Lebanon's
Third National
Communication
to the UNFCCC

National Greenhouse Gas Inventory Report and Mitigation Analysis for the Land Use, Land Use Change and Forestry Sector

Ministry of Environment
November 2013

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Acknowledgements

This report comes within the project “Provision of professional services for the preparation of GHG emissions and Mitigation chapter of Land Use and Land Use Change and Forestry (LULUCF)”.

The team is grateful to all public authorities and private organizations for their help in documenting relevant information in relation to Land Cover/Land Use studies and projects, and for their ideas and guidance.

We wish to extend our recognition to all the entities which provided data to us and who answered our numerous questions. We specifically wish to thank the Ministry of Environment (MOE), the Ministry of Agriculture (MoA), the Greenplan, the National Centre for Scientific Research (NCSR), the Association for Forests, Development and Conservation (AFDC), the Lebanese Reforestation Initiative (LRI), and the United Nations Development Program (UNDP).
Also we would like to thank all the participants to the expert meeting held on 9/9/2013 at the Ministry of Environment for the assessment of economic instruments and their suitability for the implementation of proposed mitigation scenarios.

The use of the satellite SPOT imagery was made possible through the Planet Action (SPOT initiative).

The research team is grateful for all comments and suggestions provided by colleagues and collaborators during presentations of initial drafts to the final consultations. Particularly we would like to thank the UNDP Project Management Team for their valuable comments.

List of acronyms

AFDC	Association for Forests' Development and Conservation
AFED	Arab Forum for Environment and Development
AGB	Above-Ground Biomass
BGB	Below-Ground Biomass
CBO	Community-Based Organization
CDR	Council of Development and Reconstruction
COM	Council of Ministers
DGUP	Directorate General for Urban Planning
DOM	Dead Organic Matter
EFDB	Emission Factors Database
E/R	Emission/Removal
ES	Environmental Service
EU	European Union
FAO	Food and Agriculture Organization
FRA	Forest Resources Assessment
GEF	Global Environment Fund
GHG	Greenhouse Gas
GIS	Geographic Information System
GOL	Government of Lebanon
GPG	Good Practice Guidance
GWP	Global Warming Potential
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
KIA	Kappa Index of Agreement
LRI	Lebanese Reforestation Initiative
LULUCF	Land Use, Land Use Change and Forestry
MOA	Ministry of Agriculture
MOD	Ministry of Defense
MOE	Ministry of Environment
MOEd	Ministry of Education
MOET	Ministry of Economy and Trade
MOF	Ministry of Finance
MOI	Ministry of Interior and municipalities
MOJ	Ministry of Justice
MOPT	Ministry of Public works and Transport
MOPW	Ministry of Power and Water
NCSR	National Centre for Scientific Research
NFP	National Forest Plan

NGO	Non-Governmental Organization
NLUMP	National Land Use Master Plan
NRP	National Reforestation Plan
NWFP	Non-Woody Forest Product
OEA	Order of Engineers and Architects
OWL	Other Wooded Land
PES	Payments for Environmental Services
QA	Quality Assurance
QC	Quality Control
SAR	Second Assessment Report
SNC	Second National Communication
TNC	Third National Communication
UNDP	United Nations Development Program
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollar
USFS	United States Forest Service

Table of Contents

Executive Summary

As part of Lebanon's Third National Communication to the United Nations Framework Convention on Climate Change (UNFCCC), the greenhouse gas (GHG) emissions resulting from the land use, land cover and forestry sector (LULUCF) in Lebanon were estimated for the period of 1994-2012. The sources of emissions as well as the main removals in this sector were identified in the purpose of targeting the largest contributors. This allowed the development of the potential mitigation actions for the reduction of GHG emissions and for increasing the carbon sequestration effect of the LULUCF sector.

GHG estimations results showed a remarkable increase in GHG emissions and decrease in removals from LULUCF over the past two decades, resulting in a net decrease in removals of about 12% from 1994 to 2012 (Figure 1).

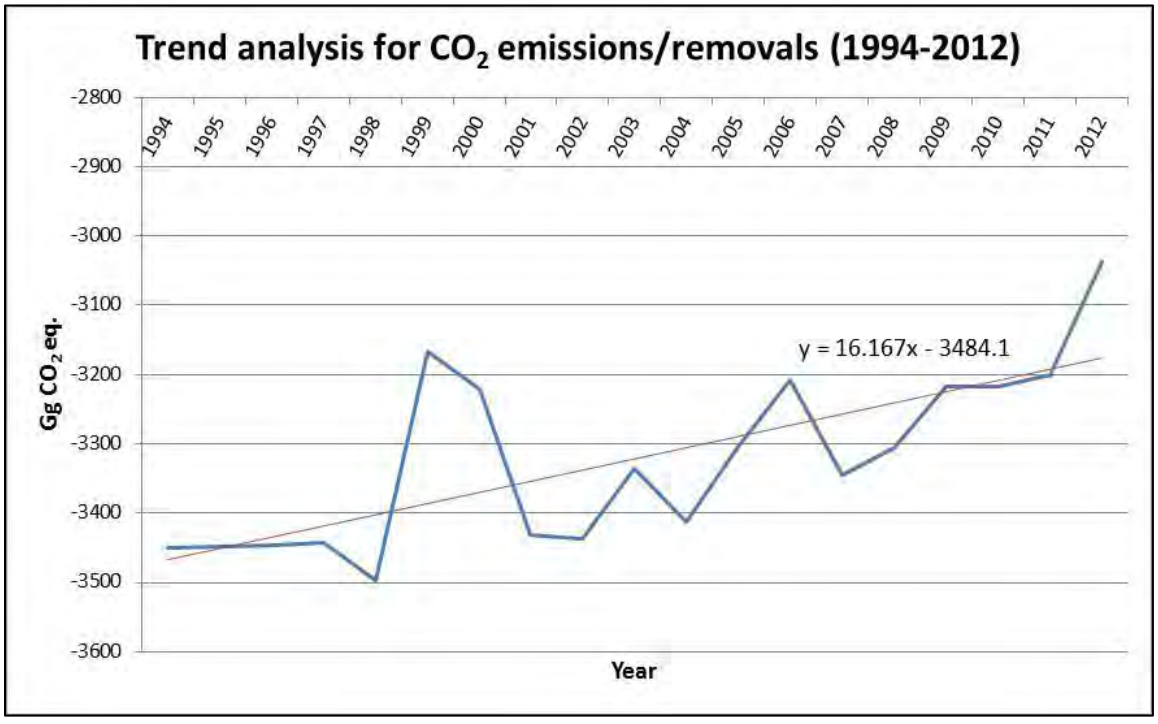

Figure 1. Trend analysis for CO_2 emissions/removals over the inventory period 1994-2012.

The main findings revealed that wildfires are highly contributing to greenhouse gas emissions (between 60 Gg and 400 Gg CO2 per year); whereas urbanization (between 10 Gg and 170 Gg

CO2 per year) and fuelwood gathering (about 27 Gg per year) are the main causes of decrease in removals. Greenhouse gas removals were mainly attributed to the growth of forest plantations from afforestation activities (between -7 Gg and -80 Gg CO2 per year), the growth of existing forest lands (about -2300 Gg per year), followed by existing croplands (about -1230 Gg per year).

The comparison of emissions and removals of changes showed that emissions from land conversions, burning of biomass and fuelwood gathering were much higher than the removals caused by the growth of new plantations (afforestation) (Figure 2). Although net emissions/removals proved that the LULUCF sector is a major sink, emissions from changes in the LULUCF sector were still high and couldn't be compensated by the afforestation activities.

Here lies the necessity for the development of mitigation scenarios which are proposed plans and projects with a potential for emission reduction or sink enhancement of the LULUCF sector.

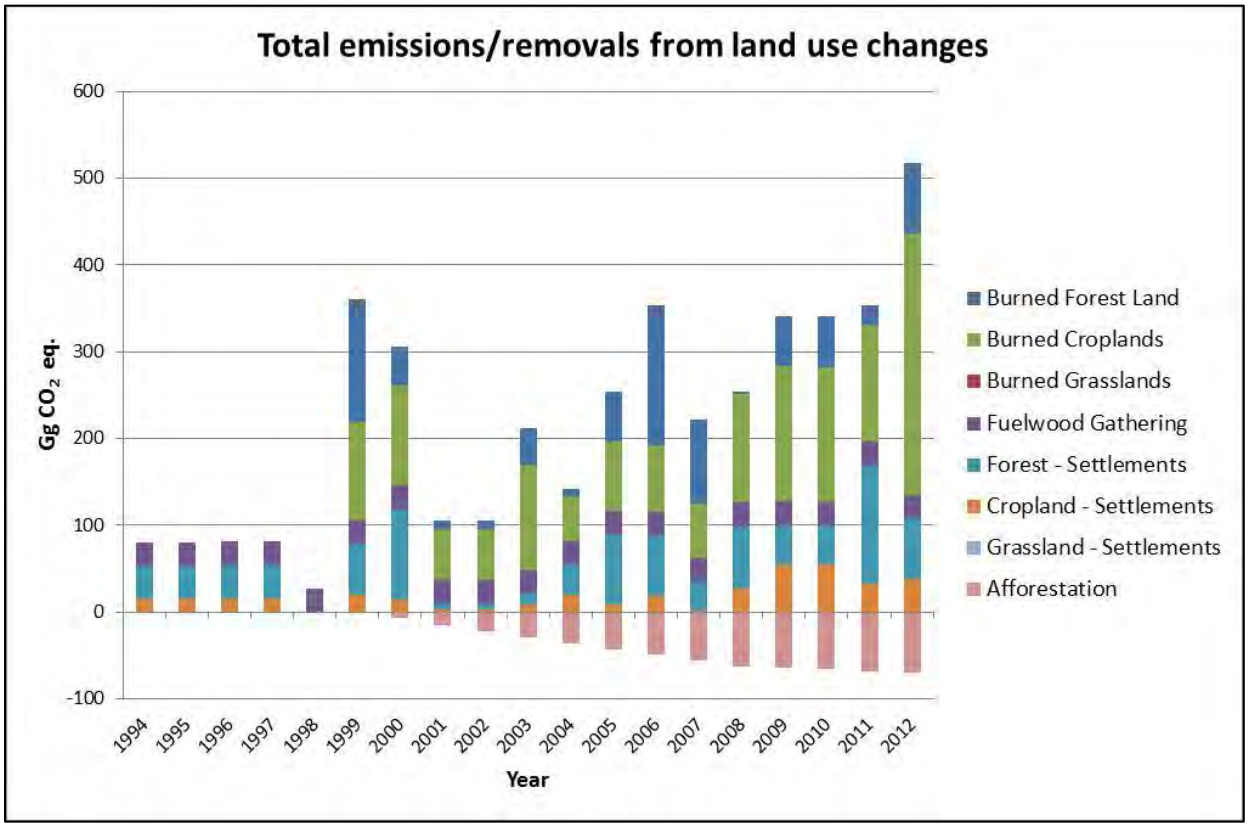

Figure 2. CO_2 emissions/removals from the changes in the LULUCF sector.

Taking into consideration the mitigation measures proposed in Lebanon's Second National Communication to the UNFCCC, the suggested mitigation actions were directed towards the

forest land category which has a major contribution to GHG emissions or removals. The future projections (2013-2030) of the baseline scenario consisted of average areas of forest land converted to settlements, average areas of burned forests and average areas of afforestation based on the trend data of 1999-2012.

Mitigation scenario 1 consisted of maintaining the current extent of Lebanon's forest and other wooded land cover and mitigation scenario 2 consisted in increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030. Both scenarios involved the implementation of Lebanon's National Strategy to Forest Fire Management (Decision No. 52, 2009) which is an essential part in "reducing the risk of intense and frequent forest fires whilst allowing for fire regimes that are socially, economically and ecologically sustainable".

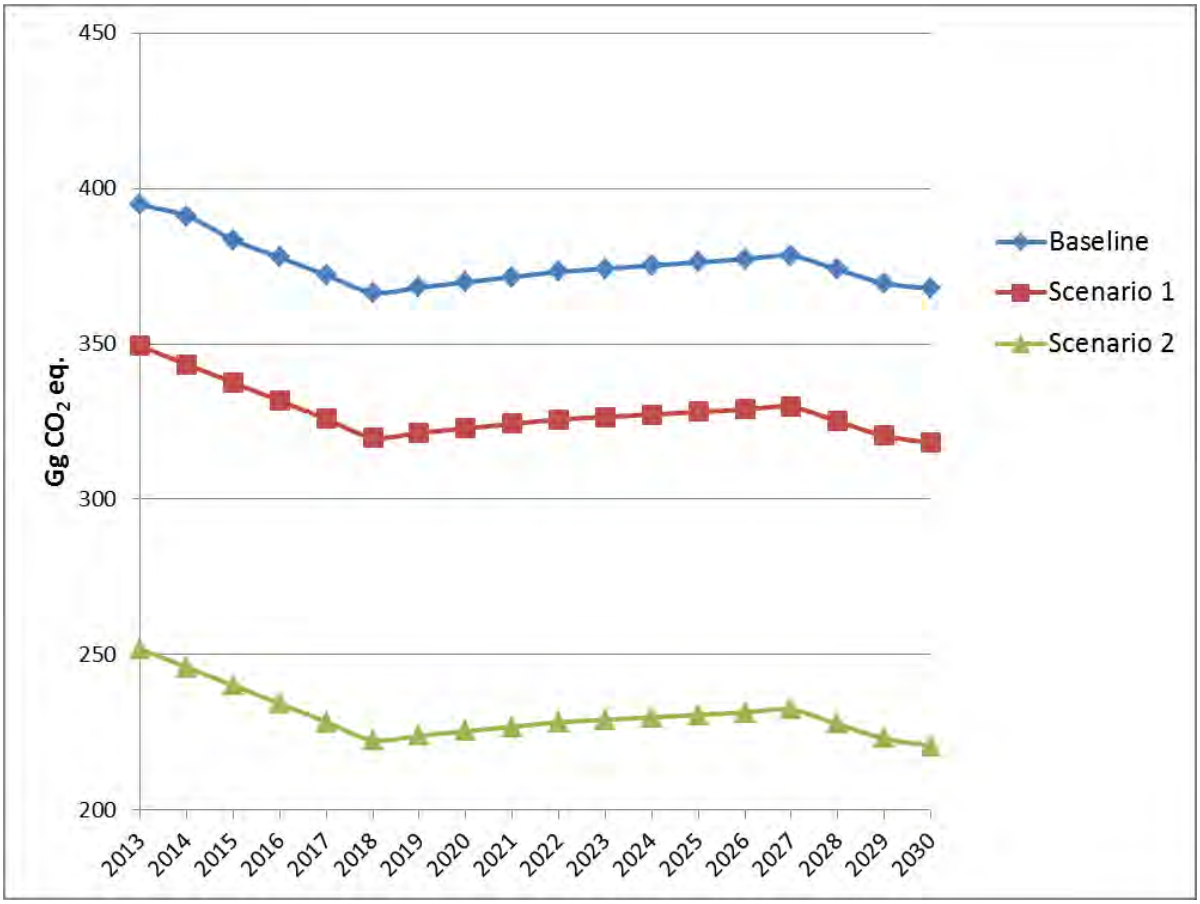

Figure 3. Net emissions from the changes in the LULUCF sector: baseline versus mitigation scenarios

The reduction potential was about 12.57% and 38.5% for scenarios 1 and 2 respectively (Figure 3). Scenario 2 has proved to be more efficient in reducing emissions and increasing removals

compared to the baseline scenario; however, scenario 1 was characterized by a shorter term for implementation and may be the first step to limit the increasing losses in the vegetation cover and the increasing GHG emissions from forest fires.

The assessment of potential tools for the achievement of the proposed mitigation scenarios identified four applicable economic instruments in Lebanon: 1) Payment for Environmental Services" (PES), 2) subsidy for reforestation, 3) conservation payment programs for land conversion and, 4) establishment of community forests. Moreover, the analysis of the main issues in the forestry sector showed that the successful implementation of the proposed mitigation actions would require an integrated approach involving improved legislation and law enforcement, land use planning, education and awareness, economic valuation of forests, and funding. In this context, the "Reforestation Fund" (so-called Sandouk al Tahrij) stipulated by the Forest Law of 1949 (article 98) represents a promising source for funding in addition to the government, private sector and international funding initiatives.

Section 1:

National Greenhouse Gas Inventory Report for the LULUCF sector in Lebanon

List of Tables

List of Figures

Summary

Lebanon's land cover, land use and forestry sector is characterized by continuous changes caused mainly by anthropogenic activities. Inappropriate human interventions coupled with a lack of management plans are negatively affecting the natural landscape. Urbanization is one of the main problems affecting Lebanon's land resources. Also, intense and recurrent wildfires represent a serious threat to the decrease of forest cover.

The objective of this study was to estimate and report the greenhouse gas emissions resulting from changes in the land use, land cover and forestry sector in Lebanon for the period of 1994-2012. The report also identified the sources of emissions as well as the main removals in this sector. The study showed the contribution of each land use category in the emissions or removals and compared the greenhouse gas estimations in Lebanon with other Mediterranean countries. The methodology consisted of adopting the Good Practice Guidance (GPG) for the land use, land use change and forestry sector of the Intergovernmental Panel on Climate Change. Most importantly, the method involved the use of up-to-date remote sensing techniques as part of the approach 3 in the GPG, which allowed more precise estimation of land use and land cover change areas.

Results of the calculations showed that the land cover, land use change and forestry sector is a major carbon sequestration sector. The changes in forest and vegetation covers at the end of the inventory period (2012) resulted in about 12% (21.8 Gg CO_2 eq. /yr) decrease in CO_2 removals from the LULUCF sector in comparison to the beginning of the inventory period (1994). The main findings revealed that the highly contributing categories to greenhouse gas emissions and decrease in removals included wildfires (between 60 Gg and 400 Gg CO_2 per year), urbanization (between 10 Gg and 170 Gg CO_2 per year), and fuelwood gathering (about 27 Gg per year). Greenhouse gas removals were mainly attributed to the growth of forest plantations from afforestation activities (between -7 Gg and -80 Gg CO_2 per year), the growth of existing forest lands (about -2300 Gg per year), followed by existing croplands (about -1230 Gg per year). In comparison to other Mediterranean countries, Lebanon showed relatively high

emissions from wildfires. In addition, Lebanon has shown a remarkable increase in greenhouse gas emissions and decrease of removals from LULUCF over the past two decades.

Overall, the process of estimation of the greenhouse gas emissions and removals from the land use, land use change and forestry sector revealed a severe deficiency in data and information availability. Even when they were available, they lacked of a proper accuracy. Although the recent estimations in this report showed improvements in comparison to previous estimates, many gaps still have to be filled at the National level for improved future calculations in this sector.

1. Scope

The Land Use, Land-Use Change, and Forestry (LULUCF) sector is a greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry activities (UNFCCC, 2013). According to the Intergovernmental Panel on Climate Change (IPCC), the LULUCF sector is described in six broad land-use categories for reporting national inventories (IPCC, 2003): 1) Forest land, 2) Cropland, 3) Grassland, 4) Wetlands, 5) Settlements and 6) Other land.

Lebanon has submitted two previous National Communications (NC) reports to the UNFCCC (1999 and 2011) and the Third National Communication report (TNC) is expected to be submitted in 2015 updating the GHG inventory of Lebanon. The aim of this work was to produce the National Inventory Report (NIR) of LULUCF Greenhouse Gas (GHG) Emission Inventory for the years 1994 up to 2012. Accordingly, the NIR will involve the use of up-to-date remote sensing techniques which are expected to allow more precise estimation of land use and land cover change areas including a trend analysis of the results. Also, it is expected to allow re-calculation of the GHG emissions/removals for the years 1994 until 2004 due to the availability of new data and the adoption of a new approach for calculations.

2. National circumstances

Land use is defined through its purpose and is characterized by management practices such as logging, ranching, and cropping. Land cover is the actual manifestation of land use (i.e., forest, grassland, and cropland) (IPCC, 2000). Land-use change and land-cover change (LUC-LCC) involve several processes that are central to the estimation of climate change and its impacts (Turner et al., 1995). In Lebanon, the status of the land cover / land use has been characterized by a continuous change over the last decades. The lack of land management plans and/or inadequate urban regulations has strongly affected the natural and built environment. This has

facilitated unplanned urban sprawl at the expense of natural landscapes (MOE/UNDP/ECODIT, 2011).

Human intervention has been strong and it is still making a significant impact on current and future vegetation patterns (FAO, 2011; FAO, 2010). Population growth is a major factor impacting land resources. Urban areas have been growing horizontally at the expense of agriculture fields, forested areas, and other natural areas. The construction of new roads and highways in mountain areas has affected landforms, vegetation cover, and ecosystems.

Several initiatives have been conducted to document and map land cover attributes in Lebanon. Accordingly, the first land cover attributes were produced in the form of a topographic map (scale 1:20,000) in 1961 by the Lebanese Army in partnership with the French "Institut Geographique National". A Land Use / Land Cover map of Lebanon was produced by the Ministry of Environment (MOE) in cooperation with the National Center for Remote Sensing of the National Council for Scientific Research (NCSR) in 2002. This involved the use of satellite remote sensing data acquired in 1998. The final map disaggregated land use and land cover into seven main categories (Figure **4**) and 23 subcategories (Appendix I). According to this map, Lebanon's forested lands covered 2,588 Km^2 while the artificial/built up area covered 648 Km^2. An update version of the 1998 Land Cover / Land Use map was recently completed by the NCSR using satellite remote sensing data acquired in 2005. In 2004, the Council for Development and Reconstruction (CDR) published the National Land Use Master Plan for Lebanon. The Master Plan was approved by the Council Of Ministers (COM) in 2009 (Decree 2366 dated 20/6/2009).

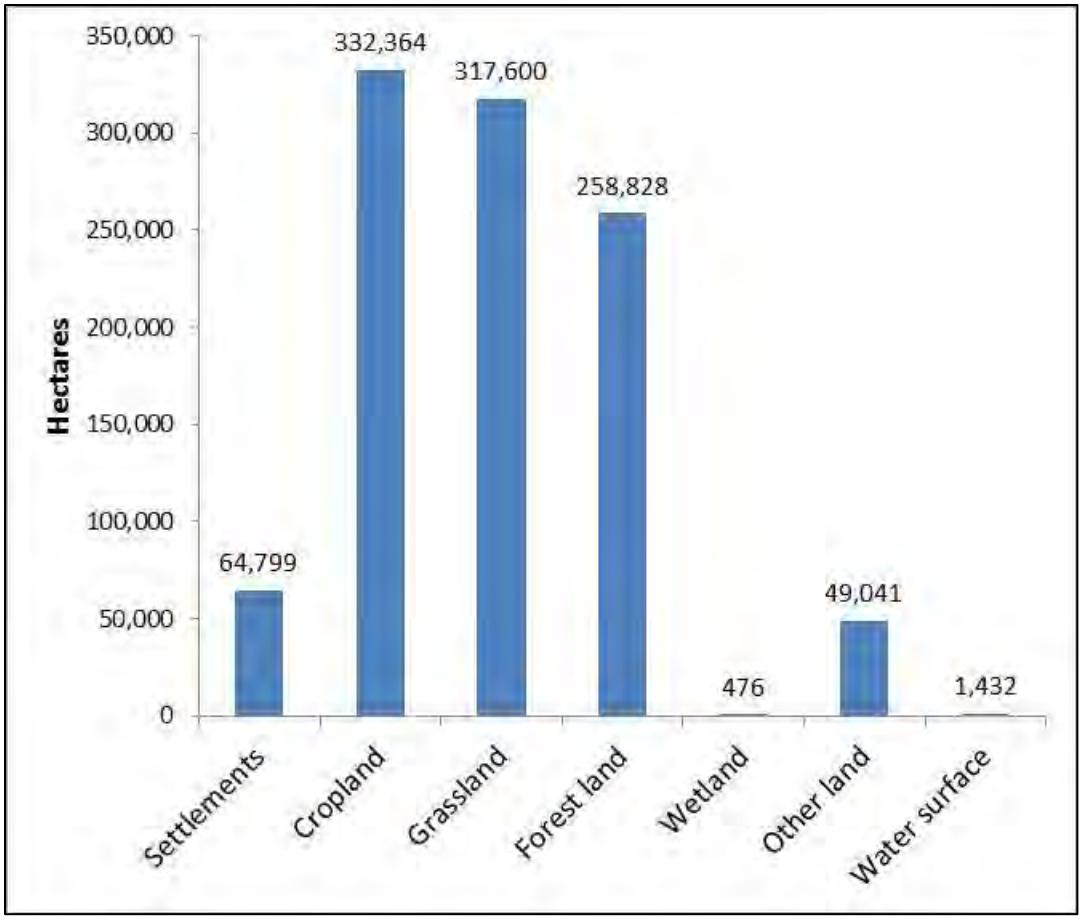

Figure 4. The 1998 Land Use/Land Cover categories.

The first national forest resources assessment was realized in 2005 by the Ministry of Agriculture (MOA) with the assistance of the Food and Agriculture Organization (FAO). The results showed that forests occupied around 13% of the total area of the country. In addition, 10% of the Lebanese territory was found to be covered by other wooded land (MOE/UNDP/ECODIT, 2011; FAO, 2010). Broadleaved forest made up 57% of the total forest cover whereas coniferous forests made up 32%, and the other 11% are mixed forests. Most abundant forests were oak forests covering 52% of total forested areas, while pine forests made up 15% and Juniper about 9%. Cedar and fir forests were much less abundant but nonetheless they represent habitats to many endemic and threatened plant species (MOE/UNDP/ECODIT, 2011; FAO, 2005).

Increasingly, Lebanon's forests, which include remnants of valuable broad-leaved trees, conifer forests and evergreen trees that cover the Lebanese mountains in patches, are exposed to degradation due to quarries, urbanization, pests and diseases, fires, wars, human neglect, improper management, outdated laws, and poor law enforcement. Like other Euro-Mediterranean countries, fires have been especially damaging Lebanon's forests in recent years, representing one of the most important elements that destroy Lebanon's natural resources. Moreover, the absence of a national forest management strategy and the lack of human and technical resources contribute to the degradation of Lebanon's forests.

The problem of forest fires in Lebanon is complex. It concerns all the aspects related to forest management, prevention, suppression, and post fire management. At the administration level, it is a problem having several authorities involved in this subject from different institutions and a problem of forest policy and legislation, as much as it is a problem of equipment and capacity building. Despite the increased efforts, fire issues increasingly threaten forest ecosystems and economic development in Lebanon. Accordingly, a National Strategy for forest fire management (AFDC/MOE, 2009) was developed and endorsed by the Lebanese COM in 2009 (Decision No. 52/2009). The aim of this Strategy was to reduce the risk of intense and frequent forest fires whilst allowing for fire regimes that are socially, economically and ecologically sustainable. Currently, the MOA is in the process of developing a National Forest Plan (NFP) built on supposed to take into account what has been agreed on in Lebanon's National Strategy for forest fire management. Until present, data on fire occurrence and affected surfaces in Lebanon is still not mutually consistent, homogenized and unified at the National level. However, an attempt has been made in 2008 to adopt the forest fire common ID card based on the decision taken by the Presidency of COM number 256 dated on 1/3/2008. The use of this ID card by involved administrations during post-fire assessment is expected to lead to the unification of information and data. Most recently, the Ministry of Environment (MOE) has started collaboration with the Biodiversity Program, at the Institute of the Environment, University of Balamand to systematically document and analyze fire data with the use of the completed fire ID cards.

Overall, the lack of land management in Lebanon is the cause for the over-exploitation and degradation of lands in many areas. It is estimated that 84% of the Lebanese territory still does not have adequate master plans, which has allowed for a lot of chaos when it comes to construction or any activities that change land cover and land use (MOE, 2012). It is estimated that there are about 1,278 quarries in Lebanon covering an area of 5,267 ha (MOE, 2012). Most recently, an indicative research study conducted showed that the largest area of artificialization on the coastal zone of Lebanon between 1998 and 2010 affected grasslands followed by forests and agricultural lands, consecutively (UNEP/MOE, 2013). Furthermore, it was found that wetlands decreased by 47%, grasslands by 27%, and forests by 9%. Further investigation showed that most of artificialization in grassland affected moderately to highly dense vegetation, while most of the artificialization in forested land affected shrublands.

In an attempt to tackle deforestation and to preserve what is left of natural areas, Lebanon has created, until now, 10 Nature Reserves, 3 Biosphere Reserves, 16 Protected Forests, 16 Protected Natural Sites/Landscapes, 4 Ramsar Sites, 5 World Heritage Sites, and 15 Important Bird Areas (MOE/UNDP/ECODIT, 2011). Reforestation and afforestation combined with the implementation of Lebanon's National Strategy for forest fire management are some of the main activities that can help in maintaining and increasing Lebanon's forest cover. Pioneer reforestation projects have started during the late 1960s and early 1970s. During the past decade, Lebanon has initiated a number of programs/initiatives to restore forested lands. Such programs/initiatives included 1) the development of the National Reforestation Plan (NRP) by MOE in 2001, 2) the development of the National Action Plan to Combat Desertification by the MOA in 2003, 3) the development of the project "Safeguarding and Restoring Lebanon's Woodland Resources" to complement what has been started under the NRP in 2009, 4) the launching of Lebanon Reforestation Initiative in 2012 with the support of the International Program of the US Forest Service to provide needed support in large-scale reforestation activities across the county, 5) the launching of the project "planting four million forest trees"

by the MOA in 2012 and 6) the simultaneous implementation of several initiatives by local Non-Governmental Organizations.

3. Gaps and constraints identified by INC and SNC

Lebanon's Initial National Communication (INC) (MOE and UNDP, 1999) and the Second National Communication (SNC) (MOE and UNDP, 2011) have faced a considerable amount of constraints while developing the national estimates of GHG emissions of the LULUCF sector, especially when it comes to the availability of data required for the estimations. Table **1** represents the gaps and needs identified in the INC and SNC in relation to LULUCF.

Table 1. Gaps and needs for the calculation of GHG emissions identified in the INC and SNC.

	1st National Communication	2nd National Communication
Gaps	• Lack of information and records of data changes in forestry and other woody biomass stocks at the institutional level • Lack of comprehensive studies of forests • Lack of studies on annual growth rate for fruit trees • Lack of data related to urban trees • Lack of data on illegal forest and grassland conversion to cropland • Lack of quantitative data on the abandoned terraced lands, and systematic monitoring for ecological indicators • Lack of technology and monitoring equipment • Lack of proper data dissemination • Use of rough estimates for forest and tree species type • Use of rough estimates for the number of urban trees • Consideration of only woodland fires as reason for CO_2 emission under forest/grassland conversion • Use of inconsistent information for terrestrial observations • Use of data for ecological observations that are specific to projects (limited in time and objectives)	• No national monitoring system • Few studies and reports on forestry • Lack of sufficient funding for research • Lack of required equipment • Lack of consistency in data collection • Deficiencies in technical expertise and cooperation between different research bodies • Overlapping mandates of different agencies • Lack of data management systems • Lack of specific emission factors of greenhouse gases

Needs	• Equipment including installation of gauging stations, monitoring stations, and maintenance of the existing ones • Data Dissemination including building database, standardization of reporting procedures, cooperation between public and private sectors, and the use of monthly bulletins	• Modernization and reorganization of climate monitoring services • Making data more available and of better quality • Training of individuals and research institutions • Development of growth models for different forest types • Update of forest map to a scale of 1/20,000 showing distribution per forest type • Improvement of access to data and information • Development of systematic observation systems. • Development of legal and institutional status • Integration of private, public sectors and international agencies • Capacity building in climate modeling, data handling, operation and maintenance of equipment used • Identification of key indicators and vulnerable areas • Establishment of monitoring system for snow • Centralization of data management • Organization of standardized inventory systems • Establishment of a specialized scientific coordination body • Enhancing terrestrial and ecological systematic monitoring

4. Methodology

4.1. Adopting the IPCC Good Practice Guidance for the LULUCF sector

For the first time in Lebanon, the preparation of the LULUCF section of the inventory followed the 2003 IPCC "Good Practice Guidance for Land use, Land-use Change and Forestry" (IPCC GPG for LULUCF), which adopts a land use category-based approach to estimate emissions/removals from all land categories and all relevant GHGs.

