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NATIONAL GREENHOUSE GAS INVENTORY REPORT AND MITIGATION ANALYSIS FOR THE AGRICULTURE SECTOR IN LEBANON

2015 MINISTRY OF ENVIRONMENT

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National Greenhouse Gas Inventory Report and Mitigation Analysis for the Agriculture Sector in Lebanon

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Foreword

Ministry of Environment

Through the publications of Lebanon's Initial and Second National Communications to the United Nations Framework Convention on Climate Change, and the Technology Needs Assessment for Climate Change, the Ministry of Environment drew the large climate change picture in the country. The picture shed the light on a number of climate change matters: Lebanon's contribution to global greenhouse gas emissions, the sectoral share of national emissions, the socio-economic and environmental risks that the country faces as a result of climate change, and the potential actions that could and should be undertaken to fight climate change both in terms of mitigation and adaptation.

Through these series of focused studies on various sectors (energy, forestry, waste, agriculture, industry, finance and transport), the Ministry of Environment is digging deeper into the analysis to identify strengths, weaknesses, threats and opportunities to climate friendly socio-economic development within each sector.

The technical findings presented in this report (National Greenhouse Gas Inventory Report and Mitigation Analysis for the Agriculture Sector) will support policy makers in making informed decisions. The findings will also help academics in orienting their research towards bridging research gaps. Finally, they will increase public awareness on climate change and its relation to each sector. In addition, the present technical work complements the strategic work of the National Climate Change Coordination Unit. This unit has been bringing together representatives from public, private and non-governmental institutions to merge efforts and promote comprehensive planning approach to optimize climate action.

We are committed to be a part of the global fight against climate change. And one of the important tools to do so is improving our national knowledge on the matter and building our development and environmental policies on solid ground.

Mohamad Al Mashnouk

Minister of Environment

Foreword

United Nations Development Programme

Climate change is one of the greatest challenges of our time; it requires immediate attention as it is already having discernible and worsening effects on communities everywhere, including Lebanon. The poorest and most vulnerable populations of the world are most likely to face the harshest impact and suffer disproportionately from the negative effects of climate change.

The right mix of policies, skills, and incentives can influence behaviour and encourage investments in climate development-friendly activities. There are many things we can do now, with existing technologies and approaches, to address it.

To facilitate this, UNDP enhances the capacity of countries to formulate, finance and implement national and sub-national plans that align climate management efforts with development goals and that promote synergies between the two.

In Lebanon, projects on Climate Change were initiated in partnership with the Ministry of Environment from the early 2000s. UNDP has been a key partner in assisting Lebanon to assess its greenhouse gas emissions and duly reporting to the UN Framework Convention on Climate Change. With the generous support of numerous donors, projects have also analysed the impact of climate change on Lebanon's environment and economy in order to prioritise interventions and integrate climate action into the national agenda. UNDP has also implemented interventions on the ground not only to mitigate the effects of climate change but also to protect local communities from its impact.

This series of publications records the progress of several climate-related activities led by the Ministry of Environment which UNDP Lebanon has managed and supported during the past few years. These reports provide Lebanon with a technically sound solid basis for designing climate-related actions, and support the integration of climate change considerations into relevant social, economic and environmental policies.

Ross Mountain

UNDP Resident Representative

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Acronyms

AAP	Annual Average Population
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AUB	American University of Beirut
BAU	Business as Usual
CA	Conservation Agriculture
CDD	Consecutive Dry Days
CSA	Climate Smart Agriculture
CV	Conventional Agriculture
DM	Dry Matter
EF	Emission Factor
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Statistics
FBMP	Fertilizer Best Management Practices
FFS	Field Farmer Schools
FMD	Food and Mouth Disease
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	The Deutsche Gesellschaft für Internationale Zusammenarbeit
GoL	Government of Lebanon
GPG	Good Practice Guidance
GWP	Global Warming Potential
ICARDA	International Center for Agricultural Research in the Dry Areas
IFAD	International Fund for Agricultural Development
IMC	Instituto Mediterraneo Di Certificazione
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPCC GL	Intergovernmental Panel on Climate Change Guidelines
LARI	Lebanese Agricultural Research Institute
LRF	Lebanon Recovery Fund

LSD	Lumpy Skin Disease
LULUCF	Land Use, Land-Use Change and Forestry
MMS	Manure Management System
MoA	Ministry of Agriculture
NAPA	Number of Animals Produced Annually
NO	Not Occurring
NPK	Nitrogen-Phosphorus-Potassium fertilizer
PRP	Pasture Range and Paddock
SNC	Second National Communication
TAD	Transboundary Animal Disease
TNA	Technology Needs Assessment
TNC	Third National Communication
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

Executive summary

In the framework of Lebanon's Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC), Greenhouse Gas (GHG) emissions resulting from the agriculture sector in Lebanon were estimated for the years 2005 through 2012. Calculations were made using the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) and the 2000 Good Practice Guidance (GPG) and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000). The tier 1 approach of the IPCC guidelines was adopted in the calculation of GHG and consequently for the development of the national greenhouse gas inventory.

Inventory

The emissions from agriculture during the period 2005-2012 slightly decreased, with emissions in 2012 about 5% lower than the base year 2005 (Table i, Figure i). This is largely a result of a decrease in emissions from enteric fermentation by 34 Gg of carbon dioxide equivalent (CO_2eq.) and to a lesser extent a decrease in nitrous oxide (N_2O) emissions from manure management by 10 Gg CO_2eq., and in methane (CH_4) emissions from manure management by 4.5 Gg CO_2eq. The decrease in this period is mainly attributed to the decrease in livestock population, primarily sheep and goats.

Table i: GHG emissions by agricultural source (Gg CO_2eq.) and contribution in 2005-2012 (% of total)

Year	CH_4 emissions enteric fermentation Gg CO_2eq. (%)	CH_4 emissions manure management Gg CO_2eq. (%)	N_2O emissions manure management Gg CO_2eq. (%)	N_2O emissions agricultural soils Gg CO_2eq. (%)	Total emissions from agriculture Gg CO_2eq.
2005	234.05 (25)	41.79 (5)	163.24 (18)	483.19 (52)	**922.27**
2006	237.70 (27)	42.36 (5)	168.56 (19)	430.14 (49)	**878.75**
2007	228.88 (25)	42.14 (5)	166.72 (18)	467.21 (52)	**904.94**
2008	238.06 (27)	42.46 (5)	168.38 (19)	438.98 (49)	**887.88**
2009	226.01 (25)	40.06 (4)	164.33 (18)	478.21 (53)	**908.61**
2010	205.17 (24)	38.34 (4)	154.17 (18)	467.67 (54)	**865.35**
2011	201.11 (23)	37.68 (4)	153.59 (18)	479.77 (55)	**872.15**
2012	200.46 (23)	37.27 (4)	153.42 (18)	485.36 (55)	**876.51**

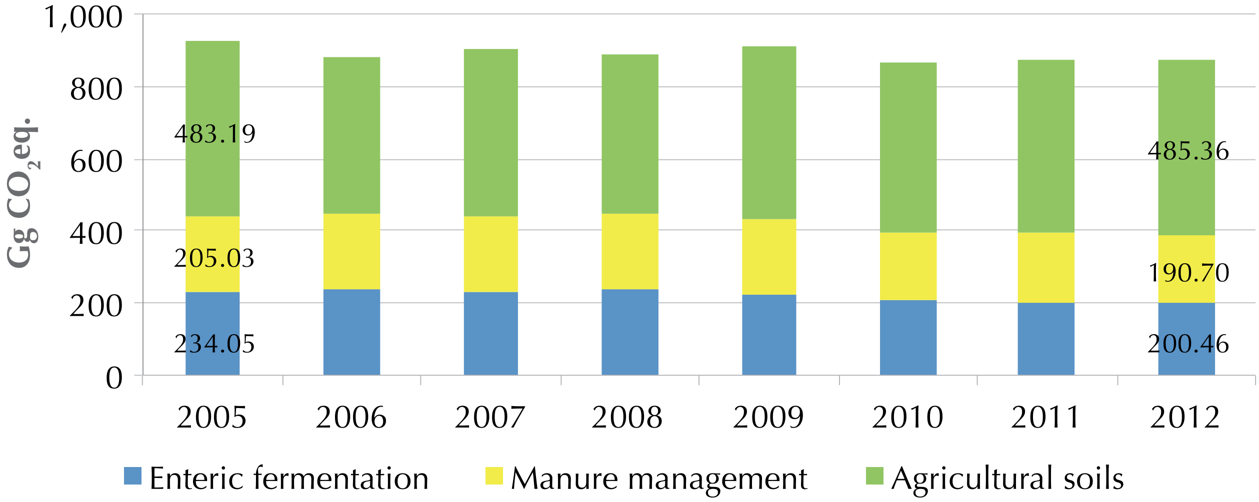


Figure i: Trend of agricultural emissions in Lebanon by category in 2005-2012 (Gg CO_2eq.)

The trend in agricultural emissions during the 1994-2012 period showed a more pronounced decrease compared with base year 1994. Emissions decreased by 160.6 Gg CO_2eq. (15%) from the 1994 level of 1,037.1 Gg CO_2eq. (Figure ii). This is largely a result of a decrease in emissions from agricultural soils by 130.7 Gg CO_2eq. (21%), and to a lesser extent, a decrease in CH_4 emissions from enteric fermentation by 31 Gg CO_2eq. (13%). The main reason for the decrease in agricultural emissions from soils - the largest contributor to GHG in the agriculture sector - is the decrease in the use of nitrogen fertilizers and in the addition of crop residues to soils during the 1994-2006 period.

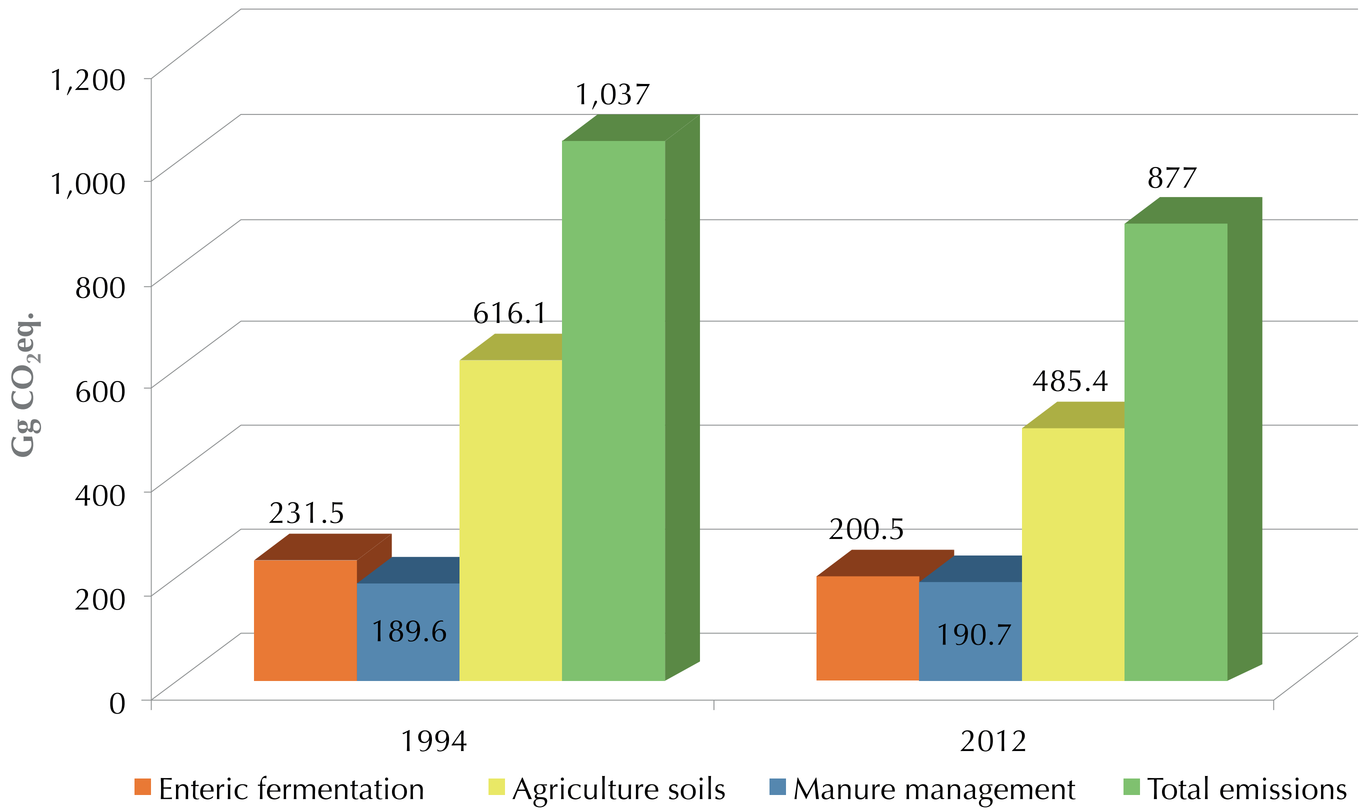


Figure ii: Agricultural GHG emissions in Lebanon in 2012 compared with base year 1994 (Gg CO_2eq.)

In 2012, total GHG emissions from the agriculture sector in Lebanon amounted to 876.51 Gg of carbon dioxide equivalent (Gg CO_2eq.). The sources of GHG emissions from agriculture[1] and their relative contributions were: N_2O emissions from agricultural soils (55%), CH_4 emissions from enteric fermentation of domestic animals (23%), and N_2O and CH_4 emissions from manure management (22%). Of the emissions from manure management, approximately 18% were from N_2O and 4% from CH_4 emissions (Figure iii).

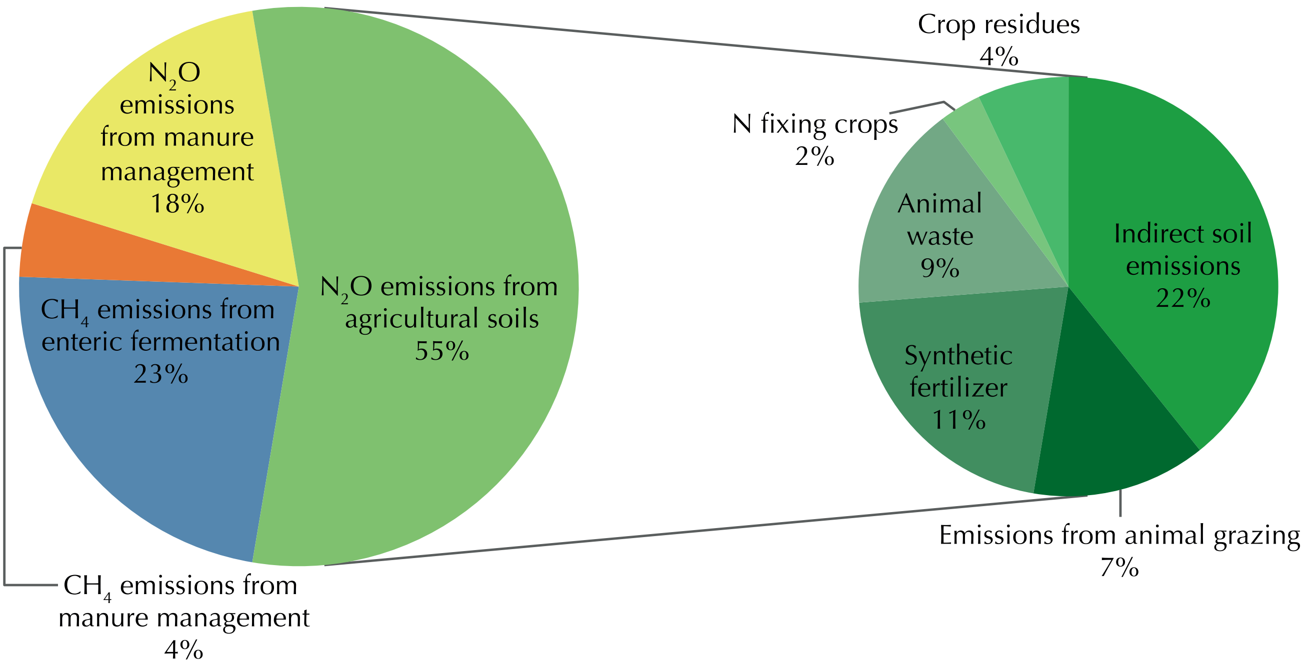


Figure iii: Sources of GHG emissions from the agriculture sector in Lebanon (2012)

Direct emissions from agricultural soils represented 26% of total emissions from agriculture and were mainly a result of synthetic fertilizers (11%) and animal waste (9%) added to soil. While indirect emissions (22% of total agricultural emissions) were due to leaching (18%) and volatilization (4%) of applied nitrogen. Emissions from animal grazing (Pasture Range and Paddock (PRP)) were 7% of total agricultural emissions.

Mitigation

The agriculture sector in Lebanon faces many challenges that are compounded by climate change. Scarcity of water resources and deteriorating water quality, recurring droughts, urban encroachment, high cost of fuel and fertilizers, and the abandonment by young people of agriculture as a profession are some of the main issues facing a Lebanese farmer.

Several projects in Lebanon aim at increasing crop and animal production while decreasing GHG emissions and increasing the resilience to climate change. These projects are sponsored by international organizations such as FAO (Food and Agriculture Organization), ICARDA (International

[1] According to the UNFCCC, some of the GHG emissions from agriculture are reported under sectors other than agriculture. CO_2 emissions released from agricultural soils are reported in the Land Use, Land-Use Change and Forestry (LULUCF) sector, and emissions from agricultural machinery and other energy use related to agriculture are reported in the energy sector.

Center for Agriculture Research in the Dry Areas), IFAD (International Fund for Agricultural Development), and USAID (United States Agency for International Development) and implemented by the MoA (Ministry of Agriculture), research centers such as LARI (Lebanese Agricultural Research Institute), universities and non-governmental organizations.

Two mitigation options are proposed to reduce GHG emissions from agricultural soils which constitute 55% of total agricultural GHG emissions in Lebanon – Conservation Agriculture (CA) and Fertilizer Best Management Practices (FBMP) through fertigation and drip irrigation.

CA increases soil carbon sequestration through retained crop residues and the practices of crop rotation and cover crops. It also decreases CO_2 emissions by decreasing fuel consumption through adopting minimum or zero tillage, and decreases N_2O emissions by decreasing fertilizer requirements. The benefits of increasing soil organic matter, reducing cost, and increasing soil moisture are illustrated in trials performed by local and international organizations and universities. The mitigation analysis shows that under a scenario where CA would increase by 10% in 2020 and 20% in 2040 of the current areas planted with cereals, olives, and fruit trees, the estimated GHG reduction potential from soil carbon sequestration alone would amount to 58.6 and 117.2 Gg CO_2eq., respectively.

FBMP via fertigation and drip irrigation reduces N (nitrogen) fertilizer use, decreases cost, increases N use efficiency, decreases runoff and leaching losses of applied N, reduces volatilization of applied N, and reduces the water demand from irrigated agriculture, the largest water consumer in Lebanon (60% of total water withdrawals). Fertigation can be applied to almost all crops that could be irrigated through drip irrigation. Using potato as an example, and assuming the adoption rate of fertigation through drip irrigation is 50% of the current irrigated potato land areas by the year 2020 and 100% by the year 2040, the estimated reduction potential in N_2O emissions from saved fertilizer alone is estimated at 20.5 Gg CO_2eq. in 2020 and 41 Gg CO_2eq. in 2040. The GHG emission reduction potential would be much higher when fertigation and drip irrigation become widely practiced in irrigated vegetable crop production in both field and protected houses, and in orchard production.

Concerning hindrances, one of the main obstacles against realizing CA is the lack of incentives for farmers and this can be addressed through subsidies that are based on no-till areas rather than the crop itself.

Through fertigation, farmers can save substantial amounts of fertilizer which is a win-win situation for the climate and the farmer. Both N use and cost are reduced significantly and farmers recuperate the initial capital for a drip system, which is a major obstacle in adopting the technology, in just one year.

الملخص التنفيذي

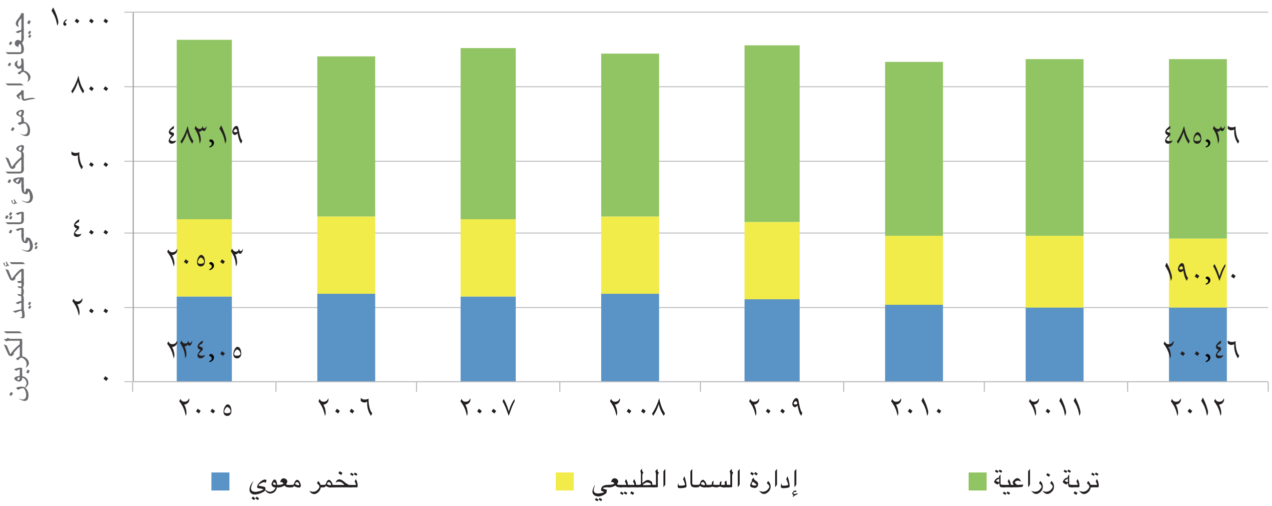
في إطار البلاغ الوطني الثالث للبنان إلى اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، تم تقدير انبعاثات غاز الاحتباس الحراري (الغازات الدفيئة) الناجمة عن قطاع الزراعة في لبنان للأعوام ٢٠٠٥ حتى عام ٢٠١٢. وتمت العملية الحسابية باستخدام الخطوط التوجيهية المنقحة للهيئة الحكومية الدولية المعنية بتغير المناخ لعام ١٩٩٦ بشأن عمليات الجرد الوطنية لغازات الإحتباس الحراري ودليل الممارسات السليمة في عمليات الجرد الوطنية لغازات الإحتباس الحراري و درجة عدم اليقين في تقديراتها . وتم اعتماد المبادئ التوجيهية لمنهجية المستوى ١ للهيئة الحكومية الدولية المعنية بتغير المناخ (IPCC) في احتساب الغازات الدفيئة ومن ثم لتطوير قوائم الجرد الوطنية للغازات الدفيئة.

قوائم الجرد

لقد شهدت الانبعاثات الناتجة من الزراعة خلال الفترة ٢٠٠٥–٢٠١٢ انخفاضًا بسيطًا، وكانت الانبعاثات الصادرة في العام ٢٠١٢ أقلّ بحوالي ٥٪ من سنة الأساس عام ٢٠٠٥ (الجدول أ، الشكل أ). وهذا، إلى حد كبير، هو نتيجة لانخفاض في الانبعاثات من التخمر المعوي بنسبة ٣٤ جيغاغرام من مكافئ ثاني أكسيد الكربون، وإلى حد أقل، لانخفاض في انبعاثات أكسيد النيتروجين من إدارة السماد الطبيعي بنسبة ١٠جيغاغرام من مكافئ ثاني أكسيد الكربون وانبعاثات الميثان من إدارة السماد الطبيعي بنسبة ٤،٥ جيغاغرام من مكافئ ثاني أكسيد الكربون. ويمكن نسب الانخفاض في هذه الفترة بشكل أساسي إلى انخفاض في أعداد الثروة الحيوانية، وفي الأغنام والماعز بالدرجة الأولى.

