Measurement and Allocating International Responsibility", in: *Oxford Review of Economic Policy,* 24,2: 354–376.

Pan, J.H.; Phillips, J.; Chen, Y., 2008b: "From Production-Based to Consumption-Based National Emissions Inventories", in: *Ecological Economics*, 65,1: 13–23.

Peters, G.P.; Weber, C.L.; Hubacek, K.; Guan, D., 2007: "China's Growing CO_2 Emissions—A Race Between Increasing Consumption and Efficiency Gains", in: *Environmental Science & Technology*, 41,17: 5939–5944.

Peters, G.P.; Andrew, R.; Lennox, J., 2011: "Constructing a Multi-regional Input-Output Table Using the GTAP Database", in: *Economic Systems Research*; at: doi:10.1080/09535314.2011.563234.

Peters, G.P.K.; Hertwich, E.G., 2008: "CO_2 Embodied in International Trade with Implications for Global Climate Policy", in: *Environmental Science and Technology*, 42, 5: 1401–1407.

Quesnay, F., 1759: *Tableau economique* (London: Macmillan) [edited by Kuczynski, M.; Meek, R., 3rd ed., reprint, 1972].

Rose, Adam Z.; Miernyk, William H., 1989: "Input-Output Analysis: The First Fifty Years", in: *Economic Systems Research*, 1, 2: 229–271.

Su, B.; Huang, H.C.; Ang, B.W.; Zhou, P., 2010: "Input-Output Analysis of CO_2 Emissions Embodied in Trade: The Effects of Sector Aggregation", in: *Energy Economics*, 32: 166–175.

Skolka, J.V., 1976: *Advances in Input-Output Analysis* (Cambridge, MA: Ballinger): 113–133.

Stone, Richard, 1984: "Where Are We Now? A Short Account of Input-Output Studies and Their Present Trends", in: *UNIDO: Proceedings of the Seventh International Conference on Input-Output Techniques* (New York, United Nations, UN Publication E 84 II B 9).

UNFCCC [United Nations Framework Convention for Climate Change], 2014; at: http://maps.unfccc.int/di/map (3 November 2014).

Xu, Y.; Dietzenbacher, E., 2014: "A Structural Decomposition Analysis of the Emissions Embodied in Trade", in: *Ecological Economics*, 101 (May): 10–20.

Chapter 7
Energy–Economy–Ecology–Engineering (4E) Integrated Approach for GHG Inventories

Egemen Sulukan, Mustafa Sağlam and Tanay Sıdkı Uyar

Abstract Energy is the main driver of modern national economies. However, energy systems are highly complex and obtaining energy-efficient and clean solutions at the lowest cost is becoming harder under these dynamic circumstances. An integrated decision-making tool is needed in these circumstances as a compass for decision makers. This study aimed to create such a model for Turkey, spanning the period 2005–2025. Firstly, energy supply commodities, sectors and sectoral demands, conversion and process technologies, consumption and demand technologies are determined for Turkey based on energy balance statistics published by the Ministry of Energy and Natural Resources. This database is called the Reference Energy System, and included parameters characterizing each of the technologies and resources used to obtain the energy equilibrium, including fixed and variable costs, technology availability, performance and pollutant emissions. The model also allows user-defined variables. After developing alternative scenarios to achieve cost-effective technology selection and running each alternative of the base scenario one by one, model responses and scenario results are analyzed to provide technical recommendations. Therefore, a functional 'energy–economy–ecology–engineering' integrated model calculating final energy consumption from primary energy supply was developed with optimal solutions including both current energy technologies and candidates for near future utilization.

Keywords ETSAP · Turkish model · Greenhouse gases (GHGs) · GHG emissions estimation

---

E. Sulukan, Ph.D., Department of Professional Sciences, Turkish Naval Academy, Tuzla, Istanbul, Turkey; E-mail: esulukan@dho.edu.tr.

M. Sağlam, Institute of Pure and Applied Sciences, Department of Mechanical Engineering, Marmara University, Göztepe, Istanbul, Turkey; E-mail: fulbars@yahoo.com.

T.S. Uyar, Prof. Dr., Marmara University, Faculty of Engineering, Mechanical Engineering Department, 34722, Istanbul, Turkey; E-mail: tanayuyar@marmara.edu.tr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_7

7.1 Introduction

Energy is extremely important to the social and economic development of a country. Nevertheless, the high complexity of energy resources, energy conversion/processes or demand technologies require an algorithm to optimize the energy system to finding the least costly way to achieve energy efficient and clean solutions that can provide sustainability and curb climate change effects.

Achieving sustainable development goal may be possible with realistic and long-term strategic plans that incorporate and seek to optimize the global and unique circumstances of individual countries, particularly in terms of economic and environmental constraints. A thorough analysis can be made that considers current status and future potential within realistic parameters. Different decision support-based approaches are also needed for planning in every country to optimize the energy, economic and ecological aspects of the system. The main objective of such efforts leads to the development of a model for Turkey that can be used for such purposes.

Market Allocation (MARKAL) is a model generator still under development but is already in use by different institutions, universities, and officials in different countries. The Energy Technology Systems Analysis Program (ETSAP) is an Implementing Agreement of the International Energy Agency (IEA) and functions as a consortium of member country teams and invited teams that actively cooperate to establish, maintain and expand a consistent multi-country energy–economy–environment–engineering (4E) analytical capability.

7.2 Review of Relevant MARKAL Model Studies

MARKAL has been used widely to analyze the energy systems economy including environment pollutants for single or multiple regions. Agoris et al. (2004) analyzed the Greek energy system and its alternatives using MARKAL and developed three scenarios that revealed different alternative policies and calculated the costs of Kyoto and non-Kyoto targets. Salvia et al. (2004) and Contaldi et al. (2007) used MARKAL to analyze the energy economy in Italy. Chen et al. (2007) used MARKAL to study China's carbon-mitigation strategies and resultant impacts on the country's economy. They analyzed the changes in both final and primary energy mix, changes in technology development, as well as marginal drop costs for given carbon constraints from MARKAL.

Jegarl et al. (2009) used the MARKAL model to study CO_2 reduction options for the Korean power generation sector. Strachan et al. (2009) used MARKAL to model hydrogen supply, demand and infrastructure anchored within an economy-wide energy systems model. The impacts of CO_2 emission reduction targets and carbon taxes on future technology selection processes, especially solar PV and energy use in Bangladesh power sector during 2005–2035 have also been analyzed (Mondal/Islam 2012).

The US energy system has also been analyzed in terms of the uncertainties associated with the outcomes of possible regulations contained in the US Environmental Protection Agency (EPA)'s Nine Region MARKAL Database (EPAUS9r) (Balash et al. 2013). The possible impacts of energy and climate policies and an economy-wide equivalent carbon tax on greenhouse gas (GHG) emissions in the US for the year 2045 were analyzed using a hybrid energy modelling approach (called MARKAL-Macro) mainly aiming to examine the impacts of two important objectives of US energy policy: GHG reduction and increased energy security (Sarica/Tyner 2013). A series of carbon dioxide (CO_2) emission-abatement scenarios for Taiwan's power sector were developed according to Sustainable Energy Policy Guidelines, a national regulation guiding to promote the sustainable use of energy, released by the Executive Yuan, the executive branch of the Government of Taiwan (Ko et al. 2010). Ireland's energy target for 2020 to reduce GHG emissions by 20 % below 2005 levels has also been analyzed (Chiodi et al. 2013). The integrated MARKAL-EFOM system (TIMES) modelling tool has been applied to examine the cost effectiveness of different evolutions of CO_2 taxes under the Emissions Trading System in Europe by 2050 (Gerbelová et al. 2014).

7.3 Methodology

The standard MARKAL model combines energy demands, capital requirements, subsidies, investment costs, GHG emissions, conversions, resource (import–export) and process technologies, energy carriers and demand (or namely end-use) technologies. The model determines the optimal solution satisfying these energy demands at the least cost by choosing an energy supply with respective technologies; this modelling process thus facilitates reaching accurate economic and environmental decisions. Such an optimization-problem formulation consists of three types of entities: (1) decision variables, (2) objective functions and (3) constraints that must be satisfied by the optimal solution.

MARKAL's objective is to minimize the total cost of the discounted energy system over the specified planning horizon. Each year, the total cost includes annualized investments in technologies; fixed and variable annual operation and maintenance (O&M) costs of technologies; cost of exogenous energy and material imports and domestic resource production (e.g. mining); revenue from exogenous energy and material exports; fuel and material delivery costs; and welfare loss resulting from reduced end-use demands, taxes and subsidies associated with energy sources, technologies and emissions (Loulou et al. 2004).

In each period, the investment costs are first annualized before being added to the other costs, which are all other annual costs to obtain the total annual cost in each period. MARKAL then computes a total net present value of all annual costs, discounted to a user-selected reference year.

In this context, Turkey's energy system has been numerically represented in the Turkish MARKAL Model as the base scenario (Business as Usual Scenario—

BAU) and various implementations have been executed regarding mitigation strategies for energy-related emissions for Turkey with different scenarios within the period 2005–2025 (Sulukan et al. 2010).

During this process, Turkey's energy supply commodities, sectors and sectoral demands, conversion and process technologies and consumption and demand technologies are determined based on energy balance statistics published by the Ministry of Energy and Natural Resources. This resulting database is called the Reference Energy System (RES), which includes parameters characterizing each of the technologies and resources used to obtain the energy equilibrium, including fixed and variable costs, technology availability, performance and pollutant emissions.

Development of a baseline scenario begins with defining scenario characteristics (e.g. BAU). Changes in independent variables are specified and entered into the model, which is run to simulate overall energy use and emissions over the selected time horizon. The baseline scenario is evaluated for reasonableness and consistency and then revised accordingly. However, it is unlikely that every parameter needed to complete the baseline scenario will be found in national documents or even that the documents will provide a consistent picture of a country's future. As with much of the modelling process, the analyst's judgment in making reasonable assumptions and choices is crucial.

The effect of changes in technology selections and CO_2 emissions are analyzed starting from this typical BAU scenario. After developing alternative scenarios to achieve cost-effective technology selection and running each alternative of the base scenario, model responses and scenario results are analyzed to provide technical recommendations. Therefore, a complete and running energy–economy–ecology–engineering integrated model calculating final energy consumption from the primary energy supply is created with an optimal solution that includes both current energy technologies and candidates for near-future utilization.

MARKAL has the capability of tracking the production or consumption of environmentally relevant quantities according to the activity, installed capacity or new investment in a resource or technology. This capacity has most often been used to track emissions of traditional pollutants such as CO_2, NO_X, SO_X, CO and particulates. However, it could also be used to track consumption of land or other resources as well as the removal of pollutants from the system. Important environmental variables, expressed in terms of pollutants, include:

- Emissions per unit of technology activity, installed capacity or new investment.
- Emission constraints, which can take the form of a cap on total emissions per year or a cumulative cap on emissions over the entire modelling horizon, if desired.

Out of all other pollutants, CO_2 emissions obtained from MARKAL Model, which are mainly caused by the specified sectoral energy consumption, are the main focus of this paper.

7.4 Results

The summary of Turkish RES-the basis for this study-contains primary energy supply, energy carriers, demand technologies and end-use demands, as illustrated in Fig. 7.1. The RES is based on BAU values. In other words, past values of energy production, consumption and emissions are simply projected into the future with no attempts for optimization such as GHGs mitigation or cost improvement. The RES mainly serves as a comparison tool with possible alternative future scenarios that have been developed for optimized emissions or cost. Hence, the RES should contain relevant data for the time period over which the analysis is performed.

These values are detailed in Table 7.1. The RES has been developed for the time period 2005–2025 and data for this article were mainly taken from the Ministry of Energy and Natural Resources and World Energy Council Turkish National Committee. The cumulative increase rate of all factors during this 20 years period 2005–2025 is 5.3 % and sectoral fuel consumption increase rates are also given. Increases in commercial, industrial and residential sectors' fuel consumption are particularly noteworthy.

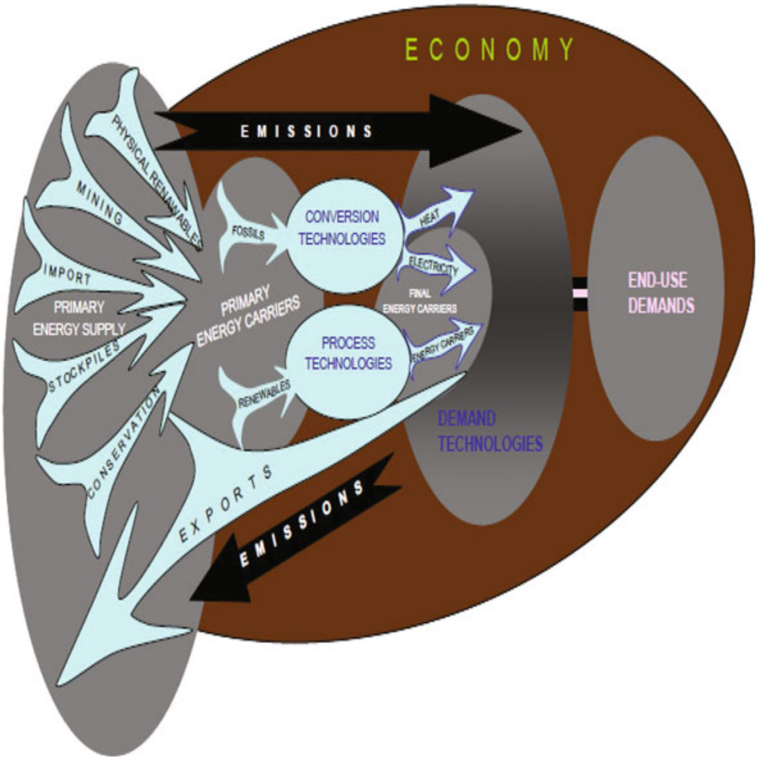


Fig. 7.1 Turkish reference energy system. *Source* Sulukan et al. (2010)

Table 7.1 Total final energy by sectors according to the RES (in PJ)

Sectors	2005	2010	2015	2020	2025
Agriculture	140.64	165.43	194.59	236.9	277.24
Commercial	13.42	15.79	18.57	21.85	25.7
Industry	1232.15	1527.90	1797.21	2113.97	2486.57
Non-energy	93.7	88.17	103.71	121.99	143.49
Residential	962.8	1132.50	1332.11	1566.91	1843.08
Transport	579.74	681.92	802.12	943.49	1109.79
Total	3022.45	3611.71	4248.31	5005.11	5885.87

Source Sulukan et al. (2010)

The values for five main sectors, namely, agriculture, commercial, industry, non-energy, residential and transportation, have been the basis for the RES. The values for primary energy carriers in these sectors have been transformed into secondary energy carriers for consumer use. The secondary carriers are organized in such a way that all end-use demands would be satisfied by implementing the final usage technologies. To this end, demand items are classified according to the sectors mentioned above.

Conversion and process technologies are also classified according to their energy sources and the demands they satisfy. As a result, 27 energy carriers, 21 source technologies that have been used in conversions, 9 process technologies, 18 conversion technologies, 137 end-use technologies and 31 demand types have been specified in the database.

The Turkish MARKAL energy system can comprehensively develop widespread policies to review CO_2 emission mitigation options and delineate the relationship among Turkey’s economic growth, energy consumption and GHG emissions. Thus, once the model is set up and various scenarios are run starting with base scenario, the model affords planners the ability to conduct detailed analyses for sectoral economic composition change, and change of carbon and energy intensities. This can be done by using new energy sources in the energy mix in sectoral bases as well as in the time series.

In Turkey, long-term energy consumption-based CO_2 emission forecasts show an escalating trend between 1990 and 2025, increasing at a rate of 183.49 % from 139594 to 479954 kt. In the base scenario, the ratios of CO_2 to electricity production are found for power plants installed in Turkey. A substantial percentage of GHG emissions in Turkey are released by fossil-fuel-based power plants. Technologies and sectors acting as emission sources under the general assumption of 3.3 % economic growth have been specified into the model. Base scenario results include the current situation and projections up to the year 2025. The CO_2 increase rate is projected as 102.6 % between 2005 and 2025 (Figs. 7.2 and 7.3).

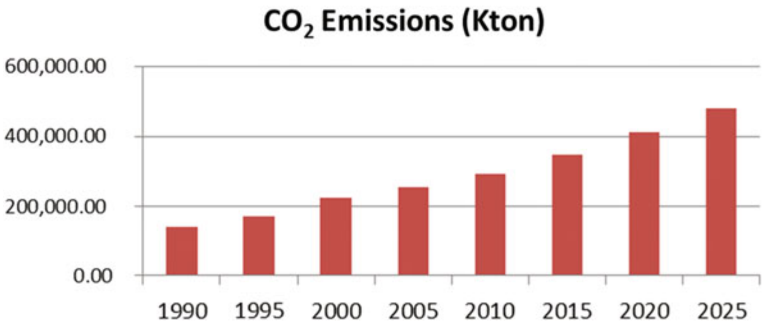


Fig. 7.2 CO_2 emission projection (1990–2025). *Source* The authors

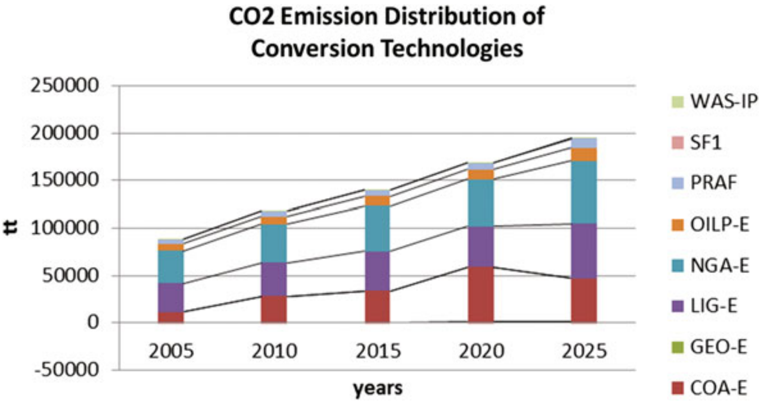


Fig. 7.3 Total CO_2 emission distribution of conversion technologies. *Source* The authors

A total of 66 % of the emission increase between 1990 and 2025 arises from electricity production and industry sectors. The transportation sector generated 17 % of total emissions.

CO_2 emission rates from the consumption in agriculture, residential, transportation and industrial sectors with forestry and electricity production are estimated in the base scenario (Fig. 7.4). Although the main focus of the scenarios is to reduce carbon emissions, reductions of other pollutants are addressed as well.

These emissions are mainly caused by mining activities and the combustion of energy carriers consumed by conversion, demand and process technologies, mainly exchange boilers, furnaces, the sugar industry, residential heating and cooking equipment and transportation vehicles.

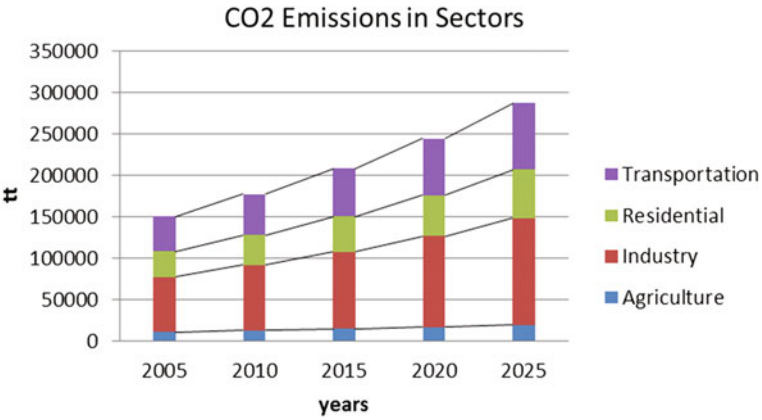


Fig. 7.4 Total CO_2 emission distribution of sectors in BAU scenario. *Source* The authors

7.5 Conclusion

This study summarizes the development of a MARKAL model for Turkey and the initial estimations arising from the BAU estimations till the year 2025. For further and more detailed Turkish MARKAL analyses, additional alternative scenarios may be created and run against the BAU scenario to analyze the possible effects and obtain the fundamentals needed to devise an effective energy policy road map for Turkey, as stated below:

- Fostering the financial mechanisms for renewable energy system investments,
- Increasing the deployment of renewable energy for heating/cooling and transportation to meet national targets,
- Developing options for efficiency improvements in thermal power plant expansion plans or technologies used in end-use sectors that affect the energy generation, consumption and GHG emission levels,
- Developing potential candidate power plant analyses to obtain annual investment levels and electricity load percentages,
- Analyzing the possible effects of increasing the alternative potentials of hydraulic, wind, solar and wave energy resources in the national energy system,
- Utilizing co-generation in all sectors, especially power generation and industrial sub-sectors,
- Analyzing candidate nuclear power plants' effects in the energy system, and
- Analyzing carbon dioxide mitigation scenarios to estimate a road map with the relevant environmental aspects (Sağlam et al. 2013).

Conventional energy resources currently govern Turkey's energy mix and dominate the current energy system composition, thus condoning externalities for fossil fuels. Energy technologies have evolved to be extremely dependent on fossil fuels since the industrial revolution. Demand technologies are mainly designed for fossil fuel combustion, causing environmental pollution.

However, political guidance is the most important element for determining an effective path for diminishing consumption of contaminating hazardous energy resource to mitigate global warming effects and sustain society. Establishing a consensus among decision-makers, engineers, local authorities and nongovernmental organizations on energy and technology selection means that environmental planning should be supported by experts possessing energy modelling capabilities. Moreover, these efforts should determine the relevant aspects of an energy system involving energy economy, environmental effects, energy production and ethical responsibilities.

References

Agoris, D.; Tigas, K.; Giannakidis, G.; et al., 2004: “An Analysis of the Greek Energy System in View of the Kyoto Commitments”, in: *Energy Policy,* 32: 2019–2033.

Balash, P.; Nichols, C.; Victor, N., 2013: “Multi-regional Evaluation of the U.S. Electricity Sector Under Technology and Policy Uncertainties: Findings from MARKAL EPA9rUS Modelling”, in: *Socio-Economic Planning Sciences,* 47: 89–119.

Chen, W.; Wu, Z.; He, J.; et al., 2007: “Carbon Emission Control Strategies for China: A Comparative Study with Partial and General Equilibrium Versions of the CHINA MARKAL Model”, in: *Energy,* 32: 59–72.

Chiodi, A.; Gargiulo, M.; Deane, J.P.; et al., 2013: “Modelling the Impacts of Challenging 2020 non-ETS GHG Emissions Reduction Targets on Ireland’s Energy System”, in: *Energy Policy,* 62: 1438–1452.

Contaldi, M.; Gracceva, F.; Tosato, G., 2007: “Evaluation of Green-Certificates Policies Using the MARKAL-MACRO-Italy Model”, in: *Energy Policy,* 35: 797–808.

Gerbelová, H.; Amorim, F.; Pina, A.; et al., 2014: “Potential of CO_2 (Carbon Dioxide) Taxes as a Policy Measure Towards Low-Carbon Portuguese Electricity Sector by 2050”, in: *Energy,* 6: 113–119.