Adopting IPCC GPG for LULUCF for GHG inventory involved the following steps (Figure **5**):

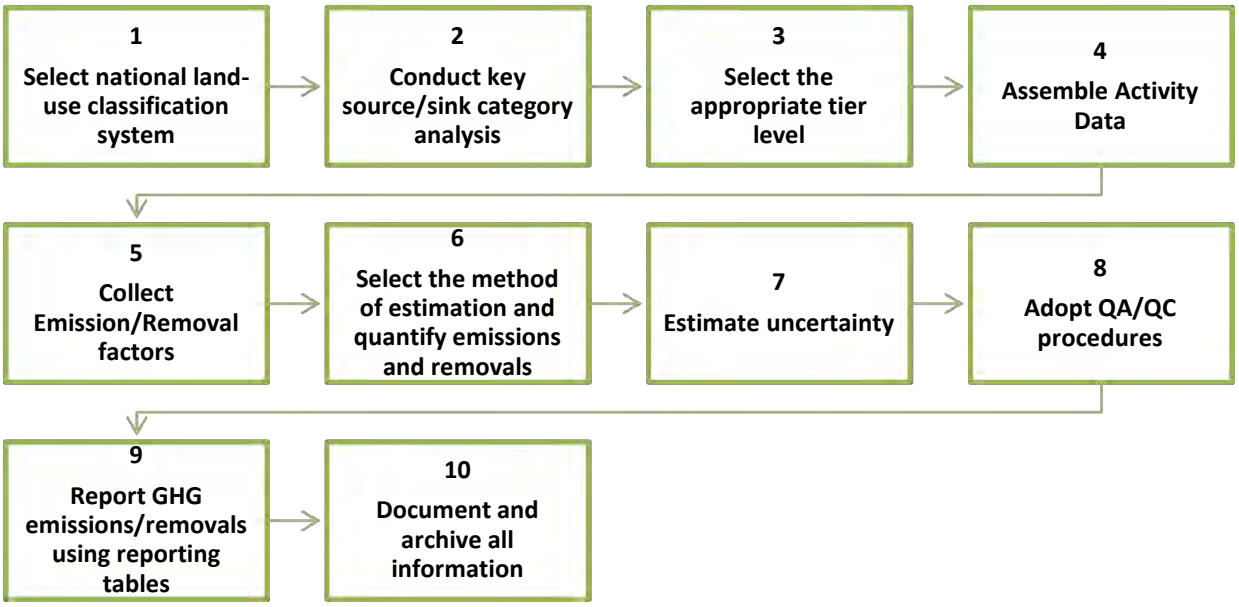

Figure 5. Steps for adopting the IPCC GPG for LULUCF.

More specifically, this included the following:

1. The nationally adopted land-use classification system of the Land Cover / Land Use map of 1998 was employed for the inventory estimation (Appendix I). Each land category was further subdivided into lands remaining in the same land use (for example, forest lands remaining forest lands) and lands converted into another land-use category (for example, forest lands converted into croplands) during the inventory period (IPCC, 2003).
2. The key category analysis recommended by the IPCC GPG for LULUCF is performed to identify those categories that have the greatest contribution to overall inventory uncertainty and thus prioritize efforts to improve their overall estimates. However, this analysis is an iterative process and initial estimates are needed for each sub-category to perform the analysis. Because of the absence of complete and reliable inventory estimation for the LULUCF sector in Lebanon up until now, the analysis was not performed. All the

categories and subcategories were accounted for in the inventory estimation depending mainly on the data availability about each land use category (Table 2).

3. Selection of the appropriate tier level for the land categories and subcategories, non-CO_2 gases and carbon pools, was mostly based on the resources available for the inventory process. Tiers correspond to a progression from the use of simple equations with default data to country-specific data in more complex national systems. The Tier 1 approach, which employs the basic method and the default emission factors provided in the IPCC Guidelines, was typically used in these inventory calculations. Tier 2 uses the same methodological approach as Tier 1 but applies emission factors and activity data which are defined by the country. Tier 2 was applied in some cases when country-specific emission factors and activity data were available from literature or through surveys. Tier 3 approach uses higher order methods including models and inventory measurement systems. Tier 3 was only used for the selection of activity data in conjunction with Approach 3 when possible.
4. The required activity data were gathered for the inventory years 1994 up until 2012 depending on the tier selected (Tier 1, Tier 2 or Tier 3). The representation of most land-use areas and land conversions however, was done following the Approach 3 which is a Tier 3 level methodology used in the selection of activity data. It is the most complex, accurate and spatially explicit method, provided by the IPCC GPG for LULUCF, which ensured the consistency of the inventory calculations. The tier levels of the activity data acquired by surveys and personal communications depended on the accuracy and completeness of the nationally available estimates.
5. The sources of emission/removal factors for the years 1994 up until 2012 included regional, national and global databases, forest inventories, national GHG inventory studies and surveys, and use of the Emission Factors Database (EFDB) default values provided by the IPCC.
6. Appropriate equations were used to quantify the emissions and removals, and default worksheets provided in IPCC GPG for LULUCF (IPCC, 2003) were adopted.
7. The uncertainty assessment was conducted by using default uncertainty values from the IPCC GPG for LULUCF and values from published sources for country-specific data.

8. Quality Control (QC) procedures were adopted to ensure data integrity, correctness and completeness, in addition to identifying errors and omissions.
9. GHG emissions and removals were reported using the UNFCCC reporting tables.
10. Documentation and archiving was conducted for all information used to produce the inventory, including all activity data, emission/removal factors, sources of data (Table 3), methods used and QC procedures adopted for different land categories and management systems, and carbon pools and non-CO_2 gases.

Table 2. Land use categories and subcategories, carbon pools and non-CO_2 gases accounted for in the inventory estimation of the LULUCF sector in Lebanon.

Categories	**Subcategories**	**Estimations calculated**[1]	**No activity data available**	**Estimations not required for calculation**[2]
Forest land	Forest land remaining forest land	x		
	Land converted to forest land	x		
Cropland	Cropland remaining cropland	x		
	Land converted to cropland		x	
Grassland	Grassland remaining grassland	x		
	Land converted to grassland		x	
Wetland	Wetland remaining wetland			x
	Land converted to wetland	x		
Settlements	Settlement remaining settlement			x
	Land converted to settlements	x		

[1] Estimations are calculated for the following carbon pools and non-CO_2 gases depending on data availability: AGB, BGB, DOM, litter and soil carbon; CH_4, N_2O, CO and NO_x

[2] Lebanon is considered as non-Annex I Party in the UNFCCC convention.

4.2. Data collection

Data collection for the inventory years 1994-2012 was conducted using satellite remote sensing and Geographic Information System (GIS) techniques, literature reviews, and surveys. Table 3 represents the type of data sources and databases used in the data collection process.

Table 3. Type of data sources and databases used for data collection.

Type of data source	**Databases**
Online database, Global databases	FAOSTAT, EFDB, Google Earth
Scientific articles and papers	Altas et al. (2007) Aksu et al. (2001) Gerard, J. A. (2009) Mitri et al. (2012) Tragsa (2012) Darwish, T., and Faour, G. (2008) AFED (2010) Hreiche, A. (2009) IPCC (2003)
National reports	FAO (2005) FAO (2010)
Satellite imagery	5 SPOT imagery (2.5 m) 30 Landsat TM and ETM+ imagery (25 m)
Maps	Land Cover Land Use map of Lebanon of 1998 Annual rainfall map Fertility and pedology maps of Lebanon (scale 1/200 000) Digital Elevation Model (DEM) of Lebanon (25 m)
Surveys and personal communications	Mr. Elie Chneis (AFDC) Mr. Jean Stephan (MOA) Dr. Talal Darwish from the NCSR (Center for Remote Sensing) Mr. Joseph Bechara (LRI) Mr. Garo Haroutunian (MOE) Mr. Raymond Khoury (Greenplan)

4.2.1. Activity data

Collection and calculation of the activity data (Appendix II) was conducted following three methodologies depending on the availability and type of country-specific data:

- Approach 3 within IPCC GPG
- Surveys and personal communications
- Extrapolations and interpolations

The top-level land categories which were considered in the change detection mapping using approach 3 (based on the IPCC GPG for LULUCF) were the following (IPCC, 2003): Forest land (F), Cropland (C), Grassland (G), Wetlands (W), Settlements (S) and Other land (O). The definitions for these categories according to the National classification system based on the Land Cover / Land Use map of 1998 are listed in Appendix I. The abbreviations FF, GG, CC, WW, SS, OO denoted land-use categories undergoing no conversions; and the abbreviations LF, LG, LC, LW, LS, LO denoted land conversions to these land-use categories:

FF = forest land remaining forest land	LF = lands converted to forest land
GG = grassland remaining grassland	LG = lands converted to grassland
CC = cropland remaining cropland	LC = lands converted to cropland
WW = wetlands remaining wetlands	LW = lands converted to wetlands
SS = settlements remaining settlements	LS = lands converted to settlements
OO = other land remaining other land	LO = lands converted to other land

The Approach 3 methodology allowed the generation of data about land use changes such as forest, croplands and grasslands conversions to settlements as well as the extent of burned areas in forest, croplands and grasslands.

It is to be noted that satellite images from the years 1993, 1994, 1995, 1996, 1997, 2001, and 2009 were not used due to lack of high quality images (e.g. low cloud coverage, non-extensive shaded areas, etc.). The inventory year 1998 was considered a reference year and the areas

extracted from the Land Cover / Land Use map of 1998 were considered as reference values. It was assumed that no land use changes happened in the year 1998.

As it was not possible to generate all the activity data using approach 3 due to the limited use of satellite data, surveys and personal communications were conducted which revealed a significant data gap in the LULUCF sector in Lebanon. Accordingly, it was only possible to gather data about lands converted to forests through communication with the MOA, the MOE, the Association for Forests, Development and Conservation (AFDC), and the Lebanese Reforestation Initiative (LRI) (Appendix II) for the period 1999-2012.

As there is no data available for the period 1994-1997 using approach 3, the land use (FF, GG, CC) and land use change (LS) areas for these inventory years were generated by extrapolation of the trend over time (1999-2012) in order to keep the consistency of the time series. However, the trend was not constant for the burned areas and for the afforestation areas (LF); therefore linear extrapolation could not be used for these subcategories. In addition, the lack of surrogate data resulted in gaps for the period 1994-1997 in comparison with the period of 1999-2012. Accordingly, the extent of burned areas and afforested areas were not estimated for the period 1994-1997. Areas of land converted to settlement were interpolated for the years 2001 and 2009 due to lack of good quality satellite imagery on those years.

4.2.2. Emission/Removal factors

Collection of the Emission/Removal (E/R) factors was done following two methodologies according to the availability and type of data:

- Tier 1: IPCC GPG Default data or assumptions
- Tier 2: Country-specific data from global databases, literature or surveys, and personal communications

A complete list of the E/R factors investigated and reported in the UNFCCC reporting tables for the calculation of GHG emissions and removals from 1994-2012 was provided in Appendix III.

E/R factors were collected or calculated (by averages and extrapolations) for each category depending on the disaggregation level required by the GHG emission/removal calculation method and depending on the data availability (

Table **4** and Appendix III). Detailed calculations, values and sources of all the E/R factors were reported and documented in the UNFCCC reporting tables.

Table 4. Land use categories and required disaggregation levels*.

Land use Categories	**Disaggregation levels**
Forest land	• Broadleaf (including shrub lands and woody perennials) • Coniferous • Mixed
Cropland	• Annual • Perennial
Grassland	• Grasses (excluding woody perennials)
Wetland	• Flooded areas (artificial reservoirs and hill lakes)
Settlement	No disaggregation is required
Other land	No disaggregation is required
Burned areas (forest land and grassland)	• Fuel type 1 • Fuel type 2 • Fuel type 3 • Fuel type 4 • Fuel type 5 • Fuel type 6 & 7

* See Appendix I

4.3. Uncertainty assessment

This assessment considers source-specific uncertainties relevant to inventory estimates made for each land category. In this work, the following types of uncertainties were identified and combined to estimate the overall uncertainty of the inventory:

- Uncertainties associated with activity data
- Uncertainties associated with emission factors from published references

Results indicated that the overall uncertainty of the LULUCF sector estimations over the inventory period (1994-2012) varied between 47% and 55%.

The uncertainty associated with activity data was derived from the accuracy assessment of the Approach 3 methodology. The overall classification accuracy of the change detection mapping between 2003 and 2004 was found to be 85%, while the Kappa Index of Agreement (KIA) was 0.82. As for the classification accuracy of 2007-2008 the overall classification accuracy was found to be 88%, while the Kappa Index of Agreement (KIA) was 0.85. It is to be noted that a kappa value closer to 1 indicates better agreement, whereas a kappa closer 0 indicates agreement closer or equivalent to chance. Overall, the average accuracy of the change detection model was found to be highly accurate (86%). This is equivalent to 14% uncertainty for the activity data generated using approach 3.

The uncertainties of the activity data collected through surveys were associated with the relevant agencies' data quality. As the data have not been already assessed as part of the data collection procedures of these agencies, it was not possible to quantify the uncertainty of this type of data. In addition, extrapolation errors estimation was not accounted for in the IPCC Guidelines. Therefore, those types of uncertainties were not included in the calculation of the uncertainty associated with activity data.

Alternatively, identified uncertainties associated with E/R factors ranged between 2% and 200% depending on the published sources from which they were derived (Appendix IV).

Consequently, the overall uncertainty of the LULUCF sector over the inventory period (1994-2012) was improved after combination of E/R and activity data uncertainties. This improvement is due to the use of Approach 3 which is the most precise and accurate method for collection of activity data proposed by the IPCC Guidelines.

5. Results and discussion

5.1. GHG inventory for the years 1994 up to 2012

The summary GHG emissions from LULUCF sector (Table 5) showed the total CO_2 and non-CO_2 emissions/removals in Gg CO_2 equivalent. The Global Warming Potential (GWP) values were used as provided by the IPCC in its Second Assessment Report (SAR) and based on the effects of greenhouse gases over a 100-year time horizon. Accordingly, the 1995 IPCC GWP values were 1 for CO_2, 21 for CH_4, and 310 for N_2O.

The new available data and more accurate methodology allowed the recalculation of the estimates for the period of 1994-2004. The improvement in the methodology for activity data collection (the use of periodical and sometimes multi-temporal satellite and remote sensing data) resulted in country-specific estimates in comparison with the SNC which used rough estimates from global and national databases and literature reviews.

Table 5. Lebanon's GHG emissions/removals summary from the LULUCF sector for the period 1994-2012.

GHG emissions/removals of the LULUCF sector	1994*	1995*	1996*	1997*	1998*	1999	2000	2001
CO_2 (Gg)	-3450.84	-3448.44	-3445.99	-3443.52	-3496.71	-3166.11	-3221.29	-3430.78
CH_4 (Gg)	NE	NE	NE	NE	NE	0.10	0.03	0.01
CH_4 (Gg CO2 eq.)	NE	NE	NE	NE	NE	2.05	0.57	0.16
N_2O (Gg)	NE	NE	NE	NE	NE	0.00	0.00	0.00
N_2O (Gg CO2 eq.)	NE	NE	NE	NE	NE	0.38	0.11	0.04
NO_x (Gg)	NE	NE	NE	NE	NE	0.01	0.00	0.00
CO (Gg)	NE	NE	NE	NE	NE	1.45	0.41	0.14
Total emissions (Gg CO_2 eq.)	NE	NE	NE	NE	NE	2.43	0.68	0.20
Total removals (Gg CO_2)	-3450.84	-3448.44	-3445.99	-3443.52	-3496.71	-3166.11	-3221.29	-3430.78
Net GHG removals (Gg CO_2 eq.)	**-3450.84**	**-3448.44**	**-3445.99**	**-3443.52**	**-3496.71**	**-3163.68**	**-3220.61**	**-3430.58**

*NE: Not Estimated. No activity data about burned areas from 1994-1998 resulting in no data about total emissions during this period.

*(*Table 5 *cont'd)*

GHG emissions of the LULUCF sector	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO_2 (Gg)	-3437.74	-3335.91	-3412.07	-3303.30	-3208.47	-3345.54	-3305.91	-3217.35	-3218.00	-3200.79	-3036.90
CH_4 (Gg)	0.01	0.03	0.01	0.04	0.10	0.06	0.00	0.04	0.04	0.01	0.05
CH_4 (Gg CO_2 eq.)	0.16	0.54	0.12	0.74	2.17	1.19	0.05	0.81	0.81	0.31	1.06
N_2O (Gg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N_2O (Gg CO2 eq.)	0.04	0.13	0.03	0.14	0.44	0.24	0.01	0.16	0.16	0.07	0.20
NO_x (Gg)	0.00	0.01	0.00	0.00	0.02	0.01	0.00	0.01	0.01	0.00	0.01
CO (Gg)	0.14	0.45	0.10	0.52	1.61	0.82	0.03	0.59	0.59	0.24	0.76
Total emissions (Gg CO_2 eq.)	0.20	0.67	0.15	0.88	2.61	1.43	0.06	0.97	0.97	0.38	1.26
Total removals (Gg CO_2)	-3437.74	-3335.91	-3412.07	-3303.30	-3208.47	-3345.54	-3305.91	-3217.35	-3218.00	-3200.79	-3036.90
Net GHG removals (Gg CO_2 eq.)	**-3437.54**	**-3335.24**	**-3411.92**	**-3302.42**	**-3205.86**	**-3344.10**	**-3305.85**	**-3216.38**	**-3217.03**	**-3200.41**	**-3035.64**

The net CO_2 emissions/removals from the LULUCF sector (Figure 6) shows that forests were important sinks of GHG in Lebanon at the beginning of the inventory period. The changes in forest and vegetation covers at the end of the inventory period (2012) resulted in about 12% (21.8 Gg CO_2 eq./yr) decrease in CO_2 removals from the LULUCF sector in comparison to the beginning of the inventory period (1994). This decrease is due to an increasing trend in land conversion to settlements equivalent to a decrease in CO_2 removals and to an increasing trend in burned areas equivalent to an increase in CO_2 emissions, given that decrease in removals from fuelwood gathering is quite constant (Figure 7).

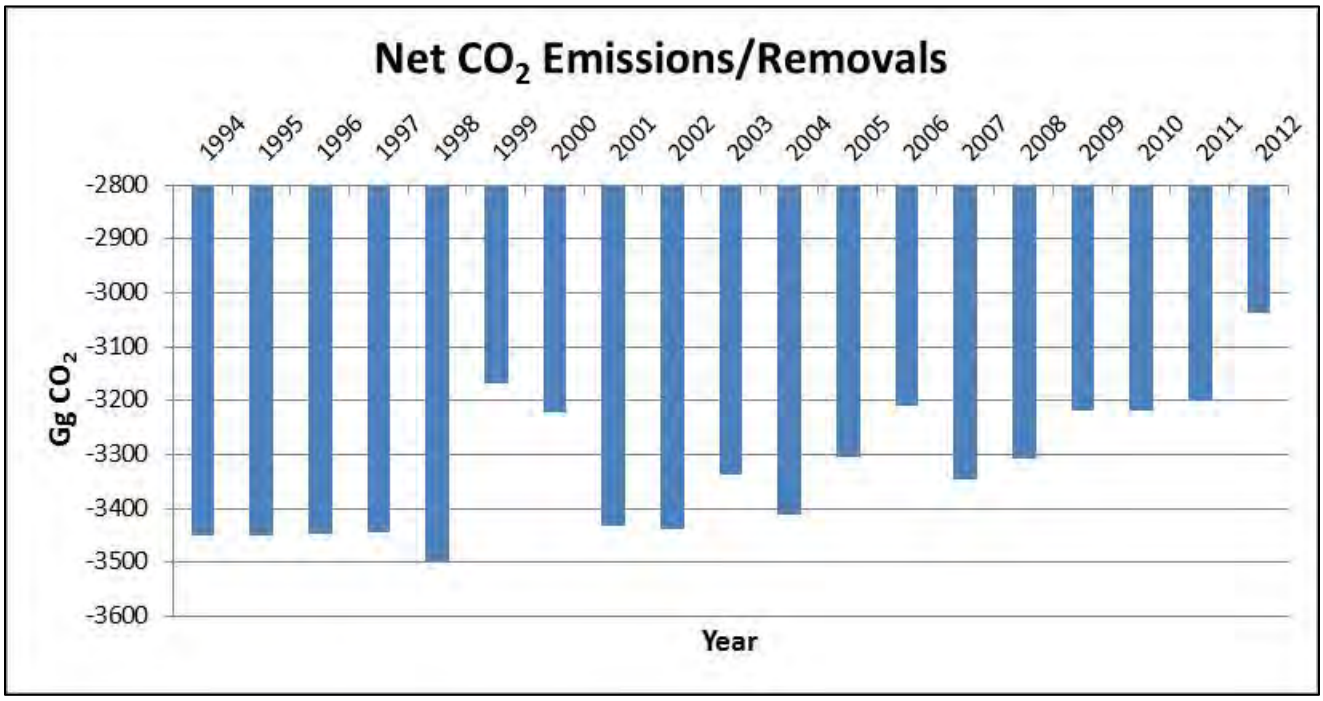

Figure 6. Net CO_2 emissions/removals from LULUCF sector for the period 1994-2012.

Figure 7 shows the CO_2 emissions/removals resulting from the identified changes in the Land Cover/Land Use areas and the changes in management activities in the LULUCF sector in Lebanon.

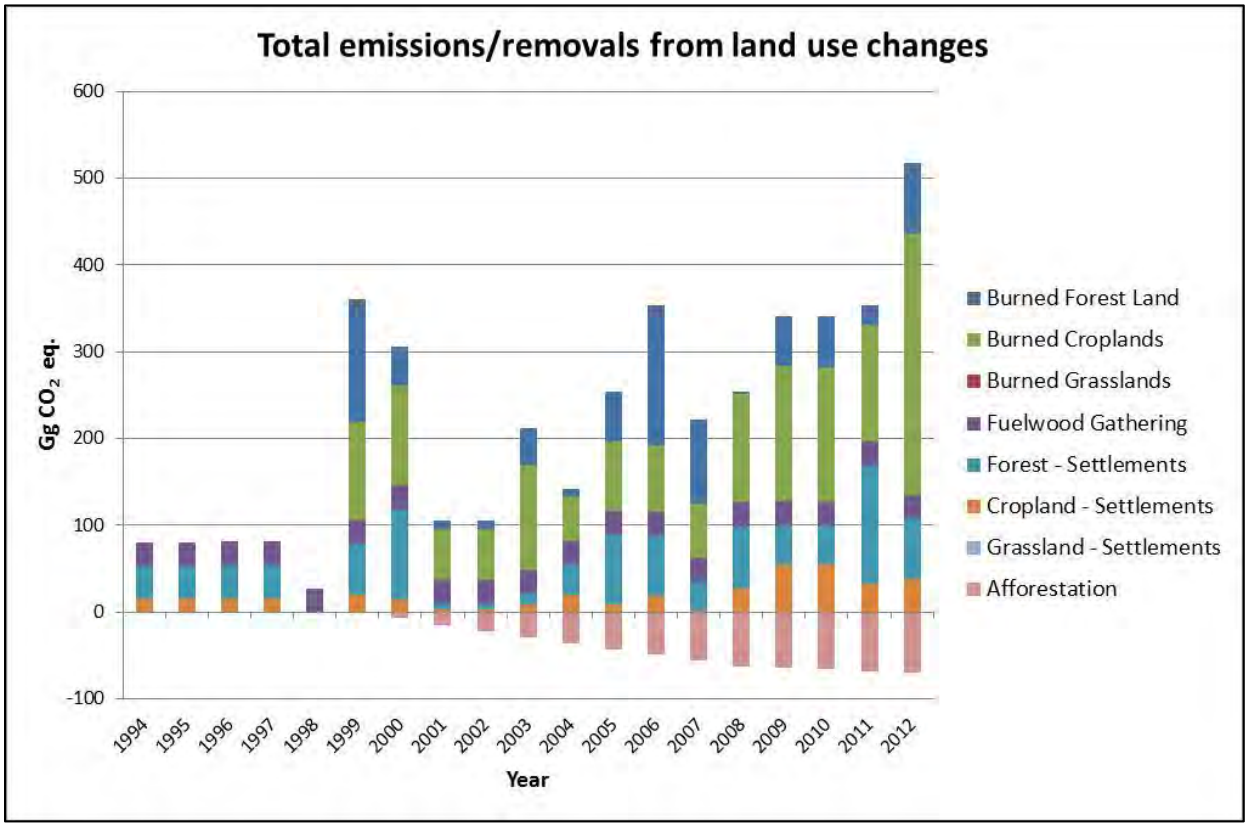

Figure 7. CO_2 emissions/removals from the changes in the LULUCF sector.

The changes in Land Cover/Land Use resulted in gains and losses in biomass and carbon stocks in soils and litter. The comparison of emissions and removals shows that emissions from land conversions, burning of biomass and fuelwood gathering are much higher than the removals caused by the growth of new plantations (afforestation) (Figure 7). Although net emissions/removals proved that the LULUCF sector is a major sink, emissions from changes in the LULUCF sector were still high and couldn't be compensated by the afforestation activities.

GHG emissions and removals reported from the LULUCF sector in Lebanon are respectively caused by biomass losses and increments and by variation in soil carbon stocks from the

different land use and land use change categories which were taken into consideration in this report (Table 6).

Table 6. Causes of GHG emissions and removals reported for the LULUCF sector in Lebanon.

Biomass losses	**Biomass increments**	**Increase in soil carbon stocks and litter**
• Forest converted to settlement • Grassland converted to settlement • Cropland converted to settlement • Burned forest lands • Burned croplands (perennial crops) • Burned grasslands • Fuelwood gathering from forests	• Growth of forest lands • Growth of croplands (Perennial crops) • Growth of lands converted to forests or plantations (Afforestation)	• Afforestation

5.2. Changes in CO_2 removals

As previously reported, the land use (FF, GG, CC) and land use change (LS) areas for the inventory years 1994-1997 were generated by extrapolation of the trend over time (1999-2012) due to lack of data using approach 3.

In general, it was observed that the changes in CO_2 removals over the inventory period (1994-2012) were mainly attributed to the decrease/increase in vegetation cover within forest lands, croplands, and grasslands.

For instance, areas of lands converted to settlements varied between 91 ha in 2001 and about 1200 ha in 2011 (Figure 8). It is important to note that the reported numbers of annual conversion to settlement accounted only for the annual sum of any conversion that is above 90 $m^{2.}$ This is mainly due to the spatial resolution of the employed satellite imagery. Counting the changes that are below 90 m^2 can slightly increase the total areas of conversion to settlement.

In general, variations in areas of land converted to settlement might be related to a number of factors including the active market of the real estate sector, the quality of the image

classification results, and the general socio-economic situation, among others. In addition, such type of changes might be related to certain policies and public plans contributing to changes in these lands (e.g. expansion and improvement of the road networks, development of areas of public and private services).

However, it is to be noted that the relatively small area reported in 2001 might be mainly related to underestimation through interpolation (as previously stated the 2001 satellite imagery was not used due to low quality of data). While the reported small areas of conversion in 2002 and 2007 might be mainly related to the characteristics and inherent conditions (e.g. shades, sun illumination) of the employed satellite imagery that were acquired on those years.
The spatial distribution per Caza of the total lands converted to settlements between 1998 and 2012 were represented in maps (Appendix V). Accordingly, it was observed that the highest rates of forest land conversion to settlement were recorded for the Cazas of Jbeil, Kesrouane, Matn, and Sour (>300 ha), followed by Aaley, Chouf, Aakkar, and Bent Jbeil (between 200 and 300 ha). The highest rates of cropland conversion to settlement were recorded for the Cazas of Baalabek and Beqaa El Gharbi (750 to 1500 ha), followed by Zahle (500 to 750 ha). As for grassland, the highest rates of conversion to settlement were attributed to Aakkar and Baalbek.

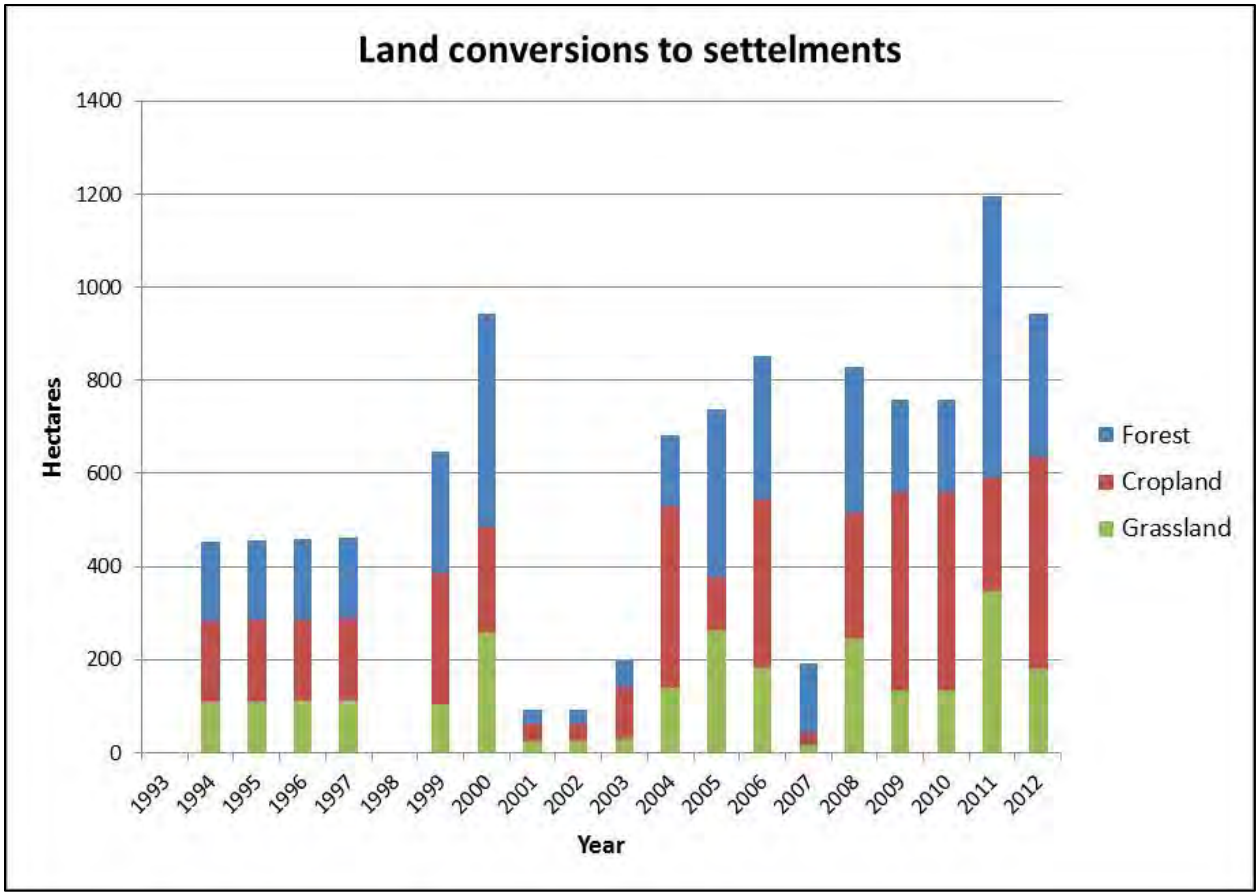

Figure 8. Areas of land categories converted to settlements.