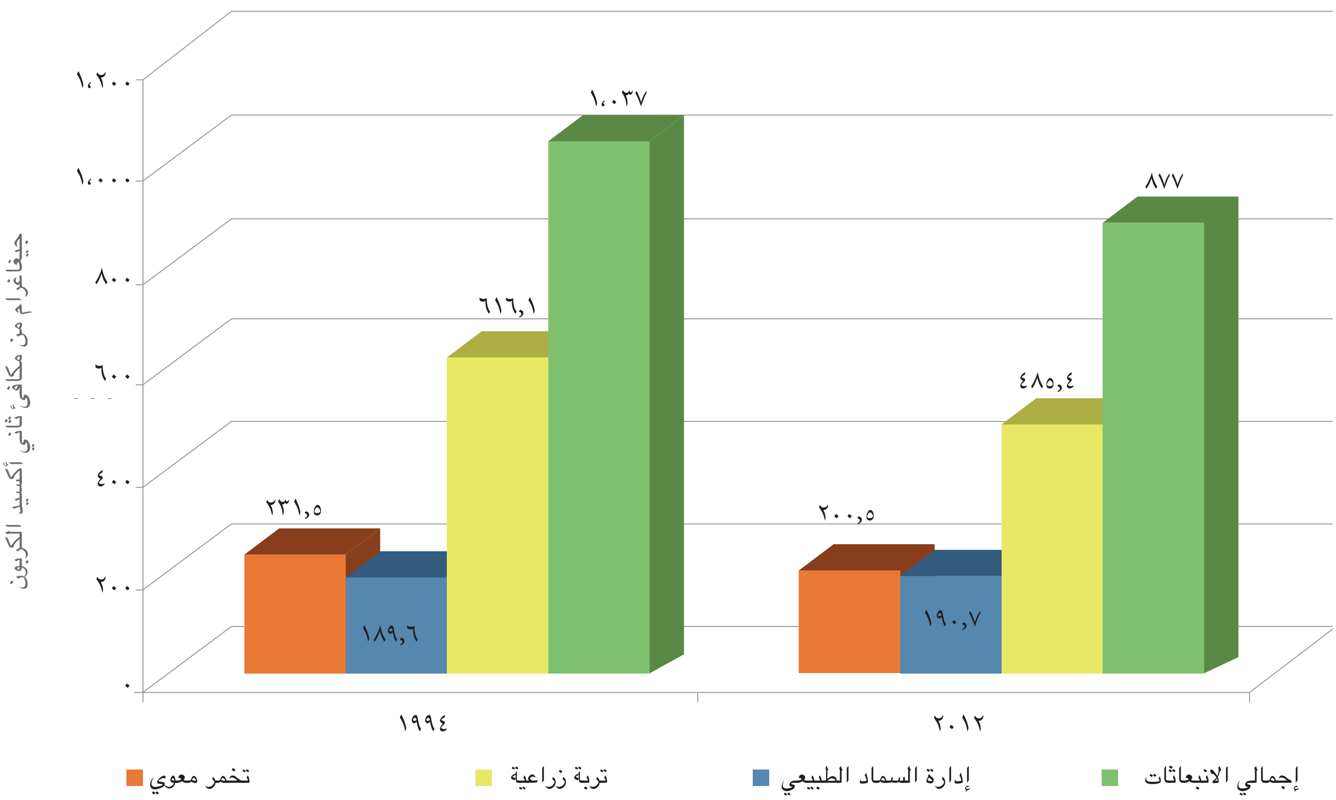
الجدول أ: انبعاثات الغازات الدفيئة من مصادر الانبعاثات الزراعية (جيغاغرام من مكافئ ثاني أكسيد الكربون) والمساهمة في الفترة ٢٠٠٥–٢٠١٢ (النسبة المئوية من المجموع الإجمالي)

السنة	انبعاثات الميثان التخمر المعوي جيغاغرام من مكافئ ثاني أكسيد الكربون (٪)	انبعاثات الميثان إدارة السماد الطبيعي جيغاغرام من مكافئ ثاني أكسيد الكربون (٪)	انبعاثات أكسيد النيتروجين إدارة السماد الطبيعي جيغاغرام من مكافئ ثاني أكسيد الكربون (٪)	انبعاثات أكسيد النيتروجين التربة الزراعية جيغاغرام من مكافئ ثاني أكسيد الكربون (٪)	إجمالي الانبعاثات من قطاع الزراعة جيغاغرام من مكافئ ثاني أكسيد الكربون (٪)
٢٠٠٥	٢٣٤,٠٥ (٢٥)	٤١,٧٩ (٥)	١٦٣,٢٤ (١٨)	٤٨٣,١٩ (٥٢)	٩٢٢,٢٧
٢٠٠٦	٢٣٧,٧٠ (٢٧)	٤٢,٣٦ (٥)	١٦٨,٥٦ (١٩)	٤٣٠,١٤ (٤٩)	٨٧٨,٧٥
٢٠٠٧	٢٢٨,٨٨ (٢٥)	٤٢,١٤ (٥)	١٦٦,٧٢ (١٨)	٤٦٧,٢١ (٥٢)	٩٠٤,٩٤
٢٠٠٨	٢٣٨,٠٦ (٢٧)	٤٢,٤٦ (٥)	١٦٨,٣٨ (١٩)	٤٣٨,٩٨ (٤٩)	٨٨٧,٨٨
٢٠٠٩	٢٢٦,٠١ (٢٥)	٤٠,٠٦ (٤)	١٦٤,٣٣ (١٨)	٤٧٨,٢١ (٥٣)	٩٠٨,٦١
٢٠١٠	٢٠٥,١٧ (٢٤)	٣٨,٣٤ (٤)	١٥٤,١٧ (١٨)	٤٦٧,٦٧ (٥٤)	٨٦٥,٣٥
٢٠١١	٢٠١,١١ (٢٣)	٣٧,٦٨ (٤)	١٥٣,٥٩ (١٨)	٤٧٩,٧٧ (٥٥)	٨٧٢,١٥
٢٠١٢	٢٠٠,٤٦ (٢٣)	٣٧,٢٧ (٤)	١٥٣,٤٢ (١٨)	٤٨٥,٣٦ (٥٥)	٨٧٦,٥١

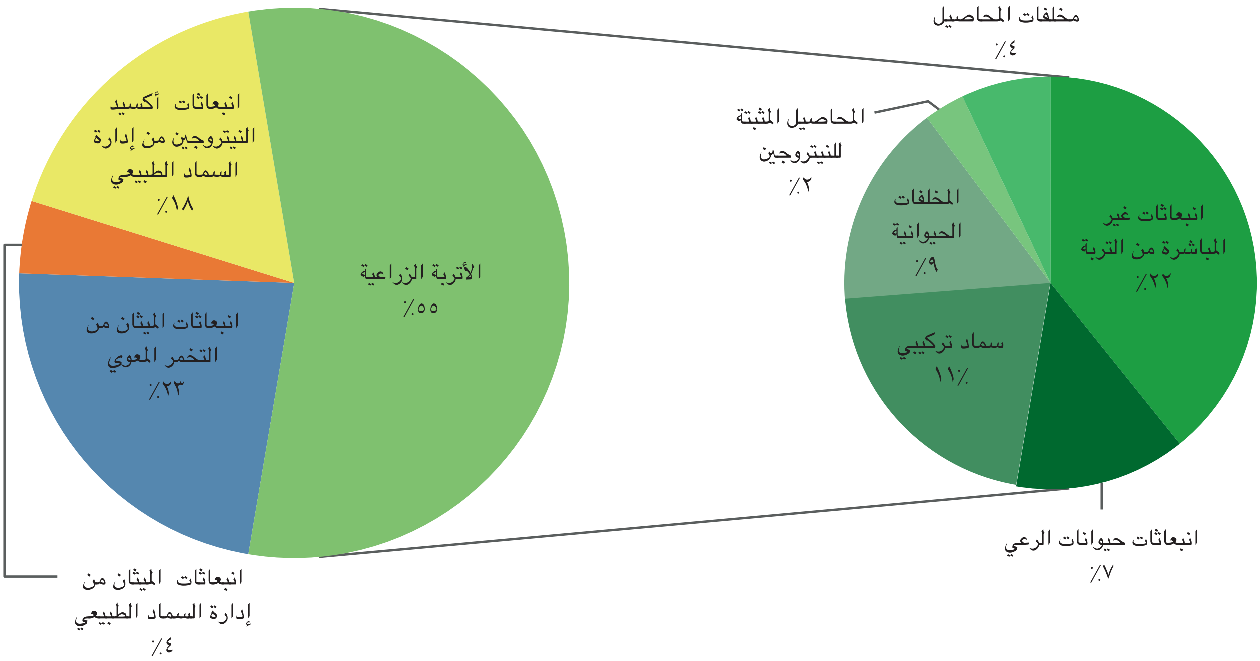


الشكل أ: حركة الانبعاثات الزراعية في لبنان بحسب الفئة في الفترة ٢٠٠٥ – ٢٠١٢ (جيغاغرام من مكافئ ثاني أكسيد الكربون)

أظهرت حركة الانبعاثات الزراعية خلال الفترة ١٩٩٤–٢٠١٢ انخفاضًا أكثر حدّة مقارنةً مع السنة الأساس ١٩٩٤. وقد انخفضت الانبعاثات بنسبة ١٦٠,٦ جيغاغرام من مكافئ ثاني أكسيد الكربون (١٥٪) عن معدل العام ١٩٩٤ والبالغ ١،٣٠٧,١ جيغاغرام من مكافئ ثاني أكسيد الكربون (الشكل ب). وهذا، إلى حد كبير، هو نتيجة لانخفاض في الانبعاثات من الأتربة الزراعية بنسبة ١٣٠,٧جيغاغرام من مكافئ ثاني أكسيد الكربون (٢١٪) وإلى حد أقل، لانخفاض في انبعاثات الميثان من التخمر المعوي بنسبة ٣١ جيغاغرام من مكافئ ثاني أكسيد الكربون (١٣٪). وأما السبب الأساسي للانخفاض في الانبعاثات الزراعية من الأتربة، وهي المساهم الأكبر في انبعاثات الغازات الدفيئة في قطاع الزراعة، فهو الانخفاض في استخدام أسمدة النيتروجين وفي فضلات المحصول المضافة إلى الأتربة خلال الفترة ١٩٩٤–٢٠٠٦.



الشكل ب: انبعاثات الغازات الدفيئة الزراعية في لبنان في العام ٢٠١٢مقارنة مع سنة الأساس ١٩٩٤(جيغاغرام من مكافئ ثاني أكسيد الكربون)



الشكل ج: مصادر انبعاثات الغازات الدفيئة من قطاع الزراعة في لبنان (٢٠١٢)

في العام ٢٠١٢، بلغ مجموع انبعاثات الغازات الدفيئة من قطاع الزراعة في لبنان ٨٧٦,٥١ جيغاغرام من مكافئ ثاني أكسيد الكربون. أما مصادر انبعاثات الغازات الدفيئة من الزراعة[١] وإسهاماتها المتصّلة فكانت (الشكل ج): انبعاثات أكسيد النيتروجين من التربة الزراعية (٥٥٪) وانبعاثات الميثان من التخمر المعوي للحيوانات الأليفة (٢٣٪) وانبعاثات أكسيد النيتروجين والميثان من إدارة السماد الطبيعي (٢٢٪). وحوالي ١٨٪ من الانبعاثات الناتجة عن إدارة السماد الطبيعي هي من انبعاثات أكسيد النيتروجين، فيما ٤٪ من انبعاثات الميثان.

شكّلت الانبعاثات المباشرة من الأتربة الزراعية نسبة ٢٦٪ من إجمالي الانبعاثات الناتجة عن الزراعة وكانت بشكل عام نتيجة الأسمدة التركيبية (١١٪) والمخلفات الحيوانية (٩٪) المضافة إلى التراب. وفيما كانت الانبعاثات غير المباشرة (٢٢٪ من إجمالي الانبعاثات الزراعية) نتيجة غسل (١٨٪) وتطاير (٤٪) النيتروجين المطبّق، بلغت الانبعاثات الناتجة عن حيوانات الرعي (المرعى والحقول الصغيرة) نسبة ٧٪ من إجمالي الانبعاثات الزراعية.

تخفيف الانبعاثات

يواجه قطاع الزراعة في لبنان الكثير من التحديات التي تتفاقم نتيجة تغيّر المناخ. أما بعض المشاكل الرئيسية التي تواجه المزارع اللبناني فهي ندرة الموارد المائية ونوعية المياه المتدهورة وحالات الجفاف المتكررة والزحف العمراني وارتفاع تكلفة الوقود والأسمدة وتخلي الشباب عن الزراعة كمهنة.

وتهدف العديد من المشاريع في لبنان إلى زيادة المحاصيل والإنتاج الحيواني وتقليص انبعاثات الغازات الدفيئة وزيادة القدرة على التأقلم مع تغير المناخ. وترعى هذه المشاريع المنظمات الدولية مثال منظمة الأمم المتحدة للأغذية والزراعة والمركز الدولي للبحوث الزراعية في المناطق القاحلة والصندوق الدولي للتنمية الزراعية ووكالة الولايات المتحدة للتنمية الدولية فيما يعمل على تنفيذها وزارة الزراعة والمراكز البحثية مثال مصلحة الأبحاث العلمية الزراعية والجامعات والمنظمات غير الحكومية.

ويتم اقتراح خيارين للتخفيف من انبعاثات الغازات الدفيئة من الأتربة الزراعية والتي تشكل ٥٥٪ من إجمالي انبعاثات الغازات الدفيئة الزراعية في لبنان – الزراعة الحافظة للموارد والممارسات الفضلى لإدارة السماد من خلال الري المسمّد والري بالتنقيط.

[١] بحسب اتفاقية الأمم المتحدة الإطارية بشأن تغير المناخ، يتم الإبلاغ عن بعض انبعاثات الغازات الدفيئة من الزراعة تحت قطاعات أخرى غير الزراعة. يتم الإبلاغ عن انبعاثات ثاني أكسيد الكربون الناتجة عن الأتربة الزراعية في استخدام الأراضي وتغيير استخدام الأراضي والحراجة (LULUCF)، ويتم الإبلاغ عن الانبعاثات الصادرة عن الآلات الزراعية وغيرها من استخدامات الطاقة المرتبطة بالزراعة في قطاع الطاقة.

تزيد الزراعة الحافظة للموارد من امتصاص الكربون في التربة من خلال احتجاز فضلات المحاصيل وممارسات الدورة الزراعية ومحاصيل التغطية. كما تقلل هذه الزراعة من انبعاثات ثاني أكسيد الكربون من خلال التخفيف من استهلاك الوقود عبر اعتماد الحد الأدنى من الحراثة أو عدمها، والتخفيف من انبعاثات أكسيد النيتروجين عبر خفض الاحتياجات من الأسمدة. وتظهر فوائد زيادة المادة العضوية في التربة والحد من التكاليف وزيادة رطوبة التربة في التجارب التي قامت بها المنظمات والجامعات المحلية والدولية. كما يظهر تحليل التخفيف من الانبعاثات أنه في ظل سيناريو حيث تزيد الزراعة الحافظة للموارد بنسبة ١٠٪ في عام ٢٠٢٠ و ٢٠٪ في ٢٠٤٠ من المناطق الحالية المزروعة بالحبوب والزيتون وأشجار الفاكهة، سيبلغ الاحتمال التقديري للحدّ من انبعاثات الغازات الدفيئة من امتصاص الكربون في التربة وحده ٥٨,٦ و ١١٧,٢جيغاغرام من مكافئ ثاني أكسيد الكربون على التوالي.

تخفف الممارسات الفضلى لإدارة السماد من خلال الري المسمّد والري بالتنقيط من استخدام أسمدة النيتروجين كما وتخفض التكلفة وتزيد من كفاءة استخدام النيتروجين وتخفض خسائر الجريان والغسل للنيتروجين المطبّق وتقلل من تطاير النيتروجين المطبّق وتقلل من الطلب على المياه في الزراعة المروية، المستهلك الأكبر للمياه في لبنان (٦٠٪ من إجمالي سحب المياه). ويمكن تطبيق الري المسّمد على كافة المحاصيل التي يمكن ريها عن طريق الري بالتنقيط تقريبًا. فإذا أخذنا البطاطس على سبيل المثال، وبافتراض أن معدل اعتماد الري المسّمد من خلال الري بالتنقيط هو ٥٠٪ من مساحات الأراضي المزروعة بطاطس والمروية الحالية بحلول عام ٢٠٢٠ و ١٠٠٪ بحلول عام ٢٠٤٠، فإن احتمال التخفيض المقدر في انبعاثات أكسيد النيتروجين من الأسمدة الموفرة وحدها يقدر بحوالي ٢٠,٥ جيغاغرام من مكافئ ثاني أكسيد الكربون في عام ٢٠٢٠ و ٤١ جيغاغرام من مكافئ ثاني أكسيد الكربون في عام ٢٠٤٠. أما احتمال التخفيف من انبعاثات الغازات الدفيئة فيكون أعلى بكثير عندما يصبح الري المسّمد والري بالتنقيط ممارسًا على نطاق واسع في إنتاج المحاصيل النباتية المروية في كل من الحقول والبيوت المحمية كما وفي إنتاج البساتين.

وفي ما يتعلق بالعوائق، فإن إحدى أهم العقبات الرئيسية التي تواجه تحقيق الزراعة الحافظة للموارد هي عدم وجود حوافز للمزارعين. ويمكن معالجة هذا الأمر من خلال الإعانات التي تعتمد على المناطق عديمة الحراثة عوضًا من المحصول نفسه.

ويمكن للمزارعين، من خلال الري المسمّد، توفير كميات كبيرة من الأسمدة، وهو وضع مربح لكلّ من المناخ والمزارع. كما يتم التخفيف من استخدام النيتروجين كما تكلفته بشكل ملحوظ فيما يسترجع المزارعون رأس المال الأولي لنظام الري بالتنقيط، وهو عقبة رئيسية في اعتماد هذه التقنية، خلال عام واحد فقط.

Part 1: Inventory

1. Scope

Lebanon ratified the United Nations Framework Convention on Climate Change (UNFCCC) on December 15, 1994 and thus became a party to the convention. As a Non-Annex I party to the UNFCCC, Lebanon submitted its Initial National Communication (INC) in 1999, with the year 1994 as the baseline for its national Greenhouse Gas (GHG) inventory. An update for phase II of the INC was submitted in 2002.

Lebanon's Second National Communication (SNC) was submitted in 2011. GHG emissions were presented for each sector for the base year 2000 and as an aggregate figure for each year from 1994 to 2004. It also presented the trend analysis of the national GHG inventory for the period 1994 to 2004. The inventory was based on the Revised 1996 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories (IPCC, 1997), and on the Good Practice Guidance (GPG) and Uncertainty Management in National GHG Inventories (IPCC, 2000). The tier 1 approach was adopted in calculating the GHG emissions for agriculture, where the appropriate default Emission Factors (EFs) were selected from the guidelines.

The first part of this report provides an inventory of the GHG emissions of the agriculture sector in Lebanon for the years extending from 2005 to 2012, and constructs time-series for the period 1994-2012 by applying established guidelines. Improvements on previous inventories include the adoption of default emission factors that reflect the national circumstances and the use of country-specific activity data better whenever possible. This includes a more accurate assessment of animal population, an updated survey of manure management practices in Lebanon, local data on fertilizer consumption, and improved calculations of crop residues added to soils. The inventory part also includes an identification of the gaps and constraints facing the implementation of the UNFCCC for the Lebanese agriculture sector. The methodologies used in the calculation of emissions are based on the Revised 1996 IPCC Guidelines for National GHG Inventories (referred to in this text as 1996 IPCC GL) and the IPCC 2000 GPG and Uncertainty Management in National GHG Inventories (referred to in this text as GPG 2000).

The second part of this report is the mitigation analysis which has two objectives:

1. Assessment of mitigation actions: identify all projects, activities and initiatives undertaken by the public and private sectors to reduce GHG emissions from the agriculture sector in Lebanon. The mitigation actions are reported in a tabular format that includes information that is available on objectives and goals, coverage, budget, GHG reduction potential, and any other information on the progress of implementation of the mitigation action.
2. Assessment of mitigation options: identify and assess two suitable mitigation options for the agriculture sector in Lebanon. This includes calculating the emission reduction potential of each proposed mitigation option for the short-term (2020) and medium-term (2040), cost/benefit analysis, and analysis of the co-benefits in terms of environmental, social, and economic sustainability of the agriculture sector.

It is important to note that agriculture is a minimal contributor to total GHG emissions in Lebanon. Although most efforts in Lebanon are directed towards adaptation to climate change rather than mitigation, many such projects and activities within the agriculture sector may simultaneously reduce GHG emissions and promote adaptation.

2. National circumstances

Agriculture is a vital part of the Lebanese economy and its social and cultural heritage. Even though the sector's share of the Gross Domestic Product (GDP) is relatively low (6.4% in 2010), agriculture employs 20-30% of the active work force and constitutes 17% of the total exports (MoA, 2010a). In rural areas, however, agriculture is reported to contribute up to 80% of the local GDP and represents the major income-earning and employment opportunity (Verner et al., 2013). In comparison with its neighbors, agriculture production in Lebanon is characterized by a higher value added per square kilometer, reflecting a higher intensity of production and greater focus on higher value fruits and vegetables (FAO, 2011a). Compared to 1970 when agriculture's share of the GDP reached 9% (Kubursi, 1999), agricultural contribution to the GDP has been steadily decreasing. There are many reasons for this decline including the post-war economic crisis, urban encroachment that changed the rural landscape of the country, government economic policies favoring other sectors, emigration of a young generation of farmers, the switch from farming to higher-paid jobs, and climate change with its concomitant effect on crops, pastures, and water resources.

According to the Food and Agriculture Organization Statistics (FAOSTAT) (FAO, 2011a) the total agricultural area is estimated at 638,000 ha (62% of total surface area). As indicated in Figure 1 below, pastures and meadows constitute approximately 39% of the total area, permanent crops 12%, arable land 11%, and forests 14% of the total surface area of Lebanon.

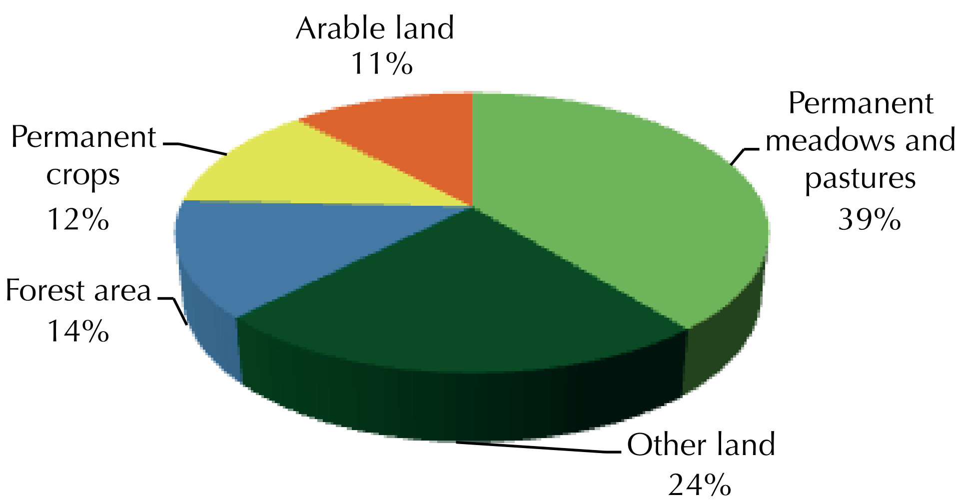


Figure 1: Agricultural land use in Lebanon (% of total agriculture area)
Source | FAO, 2011a

According to the Ministry of Agriculture (MoA) 2010 census, the utilized agricultural area was approximately 231,000 ha, which is lower by 6% in comparison with the value from a previous census in 1998. Of these, 106,272 ha were dedicated for seasonal crops (grains, vegetables, legumes, root crops, industrial crops, and forages) including 3,800 ha of greenhouse crops and 125,928 ha for permanent crops (olives, fruit trees, citrus, and grapes).

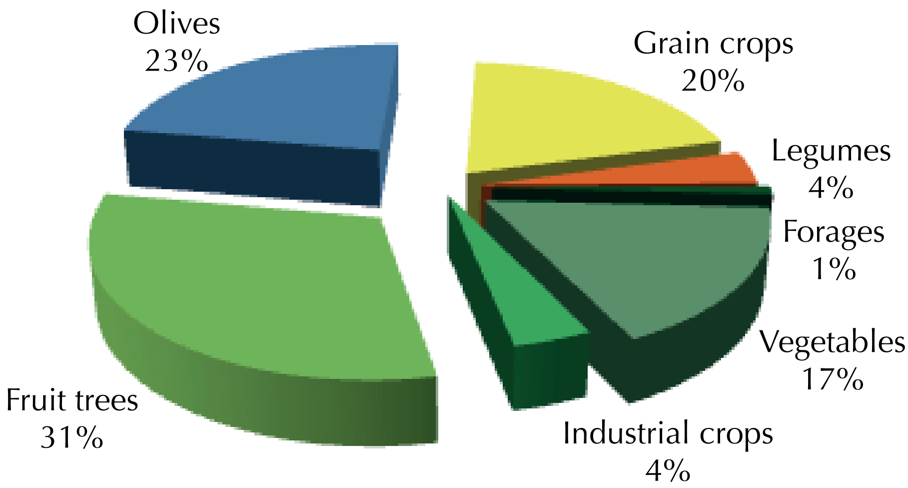


Figure 2: Agricultural production in Lebanon
Source | MoA, 2010b

Of the total utilized agricultural land, approximately half is irrigated, an increase of by 8% compared to irrigated areas in 1998. Flood and furrow irrigation comprise 50% of irrigated land, while approximately 30% is through drip and 20% through sprinkler irrigation.

Agricultural production in Lebanon is diverse reflecting a Mediterranean climate with variable temperature and precipitation regimes, and distributed in the following regions of the country:

1. The Bekaa: Once regarded as the “bread basket of the Roman Empire”, the Bekaa valley is the most important production area and accounts for the highest percentage of seasonal crops (60%): cereals, potatoes, vegetables, stone fruits and grapevines. It also contains the highest percentage of cattle population (43%), sheep (72%), goats (51%) and poultry layers (60%).
2. The North and Akkar plain: Olives, cereals, potatoes, vegetables, cattle and poultry broilers production.
3. South and Nabatieh: Olives, cereals, vegetables and tobacco production.
4. Mount Lebanon: Fruits, vegetables, poultry broilers, and swine production.

In addition, the geographical coastal strip along the Mediterranean coast from the north of the country to the south is home to intensive vegetable greenhouse production, citrus fruits, and bananas.

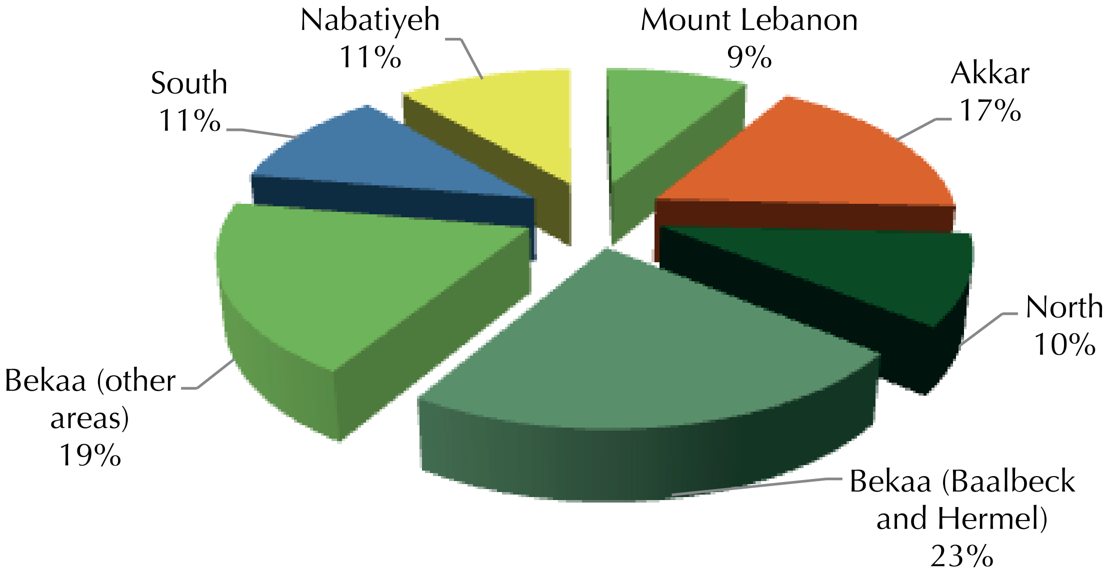


Figure 3: Utilized agricultural areas in different regions in Lebanon
Source | MoA, 2010b

Animal production

The livestock sector contributes to around 30% of the total value of production (FAO, 2011a). Although animal production is considered secondary with respect to crop production, the Lebanon poultry and dairy sectors both hold importance in terms of production and quality. The poultry sector is the only agriculture sector that satisfies domestic demand and is dominated by a few companies utilizing closed systems producing quality broilers and egg products. Cattle are mainly raised for milk production with the majority of stocks raised in large farms as well as in small-sized holdings (FAO, 2011b). Beef production is limited to imported live animals (in addition to imported chilled and frozen cuts) and provides a major source for local consumption. The size of sheep and goat herds has fluctuated since 1994 but decreased in recent years mainly due to a decrease in the number of shepherds and due to competition from imported meat from Australia, Turkey and Syria (Fady Asmar, personal communication). In addition, the crisis in Syria has caused the influx of goat and sheep herders and their flocks to Lebanese rangelands, but this is hard to quantify. Swine production has decreased steadily since 1994 due to a shift in consumer preferences towards poultry, mutton and beef, and due to fear from the swine flu.