Jegarl, S.; Baek, J.; Jang, D.; et al., 2013: “Impact Assessment of CO_2 Mitigation Options in Korea Using Energy System Analysis Model”, in: *Energy Procedia,* 1: 3747–3754.

Ko, F.K.; Huang, C.B.; Tseng, P.Y.; et al., 2010: “Long-Term CO_2 Emissions Reduction Target and Scenarios of Power Sector in Taiwan”, in: *Energy Policy,* 38: 288–300.

Loulou, R.; Goldstein, G.; Noble, K., 2004: “Standard MARKAL User Manual, Volume-I”.

Mondal, A.H.; Islam, A.K.M., 2012: “Impacts of CO_2 Emission Constraints on Penetration of Solar pv in the Bangladesh Power Sector”, in: *Renewable Energy,* 43: 418–422.

Sağlam, M.; Sulukan, E.; Uyar, T.S., 2013: “Deliberating Lower-Cost Emission Reduction Options”, in: *IRENEC Proceedings*, 370–375.

Salvia, M.; Pietrapertosa, F.; Cosmi, C.; et al., 2004: “Approaching the Kyoto Targets: A Case Study for Basilicata Region (Italy)”, in: *Renewable and Sustainable Energy Reviews,* 8: 73–90.

Sarica, K.; Tyner, W.E., 2013: “Alternative Policy Impacts on US GHG Emissions and Energy Security: A Hybrid Modelling Approach”, in: *Energy Economics,* 40: 40–50.

Strachan, N.; Balta-Ozkan, N.; Joffe, D.; et al., 2009: “Soft-linking Energy Systems and GIS Models to Investigate Spatial Hydrogen Infrastructure Development in a Low-Carbon UK Energy System”, in: *International Journal of Hydrogen Energy,* 34: 642–657.

Sulukan, E.; Sağlam, M.; Uyar, T.S., 2010; "Determining Optimum Energy Strategies for Turkey by MARKAL Model", in: *Journal of Naval Science and Engineering,* 6: 27–38.

Sulukan, E.; Sağlam, M.; Uyar, T.S., 2013: "A Native Energy Decision Model for Turkey", in: *IRENEC Proceedings*, 360–369.

Chapter 8
Cost-Benefit Assessment of Implementing LULUCF Accounting Rules in Turkey

Olivier Bouyer and Yusuf Serengil

Abstract Turkey is an Annex 1 Party with "Specific circumstances" because it has the fastest population growth rate among the Organization for Economic Cooperation and Development (OECD) countries and lowest per capita energy-related CO_2 emissions among the International Energy Agency (IEA) countries. In addition, all national indicators show that Turkey is in fact a developing country. It was deleted from Annex 2 of the United Nations Framework Convention on Climate Change (UNFCCC) and not included in the Annex B of the first term of the Kyoto Protocol (KP1). In the context of preparation of a 2015 multilateral treaty on climate change, which would enter into force in 2020, differentiation between Annex 1 and non-Annex 1 Parties may be revisited, and it seems useful to explore the possible consequences of such a reclassification. Accordingly, this study aims at providing a neutral cost/benefit assessment of implementing Land Use, Land Use Change and Forestry (LULUCF) accounting rules in Turkey in the future, as one possible scenario. The rationale for this assessment is based on a technical and objective deduction and does not in any way pre-empt the national positions put forward by Turkey in the climate negotiations or any possible COP decision that may determine its future classification, considering its specific circumstances. Turkey started reporting LULUCF under the Climate Convention in 2006. Presently, the LULUCF sink (made of a forest sink for its bigger part) is estimated to offset 12 % of Turkey's total greenhouse emissions. For afforestation/reforestation (A/R) (Article 3.3), the objectives of the 2014–2017 OGM (General Directorate of Forestry Turkish abbreviation) Strategic Plan were considered. For forest management (FM) (Article 3.4), two alternative scenarios were considered: 90 Mm^3 of roundwood harvest between 2013 and 2017 (intensive harvest) and 25 Mm^3/year of felling (industrial round wood) harvest by 2020 (extensive harvest). The corresponding volumes of firewood, felling and total round wood were forecast accordingly from 2013 to 2020. The carbon credits or Removal Units (RMUs) for

---

O. Bouyer, Director, SalvaTerra, 6 rue de Panama 75018 Paris, France; E-mail: o.bouyer@salvaterra.fr.

Y. Serengil, Prof. Dr., İstanbul University, Faculty of Forestry, Turkey; E-mail: serengil@istanbul.edu.tr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_8

Article 3.3 ARD and Article 3.4 FM (including the carbon storage in harvested wood products) were estimated using the guidelines from the intergovernmental panel of experts on climate change and taking into account the upgraded LULUCF rules. For Article 3.3, it was estimated that 119.4 million RMUs could be generated between 2013 and 2020, which is more than twice the maximum amount of RMUs to be generated under Article 3.4 FM. The total economic values (TEVs) of Turkey's forests have been estimated based on recent studies and then used to calculate benefits. Taking into account the recent European Union (EU) market price (Kyoto market) or the recent forest carbon price (Kyoto and voluntary markets), carbon benefits are reduced in all scenarios compared with other values included in the TEV of the forest. If we consider the carbon shadow price (i.e. the recommended carbon price from 2011 to 2050, to achieve the EU target of reducing GHG emissions fourfold by 2050), it is worth noting that the situation is quite different: for the 3.4 FM areas and mainly for 3.3 ARD areas, the carbon benefits are substantial. However, this price level is still far from attainable as negotiations stand now, unless the international community is able to adopt a strong political commitment in coming years.

Keywords Climate change · Mitigation · Cost-benefit analysis · Kyoto Protocol · LULUCF

8.1 Introduction

Many developed countries involved in the UNFCCC have lost their motivation in the last 4–5 years, and this is reflected in the Kyoto Protocol's second term. The number of parties that have commitments in the second Kyoto term (2013–2020) is less than the number in the first round (2008–2012). However, some achievements have been realized due to the efforts of dedicated parties and institutions, such as the creation of a register of nationally appropriate mitigation actions (NAMAs), a green climate fund, an adaptation committee and a climate technology center, and refining the REDD+ mechanism (reducing GHG emissions from deforestation and forest degradation and maintaining or increasing forest carbon stocks).

The last COP was held in Warsaw in December 2013. At the closing plenary, the Alliance of Small Island States (AOSIS) deplored *the disastrous gap in terms of ambition*. The least developed countries (LDCs) group welcomed the establishment of the mechanism on loss and damage but lamented the lack of progress on the provision of long-term finance, and called for an acceleration of negotiations under ADP. The African group called on developed countries to ratify the Doha Amendment urgently and deplored their lack of ambition.

In short, political determination failed to COP19. Those who bet, before COP19, on a 'financing COP' or an 'implementation COP', finally saw a 'REDD+ COP' (seven decisions adopted on REDD+) with limited progress on long-term finance (without numerical objectives or calendar or guidelines on measuring, reporting and verification (MRV)) and towards achieving a 'loss and damage' mechanism.

Negotiations advanced efficiently on finance and emission reduction targets for the last 2 years on the way to Paris. A new agreement has been prepared but it is unlikely that the new established working group to reveal the mechanisms of the agreement will progress efficiently in the coming years if the 'chicken and egg' blockage continues:

- As part of the post-2020 multilateral treaty, most developed countries support a review of the dichotomy between Annex 1 and Non-Annex 1 Parties; this differentiation dates from 1990, while some developing countries such as China have per capita emissions levels similar to those of developed countries;
- As part of the KP amendment 2013–2020, developing countries have called on developed countries to drastically raise their level of ambition: (i) few of them have commitments (only 15 % of global GHG emissions are covered), (ii) commitments are well below IPCC (2013a) recommendations to stay the global temperature increase less than +2 °C.

More than ever, a surge of political will is required to enter the final countdown for a post-2020 multilateral treaty. Tough debates lie ahead that touch upon the key principles of the UNFCCC: historical responsibility, common but differentiated responsibility, equity, transparency, etc. It is now hoped that the high-level event convened by the UN Secretary-General in 2014 will provide the needed spark.

8.2 Position of Turkey in the UNFCCC

Figure 8.1 seeks to summarize Turkey's current situation with regard to the Organization for Economic Cooperation and Development (OECD) and the Annexes (1 and 2) of the UNFCCC: Five countries are particularly singled out:

- USA(*): They signed the KP but did not ratify it and have no commitments under Annex B to the KP;
- Turkey (**): Part of the Annex 1 but with 'specific circumstances' (explained below) and, as such, not included in Annex 2 of the UNFCCC nor in Annex B to the KP;
- Cyprus and Malta (***): As they were considered to be developing countries at the time of Kyoto, they were not included in Annex B;
- Belarus (****): Also part of Annex 1 but not included in Annex B to the KP (Decision 10/CMP.2 amending the Annex B with Belarus was never approved by other Parties).

Since 1992, Turkey has been advocating for recognition of its special circumstances. Thus, Article 35 of the report of the second part of the fifth session of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change states that three delegations (Bulgaria, Czechoslovakia and Turkey)

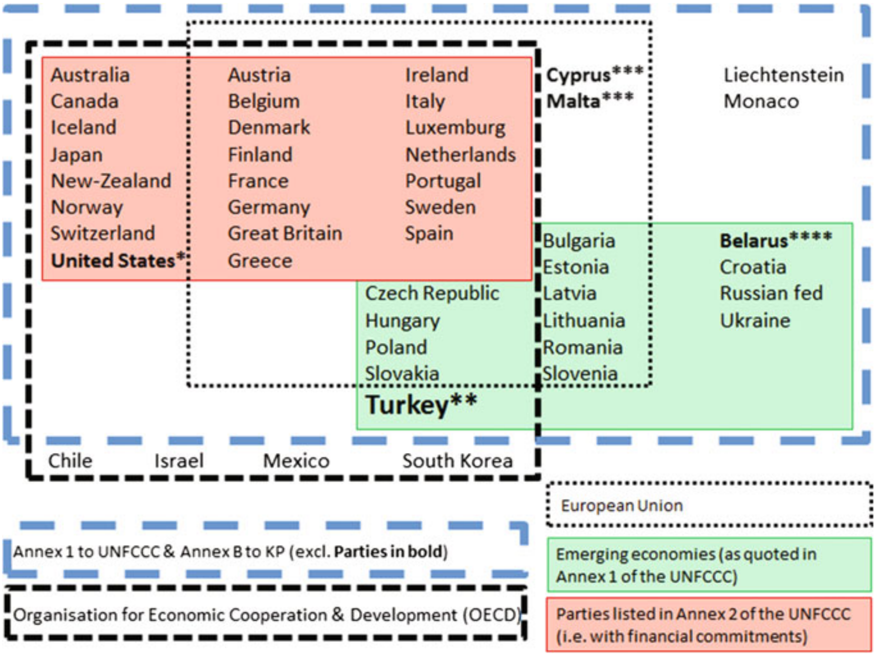


Fig. 8.1 Turkey in the OECD and Annexes 1 and 2 of the UNFCCC. *Source* Bouyer (2014)

reserved their positions regarding the listing of countries in the Annexes to the Convention (UN General Assembly 1992). In 1997, Turkey revealed its positions in detail through a submission sent to the Secretary of the UNFCCC (UNFCCC 1997a, b): (i) Turkey wants to be considered a developing country and (ii) Turkey requests its deletion from the Annexes 1 and 2 of the UNFCCC. To substantiate these requests, the following key facts were presented:

- "Turkey, with approximately 64 million inhabitants as of mid-1997, is one of the most populous countries in the world, and has the fastest population growth rate of all OECD countries (1.6 % in 1997). Population is rapidly urbanizing at 4.4 %. By 2000, 70 % of the population will be living in urban areas. Life expectancy is slightly better than the average of lower middle-income countries; the under-five mortality rate is similar. Turkey has been growing at double the average for OECD countries. As can easily be seen, Turkey is a developing country and still has some burdens to overcome regarding social and economic development";
- "Turkey's contribution to global GHG emissions is considerably below the average of Annex 1 countries. Turkey has the lowest energy-related CO_2 emissions per capita among International Energy Agency (IEA) countries";

- "Turkey is acknowledged as a developing country in the Montreal (Ozone) Protocol, relying on the fact that the World Bank, OECD and the United Nations Development Program (UNDP) have classified Turkey as a developing country".

In 1998, at COP4 in Buenos-Aires, the Decision 15/CP.4 opened an agenda item to consider the possible deletion of Turkey from the Annexes 1 and 2, pursuant to a joint proposal made by Pakistan and Azerbaijan (UNFCCC 1999).

In 2001, at COP7 in Marrakech, the Decision 26/CP.7 finally vindicated Turkey's stance by (i) Deciding to amend the list in Annex 2 to the UNFCCC by deleting the name of Turkey and (ii) Inviting the Parties to recognize the special circumstances of Turkey, which place Turkey, after becoming a Party, in a situation different from that of other Parties included in Annex 1 to the UNFCCC (UNFCCC 2001).

In 2004, Turkey ratified the UNFCCC. Five years later, in 2009, Turkey ratified the KP.

In 2010, prior to COP16 in Cancun, Turkey exposed its views, related to the preparation of an outcome to be presented to the COP16, in a submission sent to the Secretary of the UNFCCC (UNFCCC 2010): (i) Turkey's historical GHG emissions, per capita GHG emissions, basic economic and social indicators, as well as its sustainable development needs, are significantly different from other Annex 1 Parties; (ii) Turkey is located in one of the most vulnerable regions exposed to the adverse effects of climate change, according to the fourth Assessment Report of the IPCC and (iii) Turkey needs support for finance, technology and capacity building for mitigation and adaptation.

In 2010, at COP16, Article 142 of Decision 1/CP.16 recalled the key elements of the Decision 26/CP.7 (UNFCCC 2011): deletion of the name of Turkey from the Annex 2 of the UNFCCC, invitation to Parties to recognize the special circumstances of Turkey that place it in a situation different from those of other Annex 1 Parties and eligibility for support under Article 4, paragraph 5, of the UNFCCC. Turkey also requested the AWG-LCA to continue consideration of these issues with a view to promoting access by Turkey to finance, technology and capacity-building in order to enhance its ability to better implement the Convention.

In 2011, at COP17 in Durban, Article 170 of Decision 1/CP.17 recalled the key elements of the Decision 26/CP.7 and Decision 1/CP.16 (UNFCCC 2012a, b). Since COP18 in Doha and COP19 in Warsaw, the situation has remained the same: (i) Turkey is an Annex 1 Party, having specific circumstances setting it apart from the other Annex 1 Parties; (ii) Turkey is not part of Annex 2 of the UNFCCC, and thus it is not expected to contribute to the climate financing regime but rather to benefit from it and (iii) Turkey does not have a binding GHG emission-reduction commitment inscribed in Annex B to the KP. Perhaps more than for any other Party, the current debates on differentiation between Annex 1 versus Non-Annex 1, as well as the implementation of the UNFCCC principles (historical responsibility, CBDR, equity, etc.) are of interest to Turkey.

8.3 Forest Sector in the UNFCCC

8.3.1 Key Features of LULUCF and REDD+

'Biological' carbon fluxes (carbon removed from the atmosphere by photosynthesis or emitted to the atmosphere by biomass burning or decay), as well as CH_4 and N_2O (emitted to the atmosphere by biomass burning or anaerobic and aerobic fermentation, respectively), are considered through two mechanisms, LULUCF and REDD+, the key features of which are shown in Table 8.1.

8.3.2 Which Mechanism for Turkey?

It is worth noting that the concept of NAMA sometimes overlaps with the concept of REDD+. Indeed, these two mechanisms were created under the 'mitigation pillar' of the Bali Action Plan, respectively, defined in Article 1 (b) (i) and Article 1 (b) (ii) of the Decision 1/CP.13 (UNFCCC 2008), and they both apply to developing countries.

There are different interpretations of Article 142 of Decision 1/CP.16 and Article 170 of Decision 1/CP.17 regarding Turkey's 'specific circumstances' and its eligibility for NAMAs: 'Turkey is fully eligible for support in development of NAMAs' (UNDP 2011) compared to the statement 'Since Turkey is an Annex 1 country, availability of NAMA finance in the post-2012 period for Turkey has not been clarified yet. Negotiations regarding Turkey's status are ongoing' (NCCAP 2011).

In any case, considering, on one hand, the current rules governing the LULUCF and REDD+ (and NAMAs) mechanisms and, on the other hand, Turkey's current classification by the UNFCCC as a developed country and thus its inclusion in Annex 1 of the UNFCCC, the only mechanism that may theoretically apply to Turkey is the LULUCF mechanism, which is consistent with the following processes:

- Preparation of a post-2020 multilateral climate treaty: In this context, it is conceivable to have a 'reclassification' in terms of Annex 1 versus Non-Annex 1 and increased pressure placed on Annex 1 Parties to undertake binding commitments;
- Alignment with the European Union (EU) Acquis: Since the European Council of Helsinki in 1999, Turkey has been a candidate member of the EU. Accession negotiations started at the European Council of Copenhagen in 2002, and the national program for adoption of the European Acquits started in 2003. As part of this program, Turkey has to align with the EU Acquits in the field of climate change, especially as the 2013 progress report on Turkey, 'Enlargement Strategy and Main Challenges 2013–2014', deplored the fact that 'no progress' had been made in that field (European Commission 2013).

Table 8.1 REDD+ versus LULUCF: key features

LULUCF	REDD+
Developed acronym	
Land Use, Land Use Change and Forestry	Reducing Emissions from Deforestation and forest Degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks
Umbrella body	
Initially: KP1 (2008–2012). Now: KP2 (2013–2020)	UNFCCC
Key Decision	
16/CMP.1 (Marrakech Accord)	2/CP.13 (Bali Decision on REDD+)
Concerned Parties Up To 2020	
• Developed countries included in Annex 1 of the UNFCCC, and • Having taken quantified GHG emissions reduction commitments (i) under the KP1, and included in Annex B or (ii) under the KP2, and included in the Doha KP amendment (Decision 1/CMP.8)	Developing countries, not included in the Annex 1 of the UNFCCC
Concerned Parties After 2020	
A post-2020 multilateral climate treaty is being prepared under the ADP (Durban Platform), with the aim of having it adopted in COP21, 2015. In this context, the classification Annex 1 versus Non-Annex 1 is being discussed, considering UNFCCC principles: CBDR, Historical responsibility, Equity, etc. At this stage, it is not possible to prejudge what will be the final classification, but there is a probability that some Parties (e.g. BASIC, OECD) not yet included in Annex 1 could be included in Annex 1	
Objective	
Reward net removals from forest/agric. sinks: • Under Article 3.3 of the KP: net removals from afforestation/reforestation (A/R) done after 1990. This accounting is compulsory • Under Article 3.4 of the KP: net removals from managed forests in existence before 1990 (Forest Management; FM) as well as their derived harvested wood products (HWP). Accounting is compulsory · Under Article 3.4 of the KP: net removals from revegetation (woody vegetation not considered as forest) and/or cropland and/or grassland and/or wetlands. Accounting is voluntary	Reward increased net removals or avoided emissions from the following activities: • Avoiding emissions from Deforestation (1st D); • Avoiding emissions from Degradation (2nd D); • Increasing net removals from A/R (in the '+') • Increasing net removals from FM (in the '+') REDD+ is a voluntary mechanism
Political requirement	
• To be part of the KP and have a binding commitment • To have proposed the reference level for FM accounting under art. 3.4, and to have indicated the other selected activities (if any) under art. 3.4	To propose a Readiness Preparation Proposal (RPP): identification of institutional arrangements, drivers of DD and REDD+ options, roadmap for the elaboration of the reference level and the MRV of forest carbon stocks, etc.

(continued)

Table 8.1 (continued)

LULUCF	REDD+
MRV requirement	
To have a MRV system in place in accordance with IPCC guidelines on LULUCF	The same, but with more flexibility (i.e. to have a MRV on 'top of the art', according to its national capacities)
'Main costs'	
• Costs of getting prepared for either LULUCF or REDD+ (e.g. reference level for Article 3.4 FM, RPP, etc.) • Costs of implementation of 'pro-climate' forestry and agriculture activities • Costs of running the MRV system	
'Main benefits'	
• Carbon: Removal Units (RMUs) which are fungible with other 'normal' Kyoto Units (it can lessen the emission reductions in the fossil sectors). Amount of RMUs = f (accounting rules for Article 3.3 and 3.4) • Non-carbon (tradable/non-tradable goods/services): employment, taxes, timber, Non Wood Forests Products (NWFPs), etc. Depends on selected activities under LULUCF	• Carbon: subsidies for preparation phase and payments for avoided emissions or increased net removals, either through carbon market (voluntary for now. May be regulated under a post-2020 agreement?) or carbon funds (public or private). Amount of payment = f(REDD+ options implemented) • Non-carbon: the same as for LULUCF. Also depends on the REDD+ options implemented

Source Bouyer (2014)

This progress report further regrets the "lack of an overall domestic GHG emissions target in Turkey's national climate change action plan' but notes that 'preparations on setting up and implementing a MRV system, regulatory and sectoral impact assessments of EU climate policy, and capacity building on LULUCF […] are continuing", and finally "invites the country to start reflecting on its climate and energy framework for 2030, in line with the EU Green Paper 'A 2030 framework for climate and energy policies".

8.3.3 Mitigation Options in the Forest Sector

Many mitigation options exist in the forest sector:

- Avoiding deforestation and forest degradation: This is clearly the most obvious option. It is considered frequently for tropical developing countries (who often face deforestation and forest degradation due to the large-scale agroindustry, slash-and-burn cropping, illegal logging, etc.), policies and measures for avoiding deforestation and forest degradation can also be implemented in developed countries: improving the fire-fighting system, increasing forests stands' resilience to extreme events such as storms, promoting reduced-impact logging, etc. In temperate forest, gains can vary from few tCO_2eq (avoiding forest degradation) to hundreds of tCO_2eq/ha (avoiding deforestation);

- Sustainable FM (SFM): Carbon removal in existing forests can be improved by measures such as using selected species, lengthening rotations, rejuvenating old forest stands, etc. In temperate forest, gains are in the order of few tCO_2eq/ha/year (but the cumulative effect multiplied by the surface considered can be substantial);
- Afforestation/reforestation (A/R): This category covers different modalities of converting non-forest land into forest land (planting, seeding, assisted natural regeneration, etc.). In temperate forest, gains are in the order of few tCO_2eq/ha/year, rarely more than 10–15 tCO_2eq/ha/year (apart from fast-growing exotic species);
- Substitution of fossil fuel: Wood (firewood, wood pellets, granulated wood, etc.) can be used for energy production (heat and/or electricity). It is carbon neutral over the medium- to long-term if (an only if) the forest is sustainably managed. One ton of oil equivalent (toe) can be substituted by four cubic meters of fresh wood and, consequently, avoid the emission of three tCO_2eq;
- Carbon storage in harvested wood products (HWP): Carbon can be stored in long-life wood products (wood frames, wardrobes, etc.) or medium- to short-life wood products (wooden crates, cardboard, etc.). If the storage is longer than 100 years (average lifetime of the CO_2 in the atmosphere), then one cubic meter of wood equals one tCO_2eq avoided;
- Substitution of 'grey energy' in building and housing materials: The grey energy content of HWP used as building and housing materials is much lower than that of 'fossil' materials (iron, concrete, glass, etc.). In France, 1 m^3 of wood used as building or housing material avoids 0.8 tCO_2eq in average (*Institut technologique Forêt-Cellulose-Bois-construction-Ameublement*, FCBA 2011).