It was observed that broadleaf forests were the most affected by this type of conversions (Figure 9). This might be influenced by the large extent of broadleaf forests in the country and the fact that urbanization most likely occurs more on shrubland (mostly broadleaf vegetation) than on forested areas.

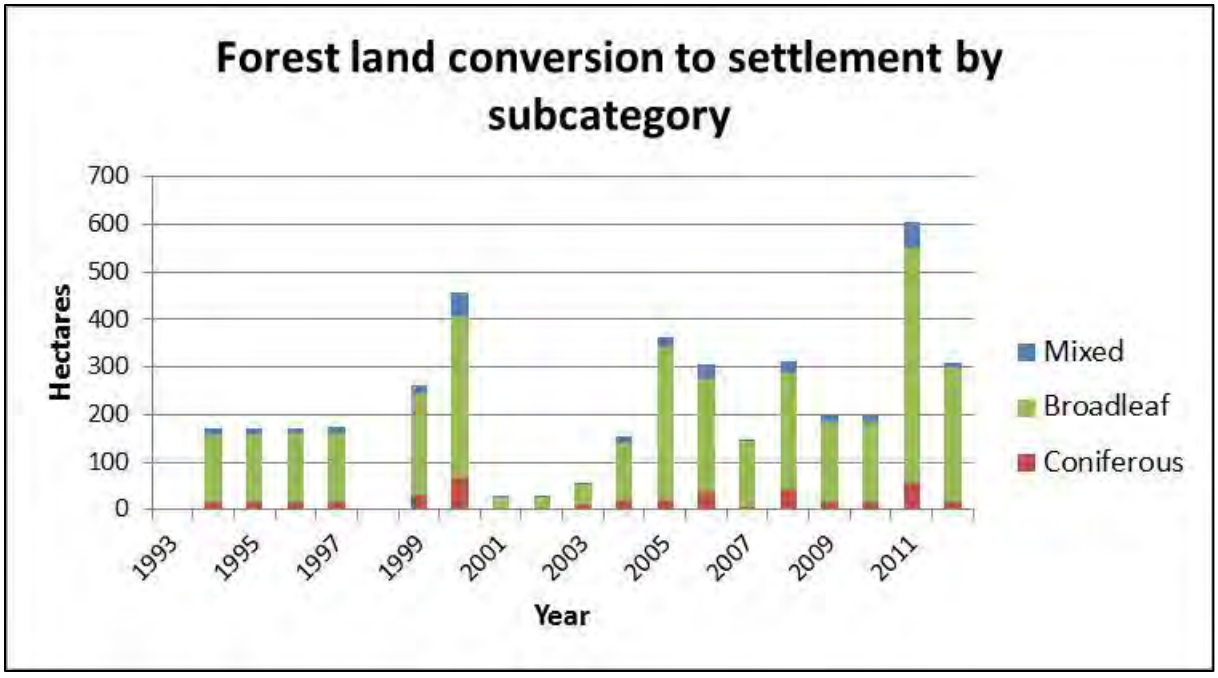

Figure 9. Areas of forest lands converted to settlements by subcategory.

Conversions to settlements have also increasingly negatively affected croplands and grasslands as shown in Figure **10** and Figure **11**. It is usually easier and more beneficial to convert annual crops than removing perennial crops (mainly comprising fruit trees and orchards). Conversions of cropland and grassland to settlement might be related to the lack of interest of owners in keeping such type of lands (e.g. increase in land prices related to an increasing number of population, increasing demand for development projects), high costs of labors and lack of a market for the agricultural products, and degrading financial situation of citizens (selling agricultural lands and grasslands which were eventually converted to urbanized areas). This has been at least confirmed for artificialized cropland on the Lebanese coast (UNEP/MOE, 2013).

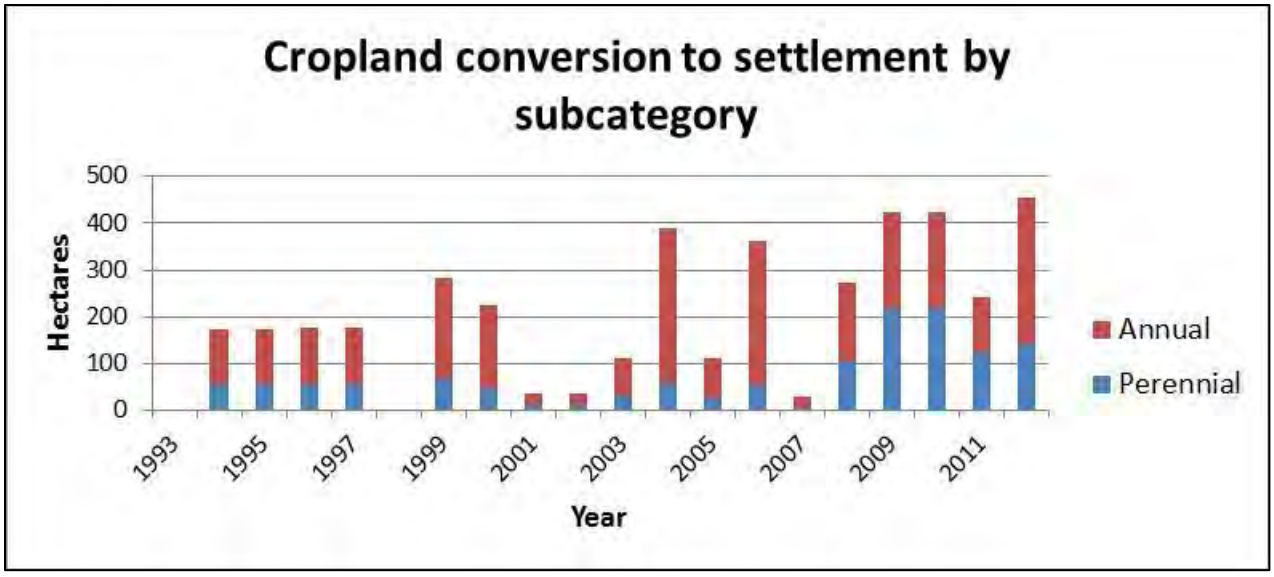

Figure 10. Areas of croplands converted to settlements by subcategory.

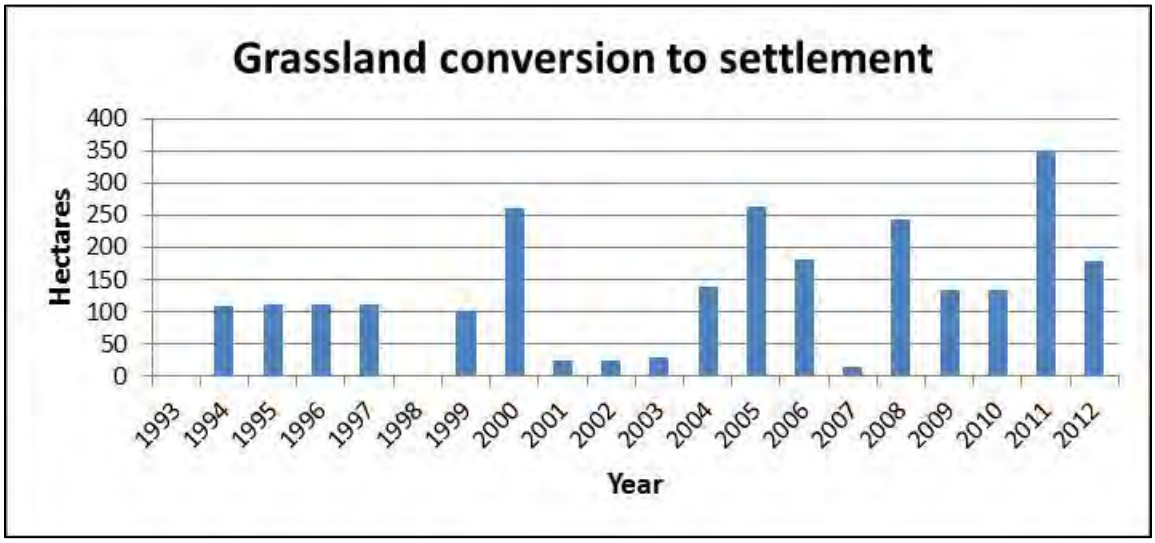

Figure 11. Areas of grasslands converted to settlements.

Decrease in CO_2 removals caused by land conversions to settlements nearly doubled between 1994 and 2012. The highest decrease in removals recorded was in 2011 with a total of about 170 Gg/yr (Figure 12).

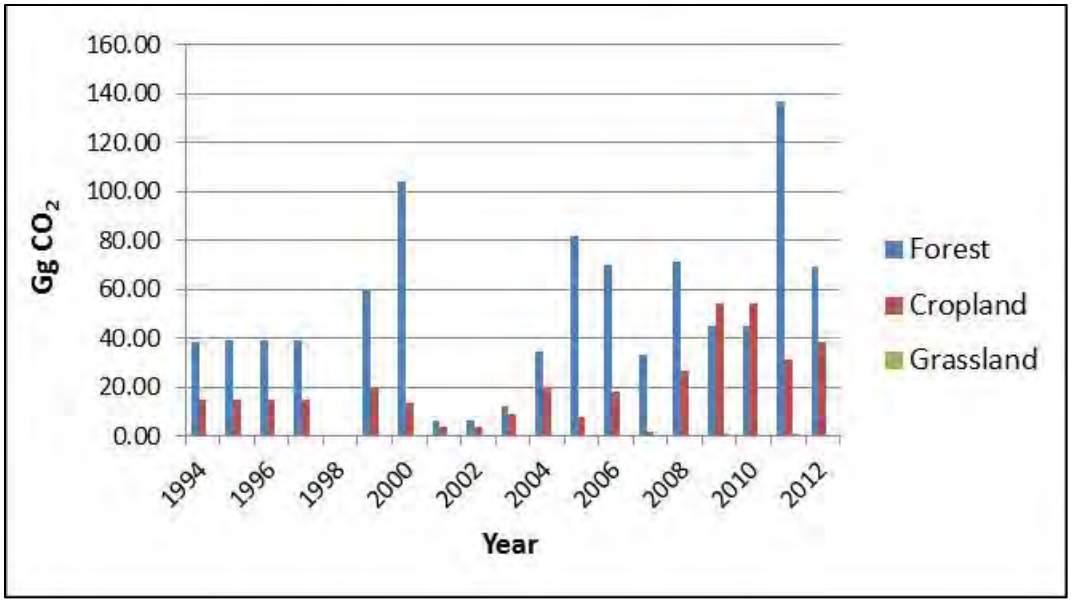

Figure 12. Decrease in CO_2 removals due to biomass losses from lands converted to settlements.

Fuelwood gathering is another cause of decrease in vegetation from forest lands. Estimates for fuelwood gathering were quite constant over the inventory time period resulting in an average CO_2 emission of about 27 Gg/yr (Figure 13 and Figure 14).

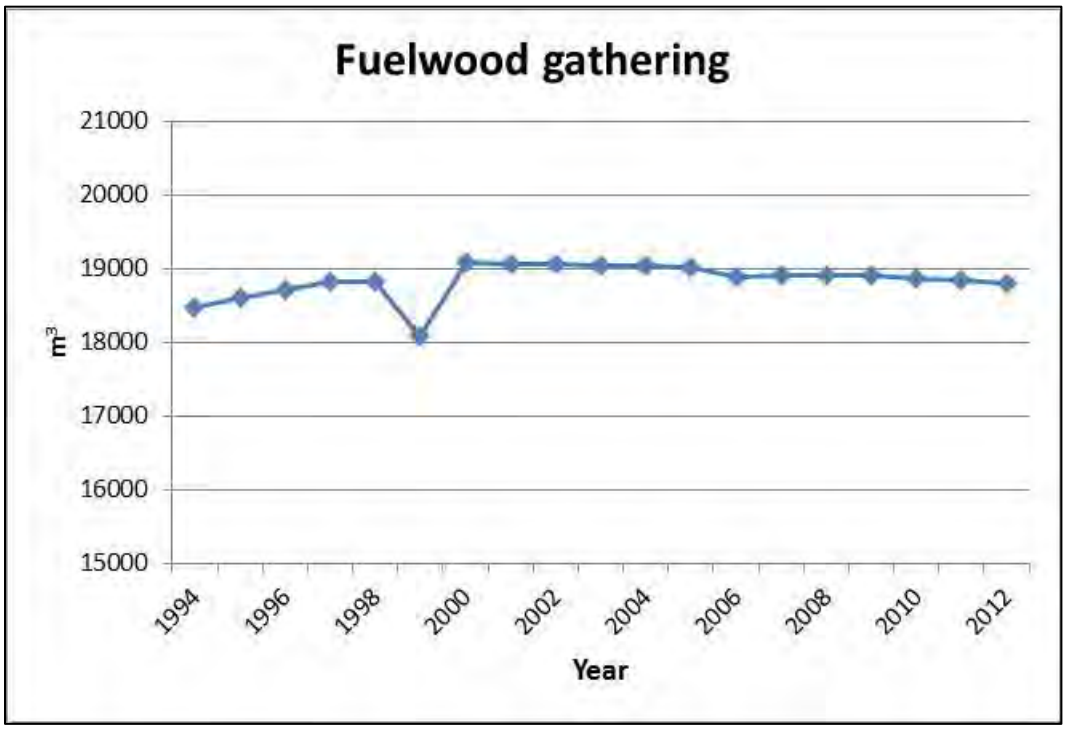

Figure 13. Volumes of fuelwood gathering.

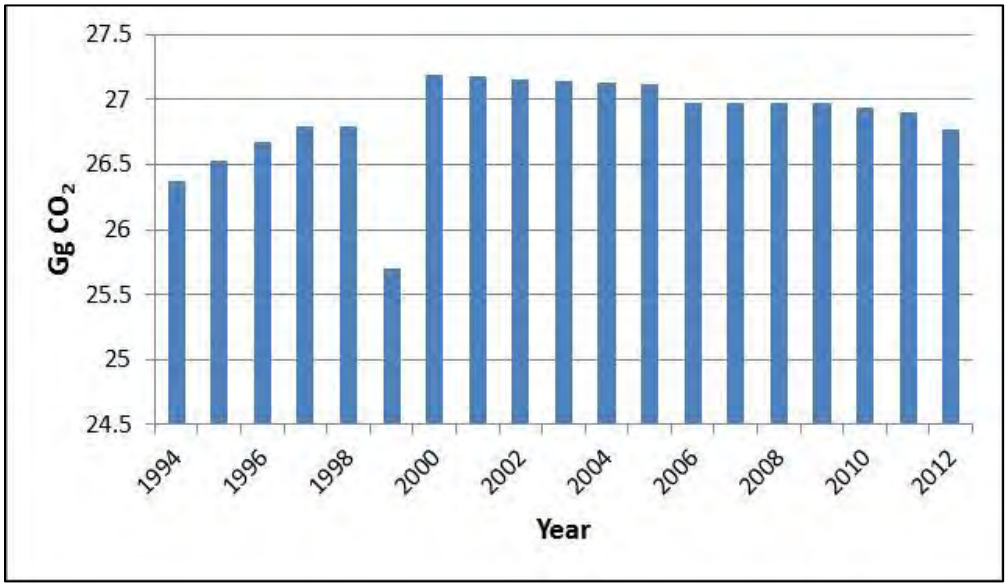

Figure 14. Decrease in CO_2 removals from fuelwood gathering.

Moreover, a decrease of about 1.55% in existing forest lands due to urbanization was shown between 1994 and 2012 (Figure 15). These losses in biomass resulted in a decrease in CO_2 removals by 1.95 Gg/yr from the forested areas (Figure 16).

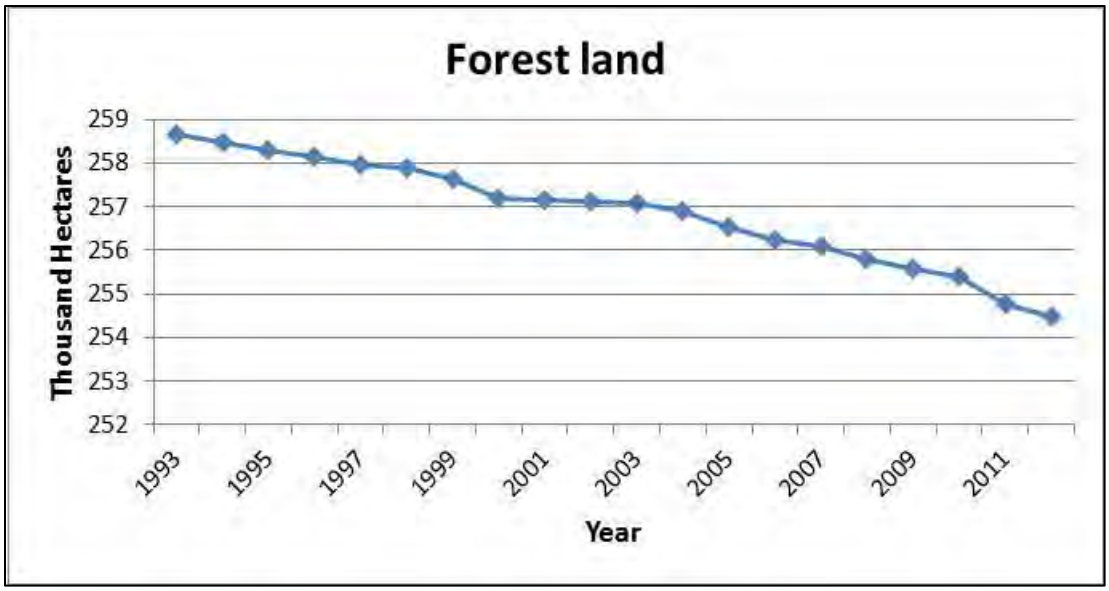

Figure 15. Forest lands remaining forest lands over the inventory period (1994-2012).

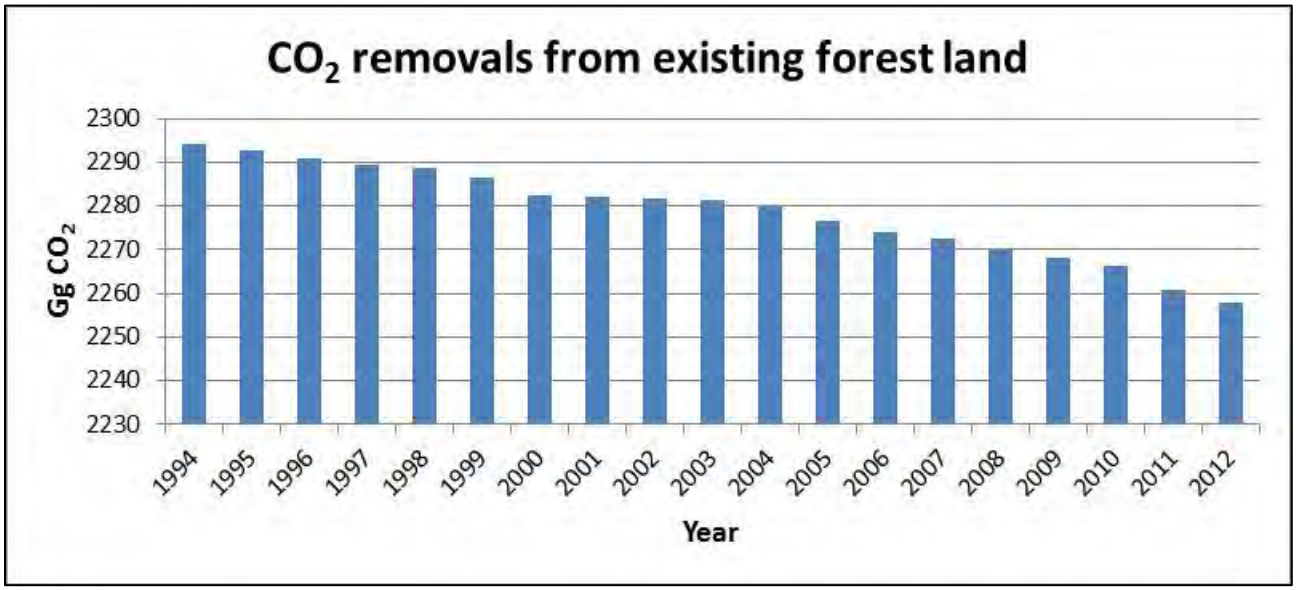

Figure 16. CO_2 removals due to biomass increments from existing forest lands.

Also, afforestation activities (Figure 17 and Figure 18) resulted in an average increase in CO_2 removal by 5.11 Gg/yr between 1999 and 2012 (Figure 19). The decrease in afforested areas after 2007 might be related to changes in certain reforestation policies especially after the 2007 fires. More efforts have been put to manage wildfire risk (e.g. the development of Lebanon's National Strategy for forest fire management, the launching of the operations room at the Directorate of the Civil Defense). Also, many reforestation activities were interrupted after the July 2006 war and reforestation contracts were subsequently terminated. In parallel to a gap of sustained reforestation activities which were observed between 2008 and 2011, the MOE resumed work on the NRP in 2009 through the project "Safeguarding and Restoring Lebanon's Woodland Resources" and signed in 2010 around 41 reforestation agreements worth $1.3 Million and covering 185 ha. Also, the US Forest Service (USFS) launched in 2010 a five-year and $12 Million Lebanon Reforestation Initiative (LRI). This has possibly contributed to an increase in afforested areas in starting 2012.

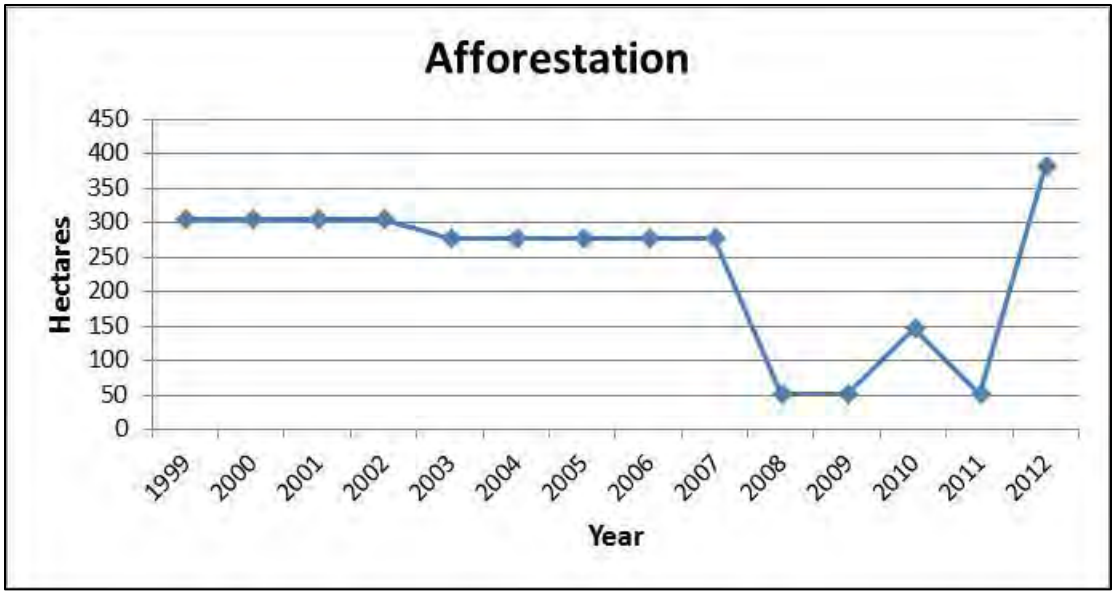

Figure 17. Afforestation areas per year.

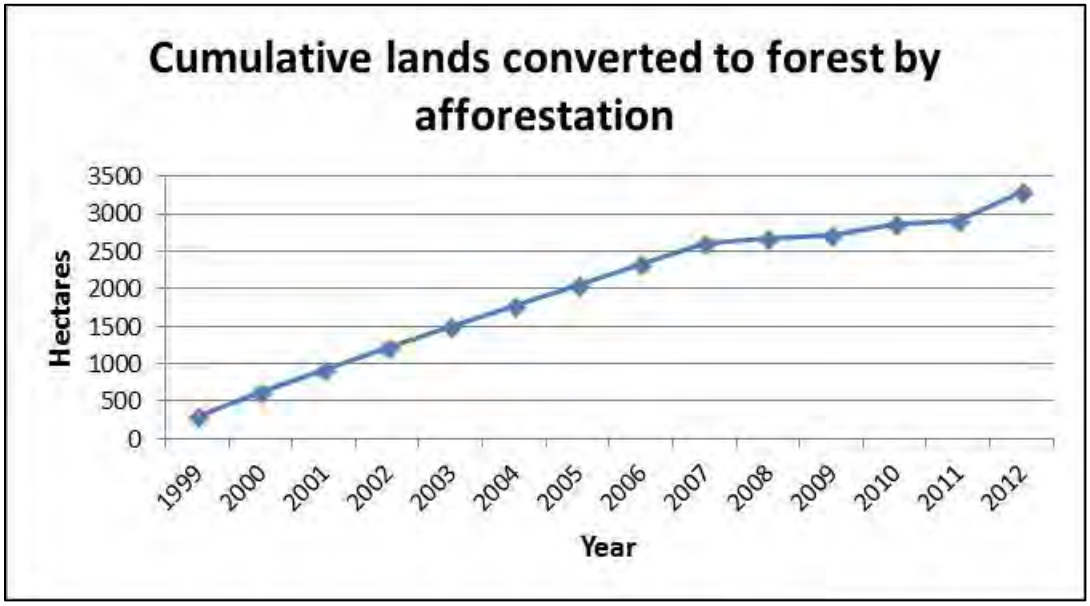

Figure 18. Cumulative lands converted to forests over the inventory period.

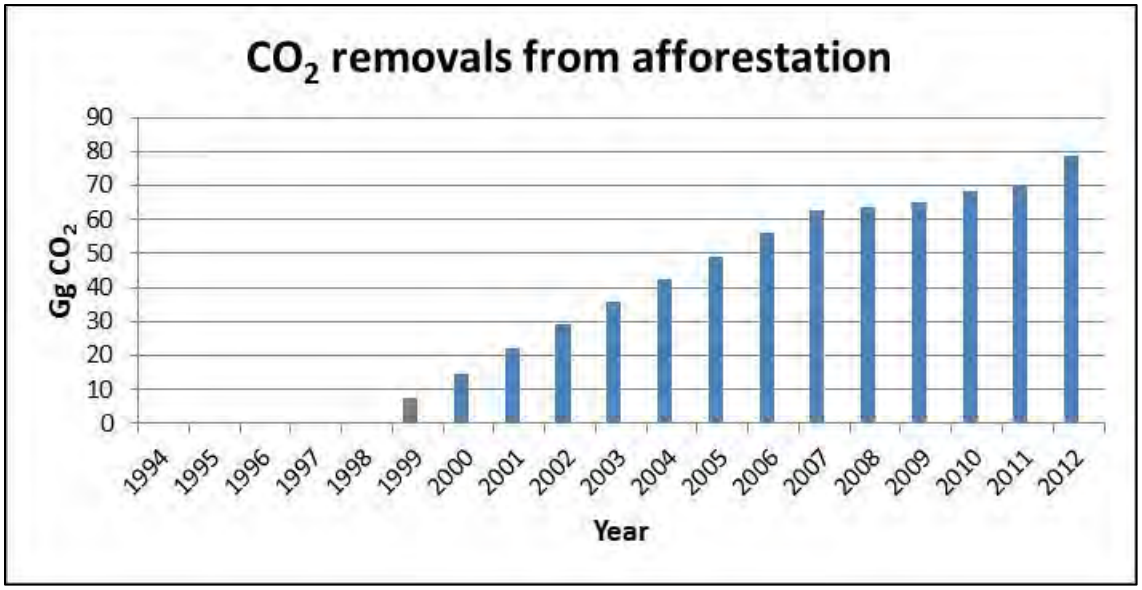

Figure 19. CO_2 removals due to biomass increments and increase in soil carbon stocks from afforestation.

Furthermore, the decline in cropland areas covered with perennial woody crops (Figure 20) resulted in the decrease of CO_2 removals by 1.7% from 1994 to 2012 with an average rate of 1.1 Gg/yr (Figure 21).

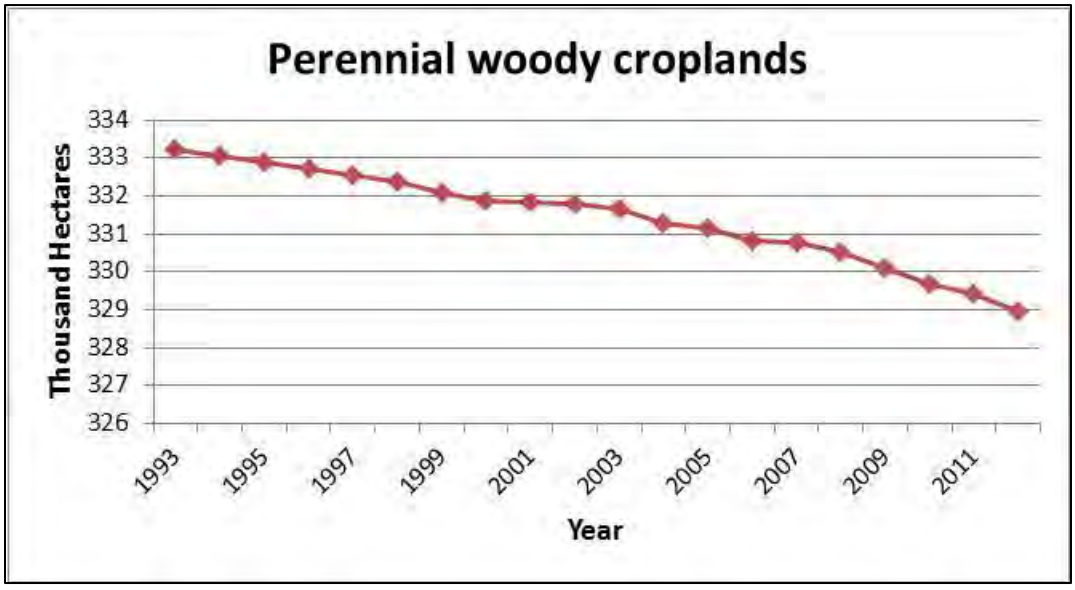

Figure 20. Areas of croplands remaining croplands over the inventory period.