Crop production

Lebanon's main agricultural crops are fruits, vegetables, olives, cereals, tubers, and legume crops. Pressure on the land base has led to a decline in cereal production in favor of high-value crops such as vegetables. Lebanon is self-sufficient in fruits and vegetables, although competition from open markets is leading to the importation of these commodities as well.

The most important cereals cultivated are wheat and barley, with some production of forage crops such as alfalfa, vetch, corn, oats, and sorghum. Most of the barley grown in the arid parts of Bekaa (Hermel and El Qaa) is left as pasture for grazing animals. It is anticipated that forage crop production would increase after recent incentives introduced by the MoA to encourage milk and forage production by farmers with small animal holdings (see Box 1).

In 2010, wheat, barley, and potato production decreased due to a combination of drought and reduction in the cultivated areas. Although wheat and barley production recovered in 2011 and 2012, potato crop production remained at least 80% less compared with 2005, mainly due to the shrinkage in hectares planted (20,000 ha in 2005 vs. 12,000 ha in 2012). Also, imports from Saudi Arabia and Egypt rendered potato farming, once a profitable and prominent enterprise, vulnerable to open markets.

Fertilizer use

Statistics on fertilizer consumption in Lebanon are sporadic and contradictory. The Lebanese Customs provides extensive data about imports but these could not be corroborated from the major agricultural importing companies. The amount of fertilizers used in Lebanon has been decreasing since 1994: approximately 122,000 tonnes of total nitrogenous fertilizers were used in 1994 (average of 31,000 tonnes of nitrogen (N)), while in 2006 total nitrogenous fertilizers used were approximately 50,000 tonnes (average of 9,500 tonnes N). However fertilizer consumption increased in recent years to reach 85,000 tonnes (19,000 tonnes of N) in 2012. Most of the nitrogenous fertilizers used were Nitrogen-Phosphorus-Potassium fertilizer (NPK) (17-17-17, 15-15-15, and other combinations), ammonium sulphate, ammonium nitrate and urea. Application rates of nitrogen fertilizers far exceed the recommended agronomic rates (Al-Hassan, 2011). For example potato growers apply on average 590 kg N/ha while the suggested agronomic rate is 220 kg N /ha. For vegetables, growers apply the average of 900 kg N/ha while the agronomic rate is 500 kg N/ha.

Unfortunately soil testing for soil nutrient content is not widely practiced and growers apply nitrogen rates based on experience or on the recommendation of agents from fertilizer distributors.

Climate and soils

Lebanon has a Mediterranean climate characterized by four distinct seasons with long hot summers and cool rainy winter. Climate is also very diverse due to the various geographical terrains: a Mediterranean temperate coastal zone, a mountainous region, and a semi-arid to arid region in the inlands (Bekaa valley) where most of the agricultural production occurs. The soils in the Bekaa are typically alfisols, inceptisols and aridisols, and the amounts of organic matter and of nitrogen are generally low. Consequently, farmers apply excess nitrogen fertilizers to boost yields.

Estimates from Lebanon's SNC indicate that by 2040 the maximum temperature in some parts of Lebanon could increase by as much as 1.8 ˚C while the minimum temperature would increase by 1.5 ˚C. The same study also estimates that precipitation countrywide would decrease by 15% to 20% by 2040. Indeed in 2010, Lebanon experienced a drought caused by high temperatures and low precipitation. As seen in the Table 1 below, the number of Consecutive Dry Days (CDD), defined as the longest consecutive stretch of days in the year without precipitation (or less than 1 mm/day) recorded in the Bekaa valley was largest for the year 2010 during the period 2005-2012 (data adapted from the Lebanese Agricultural Research Institute (LARI)). Thus the year 2010 was characterized by both a low precipitation and a high CDD number. The data also show that the Bekaa area has received less than optimal precipitation (600-650 mm) during the period 2006-2008.

Table 1: Average precipitation and consecutive dry days for the Bekaa valley in 2005-2012

	2005	2006	2007	2008	2009	2010	2011	2012
Precipitation (mm)	633	488	531	338	815	479	658	846
CDD (days with less than 1 mm/day)	164	90	172	140	154	203	117	150

Box 1 - Government of Lebanon (GoL) planning and initiatives for agriculture

Lebanon's MoA is the institution responsible for setting the agriculture strategic framework, as well as formulating and implementing policies and programs for the development of the agriculture sector. The MoA is also responsible for developing a suitable legal and regulatory framework, enhancing infrastructure development to promote investment and improving agricultural production and marketing. The MoA also plays an important role in the management of the natural resources of the country (agricultural land, irrigation water, forests, fisheries, pasturelands) and contributes to rural development.

Recent initiatives by the GoL to strengthen agriculture have included the development of the 2004 agriculture strategy, which was prepared with FAO and the World Bank, and the 2006 agricultural strategy implementation program. However the strategy and the program could not be implemented, as priorities shifted toward the relief and rehabilitation efforts of the sector which was severely affected by the July 2006 war. The total damage in the agriculture sector was estimated at USD 298 million. The past few years have been marked by further major developments in support of agricultural and rural development. In January 2010, the MoA issued an updated strategic plan 2010–2014 and, with assistance from the International Fund for Agricultural Development (IFAD), will revise the implementation plan to reflect the new strategic plan.

As part of this strategy, the MoA created a platform where all actors (public, private, civil society) could interact, as well as exchange information and experience, with the establishment in 2010 of more than 30 national technical committees. Several activities were initiated, more than 200 technical staff were recruited and 28 agricultural centers were established across all regions. Total public spending on agriculture increased almost threefold. A program to increase cereal and legume production has been introduced in 2010 with a total budget reaching USD 14 million yearly. In addition, a new program to promote fodder production and develop the dairy sector was launched in February 2012 with a total budget of USD 19 million. Finally, a program to increase agricultural exports and improve agricultural products quality (Export Plus Programme) was reinstated in 2012 with a total budget of USD 33 million annually.

3. Gaps and constraints in inventory compilation

Table 2 below lists the gaps and constraints encountered during data collection for this inventory and the proposed measures to address these constraints and improve the process.

Table 2: Gaps and constraints and proposed measures for improving GHG inventory of the agriculture sector in Lebanon

Gaps and constraints description	Proposed measures for improvement
Activity data organization - Data scattered in many agencies. - Lack of uniformity in data between different official resources.	- Centralization of data management. - Coordination of the MoA statistics division with public, private, and international agencies. - Establishment of an advisory scientific team to facilitate data coordination and ensure data uniformity.
Activity data availability - Lack of data on fertilizer consumption, Manure Management Systems (MMS), and utilization of crop residues in different regions. - Lack of data for refining inventory to higher tier levels.	- Data depths to be improved, some require data surveys. - Monitoring system is needed for manure management and crop residue utilization. - Research is needed to refine data for higher tier levels.
Activity data accessibility - Lack of institutional arrangements for data sharing. - Time delays in accessing and compiling data.	- Establish protocols and establish effective networking with data providers. - Involve industry and monitoring institutions.
Data on emission factors Inadequate data for country specific emission factors.	- Research to conduct measurements to develop local emission factors.
Technical and institutional capacity needs	- Conduct training for relevant institutions involved in planning, preparation, and analysis of GHG inventory. - Conduct workshop on data management for agriculture. - Conduct training on new inventory and mitigation softwares.

4. Methodology

4.1. Adopting the IPCC guidelines

The IPCC Guidelines for National GHG Inventories (IPCC 1996 and GPG 2000) identified six sources of GHG emissions in agriculture:

- Enteric fermentation
- Manure management
- Agricultural soils
- Rice cultivation
- Prescribed burning of savannahs
- Field burning of agricultural residues

Agricultural GHG emissions in Lebanon mainly consist of emissions from enteric fermentation (methane (CH_4) emissions), manure management (CH_4 and nitrous oxide (N_2O) emissions) and agricultural soils (N_2O emissions). The other IPCC subcategories – rice cultivation, prescribed burning of savannas, and field burning of agricultural residues, do not occur in Lebanon and are thus reported as Not Occurring (NO).

Activity data on the agriculture sector for the Third National Communication (TNC) was derived from the FAO database (FAOSTAT), the MoA, the Lebanese Customs, and the Lebanese Syndicate of Cattle Importers. Imported beefs were not included in the INC and SNC. The tier 1 approach was employed in the calculation of emissions, using the Revised 1996 IPCC Guidelines and the GPG 2000. There are no available data to adopt a tier 2 methodology.

For the GHG inventory of the agriculture sector, the UNFCCC software version 1.3.2 (Non-Annex I National GHG Inventory Software) was used. All sheets presented in the software were filled as in the module 4 (Agriculture) of the software, except for sheet (4-5s1) used for the calculation of F_{BN} and F_{CR} (nitrous oxide emissions from agricultural soils - nitrogen additions from N fixation and from crop residues). These were calculated manually and their values entered in the sheet. The calculations are presented in Annex V for F_{BN} and Annex VI for F_{CR}.

4.1.1. Livestock population characterization

Basic characterization: Basic livestock characterization was performed to assess the animal population in Lebanon. Lack of activity data precluded enhanced characterization of livestock population.

Livestock species and categories: The following species and subcategories were included: dairy cattle, non-dairy cattle, sheep, goats, poultry broilers, swine, horses, mules, asses, and camels.

Annual population: Total and dairy cattle population were taken from FAO (Food and Agriculture Organization) while non-dairy cattle population was obtained from the difference "total cattle – dairy cattle" and adding the population of imported beef to it. The imported beef population was obtained from the Lebanese Syndicate of Cattle Importers after adjusting to an average "days alive" of 30 days (expert judgment). Poultry populations (except traditional chicken), sheep, goats, camels, horses, mules, asses, and swine populations were also taken from FAO. Total poultry population was calculated by adding the total number of laying hens to the Annual Average Population (AAP) of broilers (adjusted to average "days alive" of 60 days) and the total number of traditional chicken. The traditional chicken population was obtained from the Lebanese MoA for the years of 1997-2005 and 2008-2010. The remaining years were calculated using the methods of interpolation (years 2006, 2007) and extrapolation (years 1994-1996, 2011, 2012).

AAP was calculated for poultry broilers and imported beef cattle using the following equation:

AAP = Days alive x (NAPA/365)

Where:

Days alive = Average number of days for the animal before it is slaughtered

NAPA = Number of Animals Produced Annually

Milk production: Milk production data is used in estimating an emission factor for enteric fermentation using the tier 1 method. Average annual milk production for dairy cows in Lebanon is 4,200 kg/head/year (comparable to Western Europe).

Climate: In the 1996 IPCC GL (Reference Manual, table 4.1), three climate regions are defined in terms of annual average temperature: cool (<15°C), temperate (15-25°C), and warm (>25°C). Livestock population in Lebanon all fall within the temperate region.

4.1.2. Methane emissions from enteric fermentation

IPCC tier 1 approach was adopted. Methane emissions from each livestock category (species) were calculated according to the following equation (equation 4.12, GPG 2000):

Emissions (Gg CH_4/year) = Population (head) x EF (kg/head/year) / 106 (kg/Gg)

Total CH_4 emissions are then the sum of emissions from all animal categories, except poultry as per the guidelines (enteric fermentation in poultry is insignificant).

Emission factors are default values from 1996 IPCC GL and reported in Table 3 below.

Table 3: Methane emission factors for enteric fermentation

Species	EFs (kg/head/year)
Sheep (1)	5
Goats (1)	5
Camels (1)	46
Horses (1)	18
Mules and asses (1)	10
Swine (1)	1
Dairy (2)	100
Non-dairy (2)	48

Sources | (1) 1996 IPCC GL, Reference Manual, table 4.3
(2) 1996 IPCC GL, Reference Manual, table 4.4
(Western Europe, comparable average milk production)

4.1.3. Methane emissions from manure management

The method used to estimate methane emissions from manure management is similar to that used in estimating methane emissions from enteric fermentation. The IPCC tier 1 approach was adopted using the following equation (equation 4.15, GPG 2000):

$$\text{Emissions}_{mm}\ (\text{Gg } CH_4/\text{year}) = \text{Population (head)} \times EF_{mm}\ (\text{kg/head/year}) / 10^6\ (\text{kg/Gg})$$

Table 4 below shows the emission factors used for calculating methane emissions from manure management. In addition to the livestock populations used for calculating methane emissions from enteric fermentation, poultry populations were also included for estimating methane emissions from manure management. For cattle and swine, EFs suitable for Eastern Europe were chosen as they better reflect the conditions in Lebanon for manure management (solid based systems are used for the majority of manure).

Table 4: Methane emission factors for manure management

Species	EFs (kg/head/year)
Sheep (1)	0.160
Goats (1)	0.170
Camels (1)	1.900
Horses (1)	1.600
Mules and asses (1)	0.900
Poultry (1)	0.018
Dairy cattle (2)	19.000
Non-dairy cattle (2)	13.000
Swine (2)	7.000

Sources | (1) 1996 IPCC GL, Reference Manual, table 4.5 (temperate regions)
(2) 1996 IPCC GL, Reference Manual, table 4.5 (Eastern Europe)

4.1.4. Nitrous oxide emissions from manure management

The amount of N_2O emitted from manure management is estimated using the IPCC tier 1 approach where the total amount of N excretion (from all livestock species/categories) in each type of MMS is multiplied by an emission factor for that type of MMS, as shown in the equation below (equation 4.18, GPG 2000):

$$(N_2O\text{-}N)_{(mm)} = \text{kg } N_2O\text{-}N/\text{year} = \sum_{(S)} \{[\sum_{(T)} (N_{(T)} \times N_{ex(T)} \times MS_{(T,S)})] \times EF_{3(S)}\}$$

$$N_2O \text{ emissions}_{mm} = (N_2O\text{-}N)_{(mm)} \times 44/28$$

Where:

$N_2O\text{-}N_{(mm)}$ = Direct N_2O-N emissions from manure management, kg N_2O-N/year

$N_{(T)}$ = Number of head of livestock species/category T

$N_{ex(T)}$ = Annual average N excretion per head of species/category T, kg N/animal/year

$MS_{(T,S)}$ = Fraction of total annual nitrogen excretion for each livestock species/category T that is managed in MMS, dimensionless

$EF_{3(S)}$ = Emission factor for direct N_2O emissions from manure management, kg N_2O-N/kg N in MMS

T = Species/category of livestock

44/28 = Conversion of $(N_2O\text{-}N)_{mm}$ emissions to N_2O_{mm} emissions

The same data on livestock characterization and populations, used in estimating methane emissions from domestic livestock, were used in estimating N_2O emissions from manure management. In the absence of any country-specific emission factors, the IPCC default nitrogen excretion rates N_{ex} and emission factors were used. Table 5 and Table 6 provide the nitrogen excretion rates for animal species N_{ex} and emission factors (EF_3) used for each type of MMS.

Table 5: Nitrogen excretion rate for animal species

Species	$N_{ex(T)}$ (kg/head/year) (1)
Non-dairy cattle	50
Dairy cattle	70
Poultry	0.6
Sheep and goat	12
Swine	16
Horses, mules, asses, camels	40

Source | (1) 1996 IPCC GL, Reference Manual, table 4.20

Fraction of manure managed in each MMS was determined using surveys of major dairy, non-dairy, swine, and poultry farms as well as expert judgment from academic experts (section 4.2). Adjusting the values considering the young animals as suggested in the in the GPG 2000 was not possible due to lack of data for animal population by age group.

Table 6: Emission factors for nitrous oxide emissions for each utilized manure management system

MMS	Emission factor EF_3 (kg N_2O-N/kg N excreted)
Pasture Range and Paddock (PRP)	0.020
Anaerobic lagoons	0.001
Liquid systems	0.001
Solid storage and dry lot	0.020
Poultry with bedding	0.020
Poultry without bedding	0.005

Source | GPG 2000, table 4.12 and table 4.13

4.1.5. Nitrous oxide emissions from agricultural soils

N_2O emissions from agricultural soils result from anthropogenic N inputs through both a direct and an indirect pathway. The direct pathway occurs via two mechanisms: (a) intentional additions of N directly to soils through synthetic fertilizers, nitrogen fixation by N-fixing crops, animal manure, and crop residues and (b) unintentional additions of N through animals grazing on PRP. Indirect N_2O emissions occur through two pathways: volatilization from applied fertilizer and manure as ammonia (NH_3) and nitrogen oxides (NO_x) and subsequent deposition, and through leaching and runoff of applied fertilizer and animal manure.

In order to avoid double counting, N inputs from animals on PRP is subtracted from nitrogen additions from animal manure (F_{AM}) and added separately as direct N_2O emissions from PRP.

Direct N_2O emissions from agricultural soils

Direct N_2O emissions are calculated using the tier 1a method (equation 4.20, 2000 GPG method):

$$N_2O_{Direct} - N = [(F_{SN} + F_{AM} + F_{BN} + F_{CR}) \times EF_1]$$

$$N_2O = N_2O\text{-}N \times 44/28$$

Where

F_{SN} = Synthetic fertilizer nitrogen, adjusted for volatilization

F_{AM} = Animal manure nitrogen used as fertilizer, adjusted for volatilization

F_{BN} = N fixed by crops

F_{CR} = N in crop residues returned to soils

EF_1 = Emission factor (kg N_2O-N/kg N)

Refinements suggested in tier 1b could not be adopted due to the unavailability of the residue to crop product mass ratio specific to each crop, which is needed to calculate the annual amount of nitrogen added to the soil through nitrogen fixation by N-fixing crops. Default emission factors are presented in Table 7 and default fractions in Table 8.

Table 7: Default emission factors used for calculating nitrous oxide emissions from agricultural soils

Default emission factor for direct emissions of N_2O	Default emission factor from PRP	Default emission factors for indirect emissions of N_2O	
EF_1 kg N_2O-N/kg N added	EF_3 kg N_2O–N/kg N excreted	$EF_{4(N\ deposition)}$ kg N_2O-N/kg NH_3-N and NO_x–N emitted	$EF_{5(leaching/runoff)}$ kg N_2O-N/kg N leaching-runoff
0.0125 (1)	0.02 (2)	0.01 (3)	0.025 (3)

Sources | (1) 1996 IPCC GL, Reference Manual, table 4.18

(2) GPG 2000, table 4.12

(3) 1996 IPCC GL, Reference Manual, table 4.23

Table 8: Default fractions used for calculating emissions from agricultural soils

$Frac_{GASM}$	$Frac_{GASF}$	$Frac_{LEACH}$
kg NH_3-N + NO_x-N volatilized/kg of N excreted by livestock	kg NH_3-N + NO_x-N volatilized/ kg of fertilizer N applied	kg N leached/kg of fertilizer or manure N applied
0.2 (1)	0.1 (2)	0.3 (2)

Sources | (1) 1996 IPCC GL, Reference Manual, Table 4.19
(2) 1996 IPCC GL, Reference Manual, Table 4.24

F_{SN}: nitrogen from synthetic fertilizer

F_{SN} is the annual amount of synthetic fertilizer nitrogen added to the soil, adjusted for NH_3 and NO_x volatilization. It is calculated according to (equation 4.22, 2000 GPG):

$$F_{SN} = N_{FERT} \times (1 - Frac_{GASF})$$

Where:

F_{SN} = Synthetic fertilizer nitrogen, adjusted for volatilization (tonnes N/year)

N_{FERT} = Total synthetic nitrogen consumed in the country (tonnes N/year)

$Frac_{GASF}$ = Fraction of synthetic nitrogen fertilizer that volatilizes as NH_3 and NO_x

F_{AM}: nitrogen from animal manure

F_{AM} is the annual amount of animal manure nitrogen adjusted (a) for NH_3 and NO_x volatilization, (b) for manure dropped on soil from animal grazing (PRP), and (c) for fraction of manure N used as fuel (assumed zero). It is calculated according to the tier 1a method (equation 4.23, GPG 2000):

$$F_{AM} = \sum_T (N_{(T)} \times N_{ex(T)}) \times (1 - Frac_{GASM}) \times [1 - (Frac_{FUEL\text{-}AM} + Frac_{PRP})]$$

Where:

F_{AM} = Animal manure nitrogen used as fertilizer, adjusted for volatilization (tonnes N/year)

$N_{(T)} \times N_{ex(T)}$ = Total livestock nitrogen excretion (tonnes N/year)

$Frac_{GASM}$ = Fraction of manure nitrogen that volatilizes as NH_3 and NO_x, default value used

$Frac_{PRP}$ = Fraction of manure nitrogen deposited onto soil during grazing

$Frac_{PRP}$ was calculated as the ratio of the amount of nitrogen excreted during grazing (PRP) to the total nitrogen excreted from all MMS.

F_{BN}: N fixed by crops

F_{BN} is the annual amount of nitrogen added to the soil through the process of nitrogen fixation by N-fixing crops cultivated annually. Nitrogen fixing crops include pulses (dry beans, broad beans, peas, chickpeas, and lentils), leguminous crops (green peas and green beans) and N fixing forages (alfalfa and vetch). F_{BN} is calculated using the tier 1a method (equation 4.25, 2000 GPG):

$$F_{BN} = 2 \times Crop_{BF} \times Frac_{NCRBF}$$

Where:

$Crop_{BF}$ = Yield of pulses and leguminous vegetables (kg dry matter/year)

$Frac_{NCRBF}$ = Fraction of biomass that is nitrogen

As per UNFCCC recommendations, crop production values for N-fixing crops are all reported on Dry Matter (DM) basis. Therefore all crop production values were multiplied by the appropriate DM fractions (see Annex V for calculations of F_{BN}).

The factor 2 converts the edible portion of the crop (which is reflected in the production data) to total crop biomass.

N-fixing forage crops

Tier 1b equation (equation 4.27, 2000 GPG) is used:

$$F_{BN} = \sum i\ (Crop_{BFi} \times Frac_{DMi} \times Frac_{NCRBFi})$$

Where $Frac_{DM}$ is the DM fraction of forage crop.

F_{CR}: Nitrogen from crop residues

Nitrogen returned to the soil from crop residues left to decompose in the field is estimated using the tier 1 method (equation 4.28, GPG 2000):

$$F_{CR} = 2 \times (Crop_O \times Frac_{NCRO}) + (Crop_{BF} \times Frac_{NCRBF}) \times (1 - Frac_R) \times (1 - Frac_{BURN})$$

Where:

F_{CR} = N in crop residues returned to soils (tonnes N/year)

$Crop_O$ = Production of all crops with significant residues minus $Crop_{BF}$ (tonnes dry biomass/year)

(Note: As per UNFCCC recommendations, all crop production values are reported on dry basis)

$Crop_{BF}$ = Production of legumes in the country (tonnes dry biomass/year)

$Frac_{NCRBF}$ = Fraction of nitrogen in N-fixing crops

$Frac_{NCRO}$ = Fraction of nitrogen in non-N-fixing crops

$Frac_R$ = Fraction of crop residues that is removed from the field

$Frac_{BURN}$ = Fraction of crop residue that is burned. As per consultation with LARI and grower associations, this factor is assumed zero since burning of crop residues is less than 5% in some years and not practiced in most years.

Indirect N_2O emissions from agricultural soils

Indirect N_2O emissions from nitrogen added to agricultural soils are based on two sources. These are: volatilization and subsequent atmospheric deposition of NH_3 and NO_x from the application of fertilizers and animal manure, and leaching and runoff of the nitrogen that is applied to or deposited on soils.

The indirect emissions of N_2O are calculated using the following equation (tier 1, equation 4.30, GPG 2000):

$$N_2O_{indirect} - N = N_2O_{(G)} + N_2O_{(L)}$$

$$N_2O = N_2O\text{-}N \times 44/28$$

Where:

$N_2O_{indirect}$ - N = Indirect N_2O emissions in units of nitrogen (kg N/year)

$N_2O_{(G)}$ = N_2O emissions due to atmospheric deposition of NH_3 and NO_x (kg N/year)

$N_2O_{(L)}$ = N_2O emissions due to nitrogen leaching and runoff (kg N/year)

N_2O emissions due to volatilization and to leaching are calculated according to equations 4.31 and 4.34 (GPG 2000):

$$N_2O_{(G)}\text{-}N = [(N_{FERT} \times Frac_{GASF}) + (\sum T(N_{(T)} \times N_{ex(T)}) \times Frac_{GASM})] \times EF_4$$

$$N_2O_{(L)}\text{-}N = [N_{FERT} + \sum T(N_{(T)} \times N_{ex(T)})] \times Frac_{LEACH} \times EF_5$$

The emission factors and fractions used have been previously defined and presented in Table 7 and Table 8, respectively.

4.2. Data collection

4.2.1. Data sources

Table 9 below summarizes the data sources used for the GHG inventory of the agriculture sector in Lebanon.

Table 9: Summary of data sources used in the GHG inventory for the agriculture sector

Data	Data source
Livestock population: dairy cattle	FAOSTAT under the domain production/livestock primary/ milk, whole fresh cow/producing animals
Livestock population: non-dairy cattle*	Total cattle is the summation of two sources: 1) Total cattle: Obtained from FAOSTAT under the domain production/live animals/cattle/stock. 2) Imported beef: Local data obtained from Syndicate of Cattle Importers (1997-2012), values for 1994-1996 were extrapolated.
Livestock population: sheep, goats, swine, camels, horses, mules, asses	FAOSTAT under the domain production/live animals/(name of the species)/stock
Livestock population: poultry (laying hens, and broilers)	FAOSTAT under the domain production/livestock primary/"meat poultry > (list)" and "eggs primary > (list)"/ producing animals
Livestock population: poultry (traditional chicken)	Lebanese MoA: Population was missing for 1994-1996, 2006-2007 and 2011-2012. These were obtained through extrapolation and interpolation.
Nitrogen fertilizer consumption	Consumption data was taken from local imports and the data obtained from the Lebanese Customs. Values for 1994-1996 were extrapolated.
Crop production: all except alfalfa	FAOSTAT under the domain production/crops/(name of crop)/production quantity
Crop production: alfalfa	Alfalfa production was obtained by multiplying the area harvested by the yield. Area harvested was obtained from FAOSTAT. Yield (40 tonnes fresh weight/ha) was obtained from expert judgment.
Manure management systems	Data was obtained though expert judgment and survey of selected dairy, poultry and swine farms (Libanlait, Dairy Khoury, Hariri Farms, Hawa Chicken, Tanmia, Wilco, Porky's).