8.3.4 Translation into the UNFCCC and the KP: LULUCF

The need to preserve 'reservoirs' (a component or components of the climate system where a GHG […] is stored) and 'sinks' (any process, activity or mechanism which removes a GHG […] from the atmosphere) was first mentioned in the following articles of the UNFCCC (UNFCCC 1992):

- Article 4.1 (d) states that "all parties shall […] promote sustainable management […] of sinks and reservoirs of all GHG not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems";
- Article 4.2 (a) states that "each of these Annex 1 Parties shall adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of GHG and protecting and enhancing its GHG sinks and reservoirs";

- Article 12.1 (a) states that “each Party shall communicate to the COP [...] a national inventory of anthropogenic emissions by sources and removals by sinks of all GHG not controlled by the Montreal Protocol”.

But LULUCF was created through two articles of the KP (1997a, b):

- Article 3.3 states that “all Annex 1 Parties have to account for net changes in GHG gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990”;
- Article 3.4 states that “all Annex 1 Parties shall provide—before the first Conference of the Parties serving as the meeting of the Parties to the KP (CMP)—for consideration by the Subsidiary Body for Scientific and Technological Advice (SBSTA), data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years”.

It also says that the CMP shall “at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how, and which, additional human-induced activities related to changes in GHG emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned amounts for Annex I Parties [...] and that an Annex 1 Party may choose to apply such a Decision”.

Between the COP3 held in Kyoto in 1997 and the COP7 held in Marrakech in 2001, four years of intense negotiations on the LULUCF occurred for determining the modalities, rules and guidelines for its accounting:

- Decision 9/CP.4 on LULUCF, adopted in Buenos Aires in 1998 (UNFCCC 1999);
- Decision 16/CP.5 on LULUCF, adopted in Bonn in 1999 (UNFCCC 2000);
- Decision 5/CP.6bis on LULUCF, adopted in Bonn in 2001 (UNFCCC 2001). This Decision provided a good outline of the LULUCF modalities, rules and guidelines (in Part VII) and introduced for the first time an ‘Appendix Z’ that listed the levels of the ‘cap’ to be applied to ‘Forest Management’ (FM) activities under Article 3.4 of the KP (see explanations infra).

Finally, Decision 11/CP.7 was adopted in Marrakech; it compiled all the elements of the above-mentioned LULUCF Decisions (9/CP.4, 16/CP.5 and 5/CP.6) and presented, in an annex, a draft CMP Decision containing detailed modalities, rules and guidelines for the LULUCF accounting (UNFCCC 2002).

The elements of this annex were adopted without change in the Decision 16/CMP.1, four years later at the CMP1 in Montreal, 2005 (UNFCCC 2006). Indeed, such a Decision, related to the Articles 3.3 and 3.4 of the KP, could only be adopted by the CMP, which was created in 2005, after the KP’s entry into force.

In parallel, the IPCC, following a political request from the COP and CMP and under the technical guidance of the SBSTA, developed technical guidelines and methodologies for reporting and accounting LULUCF emissions:

- Good Practice Guidance for LULUCF, often referred to as GPG-LULUCF 2003 (IPCC 2003);
- Volume 4—Agriculture, Forestry and Other Land Use (AFOLU) of the 2006 IPCC Guidelines for National GHG Inventories, often referred to as AFOLU Guidelines 2006 (IPCC 2006).

These documents were based on the Revised 1996 IPCC Guidelines for National GHG Inventories (IPCC 1996), the Good Practice Guidance and Uncertainty Management in National GHG Inventories (IPCC 2000) and the Special Report on LULUCF (IPCC 2000).

8.4 Materials and Methods

An ad hoc database on forest carbon stocks, as well as carbon and non-carbon fluxes, has been created to make the estimations in this study. We used the most recent data (Management Plans, ENVANIS—The Turkish FM Inventory System, National Inventory Report for GHG, etc.) as well as future projections, in particular the 2014–2017 Strategic Plan of General Directorate of Forestry (OGM 2012) and a wide range of data/information communicated by various experts from the Ministry of Forest and Water Affairs.

8.4.1 Upgraded LULUCF Rules

Since the start of the Kyoto Protocol, the forest sector has been more prominent in the LULUCF accounting rules than the agriculture sector (NB: carbon stock changes in agricultural soils are considered under the ‘LULUCF’ as part of the greenhouse inventory, while CH_4 and N_2O emissions are considered under the ‘Agriculture’ part). This sector offers great mitigation potential: avoided deforestation and degradation, sustainable FM, A/R, substitution of fossil fuel, carbon storage in wood products and substitution of ‘grey energy’ in building and housing materials.

However, this mitigation potential has been poorly realized until now, due to technical constraints related to the specific nature of LULUCF: high inter-/intra-annual variability of forest growth and loss, vulnerability and non-permanence of forest carbon and non-additionality of a certain part of the carbon sequestration.

Some political concerns also existed when the Kyoto Protocol was being designed: lack of scientific knowledge and consensus on forest sinks, fear of dilution of efforts, agenda inversion between the creation of the LULUCF (in Kyoto 1997) and the setting of the precise LULUCF accounting rules (in Marrakech 2001).

The initial LULUCF accounting rules—in use for the first commitment period, from 2008 to 2012—were established in Articles 3.3 and 3.4 of the Kyoto Protocol, and further detailed in the Marrakech Accords in 2001. These LULUCF accounting rules were upgraded in the recent climate talks (Cancun in 2010, Durban in 2011 and Doha in 2012) and will be used by Annex 1 Parties with binding commitments for the second commitment period, which runs from 2013 to 2020.

The main features of these upgraded rules are as follows: (i) accounting for A/R and deforestation under Article 3.3 is still mandatory (and 'gross-net'), (ii) accounting for FM under Article 3.4 is now mandatory (and 'net-net' with a cap of 3.5 % of 1990 total GHG emissions excluding LULUCF), (iii) accounting for cropland management, grassland management, revegetation under Article 3.4 is still voluntary (and 'net-net'), and (iv) a new activity appears under Article 3.4: wetland drainage and rewetting (voluntary and 'net-net').

For the specific case of Article 3.4 FM, accounting for carbon storage in HWP is now possible, while emissions due to natural disturbances can be discounted, if certain specific guidelines are followed. Forest GHG emissions and removals accounting procedures under the Kyoto Protocol are based on the same reporting requirements as under the Climate Convention: (i) estimating activity data and emissions factor for different carbon pools (living biomass, dead organic matter, soil organic carbon); (ii) respecting the principles of transparency, accuracy, precision, completeness, comparability and consistency and (iii) using adequate Tier and Approaches, according to a Key category analysis. However, LULUCF accounting presents specific challenges, especially related to tracking land-use changes according to the activities defined in Articles 3.3 and 3.4 of the Kyoto Protocol.

8.4.2 Issue Surrounding the Definition of Forest in Turkey

Turkey uses a national definition of forest in its annual submissions to the UNFCCC. According to the Forest Law number 6831, the national definition of forest is as follows:

> All natural woody and shrub areas and all plantations are accepted as forest. But, reed fields; steppes; bramble patches; parks; woody and shrub areas in cemeteries; areas which are in private ownership and covered with exotic tree species […] all the woody areas having less than three ha, all fruit tree and shrub areas […] including alder trees, chestnut trees, stone pine trees and Turkish oak trees; olive groves, pistachio trees, mastic, and carob trees; scrubs and maquis are not accepted as forests (OGM 1956).

However, a new definition of forest has to be used for calculations under Articles 3.3. and 3.4. In accordance with the request made in Article 16 of the

Annex to the Decision 16/CMP.1, the concept of forest has to be nationally defined in line with three criteria: minimum area of land (0.05–1 ha), minimum tree crown cover at maturity (more than 10–30 %) and minimum height at maturity (2–5 m). A young forest yet to reach the minimum tree crown cover and/or height can be included in this definition, as well as a temporarily unstocked forest (harvest, natural cause).

8.4.3 Perimeter of the Cost Benefit Analysis

The UNFCCC and its KP are focusing on the GHG emissions and removal, but had considered it interesting to estimate the impacts of policies and measures on other forest amenities. In that context, the numbers used in calculating the total economic value (TEV) mainly rely on Pak et al. (2010), with crosschecking of data from Turker et al. (2005) and Ok et al. (2013). The definitions of the main components are as follow (all definitions are extracted from Pak et al. (2010), with further details if underlying quotations are used):

- *Use value*: Benefit that an individual obtains directly by directly using the natural resource, e.g. values associated with outdoors recreation (Adamowicz 1995). Use values are divided into
  - *Direct use value*: This includes consumptive uses, e.g. felling and hunting, and non-consumptive uses, e.g. hiking, camping and boating (Fausold/Lilieholm 1996);
  - *Indirect use value*: This can be illustrated by reading books related to the natural resource or watching television programs about wildlife (Fausold/Lilieholm 1996);
  - *Option value*: Value of a resource that will be possibly spoiled in the future (Kula 1994);
- *Non-use value*: Value estimated for natural resources although they are not in fact used. Non-use values are divided into
  - *Existence value*: This is the value placed on an amenity even though individuals may never use or visit it; however, it is important for them to know that it will continue to exist (Klemperer 1996; Condon/Adamowicz 1998);
  - *Bequest value*: This refers to the willingness to pay to preserve some resource for future generation (Klemperer 1996).

These different values have been estimated in Turkey using the valuation techniques presented in Table 8.2.

Table 8.2 Valuation techniques to estimate the TEV of forests

Externally-value type		Outputs	Valuation techniques	Physical indicators	Monetary indicators used (€)
Positive externality	Direct use value	Grazing	Substitute goods	Quantity of forage grazed (FU)	Price of hay
	Indirect use value	Carbon sequestration	Shadow price	Net change of carbon sequestrated in forest biomass (tC)	Shadow price of carbon
	Option value	Pharmaceuticals	Rent capture	Plant species (no.)	Market price of pharmaceuticals
	Bequest-Existence	Biodiversity conservation	Cost-based approach	Protected area (ha)	Annual expenses for preserving biodiversity
Negative externality		Erosion, floods and landslides	Change in production function (Quantitative valuation) and replacement cost (monetary valuation)	Loss of soil nutrients (t)	Cost of fertilizers
		Damage caused by forest fires	Restoration cost/or value of damage	Area burnt by fires (ha)	Cost of restoration/or value of wood

Source Merlo/Croitoru (2005)

8.5 Results and Discussions

8.5.1 Current Key Facts and Figures About Turkey's Forests

The Ministry of Forestry and Water Affairs (MFWW) stands as Turkey's highest authority in Forestry. It is primarily responsible (in terms of forestry) for reforestation, erosion control, range improvement, seedling production, protected areas, national parks, wildlife, forest villages and research works. It has three General Directorates (GDs) on Forestry, which have the following tasks and responsibilities:

- GD for Forestry (OGM-Turkish acronym) is the main unit for the FM. It has 27 Regional Directorates and 217 District Directorates at the field level;
- GD for Desertification and Erosion Control (ÇEM-Turkish acronym) holds the primary responsibility for combating desertification and erosion of all classes of land, particularly eroded or degraded areas;
- GD for Nature Conservation and National Parks (DKMPGM-Turkish acronym) has been involved in the protection and conservation of Turkey's forests and their wildlife.

Forest research is under the responsibility of the Ministry's Department of International Relations, Training and Research Unit, which comprises eight Provincial Research Institutes.

OGM is responsible for the management of 21.7 Mha of 'forest land' or about 27 % of Turkey's total land area, but only about 53 % of the forests is designated as 'productive' forests, while the remaining 47 % is made up of 'degraded' or 'unproductive' forests. Besides these areas, sizeable areas corresponding to more than 40 % of the country, such as rangelands in or around forests, shrub lands, maquis shrub lands, and open alpine lands are considered part of the forest resources on technical grounds. These resources are mainly located in mountainous areas (Haase 2011).

The OGM specifies six subcategories of forest: (i) coniferous (around 76 % of the area of pure high forest), (ii) deciduous forest (around 24 %), (iii) productive forest (more than 10 % forest cover; 53 % of the total forest area), (iv) degraded forest (between 1 and 10 % forest cover; 47 % of the total forest area), (v) high forests (80 % of the total forest area) and (vi) coppices (20 %). Total respective areas are as given in Table 8.3. Several concerns have been raised about the national definition of forest.

8.5.1.1 Managed and Unmanaged

According to OGM, "Public forests represent 99.9 % of the forests, and 100 % of the Turkish forests are managed" (OGM 2012). 1 400 management plans are currently conducted (duration of 10–20 years) on productive forests and

Table 8.3 Shares of productive versus degraded, coniferous versus deciduous, high forests versus coppices

	Pure high forest		Mixed high forest	Total high forest	Coppices	Total	%
	Coniferous	Deciduous					
Productive	6 792 336	2 156 746	1 332 646	10 281 728	1 276 940	11 558 668	53
Degraded	4 983 059	950 319	1 045 486	6 978 864	3 140 602	10 119 466	47
Total	11 775 395	3 107 065	2 378 132	17 260 592	4 417 542	21 678 134	

Source OGM (2012)

10 272 000 ha of this area under management would be revised by 2020 for a moderate cost, i.e. 5.42 TL/hato 28 TL/ha. A total of 55 ‘conservation forests’ (251 409 ha) are also considered as ‘managed’ forests by OGM (pers. com. Mehmet Ceylan; FM and Planning Department of OGM, February 2014).

But, at the same time, protected areas, under the responsibility of the GD of Nature Conservation and National Parks of the MFWW, are considered as being ‘unmanaged’ by OGM (*Ibid*), which highlights an issue about the common understanding of ‘managed’ versus ‘unmanaged’ and a possible overlapping of these definitions with ‘degraded’ versus ‘productive’ ones.

Various reports also mention the existence of ‘unmanaged forest’: (i) ‘4.1 Mha of the total forests (19 %) comprising national parks, protected areas and other kinds of abandonment areas that were separated as unmanaged (out of felling) forests due to some conservative considerations’ (TurkStat quoted in National GHG Inventory Report; NIR 2006), (ii) 0.9 Mha of ‘Primary Forests’ (reported under the national classes 2.1 to 2.15) in the FAO FRA 2010 (FAO 2010), (iii) 2.2 Mha of ‘Protected areas, which include 41 national parks (898 044 ha), 39 nature parks (79 928 ha), 31 nature reserves (46 575 ha), 79 wildlife reserves (1 201 032 ha) and 106 natural monuments (4 323 ha)’ (Haase 2011). In total, these ‘unmanaged’ or ‘non-commercial’ forests could encompass 0.9 Mha, 2.2 Mha, or even 4.1 Mha. This amount, and discrepancy in measurements, have some consequences in terms of the GHG’s inventory;

8.5.1.2 Legal Boundary (Cadaster) and Technical Boundary (Management Plan)

“When cadaster and boundary marking activities are completed, in the size of legal forest areas is estimated to be crucial increments […] For example, a forest area where cadastral studies completed like İstanbul and Tekirdağ shows a 10–40 % increase in comparison with the forest area given in the management plans” (National Forest Programme; NFP 2003). The cadaster deployment is still on-going and the boundaries of FM plans are revised accordingly when they are renewed (every 10–20 years) (com. pers. Selda PAS—GIS Division of Information System Department of OGM, February 2014). Knowing that forest areas are regularly monitored using the FM plans (compiled in the Forest Inventory and Statistical

Database; ENVANIS) and that these areas are used in the GHG inventory, such revisions also have some consequences on the latter.

8.5.1.3 Private Afforestation

‘Afforestation and agro-forestry activities with poplar, salix, acacia and eucalyptus species in private lands, boundary of cultivated lands and along the creeks by villagers and farmers are in an important level. These plantations are generally outside the forest regime and their annual timber production is estimated to be some 3.5 Mm^3. […] Annual production from private sector poplar plantations and fast growing species afforestation is more than 3.3 Mm^3’ (NFP 2003). Considering the lower value (3.3 Mm^3/year) and a conservative assumption of volume increment (Iv) of 10 m^3/ha/year for these fast-growing species, private plantations would cover at least 0.33 Mha of land in 2003. Reported values for private afforestation are 24 237 ha in 2000 and 311 056 ha in 2007 (FAO FRA 2010). This last value might better fit to the reality. As it is not clear by which method these private plantations (poplar plantations on the one hand, considered as agriculture land in Turkey; other private plantations on the other hand, considered as forest land in Turkey) were considered in the GHG inventory, this lack of clarity also has some consequences on the latter.

8.5.2 Historical Changes in Forest Areas

Two National Forest Inventories (NFI) were conducted, one in 1972 and one in 2004. Between these dates, the forest area increased by 0.99 Mha, i.e. +0.15 %/ year. After 2004, ENVANIS was created based on full forest cover type mapping through 1/25 000 infrared aerial photos and a systematic sampling grid (300 m × 300 m) of circular plots ranging in size from 400 to 800 m^2, depending on crown cover. It compiles data from FM units and classifies stands according to three criteria: species mix, crown closure and age classes. Therefore, it allows the calculation of changes in area, volume increment and stock on a year-by-year basis.

It is possible to draw an historical data series of the ‘forest area’ (in line with the national definition) using FAO FRA 2010 data for the years 1972 (NFI conducted by OGM), 1996 (partial NFI conducted by OGM), 1999 (report on ‘Forests and Turkish Forestry’ by Mr Konukçu), 2004 (NFI conducted by OGM) and 2004 to 2010 (ENVANIS data compiled by the OGM), and then adding the following land use types:

- Forest Land (FL): Area > 0.5 ha; Tree height > 5 m; Tree canopy cover > 10 %; land predominantly under agricultural or urban land uses is not included. This FAO definition of FL is equivalent to the national definition of ‘productive forest’ (which can be high forest or coppice);

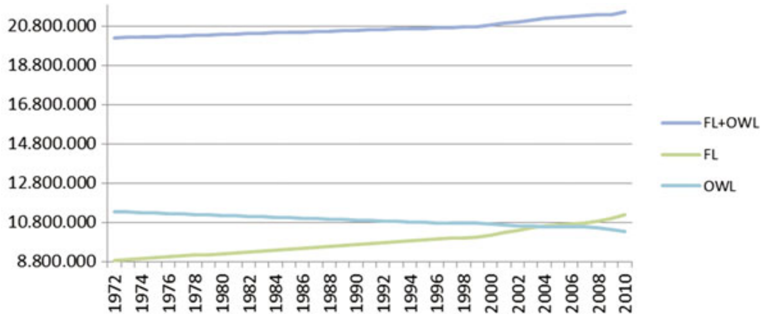


Fig. 8.2 Changes in FL and OWL areas (ha), 1972–2020. *Source* Bouyer (2014) based on FAO FRA (2010)

- Other Wooded Land (OWL): Land not classified as forest; Area > 0.5 ha; Tree height > 5 m; 5 % > Tree canopy cover > 10 %, or combined cover of shrubs, bushes and trees > 10 %; land predominantly under agricultural or urban land use is not included. This FAO definition of OWL is partially equivalent to the national definition of 'degraded forest' (which can be high forest or coppice): as the definition of degraded forest captures land with 1–10 % of tree cover, the area of degraded forest is bigger than that of OWL (with tree cover between 5–10 %).

Estimates for 1973 through 1995 were possible through linear interpolation of the data for 1972 and 1996. Estimates for 1997 through 2003 were possible through linear interpolation of the data for 1996 and 2004. Changes in FL and OWL areas from 1972 to 2010 are given in Fig. 8.2.

It is important to note that (i) the total forest area (FL + OWL) increased by 1.34 Mha between 1972 and 2010 and (ii) the FL area increased over the same time frame, whereas the OWL area decreased. Assuming a theoretical linear trend, the FL area would be 11.8 Mha by 2020 (compared with 8.9 Mha in 1972) and the OWL area would be 10.1 Mha by 2020 (compared with 11.3 Mha in 1972). On average, for 1990–2010, FL increased by 76 161 ha/year (conversion of OWL and other land uses to FL by regeneration + plantations).

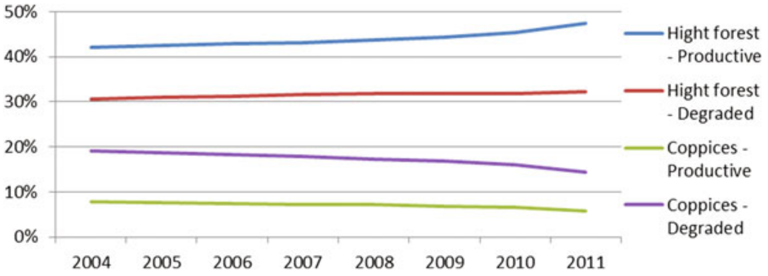


Fig. 8.3 Area changes (%): High forest versus coppices, productive versus degraded from 2004 to 2011. *Source* OGM (2012)

Focusing on forest area changes from 2004 to 2011 and using ENVANIS data, it is important to note that (i) the area of coppices is decreasing whereas that of high forests is increasing and (ii) the area of degraded forest is decreasing, whereas that of productive forest is increasing. These changes are shown in Fig. 8.3.

8.5.3 Historical Rates of Afforestation and Reforestation

In the FAO FRA 2010, various types of A/R are considered but only a certain percentage of each area is ultimately reported: 100 % for artificial regeneration, 80 % for public afforestation, 40 % for rehabilitation and erosion control, 20 % for energy forest and 10 % of private afforestation. This ‘reclassification’, based on expert judgements, aims to take three salient facts into consideration (com. pers. Yücel Fırat—General Directorate of Desertification and Erosion Control and former Lead Author for the FAO FRA 2010 report for Turkey):

- Some activities are reported for a given perimeter, but only part of it is effectively reforested: i.e. hedges and small patches
- The rate of survivals depends on the type of plantations conducted, which in turn depends on natural conditions, sometimes very difficult in Turkey: poor rainfalls, degraded soils, etc.
- In the specific case of private afforestation, the reclassification rate is extremely low (10 %), since trees are assumed to be planted in linear alignment, i.e. small patches, hedges, etc., and therefore, private afforestation is assumed to be done conducted on agricultural land.

OGM data series (compiling data from OGM, and AGM, but also other public services and A/R made by the private sector) have been available since 1947 and use the same categories as those used in FAO FRA 2010, apart for two categories: (i) ‘artificial regeneration’ is reported under ‘afforestation’ by the OGM and (ii) ‘range improvement’ is used by OGM but not the FAO categories; such areas are instead reported under ‘erosion control’ in FAO FRA 2010.