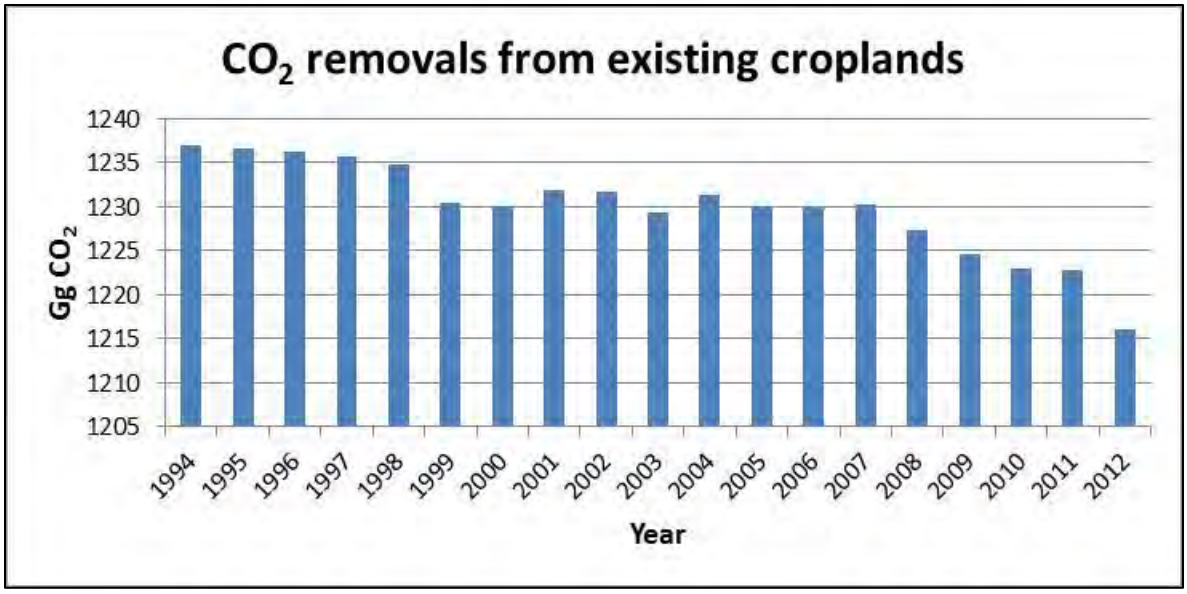

Figure 21. CO_2 removals due to biomass increments from perennial woody crops.

5.3. Changes in CO_2 emissions

Again, as previously stated, the lack of data derived from satellite imagery and surrogate data of burned areas for the period 1994-1997 resulted in gaps about emission estimation in comparison with the period of 1999-2012. The main source of GHG emissions are wildfires affecting forest land, cropland and grassland. It can be observed that the fire affected area was highly variable for the last decade. A large trend of inter-annual variability of fire extent was recorded between 1999 and 2012, with three clear peaks in 1999, 2006 and 2012 (Figure 22). More specifically, the largest forest fire affected areas were recorded in 2006 (~1197 ha), while the largest cropland fire affected areas were recorded in 2012 (~ 1305 ha).

The spatial distribution per Caza of the total burned areas between 1998 and 2012 were also represented in maps (Appendix V). Accordingly, the highest rates of burned forest land were recorded in the Cazas of Aakkar, Aaley, and Sour (>600 ha), followed by the Cazas of Chouf, Beqaa El Gharbi, and Bent Jbeil (between 400 and 600 ha). In addition, the highest rates of burned perennial cropland were recorded for the Caza of Zahle (> 4000 ha), followed by the Caza of Beqaa El Gharbi (between 1500 and 4000 ha).

The peaks in the extent of fire affected areas might be related to the remarkable extended drought conditions during those years, which significantly contribute to water stress in the vegetation cover. This allows larger fire spread across the vegetated landscape.

In a recent study conducted by Salloum and Mitri (2013), it was found that the length of the fire season has been increasing on an average of 5.2 days during the past decade. Fire occurrence was positively correlated with mean monthly temperatures, and the length of the fire season was negatively correlated with mean annual precipitation. In addition, an increasing fire occurrence risk was observed in association with high maximum temperatures and long dry seasons.

The 2006 July war might have contributed to increasing the extent of burned areas, especially in South Lebanon. Given that most of the conflict took place before the start of the normal fire season, it is likely that most of the outbreaks were caused by bombing incineration. A review of archive satellite data from NASA's MODIS Rapid Response System (MRRS) detected only two fire events in southern Lebanon between 12 July and 13 August in 2004 and 2005 respectively, but registered 48 fire events during the same period in 2006. Damages from fires affected olive trees, broadleaf species and maquis scrub vegetation (UNEP, 2007). It is to be noted that broadleaf was found to be more affected by fires mainly due to the large extent of broadleaf vegetation cover.

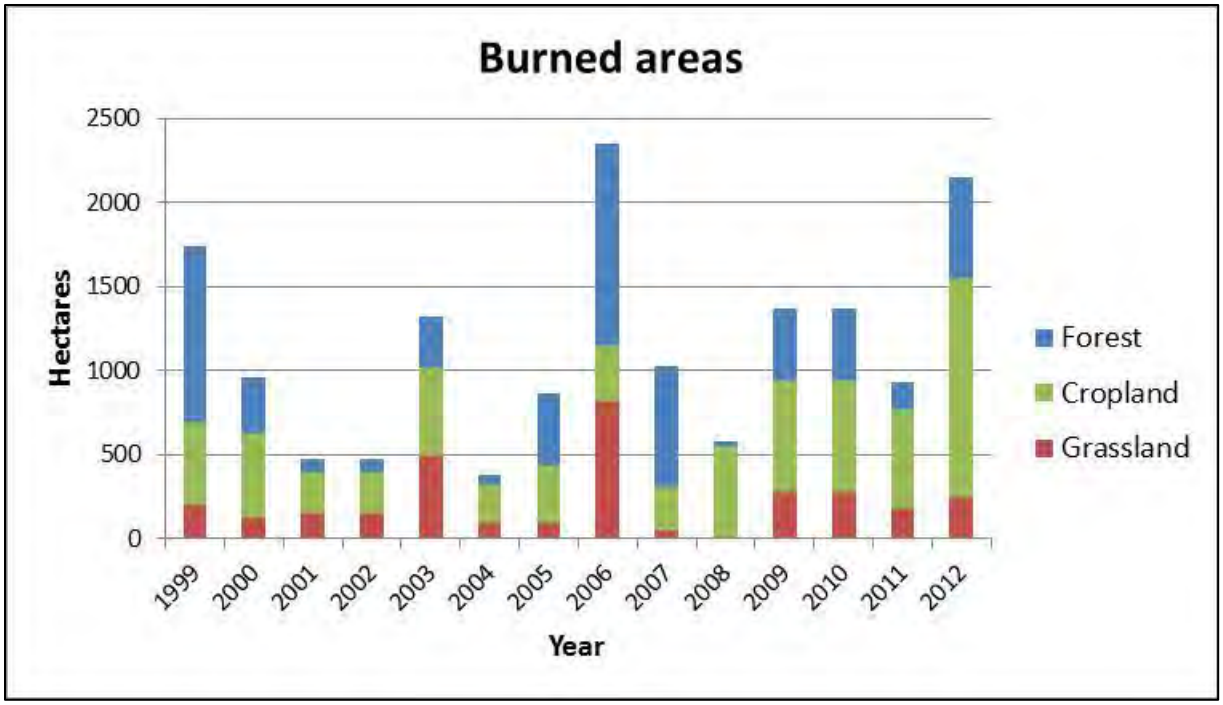

Figure 22. Burned areas.

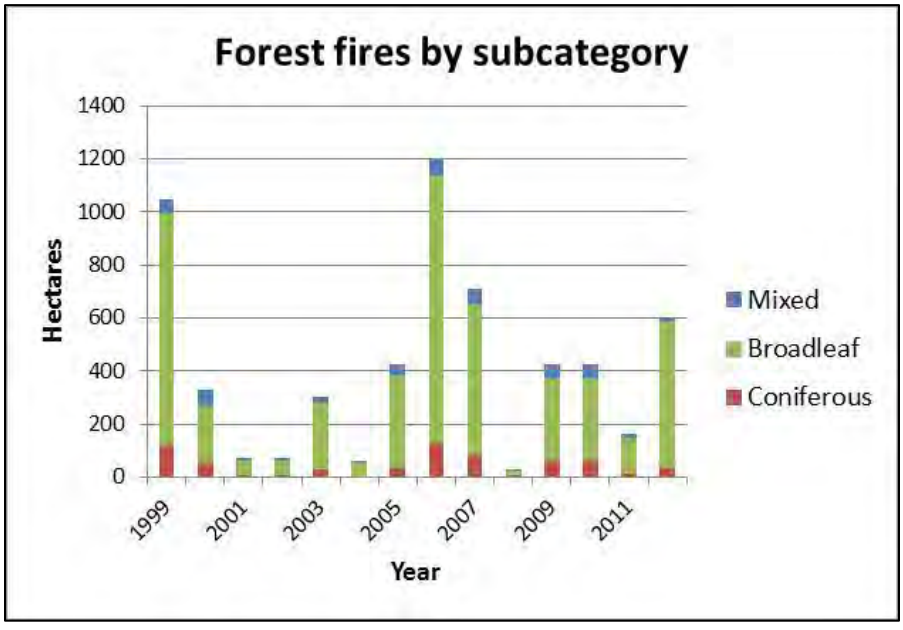

Figure 23. Areas of forest fires by subcategory.

Only non-CO_2 emissions (namely CO, CH_4, N_2O, and NO_x) from burned grasslands were accounted for in the inventory. CO_2 emissions from burned grasslands were not accounted for in Tier 1 of the IPCC GPG for LULUCF, since it was assumed that there was a balance in biomass stocks of grasslands. Therefore, losses from only burned forests and croplands were the main sources of CO_2 emissions (Figure 24).

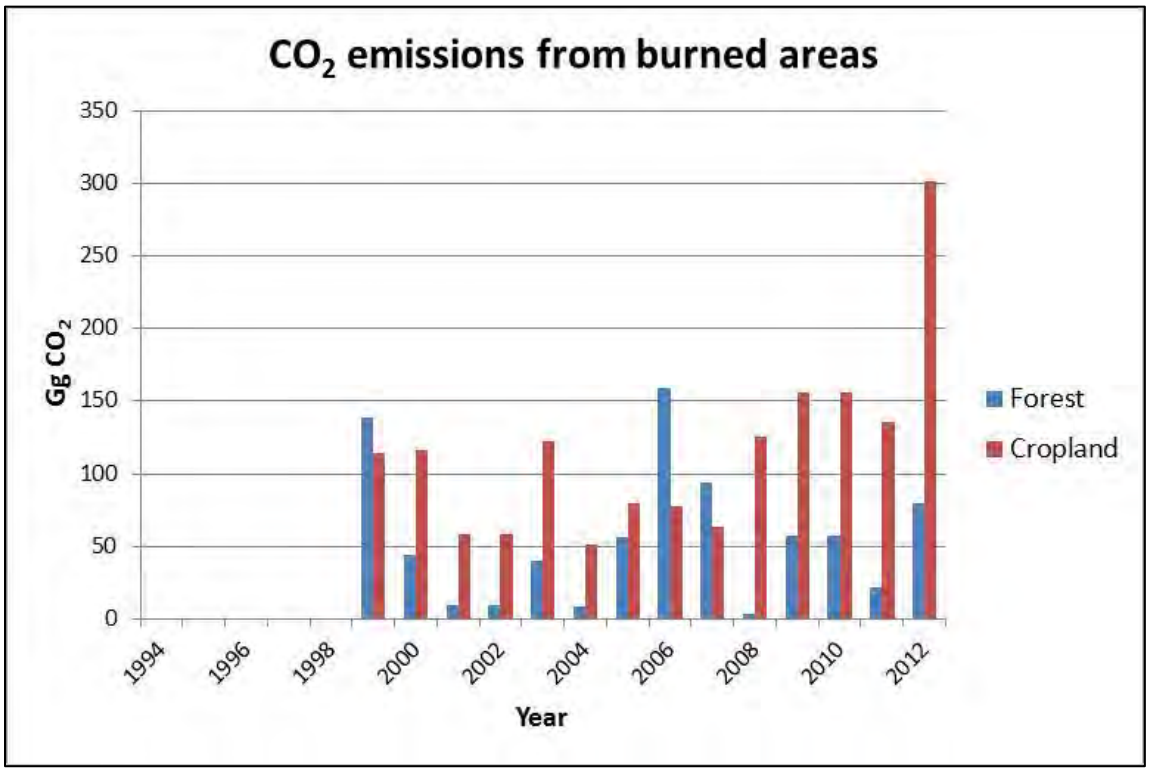

Figure 24. CO_2 emissions from burned areas.

The main source of CH_4 and N_2O emissions of the LULUCF sector were forest fires (Figure 25 and Figure 26). CH_4 and N_2O emissions from croplands were not accounted for in the GPG for LULUCF since the source of these types of emissions were mainly agricultural activities (fertilization, livestock, burning, etc…) that happen in croplands. These were included in the agricultural sector rather than in the LULUCF sector.

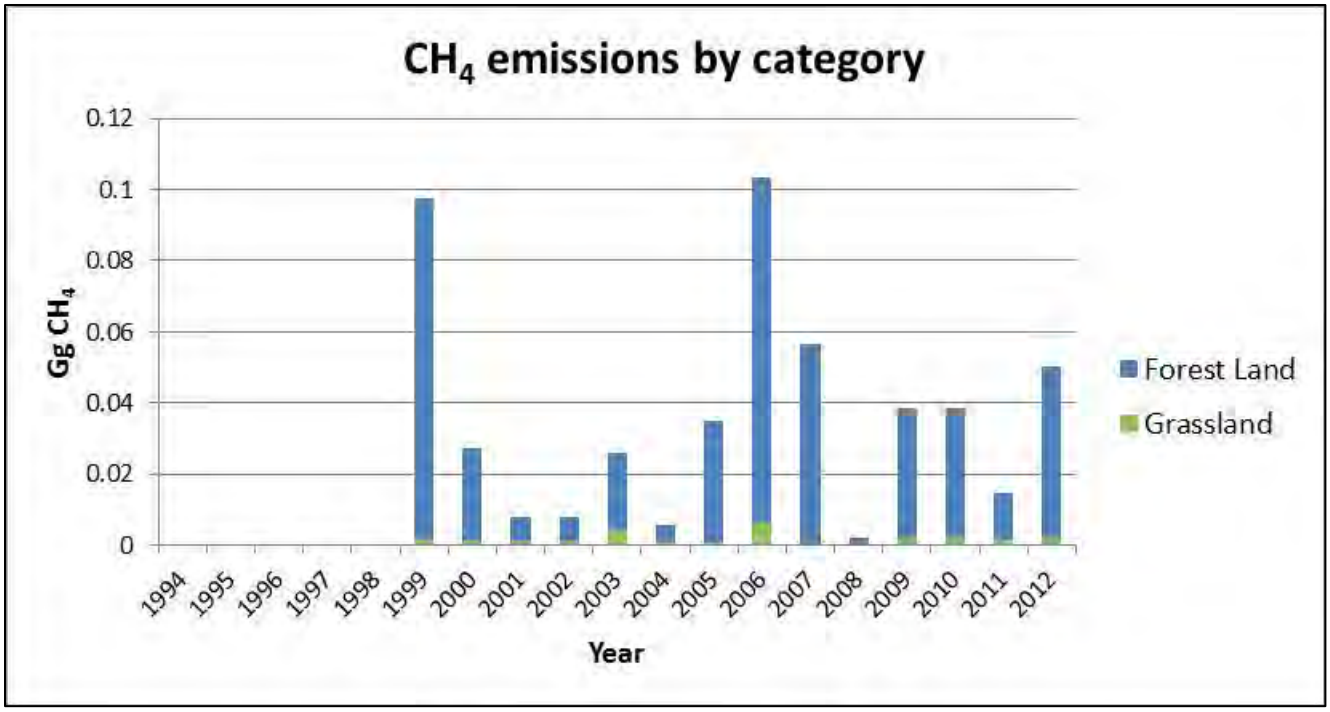

Figure 25. CH_4 emissions by category.

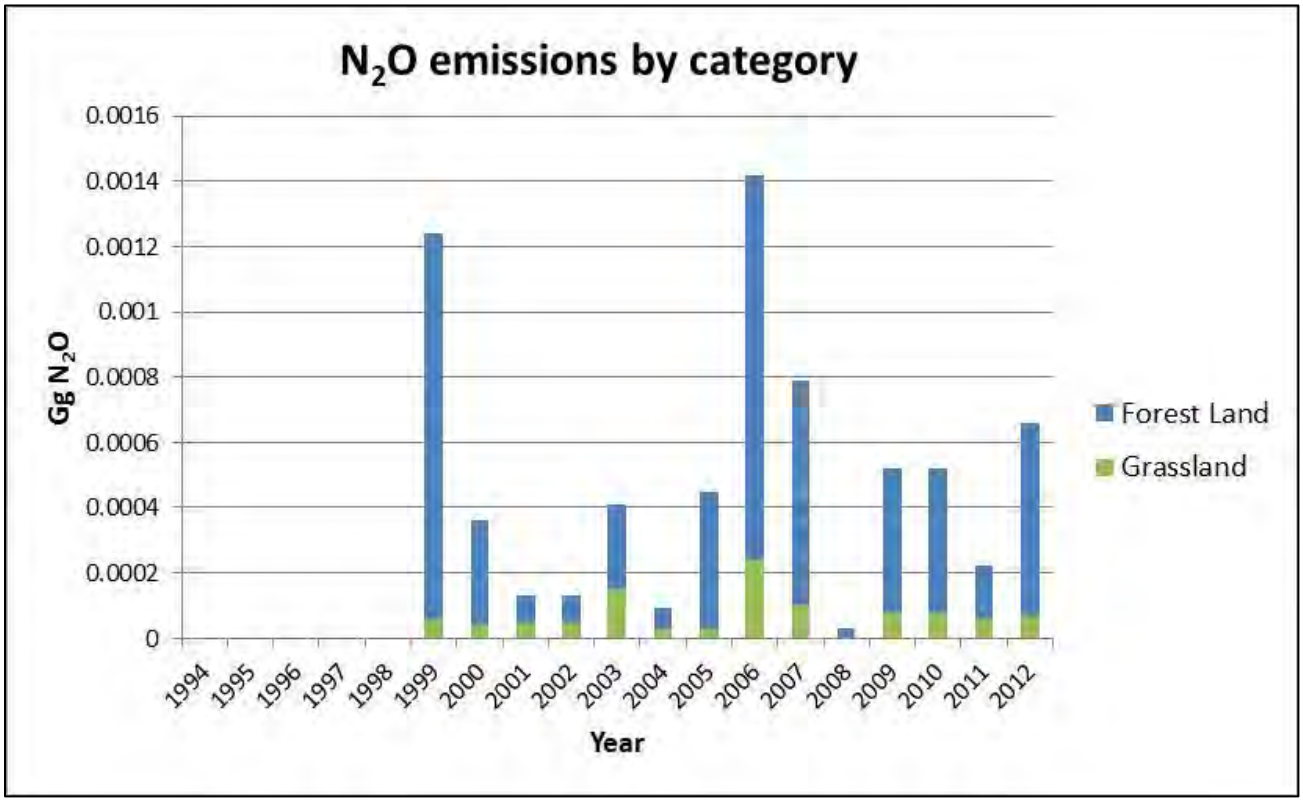

Figure 26. N_2O emissions by category.

NO_x and CO emissions were emitted by burned forest areas as well as burned grassland areas with specific emission factors according to the fuel type of each category (Figure 27 and Figure 28). Same as reported by the SNC, CO emissions from fires exceeded NO_x emissions; however, total estimates differed due to differences in activity data of burned areas which were more accurately assessed in this report through remote sensing techniques.

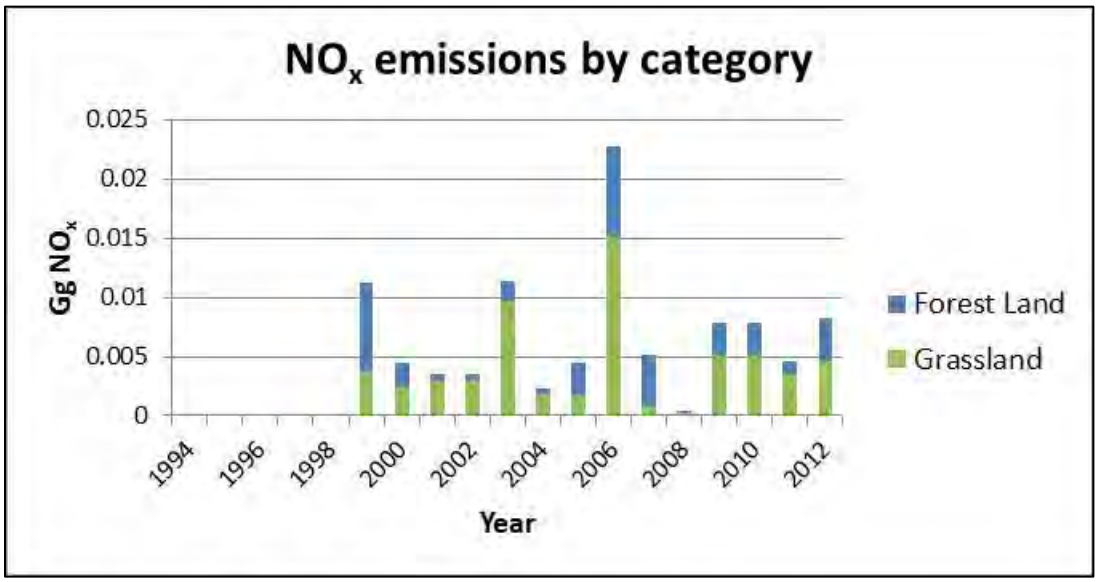

Figure 27. NO_x emissions by category.

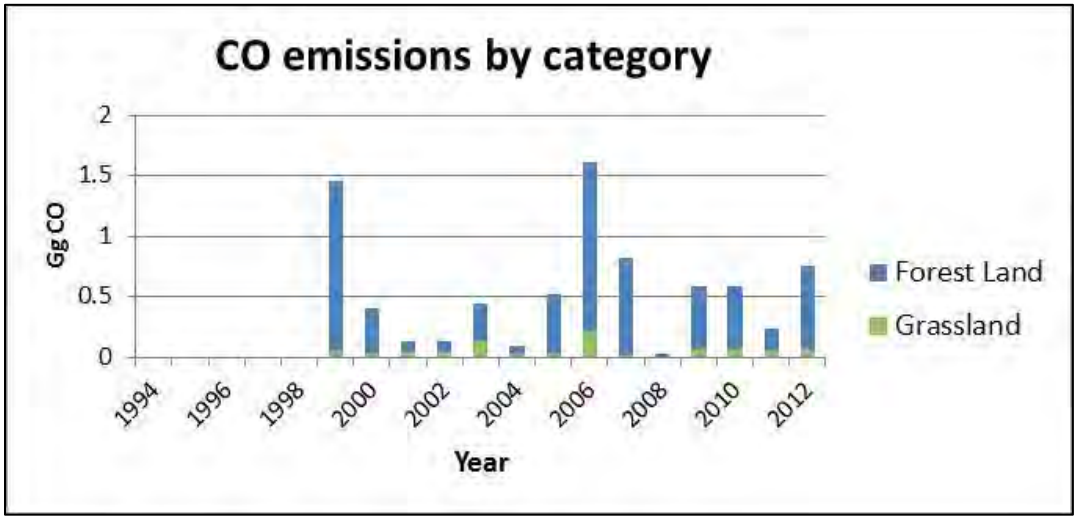

Figure 28. CO emissions by category.

5.4. Contribution of categories in GHG emissions/removals

Forests followed by croplands have the largest contribution to CO_2 emissions/removals in the LULUCF sector in Lebanon (Figure 29). However, further data (when available) on areas of wetlands (namely hill lakes) and grasslands along with their management systems (e.g. status of grazing,) can help in providing new insights on their level of contribution in GHG emissions or removals in the future.

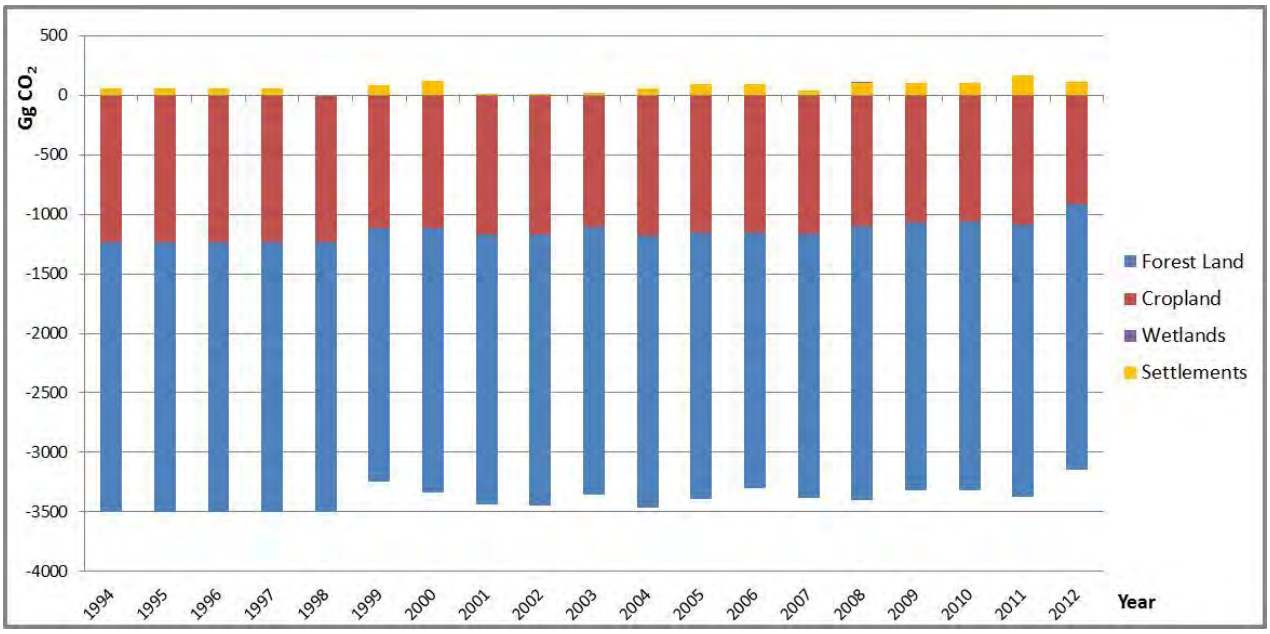

Figure 29.CO_2 emissions/removals by category.

5.5. Trend in Lebanon's GHG emissions for LULUCF sector: 1994-2012

5.5.1. Trend analysis

The GHG emissions/removals for the time series of 1994 up until 2012 was done following the QC procedures recommended by the IPCC GPG for LULUCF to ensure temporal consistency. The consistency of input data for each category of sources and sinks was taken into consideration as well as the use of a consistent methodology for the calculations and the recalculations. Some country-specific data about lands converted to wetlands, croplands and grasslands were not taken into account, either because they were incomplete, or because they were acquired using

different methodologies. Their inclusion in the calculations might have resulted in inconsistent time series.

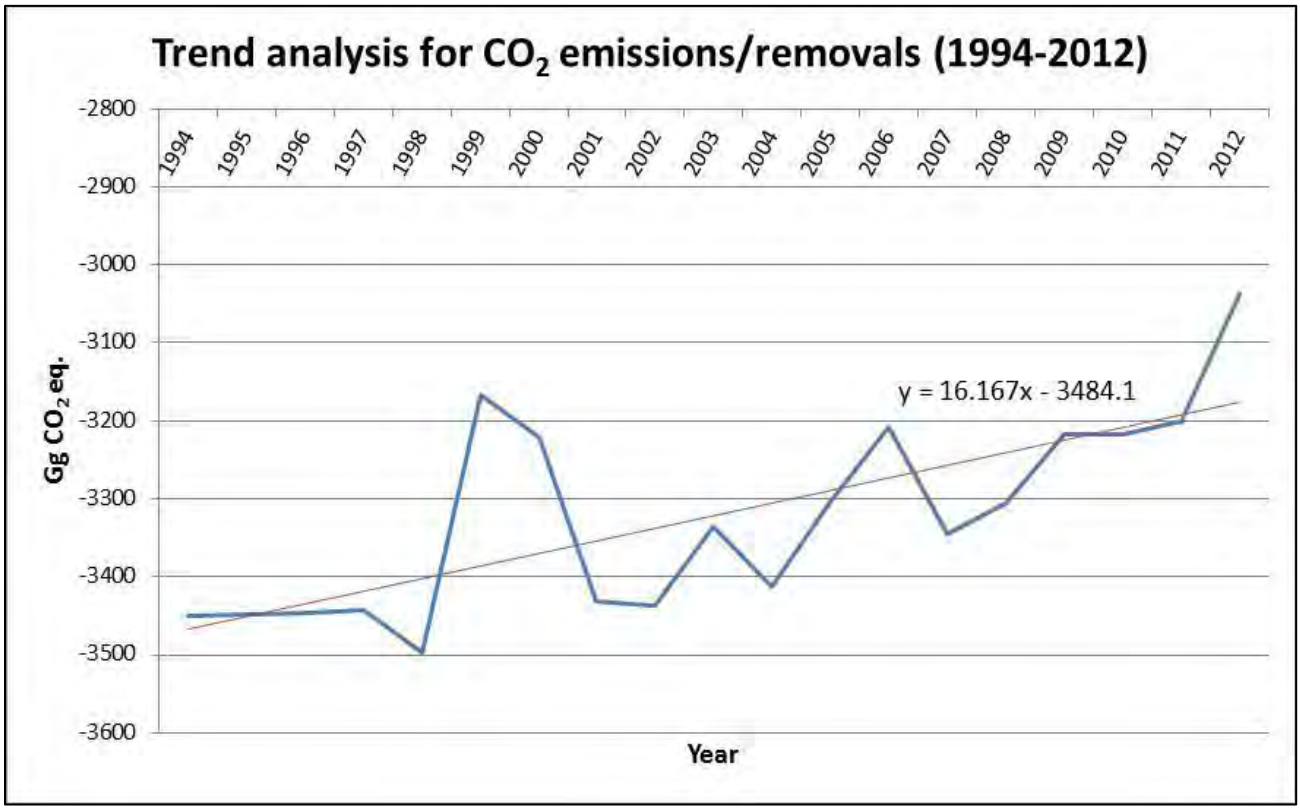

Figure 30. Trend analysis for CO_2 emissions/removals over the inventory period 1994-2012.

The analysis of the changes in CO_2 emissions/removals of the LULUCF sector over the last 19 years showed a net decrease in CO_2 removals from the LULUCF mainly due to losses in the vegetation cover resulting essentially from land conversions to settlements and wildfires among others (Figure 30).

5.5.2. LULUCF indicators and comparison with Mediterranean countries

In this report, two main indicators of emissions from the LULUCF sector were selected for comparison among Mediterranean countries: 1) Net CO_2 emissions due to forest conversions, and 2) Change in CO_2 removals from the LULUCF sector. The comparisons involving these two indicators were made possible due to availability of specific data.