*Non-dairy cattle population = total cattle population minus dairy cattle population

4.2.2. Livestock population

Table 10: Animal population in 1,000s in 2005-2012

Species	2005	2006	2007	2008	2009	2010	2011	2012
Dairy cattle	43.80	43.90	45.30	55.00	40.80	40.16	40.16	42.000
Non-dairy cattle	48.17	49.22	47.55	34.22	49.55	44.06	41.51	36.900
Sheep	337.30	370.40	324.40	330.00	372.10	265.35	255.00	258.000
Goats	494.70	484.40	434.70	450.00	430.10	403.86	400.00	398.000
Camels	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.545
Horses	3.58	3.58	3.58	3.58	3.58	3.58	3.60	3.650
Mules and asses	19.79	19.78	19.78	20.00	20.00	20.00	20.00	20.000
Swine	11.00	10.00	9.00	8.50	8.00	7.74	7.65	7.800
Poultry	16,235.62	17,072.60	17,468.49	17,696.68	17,058.90	16,662.15	16,919.87	17,166.450

Table 11: Poultry population in 1,000s in 2005-2012

Poultry type	2005	2006	2007	2008	2009	2010	2011	2012
Laying hens	3,700.0	3,600.0	3,700.0	3,846.0	3,800.0	3,757.0	3,757.0	3,800.0
Broilers	72,000.0	77,700.0	79,500.0	80,000.0	76,400.0	76,000.0	77,000.0	78,000.0
Broilers AAP [(1)]	11,835.6	12,772.6	13,068.5	13,150.7	12,558.9	12,493.2	12,657.5	12,821.9
Traditional chicken	700.0	700.0	700.0	700.0	700.0	412.0	505.3	544.5

[(1)] AAP for broilers, AAP is based on average "days alive" of 60 days

4.2.3. Manure management systems

Data on MMS utilized in Lebanon were obtained through both expert judgments and surveys of select dairy and poultry farms. Expert judgments were provided by animal scientists from academic institutions and the MoA in Lebanon (see acknowledgements section).

For dairy cattle, two companies were visited: (a) Libanlait, a major dairy company in the Bekaa area with approximately 2,000 heads of dairy cattle; (b) Les Fermes Normandises (Dairy Khoury) another major dairy in the Bekaa area with approximately 1,000 heads of dairy cattle.

For poultry, Hariri Farms in South Lebanon was visited. Three other companies were also consulted: Hawa Chicken, Tanmia, and Wilco PM. For swine, a telephone interview was conducted with Porky's, a swine production firm.

Based on these expert consultations and surveys, the fraction of manure utilized in each MMS was derived, as shown in Table 12 below.

Table 12: Fraction of manure in different manure management systems utilized in 2005-2012

Livestock species	Anaerobic lagoons	Liquid/ slurry	Solid storage and drylot	Daily spread	Pasture range and paddock	Poultry manure without bedding	Poultry manure with bedding
Non-dairy			1.000				
Dairy cattle	0.010	0.005	0.955	0.01	0.02		
Poultry					0.04	0.19	0.77
Sheep and goats			0.330		0.67		
Swine			0.900	0.10			
Horses, mules, asses, and camels					1.00		

Note:

- For dairy cattle under solid storage, the total fraction of 0.955 includes a fraction of 0.035 in which manure is composted and a fraction of 0.02 where manure is treated aerobically. Since emission factors for both solid storage and drylot and composting are the same, the calculations were similar.
- For poultry: broilers were distributed as 100% with bedding; laying hens: 85% without bedding and 15% with bedding; traditional chicken are all under PRP.

4.2.4. Fertilizer consumption

Data on fertilizer consumption were obtained from the Lebanese Customs. Since exports of nitrogenous fertilizers were not significant or absent, consumption of nitrogenous fertilizers was approximated by total imports of N fertilizers. Data on individual nitrogen fertilizer compounds imported (consumed) and corresponding N applied are presented in Annex IV (1994-2012). Table 13 shows the amount of nitrogenous fertilizer applied (tonnes of N fertilizer) and corresponding total N applied (tonnes of N) for 2005-2012.

Table 13: Nitrogen fertilizer consumption and corresponding nitrogen applied in 2005-2012

	2005	2006	2007	2008	2009	2010	2011	2012
Nitrogen fertilizers (tonnes)	68,479	49,911	69,748	51,571	71,505	80,694	83,833	85,332
Nitrogen applied (tonnes of N)	14,814	9,535	13,325	9,736	14,894	16,948	18,359	18,940

4.2.5. Crop production

Table 14 below lists the crops used in this inventory, along with fraction of dry matter, fraction of N content of biomass for nitrogen fixing crops ($Frac_{NCRBF}$) and non N fixing crops ($Frac_{NCRBO}$), and fraction of residue removed from field ($Frac_{R}$). Refer to Annex IV-4a for crop production of nitrogen fixing crops and Annex IV-4b for crop production of non-nitrogen fixing crops (1994-2012).

Table 14: List of crops, production for 2012 (tonnes), fraction of dry matter, fraction of N content of biomass ($Frac_{NCRBF}$ and $Frac_{NCRBO}$), and fraction of residue removed from field ($Frac_R$)

Crop	Production for 2012 (tonnes)	Fraction of dry matter (kg DM/kg product)	Fraction of N content of biomass (kg N/kg dry biomass)	Fraction of residue removed from field [11] ($Frac_R$)
Beans, dry	950	1.00 [1]	0.0300 [8]	0.9
Beans, green	25,000	0.85 [2]	0.0300 [8]	0.2
Broad beans, dry beans	160	1.00 [1]	0.0300 [8]	0.8
Chick peas	3,000	1.00 [1]	0.0300 [8]	0.9
Alfalfa	30,000	0.50 [3]	0.0300 [8]	0.7
Lentils	2,200	1.00 [1]	0.0300 [8]	0.9
Lupins	110	1.00 [1]	0.0300 [8]	0.9
Peas, dry	3,000	1.00 [1]	0.0300 [8]	0.9
Peas, green	6,200	0.85 [2]	0.0300 [8]	0.2
Vetches	800	0.90 [4]	0.0300 [8]	0.8
Barley	35,000	0.88 [5]	0.0043 [9]	0.8
Carrots and turnips	4,000	0.12 [3]	0.0150 [10]	0.8
Garlic	4,000	0.35 [6]	0.0150 [10]	0.7
Maize	3,000	0.88 [5]	0.0080 [9]	0.7
Oats	235	0.88 [5]	0.0070 [9]	0.7
Onions, dry	95,000	0.14 [6]	0.0150 [10]	0.2
Potatoes	280,000	0.45 [7]	0.0150 [10]	0.0
Sorghum	460	0.88 [5]	0.0108 [9]	0.7
Wheat	150,000	0.88 [5]	0.0028 [9]	0.8

Sources | (1) Pulses data from FAO are on DM basis

(2) 2000 GPG, table 4.16

(3) Washington State University, 2012

(4) 2006 IPCC GL, table 11.2 (N-fixing forages)

(5) 2006 IPCC GL, table 11.2 (grains)

(6) Slovenian National Inventory Report

(7) 1996 IPCC GL - Reference Manual, table 4.17

(8) $Frac_{NCRBF}$ default value: 1996 IPCC GL - Reference Manual, table 4.19

(9) $Frac_{NCRO}$ default value: 2000 GPG, table 4.16

(10) $Frac_{NCRO}$ default value: 1996 IPCC GL - Reference Manual, table 4.17

(11) Expert judgment: LARI

4.2.6. Recalculation

The previous national communications and TNC used the same methodology (1996 IPCC GL, GPG 2000, tier 1 level) and the same source categories and subcategories except for the subcategory - burning of crop residues - which was not included in the TNC. Recalculations were made from 1994 to 2004 based on activity data modifications and more applicable default emission factors and fractions. Table 15 to Table 17 list the differences between TNC and previous national communications that have led to an under-estimation of emissions in SNC by an average of 11% difference. Figure 4 summarizes these differences in emissions from each subcategory and in total emissions for the years 2000 – 2004.

Table 15: Differences between SNC and TNC in activity data and emission factors and fractions

Category	SNC	TNC	Explanation
Animal population	- Imported beef not included. - All poultry population adjusted to 60 days alive. - Sheep and swine population adjusted to 180 and 240 days alive, respectively.	- Imported beef included. - Broilers adjusted to 60 days alive while laying hens and traditional chicken not adjusted. - Sheep and swine population not adjusted.	Expert judgment indicated that imported beef should be included in the inventory. Broilers life cycle is approximately 60 days.
Enteric fermentation	Emission factors for dairy and non-dairy cattle are 36 and 32 kg/head/year, respectively.	Emission factors for dairy and non-dairy cattle are 100 and 48 kg/head/year, respectively.	Average milk production in Lebanon is consistent with Western Europe.
Manure management methane	Emission factors for dairy, non-dairy, and swine are 2, 1, and 3 kg/head/year, respectively.	Emission factors for dairy, non-dairy, and swine are 19, 13, and 7 kg/head/year, respectively.	EFs suitable for Eastern Europe better reflect the conditions in Lebanon for manure management (solid based system).

Category	SNC	TNC	Explanation
Manure management nitrous oxide (Table 17)	- All sheep and goats were considered grazing. - All poultry manure was considered under solid storage and dry lot.	- 67% of sheep and goats were considered grazing. - Poultry manure was divided among PRP, poultry manure with bedding, and poultry manure without bedding; 0.04%, 77% and 19%, respectively.	Expert judgment
Agricultural soils	- Non N-fixing crops: same crops considered by TNC plus taro, groundnut, cottonseed, cabbage, artichoke, cauliflower, tomatoes, pumpkin, cucumbers, watermelon, cantaloupe, sugar cane, and tobacco leaves. - N-fixing crops: did not include alfalfa and vetch. - Nitrogen content fractions were 0.03 and 0.015 for N-fixing crops and non-N fixing crops respectively. - $Frac_R$ = 0.45 for all crops	- Non N-fixing crops: TNC did not include taro, groundnut, cottonseed, cabbage, artichoke, cauliflower, tomatoes, pumpkin, cucumbers, watermelon, cantaloupe, sugar cane, and tobacco leaves. - N-fixing crops: included alfalfa and vetch. - Nitrogen content fractions were 0.03 for N-fixing crops and crop-dependent for non N-fixing crops. - $Frac_R$ was obtained for each crop.	Expert judgment

Table 16: Major animal population in SNC and TNC in 1994, 2000, and 2004 (head)

Year	Species	SNC [1]	TNC
1994	Dairy cattle	46,000	51,620
	Non-dairy cattle	30,700	43,480
	Poultry	22,700,000	11,790,620
	Sheep	249,300	242,980
	Swine	41,000	52,800
2000	Dairy cattle	38,900	38,900
	Non-dairy cattle	38,100	56,400
	Poultry	10,898,630	15,198,630
	Sheep	174,575	354,000
	Swine	17,095	26,000
2004	Dairy cattle	43,850	43,860
	Non-dairy cattle	36,550	53,790
	Poultry	13,200,000	16,793,151
	Sheep	150,558	305,360
	Swine	8,219	12,500

Source | MoE/URC/GEF, 2012

[1] Data were provided by UNDP Climate Change Office in Lebanon.

Table 17: Comparison of manure management systems between SNC and TNC for major animal species

Species	Inventory	PRP	Solid storage and drylot	Poultry manure with bedding	Poultry manure without bedding
Dairy cattle	SNC	0.10	0.85		
	TNC	0.02	0.90		
Non-dairy cattle	SNC	0.10	0.90		
	TNC		1.00		
Sheep and goats	SNC	1.00			
	TNC	0.67	0.33		
Poultry	SNC		1.00		
	TNC	0.04		0.77	0.19

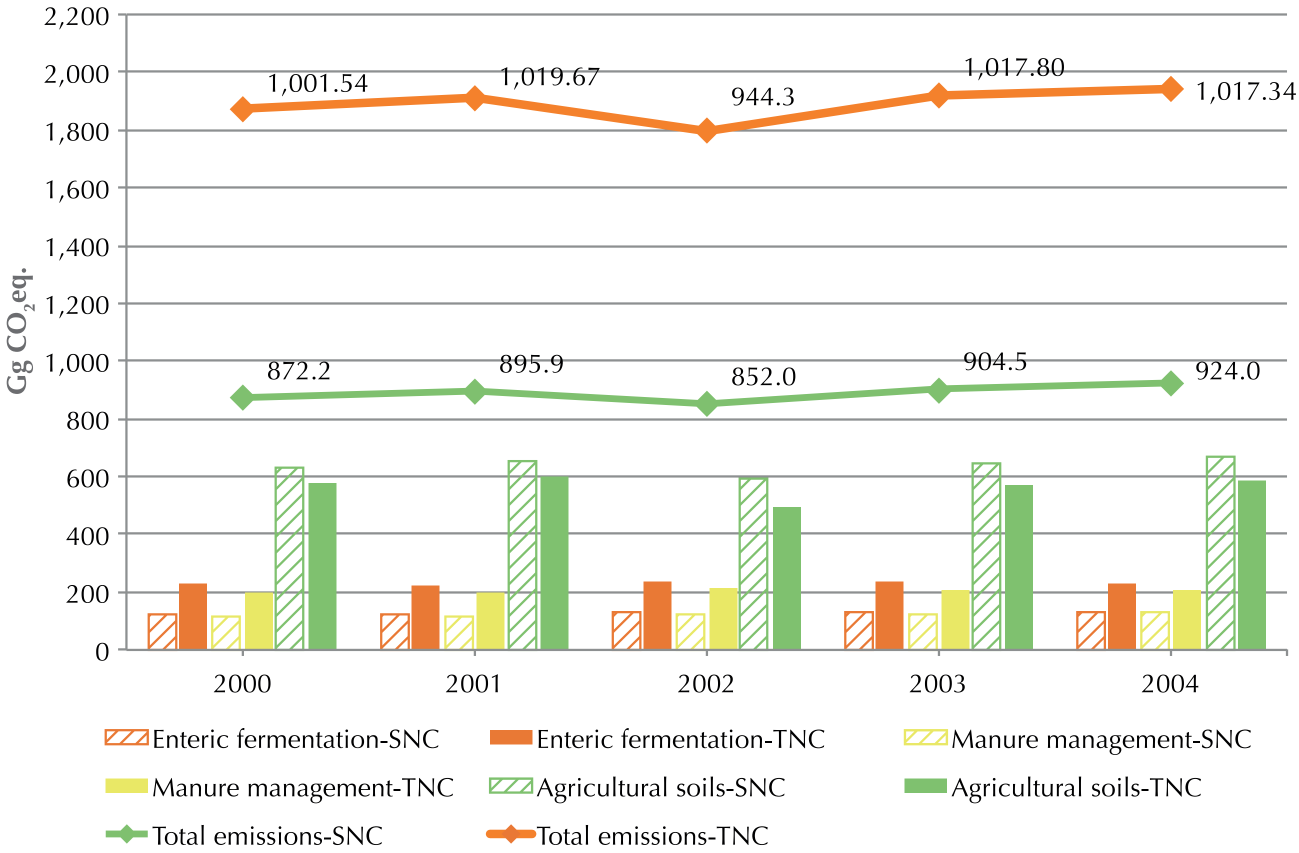


Figure 4: Comparison of GHG emissions between SNC and TNC

4.2.7. Uncertainty assessment

Uncertainty estimates are an essential element of a complete emissions inventory. They are implemented to help prioritize efforts to improve the accuracy of inventories in the future and guide decisions on methodological choices (IPCC GPG 2000).

Uncertainty of the agricultural emissions inventory was estimated according to the tier 1 methodology of the 2000 GPG. In this method, uncertainties are calculated based on the error propagation of emission factors and activity data uncertainties, both of which are presented in Table 18 below. Uncertainties of emission factors are based on default uncertainties proposed by the IPCC 1996 GL and 2000 GPG, while uncertainty estimations on activity data were set equal to ±20% across all agricultural data (mostly from FAO statistics), based on expert judgment provided by FAO.

Uncertainty calculations, based on tier 1 uncertainty assessment of the IPCC GPG 2000, are presented in Annex VII-1 and Annex VII-2 for the years 2010 and 2011, respectively. The calculations used 1994 as the base year, and since total emissions from all sectors are not yet available, the total emissions values from all sectors in the SNC for 2004 were assumed as proxy values for total emissions from all sectors for both 2010 and 2011. The calculations are presented following table 6.1 format of the GPG 2000. Table 18 below summarizes the results of the uncertainty calculations for the year 2010. Total uncertainty from agriculture is 4% of total emissions from all sectors.

Table 18: Activity data and emission factor uncertainty values used for calculation of uncertainty

IPCC category	Activity data uncertainty (%)	Emission factor	Emission factor uncertainty (%)	Source
Enteric fermentation	±20	EF	±20	IPCC 1996 Reference Manual
Methane emissions from manure management	±20	EF	±20	IPCC 1996 Reference Manual
Nitrous oxide emissions from manure management	±20	EF_3	-50/+100	GPG 2000
Direct emissions of N_2O from agricultural soils	±20	EF_1	±80	IPCC 1996 Reference Manual
Indirect emissions of N_2O from agricultural soils (volatilization)	±20	EF_4	-80/+100	IPCC 1996 Reference Manual
Indirect emissions of N_2O from agricultural soils (leaching)	±20	EF_5	-92/+380	IPCC 1996 Reference Manual
Animal grazing (PRP)	±20	EF_3	-50/+100	GPG 2000

Table 19: Summary of uncertainty calculations for the agriculture sector (2010)

IPCC source category	Gas	Combined uncertainty as percentage of total national emissions in year 2010 (%)	Uncertainty introduced into the trend in total national emissions (%)
Enteric fermentation	CH_4	0%	0.00%
Manure management	CH_4	0%	0.00%
Manure management	N_2O	1%	0.00%
Agricultural soils - direct	N_2O	1%	1.00%
Agricultural soils - indirect (volatilization)	N_2O	1%	1.00%
Agricultural soils - indirect (leaching)	N_2O	3%	3.00%
Agricultural soils - PRP	N_2O	0%	0.00%
Total		4%	3.11%

5. Results and discussion

5.1. GHG inventory for the years 2005-2012

The agricultural activities that contribute to the emission of GHGs in Lebanon originate from two sources:

- Livestock: enteric fermentation (CH_4) and manure management (CH_4, N_2O)
- Agriculture soils (N_2O)

Based on consultations with growers and with LARI, burning of agricultural residues was not included in the calculation because this activity is not practiced anymore, at least during the 2005-2012 period, and thus other gases were not considered.

Methane emissions (Gg CH_4) from enteric fermentation and manure management and nitrous oxide emissions (Gg N_2O) from manure management and agricultural soils are presented in Table 20 below for the 2005-2012 period.

Table 20: Methane emissions (Gg CH_4) and nitrous oxide emissions (Gg N_2O) by source category in 2005-2012

Year	Methane emissions/Gg CH_4			Nitrous oxide emissions/Gg N_2O		
	Enteric fermentation	Manure management	Total Gg CH_4	Manure management	Agricultural soils	Total Gg N_2O
2005	11.15	1.99	**13.14**	0.52	1.56	**2.08**
2006	11.32	2.02	**13.34**	0.54	1.39	**1.93**
2007	10.90	2.00	**12.90**	0.53	1.51	**2.04**
2008	11.34	2.02	**13.36**	0.54	1.42	**1.96**
2009	10.76	1.94	**12.70**	0.53	1.54	**2.07**
2010	9.77	1.82	**11.59**	0.49	1.51	**2.00**
2011	9.58	1.79	**11.37**	0.49	1.55	**2.04**
2012	9.55	1.77	**11.32**	0.49	1.57	**2.06**

Table 21 below shows the GHG emissions in Gg carbon dioxide equivalent (CO_2eq.) for the agriculture sector in Lebanon and the percent contribution of each category to total emissions from agriculture. The CO_2 equivalent is calculated based on the IPCC Second Assessment report values of Global Warming Potential (GWP) for 100 years (N_2O = 310, CH_4 = 21). The main sources of emissions were N_2O emissions from agricultural soils, which constitute over half of total agricultural emissions, while the remaining sources of emissions are almost equally from enteric fermentation (CH_4) and from manure management (CH_4 and N_2O).

Table 21: GHG emissions by agricultural source (Gg CO_2eq.) and contribution (% of total from agriculture)

Year	CH_4 emissions enteric fermentation Gg CO_2eq. (% of total from agriculture)	CH_4 emissions manure management Gg CO_2eq. (% of total from agriculture)	N_2O emissions manure management Gg CO_2eq. (% of total from agriculture)	N_2O emissions agricultural soils Gg CO_2eq. (% of total from agriculture)	Total emissions from agriculture Gg CO_2eq.
2005	234.05 (25)	41.79 (5)	163.24 (18)	483.19 (52)	**922.27**
2006	237.70 (27)	42.36 (5)	168.56 (19)	430.14 (49)	**878.75**
2007	228.88 (25)	42.14 (5)	166.72 (18)	467.21 (52)	**904.94**
2008	238.06 (27)	42.46 (5)	168.38 (19)	438.98 (49)	**887.88**
2009	226.01 (25)	40.06 (4)	164.33 (18)	478.21 (53)	**908.61**
2010	205.17 (24)	38.34 (4)	154.17 (18)	467.67 (54)	**865.35**
2011	201.11 (23)	37.68 (4)	153.59 (18)	479.77 (55)	**872.15**
2012	200.46 (23)	37.27 (4)	153.42 (18)	485.36 (55)	**876.51**

In 2012, total GHG emissions from the agriculture sector were 876.51 Gg CO_2eq. Nitrous oxide emissions from agricultural soils (485.36 Gg CO_2eq.) represented 55% of total emissions from agriculture, CH_4 emissions from enteric fermentation (200.46 Gg CO_2eq.) were 23%, and N_2O and CH_4 emissions from manure management (190.70 Gg CO_2eq.) were 22% of emissions. Of the emissions from manure management, 18% were due to N_2O emissions while CH_4 emissions represented 4% of total agricultural emissions. It is also noted that total N_2O emissions (Gg CO_2eq.) in 2012 represented 73% of total agricultural emissions while total CH_4 emissions were 27%.

5.2. Changes in greenhouse gas emissions

Figure 5 below depicts the trend in agricultural emissions for the period 2005-2012. Compared to 2005, emissions in 2012 decreased by 5%, primarily due to a decrease in CH_4 emissions from enteric fermentation, and to a lesser degree from N_2O and CH_4 emissions from manure management. Emissions from agricultural soils decreased in 2006 but increased thereafter to the value reported in 2005.

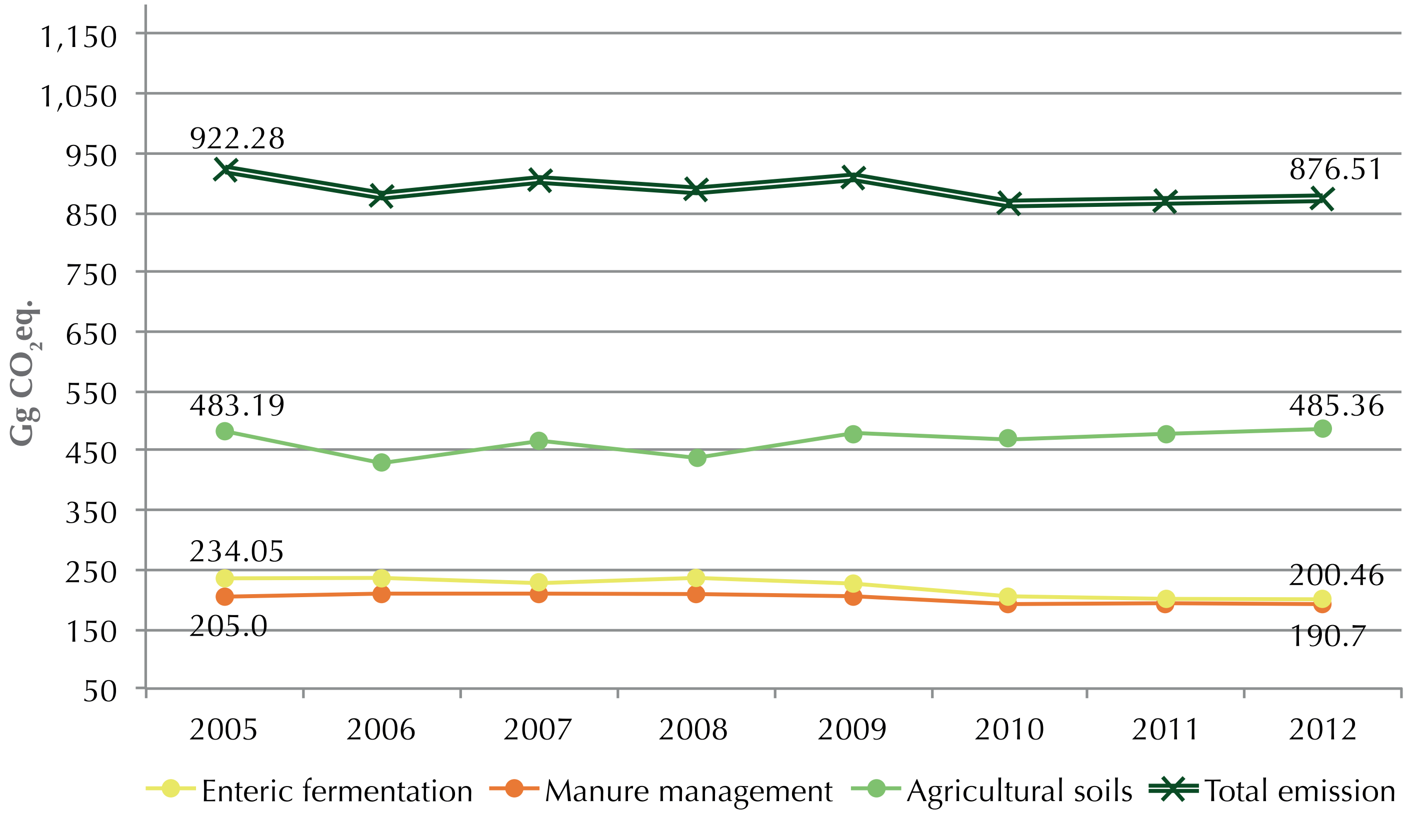


Figure 5: Trend in total agricultural emissions and in emissions from enteric fermentation, manure management and agricultural soils (2005-2012) in Gg CO_2eq.

The changes in total emissions from the agriculture sector are plotted in Figure 6 below along with changes in animal populations during the period 2005-2012. It is evident that the changes in emissions in certain years mirror those in cattle (dairy and non-dairy), sheep, and goat populations. For example the decrease in emissions in 2010 was mainly due to sharp decline in sheep and to a lesser extent goat and non-dairy populations. While in 2006, the decrease in emissions is mainly due to lower emissions from agriculture soils (Figure 5), which counteracted the slight increase in sheep population (Figure 6). Similarly in 2009 the reduction in emissions from dairy cattle was counteracted by an increase in emissions from sheep and from agricultural soils. The main reduction in emissions in 2010 were due to a combination of heat, low precipitation (Table 1), and competition from imports of fertilizers and livestock from Syria, which rendered the agriculture sector vulnerable and resulted in lower crop and animal production (Jean Stephan, personal communication).