Nonetheless, the two set of ‘reclassified’ data series are consistent: if ‘raw’ A/R is 198 774 ha/year over 1990–2013 for OGM and 174 014 ha/year over 1990–2010 for FAO, then ‘reclassified’ A/R is 87 512 ha/year over 1990–2013 for OGM and 81 996 ha/year over 1990–2010 for FAO. Thus, a difference of slightly less than 7 % exists between the two data series, in favor of OGM. In addition, as OGM data series are complete over time and documented by various archives, these data series are used in our calculations. Figure 8.4 depicts the reclassified A/R, using two different scales: one for rehabilitation and one for the other types of A/R.

“According to a survey conducted by AGM in 1999–2000, potential areas for afforestation, erosion control and range improvement are 2.4 Mha, 1.4 Mha and 0.8 Mha, respectively, (total 4.6 Mha)” (NFP 2003). From 2000 to 2013, according to quoted (and reclassified) data from OGM 2014, around 0.617 Mha have been

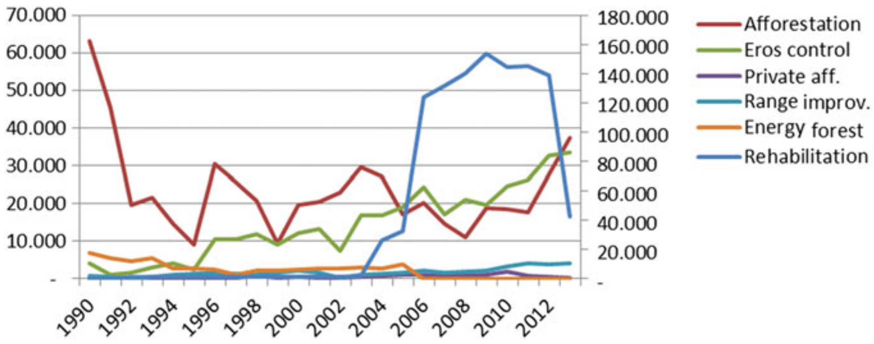


Fig. 8.4 Changes in A/R (ha/year) from 1990 to 2013. *Source* Bouyer (2014) based on OGM (2014)

covered by the mentioned activities. This means that approximately 4 Mha may still be covered by the mentioned activities.

NB: Areas of 'other land with tree cover' (land not classified as FL or OWL; Area > 0.5 ha; Tree height > 5 m; Tree canopy cover > 10 %, consisting mainly of fruit trees and olive trees in Turkey) are mentioned for years 1990, 2000, 2005, 2006, 2007, 2008 and 2010 in the FAO FRA 2010. However, (i) it is mentioned that fruit and olive tree areas were only recorded for three years, namely 2000, 2005 and 2010 by TurkStat (2013), and (ii) the national definition of forest excludes these fruit trees. For these reasons, in the rest of the study, these fruit trees will not be considered in the forest sink assessments.

8.5.4 Harvests and Damage in Managed Forests

As can be seen in Fig. 8.5, harvests were high in the 1970s (above 20 Mm^3, roughly 75 % firewood). From there, it decreased to its lowest level at the beginning of the 2000s (12.5 Mm^3/year in 2001), before rising again through the present day. It is worth noting that firewood harvests fell steadily, whereas industrial round wood harvests, which had remained stable from the 1970s to the 2000s (around 7 Mm^3/year), showed a sharp increase afterwards.

The main explanations for these trends are as follows. For industrial round wood, "Demand for industrial wood in Turkey is steadily increasing, mainly to meet the needs of the construction industry […] Imports of forest products (excluding wood furniture) was about 1 200 MUS$ in 2007 and by far exceed exports (US$ 455 MUS$)" (Haase 2011) for firewood, numerous reports point out the massive rural exodus, which can explain the decrease in demand. '*Firewood is assumed to be harvested only in productive forest and no harvesting of industrial round wood is reported for degraded forests*' (NIR 2013).

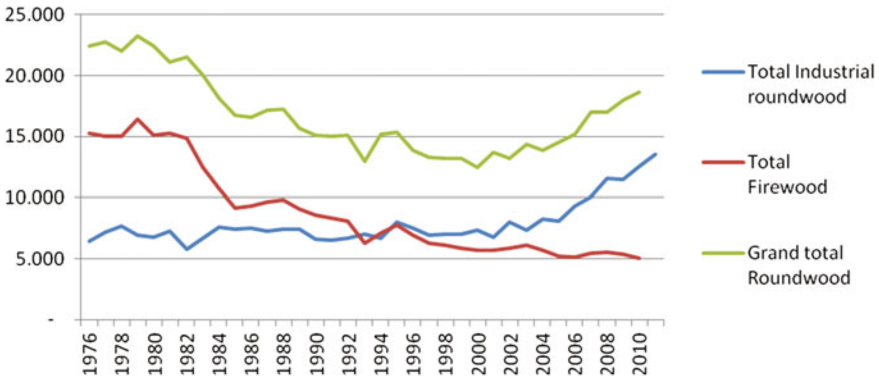


Fig. 8.5 Annual harvest (industrial round wood and firewood) in thousands of m^3 from 1976 to 2011. *Source* OGM (2014)

During 2007–2011, the average total harvest was 17.2 Mm^3 (45 % of the total volume increment, according to ENVANIS data 2014), made of 77 % coniferous and 23 % deciduous. This could be divided into 69 % industrial round wood and 31 % firewood. After firewood, logs (third quality for 98 % of the volume) are the main product (29 % of the total harvest, of which 18.5 % is coniferous and 5.5 % is deciduous), followed by fiber chips (23.8 %) and pulp wood (12 %). The remaining products (electric poles, mining poles, small logs, etc.) are marginal (8.2 %) (Wood Marketing Division of OGM 2014).

Turkey is a Mediterranean country and wildfires are very common except in winter. "With the semi-arid conditions found in much of the country, forest fires are a major threat. Most of the forest fires in Turkey occur between June and October: the majority of them are the result of human activities. Most are caused by human negligence or carelessness though a significant number are caused by intentional human interventions (clearing for agricultural land and settlement areas). OGM has developed a nation-wide forest fire management system" (Haase 2011).

"The coastal belt, which extends from Antakya to Istanbul in the North is regarded to be the region most at risk from fires, and nearly 12 Mha of forests in the area are vulnerable. The majority of forest fires are human induced, less than 2 % being attributable to natural factors About 40 % of these are high intensity crown fires that destroy most of the biomass; 60 % are ground-fires whereby about 55 % of the biomass is destroyed […] The annual frequency of fires has increased since 2004 and is expected to increase further as a consequence of climate change" (UNDP 2011).

Figure 8.6 presents historical data regarding forest fires (extracted from the forest fires database of the OGM's Forest Fire Department). NB: Since the fire monitoring system was changed in 2005 to enable better recording of forest fires, data before 2005 may be underestimated (pers. comm. Uğur Baltaci; Meteorology Division of Forest Fire Department of OGM, February 2014).

High levels of variability can be observed for both number of fires and area per fire. Comparing the average area burned, number of fires, and area per fire for the

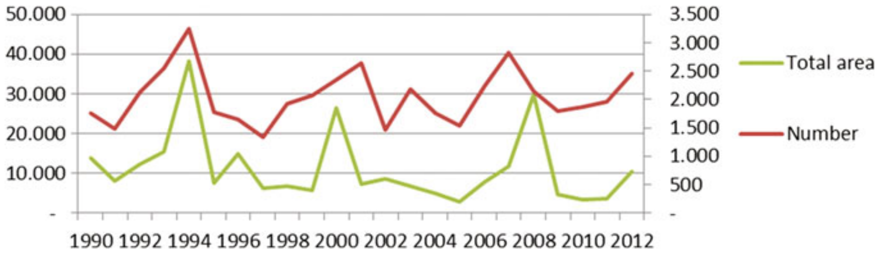


Fig. 8.6 Number of fires and area per fire (ha) from 1990 to 2012. *Source* OGM (2014)

periods 1990–2000 and 2000–2012 reveals a decreasing trend in terms of burned area (−390 ha/year), area per fire (−0.4 ha/year), and number of fires (−6.2 fires/year) (Table 8.4).

As most fires are illegal, scattered over a huge territory and therefore difficult to control, it seems reasonable to assume that the number of fires will further increase according to the fast-changing natural conditions: "One of the most important effects of climate change is the recent and possible future increase in the intensity, duration and extent of forest fires in Turkey. As a natural result of the Mediterranean climate, hot and dry summers are dominant across Turkey, except for the Black Sea Region and Northeast Anatolia. When decreasing trends of precipitation since the early 1970s are taken into account, like the hot and dry summers in 2007 and 2008 in many regions, the increased probability and severity of forest fires is likely to be an important problem" (NC5 2013).

In 2013, 3 755 fires and 11 456 ha of burned areas were recorded, giving an average of 3.05 ha/fire. 27.8 % were ground fires (mainly on Pinus brutia, with few damages) and 72.2 % were crown fires (with big damages, especially for coniferous forests, that do not reshoot) (pers. comm. Uğur Battacı; Meteorology Division of Forest fire Department of OGM, February 2014).

One other major source of damage concerns the insects. Two major insect outbreaks in terms of affected areas can be identified. The first is an infestation of Thaumetopoea pityocampa (Schiff.), which spread over 2 204 000 ha of Pinus brutia ten and Pinus nigra (Arnold.) between 1997 and 2001. The next most severe infestation was caused by Dendroctonus micans (Kug.), which spread over

Table 8.4 Changes 90/00 versus 00/12: burnt area (ha), number of fires and area (ha) per fire

	Area (ha)	Number	Area (ha/fire)
Average 1990–2000	14 128	2 022	6.6
Average 2000–2012	9 834	2 090	4.6
Change 90/00 etc. 00/12	−4 294	68	−3.9
Annual change*	−390	6.2	−0.4

Source OGM (2014)

*Over 11 years, using 1995 as the "central" year for the 90/00 period and 06 as the "central" year for the 00/12 period

990 000 ha of Picea orientalis (L.) between 1996 and 2001 (FAO FRA 2010). Compared with fires and insects, both diseases as well as abiotic factors appear marginal in terms of afforestation.

8.5.5 Projections for A/R and D Activities (Article 3.3)

The OGM strategic action plans aim at increasing the forest cover to 30 % of the country (i.e. 23.5 Mha) by 2017. It foresees reaching the following milestones between 2013 and 2017: 500 000 ha of rehabilitation (obj. 2.2); 75 000 ha of natural regeneration (obj. 2.3); 65 000 ha of artificial regeneration (obj. 2.3); 150 000 ha of public afforestation (obj. 2.6); 50 000 ha of private afforestation (obj. 2.6); 393 400 ha of erosion control (obj. 2.8) and 50 000 ha of range improvement (obj. 2.8).

If we compile these figures and apply the same rates of reclassification as previously presented, then the 256 800 ha/year of 'raw' A/R foreseen by OGM over 2013–2017 would convert into 122 872 ha/year of 'reclassified' A/R over 2013–2017. Considering an 'informal' objective of 50 000 ha/year of 'raw' A/R after 2017 to 2020 (as expressed by the participants of the inception workshop to this study, February 2014), which would convert into 23 925 ha/year of 'reclassified' A/R over 2018–2020, we can project A/R rates of A/R up to 2020: the 1990–2020 average would then be 83 509 ha/year.

To prepare the specific LULUCF calculations, we then assume that A/R species are selected in accordance with the current forest composition, i.e. 81.3 % of coniferous and 18.7 % of deciduous in pure high forests (according to ENVANIS 2014), and that they are distributed into two main management types: extensive (rehabilitation, erosion control, range rehabilitation and energy forest) and intensive (public and private afforestation).

These data and calculations thus yield four data series over 1990–2020: A/R ext, con = 49 069 ha/year, A/R int, con = 18 816 ha/year, A/R ext, dec = 11 294 ha/year, A/R int, dec = 4 331 ha/year. Cumulative A/R would then be 2 588 794 ha over 1990–2020. Knowing that the forest area (according to FAO definition) was 11 559 261 ha in 2011 (ENVANIS 2012) and 9 679 614 ha in 1990 (FAO FRA 2010), the net increase of forest cover was 1 879 647 ha over this period, or 85 439 ha/year if divided by 22 years. Knowing that the cumulative area of A/R (calculated previously) is 1 909 908 ha over the same period, i.e. 86 814 ha/year, then the difference 86 814 ha/year – 85 439 ha/year = 1 376 ha/year can be estimated as the amount of deforestation that occurred over this time frame.

As ENVANIS does not record deforestation area, even if OGM staff generally recognizes its existence, we then apply this amount of deforestation conservatively over the remaining period, 2012–2020. Figure 8.7 shows the resulting calculations.

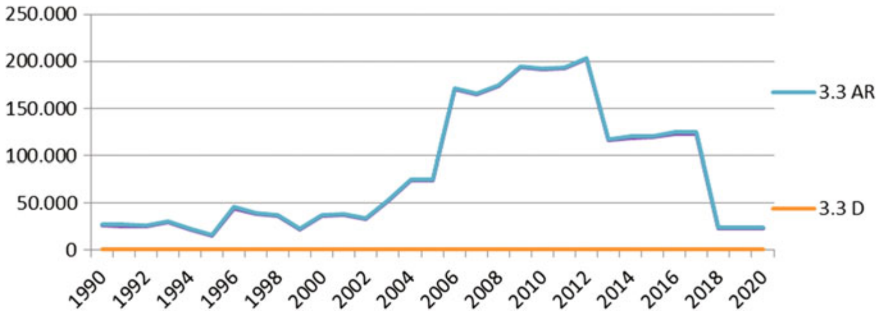


Fig. 8.7 Estimated 1990–2020 data series for 3.3 A/R and 3.3 D. *Source* Bouyer (2014)

8.5.6 Projections for FM (Article 3.4)

To prepare the specific LULUCF calculations, we estimate data series covering 1990–2020 for the main forest types to be considered under 3.4 FM. The estimation procedure entails the following four steps:

- *Area of 3.4 FM*. According to Articles 3.3 and 3.4 of the Kyoto Protocol, deforestation occurring after December 31, 1989 should be accounted for under Article 3.3. We then estimate the area to be considered under 3.4 FM by deducting deforestation from the initial 9 679 614 ha of forest found in 1990. Therefore, the area considered under 3.4 FM is 9 638 348 ha in 2020, with 41 266 ha deducted from the initial area equal to the deforestation over 1990–2020. We thus have a complete 1990–2020 data series for the 3.4 FM area;
- *Area of the forest*. We interpolate the 1990–2002 data for the forest area using the FAO FRA data for 1990 and ENVANIS data for 2002. We estimate the data series 2013–2020 for the forest area by adding the net A/R = A/R − D over year, starting in 2012 to produce a complete forest area data series for 1990–2020;

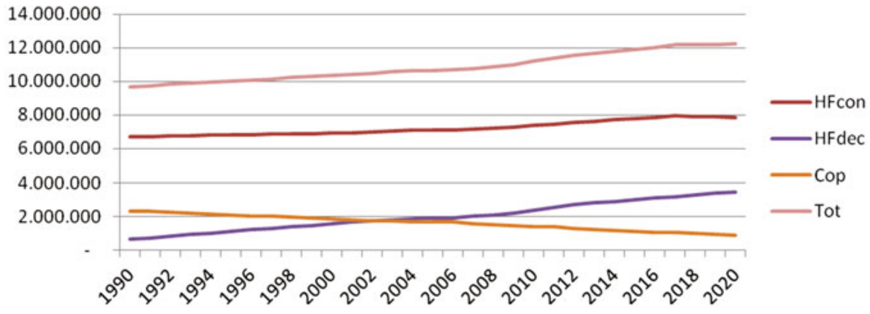


Fig. 8.8 Estimated 1990–2020 data series for forest area (ha), by forest types. *Source* Bouyer (2014)

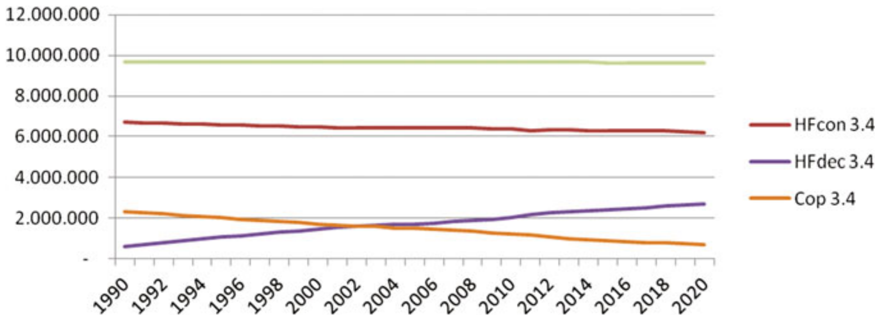


Fig. 8.9 Estimated 1990–2020 data series for 3.4 FM area (ha), by forest types. *Source* Bouyer (2014)

- *Areas of the main forest types*. The three main forest types identified in ENVANIS are high forest coniferous, high forest deciduous and coppices. Using the data series for these three forest types over 2002–2012, we extrapolate these data series back to 1990 and forward to 2020. This yields complete data series for 1990–2020 for forest type areas. The result is shown in Fig. 8.8.
- *Areas of 3.4 FM disaggregated by main forest type*. This step was conducted using the rule of three as follows: area of 3.4 FM forest type A = area for forest type A × (area for 3.4 FM/area for forest), we have complete data series 1990–2020 for 3.4 FM forest type areas. Figure 8.9 shows the results of these calculations.

Using the estimates for D (in tdm/m^3) and BEF1 (dimensionless) for the main forest types, and the stocks (in m^3/ha) reported in the NFI for 1972 and 2004 (useful only for coppices, as the NFI 1972 and 2004 did not specifically report stocks and areas for coniferous and deciduous forests) as well as the ENVANIS database for 2011, we estimate the stocks (in td m/m^3) using the following equation: S (tdm/ha) = S(m^3/ha) × D × BEF1. Table 8.5 shows the results.

Table 8.5 Estimates of stocks (in tdm/ha) for the three main forest types

	NFI	NFI	ENV	Default value Table 3A. 1.2 (GPG 2013).	Value retained
	1972	2004	2011		
S (m^3/ha) in Hfcon (ENVANIS)			121.6		
S (tdm/ha) in Hfcon			56.2	134	56.2
S (m^3/ha) in Hfdec (ENVANIS)			145.6		
S(m^3/ha) in Hfdec			100.6	122	100.6
S (m^3/ha) in Cop (ENVANIS)	33.0	41.9	41.0		
S (m^3/ha) in Cop	17.7	22.5	22	128	18.8

Source Bouyer (2014)

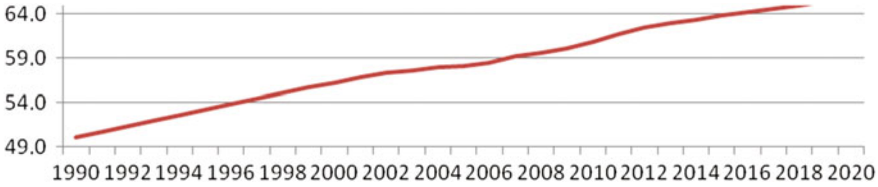


Fig. 8.10 1990–2020 data series of the average stocks (tdm/ha) in Turkish forests. *Source* Bouyer (2014)

We compare our calculated values with the default values provided in Table 3A.1.2 of the GPG LULUCF 2003 for coniferous, deciduous and mixed forests older than 20 years in temperate regions. All the default values are above (well above for coniferous and mixed forests) the country-specific values, which is understandable knowing that Turkish forests are quite degraded. We therefore retain the country-specific values.

We next used these estimated stocks together with the estimated data series of 3.4 FM areas for the three main forest types to estimate the 1990–2020 data series for average Turkish forest stocks, taking into account the respective stocks and evolution of the three main forest types. The results are shown in Fig. 8.10. Note that the average stock amount is estimated to increase by 24 % from 1990 (50.1 tdm/ha) to 2020 (66.1 tdm/ha), i.e. 0.8 %/year.

8.5.7 Projections for Harvests

The following analysis will mainly focus on 3.4 FM. Indeed, A/R harvests made after December 31, 1989—to be considered under 3.3 A/R—are very limited: the first thinning comes only after 15–20 years and only 15–40 % of the trees are harvested (personal Communication, Uğur Tüfekçioğlu; Head of the Forest Maintenance Division of OGM, February 2014). Therefore, the calculations made for 3.3 AR include a uniform thinning of 20 % of the trees after 15 years, which appears to be a conservative assumption.

Returning to 3.4 FM, the following analysis considers two options:

- *Extensive scenario*. Considering only the effective thinning of forests, then according to management plans prescriptions, a 25 Mm^3 increase of total round wood production would be possible by 2020, according to OGM. This would imply an intermediate objective of 21 Mm^3 by 2017 (personal Communication, Ramazan Bali; Head of Wood Marketing Division, February 2014);
- *Intensive scenario*. According to the OGM Strategic Plan 2013–2017, the previous Strategic Plan 2010–2014 was intended to increase industrial round wood production by OGM to 90 Mm^3 over 2010 and 2014 (i.e. 18 Mm^3/year). However, the production fell short of this objective. Even though no specific figures are given in

the OGM 2013–2017 Strategic Plan, the same increase (18 Mm^3/year) is still predicted for 2013–2017 (personal. communication. Alper Tolga Arslan; Head of Strategic Planning and Research Strategy Division, Department of Strategic Development of OGM, February 2014). This figure is not included in the current Strategic Plan because production will ultimately depend on market conditions, and OGM staff did not want this objective to be set in stone.

In the extensive scenario, we estimate the following:

- *Firewood*. Illegal harvests, private sector production and consumption are assumed to follow linear trends (extrapolation from the respective historical data series). Import–export, already very reduced, is assumed to be nil. Then, we would assume that OGM harvests of firewood are set to match consumption. The OGM firewood harvest would then be 2.6 Mm^3/year by 2020. Figure 8.11 shows these projections (expressed in thousands of m^3/year).
- *Round wood*. Illegal harvests and private-sector production are assumed to follow linear trends (extrapolation from the respective historical data series). OGM harvests are supposed to be 21 Mm^3 in 2017 and 25 Mm^3 in 2020 (harvests for the years are estimated by interpolation). Total production is calculated as illegal harvest + private sector + OGM. Consumption is also assumed to follow a linear trend (extrapolation from the historical data series). Import–export is then estimated by deducting production from consumption. Figure 8.12 shows the projections (expressed in thousands of m^3/year).