The FAOSTAT emissions land use database provides country-level estimates of GHG emissions based on FAOSTAT activity data using Tier 1 computations, following 2006 IPCC Guidelines for National GHG Inventories. The data consists of the net contribution of CO_2 sources and sinks due to deforestation and reforestation/afforestation activities within countries. FAOSTAT data about Mediterranean countries were compared to the recently collected and calculated data of Lebanon on CO_2 increase/decrease in removals from forest conversion to settlements and lands converted to forests (afforestation). Accordingly, the first indicator (Figure 31) showed the net CO_2 emissions due to forest conversions of Mediterranean forests relative to the period of 1994-2010. Lebanon's net changes in CO_2 removals were relatively low between -30 Gg CO_2 and 90 Gg CO_2 (Figure 32). Net changes in CO_2 removals in Cyprus were the closest to Lebanon's. The largest variation of CO_2 removals between 1994 and 2000 were recorded for Morocco.

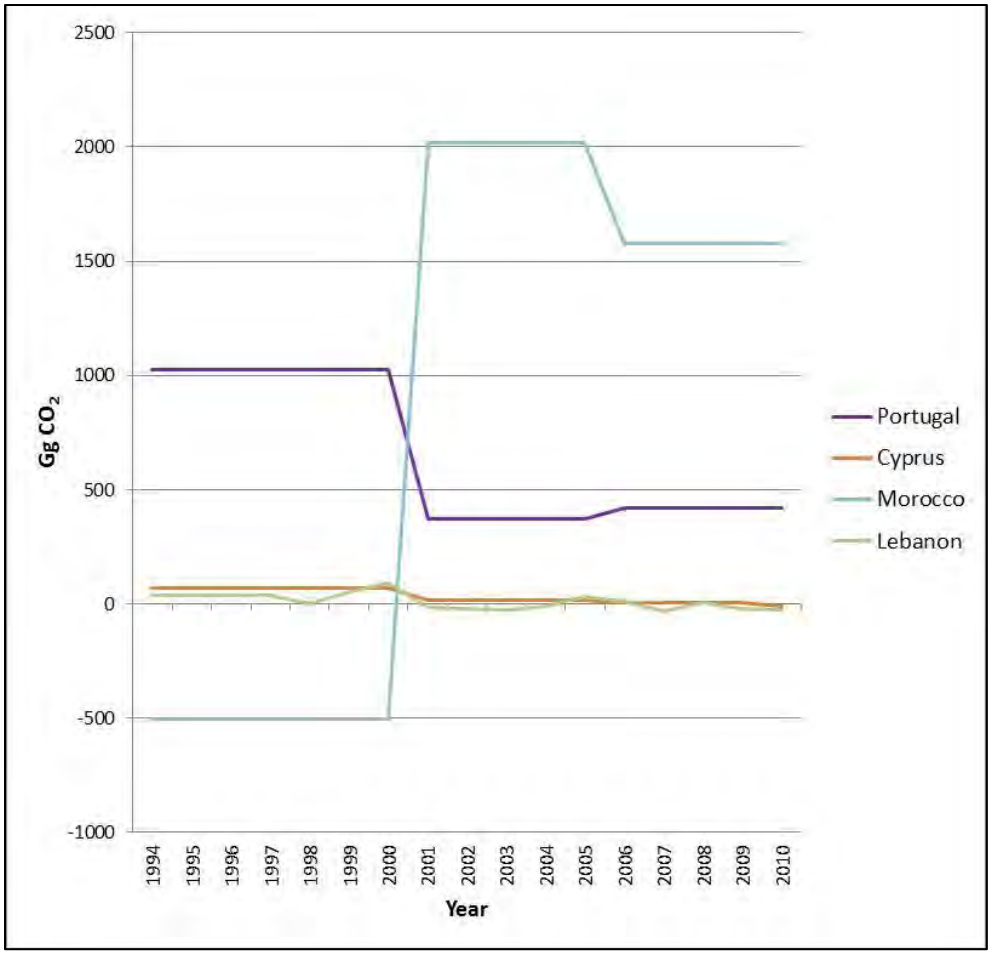

Figure 31. Net changes in CO_2 removals from forest conversions of forests in Mediterranean countries (FAOSTAT, 2013).

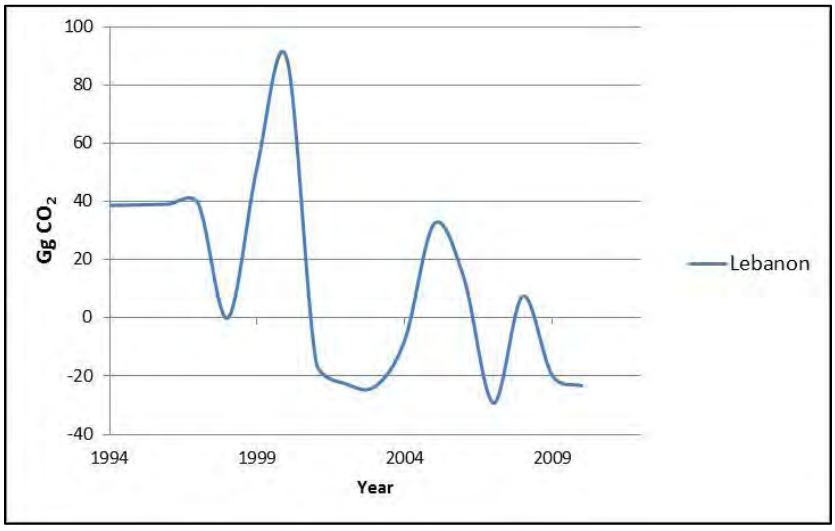

Figure 32. Net changes in CO_2 removals from forest conversions in Lebanon.

The second selected indicator was the change in CO_2 removals of the LULUCF sector between 1994 and 2010. Lebanon and Greece showed a decrease in CO_2 removals during this period that might be caused by a decrease in removals or/and an increase in CO_2 emissions (Figure 33). Italy, Turkey and Spain showed increasing CO_2 removals by about 27%, 32% and 48% respectively (UNFCCC, 2013).

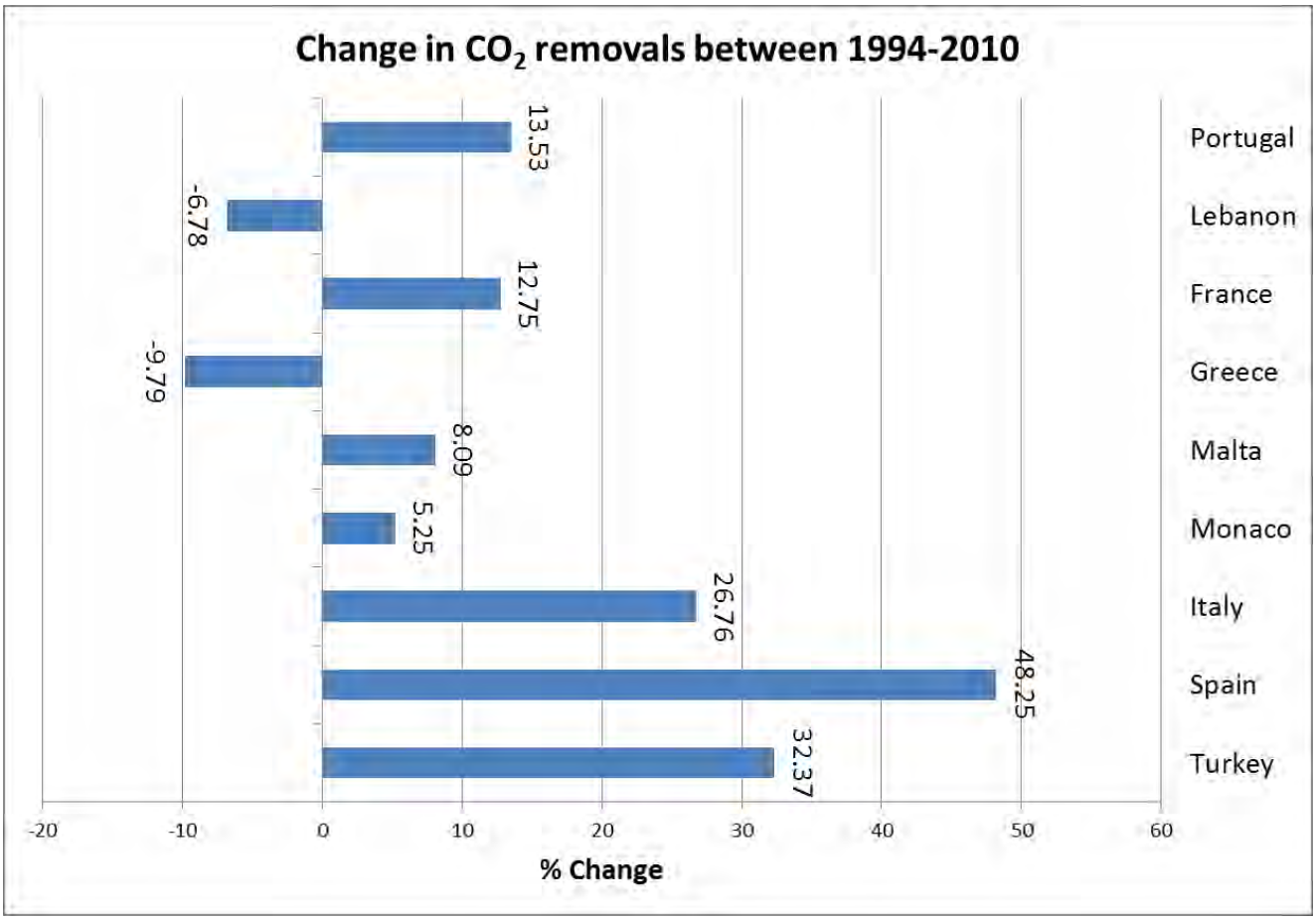

Figure 33. CO_2 removals changes between 1994 and 2010 in some Mediterranean countries (UNFCCC, 2013).

6. Conclusions

This work consisted of estimating GHG emissions for the LULUCF sector in Lebanon under the IPCC GPG. The use of a consistent methodology for activity data and emission factors collection and calculation over the inventory period (1994-2012) allowed the development of a consistent time series. The new data allowed the re-calculation of the estimations for the years 1994-2004 and the calculation of the estimations for the years 2005-2012.

More specifically, the use of multi-temporal satellite remote sensing data helped in increasing the accuracy of the activity data and decreasing the uncertainty of the overall estimates. In addition, change detection mapping involving satellite imagery allowed the generation of data about emissions from land use changes such as forest, croplands and grasslands conversions to settlements. These changes proved to be main sources for CO_2 emission and decrease in removals in the LULUCF sector in Lebanon. Moreover, the accurate mapping of burned areas allowed the identification of CO_2 as well as non-CO_2 emissions from wildfires. Likewise, the compilation of E/R factors was done following the GPG and taking into consideration the requirements of disaggregation within each of the categories.

The main findings indicated that the LULUCF sector is a major GHG sink highly contributing to the mitigation of the overall national GHG emissions. At the same time, the emissions from forests as well as croplands and grasslands due to land use changes were estimated to be higher than the removals resulting from afforestation activities.

Overall, the changes in forest and vegetation covers between 1994 and 2012 resulted in about 12% (21.8 Gg CO_2 eq. /yr) decrease in CO_2 removals from the LULUCF sector. Lebanon was found to have 6.78% decrease in CO_2 removals from the LULUCF sector between 1994 and 2010, whereas CO_2 removals significantly increased (by 5% to 48%) in other Mediterranean countries during this period.

An improved GHG estimation of emissions/removals in the future should include the development of unified national databases, documentation and reporting of national data collection and calculation methodologies, and clear reporting and referencing of information.

Such system will require the collaboration and cooperation among the different National authorities.

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Section 2:

GHG Mitigation Analysis for the LULUCF sector in Lebanon

List of Tables

List of Figures

Summary

Recent Greenhouse Gas (GHG) estimations revealed a 12 % net decrease in CO_2 removals from the Land Use, Land Use Change and Forestry (LULUCF) sector between 1994 and 2012. This was mainly due to the conversion of vegetation into settlements, in addition to relatively high emissions from forest fires. Accordingly, there is an urgent need to design mitigation actions that would limit GHG emissions and maintain the level of carbon sequestration from the LULUCF sector.

This work consisted of identifying and analyzing mitigation scenarios along with economic instruments that can be potentially used for their implementation. Taking into account the fact that forests have the largest contributions to GHG emissions/removals, the proposed two mitigation scenarios comprised: 1) maintaining the current extent of Lebanon's forest and other wooded land cover, and 2) increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030. Forest fire considerations, in both scenarios, were recommended. More specifically, the implementation of the second (risk modification), fourth (response) and fifth (recovery) components of Lebanon's National Strategy for forest fire management were addressed. At the same time, economic instruments were proposed for the implementation of the scenarios. These included: 1) Payment for Environmental Services (PES), 2) Subsidies, 3) Land conversion and 4) Community forestry. Instruments were evaluated through a SWOT analysis to determine their applicability in Lebanon and their suitability for each of the proposed scenarios.

Results of the analysis indicated a 12.57% reduction potential for scenario 1 and 38.5% reduction potential for scenario 2. The proposed mitigation actions should be accompanied by a general reform of the management plans and legislative frameworks of the forestry sector. Most importantly, it was highlighted that the reactivation of the "Reforestation Fund" (called Sandouk al Tahrij) at the Ministry of Finance (MoF) would be an essential step towards for the sustained implementation of the identified economic instruments.

1. Scope

This work aims at providing an analytical approach for identifying certain measures to reduce GHG emissions and enhance carbon sinks in the country, based on the findings of the most recent LULUCF National GHG Inventory. Mitigation options will be selected and analyzed according to their direct and indirect environmental and economic impact, consistency with national strategies (e.g. Lebanon's National strategy for forest fire management, Decision No. 52/2009, and the National Reforestation plan of the Ministry of Environment), economic feasibility, and compatibility with implementation policies (e.g. the developing National Forest Plan), sustainability, and other specific criteria such as feedback from national experts.

2. Introduction

As previously stated in Lebanon's Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC), mitigation scenarios are proposed plans and projects that have a potential for sectorial emission reduction or sink enhancing. Furthermore, mitigation options should be selected and analyzed mainly according to their direct and indirect economic impact, consistency with national development goals, and economic feasibility.

The SNC previously suggested the following mitigation options in the forestry sector:

- Scenario 1: Maintaining and conserving existing forest carbon sinks
- Scenario 2: Afforestation and reforestation including agroforestry and sylvo-pastoral systems
- Scenario 3: Substituting fossil fuels by forest-based biofuels.

Several measures have been proposed through which these mitigation options can be implemented (Table 7):

Table 7. Measures for achieving mitigation scenarios proposed in the SNC (MOE/UNDP, 2011)

Mitigation Scenario 1
- Adopting sustainable forest management practices (grazing, NWFP, harvesting of wood in forests and OWL) to address the possible threats to these ecosystems and improve their status. - Preventing forest degradation and habitat fragmentation through sustainable management, land use management, insect and pest management and forest fire fighting strategies, which will provide stability for ecosystems to permit the establishment of ecological equilibrium, and therefore the reduction of habitat loss and degradation. - Rehabilitating abandoned lands and degraded zones to ensure natural or assisted forest regeneration and development Additional activities for forest protection, management and monitoring: - Wood clipping and pruning of trees, including transportation of pruning residues; - Clearing of grass and weeds along the borders of all roads surrounding forests and OWL on a yearly basis for the purpose of fire protection; - Vehicles equipped with water tanks and pumps for patrolling all forest and OWL areas; - Forest guards in charge of monitoring a specific region to prevent fires and control grazing and deforestation of newly reforested areas. Violations would be dealt with in coordination with the Internal Security Forces; Setting up a communication system between guards; - Managing pests in forests and OWL by spraying pesticides by plane.
Mitigation Scenario 2
- Implementation of the National Reforestation Plan (NRP), which stipulated the use of native species in each site according to the ecological criteria, the climate and soil characteristics in the related ecosystem and which has banned the introduction of non-native species. - A forest genetic resources conservation and management strategy should be implemented, including the management of seeds provenances. - Including efforts of agroforestry or even urban greening (recreation areas, urban parks, etc.). Linking forests and OWL through corridors and creating contiguous forest lands reduces habitat fragmentation.
Mitigation Scenario 3
OWL can serve as the main source of biofuel from wood clipping and sylviculture practices. The density of forests and OWL can also be reduced to provide biofuel while also reducing the fire risk.

New and improved data and methodology were used in the Third National Communication (TNC), to estimate and report the greenhouse gas emissions resulting from changes in Land Use, Land Use Change and Forestry (LULUCF) sector in Lebanon for the period of 1994-2012. Most importantly, the adopted method involved the use of up-to-date remote sensing techniques as part of the approach 3 in the "*Good Practice Guidance*" adopted by the IPCC (2003), which allowed more precise estimation of land use and land cover change areas.

The LULUCF sector proved to be a major sink for Greenhouse Gases (GHGs) with an average of 3321 Gg/yr of CO_2 eq. sequestrated over the inventory period of 1994 to 2012. A 12 % net decrease in CO_2 removals from the Land Use, Land Use Change and Forestry (LULUCF) sector was recorded between 1994 and 2012. This was mainly due to the conversion of vegetated lands into settlements. In addition, forest fires appeared to have a large contribution in increasing GHG emissions and thus decreasing the net sequestration effect of the LULUCF sector.

In this context, there was a need to design and develop mitigation actions that could help in maintaining and/or increasing carbon removals from this sector, especially by targeting the forest cover which is one of the main sources of GHG emissions and removals of the sector. Accordingly, proper mitigation needed to be identified and analyzed along with their potential economic instruments.

The purpose of this work was to propose certain measures to reduce GHG emissions and enhance carbon sinks in the country based on the findings of the most recent LULUCF National GHG Inventory and taking into account what has been achieved in the Second National Communication (MOE/UNDP, 2011). The work involved extensive literature review about 1) economic instruments for environmental protection, 2) the economic perspective of forest development, and 3) policy instruments for environmental and natural resource management (an application for forestry and LULUCF in general).

3. Background information

3.1. Facts about the forest sector in Lebanon

The review of previously developed Forest Resources Assessment (FRA) reports in addition to other reports and documents addressing the forest sector in Lebanon allowed highlighting some important facts (FAO, 2005, FAO, 2010, Mitri and El Hajj, 2008 and MoE/UNDP/ECODIT, 2011):

- The majority of forests and other wooded land are privately owned (60.4% and 80% respectively) (FAO, 2005).
- 97.4% of forests are production forests (FAO, 2005)
- 85.1% of forests are somehow disturbed by human activity (FAO, 2005)
- Fuelwood collection represents the main activity undertaken in these forests followed by plant food collection. Several other products such as honey, pine, oregano, sumac are collected from the forests.
- Main threats to the forest cover include: fire, insects, diseases, urban expansion, changes in land-use, quarries, armed conflict.
- Existence of gaps in Lebanese legislation/policies on forestry:
  a) Lack of a forest policy statement.
  b) Lack of management rights of public forests.
  c) Lack of a National Forest Program (there is one under development at the Ministry of Agriculture).
  d) Overlapping responsibilities among the Ministry of Agriculture, the Ministry of Environment, the Ministry of Interior and Municipalities and the Council for Development and Reconstruction.
- Lack of efficiency, coordination, and resources in undertaken reforestation and afforestation activities.

In this context, the establishment of a National Forest Authority was previously recommended (Mitri and El Hajj, 2008). In addition, Lebanon's National strategy for forest fire management was endorsed in 2009 (Decision No 52/2009) (AFDC/MOE, 2009).

3.2. Lebanon's National Strategy for Forest Fire Management

Lebanon's National Strategy for Forest Fire Management (AFDC/MOE, 2009) aimed at reducing the risk of intense and frequent forest fires whilst allowing for fire regimes that are socially, economically and ecologically sustainable. It highlighted the importance of fire management in Lebanon within a risk-management framework, known as the 5Rs (Table 8): (1) Research, information and analysis; (2) Risk modification, including fire vulnerability reduction and prevention of harmful fires; (3) Readiness, covering all provisions intended to improve interventions and safety in the event of fire; (4) Response, including all means of intervention for fire suppression; and (5) Recovery, including the rehabilitation and ecological restoration of healthy forest conditions, and the support to individuals and communities in the short- and medium term aftermath of the fire.

Table 8. The five components for the implementation of Lebanon's National Strategy for Forest Fire Management.

Component 1: Research, Information and Analysis	To support and promote the improvement, know-how sharing, monitoring and dissemination of knowledge on fire ecology, fire management and post-fire vegetation dynamics among all relevant actors (science/research, policy makers, land managers, grassroots' groups), bridging science and traditional knowledge.
Component 2: Risk modification	To develop effective measures intending to reduce fire vulnerability, increase ecological and social resilience to fire, and prevent the occurrence of harmful fires and unsustainable fire regimes. Minimizing the risk of fire and preventing harmful fires has four main elements: a) The adoption of spatial planning processes to ensure that natural and built assets are identified in relation to fire risk and to agree on landscapes with more resilient types of land uses and spatial distribution of uses and infrastructures within territorial units. b) The adoption of management practices within the landscape to help minimizing the risk of damage to life, the natural environment and

	built assets. c) The establishment of policies and economic instruments to support land owners, users and managers in the adoption of risk reduction management practices and land uses. d) Reducing the frequency of ignitions that result from arson and carelessness.
Component 3: Readiness	To undertake all possible provisions by individuals, communities and fire and land management agencies to be prepared before a fire event occurs, and improve interventions and safety in monitoring the probability of fire and detecting the event of fire.
Component 4: Response	To suppress the fires within the first 20 minutes after they start and limit the extension of fires through the development of methods and techniques coupled with appropriate material and very well trained personnel. The highest levels of preparedness should take place during high fire risk periods. Activities to be undertaken in close collaboration among all concerned stakeholders include: a) Empower and build the capacities of the Civil Defense to fight forest fires. b) Train other stakeholders on fire suppression to assist the Civil Defense or to interfere at the early stages of the fire, thus avoiding the expansion of the fires and organizing common training activities. c) Develop the capabilities of air firefighting by helicopters. d) Develop an appropriate legal framework and empower the law enforcement agencies to better punish those in charge of the voluntary or non-voluntary (accidental) fires. e) Develop and implement an appropriate legal framework for the establishment of a common forest-fire operations room or what would insure the coordination of fire suppression activities and implement the most appropriate coordination mechanism among all concerned stakeholders. f) Provide firefighting personnel, including NGOs and CBOs with the most adapted and most appropriate equipment, based on the level of intervention of each stakeholder. g) Monitor fires after suppression to prevent restarting. h) Improve the role of municipalities in fire suppression.
Component 5: Recovery	To provide support for individuals and communities in the immediate aftermath of the fire as well as in the medium and longer term efforts of community and economic renewal, and restore healthy ecological conditions of burned forest land to facilitate the natural recovery of vegetation and increase forest resilience against future fires. Activities to be undertaken in close collaboration among all concerned stakeholders include:

	a) Analyze the post-fire emergency needs of individuals and communities and establish a 'Solidarity Fund' which gives them adequate support. b) Map fire affected areas and assess the impact of fire on different vegetation types. c) Prohibit grazing in burned forests (forest law prohibits grazing for the 10 years following a destructive forest fire) and prohibit land use change of a burned forest for the 10 years following a fire. d) Implement activities aiming at the reduction of soil erosion when the winter starts, as erosion is one of the most severe fire consequences. e) Develop post-fire active restoration/rehabilitation protocols and activities (forest landscape restoration), facilitate natural forest regeneration and undertake reforestation activities in areas where regeneration is not possible. f) Support ecological restoration actions undertaken by the Department of forests and natural resource to recover resilient vegetation types for reducing fire risk and assist the natural regeneration by protecting the burned ones. g) Develop post-fire snags and woody debris management guidelines for the Lebanese forest ecosystems and forest areas, and modify the existing legislation that prohibits the removal of burned trees accordingly. h) Develop a national reporting system, based on statistics as well as the common post-fire ID cards and expand a national data base on forest fires, their occurrence, and the ecosystems where they emerge and the exact climatic conditions at the time of emergence…This would substantively contribute to better manage the forest fires in the future. i) Involving the local communities in the different activities related to post-fire management in addition to identifying socio-economic opportunities to link forest restoration and local development.

3.3. Reforestation initiatives in Lebanon

Pioneer reforestation projects have started during the late 1960s and early 1970s. During the past decade, Lebanon has initiated a number of programs/initiatives to restore forested lands. Such programs/initiatives included 1) the development of the National Reforestation Plan (NRP) by MOE in 2001, 2) the development of the National Action Plan to Combat Desertification by

the MOA in 2003, 3) the development of the project “Safeguarding and Restoring Lebanon’s Woodland Resources” to complement what has been started under the NRP in 2009, and 4) the launching of the project “planting four million forest trees” by the MOA in 2012.

The National reforestation initiatives have been complemented by the simultaneous implementation of several other initiatives undertaken by local Non-Governmental Organizations including among others 1) the Lebanon Reforestation Initiative (LRI) launched in 2012 with the support of the International Program of the US Forest Service and USAID to provide needed support in large-scale reforestation activities across the country, 2) the Association for Forests, Development and Conservation (AFDC) established in 1993 to achieve sustainable community-based conservation of forests and natural resources, raise awareness and build capacities to contribute to the national efforts for better environmental management, and 3) Jouzour Loubnan founded in 2008 and whose mission is to participate in the restoration of Lebanese woodland and promote sustainable reforestation mainly in arid region.

3.4. National Reforestation fund

Lebanon lacks of active and properly operational financial instruments to sustain large-scale reforestation/afforestation initiatives in the country. One of the main identified potential financial instruments comprised the “Reforestation Fund” (so-called Sandouk al Tahrij) which was stipulated by the Forest Law of 1949 (article 98). The “Reforestation Fund” states that the fines belonging to the State levied for forest infractions and the fines levied for violation of the provisions of the agricultural laws and regulations are paid to the Treasury Fund on behalf of the MOA to be allocated for public afforestation activities after approval of the Commission provided for in Article 89. It is to be noted that the “Reforestation Fund” has been inactive for a long period of time without the presence of any significant initiative to re-activate it.

4. Proposed mitigation scenarios, instruments and expert evaluation

4.1. Baseline scenario

The baseline scenario was developed based on the trend data from 1999 to 2012. Forest lands were specifically targeted in this scenario since they have one of the largest contributions to the changes in emissions and removals from the LULUCF sector. The main changes taken into account were: land conversions to settlements, burned areas, and afforestation activities (MOA, MOE, AFDC, LRI). In the absence of a clear trend for these changes, the cumulative averages (1999-2012) were used as baseline values. It is to be noted that areas of lands converted to forest lands by afforestation between 1999 and 2012 were added to the forest land area after 20 years of their conversion.

4.2. Mitigation options

Two mitigation scenarios were proposed. Each of the mitigation scenarios has addressed the emissions and removals from changes in the LULUCF sector in a way to reduce emissions and increase removals.

Mitigation scenario 1: Maintaining the current extent of Lebanon's forest and other wooded land cover.

Scenario 1 involved maintaining the current extent of Lebanon's forest and other wooded land cover (

Table **9**) through the reduction of new losses in the forest cover due to urbanization and through the compensation of losses to urbanization by afforestation/reforestation activities.

Table 9. Scenario 1 factsheet

Sector: LULUCF	
Subsector: Forestry	
Description	
Title	Maintaining the current extent of Lebanon's forest and other wooded land cover.
Introduction (brief description on the strategy/policy/project	Lebanon's forests and other wooded land cover are proved to be a major carbon sink, compared to other sectors, largely contributing to removing CO_2 emissions from the atmosphere. This cover is majorly affected by 1) annual loss of vegetation due to urbanization, and 2) intense and relatively large wildfires. Accordingly, this scenario suggests maintaining the extent of the current forest and other wooded land cover by: 1) Reducing the extent of new losses in the cover due to urbanization. 2) Compensating the annual loss to urbanization through afforestation/reforestation activities. 3) Modifying fire risk through fire vulnerability reduction and prevention of harmful fires (second component of Lebanon's National strategy for forest fire management Decision No.52/2009). 4) Preventing large and intense wildfires by adopting the strategic objective from the fourth component (Response) of Lebanon's National strategy for forest fire management.
GHG reduction	
Baseline	Calculations are based on trend data of 1999-2012. The following cumulative averages were taken into account: 1) Cumulative annual average (1999-2012) decrease in forest areas to urbanization from 2012 to 2030. 2) Cumulative annual average (1999-2012) afforestation areas from 2012 to 2030. 3) Cumulative annual average (1999-2012) forest fire areas from 2012 to 2030. Based on the above: • The total net cumulative removals from the LULUCF sector until 2030 are 55547.14 Gg CO_2 eq. • The total net cumulative emissions from the changes in

	the LULUCF sector until 2030 are 6760.5 Gg CO_2 eq.
Reduction potential	Reducing and compensating losses due to urbanization through the implementation of appropriate economic instruments: the cumulative reduction potential from 2013 to 2030 is equal to 39 Gg CO_2 eq. (approx. 0.57%) Preventing large and intense wildfires: the cumulative reduction potential from 2013 to 2030 (including CH_4 and N_2O) is equal to 813 Gg CO_2 eq. (approx. 12 %) Total cumulative reduction potential of mitigation scenario 1 is equal to 852 Gg CO_2 eq. (approx. 12.57 %). It should be noted that the prevention of large and intense wildfires contributes in 95.42% of the emissions reduction of the mitigation scenario.
Timeframe for implementation	Short to medium

Mitigation scenario 2: Increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030.

Scenario 2 involved increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030 (Table 10) through afforestation/reforestation activities in line with the national programs, initiatives, and previously identified principles (Box 1) to restore forested lands.

Table 10. Scenario 2 factsheet

Sector: LULUCF	
Subsector: Forestry	
Title	Increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030.
Introduction (brief description on the strategy/policy/project	The current cover of forests and other wooded land is 24.3%. This scenario suggests: 1) increasing the current extent of Lebanon's forest and other wooded land cover up to 31.3% through afforestation; and 2) facilitating the natural post-fire recovery of vegetation (fifth component of the National fire management strategy Decision No.52/2009). 3) preventing large and intense wildfires by adopting the strategic objective from the fourth component (Response) of Lebanon's National strategy for forest fire management. To increase the forest cover by 7 % (73164 hectares) during the period of 2013-2030, there is a need to plant about 4064 hectares per year over 18 years. In addition, the increase in forest and other wooded land cover accounts for the annual average losses to urbanization (244.78 ha/year). Therefore, the total area for afforestation is around 4309 ha/year.