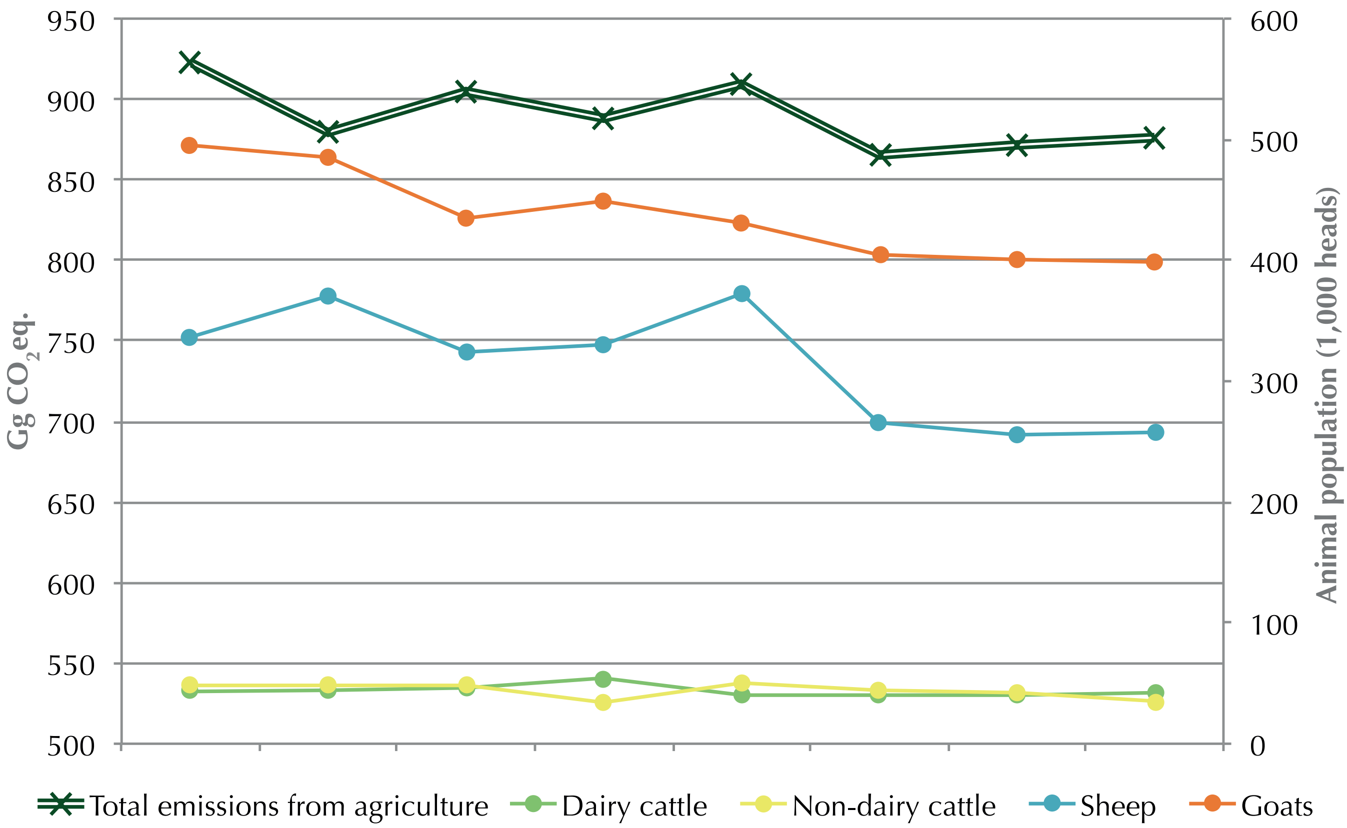


Figure 6: Changes in total GHG emissions from the agriculture sector (Gg CO_2eq.) and in major animal population in 2005-2012

5.3. Contribution of categories in GHG emissions

5.3.1. Emissions from enteric fermentation in domestic livestock – CH_4

Enteric fermentation is a major source of emissions within the agriculture sector. In 2012, it constituted 23% of all agricultural emissions and was 14% lower than in 2005. Dairy and non-dairy cattle represented 62% of emissions (mainly dairy) while 34% is from sheep and goats. As reported in Table 22 below, emissions fluctuated in the period 2005-2008, and experienced a decrease in 2009 and in 2010 which is attributed mainly to a sharp decline in dairy, sheep, and goat populations (Figure 7). As Mr. Asmar adequately puts it "Changes in land use practices, the shifting from rural to urban livelihoods and the severe fragmentation that the woodlands, rangelands and pasture lands are witnessing because of the urban sprawl, has seen herds (goats and sheep) decrease in number and pastoralism is no longer an important part of the rural mosaic" (FAO, 2011a).

Table 22: Methane emissions from enteric fermentation (Gg CH_4) and total CO_2eq. in 2005-2012

Species	2005	2006	2007	2008	2009	2010	2011	2012
Dairy cattle	4.38	4.39	4.53	5.50	4.08	4.02	4.02	4.20
Non-dairy cattle	2.31	2.36	2.28	1.64	2.38	2.11	1.99	1.77
Sheep	1.69	1.85	1.62	1.65	1.86	1.33	1.28	1.29
Goats	2.47	2.42	2.17	2.25	2.15	2.02	2.00	1.99
Camels	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Horses	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07
Mules and asses	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Swine	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total CH_4 (Gg)	11.15	11.32	10.90	11.34	10.76	9.77	9.58	9.55
Total CO_2eq. (Gg)	234.05	237.70	228.88	238.06	226.01	205.17	201.11	200.46

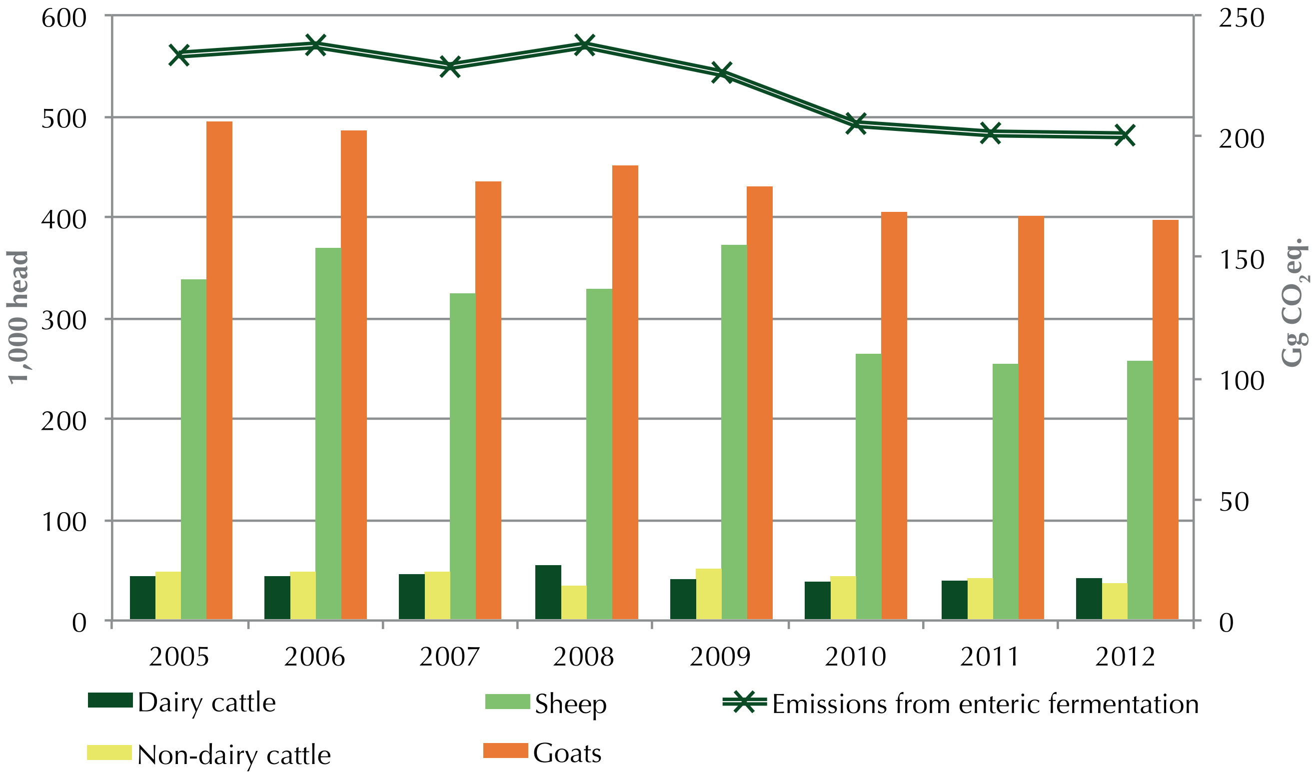


Figure 7: Population trend in cattle, sheep and goats, and emissions from enteric fermentation (Gg CO_2eq.) in 2005-2012

5.3.2. Emissions from manure management - CH_4 and N_2O

Manure management is a main source of emissions within the agriculture sector. Table 23 shows the CH_4 and N_2O emissions from manure management and total CO_2 equivalents. Emissions from CH_4 and N_2O in 2012 totaled 190.67 Gg of CO_2 equivalents, which constitutes 22% of the GHG emissions from the agriculture sector. Nitrous oxide emissions in 2012 represent 80% of total emissions from manure management (Gg CO_2eq.), while emissions from CH_4 represent 20%. Whereas both CH_4 and N_2O emissions were relatively stable during the period 2005-2009, both emissions decreased in 2010 due to the decrease in sheep and goat population and to some extent cattle.

Table 23: Methane and nitrous oxide emissions from manure management (Gg CO_2eq.) in 2005-2012

	2005	2006	2007	2008	2009	2010	2011	2012
CH_4 (Gg CO_2eq.)	41.79	42.36	42.14	42.26	40.06	38.34	37.68	37.26
N_2O (Gg CO_2eq.)	163.24	168.56	166.72	168.38	164.33	154.17	153.59	153.42
Total (Gg CO_2eq.)	205.03	210.92	208.86	210.84	204.39	192.51	191.27	190.67

As shown in Figure 8, dairy cattle are the largest contributor to CH_4 emissions from manure management, followed by non-dairy cattle, and poultry.

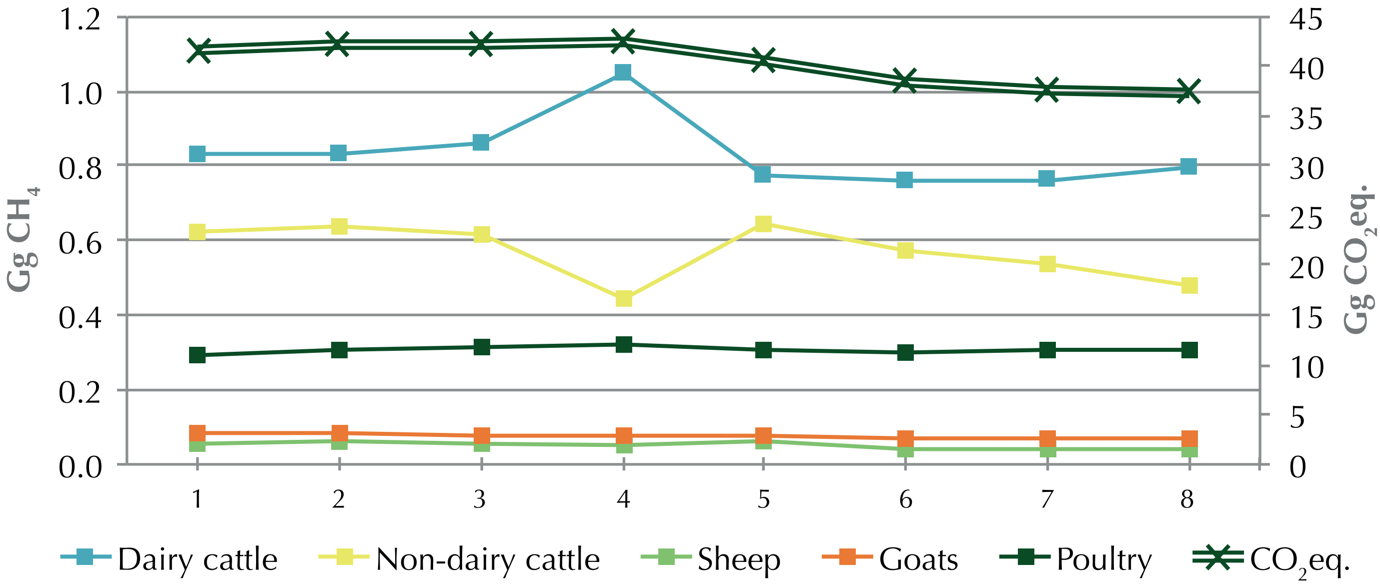


Figure 8: Total methane emissions from manure management (Gg CO_2eq.) and methane emissions (Gg CH_4) from major animal species in 2005-2012

While dairy cattle population and hence emissions slightly increased in the period 2005-2008, it decreased again during the period 2009-2012 to its level in 2005. Non-dairy cattle population decreased in 2012 compared with 2005 and hence the lower emissions from non-dairy cattle manure. Methane emissions from poultry manure increased slightly during this period which corresponds to the slight increase in population.

Nitrous oxide emissions from manure management depend on how manure for each animal species is distributed between different MMS. As summarized in Figure 9 below, cattle manure was largely managed in solid storage and drylot, whereas sheep and goats were distributed between pasture range and paddock (67%) and solid storage and drylot (33%). Poultry manure was mainly managed with bedding (77%) and to a lesser extent without bedding (19%) (traditional chicken manure is included under PRP). Emissions from daily spread and from PRP are considered under emissions from agricultural soils and therefore not included in the calculations of N_2O emissions from manure management.

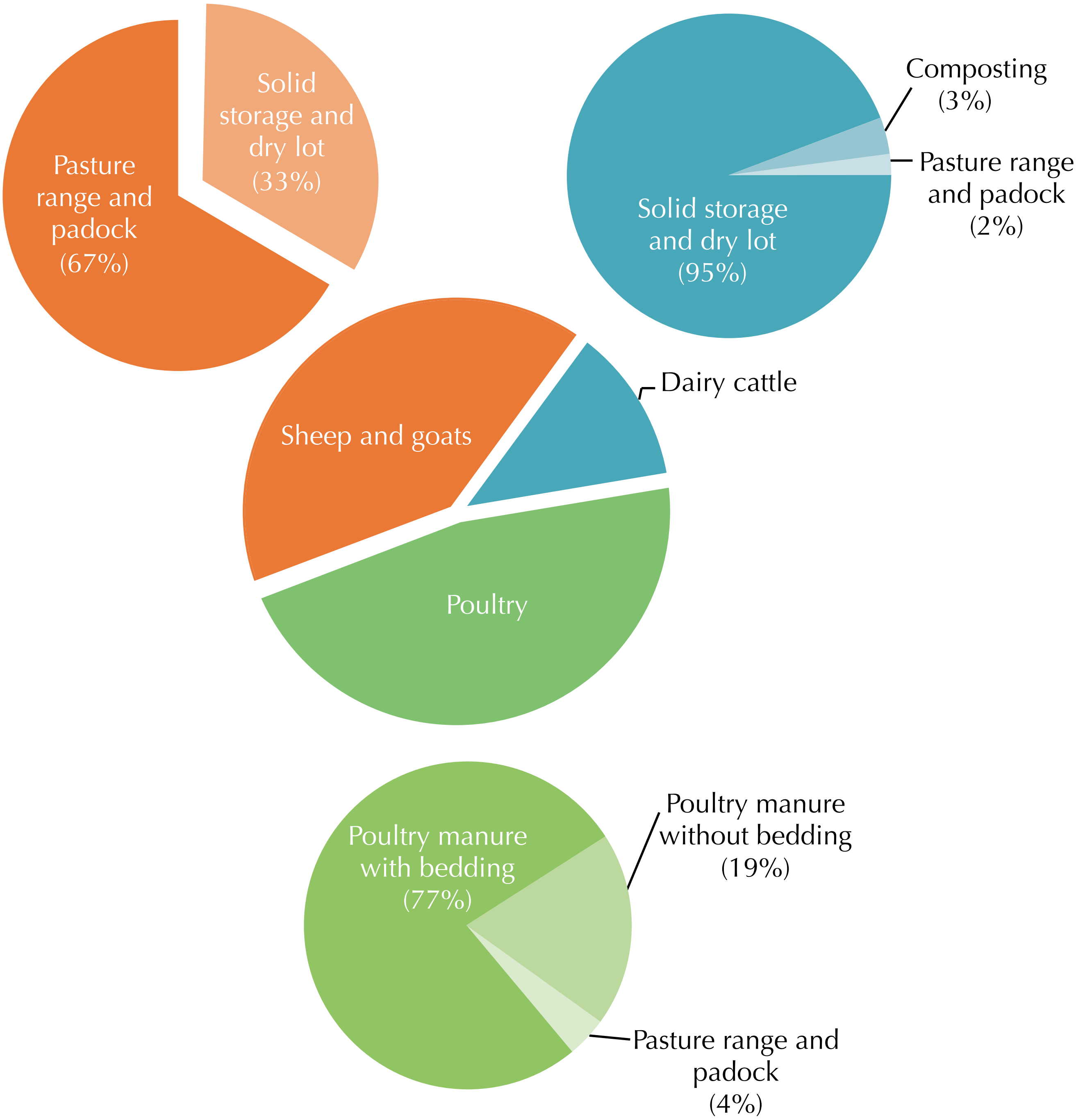


Figure 9: Manure management systems utilized for major animal species

Nitrogen excretions from animals in different MMS are shown in Table 24. Nitrogen excretions from manure managed in solid storage and drylot (sheep, goat, dairy cattle) and from poultry manure with bedding represent almost 90% of the total excretions. The remaining is largely poultry manure without bedding.

Table 24: Amount of nitrogen (tonnes N/year) excreted from animals in different manure management systems in 2005-2012

MMS	2005	2006	2007	2008	2009	2010	2011	2012
Anaerobic lagoons	30.66	30.73	31.71	38.50	28.56	28.11	28.11	29.40
Liquid system	15.33	15.37	15.86	19.25	14.28	14.06	14.06	14.70
Solid storage and dry lot	8,789.42	8,924.51	8,541.20	8,599.18	8,496.96	7,649.28	7,464.35	7,362.91
Poultry manure without bedding	1,850.86	1,946.28	1,991.41	2,017.42	1,944.72	1,899.49	1,928.63	1,956.98
Poultry manure with bedding	7,500.85	7,887.54	8,070.44	8,175.87	7,881.21	7,697.91	7,816.03	7,892.68
Total	18,187.12	18,804.43	18,650.62	18,850.22	18,365.73	17,288.85	17,251.18	17,256.67

Table 25 below shows the amount of nitrogen excreted from daily spread manure and from PRP. In order not to double count these sources of nitrogen when calculating the amount of manure added to soils (F_{AM}), nitrogen from daily spread is added to the nitrogen from MMS listed in Table 25 and then subtracting the fraction from PRP. Nitrogen excreted from grazing animals (PRP) is added separately to the total emissions from agricultural soils (done automatically by software).

Table 25: Amount of nitrogen (tonnes N/year) excreted from animals under daily spread and pasture range and paddock in 2005-2012

MMS	2005	2006	2007	2008	2009	2010	2011	2012
Daily spread	48.26	46.73	46.11	52.10	41.36	40.49	40.35	41.88
PRP	8,092.25	8,295.80	7,537.83	7,734.12	7,877.42	6,797.73	6,690.45	6,709.03
Total	8,140.51	8,342.53	7,583.94	7,786.22	7,918.78	6,838.22	6,730.80	6,750.91

Nitrous oxide emissions from major MMS are presented in Table 26 below. Manure managed under solid storage and drylot, and poultry manure managed with bedding equally represents the largest sources of emissions. There was a slight decrease in total N_2O emissions during the period 2005-2012, mainly from solid manure storage and drylots. This is due to the decrease in the number of sheep, goats, and non-dairy cattle. The three species have a large portion of their manure deposited in lots or piled up in a nearby location (Table 12). Figure 10 below summarizes the contributions of N_2O and CH_4 emissions to the total emissions from MMS.

Table 26: Nitrous oxide emissions (Gg N_2O) from major manure management systems utilized in 2005-2012

MMS	2005	2006	2007	2008	2009	2010	2011	2012
Anaerobic lagoons	0.05×10^{-3}	0.05×10^{-3}	0.05×10^{-3}	0.06×10^{-3}	0.04×10^{-3}	0.04×10^{-3}	0.04×10^{-3}	0.05×10^{-3}
Liquid systems	0.02×10^{-3}	0.02×10^{-3}	0.02×10^{-3}	0.03×10^{-3}	0.02×10^{-3}	0.02×10^{-3}	0.02×10^{-3}	0.02×10^{-3}
Solid storage and drylot	0.28	0.28	0.27	0.27	0.26	0.24	0.23	0.23
Poultry manure without bedding	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02
Poultry manure with bedding	0.24	0.25	0.25	0.26	0.25	0.24	0.25	0.25
Total N_2O emissions (Gg)	0.53	0.54	0.54	0.54	0.53	0.50	0.49	0.49

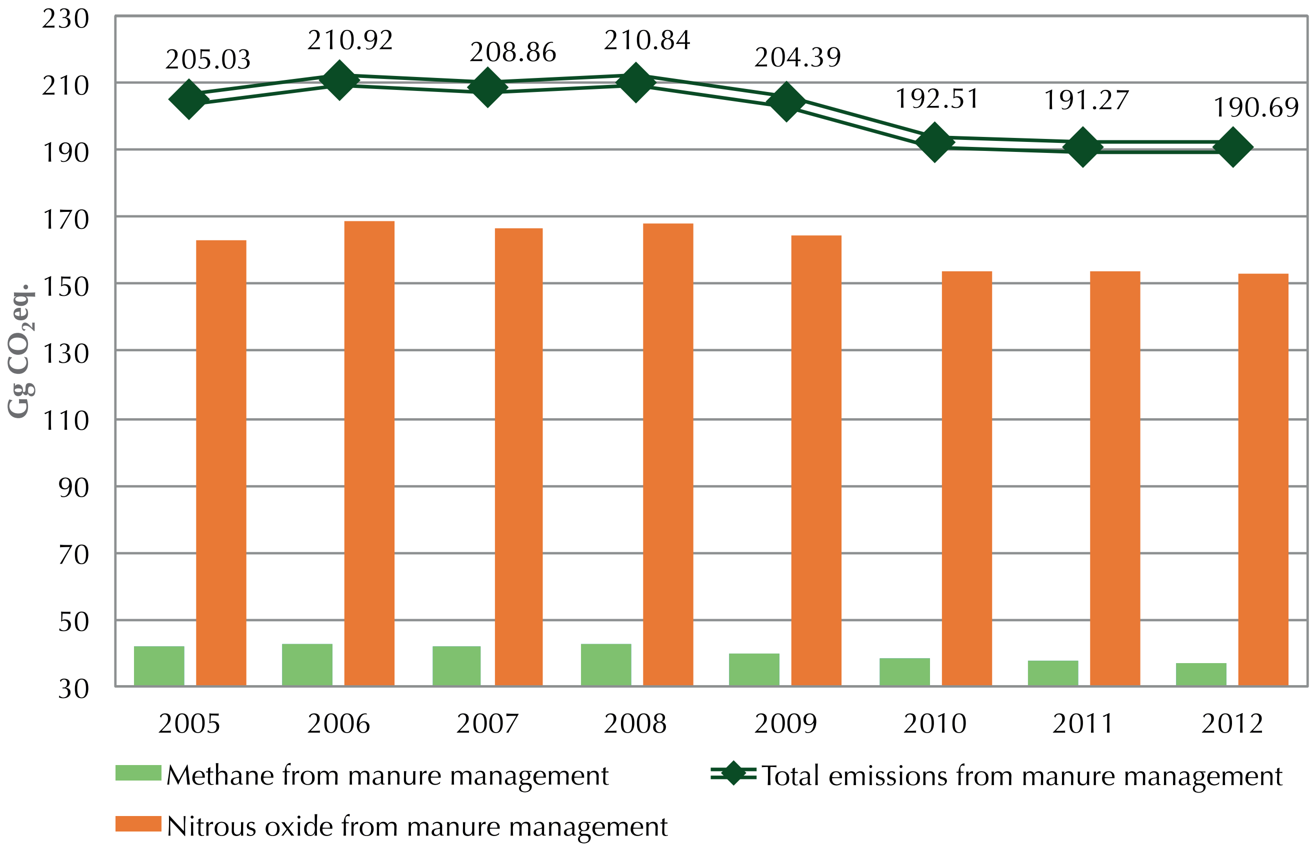


Figure 10: Methane, nitrous oxide and total emissions from MMS (Gg CO_2eq.) in 2005-2012

5.3.3. Emissions of N_2O from agricultural soils

Emissions of N_2O from agricultural soils are due to direct and indirect emissions from this category and emissions from animal grazing (PRP). As shown in Table 27, total emissions from agricultural soils amounted to 485 Gg CO_2eq. representing 55% of total agricultural emissions in 2012. Almost 48% of total N_2O emissions from soils are due to direct emissions, while indirect emissions are 39%, and emissions from grazing are 13% (Table 28). While direct and indirect emissions fluctuated during 2005-2012, N_2O emissions from animal grazing (PRP) decreased by ≈ 16%, reflecting the decline of pasture productivity in the country and the reduction in grazing sheep and goat populations.

As shown in Figure 11, total soil emissions are largely influenced by changes in direct emissions; for example the decrease in emissions in 2006 is mainly due to the decrease in direct soil emissions. Table 28 shows that this is due to the drop in fertilizer use (F_{SN}) in 2006. However, emissions increased thereafter due to higher fertilizer consumption. The table also shows that indirect emissions from soils are mainly a result of leaching of N added as fertilizer or manure comprising more than 80% of total indirect emissions.

Table 27: Total emissions (Gg CO_2eq.) from agricultural soils and its subcategories in 2005-2012

Year	Total direct emissions		Total indirect emissions		Emissions from animal grazing		Total emissions[(1)]
	Gg CO_2eq.	% total	Gg CO_2eq.	% total	Gg CO_2eq.	% total	Gg CO_2eq.
2005	220.10	45%	185.11	38%	80.60	17%	483.19
2006	186.00	43%	165.63	39%	80.60	18%	430.14
2007	217.00	46%	180.24	38%	74.40	16%	467.21
2008	198.40	45%	160.76	37%	74.40	17%	438.98
2009	217.00	45%	185.11	39%	77.50	16%	478.21
2010	220.10	47%	185.11	39%	65.10	14%	467.67
2011	226.30	48%	189.99	38%	65.10	14%	479.77
2012	232.50	48%	189.99	39%	65.10	13%	485.36

(1) Total emissions may not match the sum of individual categories due to rounding errors and to discrepancies between our calculations of emissions from each subcategory and those reported by the software for the total emissions from a category.