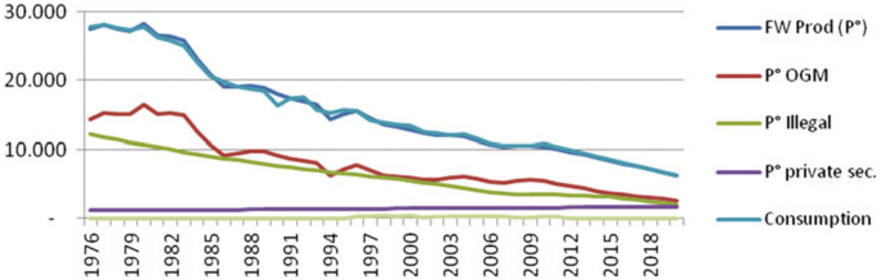


Fig. 8.11 2020 projections of firewood production and consumption in the extensive scenario. *Source* Bouyer (2014)

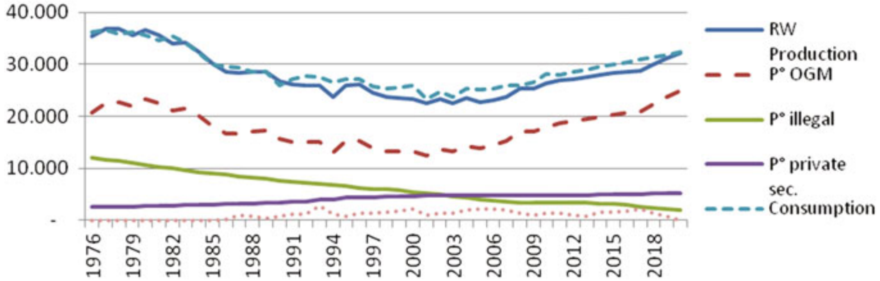


Fig. 8.12 2020 projections of round wood production and consumption in the extensive scenario. *Source* Bouyer (2014)

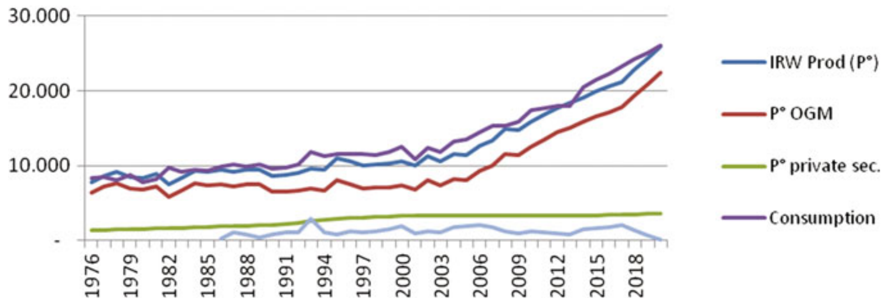


Fig. 8.13 2020 projections of industrial round wood production and consumption in the extensive scenario. *Source* Bouyer (2014)

- *Industrial round wood*. Private sector production is assumed to also follow a linear trend (extrapolation from the respective historical data series). Illegal harvests are assumed to be nil (as already assumed by OGM). The OGM harvest of industrial round wood amounts to the difference between its total harvest and its firewood harvest. Consumption of industrial round wood is calculated as the difference between total consumption and firewood consumption. Production is estimated by adding OGM production and private sector production. Import–export of industrial round wood is equal to total import–export (import–export of firewood being nil). Figure 8.13 shows the projections (expressed in thousands of m^3/year).

In the intensive scenario, we estimate the following:

- *Firewood*. This subscenario is the same as in the extensive scenario (increased production does not impact domestic demand, which is inelastic to the supply);
- *Round wood*. Assuming OGM harvests 90 Mm^3 of industrial round wood from 2013 to 2017, OGM production of industrial round wood is estimated to gradually increase, from 14.7 Mm^3 in 2013 to 16 Mm^3 in 2014, 18 Mm^3 in 2015, 20 Mm^3 in 2016 and 21.3 Mm^3 in 2017 (90 Mm^3 in total). After that, we assume the same trend will continue up to 26.4 Mm^3 by 2020.

By knowing OGM production levels of industrial round wood and firewood, its total production of round wood can be calculated. Then, assuming that private sector production of round wood follows a linear trend (extrapolation from the historical data series) and knowing that the illegal sector production of round wood is equal to its production of firewood, the total production of round wood is known through the following calculation: levels of production of OGM + private sector + illegal harvest.

Then, assuming that the consumption of round wood will also follow a linear trend, import–export is calculated by subtracting consumption from production. It is worth noting that, under this intensive (and ambitious) scenario, Turkey is assumed to be a net exporter of round wood. Figure 8.14 shows the projections (expressed in thousands of m^3/year):

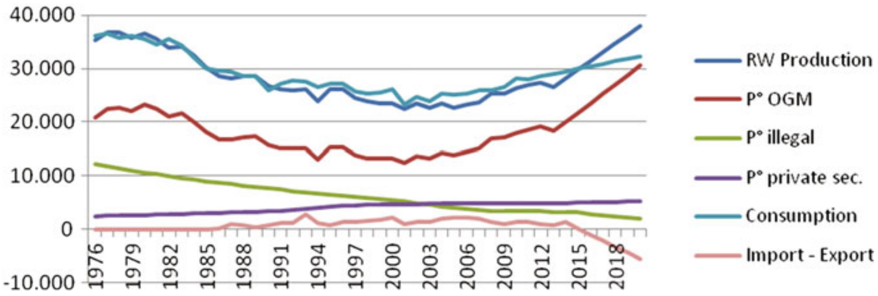


Fig. 8.14 2020 projections of round wood production and consumption in the intensive scenario. *Source* Bouyer (2014)

- *Industrial round wood*. Estimated OGM production of industrial round wood follows the scenario presented above (Sect. 5.7). Import–export of industrial round wood is equal to total import–export (with import–export of firewood being nil). Private-sector production of industrial round wood is calculated as the difference between total harvest and firewood harvest. Consumption of industrial round wood is calculated as the difference between total consumption and firewood consumption. Production is estimated by totaling OGM production and private sector production. Figure 8.15 presents these projections (expressed in thousands of m^3/year):

Having estimated two 1990–2020 data series for round wood production for OGM, one extensive (25 Mm^3/year by 2020) and one intensive (29 Mm^3/year by 2020, 4 Mm^3/year more compared with the other). We then allocate this harvest among the three main forest types.

Indeed, we know the permitted cut for 2002–2012 (ENVANIS 2013), which is divided among high forest coniferous and high forest deciduous (99.9 % of industrial round wood; therefore, firewood harvests in high forest areas are neglected order to simplify the calculations) on the one hand and coppices (100 %

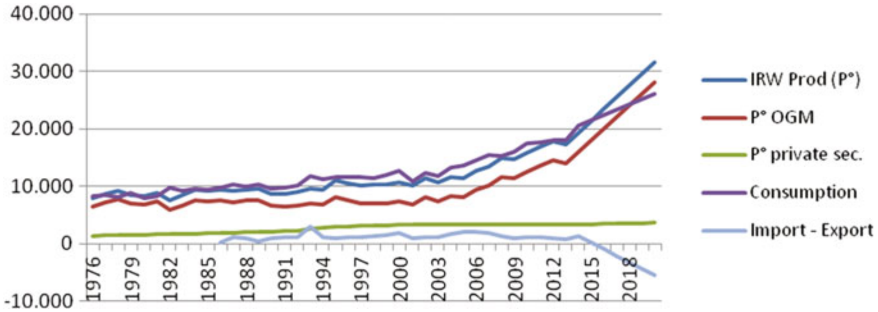


Fig. 8.15 2020 projections of industrial round wood production and consumption in the intensive scenario. *Source* Bouyer (2014)

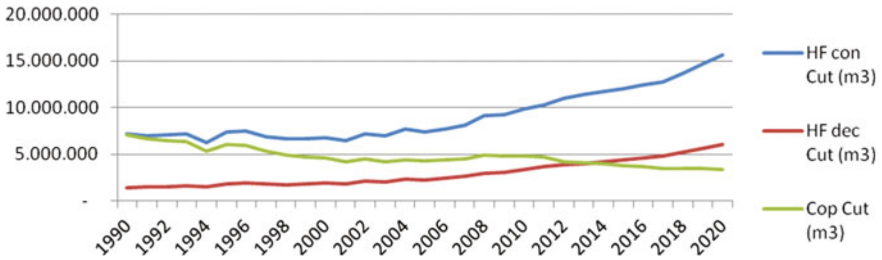


Fig. 8.16 2020 projections of harvest per forest types in the extensive scenario. *Source* Bouyer (2014)

of firewood) on the other hand. We also estimate a 3 % difference in average over 2002–2012 between allowable cut and real cut (the last one being lower), and we therefore assume the two are equal to simplify the calculations.

Next, we extrapolate the shares (in %) of total harvest for the three main forest types for 1990–2001 and 2013–2020 using 2002–2012 ENVANIS data. Then, we allocate the estimated 1990–2012 data series for harvests using the estimated percent of harvest for each forest types. Figures 8.16 and 8.17 show the results (expressed in thousands of m^3/year):

At the inception workshop to this study, a debate arose about the development of bioenergy and its possible impact in terms of harvests. Indeed, in addition to the use of 'traditional' firewood by forest villagers and the rural population in general, some documents point to the potential development of pellets for use in industrial power plants.

- "As a result of the wood energy initiatives, it may increase again in the future […] wood energy activities have been further encouraged within the framework of the adaptation and mitigation efforts for climate change. For this purpose, OGM experts prepared a report on 'The Status of Forest Biomass in Renewable Energy' […] and OGM organized a workshop on 'Forest biomass and bioenergy'" (Haase 2011). During this workshop held in Kastamonu, in February 2010, the OGM declared that '*we expect that much of the extra 5 Mt/year of*

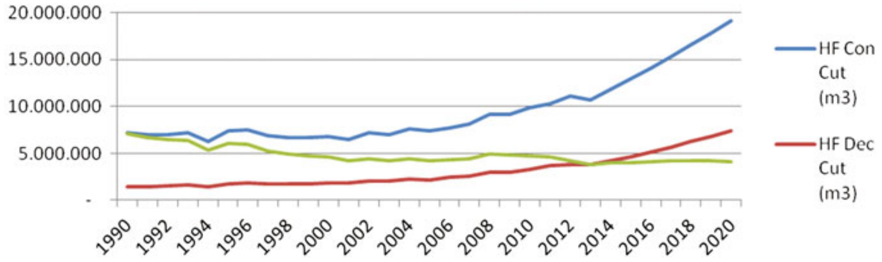


Fig. 8.17 2020 projections of harvest per forest types in the intensive scenario. *Source* Bouyer (2014)

production will be available as forest residues fuel' (Flyer Kastamonu 2010). It is difficult to use this last figure since it is expressed in relative terms ('extra') and since the 'baseline' level is not specified;

- The 2020 projection for final energy consumption (BALANCE) presented in the First National Communication (NC1 2007), assumes that the share of renewable energy will increase from 6.9 to 9.3 Mtoe and that the share of woody biomass is expected to decrease from 5.7 to 3.9 Mtoe, e.g. 8.58 Mtdm in 2020 (using a usual conversion factor of 2.2 tdm/toe).

Using this last official projection and considering the assumptions already presented (see default values for the BCEF from Table 5.4 of the FAO FRA 2010 Guidelines), the firewood harvest in 2020 can be estimated for the main forest types: 6.73 Mm^3 (8.58 Mtdm × 59 % × 1.33 tdm/m^3) in coniferous forests; 1.55 Mm^3 (8.58 Mtdm × 19 % × 0.95 tdm/m^3) in deciduous forests and 2.25 Mm^3 (8.58 Mtdm × 23 % × 1.14 tdm/m^3) in mixed forests. In total, the BALANCE projection leads to a total firewood harvest of 10.53 Mm^3/year in 2020, i.e. 67 % more than the projections made under either the intensive or extensive scenario.

According to inception workshop participants, the BALANCE projection is no longer pertinent. Indeed, the Scientific and Technological Research Council of Turkey (TÜBİTAK) conducted a feasibility study into the development of an industrial biomass plant. This study concluded that electricity production from forest biomass is only feasible for plants over 20 MW. But OGM realized it is not logistically or economically feasible to provide such large amounts of biomass. OGM was initially looking for plants of one to two MW. Therefore, the pilot plant discussed in the TÜBİTAK project was not installed and the objective of developing an industrial biomass value chain was abandoned.

8.5.8 Biotic and Abiotic Damage

We can consider the consequences of these damage types on biomass growth, on the one hand, and biomass loss, on the other hand:

- *Biomass growth*: As the growth of productive forest area affected by all biotic (pests and diseases) and abiotic (storm, avalanche, snow, flooding and forest fire) damage is reported together with the growth of the non-affected areas in ENVANIS, the decrease of forest growth due to these damage types is captured in the historical ENVANIS data series;
- *Biomass loss*: As explained previously, salvage logging is conducted for most abiotic and biotic damages (excluding forest fires). Therefore, for these damage types, feeling and/or firewood (biomass loss) is already incorporated in ENVANIS and Wood Marketing Department data series.

Therefore, this study only concentrates on the projection of forest fires through 2020 to estimate the related biomass loss. This exercise is difficult and subject to discussion since some of the factors determining the impact of forest fires can be controlled, whereas other cannot. For instance:

- The number of forest fires started due to negligence might be reduced by increasing information and prevention measures, but such measures will have limited effect on criminal forest fires;
- The ability to stop forest fires in the crucial first 20 min can be improved using a real-time fire alert system (as does OGM) and making sure the firemen arrive on site as fast as possible;
- Whatever efforts are made in terms of prevention, measures such as a fire alert system, forest firefighting equipment, etc. will not enable the avoidance of large forest fires if natural conditions are conducive (e.g. firemen often refer to the rule of the '3 × 30': when air humidity is below 30 %, wind speed above 30 km/h, and ground temperature above 30 °C, there are few chances to stop a forest fire).

  This being said, we forecast future forest fire trends as follow:
- *Area per fire*: The average area is 4.6 ha/fire over the period 2000–2012. This rate could be reasonably decreased to 2.5 ha/fire by 2020 (personal Communication, Uğur Battaci, Meteorology Division of Forest fire Department of OGM, February 2014, corroborated by personal communication, Alper Tolga Arslan, Head of Strategic Planning and Research Strategy Division, Department of Strategic Development of OGM, February 2014). Then, the area per fire for the period 2013–2020 can be interpolated using 4.6 ha/fire as a reference value in 2012 and 2.5 ha/fire as an objective by 2020;
- *Number of fires*: The number of fires between 2013–2020 is set equal to the average over 2000–2012, i.e. 2 072 fires/year.
- *Area burned*: The burned area is equal to area per fire × number of fires. A decreasing trend can be identified, up to 5 180 ha in 2020. The average over 2013–2020 is 7 063 ha, which is 28 % below the average during the 2000–2012 period (9 834 ha). This projection seems ambitious, but considering the progress made by OGM's Forest Fire Fighting Department over the last two decades, it seems achievable.

8.5.9 Accounting Carbon Credits for 3.4 FM

Having calculated the required values, we can now estimate net removals including HWP for the 1990–2020 time series for the two scenarios. The results are shown in Fig. 8.18, expressed in $MtCO_2eq$/year of net removals.

Based on these results and considering the upgraded LULUCF accounting rules for Article 3.4 FM as well as the *Synthesis Report of the Technical Assessments of the FM Reference Level (REL) Submissions* published in November 2011 by the UNFCCC Secretariat, we can envisage five different possible interpretations for the

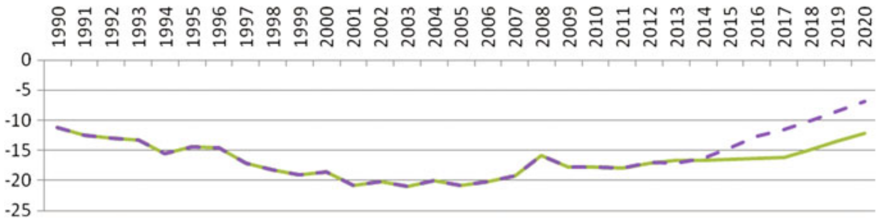


Fig. 8.18 1990–2020 net removals in 3.4 FM area under intensive vs extensive scenarios. *Source* Bouyer (2014)

Table 8.6 Five different RELs for Article 3.4 FM in Turkey and numerical consequences

All numbers in $MtCO_2eq$	Number of Annex 1 Parties	Corresponding	Difference if		Removal Units	
Choice of REL		REL in Turkey	Int. Scen.	Ext. Scen	Int. Scen	Ext. Scen
2020 projections	31 (incl. 24 EU States)	−235.7	0.0	−46.5	–	46.5
Historical 1990	3 (Belarus, Norway, Russia)	−157.0	−78.7	−125.2	52.8	52.8
Average 1990–2009	1 Greece	−176.2	−59.5	−106.0	52.8	52.8
Linear trend 1900–2008	2 (Cyprus and Malta)	na (no linear trend)			–	–
0	1 (Japan)	0	−235.7	−282.2	52.8	52.8
1990 GHG emissions in Turkey excl. LULUCF (tCO_2eq/yr)		188.4		Cap of 3.5 %	−52.8	

Source Bouyer (2014)

elements of footnote 1 in Annex of 16/CMP.1 in order to set the REL for Article 3.4 FM in Turkey.

Five proposed RELs are possible (Table 8.6). In particular, a 2020 projection based on the intensive scenario in terms of harvest rate would be defensible since it was publicly announced before 2009, during the preparation of the OGM Strategic Plan 2010–2014: as such, this harvest rate can be considered part of the projected REL (see elements of footnote in Annex of 16/CMP.1).

8.5.10 *Accounting Carbon Credits for 3.3 A/R/D*

The previous calculations can also be used to estimate net removals due to A/R and D for the 1990–2020 time series. The results are shown in Fig. 8.19, expressed in $MtCO_2eq$/year of net removals.

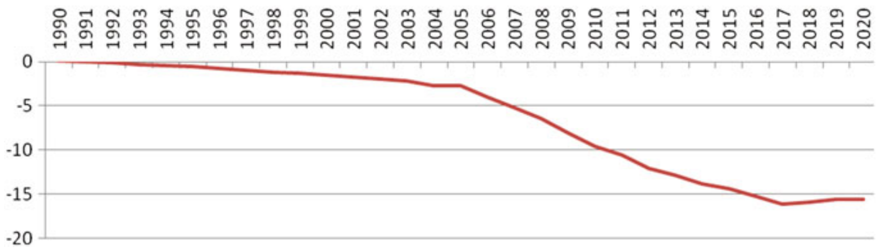


Fig. 8.19 1990–2020 net removals due to A/R and D. *Source* Bouyer (2014)

Based on these results and considering the upgraded LULUCF accounting rules for Article 3.3 ARD, 119.4 million of RMUs would be generated under this Article between 2013 and 2020. According to Article 3.3, an estimated 119.4 million of RMUs will be generated between 2013 and 2020, which is more than two times the maximum amount of RMUs to be generated under Article 3.4 FM.

8.5.11 *Operation and Transaction Costs*

The operation and transaction costs associated with Article 3.3 and Article 3.4 were estimated using the following approach:

- For Article 3.4, operation costs are equal to FM costs, which converts to 14.6 US$/RMU. If the REL is projected, then an additional 52.1 US$/RMU of opportunity cost for reduced felling has to be added, totaling 66.7 US$/RMU;
- For Article 3.3, the operation cost comprises plantation costs (for years 1 to 4) and FM costs (from year 5 onward) and amounts to 86.4 US$/RMU;
- For Article 3.3 and Article 3.4, transaction costs mainly comprise upgrading the current LULUCF inventory. They are assumed to be marginal, around 1.2 MUS $ in total as most of the data sources are already available and the main efforts required are in terms of human resources. Transaction costs would therefore range from 0.01 to 0.007 US$/RMU.

8.5.12 *Quantification of Non-carbon Benefits*

The most recent estimates for the TEV of Turkish forests are given in Table 8.7.

Comparing these values with other existing estimates is quite difficult since these other estimates were either classified by economic agents (e.g. percent of GNP for the state, wages for the forest workers, and revenue and forest livelihood for the forest villagers) or were not based on the same perimeter (e.g. most of the estimates

Table 8.7 Disaggregation of the TEV of the Turkish forests

TEV components	Type of outputs	Value (US $) per year		%	
Direct use values	Wood based forest products	1165178097.46	68.35		
	Non-wood forest products	454292.02	0.03		
	Grazing	225000000.00	13.20		84.03
	Hunting	35948500.00	2.11		
	Recreation	5950000.00	0.35		
Indirect use values	Carbon storage	158400000.00		9.29	
Option value	Pharmaceuticals	112500000.00		6.60	
Non use values	Existence value (to converse biodiversity)	1380000.00 1704810889.48		0.08	
Positive TEV components		1704810889.48		100.00	
Negative externalities	Erosion	−125000000.00		93.56	
	Risk of damage by forest fires	−8607537.00		6.44	
Negative TEV components		−133607537.00		100.00	
Net total economic value of Turkish forests		1620459352.58			

Source Pak et al. (2010)

for NWFPs are only considering the OGM revenue and not the overall revenue for OGM + middlemen + forest villagers). These discrepancies highlight the crucial need to try, as much as possible, to use common terminologies and assumptions when valuing forest amenities.

Accordingly, if we compare the data from Pak et al. (2010) with other data sets, we can determine the following amounts:

- *Wood-based products*: This estimate (roughly 1.17 trillion US$/year) is considerably higher than the values of 0.45 trillion US$/year from Bann/Clemens (2001), quoted in Türker et al. (2002, 2005), as well as the value of 0.86 trillion U$/year from Ok et al. (2013). Indeed, this estimate is more recent (more felling occurred than that in 2001, explaining the difference with Bann/Clemens (2001)) and considers a larger perimeter than the sole OGM wood-based products (existence of private felling explains the difference with Ok et al. (2013)). It therefore appears reasonable to use this estimate.
- *NWFPs*: This estimate (roughly 0.45 MUS$/year) appears extremely low compared with 86 MUS$/year from Bann/Clemens (2001), quoted in Türker et al. (2002, 2005). It is roughly three times less than the 1.35 MU$/year from Ok et al. (2013), but this latter one may itself be an underestimate since it considers only OGM revenue.