GHG reduction	
Baseline	Calculations are based on trend data of 1999-2012. The following cumulative averages were taken into account: 4) Cumulative annual average (1999-2012) decrease in forest areas to urbanization from 2012 to 2030. 5) Cumulative annual average (1999-2012) afforestation areas from 2012 to 2030. 6) Cumulative annual average (1999-2012) forest fire areas from 2012 to 2030. Based on the above: • The total net cumulative removals from the LULUCF sector until 2030 are 55547.14 Gg CO_2 eq. • The total net cumulative emissions from the changes in the LULUCF sector until 2030 are 6760.5 Gg CO_2 eq.
Reduction potential	Increasing the current extent by 7% through the implementation of appropriate economic instruments: The cumulative reduction potential from 2013 to 2030 is equal to: 1792 Gg CO_2 eq. (approx. 26.5 %) Preventing large and intense wildfires: the cumulative reduction potential from 2013 to 2030 is equal to: 813 Gg CO_2 eq. (approx. 12 %) Total cumulative reduction potential of mitigation scenario 2 is equal to 2605 Gg CO_2 eq. (approx. 38.5 %). It should be noted that the prevention of large and intense wildfires contributes to 31.2% of the emissions reduction of the mitigation scenario.
Timeframe for implementation	Medium to long

Box 1: Principles for Forest Landscape Restoration in Lebanon

A recent publication in Lebanon comprised a numbers of measure that can help managers in forest landscape restoration activities (Navarrete Poyatos et al., 2011):

- Prioritize soil conservation and water regulation: loss of fertile soil remains the main reason for land degradation.
- Use native species: non-native species often lack natural control mechanisms like pests or competition, and can become invasive thereby threatening local biodiversity.
- Conserve and support biodiversity: restoration must safeguard the biological diversity of species at all scales.
- Promote diversity and heterogeneity at landscape scale: varied patches of vegetation at landscape level reduce vulnerability to perturbations and increase resilience.
- Design reforestation activities according to forest-fire prevention principles: although restoration techniques very often imitate the successional stages of the vegetation, intermediate stages with highly flammable components must be avoided.
- Promote forest multi-functionality and productivity: strike a balance between traditional goods and services, such as timber products, and new values demanded by society, including recreation and carbon sequestration

Available tools to achieve the above principles included:

- The implementation of Lebanon's strategy for forest fires management (AFDC/MOE, 2009)
- The establishment of native forest trees' nurseries:
  When planting trees, it is always best to utilize native tree and shrub seedlings from a locally adapted seed source because they are better adapted to Lebanon's extremes in weather and to regional planting sites; they are less likely to be stressed than non-native plants; and they are more resistant to insect and disease attacks (AFDC, 2008).
  Accordingly, a handbook was provided that covers all the technical aspects of restoration, from seed collection, through seedling production in the nursery, to planting out in the field (Navarrete Poyatos et al., 2011).
- The use of mapping tools.

One of the recent mapping tools is "The Reforestation Web-Mapping Platform of Lebanon" (www.lri-lb.org), developed by Lebanon Reforestation Initiative (LRI). It is a user–friendly mapping database that will serve as an online reference center for sustainable reforestation in Lebanon. The new reforestation mapping platform delivers cutting-edge online interactive maps that are accessible and easily used by reforestation practitioners to identify priority sites for reforestation, monitor forest tracks, anticipate appropriate native tree species, consider forest fire threats – all at a high community-level resolution. Maps include an updated digital vegetation map of Lebanon, environmentally suitable reforestation sites nationwide, including their biophysical characteristics and recommended native tree species to be planted. Also, maps about fuel type, fire hazard, and burned areas were developed by the Biodiversity Program - Institute of the Environment at the University of Balamand and were integrated in the mapping tool to provide updated and detailed online mapping information about wildland fire risks by locality.

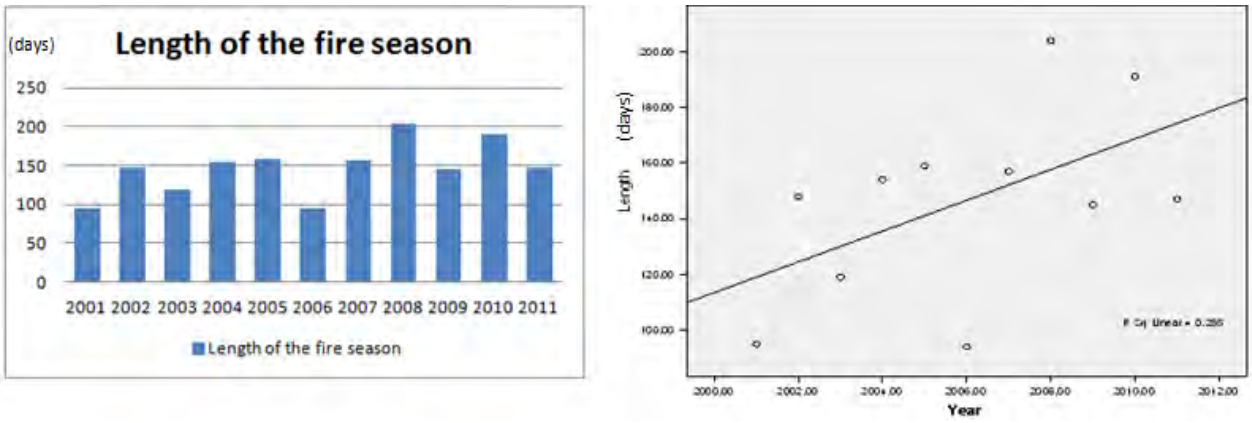
4.3. Forest fire considerations

Both scenarios involved the implementation of Lebanon's National Strategy to Forest Fire Management (AFDC/MOE, 2009). More specifically, the two scenarios involve mainly the adoption of the second, fourth and fifth components of the Strategy. Box 2 included the most recent research findings in assessing and managing wildfire risk in Lebanon under a climate and socio-economic change scenario in Lebanon undertaken within ongoing research at the Biodiversity Program, Institute of the Environment, University of Balamand (BP-UO-UOB) and especially within the framework of the USAID funded project "towards a better assessment and management of wildfire risk in the Wild-Urban Interface in Lebanon: gaining from the US experience". The primary objective of the project was to use models to identify areas most vulnerable to wildfire risk due to changing fuel conditions, land-use and climate warming. This project was managed by BP-IO-UOB and funded by the Agency for International development (USAID) in agreement with the US National Academies of Science (NAS).

Box 2: Towards an improved fire risk assessment and management in Lebanon

Salloum and Mitri (2013) investigated the yearly temporal pattern of fire activity and its relationship to weather in Lebanon during the past decade. The results showed that the length of the fire season has been increasing on an average of 5.2 days during the past decade. Also, it was found that the average start date of the fire season was June 14, while the average end date of the fire season was November 12, and the average peak month was September.

Fire occurrence was positively correlated with mean monthly temperatures, and the length of the fire season was negatively correlated with mean annual precipitation. In addition, an increasing fire occurrence risk was observed in association with high maximum temperatures and long dry seasons.



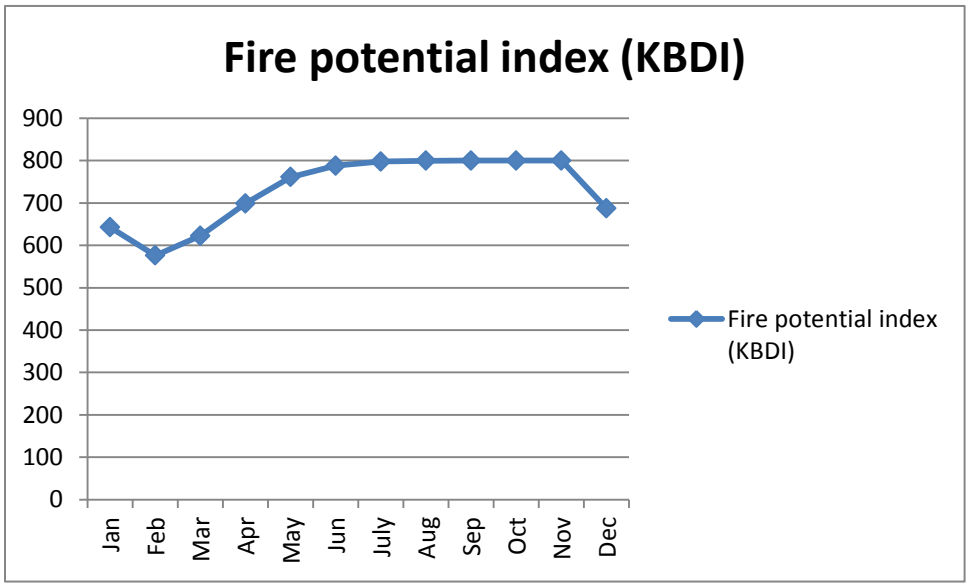
Temporal variation in the length of the fire season (left), and a scatter plot of the variation (right)

Fire season Calendar	January	February	March	April	May	June	July	August	September	October	November	De
2001						11				13		
2002						9					3	
2003							8				3	
2004						13					13	
2005					19					24		
2006							12			13		
2007						10					13	
2008			22								10	
2009						4				26		
2010					29						5	
2011							12				4	
Fire season							Peak month of the fire season					

Fire calendar of 2001 throughout 2011

Mitri et al. (2013) evaluated wildfire potential by measuring the Keetch-Byram Drought Index (KBDI). It is an index used to determining forest fire potential. The drought index is based on a daily water balance, where a drought factor is balanced with precipitation and soil moisture. The drought index ranges from 0 to 800, where a drought index of 0 represents saturated soil (no moisture depletion), and an index of 800 represents absolutely dry conditions. In addition, a number of fire risk related maps (e.g. Lebanon's wildfire hazard in the Wildland-Urban Interface map, Lebanon's overall wildfire risk map as a product of biophysical and socioeconomic risks, and Lebanon biophysical-based wildfire risk map as a product of wildfire hazard and vulnerability) were made available on the project's webpage

(home.balamand.edu.lb/wildfire)



Variation of KBDI throughout the year for current climatic conditions of a location in North Lebanon at an elevation of 195 m.

4.4. Reduction potentials

The results of the mitigation scenarios (Figure 34) indicate 12.57% reduction potential for scenario 1 and 38.5% reduction potential for scenario 2 in comparison to the baseline scenario.

Scenario 1 reduction potential is due to two mitigation actions: 1) reducing and compensating losses due to urbanization by afforestation (0.57% reduction potential) and 2) preventing intense and large wildfires (12% reduction potential). Scenario 2 reduction potential is due to the following mitigation actions: 1) increasing the forest cover by afforestation including the compensation of losses due to urbanization (26.5% reduction potential) and 2) preventing intense and large wildfires (12 % reduction potential).

It was found that preventing forest fires was the most effective action in reducing GHG emissions in scenario 1 (95.42% contribution); whereas afforestation activities have the largest effect in reducing GHG emissions in scenario 2 (68.8% contribution). Generally, fire prevention

would involve short to medium-term activities, while afforestation would involve medium-to long term activities.

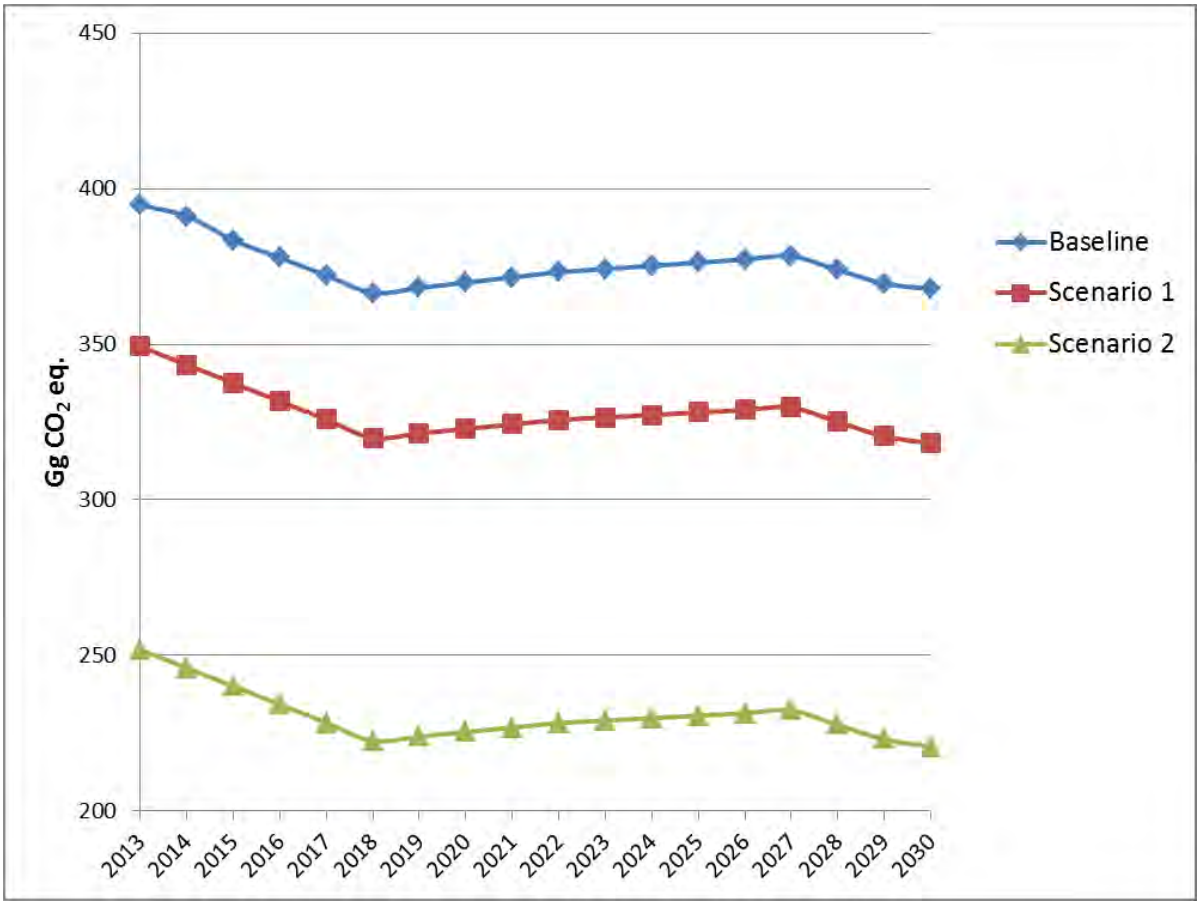


Figure 34. Net emissions from the changes in the LULUCF sector: baseline versus mitigation scenarios

The trends of the scenarios are greatly influenced by the previously conducted afforestation activities. For instance, the decrease in emissions between 2013 and 2018 is closely associated with the afforestation activities resulting in the increase of CO_2 removals. Starting 2019, the CO_2 removals capacity of forested areas planted between 1999 and 2012 (followed in conversion for 20 years) slightly decreases. The growth rate of the mature forests becomes quite constant in comparison with their growth as new plantations. Consequently, their CO_2 removal capacity decreases resulting in a slight increase in the net emissions from the changes (as shown in Figure 34).

4.5. Economic instruments

A number of economic instruments for maintaining and increasing the forest cover were investigated. Their definitions as well as examples of their implementation are presented in the below factsheets (Table 12, Table 13, Table 14 and Table 14).

Table 11. Payment for Environmental Services

Instrument name	**Payment for Environmental Services (PES)**
Instrument definition	"A voluntary transaction where a well-defined ES (or a land-use likely to secure that service) is being 'bought' by a (minimum one) ES buyer from a (minimum one) ES provider if and only if the ES provider secures ES provision (conditionality)" (Wunder, 2005).
Instrument applicability	Carbon sequestration and storage, protection of biodiversity, protection of watershed and landscape beauty
Case studies around the world	Costa Rica: - Instrument applicable to several services provided by forests: water, biodiversity, carbon sequestration, landscape - Landowners present a sustainable forest management plan prepared by a licensed forester. They receive payment if the plan is approved. - Forest conservation contracts payments reached 64 USD/ha/year. - Duration of contract: 5 years. - Bulk of the financing of the program: fuel tax - Impact: 270,000 ha enrolled by end of 2005. Columbia: - Compensation to landowners for the cost of conservation of undisturbed forest ecosystems. - Incentive was defined by government and NGOs
Sources	Pagiola, 2006 and Gaviria, 1996

Table 12. Subsidies

Instrument name	**Subsidy for reforestation**
Instrument definition	"A benefit given by the government to groups or individuals usually in the form of a cash payment or tax reduction for the plantation of new areas. The subsidy is usually given to remove some type of burden and is often considered to be in the interest of the public".
Case studies around the world	Columbia: Certificate for Forestry Incentive which subsidized 50% of the cost of reforestation with exotic species and 75% of the cost of

	reforestation with native species. This subsidy was directed towards medium-sized owners. In addition to this program, the government promotes reforestation via subsidies financed by international organizations. Drawback: confusion among communities and users.
Sources	Gaviria, 1996

Table 13. Conservation payment program for land conversion

Instrument name	**Conservation payment programs for land conversion**
Instrument definition	Establishment of a payments system for farmers to convert agricultural land to other uses, including forests or agroforestry. However, one must be careful because afforestation seems to be a by-product to these programs and not an end by itself.
Case studies around the world	Conservation Reserve Program (USA): - Main objective: reducing soil erosion due to agriculture with secondary objectives such as habitat creation, better water quality, and income transfer to farmers. - Enrolled farmers receive payments for converting erodible or sensitive cropland to grass, trees through a 10-year contract. - End of 2005: 35.9 acres enrolled at a cost of 1.8 billion USD Permanent Cover Program (Canada) - Objective: conserve and improve soil productivity by retiring crop land suffering from soil damage. - 1.3 million acres of cropland converted to forests. - Payments made to farmers (15 and 22 USD per acre for 10 year contracts and 36 and 47 USD per acre for 21 year contract for pasture and forest. Europe (EU): - Afforestation scheme which pays for afforestation of agricultural land to reduce wood shortage. - Farmers receive payment for afforestation and for conservation. - By 1997, this scheme had converted 930,000 ha of land for a cost of 2.6 billion USD.
Sources	Chen et al., 2009

Table 14. Community forests

Instrument name	**Establishment of community forests**
Instrument definition	According to FAO "Community forestry was initially defined as, “any situation which intimately involves local people in a forestry activity. It embraces a spectrum of situations ranging from woodlots in areas which

	are short of wood and other forest products for local needs, through the growing of trees at the farm level to provide cash crops and the processing of forest products at the household, artisan or small industry level to generate income, to the activities of forest dwelling communities". "The fundamental concept of community forestry is to establish community-based organizations through which forest users are given collective management responsibility (but not ownership for the local forests on which they depend for product flows" (Springate-Baginski et al., 2003)
Case studies around the world	England: - Established more than 10,000 hectares of new woodland - Brought more than 27,000 hectares of exiting woodland under management - Created or improved 12,000 hectares of other habitats - Planted or restored 1,200 km of hedgerows - Opened up 16,000 ha of woods and green-space for recreation and leisure - Restored/created more than 4,000 km of footpaths and cycle routes - Engaged and involved hundreds of thousands of people in finding out about and improving their local areas - Secured investment of over £175 million to improve people's quality of life" Nepal: - Emergence of community forests through a series of steps between 1975 and 1993 after nationalization of private forests. - Initially adopted for improved resource management but also evolved into improved livelihoods. - Formation of Forest User Groups (FUG). Three types of users identified: regular forest users, occasional forest users and future forest users. - Over 12,000 FUGs formed to date of article, managing 15% of forestland. Most FUGs found to be "diligently protecting their forests and regulating product extraction. The previous trend of widespread forest degradation has generally been reversed and communities are beginning to benefit from improved forest product flow".
Sources	communityforest.org.uk, Springate-Baginski et al., 2003

4.6. Discussion and evaluation

The proposed economic instruments were evaluated based on expert judgment (expert meeting conducted on 9/9/2013 at the MOE – Appendix VI). First, the main problems of the forestry sector in Lebanon were identified. Second, the most important laws/rules/regulations being applied to the forestry sector, their efficiency and the main issues facing their implementation were discussed (Table 15). Third, the proposed economic instruments were evaluated accordingly.

Table 15. Main problems of the forestry sector in Lebanon as identified by national experts

1) Land tenure rules/law enforcement: low control on forest activities conducted in privately owned forests under the Decision No. 1/433 dated 30/8/2010.
2) Absence of law enforcement and weakness in the implementation of policy.
3) Lack of awareness among the public about the importance of the forest cover.
4) Urbanization: there is a need for collaboration with the Directorate General of Urban Planning (DGUP), MOA and other entities such as the Order of Engineers and Architects (OEA) in order to coordinate an improved land zoning for the benefit of a reduced impact on the forest cover from urban expansion. The forest law 1949 (Article 93) imposes on those who cut conifer trees to reforest/afforest an area of 2000 m^2 for every 50 trees of the cut tree species. In contrast, more recent Decrees related to the conservation of forest resources (No. 141-1977; No. 43 dated 17/3/1983; and No. 85 dated 7/9/1991) excluded some licensed or future construction projects and public works from the implementation of the above mentioned law.
5) The increasing problem of intense and large forest fires in the last decades.
6) Poor land management: lack of enforcement of zoning decrees. In this respect the joint responsibility of municipalities and the DGUP should be emphasized.
7) Land classification problems: in some cases, the forest cover exists on what used to be abandoned agricultural land that evolved into forests. In that case, the owner is able to prove that the land is classified as agricultural. This enables the landowners to cut existing trees.
8) The absence of a monetary valuation of forestry services.
9) Absence of sustainable forest management: this is mainly caused by the ongoing lack of national policies and programs.
10) Continuous decrease in the forest area due to urbanization, severe forest fires, illegal clear cutting and uncontrolled fuelwood gathering.
11) The limited financial resources for reforestation activities are a major obstacle for the restoration of the forest cover.
12) The weak law enforcement concerning the controlled grazing in the newly reforested

lands (Law 1949, Article 88).

13) The law 558 for the conservation of forests (nature reserves and others) is relatively well implemented. However, there are also special provisions in that law concerning buffer zones around the reserves where in principle the land owner does not have the right to exploit the land as wished (Article 8).
14) There is a lack of implementation of the National Land Use Master Plan: "Schéma d'Aménagement du Territoire Libanais" (SDATL). The SDATL was endorsed in June 2009 (Decree No. 2366 dated 20/6/2009). The Master Plan is a reference document for several administrations including the DGUP.
15) The legislative framework lacks an integrated approach and should be accompanied by a national policy or strategy for forest management.

The framework for evaluating the four proposed economic instruments was inspired by the SWOT analysis: Strength, Weaknesses, Opportunities, and Threats. Accordingly, the following have been identified for each instrument:

- Advantages (strengths)
- Disadvantages (weaknesses)
- External facilitating factors for the adoption of the instrument (opportunities)
- External hindering factors for the adoption of the instrument (threats)

"Payment for Environmental Services"

The fragmentation of land ownership in Lebanon and the increase in the value of built estate is a major obstacle for the implementation of PES. Local populations are usually not much interested in the realization of forest-based community activities especially that most of them are small land owners and the income from environmental services of the forests cannot compensate that of real estate projects. However, PES might be more efficient with large land owners such as religious endowments. Nevertheless, many land owners can be motivated by the increasing need for a natural landscape, which in turn, positively affects property prices (increasing demand of having a property in areas where forests are dominant).

In addition, the acknowledgement of the long term economic services of forests might provide a solution to limit the problem of expanding quarries and stimulate the protection of forests with the provision of incentives especially in communal lands. More specifically, the

applicability of PES in areas where people are already harvesting non-wood forest products is increasing since payments for forest management activities would present an additional income (e.g. the successful cases of large stone pine forests in Jezzine and Metn).

In general, the successful implementation of PES would initially require a detailed environmental valuation of the services provided by forests. This would help in realizing the real value a forest and, therefore, the importance of its protection.

"Subsidies for reforestation"

This instrument is similar to the existing "Reforestation Certificate" (namely, Ifedet El Tehrij) which is currently not properly implemented mainly due to lack of incentives. The "Reforestation Certificate" was devised in the 1940's to help local communities planting forest land with a given right to harvest the forest in 20 years. This can be assimilated to subsidizing forestry management. It requires a sustained commitment from the community to maintain the new plantations. In this context, local community groups might ensure longer sustainability of the planted sites than temporarily elected municipal councils.

Subsidy for reforestation on private lands might attract mainly landowners with interest in planting their lands. Many native species are economically exploitable and can be planted on abandoned private land. It is however better applied on large privately owned lands. Similarly to the PES, a good economic valuation of the forests will provide incentives for conservation as well as a good basis for the calculation of the subsidy. When the subsidy takes the form of a tax reduction the implementation of the instrument becomes problematic due to an improper implementation of a tax payment system in Lebanon.

"Land conversion"

The most applicable land conversion in this context is the conversion of croplands to agroforestry which still provides the economic opportunities of agricultural products. However, the long-term investment of 20 years for a forest to become fully productive can be an issue of

concern. Therefore, farm owners can be encouraged to start creating forest corridors around their agricultural land.

The implementation of such an instrument is usually acceptable by farmers since it does not require the conversion of the whole area to forest but rather creating corridors around the fields which can in turn be complementary to agriculture (e.g. wind breaks, and use of wood products in the production of wooden boxes for harvested crops, among others).

Other cases where land conversion could be applied involve unsuitable lands for agriculture such as steep slopes and rocky terrain. In addition, the introduction of trees into cities and residential areas could be a complementary alternative given the fact that urban sprawl is one of the main problems deceasing the forest cover.

"Community forests"

A similar existing setting to community forests is being implemented in Lebanon by the forest law of 1949 (especially through what is called communal lands or "Mouchaa" by law – Articles 54 to 63). In this case the municipality or the land committee rents municipal land to users and use the income for developmental projects within the community. It also provides a source of income for communities through bidding for grazing and pruning for charcoal production (Decree No. 1576 dated 05/04/1950).

The successful implementation of community forests requires a well-defined land management plan developed with the cooperation among all residents of the community and involved public entities to agree on a specific land use (examples of such settings existed in Metn, Baabda, Aakkar, Anjar, and Sour regions).

It is to be noted that the absence of a detailed plan and monitoring system may result in the overexploitation of the forest resources (e.g. overgrazing, uncontrolled pruning and fuelwood gathering, among others), in addition to possible managerial conflicts within the committees in charge of the land.

Table 16 provides a classification for the instruments according to the SWOT framework and summarizes the main points pertaining to the above mentioned instruments.

Table 16. SWOT Analysis

Instrument	Strengths	Weaknesses	Opportunities	Threats
PES	• Contributes to maintaining the forest cover • Might be a good alternative for limiting the expansion of quarries	• Implementation requires large public funds • Calculation of the payment might be problematic	• Need for natural landscape • A good economic valuation of the forest will make it possible to realize the value of the forest and the importance of its protection	• Mentality/culture • Limited applicability to certain regions/large land • Fragmentation of land • Increase in the value of built estate
Subsidies	• Possibility to build on a similar existing instrument the "Reforestation Certificate"	• Difficulty in applicability to owners of small lands • Improper implementation of a tax payment system in Lebanon impeding the implementation of tax reduction	• Requires also a good economic valuation of the forest	• Mentality/culture
Land conversion	• Applicable in regions where land doesn't have a very high value (e.g. steep slopes)	-	• Creation of agroforestry corridors around agricultural land	• Long time frame for conversion/investment
Community forests	• Source of income for communities	-	• Need for a land management plan	• Risk of overexploitation of rented land • Conflict within the land committees.

4.7. The scenarios' implementation framework

The implementation framework (Table 17) for the application of the proposed scenarios through the use of the appropriate economic instruments was formulated as per the experts' recommendations and the interpretation of the SWOT analysis results. It was found that "PES" could be mainly applied to Scenario 1, while "Subsidy" could be mainly applied to Scenario 2. "Land conversion" and "community forestry" could be applied to both scenarios.

Table 17. Implementation Framework of scenarios

Scenario	Objective	Economic instruments	Activities	Target Group	Public Authorities in charge
Mitigation Scenario 1	*Maintaining the current extent of Lebanon's forest and other wooded land cover.*	• Payment for Environmental Services (PES). • Conservation payment programs for land conversion. • Establishment of community forests.	Reducing the extent of new losses in the cover due to urbanization.	• Land owners • Municipalities • Local communities	• DGUP • MOA • MOE • MOI • CDR
			Compensating the annual loss to urbanization through afforestation/reforestation * activities.	• NGO's • Municipalities • Local communities • Land owners • Farmers • Volunteers • Tree nursery owners • Research institutions • Private institutions	• MOA • MOE • CDR • MOI • MOPT • NCRS
			Modifying fire risk through fire vulnerability reduction and prevention of harmful fires (second component of Lebanon's National strategy for forest fire management Decision No.52/2009).	• National and regional research institutions • NGO's • Municipalities • Universities • Land managers (agriculture agents, rangers, etc) • Land owners • Land users • Regional development offices (agriculture forestry) • Private enterprises • Residents and tourists in areas of risk • School children • Civil works managers • Local authorities • Regional/Local governmental institutions • Local communities • Hunter associations • Forest guards	• MOA • MOE • MOEd • MOD • MOI • NSRC • CDR • MOET • MOPW • MOJ • MOPT
			Preventing large and intense wildfires by adopting the strategic objective from the fourth component (Response) of Lebanon's National strategy for forest fire management (Decision No.52/2009).	• Forestry and Natural Resources Department • Research institutions • NGOs • Municipalities • Decision makers from all relevant governmental departments • Forest guards • Volunteers	• MOEd • MOE • MOA • MOI • Directorate of Civil Defense • Lebanese Army • MOI • MOJ

				• Fire brigade at the Civil Defense • Forest guards • Fight-fighters • Fire fighters at the Lebanese air forces • Local community fire units • Local communities	
Scenario	**Objective**	**Economic Instruments**	**Activities**	**Target Group**	**Public authorities in charge**
Mitigation Scenario 2	*Increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030.*	• Subsidy for reforestation*. • Conservation payment programs for land conversion. • Establishment of community forests.	Increasing the current extent of Lebanon's forest and other wooded land cover up to 31.3% through afforestation*.	• NGO's • Municipalities • Local communities • Land owners • Farmers • Volunteers • Tree nursery owners • Research institutions • Private institutions	• MOA • MOE • CDR • MOI • MOPT • NCRS
			Facilitating the natural post-fire recovery of vegetation (fifth component of the National fire management strategy Decision No.52/2009).	• Municipalities • NGOs • Local communities • National research institutions • Universities • Forest guards • Land owners • Land managers & users	• MOI • Directorate of Civil Defense • MOET • MOA • MOE • MOEd • NCSR • MOJ
			Preventing large and intense wildfires by adopting the strategic objective from the fourth component (Response) of Lebanon's National strategy for forest fire management (Decision No.52/2009).	• Forestry and Natural Resources Department • Research institutions • NGOs • Municipalities • Decision makers from all relevant governmental departments • Forest guards • Volunteers • Fire brigade at the Civil Defense • Forest guards • Fight-fighters • Fire fighters at the Lebanese air forces • Local community fire units • Local communities	• MOEd • MOE • MOA • MOI • Directorate of Civil Defense • Lebanese Army • MOI • MOJ
***Afforestation's potential funding sources and estimated costs**					
Funding agencies	• National: GOL (Reforestation Fund, National Environmental Fund, MOF-BDL), municipalities (revenues from forest investments), private sector. • International: EU, FAO, IUCN, UNDP (GEF), USAID (USFS)				

Estimated build-up costs	• 15 USD per tree • 7,700 USD per Hectare (for a total 4309 ha/year) • Approximate cost: 33,180,000 USD per year (Over 20 years)

4.8. Sources for funding and technical support

The need for a fund for financing the above mentioned instruments was emphasized. In this context, the "Reforestation Fund" (so-called Sandouk al Tahrij) stipulated by the Forest Law of 1949 (Article 98) is the principal source of funding. However, the law needs reactivation and improved management through the responsible Commission (Article 89) consisting of the Minister of Agriculture as president, and the ministry's Director General and the Chairman of the Forestry Department as members. Once reactivated, the "Reforestation Fund" can help in funding the implementation of the previously discussed instruments. It is needless to say that the reactivation of this fund might help in getting better access to international funds in the form of grants and loans, among others.