Table 28: Contribution of subcategories to direct and indirect emissions (Gg CO_2eq.) from agricultural soils in 2005-2012

Year	Direct emissions (Gg CO_2eq.)					Indirect emissions (Gg CO_2eq.)		
	F_{SN}	F_{AM}	F_{BN}	F_{CR}	Total[(1)]	Leached	Volatilized	Total[(1)]
2005	83.70	77.50	9.30	49.60	220.10	151.01	34.10	185.11
2006	52.70	83.70	9.30	40.30	186.00	136.40	29.23	165.63
2007	74.40	83.70	9.30	52.70	217.00	146.14	34.10	180.24
2008	52.70	83.70	9.30	52.70	198.40	131.53	29.23	160.76
2009	83.70	77.50	9.30	43.40	217.00	151.01	34.10	185.11
2010	93.00	77.50	15.00	34.10	220.10	151.01	34.10	185.11
2011	102.30	77.50	15.50	34.10	226.30	155.89	34.10	189.99
2012	107.30	77.50	15.50	34.10	232.50	155.89	34.10	189.99

(1) Total emissions may not match the sum of individual subcategories due to rounding errors and to discrepancies between our calculations of emissions from each subcategory and those reported by the software for the total emissions from a category.

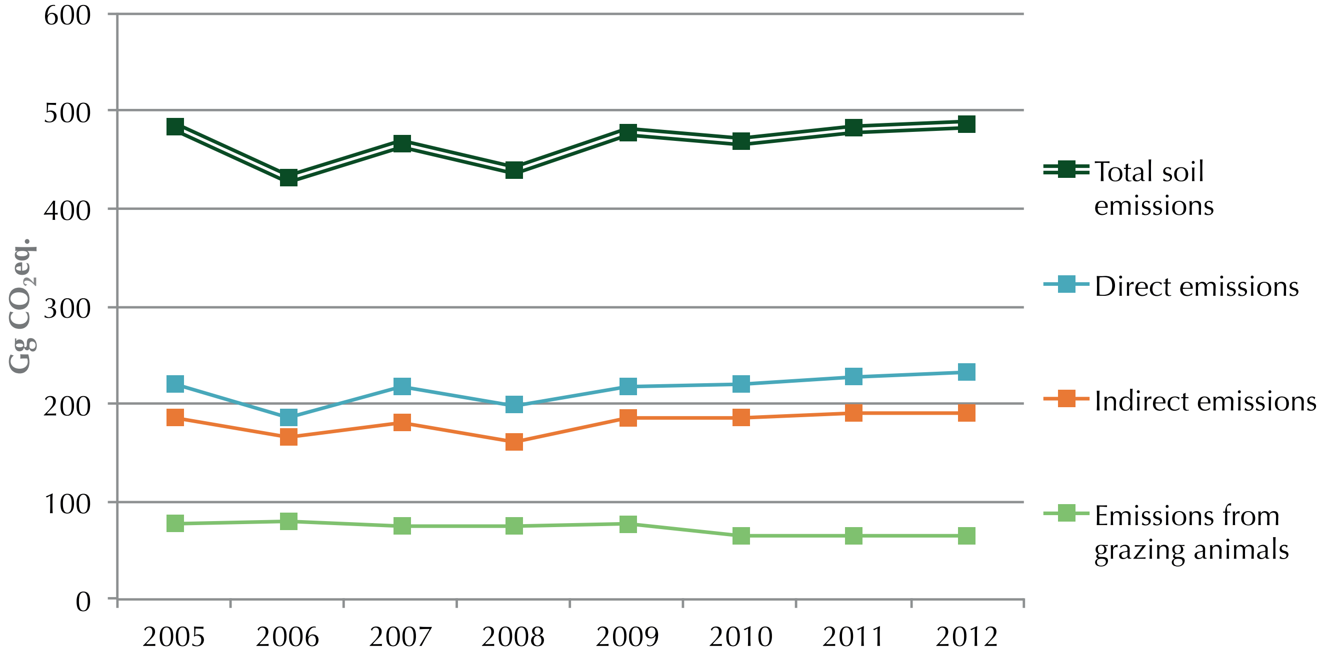


Figure 11: Trend in nitrous oxide emissions (Gg CO_2eq.) from agricultural soils in 2005-2012

Direct emissions

Direct emissions from agricultural soils originate from four sources (subcategories) - synthetic nitrogen fertilizers, biological nitrogen fixation, crop residues, and animal manure applied to soils (corrected for the amount added from animal grazing in PRP and for the amount volatilized). Total direct emissions from these four subcategories are summarized in Figure 12. Total direct emissions decreased in 2006 due to reduction in emissions from fertilizer use and crop residues. Although crop residues continued to decline, fertilizer consumption and hence emissions from N fertilizers increased after 2008. Production of N-fixing crops showed an increase during 2005-2012, consistent with increased harvested areas and production of leguminous crops (see Annex IV-4a). Emissions thus increased, especially during the period 2010-2012. Animal manure applied to soils (F_{AM}) fluctuated during the period 2005-2012 and N_2O emissions did not change much in 2012 when compared to 2005 (Figure 12). Thus total N_2O direct emissions from soils increased slightly in 2012 compared to 2005.

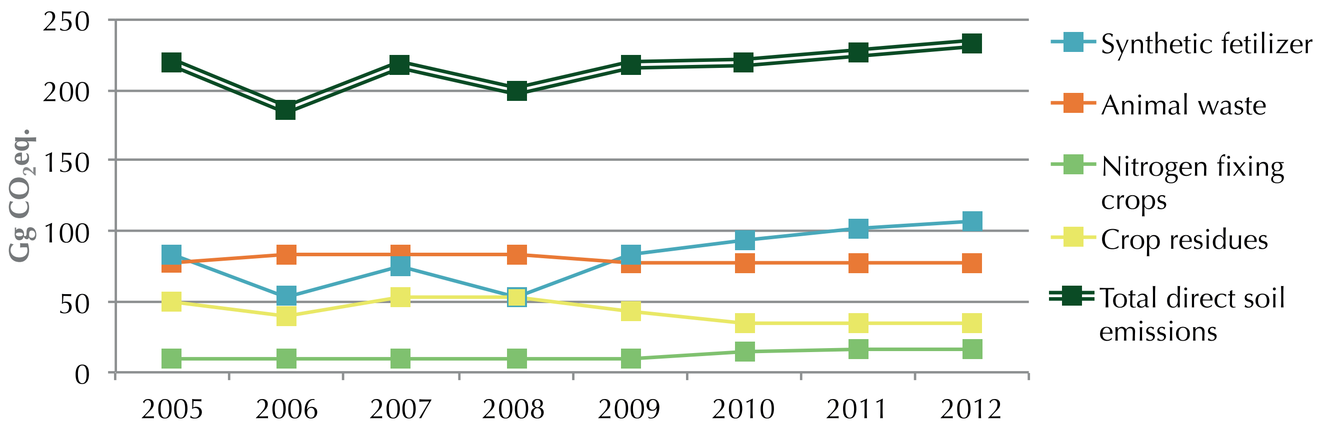


Figure 12: Direct soil emissions from different subcategories in 2005-2012

Figure 13 shows the amount of N applied to soils as synthetic fertilizer and the amount of crop residues added to soils in 2005-2012. Although fertilizer use declined in 2006 and 2008, the amount applied increased thereafter. Global fertilizer prices increased rapidly in 2007 and skyrocketed in 2008, this was due to increases in energy and raw material prices and growth in demand from emerging markets and the biofuel sector in USA and Europe (IFDC, 2012). For example, the prices of urea and diammonium phosphate (DAP) increased more than four-fold between August 2007 and October 2008. This explains the observed decline in fertilizer use in 2007 and 2008, while the reduction in 2006 was due to the July 2006 war. Fertilizer use increased in 2009 and thereafter most probably due to increased consumption in agriculture or in other industries but reported under agriculture use.

The amount of nitrogen added from crop residues (Figure 13) also decreased in 2006, 2009, and 2010. This is mainly due to the sharp decrease in potato production, one of the main residue forming crops included in this inventory (See Annex IV-4b).

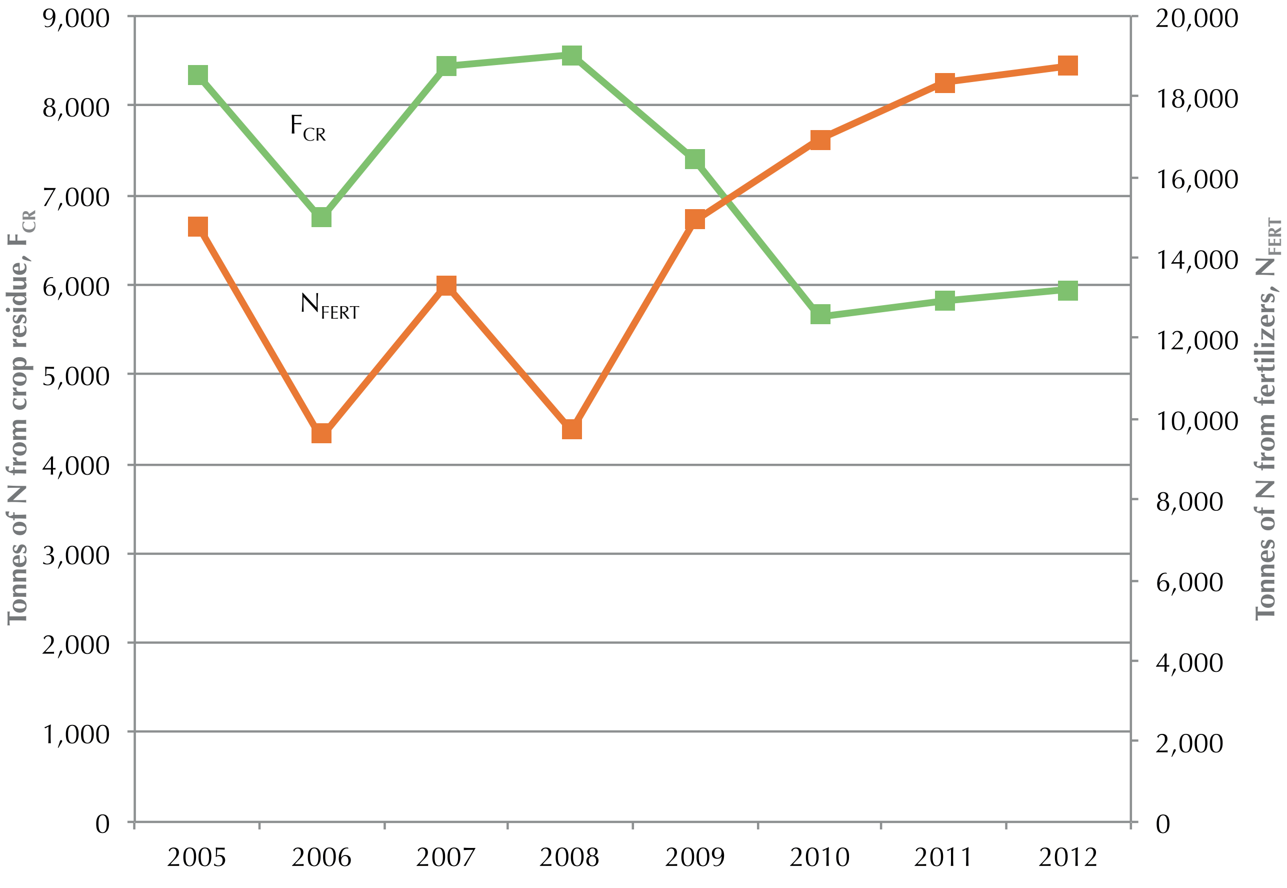


Figure 13: Amount of N applied to soil from synthetic fertilizers (N_{FERT}) and crop residues (F_{CR}) in 2005-2012

Emissions from animal grazing

Emissions of nitrous oxide during animal grazing (PRP) are not significant, as summarized in Table 29 below. The decrease in sheep and goat populations, which are the main contributors to manure from PRP, is the reason for the lower emissions in 2007. The drought conditions experienced since 2010 are the reason for the lower rangeland productivity and hence the lower nitrogen excreted from PRP in 2010-2012.

Table 29: Emissions from pasture range and paddock (Gg N_2O) in 2005-2012

	2005	2006	2007	2008	2009	2010	2011	2012
Nitrogen excreted during grazing (tonnes of N/year)	8,092.25	8,295.79	7,537.81	7,734.12	7,877.43	6,797.73	6,690.45	6,709.10
N_2O emissions from animal grazing (Gg N_2O)	0.25	0.26	0.24	0.24	0.25	0.22	0.21	0.21

Indirect emissions

Indirect N_2O emissions from agricultural soils are due to two sources: atmospheric deposition of NH_3 and NO_x and subsequent transformation to N_2O, and to leaching and runoff of nitrogen and subsequent transformation to N_2O. Atmospheric deposition of nitrogen compounds such as NO_x and ammonium (NH_4) fertilizes soils resulting in enhanced biogenic N_2O formation. As seen in Table 30, indirect emissions in 2012 from leaching constitute a larger fraction (83%) than atmospheric deposition (17%). This leached nitrogen enters the groundwater, riparian areas, and rivers where it enhances biogenic production of N_2O. Leaching of added N decreased during the period 2005-2008 and then increased thereafter reflecting the similar changes in N fertilizer consumption (Table 13). The overall indirect emissions increased slightly in 2012 compared to 2005.

Table 30: Indirect nitrous oxide emissions from agricultural soils (Gg N_2O) in 2005-2012

	2005	2006	2007	2008	2009	2010	2011	2012
N_2O volatilized	0.10	0.09	0.11	0.10	0.10	0.10	0.10	0.11
N_2O leached	0.49	0.44	0.48	0.42	0.49	0.49	0.50	0.50
Total Gg N_2O	0.59	0.53	0.57	0.53	0.59	0.59	0.60	0.61

5.4. Trend in Lebanon's GHG emissions for the agriculture sector: 1994-2012

5.4.1. Trend analysis

The trend in agricultural emissions during the period 1994-2012 is shown in Figure 14 below. Emissions in 2012 were 876 Gg CO_2eq. and decreased by 161 Gg CO_2eq. (15%) from the 1994 level of 1,037 Gg CO_2eq. This is largely the result of the decrease in emissions from agricultural soils by 131 Gg CO_2eq. (21%), and to a lesser extent, a decrease in CH_4 emissions from enteric fermentation by 31 Gg CO_2eq. (13.4%). The main reason for the decrease in agricultural emissions from soils, the largest contributor to GHG in the agriculture sector, is the decrease in the use of nitrogen fertilizers and in crop residues added to soils during the period 1998-2010, while the decrease in emissions from enteric fermentation is largely due to the decline in dairy, sheep, and swine populations.

As shown in Figure 15, total emissions from manure management were relatively stable, as there was a slight decrease in CH_4 emissions and slight increase in N_2O emissions during this period.

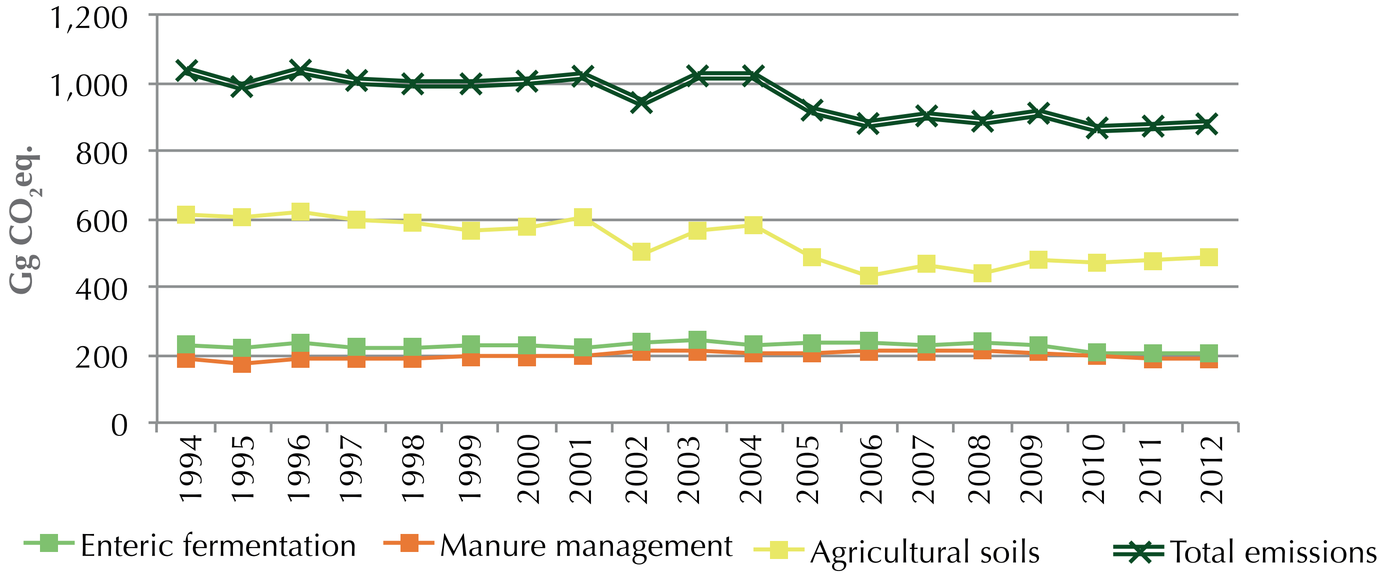


Figure 14: Trend in total GHG emissions from the agriculture sector and its categories in 1994-2012 (Gg CO_2eq.)

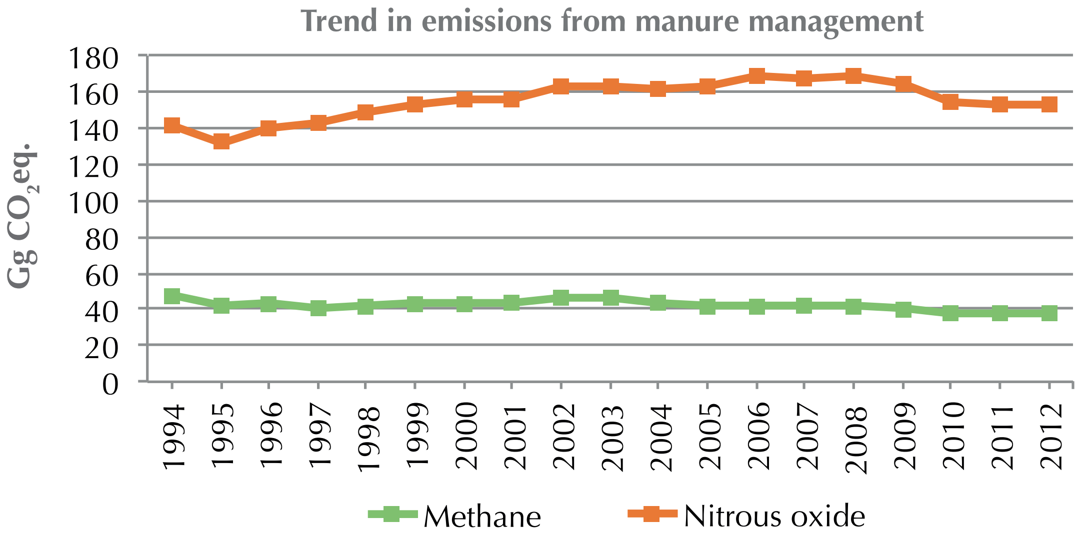


Figure 15: Methane and nitrous oxide emissions from manure management in 1994-2012 (Gg CO_2eq.)

As depicted in Figure 16, N inputs from fertilizer and animal manure are the major sources of direct emissions from soils while leaching is the dominant indirect source. Emissions from fertilizers exhibited a sharp decline during the period 1994-2008 and then increased thereafter. A similar trend was observed for emissions from leached nitrogen during the period 1994-2012.

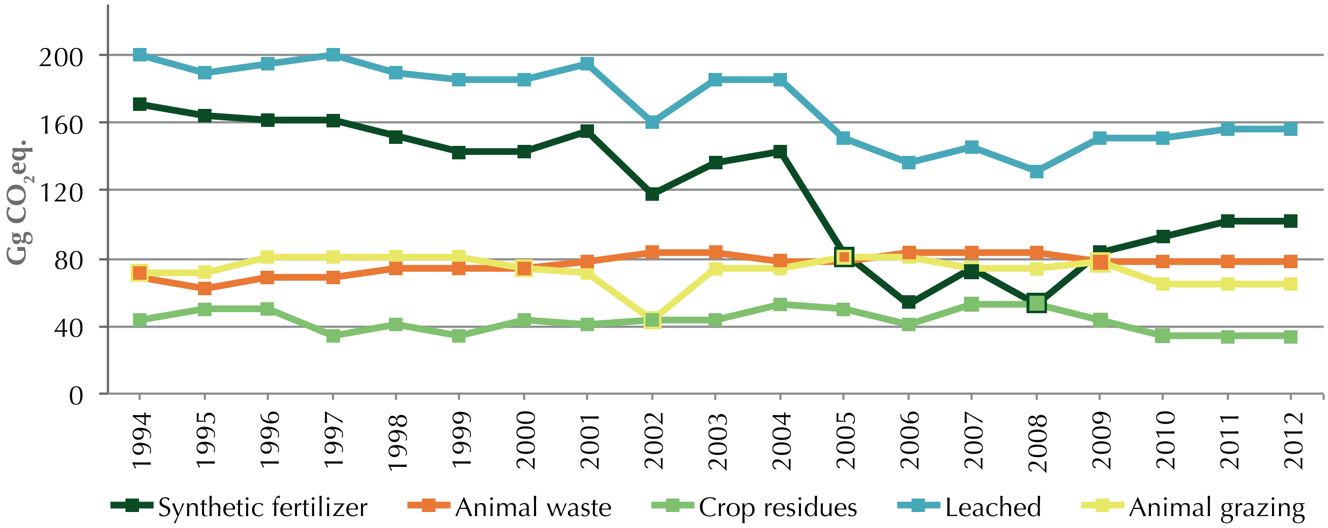


Figure 16: Trend in GHG emissions from subcategories with major contributions to direct and indirect soil emissions in 1994-2012 (Gg CO_2eq.)

5.4.2. Trend analysis by gas

Figure 17 below shows the trend in total CH_4 and N_2O emissions from the agriculture sector during the period 1994-2012. Total CH_4 emissions decreased by 15% while total N_2O emissions decreased by 16% during this period. The decrease in CH_4 emissions is due to a decrease in emissions from enteric fermentation and manure management as a result of lower animal populations, while the decrease in N_2O emissions is mainly due to the decrease in fertilizer consumption as a result of shrinkage in agricultural land utilized for crop production.

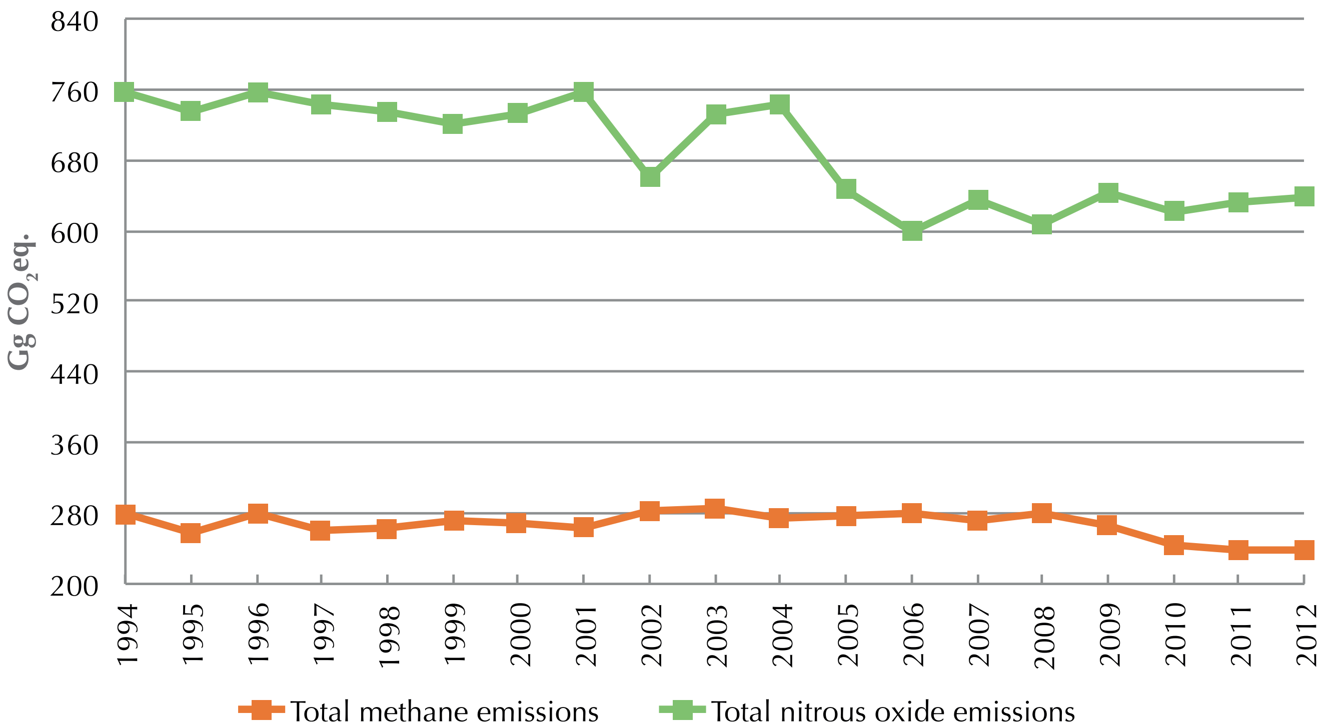


Figure 17: Trend in total nitrous oxide and total methane emissions (Gg CO_2eq.) from agriculture in 1994-2012

5.5. Comparison with Mediterranean countries

Table 31 below compares agricultural GHG emissions from Lebanon in 2011 with select Mediterranean countries. Data for emissions from these countries were obtained from the UNFCCC GHG Inventory Data (UNFCCC, 2014). Due to similarities in land area, Cyprus is the only country with comparable emissions from the agriculture sector, though emissions from agricultural soils are higher in Lebanon due to larger utilized agricultural land. Table 32 shows the trend in emissions observed in these countries.

Table 31: Agricultural GHG emissions in 2011 in select Mediterranean countries[1], and comparison with Lebanon country report (Gg CO_2eq.)