For these reasons, it appears preferable to use the latest estimates produced by the NWFPs Division of OGM of roughly 335 MTL in 2012 and 514 MTL in 2013, considering OGM revenue + middlemen revenue + forest villagers' revenue. Once averaged and converted in US$, it affords 195 MUS$/year;

- *Hunting*: This estimate, roughly 35.9 MUS$/year, includes both hunting and fishing activities. The estimates in Bann/Clemens (2001), quoted in Türker et al. (2002, 2005), are of the same order of magnitude: 17.8 MUS$/year for hunting and 20.1 MUS$/year for fishing, i.e. 37.9 MUS$/year in total. Since the estimate from Pak et al. (2010) is of the same order of magnitude and more recent, this is the one that will be used;
- *Recreation*: The estimate, roughly 5.9 MUS$/year, is three times less than the sole official revenue from national parks (33.4 MTL in 2012, i.e. 15.4 MUS$/year), according to Ok et al. (2013). Since this last estimate is conservative (it does not include the recreational value of forests outside National Parks) and official, this is the one that will be used;

Table 8.8 Revised disaggregation of the TEV for Turkish forests, according to the above data sources and calculation methods

TEV components (US $) per year	Type of outputs	Value	Source	%
Direct use values	Wood based forest products	1 165 178 097	Pak et al. (2010)	66.6
	NWFPs	195 359 161	OGM (2014)	11.2
	Grazing	225 000 000	Pak et al. (2010)	12.9
	Hunting	35 948 500	Pak et al. (2010)	2.1
	Recreation	15 373 881	OGM (2013)	0.9
Indirect use value	Carbon storage (treated in Parts 4.1 and 4.2 supra)			
Option values	Pharmaceuticals	112 500 000	Pak et al. (2010)	6.4
Nonuse values	Existence value (to converse biodiversity)	1 380 000	Pak et al. (2010)	0.1
Positive TEV components 1 750 739 640				
Negative externalities	Erosion	−125 000 000	Pak et al. (2010)	94
	Forest fires	−8 607 537	Pak et al. (2010)	6
Negative TEV components		−133 607 537		
Net total TEV of forests (excl. C. storage) in US $/year		1 617 132 103		
Average area of productive forest in 2010–2013 in ha		11 374 414		
Net total TEV of forests (excl. C. storage) in US $/year/ha		142		

Source The authors

- *Carbon storage*: This value has been reviewed according to the IPCC (2013b) inventory guidelines and Kyoto accounting rules;
- *Other values and costs*: This category includes activities such as grazing and pharmaceutical values, as well as the erosion and forest fire costs, which are the same as in Pak et al. (2010), and Bann/Clemens (2001), quoted in Türker et al. (2001, 2005). Given the lack of other sources of data for these elements, we use these estimates.

Table 8.8 presents a revised disaggregation of the TEV for Turkish forests, according to the above data sources and calculation methods.

After reviewing the different non-carbon values (wood and non-wood products, grazing, hunting, recreation, pharmaceuticals use) and costs (erosion, forest fires) forming the TEV of the Turkish forest, the revised TEV can be estimated at 142 US $/ha/year.

8.6 Conclusions

Overall, impressive improvements concerning the Turkish forests can be observed over the past decades, namely in the massive efforts in terms of rehabilitation of degraded forests and afforestation, conversion of coppices to high forests and in the technology attained to combat fire events and forest health. These measures have resulted in the increase of the forest biomass stocks, allowing for an increase of felling since the 2000s.

Finally, a complete assessment of carbon and non-carbon costs and benefits of implementing the LULUCF rules was conducted, for four different 3.4 FM scenarios (extensive versus intensive harvest, projected versus non-projected REL) and one single 3.3 A/R scenario, with the results shown in Table 8.9.

All the costs are assumed to be constant across all scenarios. The sensitivity of the estimated benefits to different carbon price assumption was calculated:

- 4 US\$/tCO_2eq: This is the lowest value observed, and it occurred in 2013 on the European carbon market, the bigger Kyoto market worldwide;
- 7 US\$/tCO_2eq: In 2013, the average forest carbon price on both Kyoto and voluntary markets was 7 US\$, according to the Ecosystem Marketplace report from 2013;
- 52 US\$/tCO_2eq. A report commissioned by the French Prime Minister in 2008 estimated the ‘shadow price’ of carbon, i.e. the recommended carbon price from 2011 up to 2050, needed to achieve the EU target of a fourfold reduction in GHG emissions by 2050 (Quinet 2009). The estimated value (by linear interpolation) for 2013 is 52 US\$/tCO_2eq, as shown in Table 8.9.

As can be observed, considering the recent EU market price (Kyoto market) or the recent forest carbon price (Kyoto and voluntary markets), carbon benefits show

Table 8.9 Recap of costs and benefits estimates of LULUCF accounting for different scenarios

Scenario for 3.4 FM, depending on the level of harvest by 2020 (in Mm^3/yr)	REL non projected*		REL projected	
	Ext. harvest 32.3 Sc NP-Ex	Int. harvest 36.3 Sc NP-ınt	Ext. harvest 32.3 Sc P-Ex	Int. harvest 36.3 Sc P-int
Scenario for 3.3 ARD. 2013–2017 OGM Strategic Plan, followed by linear trend from 2018 to 2020.				
Cumulative area under 3.4 FM (ha, over 2013–2020)	77.145.301			
Non-C benefit for 3.4 FM (MUS $)	10.968			
Cumulative gain of forest under 3.3 ARD (ha, over 2013–2020)	19.046.995			
Non-C benefit for 3.3 AR (MUS $)	2.708			
3.4 FM RMUs between 2013–2020 (Millions of RMUs)	52.8	52.8	46.5	0
C benefit for 3.4 FM (MUS $)	26.4	26.4	232	0
3.3 ARD RMUs between 2013–2020 (Millions of RMUs)	119.4			
C benefit for 3.3 ARD (MUS $)	597			
Operation costs for 3.4 FM: forest management (MUS $)	771			
Operation costs for 3.3 ARD: forest management (MUS $)	3221			
Transaction costs for GHG LULUCF inventory (MUS $)	1			
Total	7.835	7.835	7.804	7.571

Source Bouyer (2014)

great reductions in all the scenarios, compared with other values included in the forest TEV.

Negotiations are still on-going regarding the precise status of Turkey in the UNFCCC, which would in turn determine whether Turkey has to make binding commitments (including on LULUCF). But whatever choices are made by Turkey in terms of LULUCF accounting (esp. on Article 3.4 FM) and whatever assumptions on future carbon prices are made, the carbon benefit remains positive but marginal compared with non-carbon benefits, which are substantial.

However, since most operating costs would have been disbursed in any case (apart from the transaction costs for upgrading the GHG LULUCF inventory, which is marginal at 1.2 MUS$), the carbon benefits can be assumed to be 'extra net-benefits'. Furthermore, contrary to many forest values, carbon benefits can materialize.

Last but not the least, it is worth considering the carbon shadow price. It is worth noting that the situation is quite different for the 3.4 FM areas, and especially for 3.3 ARD areas, where the carbon benefits are substantial. However, this price level is still far from attainable as the negotiations stand now, unless the international community is able to adopt a strong political commitment in the coming years.

References

Bann, C.; Clemens, M., 2001: “Turkey Forest Sector Review-Global Environmental Overlays Program Final Report (in Turkish)” (Ankara: Isir Publisher Ltd.).

Başgül, E., 2011: “Aide-mémoire: Outcomes of the AFD Mission in Turkey to Set Up a Cooperation Programme Related to Forestry and Climate Change”; 10.

Basgul, E., 2011: “Aide-mémoire: Outcomes of the AFD Mission in Turkey to Set Up a Cooperation Programme Related to Forestry and Climate Change”; 8.

Bouyer, O., 2010: “Note: Preliminary Views on a Consolidated Turkish Position in the Post-2012 Forest/Climate Mechanisms, REDD+ and LULUCF”.

Bouyer, O., 2011: “Note: Possible Areas for a French-Turkish Co-operation in the Forestry Sector: LULUCF, GIS, Corine Land Cover, and Canopée”.

Bouyer, O., 2014: “Cost-Benefit Assessment of LULUCF in Turkey”, GIZ, OGM, SalvaTerra (Salva Terra, Paris): 86.

Dinu, A., 2011: “Project Identification Form: Integrated Approach to Management of Forests in Turkey with Demonstration in High Conservation Value Forests in the Mediterranean Region”.

Duriez, L., 2011: “Diplomatic Telegram: Outcomes of the AFD Mission in Turkey to Set Up a Cooperation Programme Related to Forestry and Climate Change”.

Ecosystem Market Place, 2013: “Maneuvering the Mosaic: State of the Voluntary Carbon Markets 2013”; at: http://www.forest-trends.org/vcm2013.php.

Erdoğan, E.H., 2013: “Current Status on the Estimation and Reporting of LULUCF in Agricultural Sector of Turkey”; at: http://forest.jrc.ec.europa.eu/media/cms_page_media/110/Erdogan_TRK.pdf.

European Commission, 2013: “Commission Staff Working Document: Turkey 2013 Progress Report—Enlargement Strategy and the Main Challenges 2013–2014”; at: http://ec.europa.eu/enlargement/pdf/key_documents/2013/package/brochures/turkey_2013.pdf.

FAO, GFRA, 2010: “Country Report for Turkey”.

FAO, 2014: “Excel Database of Planted Forests 1990–2005 in Turkey”.

FCBA, 2011: “Carbone Forêt-Bois: Des faits et des chiffres”; at: http://www.pepiniereforestiere.fr/images/telechargements/le-vademecumcarbone-foret-bois.pdf.

Grassi, G.; Monni, S.; Federici, S.; et al., 2008: “Addressing Uncertainties of REDD Estimates: Implantation of the Conservativeness Concept”, in: *Environmental Research Letters*, 3: 7.

Haase, P., 2011: “Overview of the Forestry Sector in Turkey”.

IPCC, 2003: *Good Practice Guidance for LULUCF* (Geneva: IPCC).

IPCC, 2006: Chapter 12: “HWP of the AFOLU Guidelines” (Geneva: IPCC).

IPCC, 2013a: *Supplement to the 2006 IPCC Guidelines for GHG Inventories: Wetlands* (Geneva: IPCC).

IPCC, 2013b: *Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (Geneva: IPCC).

Kayacan, B., 2007: “The Forestry Sector in National Economy” [in Turkish], in: *Verimlilik Dergisi*, 1: 147–176.

Kiaei, M., 2010: “Relationship Between Altitude Index and Wood Properties of Pinus eldarica Medw: Case Study in North of Iran”, in: *Gazi University Journal of Science*, 23: 110–119.

Liabastre, T., 2011: “Draft Memorandum of Understanding between AFD and MEF French-Turkish Co-operation in the Forestry Sector”.

OGM, 2012: *Strategic Plan, 2012. 2014–2017* (Ankara: OGM); at: http://www.ogm.gov.tr/ekutuphane/FaaliyetRaporu/Forms/AllItems.aspx.

OGM, 2013: “Financing in Forestry, Final Report” [in Turkish] (Ankara: General Directorate of Forestry): 42.

OGM, 2014: “Acitivity Report of 2014”, (Ankara: OGM); at: http://www.ogm.gov.tr/ekutuphane/FaaliyetRaporu/Forms/AllItems.aspx.

Ok, K.; Kaya, G.; Güneş, Y.; et al., 2013: "United Nations Forest Forum, 10th Session (Unff10, İstanbul 2013) Financing Forestry Report" (İstanbul: UN Technical Report).

Özbağdatlı, N., 2013: "Enhancing Forest Goods and Services in Turkey: NAMA, MRV, Carbon Projects with a Revenue Sharing Mechanism"; at: http://med.forestweek.org/sites/default/files/press/04_ozbagdatli.pdf.

Pak, M.; Türker, M.F.; Öztürk, A., 2010: "Total Economic Value of Forest Resources in Turkey", in: *African Journal of Agricultural Research*, 5,15: 1908–1916.

Quinet, A., 2009: *La valeur tutélaire du carbone* (Paris: Centre d'analyse stratégique): 424.

Sanz, S., 2013: "Approaches to Reporting of LULUCF, Land-Based vs Activity-Based"; at: https://unfccc.int/files/focus/mitigation/application/pdf/01_lulucf_convention_kp_tech_briefing.pdf.

TurkStat, 2013: *LULUCF section of the Turkey GHG inventory 1990 to 2011* (Ankara: Turkish Statistical Institute).

Türker, M.F.; Öztürk A.; Pak M., 2002: "Evaluation of the Method Used in the Determination of Economic Loss Arisen from Forest Fires: Forest Economics Perspective", in: *The Economics of Natural Hazards in Forestry, 7–10 June 2001, Solsona, Catalonia* (Padua University Press): 71–77.

Türker, M.F.; Pak, M.; Öztürk A., 2005: "Turkey", in: Merlo, M.; Croitoru L. (Eds.): *Valuing Mediterranean Forests: Towards the Total Economic Value* (Wallingford Oxfordshire: CABI Publishing): 195–211.

TurkStat: *Turkey GHG National Inventory 1990 to 2004* (Ankara: TurkStat).

UNDP, 2011: "Press Release: Ecosystems Services Valuation in Turkey"; at: http://www.tr.undp.org/content/turkey/tr/home/presscenter/news-from-new-horizons/2011/07/time-for-forest-and-ecosystems-services-valuation-in-turkey.html.

UNFCCC, 1997a: "Kyoto Protocol"; at: http://unfccc.int/resource/docs/convkp/kpeng.pdf.

UNFCCC, 1997b: "Review of Information and Possible Decisions Under Article 4.2(f): Submission by Turkey and Note by the Secretariat".

UNFCCC, 1999: "Decisions 9/CP4, 15/CP4, 16/CP5"; at: http://unfccc.int/documentation/decisions/items/2964.php.

UNFCCC, 2001: "Decisions 5/CP6bis"; at: http://unfccc.int/documentation/decisions/items/2964.php.

UNFCCC, 2002: "Decisions 11/CP7, 26/CP7"; at: http://unfccc.int/documentation/decisions/items/2964.php.

UNFCCC, 2006: "Decision 1 to 27/CMP1"; at: http://unfccc.int/documentation/decisions/items/2964.php.

UNFCCC, 2008: "Decisions 1 to 11/CMP3"; at: http://unfccc.int/documentation/decisions/items/2964.php.

UNFCCC, 2009: "Technical Paper: Cost of Implementing Methodologies and Monitoring Systems Relating to Estimates of Emissions from Deforestation and Forest Degradation, the Assessment of Carbon Stocks and GHG Emissions from Changes in Forest Cover, and the Enhancement of Forest Carbon Stocks"; at: http://unfccc.int/resource/docs/2009/tp/01.pdf.

UNFCCC, 2010: "Submissions from Turkey: Preparation of an Outcome to Be Presented at to the COP for Adoption at its 16th Session to Enable the Full, Effective, and Sustained Implementation of the Convention Through the Long-Term Cooperative Action Now, Up, and Beyond 2012".

UNFCCC, 2011: "Decisions"; at: http://unfccc.int/resource/docs/2011/cmp7/eng/10a01.pdf.

UNFCCC, 2012a: "Decisions"; at: http://unfccc.int/meetings/doha_nov_2012/meeting/6815/php/view/decisions.php.

UNFCCC, 2012b: "Report of the Individual Review of the Inventory Submission of Turkey Submitted in 2011"; at: http://unfccc.int/resource/docs/2012/arr/tur.pdf.

UNFCCC, 2013a: "Decision 1 to 2/CMP8"; at: http://unfccc.int/resource/docs/2012/cmp8/eng/13a01.pdf.

UNFCCC, 2013b: "Annual Status Report of the GHG Inventory of Turkey"; at: http://unfccc.int/resource/docs/2012/asr/ukr.pdf.

UN, 1992: "General Assembly. Report of the Intergovernmental Negotiating Committee for a Framework Convention on Climate Change on the Work of the 2nd Part of its 5th Session, Held at New-York from 30 April to 9 May 1992"; at: http://unfccc.int/resource/docs/1992/a/eng/19.pdf.

Wood Marketing Division, 2014: *Excel Database of Roundwood 1976–2013 in Turkey* (Ankara: OGM).

Chapter 9

Carbon Certification of Afforestation and Reforestation Areas in Turkey

Melike Kuş, Hüma Ülgen, Yusuf Güneş, Rüstem Kırış, Ali Özel and Uğur Zeydanlı

Abstract Climate change is a major threat to ecosystems and livelihoods. Forest ecosystems can be carbon sinks if they are untouched or well managed. They can also become carbon sources if destroyed. Forest ecosystems are important in international climate policy because of their capacity to reduce carbon dioxide in the atmosphere and their contributions to biodiversity and sustainability. The Clean Development Mechanism of the Kyoto Protocol has provisions and methodologies for afforestation/reforestation (A/R) activities. There is a growing demand from private companies for afforestation/reforestation (A/R) projects due to increasing environmental and social responsibility concerns. However, some industries are interested in accumulating A/R carbon credits to prepare for the possible enactment of a future quantitative carbon emission limitation scheme in Turkey. This study examines recent developments, conditions, opportunities and threats within the A/R carbon sector in Turkey. Details of the only A/R carbon project in Turkey proposed by the Nature Conservation Centre are provided. The results of the certification application process revealed three main points. (1) The certification cost in Turkey is disproportionately high compared with the smaller amount of A/R carbon credits to be obtained per hectare basis. (2) A new level in the certification system might better serve the needs of this country and the others in similar situation. (3) The

---

M. Kuş, Land and Water Programme Officer, Nature Conservation Centre, 1293. Sok. No: 9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya Ankara, Turkey; E-mail: melike.kus@dkm.org.tr.

H. Ülgen, Green Business Expert, Nature Conservation Centre, 1293. Sok. No: 9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya Ankara, Turkey; E-mail: huma.ulgen@dkmorg.tr.

Y. Güneş, Prof. Dr., İstanbul University, Faculty of Forestry, Department of Forest and Environmental Law, 34473 Bahçeköy Sarıyer İstanbul, Turkey; E-mail: gunesy@istanbul.edu.tr.

R. Kiriş, Inspector, Department of Inspection, The Ministry of Forestry and Water Affairs, Söğütözü Cad. No: 14/E Ankara, Turkey; E-mail: rustemkiris@ogm.gov.tr.

A. Özel, Unit Head, Forest Management Unit, The Ministry of Forestry and Water Affairs, Söğütözü Cad. No: 14/E Ankara, Turkey; E-mail: aliozel@ogm.gov.tr.

U. Zeydanlı, Dr, Head of Board, Nature Conservation Centre, 1293. Sok. No: 9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya, Ankara, Turkey; E-mail: ugur.zeydanli@dkm.org.tr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_9

relevant government institutions require an increased capacity to address carbon issues. They must develop a vision, initiate necessary inter- and intra-institutional coordination and amend regulations appropriately to facilitate A/R certification in Turkey.

Keywords Climate change · Sequestration · Clean development mechanism · Carbon certification · Forest carbon

9.1 Introduction

This study summarizes the results of a project that investigated the legal and technical conditions for providing carbon credits from afforestation/reforestation (A/R) projects to the voluntary carbon market in Turkey. During this project, The State of Voluntary Carbon Markets 2013 reported that A/R carbon has the second largest share within the voluntary market and constitutes 12 % of all transactions (Peters-Stanley/Yin 2013). In addition, despite the 2012 economic crisis, the voluntary carbon market grew in volume by 4 % between 2011 and 2012 (Peters-Stanley/Yin 2013). Projections predicted that the market would benefit from an annual average growth rate between 13 % and 17 % until 2020. In 2012, total voluntary carbon market transactions were 523 million USD (Peters-Stanley/Yin 2013).

However, the predictions were not accurate and The State of Voluntary Carbon Markets 2014 reported that the A/R share dwindled to 4 % of the voluntary market and transaction volume decreased by 70 %. This share decrease is largely due to a significant increase in REDD[1] projects in the market. In 2014, the extensive pre-compliance demand that supported the high A/R transaction volume in Australia ceased as a result of regulatory uncertainty (Peters-Stanley/Gonzalez 2014).

On the other hand, many private sector companies in Turkey continue to invest in afforestation projects. These projects constitute the main portion of their social and environmental responsibility projects. Therefore, the private sector has expressed an interest in the legal and technical conditions related to investment in afforestation activity that will lead to carbon certification. Although Turkey is an important provider of carbon credits to the voluntary market, the share of credits issued from forestry projects is null (Ministry of Environment and Urbanization 2012). The Nature Conservation Centre (DKM) decided that these were opportune conditions for the investigation of the potential for A/R carbon credits in Turkey.

---

[1] Reducing Emissions from Deforestation and Forest Degradation (REDD) is a programme developed by the United Nations; at: www.un-redd.org.

9.2 Materials and Methods

The project team was formed as a result of a partnership among the DKM, the General Directorate of Forestry (GDF), ClearSky Climate Solutions, the United Nations Development Program and the Baku-Tbilisi-Ceyhan Pipeline Company, Turkey with financial support from the Prosperity Fund of the British Embassy in Ankara.

An expert in both forestry and law from Istanbul University carefully studied the current regulations related to forest carbon issues. DKM identified possible stakeholders in the government, private sector, NGOs and academia who might be interested in A/R carbon projects. Analysis of survey results revealed information gaps to be filled before relevant stakeholders could pursue A/R carbon projects. A team of forest carbon experts from ClearSky Climate Solutions prepared and delivered a three-day training session to these stakeholders. DKM, the legal expert and the forest carbon experts hosted two informational meetings. One meeting focused on answering questions from the private sector, while the other addressed questions relevant to governmental institutes. The team initiated a pilot afforestation project for carbon accreditation based on the results of the information gathered according to the existing conditions.

Two major issues to be considered in the certification process are the additionality and applicability of an A/R project. Additionality refers to the requirement that the project will be feasible only with the added carbon revenue, as carbon certification is a mechanism to provide financial incentives to the projects that will have a contribution to emission reduction. The goal is the reduction of atmospheric emissions through carbon credits. Two major pathways according to The Gold Standard[2] rules can justify the additionality of a project. The first pathway involves financial and barrier analyses, while the second requires the project to occur in a region where A/R is difficult due to climatic and soil quality factors.

The second pathway option, also referred to as the ‘Positive List’, was more appropriate for this pilot project. The project area is within the borders of Ankara Province, which clearly has unfavorable growing conditions, with average yearly precipitation well below 600 mm/m^2. Applicability criteria ensured that the project did not harm wetlands, soil quality or the existing biodiversity.

A local stakeholder consultation (LSC) meeting was held as part of the carbon certification procedure. Stakeholders were informed of project details, input and grievance procedures, project impacts on sustainable development, measures to prevent/mitigate negative impacts, methods of monitoring mitigation measures and the positive impacts of the project. All relevant stakeholders were invited to the LSC meeting via email, fax, phone call and newspaper announcement. Relevant government representatives and local people also participated in the meeting.

---

[2] The Gold Standard is an international standard and certification body (http://www.goldstandard.org/).

9.3 Results

Compliance with the international standard institution and national forestry regulation requirements is necessary to obtain carbon credits from A/R projects. Due to the additionality requirement, areas under control of the General Directorate of Forestry (GDF) are not eligible as the Directorate is responsible for the afforestation or reforestation of these areas by law. However, there might be exceptions. For example, if the proposed project area is within the purview of GDF but is not included in any future A/R plans, the area could possibly benefit from carbon revenue. In this case, carbon financing ensures afforestation of the area much sooner and sequesters carbon that would otherwise be in the atmosphere. Another exception that might lead to A/R carbon certification eligibility on GDF land requires carbon financing to overcome technical or social barriers that prevent afforestation in the proposed area.

Permanence is important to certification institutions. The forested area should remain forested for 20–50 years after the certification period is complete. This requires strong agreement on land and carbon rights. Land appropriation for ‘public benefit’ could create a major problem for both private land and land leased from the state or GDF. If trees are cut after appropriation, carbon certification rights are lost and a penalty from the certification body applies. Therefore, it is necessary for Turkey to have legislation regarding both private and public land that has been afforested and carbon certified in order to protect investments. Treasury land allocated for private afforestation may also be potentially eligible because afforestation of these areas is not compulsory by law.