Also, the Forest Law of 1949 mentioned that municipalities and villages are required to keep the third of the net revenues from forestry products and forest investments as reserved funds for later afforestation/reforestation activities within the municipalities' lands. This resource can be used in the implementation of community forests as part of the mitigation actions.

Investigation of other potential sources for funding and possible financial support identified the following:

- The National Reforestation Plan (NRP): In 2001, the Lebanese Government allocated a fund of 25 billion Lebanese pounds issued through the national budget law number 326 date 28/6/2001. The MOE has handled the prerogative of initiating the NRP, aiming at restoration of the country's green cover loss throughout the years. In 2009 the MOE resumed work on the NRP with supplemental funding of GEF and implemented by UNDP.

- The MOE drafted a decree to setup the National Environmental Fund (NEF) pursuant to Law 444/2002. Accordingly, the fund would have a legal identity, financial and administrative autonomy, and would be under the mandate of the Ministry of Environment. Funding and fund replenishment would come from several sources including provisions in the Government of Lebanon's (GOL) annual budget, environmental fees, grants, fines, and compensations, and interest on deposits. The final application decrees of the NEF are however not in place yet, and the fund is not functional until present.
- The MOF, through the central bank of Lebanon, Banque du Liban (BDL), introduced in 2001 a subsidized interest loan to support investment in three key economic sectors (industry, agriculture and tourism) – BDL Circular 7743/2001. In June of 2009, BDL also introduced a new policy to facilitate loans for environmentally-friendly projects (new projects as well as retrofits) –BDL Circular 197/2009.
- In November 2010, the BDL further introduced new loan incentives to finance environmental projects in energy (renewable energy, energy efficiency, and green buildings) and non-energy – BDL Circular 236/2010. The underlying pillars of BDL's policy to support green projects are longer loan maturity, lower interest rates, and no ceiling on loan amounts.
- The private sector is a very important partner that can financially help in conducting reforestation activities. The private sector proved to be an important partner in funding reforestation activities, especially after the fire events of 2007.
- Other International initiatives might also contribute to provide additional technical and financial support for reforestation activities. The US Forest Service (USFS) launched in 2010 a five-year and $12 Million Lebanon Reforestation Initiative (LRI).

All of these initiatives emphasize the opportunities which can be grasped in order to pool resources into a national fund with sustainable sources of income that will not only allow the implementation of forest-protection programs, but also allow for the funding of the proposed instruments.

5. Conclusions

The main objective of this work was to identify proper mitigation measures which would help in reducing GHG emissions and maintaining/increasing removals from the LULUCF sector in Lebanon. Accordingly, the following mitigation scenarios along with their economic instruments have been identified:

- Mitigation scenario 1: Maintaining the current extent of Lebanon's forest and other wooded land cover (while preventing large and intense wildfires considerations) with a reduction potential of 12.57% and time frame for implementation of short to medium-term. The relevant economic instruments for implementation comprised: PES, land conversion and community forests.
- Mitigation scenario 2: Increasing the current extent of Lebanon's forest and other wooded land cover 7% by 2030 (while preventing large and intense wildfires considerations) with a reduction potential of 38.5% and a time frame: for implementation of medium to long-term. The associated economic instruments for implementation comprised: subsidy, land conversion and community forests.

The implementation of the proposed mitigation actions would require an integrated approach involving improved legislation and law enforcement, land use planning, education and awareness, economic valuation of forests, and funding. In this context, the "Reforestation Fund" (so-called Sandouk al Tahrij) stipulated by the Forest Law of 1949 (article 98) represents a promising source for funding.

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Appendices

Appendix I
Land-use classification, definitions and disaggregation

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
Settlements	This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.	This category includes all developed land, including transportation infrastructure and human settlements	Dense urban area	No disaggregation needed
			Unorganized dense urban area	
			Moderately dense urban area	
			Moderately dense unorganized urban area	
			Low density urban area	
			Low density unorganized urban area	
			Tourist resort	
			Archeological site	
			Large equipment	
			Industrial or commercial zone	
			Harbor zone	
			Airport	
			Train station	
			Highway	
			Other type of road	
			Farm building	
			Farm building with field crops	
			Farm building with deciduous fruit trees	
			Quarry	

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
			Dump	
			Sea filling	
			Urban sprawl and /or construction site	
			Vacant urban land	
			Green urban space	
			Large sport or leisure equipment	
Cropland	This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the threshold used for the forest land category, consistent with the selection of national definitions.	This category includes arable and tillage land. More specifically, the following classes were considered under this category: crops, olive groves, vineyards, deciduous fruit trees, bananas, citrus trees, and greenhouse cultivations.	Field crops in large area	Annual
			Field crops combined with olive	Annual
			Field crops combined with vines	Annual
			Field crops combined with deciduous fruit trees	Annual
			Field crops combined with citrus trees	Annual
			Field crops combined with greenhouses	Annual
			Field crops in small plots or terraces	Annual
			Urban sprawl on field crops	Annual
			Olives	Perennial
			Olives combined with field crops	Perennial
			Olives combined with vines	Perennial
			Olives combined with deciduous fruit trees	Perennial
			Olives combined with citrus trees	Perennial
			Olives combined with intensive field crops	Perennial
			Olives combined with greenhouses	Perennial
			Vineyards	Perennial
			Vineyards combined with field crops	Perennial
			Vineyards combined with olives	Perennial
			Vineyards combined with deciduous fruit	Perennial

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
			trees	
			Vineyards combined with intensive field crops	Perennial
			Vineyards combined with greenhouses	Perennial
			Deciduous fruit trees	Perennial
			Deciduous fruit trees combined with field crops	Perennial
			Deciduous fruit trees combined with olives	Perennial
			Deciduous fruit trees combined with vines	Perennial
			Deciduous fruit trees combined with citrus trees	Perennial
			Deciduous fruit trees combined with banana trees	Perennial
			Deciduous fruit trees combined with intensive field crops	Perennial
			Deciduous fruit trees combined with greenhouses	Perennial
			Citrus trees	Perennial
			Citrus trees combined with field crops	Perennial
			Citrus trees combined with olives	Perennial
			Citrus trees combined with deciduous fruit trees	Perennial
			Citrus trees combined with banana trees	Perennial
			Citrus trees combined with intensive field crops	Perennial
			Citrus trees combined with greenhouses	Perennial
			Banana trees	Perennial

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
			Banana trees combined with deciduous fruit trees	Perennial
			Banana trees combined with citrus trees	Perennial
			Banana trees combined with intensive field crops	Perennial
			Banana trees combined with greenhouses	Perennial
			Urban sprawl on orchard	Perennial
			Intensive filed crops	Annual
			Intensive filed crops combined with olives	Annual
			Intensive filed crops combined with deciduous fruit trees	Annual
			Intensive filed crops combined with citrus trees	Annual
			Intensive filed crops combined with greenhouses	Annual
			Greenhouses	Annual
			Greenhouses combined with field crops	Annual
			Greenhouses combined with vines	Annual
			Greenhouses combined with deciduous fruit trees	Annual
			Greenhouses combined with citrus trees	Annual
			Greenhouses combined with banana trees	Annual
			Greenhouses combined with intensive field crops	Annual
			Urban sprawl on greenhouses	Annual
Forest land	Forest: This category includes all land with woody vegetation	This category included the following:	Dense pine forests (mainly *Pinus brutia* and *Pinus pinea*)	Coniferous

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
	consistent with thresholds used to define forest land in the national GHG inventory, sub-divided at the national level into managed and unmanaged and also by ecosystem type as specified in the IPCC Guidelines.6 It also includes systems with vegetation that currently falls below, but is expected to exceed, the threshold of the forest land category. Managed forest: All forests subject to some kind of human interactions (notably commercial management, harvest of industrial round-wood (logs) and fuelwood, production and use of wood commodities, and forest managed for amenity value or environmental protection if specified by the country), with defined geographical boundaries.		Dense cedre forests (*Cedrus libani*)	Coniferous
			Dense fir forests (*Abies Cilicia*)	Coniferous
			Dense cypress forests (*Cupressus ssp.*)	Coniferous
			Dense oak forests (*Quercus ssp.*)	Broadleaf
			Dense broadleaves forests (*Platanus, Populus, Salix*)	Broadleaf
			Mixed dense forests	Mixed
			Urban sprawl on dense forest	Mixed
			Low density pine forests (*Pinus brutia* and *Pinus pinea*)	Coniferous
			Low density cedre forests (*Cedrus libani*)	Coniferous
			Low density Juniper forests (*Juniperus ssp.*)	Coniferous
			Low density fir forests (*Abies, Cilicia*)	Coniferous
			Low density cypress forests (*Cupressus ssp.*)	Coniferous
			Low density oak forests (*Quercus ssp.*)	Broadleaf
			Low density broadleaves forests (*Platanus, Populus, Salix*)	Broadleaf
			Low density mixed forests	Mixed
			Urban sprawl on low density forest	Mixed
			Shrubland	Broadleaf
			Shrubland with dispersed trees	Broadleaf
			Urban sprawl on shrubland	Broadleaf
Grassland	This category includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the	This category includes rangelands and pasture land that is not considered as cropland. More specifically, it included moderately dense herbaceous vegetation, and highly dense	Moderately dense herbaceous vegetation	Annual grasses
			Low density herbaceous vegetation	Annual grasses

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
	threshold used in the forest land category and is not expected to exceed, without human intervention, the thresholds used in the forest land category. This category also includes all grassland from wild lands to recreational areas as well as agricultural and silvo-pastural systems, subdivided into managed and unmanaged, consistent with national definitions.	herbaceous vegetation.		
Wetland	This category includes land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. This category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.	This category includes land that is covered or saturated by water for all or part of the year. More specifically, it included the following classes: surface water bodies, lakes, rivers, and reservoirs.	Continental humid zone Marine humid zone Water plane (reservoir) Hill lake Stream or river Harbor basin	Flooded areas (Artificial reservoirs and hill lakes)

	Definition according to IPCC GPG for LULUCF	Definition according to the national classification system	Disaggregation adopted according to the national classification system (land use map of 1998)	Disaggregation as per the IPCC GPG for LULUCF recommendations
Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.	This category included bare soil, rock, ice, and recently burned forested lands	Bare rock	No need for disaggregation
			Urban sprawl on bare rock	
			Bare soil	
			Beach	
			Sand dune	
			Burned area	

Appendix II
List of activity data

	only 4 calc. purposes	Extrapolation				Baseline	Interpolation										Interpolation			
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
FF-Total	**258646.65**	**258475.95**	**258304.34**	**258131.73**	**257957.98**	257890.00	257628.13	257172.00	257142.81	257113.63	257059.19	256905.94	256543.94	256236.63	256088.25	255775.00	255575.03	255375.06	254771.13	254463.13
Coniferous	35274.24	35257.05	35239.76	35222.37	35204.87	35216.00	35187.56	35121.00	35116.50	35112.00	35102.81	35083.69	35063.13	35028.06	35022.31	34977.44	34960.44	34943.44	34887.56	34871.06
Broadleaf	196658.18	196517.58	196376.23	196234.06	196090.95	196008.00	195792.44	195451.75	195431.06	195410.38	195366.69	195244.75	194924.19	194682.31	194544.06	194300.38	194131.47	193962.56	193467.06	193184.13
Mixed	26714.23	26701.32	26688.35	26675.30	26662.16	26666.00	26648.13	26599.25	26595.25	26591.25	26589.69	26577.50	26556.63	26526.25	26521.88	26497.19	26483.13	26469.06	26416.50	26407.94
GG-Total	318130.90	318023.29	317915.11	317806.28	317696.75	317600.00	317497.13	317237.13	317212.41	317187.69	317158.00	317018.88	316755.56	316573.94	316558.25	316314.69	316180.03	316045.37	315697.12	315518.06
CC-Total	333242.83	333069.80	332895.87	332720.90	332544.79	332364.00	332082.13	331856.69	331819.22	331781.75	331669.56	331279.94	331167.25	330804.06	330776.75	330505.06	330081.53	329658.00	329415.12	328959.31
Perennial	160701.36	160646.49	160591.33	160535.84	160479.98	160354.00	160287.75	160243.25	160230.06	160216.88	160185.56	160126.56	160100.63	160047.50	160041.00	159937.69	159719.69	159501.69	159376.06	159235.25
Annual	172541.46	172423.32	172304.54	172185.07	172064.81	172010.00	171794.38	171613.44	171589.16	171564.88	171484.00	171153.38	171066.63	170756.56	170735.75	170567.38	170361.84	170156.31	170039.06	169724.06
FO		**NE**	**NE**	**NE**	**NE**	0.00	1048.63	330.00	73.19	73.19	304.00	62.50	423.69	1197.00	708.00	25.81	427.72	427.72	161.13	603.00
Coniferous		NE	NE	NE	NE	0.00	122.88	54.25	6.47	6.47	31.25	5.31	37.44	126.56	83.44	6.56	59.97	59.97	14.63	37.69
Broadleaf		NE	NE	NE	NE	0.00	870.00	217.06	53.66	53.66	251.88	53.31	347.56	1012.63	568.38	16.56	311.59	311.59	133.56	548.31
Mixed		NE	NE	NE	NE	0.00	55.75	58.69	13.06	13.06	20.88	3.88	38.69	57.81	56.19	2.69	56.16	56.16	12.94	17.00
FO		**NE**	**NE**	**NE**	**NE**	0.00	1048.63	330.00	73.19	73.19	304.00	62.50	423.69	1197.00	708.00	25.81	427.72	427.72	161.13	603.00
Fuel Type 3		NE	NE	NE	NE	0.00	280.50	98.63	5.94	5.94	204.81	34.44	163.69	631.69	157.81	13.69	184.59	184.59	58.06	262.31
Fuel Type 4		NE	NE	NE	NE	0.00	482.69	97.63	31.38	31.38	59.69	17.06	134.56	379.81	213.00	8.00	155.59	155.59	53.06	185.13
Fuel Type 5		NE	NE	NE	NE	0.00	6.94	14.75	5.34	5.34	12.75	4.19	1.81	32.56	24.56	0.00	7.00	7.00	2.88	10.25
Fuel Types 6&7		NE	NE	NE	NE	0.00	278.50	119.00	30.53	30.53	26.75	6.81	123.63	152.94	312.63	4.13	80.53	80.53	47.13	145.31
GO		**NE**	**NE**	**NE**	**NE**	0.00	198.38	125.50	148.47	148.47	492.19	96.44	95.94	815.06	42.75	12.56	271.00	271.00	182.38	242.75
Fuel Type 1		NE	NE	NE	NE	0.00	148.13	78.50	76.44	76.44	287.44	50.06	74.69	638.69	28.19	6.13	206.72	206.72	109.06	184.88
Fuel Type 2		NE	NE	NE	NE	0.00	50.25	47.00	72.03	72.03	204.75	46.38	21.25	176.38	14.56	6.44	64.28	64.28	73.31	57.88
CO		**NE**	**NE**	**NE**	**NE**	0.00	493.56	501.75	250.94	250.94	528.50	222.69	344.06	334.44	274.81	542.00	675.09	675.09	585.19	1305.81
LS-Total		**451.34**	**453.73**	**456.40**	**459.40**	0.00	646.62	941.56	91.38	91.38	196.31	682.00	738.00	852.13	191.38	828.50	758.16	758.16	1195.06	942.88

FS		**170.70**	**171.60**	**172.61**	**173.75**		261.87	456.13	29.19	29.19	54.44	153.25	362.00	307.31	148.38	313.25	199.97	199.97	603.94	308.00
Coniferous		17.19	17.28	17.39	17.50	0.00	28.44	66.56	4.50	4.50	9.19	19.13	20.56	35.06	5.75	44.88	17.00	17.00	55.88	16.50
Broadleaf		140.60	141.34	142.18	143.11	0.00	215.56	340.69	20.69	20.69	43.69	121.94	320.56	241.88	138.25	243.69	168.91	168.91	495.50	282.94
Mixed		12.91	12.98	13.05	13.14	0.00	17.88	48.88	4.00	4.00	1.56	12.19	20.88	30.38	4.38	24.69	14.06	14.06	52.56	8.56
GS		107.61	108.18	108.82	109.54	0.00	102.88	260.00	24.72	24.72	29.69	139.13	263.31	181.63	15.69	243.56	134.66	134.66	348.25	179.06
CS		173.02	173.94	174.96	176.11	0.00	281.88	225.44	37.47	37.47	112.19	389.63	112.69	363.19	27.31	271.69	423.53	423.53	242.88	455.81
Perennial		54.87	55.16	55.49	55.85	0.00	66.25	44.50	13.19	13.19	31.31	59.00	25.94	53.13	6.50	103.31	218.00	218.00	125.63	140.81
Annual		118.15	118.77	119.47	120.26	0.00	215.63	180.94	24.28	24.28	80.88	330.63	86.75	310.06	20.81	168.38	205.53	205.53	117.25	315.00
LF-Total		**NE**	**NE**	**NE**	**NE**	0.00	305.00	305.00	305.00	305.00	278.00	278.00	278.00	278.00	278.00	52.00	52.00	147.73	52.00	381.21
FAO, 2010 & MOE, 2013		NE	NE	NE	NE	0.00	305.00	305.00	305.00	305.00	278.00	278.00	278.00	278.00	278.00	0.00	0.00	95.73	0.00	95.73
AFDC		NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	52.00	52.00	52.00	52.00	52.00
LRI		NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	233.48
LW-Total		**NE**	**NE**	**NE**	**NE**	0.00	NE	NE	NE	NE	NE	NE	NE	NE	NE	37	NE	NE	NE	NE
OW		**NE**	**NE**	**NE**	**NE**	0.00	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**NE**	**37**	**NE**	**NE**	**NE**	**NE**

NE: Not Estimated (No activity data available)
NO: Not Occuring

Appendix III
List of E/R factors

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Average annual net increment in volume suitable for industrial processing	I_V	3.26	FF/ FL-1a_1of4	0	IR	not needed anymore since a default for G_W is used
Basic wood density	D	3.26	FF/ FL-1a_1of4	0	IR	not needed anymore since a default for G_W is used
Biomass Expansion factor for conversion of annual net increment (including bark) to above ground tree biomass increment	BEF_1	3.26	FF/ FL-1a_1of4	0	IR	not needed anymore since a default for G_W is used
Average annual aboveground biomass increment	G_W	3.26 3.26	FF/ FL-1a_1of4 LF/ FL-2a_1of1	3 (Coniferous), 4 (Broadleaved), 3.5 (Mixed) 5.725 (Coniferous)	IPCC GPG Default Table 3A.1.5 IPCC GPG Default Table 3A.1.6, experts' surveys (E. Chneis)	
Root-shoot ratio appropriate to increments	R	3.26 3.26	FF/ FL-1a_1of4 LF/ FL-2a_1of1	0.27	FAO 2005	

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Carbon fraction of dry matter	CF	3.25 3.33 3.25 3.57 3.107 3.140	FF/ FL-1a_2of4 FF/ FL-1b_1of3 LF/ FL-2a_1of1 LF/ FL-2b_2of2 GG/GL-1a_2of2 WL-2a2_1of1	0.5	IPCC GPG Default	
Annually extracted volume of roundwood	H	3.27	FF/ FL-1a_2of4	0	experts' surveys (E. Chneis, J. Stephan)	
Biomass density	D	3.27	FF/ FL-1a_2of4 FF/ FL-1a_3of4	0.5001 (Coniferous), 0.58 (Broadleaved), 0.54 (Mixed)	FAO 2005, IPCC GPG Table 3A.1.9, (Altaş et al., 2007), (Aksu et al., 2001)	
Biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark)	BEF_2	3.27	FF/ FL-1a_2of4 FF/ FL-1a_3of4	1.3 (Coniferous), 1.4 (Broadleaved), 1.35 (Mixed)	IPCC GPG Default Table 3A.1.10	
Fraction of biomass left to decay in forest due to commercial	F_{BL}	3.27	FF/ FL-1a_2of4	0.15	IPCC GPG Default Table 3A.1.11	

<table>
<tr><th>Emission Factor</th><th>Symbol/ Abbreviation</th><th>Page in GPG</th><th>Land use Category /Sheet name</th><th>Value(s) used</th><th>Source of Value</th><th>Notes</th></tr>
<tr><td>roundwood gathering</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Annual volume of fuelwood gathering</td><td>FG</td><td>3.27</td><td>FF/ FL-1a_3of4</td><td>
<table>
<tr><th>Year</th><th>Non-coniferous NC (m^3)</th><th>Coniferous C (m^3)</th></tr>
<tr><td>1994</td><td>14628.44249</td><td>3853</td></tr>
<tr><td>1995</td><td>14652.39207</td><td>3952</td></tr>
<tr><td>1996</td><td>14676.49922</td><td>4045</td></tr>
<tr><td>1997</td><td>14700.78493</td><td>4114</td></tr>
<tr><td>1998</td><td>14725.27473</td><td>4089</td></tr>
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<tr><td>2003</td><td>15000</td><td>4040</td></tr>
<tr><td>2004</td><td>15000</td><td>4028</td></tr>
<tr><td>2005</td><td>15000</td><td>4017</td></tr>
<tr><td>2006</td><td>15000</td><td>3896</td></tr>
<tr><td>2007</td><td>15000</td><td>3900</td></tr>
<tr><td>2008</td><td>15000</td><td>3900</td></tr>
<tr><td>2009</td><td>15000</td><td>3900</td></tr>
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<tr><td>2011</td><td>15000</td><td>3833</td></tr>
<tr><td>2012</td><td>14725.27473</td><td>4064.725146</td></tr>
</table>
</td><td>FOASTAT 2013</td><td>NC volumes for the years 1994-1998 and 2012 are generated by extrapolation of the trend from the years 1999-2011

C volume for the year is generated by extrapolation of the trend from the years 1994-2011</td></tr>
<tr><td>Average biomass stock of forest areas</td><td>B_W</td><td>3.28</td><td>FF/ FL-1a_3of4</td><td>134 (Coniferous), 122 (Broadleaved), 128 (Mixed)</td><td>IPCC GPG Default Table 3A.1.2</td><td></td></tr>
</table>

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Fraction of biomass left to decay in forest due to disturbance	F_{bl}	3.28	FF/ FL-1a_4of4	0.415	IPCC GPG Default Table 3A.1.12	
Annual transfer into dead wood	B_{into}	3.33	FF/FL-1b_1of3	0	NA	Tier 1 assumes no change
Annual transfer out of dead wood	B_{out}	3.33	FF/FL-1b_1of3	0	NA	Tier 1 assumes no change
Reference stock of litter under native, unmanaged forest corresponding to state i	$LT_{ref\ (i)}$	3.35	FF/FL-1b_1of3	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of management intensity or practices on LTref(i) in state i	$f_{mgt\ intensity(i)}$	3.35	FF/FL-1b_2of3	0	NA	Tier 1 assumes no change
Adjustment factor reflecting a change in the disturbance regime on LTref (i) in state i	$f_{dist\ regime(i)}$	3.35	FF/FL-1b_2of3	0	NA	Tier 1 assumes no change
Reference stock of litter under previous state j	$LT_{ref\ (j)}$	3.35	FF/FL-1b_2of3	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of management intensity or practices on LTref (j)	$f_{mgt\ intensity(j)}$	3.35	FF/FL-1b_2of3	0	NA	Tier 1 assumes no change

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Adjustment factor reflecting a change in the disturbance regime on LTref (j)	$f_{dist\ regime(j)}$	3.35	FF/FL-1b_2of3	0	NA	Tier 1 assumes no change
Time period of the transition from state i to j	T_{ij}	3.35 3.40	FF/ FL-1b_3of3 FF/ FL-1c1_1of2	20	IPCC GPG Default	
Reference carbon stock	SOC_{REF}	3.40 3.63 3.75 3.112	FF/FL-1c1_1of2 LF/FL-2c1_1of1 CC/CL-1c1_1of2 GG/GL-1c1_1of2	38 (forest soils) 38 (cropland soils) 38 (grassland soils)	IPCC GPG Default Table 3.2.4 IPCC GPG Default Table 3.3.3 IPCC GPG Default Table 3.4.4	
Adjustment factor reflecting the effect of a change from the native forest to the forest type in state i	$f_{forest\ type\ i}$	3.40	FF/FL-1c1_1of2	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of management intensity or practices on forest in state i	$f_{man\ intensity\ i}$	3.40	FF/FL-1c1_1of2	0	NA	Tier 1 assumes no change

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Adjustment factor reflecting the effect of a change in the disturbance regime to state i with respect to the native forest	$f_{dist\ regime\ i}$	3.40	FF/FL-1c1_1of2	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of a change from the native forest to the forest type in state j	$f_{forest\ type\ j}$	3.40	FF/FL-1c1_2of2	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of management intensity or practices on forest in state j	$f_{man\ intensity\ j}$	3.40	FF/FL-1c1_2of2	0	NA	Tier 1 assumes no change
Adjustment factor reflecting the effect of a change in the disturbance regime to state j with respect to the native forest	$f_{dist\ regime\ j}$	3.40	FF/FL-1c1_2of2	0	NA	Tier 1 assumes no change
Emission factor for CO2 from drained organic forest soils	$EF_{Drainage}$	3.42	FF/FL-1c2_1of1	0	IR	No organic soils (Expert's surveys, T. Darwish)
		3.63	LF/FL-2c1_1of1			

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Mass of available fuel	B	3.49	FF/FL-1d_1of1	12,500 (fuel type 3), 30,000 (fuel type 4), 9,500 (fuel type 5), 12,500 (fuel type 6, 7)	(TRAGSA, 2012)	
Combustion efficiency or fraction of biomass combusted	C	3.49 3.120	FF/FL-1d_1of1 GG/GL-1d_1of1	0.5	IPCC GPG Default Table	
CH4 Emission factor	D	3.49	FF/FL-1d_1of1	9	IPCC GPG Default Table 3A.1.16	
CO Emission factor	F	3.49	FF/FL-1d_1of1	130	IPCC GPG Default Table 3A.1.16	
N2O Emission factor	H	3.49	FF/FL-1d_1of1	0.11	IPCC GPG Default Table 3A.1.16	
NOx Emission factor	J	3.49	FF/FL-1d_1of1	0.7	IPCC GPG Default Table 3A.1.16	
Standing biomass stock in terms of carbon in naturally regenerated forest	$B_{standing\ NatR}$	3.57	LF/FL-2b_1of2	0	IR	No data on natural regeneration
Mortality rate in naturally regenerated forest	M_{NatR}	3.57	LF/FL-2b_1of2	0	IR	No data on natural regeneration
Annual transfer out of dead wood for naturally regenerated forest area	$B_{out\ NatR}$	3.57	LF/FL-2b_1of2	0	IR	No data on natural regeneration

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Standing biomass stock in terms of carbon in artificially regenerated forest	$B_{standing\ ArtR}$	3.57	LF/FL-2b_1of2	0	NA	Tier 1 assumes no change
Mortality rate in artificially regenerated forest	M_{ArtR}	3.57	LF/FL-2b_1of2	0	NA	Tier 1 assumes no change
Annual transfer out of dead wood for artificially regenerated forest area	$B_{out\ ArtR}$	3.57	LF/FL-2b_2of2	0	NA	Tier 1 assumes no change
Annual change in litter carbon for naturally regenerated forest	DC_{NatR}	3.57	LF/FL-2b_2of2	0	IR	No data on natural regeneration
Annual change in litter carbon for artificially regenerated forest	DC_{ArtR}	3.57	LF/FL-2b_2of2	1	IPCC GPG Default Table 3.2.1, experts' surveys (E. Chneis)	
Stable soil organic carbon on previous land use, either cropland or grassland, SOCNon-forest Land	$SOC_{Non-forest\_land}$	3.63	LF/FL-2c1_1of1	0	IPCC GPG Default	
Duration of the transition from $SOC_{Non-forest\ Land}$ to SOC_{ref}	T_{AFF}	3.63	LF/FL-2c1_1of1	20	IPCC GPG Default	
Annual growth rate of perennial woody	G	3.71	CC/CL-1a_1of1	2.1 (unburned perennial woody crops)	IPCC GPG Default Table	

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
biomass					3.3.2	
Annual carbon stock in biomass removed	L	3.71	CC/CL-1a_1of1	63 (burned perennial woody crops)	IPCC GPG Default Table 3.3.2	
Inventory time period	T	3.75 3.112	CC/CL-1c1_1of2 GG/GL-1c1_1of2	20	IPCC GPG Default	
Stock change factor for land use or land-use change type in the beginning of inventory year	$FLU_{(0-T)}$	3.75	CC/CL-1c1_1of2	0.82	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	
Stock change factor for management regime in the beginning of inventory year	$FMG_{(0-T)}$	3.75	CC/CL-1c1_1of2	1	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	
Stock change factor for input of organic matter in the beginning of inventory year	$FI_{(0-T)}$	3.75	CC/CL-1c1_1of2	1	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	
Stock change factor for land use or land-use change type in current inventory year	$FLU_{(0)}$	3.75	CC/CL-1c1_2of2	0.82	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Stock change factor for management regime in current inventory year	$FMG_{(0)}$	3.75	CC/CL-1c1_2of2	1	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	
Stock change factor for input of organic matter in current inventory year	$FI_{(0)}$	3.75	CC/CL-1c1_2of2	1	IPCC GPG Default Table 3.3.4, experts' surveys (J. Stephan)	
Emission factor for climate type c	EF	3.79 3.114	CC/CL-1c2_1of1 GG/GL-1c2_1of1	0	IR	No organic soils (Expert's surveys, T. Darwish)
Type of lime	type	3.80 3.115	CC/CL-1c3_1of1 GG/GL-1c3_1of1	0	IR	No lime applied (experts' surveys, J. Stephan)
Total Annual amount of lime applied	amount	3.80 3.115	CC/CL-1c3_1of1 GG/GL-1c3_1of1	0	Experts' surveys (J. Stephan)	No lime applied
Emission Factor (carbonate carbon contents of the materials)	EF	3.80 3.115	CC/CL-1c3_1of1 GG/GL-1c3_1of1	0	IR	No lime applied
Average annual biomass growth of perennial woody biomass	$G_{perennial}$	3.107	GG/GL-1a_1of2	0	IR	No grasslands covered with perennial woody biomass

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Average annual biomass loss of perennial woody biomass	$L_{perennial}$	3.107	GG/GL-1a_1of2	0	IR	No grasslands covered with perennial woody biomass
Average annual biomass growth of grasses	$G_{grasses}$	3.107	GG/GL-1a_2of2	0	NA	Tier 1 assumes no change
Average annual biomass loss of grasses	$L_{grasses}$	3.107	GG/GL-1a_2of2	0	NA	Tier 1 assumes no change
Stock change factor for land use or land-use change type in the beginning of inventory year	$FLU_{(0-T)}$	3.112	GG/GL-1c1_1of2	1	IPCC GPG Default Table 3.4.5	
Stock change factor for management regime in the beginning of inventory year	$FMG_{(0-T)}$	3.112	GG/GL-1c1_1of2	0.95	IPCC GPG Default Table 3.4.5, Darwish & Faour (2008)	
Stock change factor for input of organic matter in the beginning of inventory year	$FI_{(0-T)}$	3.112	GG/GL-1c1_1of2	1	IPCC GPG Default Table 3.4.5, experts' surveys (J. Stephan)	
Stock change factor for land use or land-use change type in current inventory year	$FLU_{(0)}$	3.112	GG/GL-1c1_2of2	1	IPCC GPG Default Table 3.4.5	
Stock change factor for management regime in current	$FMG_{(0)}$	3.112	GG/GL-1c1_2of2	0.95	IPCC GPG Default Table 3.4.5, Darwish	