Country	Enteric fermentation Gg CO_2eq.	Manure management Gg CO_2eq.	Agricultural soils Gg CO_2eq.	Others* Gg CO_2eq.	Total Gg CO_2eq.
Cyprus	190.47	273.16	265.29	1.01	729.94
Greece	3,224.07	600.32	4,980.20	161.21	8,965.84
Slovenia	652.96	538.30	709.47	-	1,900.73
Turkey	17,305.45	3,879.27	7,348.93	470.53	28,833.07
Lebanon (country report)	201.11	191.27	479.77	0	872.15

Source | [1] http://unfccc.int/di/DetailedByCategory/Event.do?event=go

*Others include field burning of agricultural residues, and rice cultivation.

Table 32: Changes in total agricultural emissions in select Mediterranean countries (Gg CO_2eq.)

Country	1994	2011	Percent change
Cyprus	757.99	729.94	-4%
Greece	10,015.51	8,965.84	-12%
Slovenia	2,053.00	1,900.73	-8%
Turkey	29,768.06	28,833.07	-3%
Lebanon	1,037.10	872.15	-19%

6. Conclusions of the national inventory

This report provides an inventory of the GHG emissions of the agriculture sector in Lebanon prepared in accordance with the 1996 IPCC GL. It provides an inventory of GHG emissions for the years extending from 2005 to 2012 with 2005 as a baseline year, and presents a trend in emissions for the period 1994-2012. Improvements on previous inventories include the adoption of default emission factors that better reflect the national circumstances and the use of country-specific activity data whenever possible. The improved emission factors and new data allowed re-calculation of estimations for the years 1994-2004.

The main findings indicated that total GHG emissions from the agriculture sector in 2012 amounted to 876 Gg of carbon dioxide equivalent (Gg CO_2eq.). Of this total, 55% were from N_2O emissions from agricultural soils, 23% from CH_4 emissions from enteric fermentation, and 22% from N_2O and CH_4 emissions from manure management. Of the emissions from agricultural soils, 22% (of total agricultural emissions) were due to indirect N additions from leaching and volatilization of applied N, 11% from direct N fertilizer applications, and 9% from direct manure application.

Emissions from agriculture during the period 2005-2012 decreased slightly, with emissions in 2012 about 5% lower than the base year 2005, largely a result of a decrease in emissions from enteric fermentation by 34 Gg CO_2eq. and to a lesser extent a decrease in N_2O emissions from manure management by 10 Gg CO_2eq. The trend of emissions in the period 1994-2012 showed a more pronounced decline – emissions decreased by 161 Gg CO_2eq. (15%) from the 1994 level of 1,037 Gg CO_2eq. This is largely a result of decrease in N_2O emissions from agricultural soils and to a lesser extent in CH_4 emissions from enteric fermentation. The main reason for the decrease in these emissions is the reduction in fertilizer use and the lower animal population in 2012 compared to 1994. This was a result of the shrinking of utilized agricultural land by 5% and the decrease in cattle, sheep, and goat populations.

Suggestions to improve GHG estimation of emissions in the future were also presented. This includes the establishment of an advisory scientific team to facilitate data coordination among MoA, public, private, and international agencies, establishment of a monitoring system within MoA for manure management, encouraging research to conduct measurements to develop local EFs, conduct training for relevant institutions involved in planning, preparation, and analysis of GHG inventory, and conduct workshops on data management and on inventory and mitigation softwares for the agriculture sector.

Part 2: Mitigation analysis

7. Existing mitigation actions

7.1. Review of global mitigation measures in the agriculture sector

There are five mitigation measures that are applicable to GHG mitigation from the agriculture sector in Lebanon:

A. Cropland management
B. Livestock management
C. Manure management
D. Organic farming
E. Grazing land management/pasture improvement

These measures contribute to mitigation by reducing emissions of CH_4 and N_2O from agriculture, by enhancing removal of atmospheric GHGs, and by avoiding emissions of fossil fuels consumed during agricultural production.

Table 33 below outlines the activities and associated technologies associated with these mitigation measures as adopted from a classification provided by Smith et al. (2007).

Table 33: Summary of mitigation measures and associated technology practices

Mitigation measure	Technology practices
A. Cropland management	
1. Agronomy	- Improved crop varieties - Crop rotation - Cover crops
2. Nutrient management	- Organic fertilizers - Soil N tests - Fertigation - Slow release fertilizers
3. Tillage and residue management	- Conservation agriculture
4. Water management	- Irrigation efficiency (drip/sprinkler irrigation)
	- Water supply (rainwater harvesting)
B. Livestock management	
1. Improving feeding practices	- Feed optimization
2. Animal breeding	- Improve animal performance
C. Manure management	
1. Manure storage and handling	- Cover piles of manure, avoid addition of straw, apply immediately onto lands and incorporate into soil
2. Manure treatment	- Anaerobic digestion (biogas)
	- Composting
D. Organic agriculture	
E. Grazing/pasture management	
	- Introduce new grass species and legumes into pastures - Improve grazing intensity

Source | Adapted from Smith et al., 2007

The following is a brief description of each measure as it pertains to the agriculture sector in Lebanon (adapted from the IPCC report by Smith et al., 2007):

Cropland management

1. **Agronomy:** Improved agronomic practices that increase crop yields, use nitrogen fixing plants in rotations, and allow for maximum return of plant residues to soils to lead to increased soil carbon storage. Such practices include: i) having improved crop varieties that are resistant to disease and insects leading to increased residues available for sequestration, ii) adopting techniques that could lower the use of pesticides and nitrogenous fertilizers by using crop rotation with legumes, iii) using cover crops that can add carbon to the soil and uptake unused nitrogen, thus reducing N_2O emissions.

2. **Nutrient management:** Growers in Lebanon apply far more fertilizer nitrogen than the amount used efficiently by crops. The surplus N increases the amount of direct and indirect N_2O emissions from soils. Consequently, improving N use efficiency can reduce N_2O emissions and indirectly reduce GHG emissions from N fertilizer manufacture. Practices that improve N use efficiency include the use of organic fertilizers (manure, compost), adjusting application rates based on precise estimation of crop needs (via soil N tests), and applying N via fertigation which ensures that N is less susceptible to loss and places N more precisely into the soil to make it more accessible to crops roots.

3. **Tillage and residue management:** Adopting minimum or no tillage and leaving crop residues in the field are proven Conservation Agriculture (CA) techniques which increase carbon sequestration in soils and decrease CO_2 emissions due to less mechanization and less fertilizer use due to an increase in soil fertility and soil organic matter. However the effect on reducing N_2O emissions is not conclusive especially under cool and moist climates.

4. **Water management:** Using more effective irrigation measures can enhance carbon storage in soils through enhanced yields and residue returns. Drip irrigation can reduce energy use and when combined with fertigation, less fertilizer N is used and higher fertilizer use efficiency results, thus lowering GHG emissions.

Livestock management

Ruminant animals such as cattle and sheep are important sources of CH_4 which is released through enteric fermentation. The emissions of CH_4 from enteric fermentation account for about one-third of global anthropogenic emissions of this gas (Smith et al., 2007). All livestock also generate N_2O emissions from manure as a result of excretion of N in urine and feces. Practices for reducing CH_4 and N_2O emissions from this source fall into three general categories: improved feeding practices, use of specific agents or dietary additives, and longer-term management changes and animal breeding. Methane emissions can be reduced by feeding more concentrates, normally replacing forages. Maintaining the health of livestock and choosing a fast growing breed and higher milk producing cows will reduce GHG emissions. By improving health and decreasing mortality, less gas is emitted per production unit.

Manure management

Animal manures can release significant amounts of N_2O and CH_4 during storage. Covering the manure with either permeable or impermeable cover will retain the nutrients within the manure rendering it more valuable for land application. However, it can also create anaerobic conditions within the manure pile leading to emissions of CH_4. In such cases, different factors affect the GHG emissions such as manure pH, temperature, and moisture contents. Another convenient solution for animal manure is to collect the methane and convert it into biogas, thus reducing CH_4 emissions as well as avoiding CO_2 emissions from the replaced fuel. Handling manures in solid form (e.g., composting) rather than liquid form can suppress CH_4 emissions, but may increase N_2O formation and, if aeration is inadequate, CH_4 emissions during composting can still be substantial. Composting is gaining widespread use and one company in Lebanon is already producing compost from cow and poultry manure (GreenCo, Lebanon) to be used on orchards, vines and field crops.

Organic agriculture

Organic agriculture prohibits the use of synthetic products (pesticides, fertilizers, and growth regulators) for crop or animal production. It relies on crop rotation, crop residues, animal manure, and legumes for soil and crop management. For fertilizer, organic farmers use a variety of sources: compost, green manure, organic fertilizers, and the integration of animals in crop production. Besides reducing the emissions of N_2O, organic farming improves soil fertility, increases soil water content, and reduces water and air pollution. Organic farming is practiced on more than 2,800 ha in Lebanon, increasing at the rate of 15% yearly (Yousef El Khoury, IMC, personal communication).

Grazing land management/pasture improvement

One of the major GHG emissions contributions from livestock production is from forage or feed crop production and related land use (IFAD, 2009). Proper pasture management through rotational grazing would be the most cost-effective way to mitigate GHG emissions from feed crop production. Animal grazing on pastures helps reduce emissions attributable to animal manure storage. Introducing grass species and legumes into grazing lands can enhance carbon storage in soils. Improving grazing intensity improves carbon sequestration as overgrazed or under grazed land sequesters less carbon than optimally grazed one.

7.2. Existing and planned mitigation actions in Lebanon

Table 34 to Table 39 list the current or planned mitigation actions in the agriculture sector in Lebanon, as initiated and implemented by public and private institutions. Even though most if not all of these projects are primarily focused on sustainable crop and animal production and/or adaptation to climate change, it is envisioned that each activity or technology used or suggested would eventually contribute to GHG mitigation. Thus the authors have identified, in addition to the goals and outcomes associated with these projects, the expected GHG mitigation potential in a qualitative or semi-quantitative sense. Unfortunately, there is not enough information to assess quantitatively and accurately the expected GHG reduction potential of such projects/actions.

Cropland management

Table 34: Conservation agriculture, Lebanese Agricultural Research Institute (LARI)

Conservation agriculture	
General information: Introducing conservation agriculture in the Bekaa to wheat and barley crop production in rain-fed areas. LARI, and GIZ (the Deutsche Gesellschaft für Internationale Zusammenarbeit) successfully implemented demonstration trials at farmers' fields, showing lower cost, lower fuel consumption, higher soil moisture, and improved yield.	
Implementing agency	LARI
Geographical coverage	Bekaa
Budget	Not available 70% of seeder machine price (approximately USD 10,000)
Timeframe	Funded: 2007-2010; Non-funded: 2011-present
Source of funding	GIZ (till 2010)
Goals	1. Reduce energy used and CO_2 emissions by reducing fuel use 2. Reduce fertilizer used and N_2O emissions 3. Increase conservation of water 4. Increase total cost savings to farmer per ha
Achievements or progress	1,800 ha of CA by 2012
GHG reduction	Increase CO_2 sequestration and decrease N_2O emissions
Emission reduction expected by completion of action	N/A
Methodology	1996 IPCC
Assumption	By implementing CA, N_2O emissions will decrease

Table 35: The improvement of the cattle production sector, Rene Moawad Foundation

Improvement of the cattle production sector	
General information: Improving the health status of cows in the North region The project involved 107 farmers from 38 villages and treated around 1,922 cows. Around 80% of the farmers adopted the new technologies, milk production increased by 20-40%, and there was 70% improvement in the herd's health.	
Implementing agency	Moawad Foundation
Geographical coverage	Cazas of Akkar, Zgharta, Minnieh, Dennieh, Becharre, Koura, Batroun and Jbeil in North Lebanon
Budget	USD 633,000
Timeframe	Two years (2009-2011)
Source of funding	United States Department of Agriculture (USDA)
Goals	Goal 1: Development of cattle breeding - Create a training program for cattle breeders. - Better herd health Goal 2: Improvement of the cattle's nutrition - Pellet production - Expansion of forage cultivation in Akkar/North Lebanon
Achievements or progress	- Milk production increased by 20-40%. - Around 70% improvement in the herd's health - Artificial insemination for 484 cows belonging to 46 farmers
GHG emission reduction expected	CH_4 from enteric fermentation and MMS: 1,155 tonnes CO_2eq. during the two year period
Methodology	1996 IPCC
Assumptions	- Assuming 80% of the cow herd was improved (1,538 head) since 80% of farmers adopted the new technology - Production of milk before this initiative: 1,538 x 20 kg milk/day = 30,760 kg milk/day - This initiative increased milk production by an average of 30%. - By implementing this initiative and in order to produce the same quantity of milk, the herd is reduced by an average of 461 cows thus leading to a reduction of GHG emissions.

Table 36: Livestock vaccination, Food and Agriculture Organization (FAO) and the Lebanese Ministry of Agriculture (MoA)

Emergency vaccination and targeted feeding of livestock grazing in areas along the Syria-Lebanon border	
General information: Due to the war in Syria, Syrian shepherds have been crossing the border with their livestock, increasing the risk of disease transmissions. This project aims to benefit both Syrian and Lebanese farmers and shepherds.	
Implementing agencies	FAO and MoA
Geographical coverage	Lebanese-Syrian border
Budget	In 2012 MoA spent USD 6.44 million.
Timeframe	Annually
Sources of funding	FAO and MoA
Goals	Goal 1: Improved delivery of veterinary services for a higher percentage of sheep: 1) by conducting rapid need assessments to identify livestock population and risk, 2) by undertaking emergency vaccination strategies for Lumpy Skin Disease (LSD) and Food and Mouth Disease (FMD), for sheep, goats and cattle, 3) and by training professional veterinarians. Goal 2: Increased number of livestock keepers able to retain and make a living from their herds of sheep by: 1) distributing feed to target beneficiaries, 2) enabling farmers to adopt new technologies and practices on improving pasture/rangeland management.
Achievements or progress	- Increased number of sheep, goats and cattle adequately nourished and vaccinated against circulating serotypes of LSD and FMD. Veterinary and livestock extension services developed and functioning at the community level in remote areas along the Syrian border. - Assessing risks and outbreaks for rapid containment of Transboundary Animal Disease (TAD).
GHG emission reduction expected	CH_4 and N_2O reduction Not quantified

Table 37: Recovery and rehabilitation of the dairy sector in Bekaa Valley and Hermel-Akkar uplands, FAO and MoA

Recovery and rehabilitation of dairy sector in Bekaa valley and Hermel-Akkar uplands	
General information: This project covered the regions of North Lebanon, through Dairy Producers' Association covering 300 villages and 2,900 farmers. This project decreased cow diseases related to feeding excessive concentrate (by increasing forage distribution), thus increasing milk productivity by 15%.	
Implementing agencies	FAO and MoA
Geographical coverage	Akkar, Hermel and Bekaa
Budget	USD 2.5 million
Timeframe	Three years (2009 - 2012)
Source of funding	Lebanon Recovery Fund (LRF)
Number of farmers helped	2,900 farmers
Goals	Support the small and poor dairy farmers and producers in the Bekaa and Akkar and the goat and sheep farmers in Hermel and Akkar uplands by: - Conducting training programs to improve farm management practices, milk hygiene, feeding and promoting fodder crops - Improving dairy cattle feeding, and increasing milk production and maintaining livestock health
Achievements or progress	The project was completed in 2012.
GHG emission reduction expected	CH_4 from enteric fermentation and MMS: 9,289 tonnes CO_2eq. reduced as a result of this project. N_2O from MMS: 3,100 tonnes CO_2eq. reduced as a result of this project.
Methodology	1996 IPCC
Assumptions	- According to MoA, 59% of dairy cattle are located in the North and Bekaa region. - Production of milk before this initiative: 24,780 x 20 kg milk/day = 495,600 kg milk/day - This initiative increased milk production by 15%. - By implementing this initiative and in order to produce the same quantity of milk, the herd is reduced by 3,717 cows leading to a reduction of GHG emissions.

Manure management

Table 38: Composting of dairy manure, Libanlait

Composting of dairy manure	
General information: A private company is applying this project. Every year, 500-800 tonnes of high quality compost is produced and sold to farmers.	
Implementing agency	Libanlait
Geographical coverage	Bekaa
Cost of production	USD 25,000-40,000
Timeframe	Annually
Source of funding	Libanlait
Quantity of manure treated	2,800 tonnes
Goal	Produce high quality compost from dairy cow manure produced at the farm
Achievements or progress	Increase in compost quantity by 10% on yearly basis
GHG reduction	CH_4 and N_2O
Emission reduction expected by completion of action	N_2O from MMS: 620 tonnes CO_2eq. reduced as a result of this project. CH_4 from MMS: 400 tonnes CO_2eq. reduced as a result of this project.
Methodology	1996 IPCC
Assumption	The calculations were based on the assumption that manure from 1,000 cows is being converted to compost.

Organic agriculture

Table 39: Organic agriculture in Lebanon

Organic agriculture reduces GHG emissions through an appropriate combination of organic fertilizers, crop rotation, cover crops, less intensive tillage, and integrated pest management	
General information: Organic farming is increasingly utilized in crop and animal production in Lebanon in response to consumer demand for nutritious and safe products. This includes dairy, vegetables, fruits, citrus, olives, herbs and medicinal plants. Most organic farms are currently certified by Instituto Mediterraneo Di Certificazione (IMC).	
Certification agency	IMC
Geographical coverage	Currently 2,800 ha all over Lebanon
Achievements or progress	2,500 ha in 2005 increased to 2,800 ha by 2012
GHG emission reduction mechanisms	Increase CO_2 sequestration and decrease CO_2, N_2O, and CH_4 emissions through: - Use of organic rather than synthetic fertilizers and prohibitive use of chemical herbicides or insecticides - Use of legumes (N-fixing from atmosphere) - Less use of fuel through less tillage - Use of less concentrate feed and increased grazing
GHG emission reduction potential	No local data Global (Niggli et al., 2009): - Reduce industrial N-fertilizer use that emits 6.7 kg CO_2eq. per kg N on manufacture and another 1.6% of the applied N as soil N_2O emissions. - Sequestration rate of 200 kg C/ha/year for arable and permanent crops and 100 kg C /ha/year for pastures. - Combining organic farming with reduced tillage on arable land sequesters 500 kg C/ha/year.

8. Mitigation options for the agriculture sector in Lebanon

A comprehensive GHG mitigation strategy requires consideration of the relative mitigation potential and cost-effectiveness of GHG mitigation opportunities related to cropland and manure management. The main driver of success for these measures in Lebanon is in fact more related to their co-benefits in terms of increased income and resource efficiency (water, fertilizers, seeds, fuel) than their GHG mitigation potential. This is mainly a consequence of two factors:

1. Lebanon's land tenure system which is characterized by many small holdings. The agriculture census of 2000 (MoA, 2000) recorded some 170,000 farm holdings utilizing 231,000 ha. Of these farms, 49% were smaller than 5 ha while only 2% had 10 ha or more. Another important factor is the fact that most large agriculture holdings are leased on a year by year basis to growers who do not feel motivated to pursue long term sustainable or environmental best management practices.

2. Lack of motivation in GHG mitigation measures, as adaptation to climate change takes precedence in light of recent and recurrent droughts. The main concern for farmers in Lebanon is focused on water and food security, competition from neighboring markets, and climate change adaptation. Therefore GHG mitigation measures in the agriculture sector have a greater impact and probability of success when concurrently addressing the concerns of farmers namely water scarcity, resource scarcity, drought and climate change variability.

This report therefore concentrates on two mitigation options that have the potential of conserving resources (water, fuel, and labor) and increasing income while at the same time contributing to GHG mitigation. These are (a) conservation agriculture and (b) fertilizer best management practices using fertigation and drip irrigation.

8.1. Baseline scenario

The Business as Usual (BAU) or baseline scenario is defined as the emissions' pathway that would be followed if development targets are achieved (including food security) but low-emissions policies and measures are not adopted (FAO, 2013). The purpose of the analysis is to identify specific priorities for mitigation within the agriculture sector, by estimating future trends in GHG emissions. Constructing this scenario involves modeling the future development trajectory of the agriculture sector, a particular subsector or agricultural activity. For example, FAOSTAT use projected 2030 and 2050 activity data (e.g., crop area; livestock numbers) to estimate future GHG trends. This is done by first setting a baseline value, defined as the 2005-2007 average of the corresponding FAOSTAT activity data, and then by applying to it the projected growth rate to 2030 and 2050 from the FAO perspective studies (FAO, 2014). Due to limited resources, the future projection in this report was done through a simple trend line analysis of GHG emissions of 1994-2011 based on historical emissions and extrapolating emissions to the years 2020 and 2040.

Figure 18 below shows the trend line of the GHG emissions of the agriculture sector for 1994-2011, extrapolated to 2020 and 2040. It shows that with BAU (without mitigation) the emissions in 2020 and 2040 would be 788 and 595 Gg CO_2eq., respectively. This corresponds to emission reductions, compared to reporting year 2005, of 15% by 2020 and 35% by 2040. These results should be interpreted with extreme caution as the trend line itself consists of two periods with contrasting trends - the period from 1994-2004 with a slightly decreasing trend, and the period of 2005-2011 with more significant decrease in emissions. Also, this contrasts with FAOSTAT projections of an actual increase in total emissions by 4% in 2020 and 21% in 2050 when compared to baseline years (average of 2005-2007).

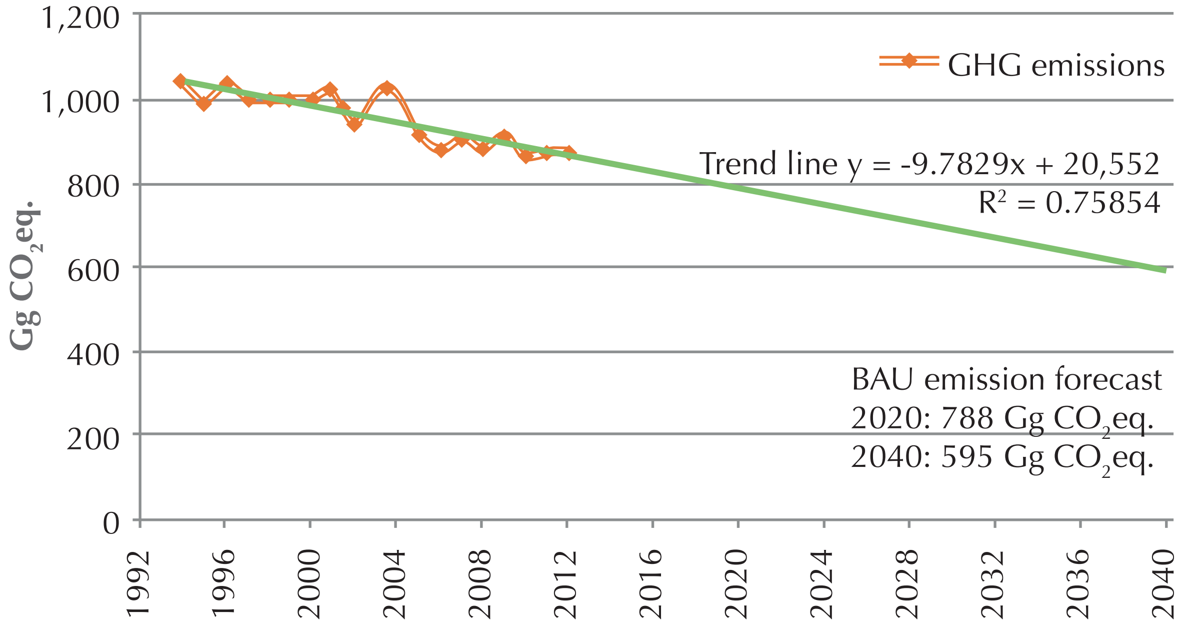


Figure 18: BAU emission trend for the agriculture sector

8.2. Mitigation option 1: conservation agriculture

Description of the measure

Conservation agriculture (CA) is a production system based on three linked principles: (a) conservation tillage, (b) permanent soil cover through crop residues or cover crops, and (c) crop rotation which is the diversification of crop species grown in sequences and/or associations. Conservation tillage is any tillage reduction practice that leaves at least 30% of the soil surface covered by residue through the practice of reduced or minimum tillage or through no tillage at all. This assessment concentrates on no tillage (known as no-till), since it is the most commonly studied and implemented GHG-mitigating agricultural land management practice.

By reducing soil disturbance, decomposition of organic matter is reduced and thereby decreasing CO_2 emissions and increasing soil carbon sequestration. By reducing or eliminating tractor passes for ploughing and seedbed preparation, fuel reduction is reduced resulting in lower CO_2 emissions. CA should not be limited only to no-till, as this approach leads only to a reduction in fuel consumption (and thus CO_2 emissions). CA has to include other agronomic practices such as cover crops and long crop rotation. Both cover crops and long crop rotation further improve the content of nitrogen in soils and organic matter, and the annual increase of carbon stocks in soils. In addition to reduced CO_2 emissions, decreases in nitrous oxide fluxes have also been documented in drier and warmer regions by adopting CA (Halvorson et al., 2010; Abdalla et al., 2013), thus adding to the GHG mitigation potential of CA. Globally, it has been estimated that potentially one-third of the carbon emitted in current fossil fuel use could be offset by implementing conservation agriculture in the next decade (FAO, 2008).

Significance of CA in GHG mitigation and adaptation

Conservation agriculture contributes to climate change mitigation through reduced emissions due to 60-70% lower fuel use, 20-50% lower fertilizer and pesticides use, 50% reduction in machinery and labor requirement, C-sequestration of 0.2-0.7 tonnes C/ha/year (Basch et al., 2012), and nitrous oxide emissions reduction due to both direct and indirect effects (less leaching and volatilization). Conservation agriculture generally reduces the need for mineral N by 30–50%, and enhances nitrogen productivity. Also, nitrogen leaching and runoff are minimal under CA systems. Thus overall, CA has the potential to lower N_2O emissions.

Conservation agriculture also increases system resilience which involves adaptation to climate change due to increased infiltration and availability of soil moisture to crops, reduced risks of runoff and flooding, and improved drought and heat tolerance by crops (Basch et al., 2012).

Co-benefits

Continuous soil degradation and increasing water scarcity are threatening agricultural productivity in Lebanon and most countries in the Middle East. The major factors that are causing soil degradation are: intensive ploughing, removal or overgrazing of crop residues that leave the soil exposed, rain and wind erosion and desertification. Climate change has contributed to these effects through frequent drought, temperature extremes and both an increase in rainfall intensity and decrease in rainfall amount. These practices and conditions have led to loss of soil organic matter and decline in crop yields due to soil degradation and reduced moisture in the root zone.

Conservation agriculture can contribute to sustainable agriculture and rural development in Lebanon by improving fertilizer efficiency, decreasing GHG emissions, increasing yield and farm income, sustaining or increasing agricultural land, reducing irrigation water need and conserving effective rainfall, reducing N fertilizer runoff and leaching which reduces surface and groundwater pollution, and maintaining the diversity of rural landscape through enhanced crop diversity and cover crops.