Forests on land owned by either GDF or the Treasury have management plans that usually prescribe a harvest at the end of the tree maturation cycle. If these forests have been carbon certified, the permanence framework still applies. If the trees are harvested, replanting must occur so that the area reacquires the same carbon capture capacity. Otherwise, the carbon credits previously issued will be lost. Moreover, it is not possible to receive a second certification for the renewed afforestation. Forest management plans currently apply to a specific purpose. This could be timber production, water production, ecosystem conservation, etc. Results of this project demonstrate the necessity to designate an additional special forest management purpose specifically designed for carbon credit production. If the harvested trees are used in non-carbon emitting industries and additional trees are not planted, the project owner only receives a portion between 15 and 20 % of the carbon credits provided if the trees remained for over 50 years.

Certification bodies retain up to 60 % of the credits to buffer high-risk projects. These risks include natural hazards such as fire or pests, management or financial risks and external risks such as land tenure conflicts (Olander/Ebeling 2011). Some certification bodies return these certificates to the project proponent at the end of the project period, whereas some do not.

When the carbon market mechanism was first established, carbon sequestration was the main focus. Eventually, the zero net harm policy began to gain more importance. At present, projects are expected to prove that no harm will occur to natural, social, cultural and economic structures in the region. In this context, it is highly probable that the project will be eliminated during the evaluation process if it causes harm to the biological or social structure of the area, even if it fulfils all other certification requirements. An indirect negative impact of an afforestation project might be the deforestation of another area, referred to as 'leakage'. For example, if the pastureland of a village is afforested, it might lead to the deforestation of another area to be used for grazing. In this case, discounts to the amount of carbon credits issued will apply for the leakage amount caused by carbon emissions in the deforested area.

Results of the LSC meetings have significant implications for the proposed projects. Feedback provided by the stakeholders, especially local stakeholders, should be considered in the design phase of the project. The main issue raised during the LSC meeting of this project was that the land designated for A/R activity serves as a migration route for the cattle and sheep of the nearby village to their grazing grounds. The project had to consider the concerns of the local people even though the identified land was on private property. If we pursued the application process further, our project would have been eliminated from the selection process due to the overwhelming amount of unsettled complaints.

We discovered that project size affects the dispute settlement. We planned to afforest one hectare of land because we were conducting a 'pilot' project. If we had proposed to forest hundreds or thousands of hectares, we could have suggested many solutions to satisfy the concerns of the local stakeholders. Possible solutions ranged from creation of migration routes within the proposed afforestation land to offers of income diversification that could expand animal husbandry to include forestry activities. A larger A/R area would have also made a more significant difference in the micro-climate of the area and provided benefits to the village through more diverse ecosystem services.

Approximate calculations suggest the estimated area required for the financial return of a carbon certification investment. We estimated the carbon certification cost of a 30-year A/R project cycle to be around 110.00 USD. This amount includes Project Design Document development, registration, validation and all verifications. However, one hectare of black pine (*Pinus nigra*) afforestation within the Ankara Province region captures 5 tons of CO_2 per year on average. According to the average carbon credit cost of 4.9 USD in the 2013 (Peters-Stanley/Gonzalez 2014), the approximate area of afforestation required for carbon financing to pay for the certification investment only is calculated as follows:

$$\mathrm{I} = \mathrm{P}\ (\mathrm{A} \times \mathrm{B} \times \mathrm{C} \times \mathrm{D} \times \mathrm{E}) \tag{1}$$

where,

I = Investment for carbon certification = 110.00 USD

P = Profit from Carbon Finance

A = Area size (ha)

B = Tons of CO_2 captured per hectare per year

C = Number of years in the chosen project cycle
D = Credit discount for risk (20 %)
E = Value of 1 carbon credit in the voluntary market in 2012

I should equal P
and $P = A \times B \times C \times D \times E$
or,
110.00 USD = A ha × 5 t CO_2/year × 30 years × 0.8 × 4.9 USD
$A = 110.000/(5 \times 30 \times 0.8 \times 4.9)$
A = 187 ha

An area of about 187 ha of afforestation is needed in the Ankara climatic zone for the revenue from carbon credit sales over 30 years to equal the cost of carbon certification. This calculation does not take into account the cost of afforestation itself and net present values.

9.4 Discussion

It does not seem economically and technically feasible to apply for carbon certification in these A/R areas considering the afforestation efforts of the private sector range between 5 and 20 hectares per afforestation. Although it is not impossible, a small A/R area can rarely satisfy the eligibility criteria as mentioned. Economically, a company investing in afforestation either has to spend an extra 110.00 USD to apply for certification or increase the A/R area to at least 187 ha just to cover the costs of certification through carbon financing. However, the investor would also incur the cost of afforestation for the additional 187 ha. Application for carbon certification for afforestation through the social-environmental responsibility programs in the private sector in Turkey does not seem technically or economically practical.

Relevant legislation in Turkey combined with unfavorable climatic conditions and a larger workforce compared with that in tropical countries make it difficult to justify carbon certification expenditures on environmental and social responsibility projects. Therefore, climatically conscious companies in Turkey have begun to examine potential methods to offset their carbon emissions aside from taking measures to reduce them. Current international certification systems do not seem to be conducive to increased investments in afforestation. A ‘Turkish Forest Carbon Code’, designed for the specific circumstances and needs of the country, may prove to be effective in driving more private sector investment towards afforestation activities. Although credits issued by the Turkish Forest Carbon Code cannot be initially traded in the international voluntary carbon markets, they will nevertheless serve to offset the carbon emissions of the investing private sector company (at least in the national rosters) and simultaneously provide incentive for additional afforestation.

Based on this study’s results, DKM is working with GDF to create a national A/R certification program. This program aims to bring legitimacy to carbon reductions obtained through A/R projects issued from corporate environmental programs. Examination of various current forest carbon standards and comparisons of their advantages and disadvantages within the Turkish context contribute to the design of the proposed code.

Acknowledgments DKM would like to thank the British Embassy Prosperity Fund for financing all the activities described in this study, Trees Forest Carbon Consulting for their technical guidance, and The Gold Standard's support throughout the project.

References

Olander, J.; Ebeling, J., 2011: *Building Forest Carbon Projects: Step-by-Step Overview and Guide* (Washington, DC: Forest Trends).

Peters-Stanley., M.; Gonzalez, G., 2014: *Sharing the Stage: State of the Voluntary Carbon Markets. Forest Trends* (Washington, DC: The Ecosystem Marketplace).

Peters-Stanley, M.; Yin, D., 2013: *Maneuvering the Mosaic: State of the Voluntary Carbon Markets—Executive Summary* (Washington, DC: Forest Trends, The Ecosystem Marketplace).

Ministry of Environment and Urbanization, 2012: *Carbon Market of Turkey* (Ankara: Ministry of Environment and Urbanization of Turkey).

Chapter 10
Carbon Sequestration and Mycorrhizae in Turkish Soils

İbrahim Ortaş, Rattan Lal and Selim Kapur

Abstract The atmospheric carbon dioxide (CO_2) concentration has increased by 31 % since the onset of industrial revolution around 1850, from 280 ppm/year to 400 ppm/year in 2013. Chemical fertilizers, pesticides, tillage, irrigation and seed use improvements have increased agricultural production. Moreover, agricultural mismanagement may have affected atmospheric CO_2 through the intensified degradation of soil organic matter (SOM). Water deficiency, high temperatures and land degradation could be the result of increasing atmospheric CO_2 concentrations, particularly in semi-arid Mediterranean regions. High temperatures, decreased water availability and post-harvest straw burning in preparation for the next crop reduce the soil organic carbon (SOC). Note that soil quality and productivity are also declining. In addition, the intensity of climate change is expected to increase. Soil provides a sink for atmospheric CO_2 and therefore reduces net CO_2 emissions associated with agricultural ecosystems, mitigating the 'greenhouse effect'. There are several techniques to mitigate atmospheric CO_2. One approach involves fixing atmospheric CO_2 via the natural process of photosynthesis in terrestrial ecosystems (soil and biota). Plants fix atmospheric CO_2 in soil and biota because plant roots and mycorrhizal fungi require carbon (C) and contribute to C sequestration (CSQ). Therefore, small changes in the soil C cycle could have large impacts on atmospheric CO_2 concentrations. Arbuscular mycorrhizal fungi (AMF) are obligate symbionts of most plant species, and they are important for soil aggregation and stabilization. Mycorrhizae fungi are the major component of soil microbial biomass. AMF hyphae produce glomalin that contains C and that is an important part of the terrestrial C pool. The effects of mycorrhizal colonization on nutrient uptake and root growth have been extensively studied. CSQ and aggregate C storage have become priority topics in soil science since 1990s. Interest in the effects of mycorrhizal hyphae (glomalin as the by-product) and humic substances that enhance

---

İ. Ortaş, Prof. Dr., Department of Soil Science and Plant Nutrition, University of Çukurova, Adana, Turkey; E-mail: iortas@cu.edu.tr.

R. Lal, Prof. Dr., Carbon Management & Sequestration Center, The Ohio State University, 2021 Coffey Rd., Columbus, OH, USA; E-mail: lal1@ohio.edu.

S. Kapur, Prof. Dr., Department of Soil Science and Plant Nutrition, University of Çukurova, Adana, Turkey; E-mail: kapurs@cu.edu.tr.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3_10

aggregate stability is increasing. AMF play a key role in soil aggregate formation and stabilization. This long-term experiment was established in 1996 to assess crop and soil management effects on mycorrhizal development and SOC accumulation. The principal objective was to determine how soil management affects indigenous mycorrhizae and SOC dynamics. Results show that mycorrhizal colonization and sporulation depend on soil and crop management and that soil aggregate development is affected by SOC content and mycorrhizal presence.

Keywords Soil organic carbon dynamics · Soil development · Mycorrhizae and carbon sequestration · Plant and soil management effects on carbon pool

10.1 Introduction

The atmospheric carbon dioxide (CO_2) concentration increased by 31 % between the onsets of the industrial revolution around 1850 when it was 280 ppm/year to 400 ppm in 2013. It is presently increasing at a rate of 2.3 ppm/year or 0.58 % year^{-1} (Le Quere et al. 2015). Despite enhanced crop production, the Green Revolution has been a major contributor to increased atmospheric CO_2 via agricultural input enhancements such as chemical fertilizers, pesticides, increased tillage practices, irrigation and seed use improvements. However, increased agricultural input does not result in continuous yield increases. Eventually, increased temperatures because of climate change, distortion of $CaCO_3$ horizons in the profile, heavy tillage and high clay content decrease soil organic matter (SOM) content and consequently reduce agronomic productivity. This situation is particularly apparent in the eastern Mediterranean region of Europe (Ortaş/Lal 2012). Singh et al. (2009) reported that loss of SOM, and soil structure degradation has a detrimental effect on soil fertility and crop productivity. Since root carbon (C) has longer soil residence time than shoot C (Gale/Cambardella 2000; Gale et al. 2000, 2002; Rasse et al. 2005), it is important to manage plant roots in the sub-soil to maintain the soil organic C (SOC) pool. Lal/Kimble (1997) indicated that agricultural soils depleted of SOC because of cultivation have significant potential for atmospheric CO_2 sequestration. Thus, there is a strong interest in stabilization of the atmospheric CO_2 abundance to reduce its effect on global warming.

There are three strategies of reducing net CO_2 emissions to mitigate climate change (Schrag 2007): the reduction of fossil energy use, development of low- or no-C fuels and CO_2 sequestration from point sources or from the atmosphere through natural (photosynthesis/biotic) and engineered techniques.

The basic processes of the C cycle involve CO_2 input through photosynthesis and CO_2 output through decomposition. The net gain of C in the soil is a function of the balance between inputs (i.e. net primary productivity or NPP plus any external inputs) and losses (i.e. decomposition, erosion and leaching).

Photosynthesis is a crucial natural mechanism for fixing CO_2 from the atmosphere to the soil. The process of photosynthesis involves the absorption of CO_2 from the atmosphere by plants, CO_2 transformation into plant C and sequestration either above or below the ground as biomass and/or as SOC pool. Shoots, roots and mycorrhiza are responsible for the uptake of substrate C. Roots and mycorrhizae absorb substrates N and P. Thornley/Parsons (2014) reported that transferring dry matter to shoots, roots, and mycorrhizae maximizes growth rate.

Agricultural soils are both a sink and source of atmospheric CO_2 (depending on land use and management) and may be managed to moderate net CO_2 emissions. SOM is an important component of soil fertility, productivity and quality because of its crucial role in the chemical, physical and biological properties of soil (Ortaş 2006).

Although the SOC pool and accompanying relationships with climate and vegetation are still incompletely understood (Lorenz/Lal 2005), numerous field experiments have revealed a direct relationship among soil management, SOC pool and its dynamics. Land use types and soil cultivation are important controls of SOC pool. They may also change the relative importance of various mechanisms for SOM stabilization. Li et al. (2014) reported that SOC was higher in non-degraded grasslands than in degraded areas. Grassland degradation has also been shown (Wen et al. 2013) to decrease biomass and C content and change the ratio of roots to shoots. Repeated soil disturbance can lead to a rapid mineralization of SOM under field conditions (Williams/Hedlund 2013). Moreover, misuse and/or soil extraction for uses other than agriculture or forestry and/or use of prime agricultural soil sites as building foundations (soil stripping) cause highly significant soil losses in both the developed and developing world. This often results from an unawareness of appropriate natural resource uses.

Puget/Lal (2005) showed that the effects of tillage on soil aggregation and SOC vary depending on regional climate, soil type, residue management practices and crop rotation. A recommended management practice is conservation agriculture (CA) that reduces soil loss, increases SOC and increases carbon sequestration (CSQ) through aggregate development (Lal 2015a, b). Effects of conversion to CA on SOM quantity, quality and soil aggregation may be relatively more in the surface than in the sub-soil (Ortaş et al. 2013). Therefore, the principal aim of this study was to assess the effects of several soil and crop management systems (including mycorrhizae inoculation) on CSQ.

10.2 Materials and Methods

Two monitoring studies were conducted on the change of SOC and CSQ in the rhizospheres of the Menzilat clay-loam (Typic Xerofluvent, widespread soil in the Çukurova University farm area) (Fig. 10.1) and Kızıltapır (Lithic Rhodoxeralf,

Fig. 10.1 The prime agricultural soil stripped for the construction of a building foundation, the Menzilat soil series. *Source* The authors

widespread soil in the Çukurova University area) soils (olive-Olea europea L.-tree rhizosphere) from 1974 to 2012 (Table 10.1). Moreover, a comparison of the CSQ in the rhizosphere-non-rhizosphere soils of the Kızıltapır series (in 2010) were accomplished in order to understand the variable root-zone potential in carbon sequestration. A long term experiment from 1996 to 2010 concerning the effect of mycorrhizae inoculation on CSQ in the soil was also conducted at the Menzilat soils of the Research Farm of the Çukurova University in the eastern part of the Mediterranean region of Adana, Turkey. The regional climate of the study area is typical Mediterranean where the long-term average annual temperature is 19.1 °C (varying between 14.2 °C in January–February to 25.5 °C in July–August) and precipitation is 670.8 mm. The mean annual humidity is 66 %, and as much as 80 % of the annual precipitation occurs between November and April (Anonymous 2008).

Mycorrhizal inoculation was applied in three replicates to the Menzilat soil for the long term experiment. Each plot had 10 × 20 m (200 m^2) dimensions. Treatments included a control plot and mycorrhiza-inoculated compost at 10 Mg ha^{-1}. Experimental plots were moldboard ploughed to 0.15–0.20 m depth after each harvest.

Soil samples were air dried, gently ground and passed through a 2 mm sieve. Air-dried bulk soil was ground further and sieved through a 0.25 mm sieve. Total C and nitrogen (N) concentrations were determined by the dry combustion method at 900 °C using a C and N elemental analyzer. Inorganic C was determined by measuring total $CaCO_3$ content (Ortaş/Lal 2012). The SOC concentration was obtained by subtracting soil inorganic carbon (SIC) from the total C concentration. Selected initial soil properties were analyzed by the method described by Page et al. (1982).

Table 10.1 Selected soil properties in the Menzilat and Kızıltapır soil series from 1974

	pH	EC (mmhos cm^{-1})	P_2O_5 (kg ha^{-1})	CEC (cmol$_c$ kg^{-1})	K_2O (kg ha^{-1})	$CaCO_3$ (%)	OM (%)	PSD (%)			Soil texture	Bulk density (g cm^{-3})
								Sand	Silt	Clay		
Kızıltapır	6.68	0.16	18.7	20.65	759.1	0	1.6	25	17	58	C	1.3
Menzilat	7.57	0.045	49.9	20.5	615.8	31.5	1.51	36	27	37	CL	1.6

Source Özbek et al. (1974)

EC Electrical conductivity, *CEC* Cation exchange capacity, *OM* Organic matter, *PSD* Particle size distribution

10.2.1 Calculation of SOC and Nitrogen Pools

The SOC pool was calculated for samples from specific soil depths and aggregate size fractions (4.75, 2, 1, 0.5, 0.25 and <0.25 mm) using Eq. 10.1 (Lal et al. 1998):

$$\begin{aligned}\text{Mg SOC or TSN ha}^{-1} = \text{C\% or N\%} \times \text{soil depth (m)} \times \rho_b\left(\text{Mg m}^{-3}\right) \\ \times 10^4\ \text{m}^2\ \text{ha}^{-1}/100\end{aligned} \tag{10.1}$$

The SOC sequestration rate was calculated with reference to the baseline control treatment by dividing the difference in the total SOC pool by 14 years (experiment duration).

10.3 Results and Discussion

10.3.1 Monitoring SOC in Menzilat Soils

A large fraction of the C in the terrestrial biosphere is contained in soil in the form of SOM (Lal 2004; Lal et al. 2007). However, SOM is reduced by excessive tillage that increases emission of greenhouse gases (GHG) from agroecosystems.

The data presented in Table 10.2 show that 78.7 Mg ha^{-1} SOC and 408.0 Mg ha^{-1} SIC were lost from the soil (Menzilat soil series, dominant soil in the Çukurova University experimental Farm as well as the Çukurova region, Adana, Turkey) from 1974 to 2010 (Özbek et al. 1974). Furthermore, there are clear differences between SOC and SIC contents: the former decreases, whereas the latter increases with soil depth (Table 10.2). Overall mean values for SOC decrease with depth, and the SOC concentrations in the surface layer are significantly higher than those in the lower horizons.

SOC is vitally important for agriculture and mitigation of climate change in a fragile semi-arid environment. SOM is an important component of soil fertility as a nutrient sink. It enhances and promotes biological activity in many agro-ecosystems (Ortaş 2006). Srinivasarao et al. (2012) indicated that SOC is a strong determinant of soil quality and agronomic productivity especially in harsh arid and semi-arid environments. SOC is important for long-term soil quality and also for carbon dynamics in relation to climate change (Lal et al. 2007).

Thus, the effect of management practices on CSQ changes and the soil C budget were calculated from 1974 to 2010 using data from 1974 as the baseline (Table 10.2, Fig. 10.1). The total SOC ranges from 877.4 kg ha^{-1} in 1974 to 117.2 kg ha^{-1} in 2010 in the Menzilat soils. The CSQ in the top layer is 997.9 kg C ha^{-1} year^{-1}. However, the magnitude and rate of soil CSQ decreases with increased

Table 10.2 Carbon sequestration (CSQ) rates in the Menzilat soils from 1974 to 2010

		2010					1974
		A_p	CA	C1	C2	Total	A_p
Soil depth		0–30	30–60	60–94	94–125		0–6
PSD	Sand	32.5	30	16	14.5		34.4
	Silt	40.5	24.5	30	31.5		40.2
	clay	27.0	45.5	54	7.6		25.4
pH		7.4	7.6	7.5	7.6		7.5
Salt		0.113	0.123	0.133	0.131		0.25
P_2O_5 (kg ha^{-1})		43.6	14.2	10.9	9.5		15.4
CEC (cmol$_c$ kg^{-1})		17.6	17.6	21.2	18		18.3
$CaCO_3$ (%)		21.9	30.4	28.4	33.6		51.48
OM (%)		1.51	0.49	0.51	0.52		1.59
OC (%)		0.87	0.28	0.3	0.3		0.92
BD (g cm $^{-3}$)		1.6	1.3	1.3	1.35		1.44
SOC (Mg ha^{-1})		41.9	11.1	13.1	12.6	78.7	8
SIC (Mg ha^{-1})		87.4	98.8	104.6	117.2	408.0	37.1
Rate of CSQ 1974–2010 (kg C ha^{-1})		997.9	−353.4	−534.8	−106.2	3.7	

Carbon and nitrogen sequestration calculated using 1974 baseline data. *Source* Özbek et al. (1974)
EC Electrical conductivity, *CEC* Cation exchange capacity, *OM* Organic matter, *PSD* Particle size distribution, *SIC* Soil inorganic carbon

depth to −534.8 kg C ha^{-1}. CSQ is higher in surface than in the sub-soil layers because of the concentration of plant roots and positive effects of management practices (e.g., fertilization, irrigation residue retention).

10.3.2 *Monitoring (1974–2010) and Comparison of SOC in the Rhizosphere and Non-rhizospheres (2010) of the Kızıltapır Soils*

Olive trees sequester high amounts of SOM within their rhizosphere (Fig. 10.2), which consequently decrease soil loss by reducing erosion. The SOM can be as much as 12 % of the root zone soil of a 100-year-old olive tree as stated by Koçak/Kapur (2010). Moreover, branches pruned from olive trees are used for fuel and making high quality biochar (Aydıncak et al. 2012).

The Kızıltapır soil (widespread soil series in the Mediterranean Basin, Özbek et al. 1974) located on the Çukurova University experimental farm, contains olive orchards established in 1974. While, some trees were uprooted for construction

Fig. 10.2 A mature olive tree root system (*Olea europea*) with large amount of biomass C added into the soil. *Source* The authors

purposes, the C budget of the root zone of these trees was calculated. This analysis was conducted during the struggle against inappropriate land use to demonstrate the C sequestration potential of the olive root zone. The magnitude of C sequestered 36 years after the establishment of the orchard is higher in the rhizosphere than in the non-rhizosphere soil (Table 10.3). The magnitude of non-rhizosphere (0–0.13 m) CSQ is 176.7 Mg ha^{-1} and 636.5 Mg ha^{-1} at 13–28 cm depth (Table 10.3). Similarly, the rhizosphere CSQ of the olive tree at 0–20 cm depth is 183.7 Mg C ha^{-1} and 133.8 Mg C ha^{-1} at 40–60 cm depth. The calculated rate of CSQ is 36.3 Mg C ha^{-1} $year^{-1}$ at 0–20 m depth compared to 42.6 Mg C ha^{-1} $year^{-1}$ at 40–60 m depth (Table 10.3).