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
inventory year					& Faour (2008)	
Stock change factor for input of organic matter in current inventory year	$FI_{(0)}$	3.112	GG/GL-1c1_2of2	1	IPCC GPG Default Table 3.4.5, experts' surveys (J. Stephan)	
Mass of available fuel	B	3.120	GG/GL-1d_1of1	5,000 (fuel type 1), 6,500 (fuel type 2)	(TRAGSA, 2012)	
CH4 Emission factor	D	3.120	GG/GL-1d_1of1	3	IPCC GPG Default Table 3A.1.16	
CO Emission factor	F	3.120	GG/GL-1d_1of1	97	IPCC GPG Default Table 3A.1.16	
N2O Emission factor	H	3.120	GG/GL-1d_1of1	0.11	IPCC GPG Default Table 3A.1.16	
NOx Emission factor	J	3.120	GG/GL-1d_1of1	7	IPCC GPG Default Table 3A.1.16	
Living biomass immediately following conversion to flooded land	B_{After}	3.140	WL-2a2_1of1	0	IPCC GPG Default	
Living biomass in land immediately before conversion to flooded land	B_{Before}	3.140	WL-2a2_1of1	6.08	IPCC GPG Default Tables 3.4.2, 3.4.3	

Emission Factor	Symbol/ Abbreviation	Page in GPG	Land use Category /Sheet name	Value(s) used	Source of Value	Notes
Carbon stock in living biomass immediately following conversion to settlements	C_{After}	3.143	LS/ SL-2a_1of1	0	IPCC GPG Default	
Carbon stock in living biomass in forest immediately before conversion to settlements	C_{Before}	3.143	LS/ SL-2a_1of1	5 (Annual crops), 63 (Perennial woody crops), 0.8 (Grasslands), 67 (Coniferous forests), 61 (Broadleaved forests), 64 (Mixed forests)	IPCC GPG Default Tables 3.4.8, 3.3.2, 3.4.2, 3A.1.2	

IR: Irrelevant
NA: Not Available

Appendix IV
Identified uncertainties of E/R factors

Emission Factor	Symbol/Abbreviation	Uncertainty assessment value (%)	Source
Average annual aboveground biomass increment in natural regeneration and in plantations	G_W	50	IPCC, 2003 - p.3.32
Root-shoot ratio appropriate to increments	R	30	IPCC, 2003 - p.3.31
Carbon fraction of dry matter	CF	2	IPCC, 2003 – p.5.17
Biomass density	D	20 (Coniferous), 30 (Broadleaf and mixed)	IPCC, 2003 – p.3.31

Biomass expansion factor for converting volumes of extracted roundwood to total aboveground biomass (including bark)	BEF_2	30	IPCC, 2003 - p.3.31
Fraction of biomass left to decay in forest from fuelwood gathering	F_{BL}	NA	Not relevant since tier 1 assumes that no biomass left to decay is transferred to DOM
Annual volume of fuelwood gathering	FG	NE	Undetermined FAOSTAT data uncertainty depends on the data quality of many sources combined and depending on the methodology used to collect the data from different sources
Average biomass stock of forest areas	B_W	216.42 (Coniferous), 123.77 (Broadleaf), 121.09 (mixed)	Calculated using the ranges in Table 3A.1.2. (IPCC, 2003- p.3.157).
Fraction of biomass left to decay in forest due to disturbance	F_{bl}	50.74	Calculated using the values in Table 3 A.1.13 (IPCC, 2003 – p.3.180)

Reference carbon stock	SOC_{REF}	95	IPCC, 2003, Table 3.2.4 - p.3.43
Mass of available fuel	B	10	Liu et al. (2013)
Combustion efficiency or fraction of biomass combusted	C	2	IPCC, 2003 - p.5.17
CH4 Emission factor	D	70	IPCC, 2003 - p.3.50
CO Emission factor	F	70	IPCC, 2003 - p.3.50
N2O Emission factor	H	70	IPCC, 2003 - p.3.50

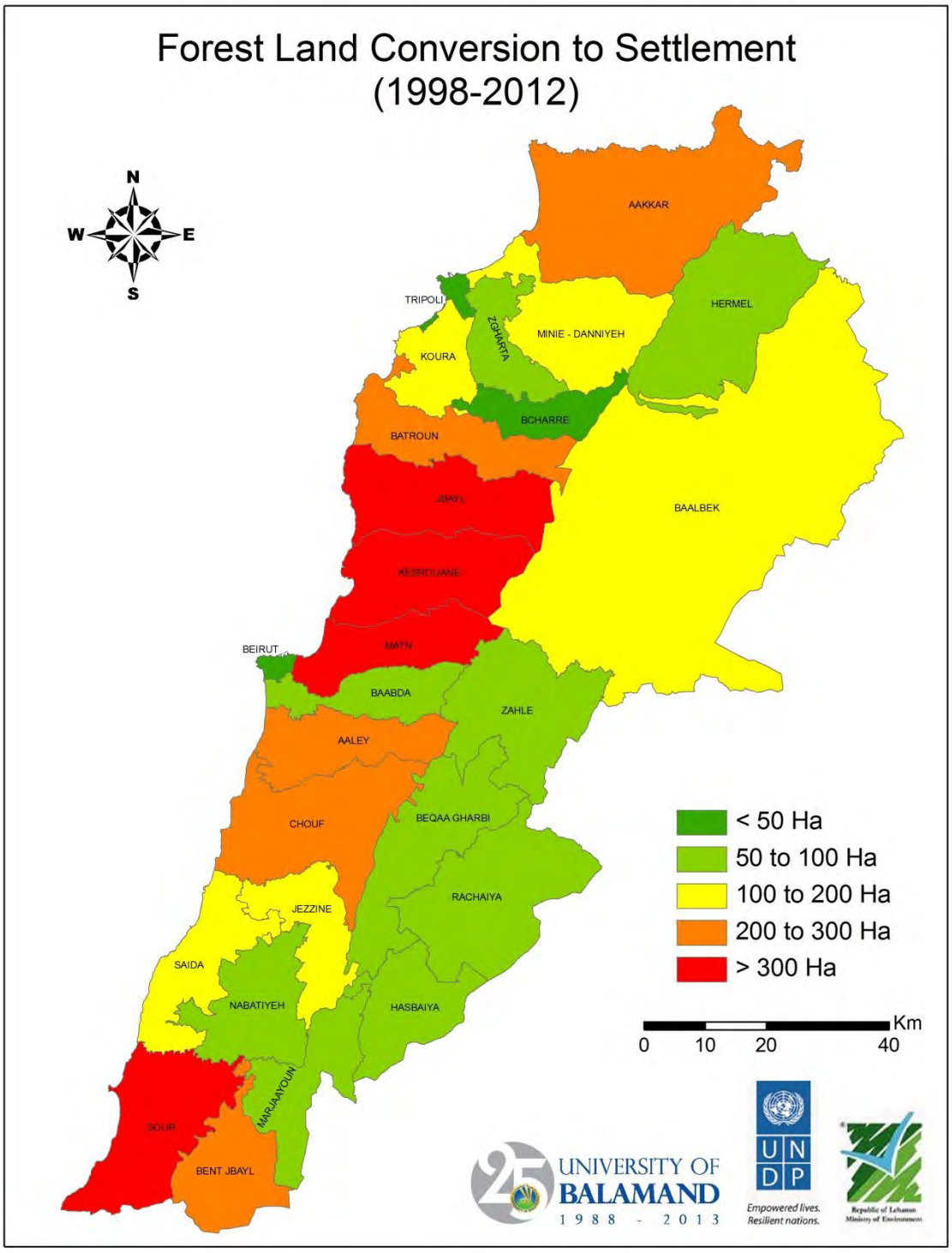
NOx Emission factor	J	70	IPCC, 2003 - p.3.50
Annual growth rate of perennial woody biomass	G	75	IPCC, 2003 – p.3.73
Annual carbon stock in biomass removed	L	75	IPCC, 2003 – p.3.73
Living biomass in land immediately before conversion to flooded land	B_{Before}	75	IPCC,2003, Table 3.4.2 – p.109
Root to shoot ratio in living biomass in lands converted to wetlands	R	95	IPCC,2003, Table 3.4.3 – p.3.110
Carbon stock in living biomass in forest immediately before conversion to settlements	C_{Before}	Annual crops 75, perennial 75, grass 75,	IPCC, 2003, p.3.73 and Table 3.3.7 - p.3.87

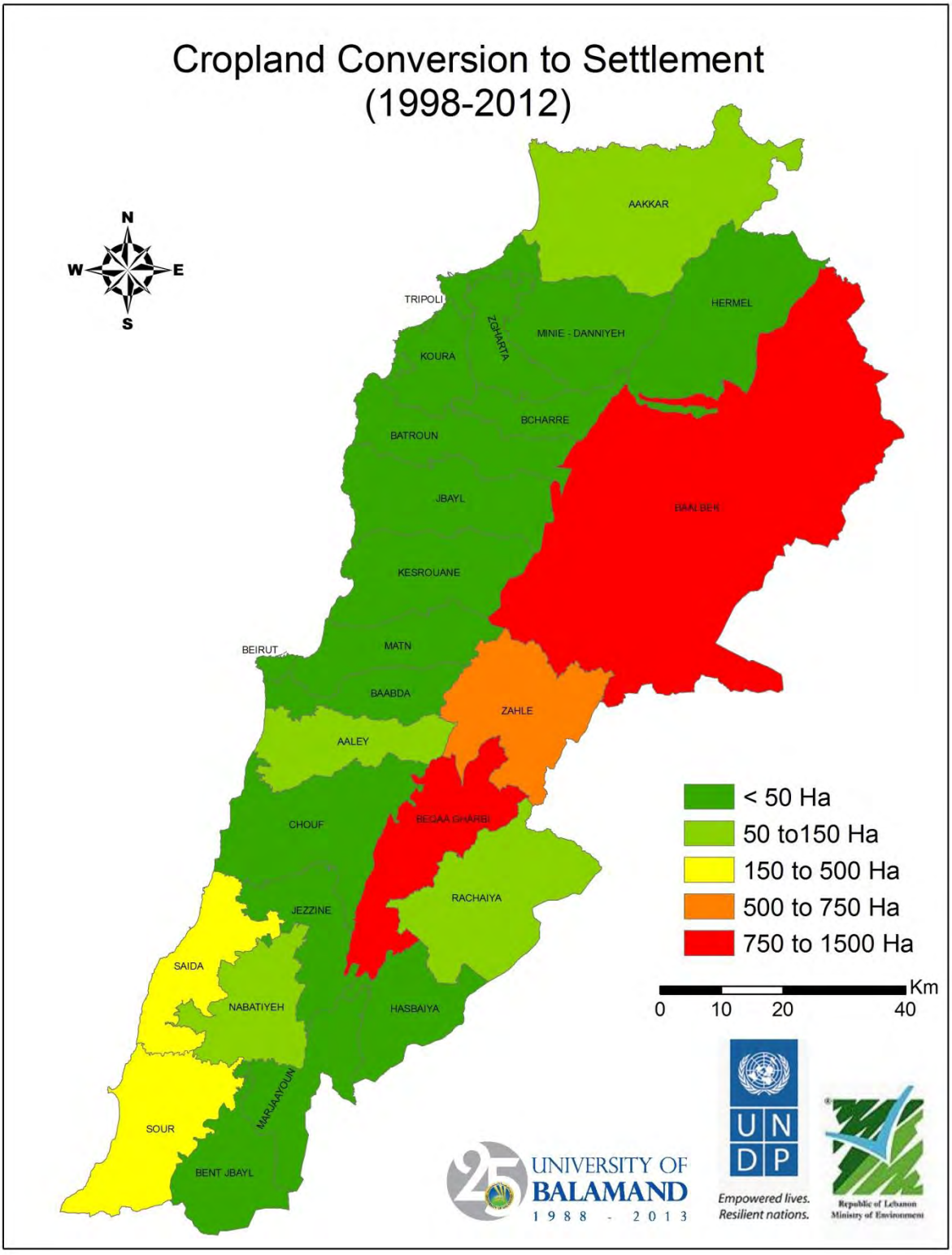
NA: Not Applicable

NE: Not Estimated

Appendix V

Maps




Cropland Conversion to Settlement
(1998-2012)
N
W
E
S
AAKKAR
TRIPOLI
ZGHARTA
HERMEL
MINIE - DANNIYEH
KOURA
BCHARRE
BATROUN
JBAYL
BAALBEK
KESROUANE
BEIRUT
MATN
BAABDA
ZAHLE
AALEY
CHOUF
BEQAA GHARBI
RACHAIYA
JEZZINE
SAIDA
NABATIYEH
HASBAIYA
MARJAAYOUN
SOUR
BENT JBAYL
< 50 Ha
50 to150 Ha
150 to 500 Ha
500 to 750 Ha
750 to 1500 Ha
Km
0
10
20
40
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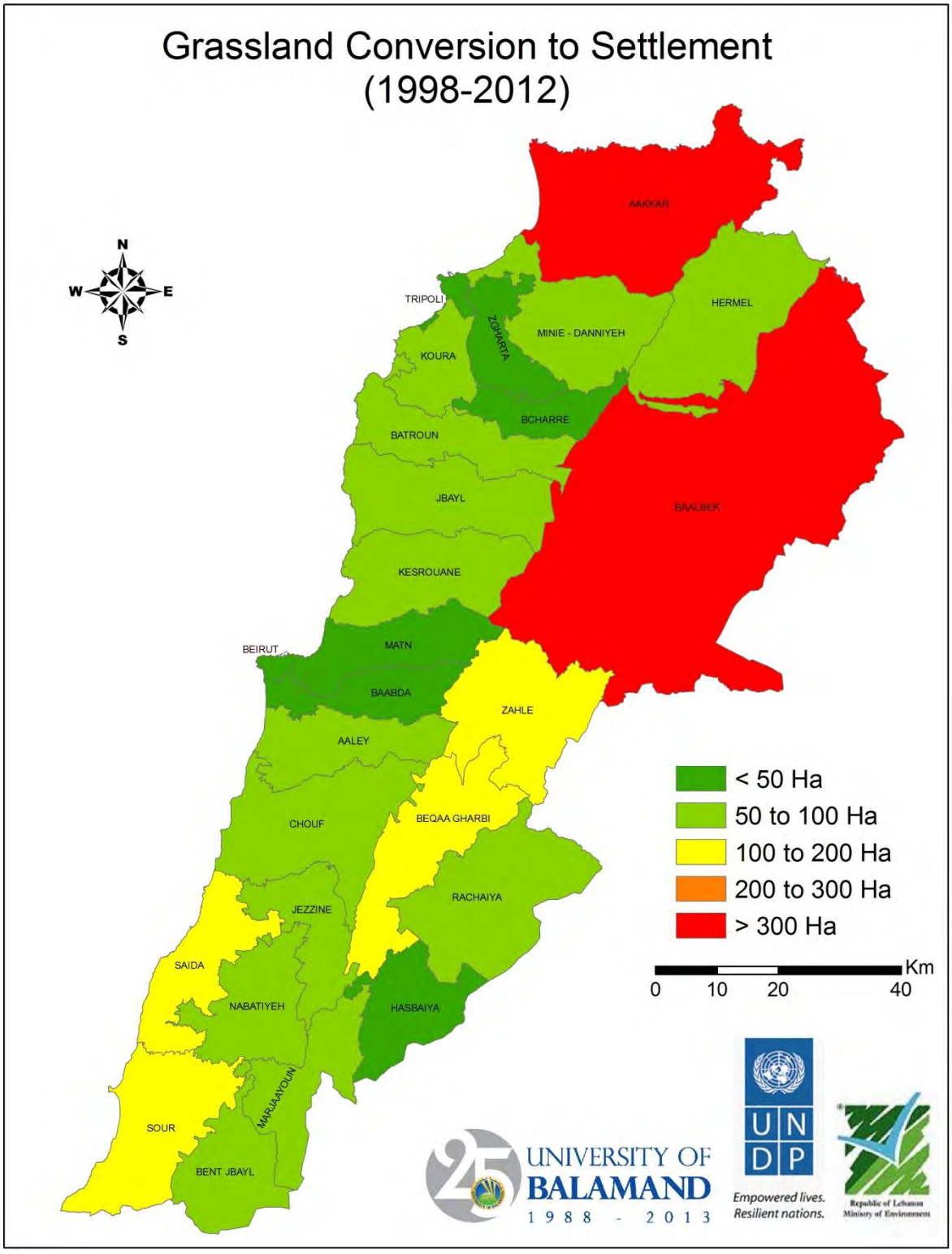
Grassland Conversion to Settlement
(1998-2012)
N
W
E
S
AAKKAR
TRIPOLI
ZGHARTA
MINIE - DANNIYEH
HERMEL
KOURA
BCHARRE
BATROUN
JBAYL
BAALBEK
KESROUANE
BEIRUT
MATN
BAABDA
ZAHLE
AALEY
CHOUF
BEQAA GHARBI
RACHAIYA
JEZZINE
SAIDA
NABATIYEH
HASBAIYA
MARJAAYOUN
SOUR
BENT JBAYL
< 50 Ha
50 to 100 Ha
100 to 200 Ha
200 to 300 Ha
> 300 Ha
Km
0 10 20 40
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UNDP
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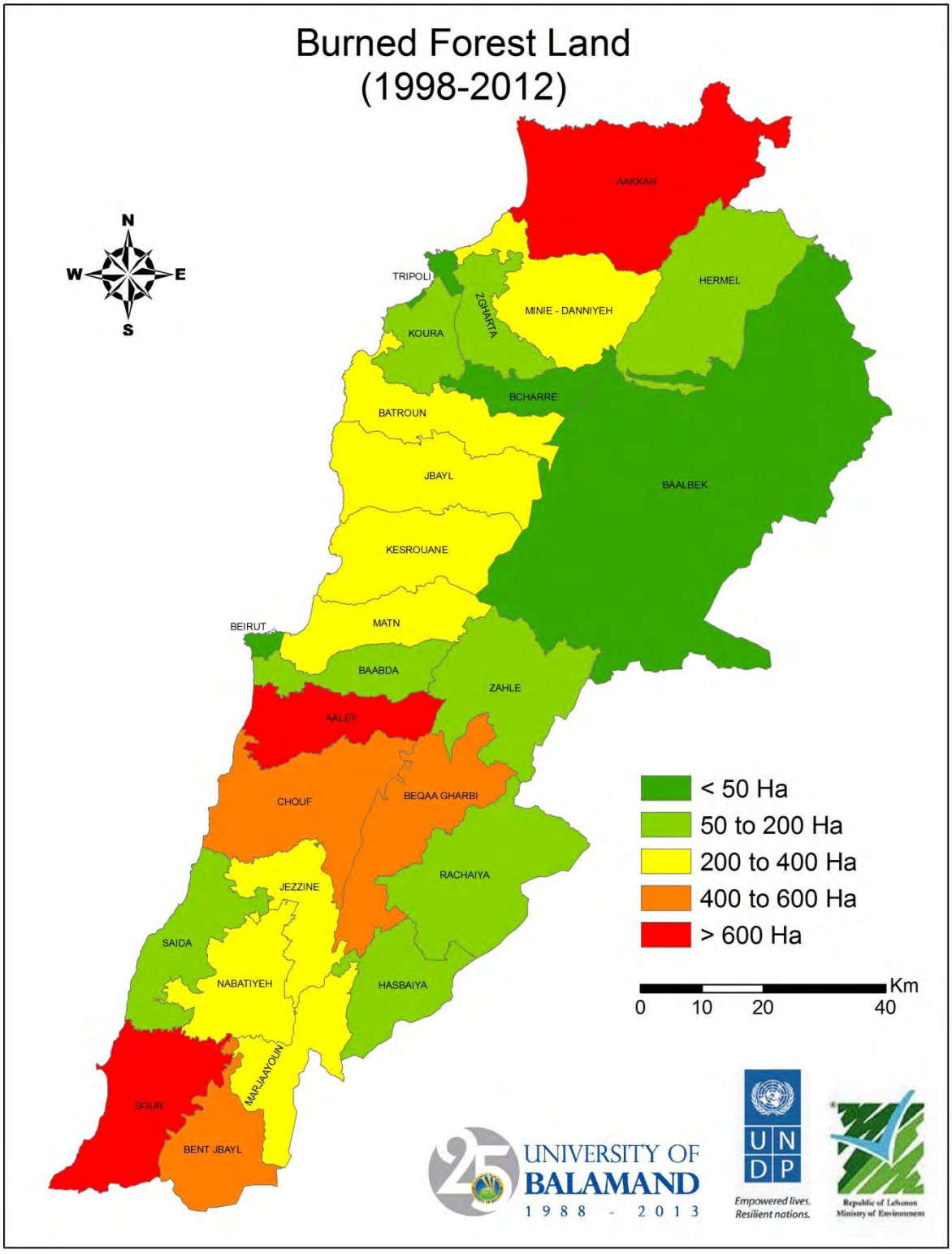
Ministry of Environment


Burned Forest Land
(1998-2012)
N
W
E
S
AAKKAR
TRIPOLI
ZGHARTA
MINIE - DANNIYEH
HERMEL
KOURA
BCHARRE
BATROUN
JBAYL
BAALBEK
KESROUANE
MATN
BEIRUT
BAABDA
ZAHLE
AALEY
CHOUF
BEQAA GHARBI
RACHAIYA
JEZZINE
SAIDA
NABATIYEH
HASBAIYA
MARJAAYOUN
SOUR
BENT JBAYL
< 50 Ha
50 to 200 Ha
200 to 400 Ha
400 to 600 Ha
> 600 Ha
Km
0
10
20
40
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UNDP
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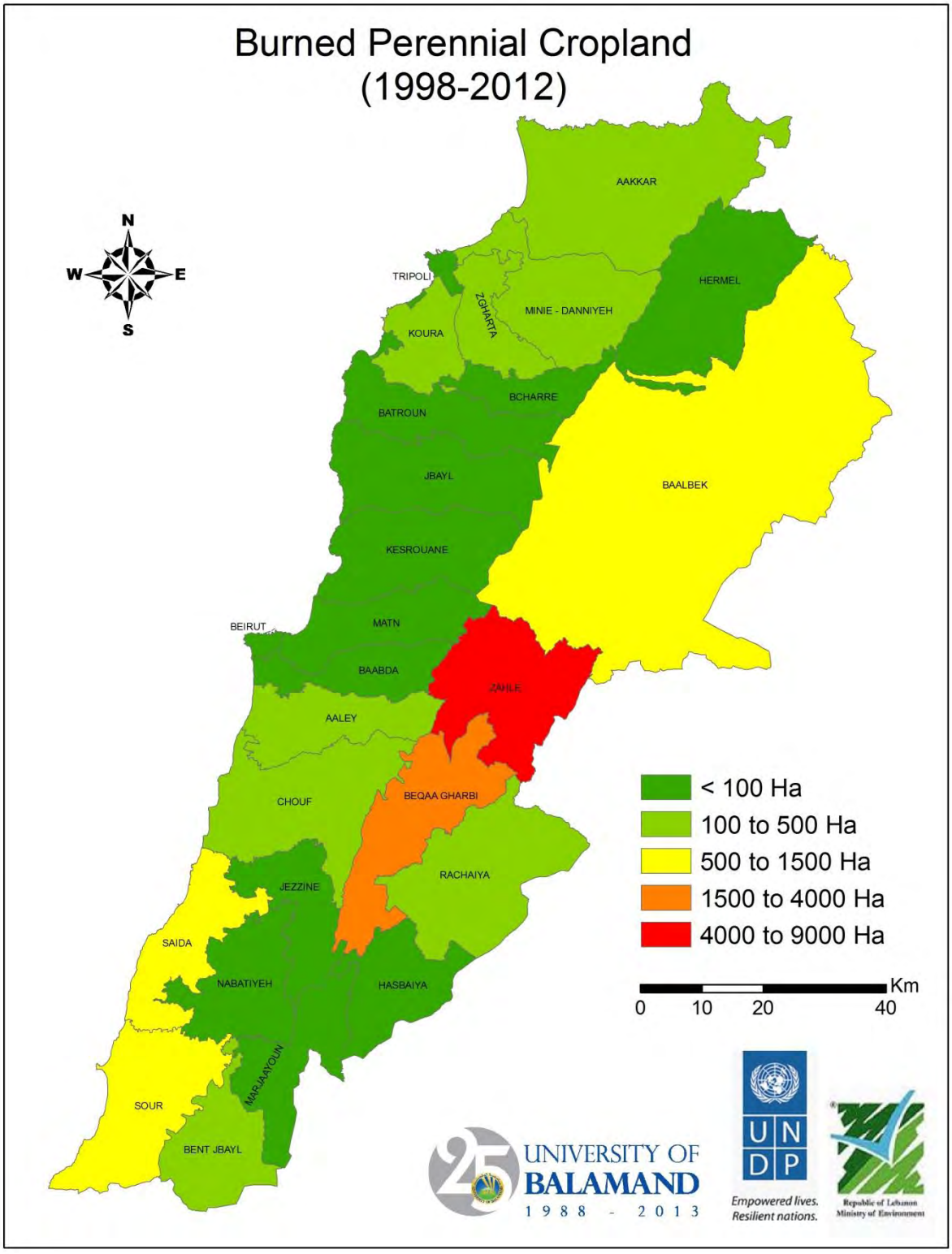
Burned Perennial Cropland
(1998-2012)
N
W
E
S
AAKKAR
TRIPOLI
ZGHARTA
MINIE - DANNIYEH
HERMEL
KOURA
BCHARRE
BATROUN
JBAYL
BAALBEK
KESROUANE
BEIRUT
MATN
BAABDA
ZAHLE
AALEY
CHOUF
BEQAA GHARBI
RACHAIYA
JEZZINE
SAIDA
NABATIYEH
HASBAIYA
MARJAAYOUN
SOUR
BENT JBAYL
< 100 Ha
100 to 500 Ha
500 to 1500 Ha
1500 to 4000 Ha
4000 to 9000 Ha
Km
0
10
20
40
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UNDP
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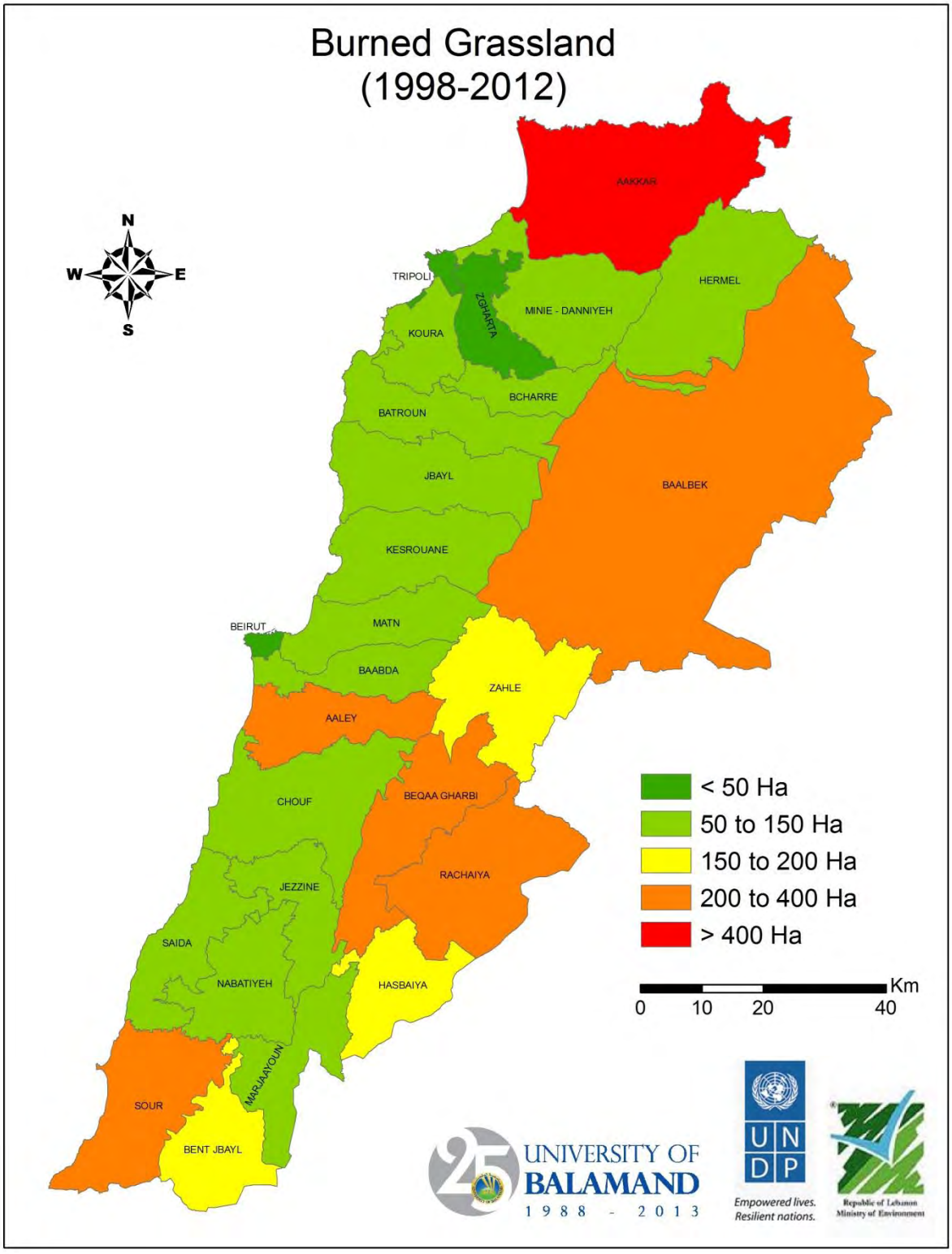
Resilient nations.
Republic of Lebanon
Ministry of Environment


Burned Grassland
(1998-2012)
N
W
E
S
AAKKAR
TRIPOLI
ZGHARTA
MINIE - DANNIYEH
HERMEL
KOURA
BCHARRE
BATROUN
JBAYL
BAALBEK
KESROUANE
BEIRUT
MATN
BAABDA
ZAHLE
AALEY
CHOUF
BEQAA GHARBI
RACHAIYA
JEZZINE
SAIDA
NABATIYEH
HASBAIYA
MARJAAYOUN
SOUR
BENT JBAYL
< 50 Ha
50 to 150 Ha
150 to 200 Ha
200 to 400 Ha
> 400 Ha
Km
0 10 20 40
UNIVERSITY OF BALAMAND
1988 - 2013
UNDP
Empowered lives.
Resilient nations.
Republic of Lebanon
Ministry of Environment

Appendix VI
Expert meeting participants
(9/9/2013 at the MOE)

Participants *(in alphabetical order)*	**Institution/Organization**
Christine Maksoud	National Council for Scientific Research
Dalia Jawhary	Society for the Protection of Nature in Lebanon
Fady Asmar	Freelance consultant
Garo Haroutunian	United Nations Development Programme-Ministry of Environment
George Mitri	Institute of the Environment – University of Balamand
Hanadi Musharrafiyeh	ELARD
Karine Zoghby	United Nations Development Programme-Association for Forests, Development and Conservation
Lea Kai Abou Jaoudeh	United Nations Development Programme-Ministry of Environment
Maya Nehme	Lebanon Reforestation Initiative
Mireille Jazi	Institute of the Environment – University of Balamand
Raymond Khoury	Green Plan
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