Table 10.3 Kızıltapır soil series CSQ changes from 1974 to 2010

	Soil horizon	Soil depth (cm)	Organic carbon (%)	ρ_b (g cm^{-3})	SOC (Mg ha^{-1})	CSQ NR (kg C ha^{-1})	SCQ R (kg C ha^{-1})	Differences between R-NR CSQ (kg C ha^{-1})
Non-rhizosphere 2010	Ap	0–13	1.45	1.3	24.5	176.7		
	Bt1(BA)	13–28	0.93	1.3	18.1	−636.5		
	Bt2	28–43	0.99	1.4	20.7	153.8		
Rhizosphere 2010	Ap	0–20	2.43	1.25	60.8		1183.7	36.3
	Bt1	20–40	1.62	1.3	42.2		33.7	24.2
	B2t	40–60	2.11	1.5	63.3		1338.0	42.6
1974 Non-rhizosphere	Ap	0–11	1.32	1.25	18.1			
	B1	11–38	1.21	1.25	41.0			
	B2t	38–50	1.11	1.15	15.2			

Carbon and nitrogen sequestration was calculated using 1974 baseline data. *Source* Özbek et al. (1974) and comparison of the rhizosphere and non-rhizosphere Kızıltapır soils

R Rhizosphere, *NR* Non-rhizosphere, *SOC* Soil organic carbon, ρ_b Bulk density

10.3.3 Effects of Long-Term Mycorrhizae Application on SOC and CSQ of the Menzilat Soils

The long-term mycorrhizae application experiment conducted in the Çukurova University Farm (the Menzilat soil series) determined that the SOM content increased in treated plots compared to control plots. CSQ was calculated for the period from 1996 to 2013.

The effect of the mycorrhizae treatment on CSQ was calculated on data collected between 1996 and 2013 using 1996 data as the baseline (Table 10.4). Total CSQ ranges from 0.10 to 5.83 Mg ha^{-1} at 0–0.15 m and 2.73 to 7.10 Mg ha^{-1} at 0.15–0.30 m depth. The average CSQ is 2.96 Mg ha^{-1} at 0–0.15 m and 4.92 Mg ha^{-1} at 0.15–0.30 m depth (Table 10.4).

After 17 years, the per year CSQ was also calculated for the 0–0.15 m depth revealing a 5.9 kg ha^{-1} sequestration in the control treatment and 342.8 kg ha^{-1} in the compost + mycorrhizae application. In this context, several long term experiments are currently being conducted on mycorrhizal species inoculation at citrus orchards. Studies are also being conducted for examining the indigenous mycorrhizae effects on CSQ using a long-term agricultural management approach. The results obtained thus far show that CSQ is related to the SOC pool and yield variability. Mycorrhizae and other beneficial organisms affect SOC and CSQ because the organisms in the sub-soil regulate the C storage and release in soil.

Table 10.4 Long-term mycorrhizae application and CSQ change from 1996 to 2013 of the Menzilat soils

		C (%)	ρ_b (g cm^{-3})	1996	2013	Carbon sequestration 1996–2013		
				SOC (Mg ha^{-1})	SOC (Mg ha^{-1})	SOC 2013–SOC 1996 (kg C ha^{-1})		CSQ (kg C ha^{-1})
0–15	Control	0.88	1.34	17.59	17.69	0.10	5.9	
	Compost + Mycorrhizae				23.42	5.83	0.3	342.8
	Mean				20.55	2.96	174.4	
15–30	Control	0.78	1.34	15.70	18.43	2.73	160.6	
	Compost + Mycorrhizae				22.80	7.10	0.3	417.7
	Mean				20.62	4.92	289.2	

Source The authors

10.4 Conclusions

Soil management under inoculated and indigenous mycorrhizae (long term experiment on Menzilat soil) were determined to affect SOC dynamics and increase soil carbon sequestration in long term monitored agricultural soils. Carbon sequestration was significantly quantity-wise improved and the rhizosphere effects on CSQ were high under olive canopies. Moreover, the CSQ of the surface horizons (non-rhizosphere soils) of the widespread Menzilat and Kızıltapır soils were found to increase within a 36-year period (1974–2010) of land use. This reveals the resilience capacity of soils in Mediterranean is very fragile if not managed sustainably.

References

Anonymous, 2008: *Meteorological Yearbook* (Ankara: Turkish Meteorology Service).

Aydıncak, K.; Yumak, T.; Sinag, A.; et al., 2012: "Synthesis and Characterization of Carbonaceous Materials from Saccharides (Glucose and Lactose) and Two Waste Biomasses by Hydrothermal Carbonization", in: *Industrial & Engineering Chemistry Research*, 51: 9145–9152.

Gale, W.J.; Cambardella, C.A., 2000: "Carbon Dynamics of Surface Residue- and Root-Derived Organic Matter Under Simulated No-till", in: *Soil Science Society of America Journal*, 64: 190–195.

Gale, W.J.; Cambardella, C.A.; Bailey, T.B., 2000: "Root-Derived Carbon and the Formation and Stabilization of Aggregates", in: *Soil Science Society of America Journal*, 64: 201–207.

Gale, W.J.; Cambardella, C.A.; Bailey, T.B., 2002: "Root-Derived Carbon and the Formation and Stabilization of Aggregates", in: *Soil Science Society of America Journal*, 66: 2040–2040.

Koçak, Z.; Kapur, S., 2010: "Physical and Chemical Properties of the Root-Zone Soils of Carob and Olive Trees of the Eastern Mediterranean Region of Turkey", in: University of Çukurova, in: *Institute of Science Journal*, (in Turkish) 25: 129–138.

Lal, R., 2004: "Soil Carbon Sequestration Impacts on Global Climate Change and Food Security", in: *Science*, 304: 1623–1627.

Lal, R., 2015a: "Restoring Soil Quality to Mitigate Soil Degradation", in: *Sustainability*, 7: 5875–5895.

Lal, R., 2015b: "Sequestering Carbon and Increasing Productivity by Conservation Agriculture", in: *Journal of Soil and Water Conservation*, 70: 55A–62A.

Lal, R.; Kimble, J.M., 1997: "Conservation Tillage for Carbon Sequestration", in: *Nutrient Cycling in Agroecosystems*, 49: 243–253.

Lal, R.; Follett, F.; Stewart. B.A.; et al., 2007: "Soil Carbon Sequestration to Mitigate Climate Change and Advance Food Security", in: *Soil Science*, 172: 943–956.

Lal, R.; Kimble, J.M.; Follett, R.F., 1998: "Land Use and Soil Carbon Pools in Terrestrial Ecosystems", in: Lal, R.; Kimble J.M.; Follett R.F. (Eds.): *Management of Carbon Sequestration in Soils* (Boca Raton, FL: CRC Lewis Publisher).

Le Quere, C.; Moriarty, R.; Andrew, R.M.; et al., 2015: "Global Carbon Budget 2014", in: *Earth System Science Data*, 7: 47–85.

Li, Y.Y.; Dong, S.K.; Wen, L.; et al., 2014: "Soil Carbon and Nitrogen Pools and Their Relationship to Plant and Soil Dynamics of Degraded and Artificially Restored Grasslands of the Qinghai-Tibetan Plateau", in: *Geoderma*, 213: 178–184.

Lorenz, K.; Lal, R., 2005: "The Depth Distribution of Soil Organic Carbon in Relation to Land Use and Management and the Potential of Carbon Sequestration in Subsoil Horizons", in: *Advances in Agronomy*, 88: 35–66.

Moore, J.A.M.; Jiang, J.; Post, W.M.; et al., 2015: "Decomposition by Ectomycorrhizal Fungi Alters Soil Carbon Storage in a Simulation Model", in: *Ecosphere*; at: doi:10.1890/es14-00301.1.

Ortaş, İ., 2006: "Soil Biological Degradation" in: Lal, R. (Ed.): *Encyclopedia of Soil Science* (New York: Marcel Dekker).

Ortaş, İ.; Lal, R., 2012: "Long-Term Phosphorus Application Impacts on Aggregate-Associated Carbon and Nitrogen Sequestration in a Vertisol in the Mediterranean Turkey", in: *Soil Science*, 177: 241–250.

Ortaş, İ.; Akpınar, Ç.; Lal, R., 2013: "Long-Term Impacts of Organic and Inorganic Fertilizers on Carbon Sequestration in Aggregates of an Entisol in Mediterranean Turkey", in: *Soil Science*, 178: 12–23.

Özbek, H.; Dinç, U.; Kapur, S., 1974: *Soils of the University of Çukurova Campus* [in Turkish] (Adana: University of Ankara Press): 110.

Page, A.L.; Miller, R.H.; Keeney, D.R., 1982: *Methods of Soil Analysis* (Madison, WI: ASA SSSA).

Puget, P.; Lal, R., 2005: "Soil Organic Carbon and Nitrogen in a Mollisol in Central Ohio as Affected by Tillage and Land Use", in: *Soil & Tillage Research*, 80: 201–213.

Rasse, D.P.; Rumpel, C.; Dignac, M.F., 2005: "Is Soil Carbon Mostly Root Carbon? Mechanisms for a Specific Stabilisation", in: *Plant and Soil*, 269: 341–356.

Schrag, D.P., 2007: "About Climate Change—Reply", in: *Elements*, 3: 375–375.

Singh, S.; Mishra, R.; Singh, A.; et al., 2009: "Soil Physicochemical Properties in a Grassland and Agroecosystem Receiving Varying Organic Inputs", in: *Soil Science Society of America Journal*, 73: 1530–1538.

Srinivasarao, C.; Venkateswarlu, B.; Lal, R.; et al., 2012: "Soil Carbon Sequestration and Agronomic Productivity of an Alfisol for a Groundnut-Based System in a Semiarid Environment in Southern India", in: *European Journal of Agronomy*, 43: 40–48.

SSS, 1996: Keys *to Soil Taxonomy. Natural Resources Conservation Service*. 7th ed. (Wahington, D.C.: Soil Survey Staff).

Thornley, J.H.M.; Parsons, A.J., 2014: "Allocation of New Growth Between Shoot, Root and Mycorrhiza in Relation to Carbon, Nitrogen and Phosphate Supply: Teleonomy with Maximum Growth Rate", in: *The Journal of Theoretical Biology*, 342: 1–14.

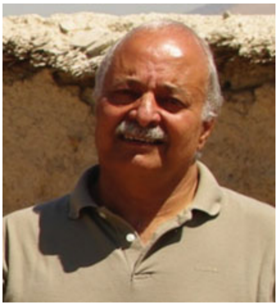
Wen, L.; Dong, S.K.; Li, Y.Y.; et al., 2013: "The Impact of Land Degradation on the C Pools in Alpine Grasslands of the Qinghai-Tibet Plateau", in: *Plant and Soil*, 368: 329–340.

Williams, A.; Hedlund, K., 2013: "Indicators of Soil Ecosystem Services in Conventional and Organic Arable Fields Along a Gradient of Landscape Heterogeneity in Southern Sweden", in: *Applied Soil Ecology*, 65: 1–7.

About the Editors

Sabit Erşahin, born in 1963 in Artvin, Turkey. Prof. in Soil Science at the Faculty of Forestry of Çankırı Karatekin University, Turkey. He is active member of Soil Science Society of America for 22 years and Soil Science Society of Turkey for 26 years. He served as scientific committee member at Food, Agriculture and Forestry division of Scientific and Technological Committee of Turkey from 2005 to 2008. He has expertise in soil physics, hydropedology, and computer modeling of soil processes. He has been member of scientific board for General Directorate of Agricultural Research under Ministry of Food, Agriculture, and livestock and General Directorate of Combating Desertification and Erosion Control under Ministry of Forestry and Water Affairs of Turkey.

Address: Çankırı Karatekin University, Faculty of Forestry, 18200 Bademlik, Çankırı, Turkey.
Email: ersahin@karatekin.edu.tr.
Website: http://acapsu.wix.com/sabitersahin.



Selim Kapur, born in 1946 in Ankara, Turkey. Professor of Soil Science at the Faculty of Agriculture, University of Çukurova, Adana, Turkey. He is the Scientific Comm. Member of the European Soil Bureau Network of the EU-JRC-IES in Ispra, Milan, Italy. He is the earlier Secretary of the International Working Group of Land Degradation and Desertification. Has acted as the Science and Technology Correspondent of Turkey for the UNCCD. Has organized the First International Meeting on Land Degradation and Desertification in 1996 in Adana, Turkey. He led projects supported by NATO, EU, JSPS, TUBITAK, Mitsui Environmental Fund, FAO and GEF concerning soil protection and environmental issues. He authored numerous papers in

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3

cited and authored/edited books on Land degradation and desertification, archaeometry and micromorphology.

Address: University of Çukurova, Department of Soil Science and Plant Nutrition, 01330, Adana, Turkey.
Email: kapurs@cu.edu.tr
Website: www.cu.edu.tr.

Erhan Akça, born in 1969 in Adana, Turkey. Assoc. Prof. Dr. at Adıyaman University School of Technical Sciences, Adıyaman, Turkey. His profession is on soil mineralogy, archaeometry and natural resource management. He wrote and contributed to more than 110 scientific publications (papers, chapters, books) on soil science, archaeometry, land use and desertification. he participated to projects supported by NATO, EU, JSPS, TÜBİTAK, Mitsui Environmental Fund, FAO and GEF. He is currently scientific board member of Ministry of Forestry and Water Works, General Directorate of Combating to Desertification and Erosion Control of Turkey.

Address: Adıyaman University, School of Technical Sciences, 02040, Adıyaman, Turkey.
Email: eakca@adiyaman.edu.tr.
Website: www.adiyaman.edu.tr.

Ayten Namlı, born in 1965 in Hatay, Turkey. Prof. Dr. at Ankara University Faculty of Agriculture, Ankara, Turkey.

She is working on land degradation, soil health, soil biology, water and soil pollution and bioremediation, waste management, waste water sewage sludge. Supervising: Alignment of Turkey's National Action Plan With UNCCD 10-Years Strategy and Reporting Process, FAO Project Symbol: GCP/TUR/060/GFF. Executive member of TUBITAK-TEYDEB since 2012; National Committee Member of GEF—UNDP Small Grant Project from 2011; Environment Office in TBMM (Turkish Grand National Assembly); Presidents of the Federation of Eurasia Soil Science Society and Soil Science Society of Turkey. International Advisory Committee member of 20th World Soil Congress of 2014; member of Land degradation/desertification thematic working group in National Capacity Self-Assessment Project (NCSA); Scientific committee member in UN-CRIC 7; NGO's expert's team member in the International Training on Combating Desertification.

Address: Ankara University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, 06100, Ankara, Turkey.
Email: namli@ankara.edu.tr.
Website: www.agri.ankara.edu.tr.

Dr. Hakkı Emrah Erdoğan, born in 1976 in Ankara, Turkey. His background is soil science, and specialist on earth monitoring systems. Formerly, he was a scientific officer at the EC-JRC in Ispra, Italy. Currently, he is a coordinator of Agro-Environment and Natural Resource Protection Division at the Ministry of Food, Agriculture and Livestock, Ankara, Turkey. His responsibility is specifically on the GHG emissions and biomass management in agricultural lands, and he performs to ensure the synergies between soil management, food security and climate change.

In international era, he is vice-chair of European Soil Partnership and member of national delegation for the UNCCD and UNFCCC discussions. He is also coordinating technical outcomes for reporting mechanism of LULUCF sector in the part of the UNFCCC National Inventory Report. His writing includes several articles on soil science, land degradation, land use/cover changes and geospatial analysis.

Address: Ministry of Food, Agriculture and Livestock, Agro-Environment and Protection of Natural Resources, Ankara, Turkey.
Email: hakkı.erdogan@tarim.gov.tr.
Website: www.tarim.gov.tr.

About the Authors

- *Prof. Dr. Lal Rattan,* School of Environment and Natural Resources, Ohio State University, 422B Kottman Hall, 2021 Coffey Rd., Columbus, OH 43210, USA.
- *Prof. Dr. Selim Kapur,* University of Çukurova, Department of Soil Science and Plant Nutrition, 01330, Adana, Turkey.
- *Prof. Dr. Pandi Zdruli,* International Centre for Advanced Mediterranean Agronomic Studies, Mediterranean Agronomic Institute of Bari (CIHEAM IAMB), Bari, Italy.
- *Dr. Michael Cherlet*, European Commission, Joint Research Centre, Institute for Environment and Sustainability, Land Resource Management Unit Via Enrico Fermi 2749 TP280, I-21027 Ispra (VA), Italy.
- *Prof. Dr. Sabit Erşahin,* Department of Forest Engineering, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey.
- *Prof. Dr. Gönül Aydın*, Adnan Menderes University, Department of Plant Nutrition and Soil Science, Muğla, Turkey.
- *Assoc. Prof. Dr. Erhan Akça,* Adıyaman University, School of Technical Sciences, Adıyaman, Turkey.
- *Prof. Dr. Doğanay Tolunay,* Department of Forest Engineering, Faculty of Forestry, İstanbul University, İstanbul, Turkey.
- *Prof. Dr. Özden Görücü*, Kahramanmaraş Sütçü İmam University, Department of Forestry, Kahmaramaraş, Turkey.
- *Ass. Prof. Dr. Gülay Karahan*, Department of Landscape Architecture, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey.
- *Assoc. Prof. Dr. Bayram C. Bilgili*, Department of Landscape Architecture, Faculty of Forestry, Çankırı Karatekin University, 18100 Bademlik, Çankırı, Turkey.
- *Dr. Christina-Stavrula Hatzilau*, School of Mechanical Engineering. Thermal Engineering Section, National Technical University of Athens, 9. Heroon Polytechniou Str. 15780 Athens, Greece.
- *Dr. Dionysios Giannakopoulos*, Centre for Research and Technology Hellas/ Chemical Process & Energy Resources Institute 4th km, Ptolemais-Mpodosakeio, P.O. box 95, GR 502 00 Ptolemais, Greece.

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3

- *Assoc. Prof. Dr. Sotirios Karellas*, Laboratory of Steam Boilers and Thermal Plants. School of Mechanical Engineering. Thermal Engineering Section, National Technical University of Athens, 9. Heroon Polytechniou Str. 15780 Athens, Greece.
- *Prof. Dr. Emmanuel Kakaras*, Laboratory of Steam Boilers and Thermal Plants. School of Mechanical Engineering. Thermal Engineering Section, National Technical University of Athens, 9. Heroon Polytechniou Str. 15780 Athens, Greece.
- *Dr. Essam Hassan Mohamed Ahmed*, Climate Change and Sustainable Development, El Haram, Giza, Egypt.
- *Prof. Dr. Nejat Erk,* Çukurova University, School of Economics and Administrative Studies, Adana, Turkey.
- *Dr. Ali Vural Cengiz*, Çukurova University, Institute of Social Sciences, Adana, Turkey.
- *Dr. Egemen Sulukan*, Department of Professional Sciences, Turkish Naval Academy, Tuzla, Istanbul, Turkey.
- *Mustafa Sağlam*, Institute of Pure and Applied Sciences, Department of Mechanical Engineering, Marmara University, Göztepe, Istanbul, Turkey.
- *Prof. Dr. Tanay Sıdkı Uyar*, Marmara University, Faculty of Engineering, Mechanical Engineering Department, 34722, Istanbul, Turkey.
- *Olivier Bouyer*, SalvaTerra, 6 rue de Panama 75018 Paris, France.
- *Prof. Dr. Yusuf Serengil*, İstanbul University, Faculty of Forestry, Turkey.
- *Hüma Ülgen*, Nature Conservation Centre, 1293. Sok. No:9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya Ankara, Turkey.
- *Melike Kuş*, Nature Conservation Centre, 1293. Sok. No:9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya Ankara, Turkey.
- *Prof. Dr. Yusuf Güneş*, İstanbul University, Faculty of Forestry, Department of Forest and Environmental Law, 34473 Bahçeköy Sarıyer İstanbul, Turkey.
- *Rüstem Kiriş*, Department of Inspection, the Ministry of Forestry and Water Affairs, Söğütözü Cad. No: 14/E Ankara, Turkey.
- *Ali Özel*, Forest Management Unit, the Ministry of Forestry and Water Affairs, Söğütözü Cad. No: 14/E Ankara, Turkey.
- *Dr. Uğur Zeydanli*, Nature Conservation Centre, 1293. Sok. No:9/32 Beyazıt Apt. Aşağı Öveçler 06460 Çankaya Ankara, Turkey.
- *Prof. Dr. İbrahim Ortaş,* University of Çukurova, Department of Soil Science and Plant Nutrition, 01330, Adana, Turkey.

About this Book

This book is unique covering both ecologic and socio-economic aspects of carbon management in Mediterranean ecosystems. The chapters were originally presented at the 1st Istanbul Carbon Summit that was held at Istanbul Technical University, 2–4 April 2014 and subsequently revised after a peer review process. The summit focused on carbon management, carbon technologies, and carbon trends. This book includes chapters on economic aspects of carbon management and on ecological aspects of the carbon cycle. The chapters on economic aspects analyse carbon trade and its institutional, political, and legislative structures in different Mediterranean nations, while those on ecological aspects review the discussion and analysis of the related ecological factors and their feedbacks due to governance processes.

This book:

1. discusses carbon trade in Mediterranean countries;
2. examines social ecology of carbon management in ecosystems taking different socio-economic and socio-ecologic structures in the Mediterranean region into account;
3. offers original research results on carbon sequestration.

Contents

1: Soil Carbon Impacts on Functionality and Environmental Sustainability (Rattan Lal)—2: New World Atlas of Desertification and Issues of Carbon Sequestration, Organic Carbon Stocks, Nutrient Depletion and Implications for Food Security (P. Zdruli, R. Lal, M. Cherlet, S. Kapur)—3: Terrestrial Ecosystem Carbon Dynamics as Influenced by Land use and Climate (S. Erşahin, S. Kapur, G. Aydın, E. Akça, D. Tolunay, Ö. Görücü, G. Karahan, B.C. Bilgili)— 4: EU Emissions Trading Scheme Application in Bulgaria, Greece and Romania from 2008 to 2012 (C.-S. Hatzilau, D. Giannakopoulos, S. Karellas, E. Kakaras)—5: Indigenous Egyptian Nubians and Climate Change Mitigation (E.H.M. Ahmed)—6: Carbon Trading Via Exports: Comparison of the Emissions Embodied in Exports in China and Turkey (N. Erk, A. Vural Cengiz)—7: Energy–Economy–Ecology–Engineering (4E) Integrated Approach for GHG Inventories (E. Sulukan, M. Sağlam, T. Sıdkı Uyar)—8: Cost-Benefit Assessment of Implementing LULUCF Accounting Rules

S. Erşahin et al. (eds.), *Carbon Management, Technologies, and Trends in Mediterranean Ecosystems*, The Anthropocene: Politik–Economics–Society–Science 15, DOI 10.1007/978-3-319-45035-3

in Turkey (O. Bouyer, Y. Serengil)—9: Carbon Certification of Afforestation/Reforestation Areas in Turkey (M. Kuş, H. Ülgen, Y. Güneş, R. Kiriş, A. Özel, U. Zeydanli)—10: Carbon Sequestration and Mycorrhizae in Turkish Soils (I. Ortaş, R. Lal, S. Kapur).
Backmatter: About the Editors—About the Authors.

More on this book is at:
http://www.afes-press-books.de/html/APESS_15.htm.