GHG mitigation potential in Lebanon

Target: As of 2010, land areas that were put under CA in Lebanon were 1,100 ha, mostly cereals (ACSAD-GTZ, 2010). CA can be adopted on virtually any arable (field crops) or perennial (orchards) cropping system. However, it is conceived that in Lebanon, CA will be most successful on cereals, olive trees, and fruit orchards. It is envisioned that 10% of these areas could be converted to CA by 2020 and 20% by 2040.

Lebanon has an average total area of 205,670 ha planted with cereals, olives and fruit trees (average of five years: 2006 through 2010; MoA, 2010b). Assuming area under CA would increase by 10% in 2020 and 20% in 2040 of the current areas planted with cereals, olives, and fruit trees, the projected area under CA would thus be 20,567 ha in 2020, and 41,134 ha in 2040.

GHG emission reduction potential

GHG emission reduction in CA is largely due to carbon sequestration resulting from the combination of no till, cover crops, and long crop rotation. Smaller amounts of CO_2 emissions are also avoided due to fuel savings made in comparison with conventional systems (≈50 liters/ha/year) but these are usually accounted for under the energy sector.

The potential of CA to reduce CO_2 emissions is given in Table 40 below. The calculation is based on potential carbon sequestration rate (given by Basch et al., 2012) of 0.77 tonnes C/ha/year or 2.85 tonnes CO_2/ha/year.

Reduction potential in 2020

20,567 ha x 2.85 tonnes CO_2/ha/year = **58.6 Gg CO_2eq.**

Reduction potential in 2040

41,134 ha x 2.85 tonnes CO_2/ha/year = **117.2 Gg CO_2eq.**

Table 40: GHG reduction potential of conservation agriculture from carbon sequestration for 2020 and 2040

Scenario	2020	2040
Areas converted to conservation agriculture (ha)	20,567.0	41,134.0
Reduction potential Gg CO_2eq.	58.6	117.2

Not factored in this calculation is the GHG emission reduction from fuel savings, and the possible reduction due to direct and indirect emissions of N fertilizers saved when leguminous cover crops are used as well as the potential reduction in applied fertilizer nitrogen due to the improvement of soil organic matter and reduced leaching of applied nitrogen.

It is difficult to put a monetary value for soil carbon sequestration since the market is not developed yet. However, if farmers were compensated at the price of USD 100 per tonne of carbon sequestered (Lal, 2010), which is equivalent to USD 27 per tonne of CO_2, the economic worth of the carbon (C) sequestration potential of CA in Lebanon in 2020 would be USD 27 x 58.6 x 1,000 = USD 1.58 million. The agronomic, ecologic, and economic potential of soil-C sequestration thus cannot be overemphasized.

Abatement cost

A recent report on Technology Needs Assessment (TNA) for climate change in Lebanon (MoE/URC/GEF, 2012) proposed CA as a potential measure for adaptation of the agriculture sector to climate change. The report contains a detailed analysis of costs and benefits of shifting 4,000 ha of fruit trees and 15,000 ha of cereals and legumes to CA over a 10-year period. Thus the target area (19,000 ha) is close to the target area presented above for 2020 (20,567 ha). The estimated cost reported in that report was USD 3.47 million, which roughly translates to a cost of USD 183/ha. This included the cost for research and development, training programs, and subsidies to farmers.

Assuming this cost to hold for the scenario presented here, the cost of converting 20,567 ha can roughly be estimated to approximately USD 3.7 million. The abatement cost of reducing GHG in 2020 by 58.6 Gg CO_2 would thus be USD 0.06 per kg CO_2.

Cost benefit analysis

The major costs associated with CA are for the equipment (new seed planter that directly plants seeds into existing plant residues), seeds, herbicides, and labor. Increased profitability of CA is due to lower expenditures on energy, reduced cost of mechanization, reduced cost of fertilizer, more efficient use of water, and higher yield. There are many small demonstration projects conducted by LARI, AUB (American University of Beirut), GIZ, the International Center for Agricultural Research in the Dry Areas (ICARDA) and others that compare the cost of production and income under CA with those under Conventional Agriculture (CV). The next two cases from the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and GIZ illustrate the economic advantage of CA in Lebanon. The first case is a study on cereals in the Bekaa region of Lebanon where farmers obtained higher net revenues when applying CA, USD 400/ha for barley and USD 560 /ha for barley-vetch mixture (Table 41).

Table 41: Cost/benefit comparison of cereal growing in Lebanon under conservation agriculture (CA) and conventional agriculture (CV)

USD/ha	Barley		Barley-vetch	
	CV	CA	CV	CA
Production costs	1,200	850	1,150	800
Income	1,890	1,940	2,040	2,250
Net revenue	690	1,090	890	1,450

The second case is utilizing CA and drip irrigation on summer crops like maize for silage. Net revenue under CA with drip was USD 980/ha higher than conventional tillage with sprinklers (Table 42).

Table 42: Cost/benefit comparison of maize growing in Lebanon under CA with drip irrigation and CV with sprinklers

USD/ha	CV – sprinkler	CA – drip
Production costs	1,330	1,450
Income	2,500	3,600
Net revenue	1,170	2,150

There are other economic benefits associated with environmental protection (mainly surface and groundwater quality) and ecosystem services that CA provides and should be included in the cost-benefit analysis but these are hard to quantify monetarily. Table 43 below lists some of these benefits as adapted from FAO (2001).

Links to adaptation

Conservation agriculture has strong mitigation and adaptation synergies. Conservation tillage has been shown to enhance soil structure and thus water holding capacity, making agriculture more resilient to extreme weather events such as heavy rains and drought. In addition, the increase in soil water content in dry climates can limit soil erosion, decrease desertification and make agricultural lands more resilient to climate change. Furthermore, the buildup of soil organic matter improves soil fertility and plant health and thus enhances the capacity of crops for climate change adaptation.

Table 43: Potential economic benefits and costs associated with CA

Benefits	Cost
Reduction of GHG emissions, resulting from carbon sequestration and reduced use of N fertilizers	Purchase of specialized planting equipment
Reduction in on-farm costs: savings in time, labor and mechanized machinery	Short-term pest problems due to the change in crop management
Increase in soil fertility and retention of soil moisture, resulting in long-term yield increase, decreasing yield variations and greater food security	CA involvement of additional herbicides application
Stabilization of soil and protection from erosion leading to reduced downstream sedimentation	Development of appropriate technical packages and training programs
Reduction in nitrate contamination of surface water and groundwater	Opportunity cost of crop residues (crop residues are used as livestock fodder)
More regular river flows, reduced flooding and the re-emergence of dried wells	Cost of cover crops
Recharge of aquifers as a result of better infiltration	Possible cost of additional labor
Reduction in air pollution resulting from soil tillage machinery	

Source | Adapted from FAO, 2001

Constraints and barriers to adoption of conservation agriculture in Lebanon

General constraints to the adoption of CA are outlined in Table 44 below:

Table 44: Gaps and constraints for adopting conservation agriculture and measures to overcome them

Gaps and constraints	Measures
Farmer perception that cultivation (ploughing) is essential for crop production Limited knowledge and know-how to adopt the practices of CA	Awareness campaigns and Field Farmer Schools (FFS): These include demonstration classes on CA and training of landowners, farmers and extension personnel on the practices and benefits of CA in dryland and irrigated farming.
Limited availability of affordable seeding machinery appropriate for CA	Leverage international financial support for capacity building and assist farmers in financing the high initial cost associated with CA.
Perceptions of worsening of weeds, pests, and disease infestation	Conduct trials with farmer participatory approach to reduce or eliminate pests and weeds.
Unwelcoming policy and extension environments Lack of research to fully explore the potential of CA for GHG mitigation.	Change government policy from crop-oriented subsidies to practice oriented subsidies. Increase research to fully explore the potential of CA for increased carbon sequestration and reduced N_2O emissions.
Inappropriate land tenure system in Lebanon: the majority of growers are either small-land owners with less than 5 ha or growers that lease land on a yearly basis from large-land owners and thus do not have the incentive to pursue CA, the benefits of which require several years to reap.	Involve landowners early on in the decision-making process of adopting the technology and in participatory research. Improve research on small mechanization (small no-till planters) adapted to small farms.
Competing demands for crop residues and lack of interest in cover crops. Cereal growers usually rent their land for grazing after harvest. Resource poor farmers are hesitant to invest in cover crops they do not consume.	Set up pilot projects on different cropping patterns that address the competing demands for crop residues and the reluctance to use cover crops.

Source | Adapted from ICARDA, 2012

8.3. Mitigation option 2: fertilizer best management practices: fertigation

Description of the measure

The use of N fertilizers in agriculture is a major cause of N_2O emissions. Nitrogen fertilizer applications to soils, whether organic or synthetic, result in N_2O emissions as this gas is a by-product of the transformation of N compounds added to the soil. The two major field practices responsible for the increased N_2O emissions from agricultural land are surface irrigation (flood or furrow), and application of solid N-fertilizers in high dosages. Surface irrigation is regarded as the most wasteful practice as irrigation efficiency is mostly below 40%, and flooding the field would result in the formation of water logged zones leading to denitrification and N_2O emissions.

Irrigation water is increasingly becoming a limiting factor for increased crop production in the Bekaa valley of Lebanon in light of recurrent droughts and decreased groundwater levels. This is especially true for potatoes, once regarded as the most important crop in the Bekaa, and which heavily relies on available irrigation water and fertilizer use. More efficient irrigation methods such as sprinkler and micro-sprinklers are widely used for potato production in the Bekaa valley of Lebanon, but both water use and fertilizer efficiency are not optimal. Furthermore, in a recent review on the effect of water management on N_2O emissions in Mediterranean cropping systems (Aguilera et al., 2013), emissions of N_2O from drip irrigation were almost a quarter of emissions from high water use technologies (furrow, sprinkler, and microsprinklers).

Fertigation is the practice where fertilizers are applied with irrigation water. Marked reductions in N_2O emissions are realized when irrigation water was applied in a controlled manner via drip irrigation, coupled with administering N fertilizer in small repeated dosing. This reduction in N_2O emissions is explained to be the result of evading the formation of water-logged zones, maintaining properly aerated soil condition, providing crop fertilizer-N requirement in small applications at the time it is needed, and minimizing the leaching of nitrate-N to zones inducing to denitrification.

General benefits of fertigation over traditional fertilization methods are many, among which are:

- Lower cumulative N_2O emissions and lower emission factor
- Low energy requirement; or reduced cost of application
- 85-90% efficiency in water use
- Reduced leaching of N fertilizers and fertilizer loss in surface water runoff
- Improved plant nutrition management
- Reduction in the amounts of fertilizer needed
- Increased fertilizer N uptake efficiency by plants
- Potential agronomic gains in yield through more frequent fertilizer applications

Significance of fertigation in GHG mitigation and adaptation

Fertigation reduces GHG emissions through the following mechanisms:

1. Precision in administering N fertilizer at low doses at the time it is needed, with repeated dosing to provide crop fertilizer requirement. This results in lower direct N_2O emissions from soils.
2. Efficiency in applying irrigation water and its controlled application to properly maintain aerated soil conditions and minimize leaching losses. This results in lower direct and indirect N_2O emissions from soils.
3. Solid fertilizers containing ammonium-N applied on soil surface are subject to the volatilization of NH_3 to the air, especially with Lebanese calcareous soils. Using fertigation allows fertilizers to be applied in smaller quantities at the root zone, thus dramatically reducing NH_3 volatilization losses to the air. This results in lower indirect N_2O emissions from soils.

Co-benefits

Increasing water scarcity and groundwater and surface water pollution are threatening agricultural productivity and public health in Lebanon. Excessive fertilizer use, over-abstraction of groundwater through legal and illegal wells, and the use of untreated wastewater are the major causes of water pollution. Fertigation reduces water pollution through reduced use of N fertilizers, more efficient fertilizer use, less leaching and runoff of N fertilizer, and more efficient water use. Fertigation reduces reliance on fuel and thus reduces CO_2 emissions and air pollution. Fertigation can contribute to sustainable agriculture and rural development in Lebanon by improving input use efficiency, increasing yield and farm income, increasing irrigated agricultural land, and reducing irrigation water demand.

GHG mitigation potential in Lebanon

Fertigation can be applied to almost all crops that could be irrigated through drip irrigation. In this measure, potato is used as an example, and the benefits could be applied to other crops. Potato is a major cash crop in Lebanon. It occupies an area of about 12,000 ha (FAO, 2012), corresponding to 17% of the irrigated area. It is grown mostly in the Bekaa and Akkar plain. The general practice followed by farmers in fertilizing potatoes is to add most of the NPK (nitrogen, phosphorus and potassium) fertilizers in a pre-plant application, either with plowing or when making the furrows. It is also common to find farmers making a second split-application (4-6 weeks after germination). With respect to rates of fertilizer application, it seems that Lebanese farmers tend to exceed what is required. This is in spite of the high prices of chemical fertilizers. The N fertilization rate adopted by most potato farmers indicate the average use of 590 kg N/ha while the recommended agronomic rate is 220 kg/ha (FAO, 2006). Thus a fertigation program should improve the application amount and use the recommended rather than the customary usage. This will save 370 kg N/ha which is the basis of the calculation for emission reductions.

Target: Potato crop harvested area is computed from the average of the last three years of this inventory (2010, 2011, and 2012) and is equal to **11,533 ha**. Almost all of this area is under sprinkler or microsprinkler irrigation.

It is assumed that the adoption rate of fertigation through drip irrigation is 50% of the current irrigated potato land areas by the year 2020 and 100% by the year 2040, i.e. **5,767 ha and 11,533 ha**, respectively. This is a reasonable target when considering that potato cropped areas might increase by 2020 and 2040. Emission reductions are due to direct or indirect mechanisms associated with N fertilizer application.

Reduction potential in 2020

Direct emission reduction in 2020

370 kg N saved/ha x 5,767 ha x 0.9 (to account for fraction volatilized) x 0.0125 kg N_2O-N/kg N x 44/28 x 310 kg CO_2eq./kg N_2O = **11.69 Gg CO_2eq.**

Indirect emission reduction in 2020

a) Emission reduction from volatilization

370 kg N saved/ha x 5,767 ha x 0.1 kg N volatilized/kg N applied x 0.01 kg N_2O N/kg N x 44/28 x 310 = **1.04 Gg CO_2eq./year**

b) Emission reduction from leaching

370 kg N saved/ha x 5,767 ha x 0.3 kg N leached/kg N applied x 0.025 kg N_2O N/kg N x 44/28 x 310 = **7.80 Gg CO_2eq./year**

c) Total indirect emission reduction

7.80 + 1.04 = **8.84 Gg CO_2eq./year**

Thus total GHG emission reduction in 2020 is: 11.69 + 8.84 = 20.53 Gg CO_2eq./year

Reduction potential in 2040

20.53 x 2 = **41.06 Gg CO_2eq./year**

These results are summarized in Table 45.

Table 45: GHG reduction potential of fertigation on potatoes for 2020 and 2040

Scenario	2020	2040
Areas converted to fertigation (ha)	5,767.00	11,533.00
Reduction potential - Gg CO_2eq.	20.53	41.06

Cost benefit analysis

Adoption of fertigation and the introduction of relevant changes in field management practices, are practical, feasible and do not impose serious economic constraints. When it comes to labor, using fertigation does not demand additional labor to what is already required for the running of the irrigation system. Nowadays, labor cost is not cheap in Lebanon. Also, prices of fertilizers and cost of fuel consumed by the machinery to apply solid fertilizers are quite high. The implementation of fertigation practices should bring savings and reductions in the cost of production.

For fertigation, fertilizer savings is due to two reasons: the first is the savings in the type of fertilizers used and the second due to the decrease in the amount of fertilizer. For the type of fertilizers, the following is recommended:

a) Using urea as the main nitrogen source. Urea is a conventional and reasonably priced N fertilizer. It is widely produced and becoming the most common and the cheapest N-source, it has the highest analysis of N (46% N), and it is highly soluble in water.

b) Using diammonium phosphate (DAP) as the main phosphorus (P) fertilizer source and to provide part of the N requirements as well. Other forms of P fertilizers could be used such as urea phosphate, which is more acidic and might prove useful for the calcareous soils of Lebanon (Ryan and Tabbara, 1989). With respect to the P-source, merchants have succeeded in convincing farmers that for fertigation, technical-grade P-compounds are needed. This is true when P fertilizers are to be dissolved in a reservoir tank with a fixed volume of water. But with a bypass fertilizer tank, DAP is soluble enough to be successfully used in fertigation. It is true that technical-grade P-compounds are more readily soluble than conventional DAP, but it is much more expensive. When the irrigation system is provided with a bypass fertilizer tank, the speed with which chemical fertilizers go into solution is not a determining factor limiting the timely delivery of fertilizer-P.

c) Potassium sulphate (K_2SO_4) is a conventional and reasonably priced potassium (K) fertilizer. Its solubility is high enough to be used in fertigation when a bypass fertilizer tank is provided. With fertigation, considerable cuts in the K application rate can be made because of its placement in the root zone and the timing of its application during the growing season. A suggested fertilizer scheme with type and amount of fertilizers applied in fertigation via drip irrigation in comparison with sprinkler irrigation is presented in Table 46 below.

Table 46: Comparison of amount of fertilizer (kg or kg N/ha), price per tonne (USD/t) and total price (USD) of applied fertilizer in fertigation in comparison with sprinkler irrigation on potatoes

Conventional (sprinkler)				Fertigation (drip)			
Fertilizer	Amount kg/ha (kg N /ha)	Price USD/t	Total price USD	Fertilizer	Amount kg/ha (kg N /ha)	Price USD/t	Total price USD
N-P-K 15-15-15	1,500 (225)	700	1,050	**Urea**	376 (173)	500	188
Ammonium nitrate	1,000 (330)	500	500	**Diammonium ammonium**	260 (47)	700	182
N-P-K 20-20-20	100 (20)	2,000	200	**Potassium sulphate**	330	700	221
Potassium nitrate	100 (13)	800	80				
Total	2,700 (590)		1,830	**Total**	966 (220)		591

The suggested rates are based on FAO recommendations for fertigation on potatoes in the near-east region (FAO, 2006). The comparison shows that more than 1,700 kg of fertilizer (370 kg N) could be saved, corresponding to a saving of USD 1,239 per ha when adopting fertigation and improved fertilizer practices via drip irrigation.

Table 47 compares the cost of implementation of fertigation on potatoes compared to the benefits. It is adapted from Bashour and Nimah (2004) and from a recent United States Agency for International Development (USAID) report on demonstration projects of fertigation on potatoes in the Bekaa valley (USAID, 2011). The calculations are based on the following:

1. Cost of drip irrigation system of USD 3,500/ha (Bashour and Nimah, 2004). Consultation with irrigation equipment dealers confirmed that this price is still valid nowadays.

2. Yield increase of 20% when using drip irrigation. In the USAID study, the yield increase when compared to sprinklers was 5 tonnes/ha, which at the price of USD 250 per tonne amounts to an extra revenue of USD 1,250/ha.

3. Fertilizer savings of USD 1,239/ha (see Table 46 above).

4. Labor savings of USD 70/ha which is the cost of moving sprinklers in the field (USAID, 2011).

5. Fuel savings estimated at 1,100 liters of diesel per ha, or USD 1,100 (USAID, 2011).

In addition, water savings were 1,656 m^3/ha (30% over sprinkler, USAID) which is difficult to value since farmers in the Bekaa either use their own wells or receive water from the Litani river at a flat rate based on the hectares planted and not the volume of water use. Nevertheless, the saved water is appreciable given the scarcity of water resources in recent years and the projected decline in available water supplies.

Thus the net profit each year from adopting irrigation using drip and best fertilizer management using fertigation is USD 3,096 per hectare. It should be pointed out that the amount of nitrate leaching that is avoided by using drip irrigation has not been accounted for in the cost calculations in this report. In addition, nitrate leaching is also reduced using the applied rates via fertigation rather than the much larger amounts applied via conventional methods. This is an important factor in the Bekaa where evidence of groundwater contamination of nitrates and deteriorating water quality has been mounting.

Table 47: Cost/benefit analysis of fertigation and drip irrigation on potatoes in Lebanon

Cost of drip irrigation (USD/ha)	3,500
Lifetime of the project 10 years Cost per year (USD/ha/year)	350
Annual interest on investment + maintenance = 6% (USD/ha)	213
Total annual cost per year (USD/ha)	563
Value of saved labor (USD/ha)	-70
Value of saved fuel (USD/ha)	-1,100
Value of saved fertilizer (USD/ha)	-1,239
Value of increased yield (USD/ha)	-1,250
Net profit per year (USD/ha)	**3,096**

Constraints, barriers to adoption, and solutions

Drip irrigation and fertigation are technologies mainly aimed at conserving water. The GHG mitigation potential is not high compared with other mitigation technologies. However the co-benefits in terms of energy savings, water savings, labor, and higher income could motivate the grower to switch to drip irrigation. The difficulties in convincing farmers to switch to drip irrigation and fertigation on potato crops are the following:

1. Farmers have little economic incentives to reduce GHG emissions or to save water. However, recent droughts and water scarcity in Lebanon might change this attitude and farmers could be more open to embracing this technology.

2. Farmers believe that drip is not suitable for potato growing. More field demonstrations can prove that this is not the case. It should be clear that this mitigation option is applicable to all irrigated crops. Fertigation should be expanded to other crops that could be irrigated via drip (vegetables, fruit trees, banana plantations, etc…) in addition to tubers.

3. High initial capital cost of drip irrigation. The analysis in this report shows that the additional revenue from the saved fertilizer use and fuel cost will recuperate the initial investment after just one year.

4. Clogging remains a main obstacle in the operation of drip systems but advances in filtration technology should alleviate this problem.

8.4. Mitigation analysis

Total GHG emissions for 2020 and 2040 without mitigation (BAU) and with mitigation using CA or Fertilizer Best Management Practices (FBMP using fertigation and drip irrigation are presented in Table 48 below). Compared with BAU, CA would decrease emissions by 7.5% in 2020 and 20% in 2040, while FBMP on potatoes would decrease emissions by 3% in 2020 and 7% in 2040. This is depicted in Figure 19.

Table 48: Total GHG emissions (Gg CO_2eq.) for 2020 and 2040 without mitigation (BAU) and with conservation agriculture and fertigation

Year	BAU	Conservation agriculture	Fertigation
2020	788	729	767
2040	595	478	554

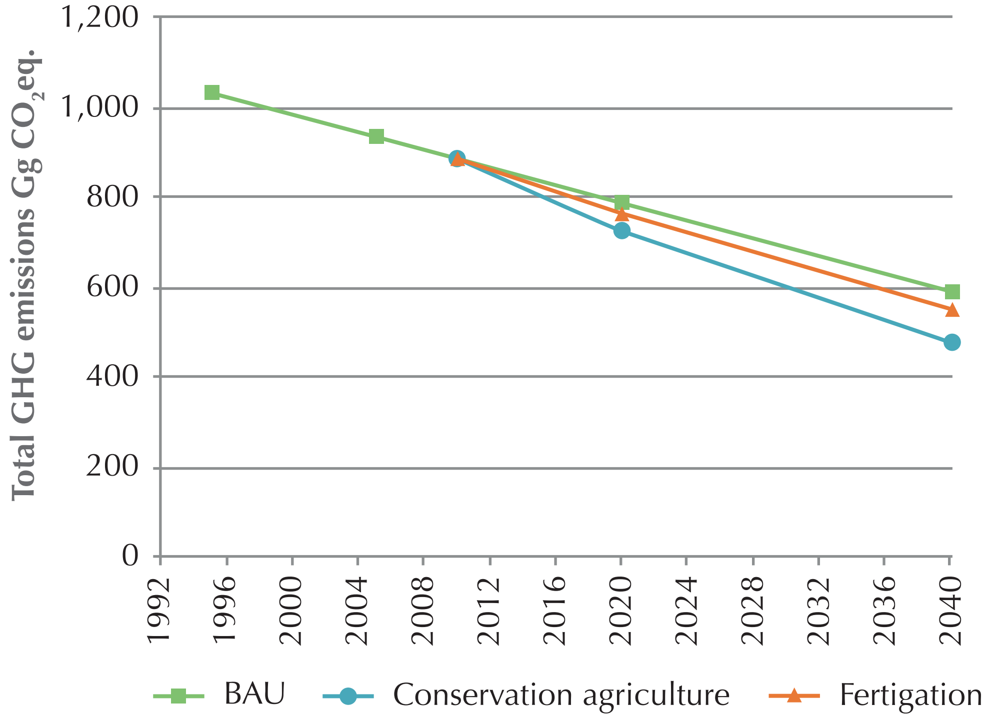


Figure 19: Emission reduction under CA and fertigation compared to BAU

8.5. Conclusion of mitigation analysis

Greenhouse gas emissions from the agriculture sector in Lebanon are low compared to other sectors. Mitigation of GHGs, therefore, is not a priority in the environmental agenda of the country. However, Lebanon is experiencing the effects of global warming firsthand, evidenced by recurrent droughts not seen in decades. Thus projects that address adaption to climate change and the prevailing water scarcity are taking precedence over GHG mitigation. In fact, the demarcation between adaptation and mitigation is no longer valid as synergies between the two are becoming so vital for tackling the compounded issues arising from climate change, especially those pertaining to the agriculture sector in developing countries. FAO's "Climate Smart Agriculture" (CSA) program (http://www.fao.org/climate-smart-agriculture) promulgates exactly this new paradigm, founded on three pillars:

- Sustainably increasing agricultural productivity and incomes;
- Adapting and building resilience to climate change;
- Reducing and/or removing greenhouse gas emissions, where possible.

This report suggested two climate smart projects – conservation agriculture, and fertilizer best management practices through fertigation and drip irrigation. Both options can increase agricultural productivity and resilience to climate change while at the same time reducing GHG emissions, decrease water demand, and improve water quality. In order for these options to succeed, there should be institutional policies in place to subsidize the shift to CA and to drip irrigation.

Conservation agriculture (no till) should be promoted especially in dryland agriculture where moisture is conserved ensuring adaptability to drought, and where reduced fertilizer use as a result of improved soil fertility leads to reduction in GHG emissions. The second mitigation option, fertilizer best management practices through fertigation and drip irrigation would reduce cost (which is the bottleneck in adopting drip irrigation), reduce water demand for irrigation, and reduce emissions from GHGs, both N_2O and CO_2.

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Annex I

Annex I-1: Average annual population of animals in 1994-2012 (1,000s head)

Year	Dairy cattle	Non-dairy cattle*	Sheep	Goats	Camels	Horses	Mules and asses	Swine	Poultry**
1994	51.62	43.48	242.98	418.98	0.53	6.81	26.50	52.80	11,790.26
1995	52.00	25.71	250.00	437.63	0.49	5.28	26.00	45.00	11,580.42
1996	50.55	37.07	312.55	482.22	0.47	4.92	23.18	40.00	11,883.62
1997	34.22	51.86	322.05	496.71	0.46	5.00	23.50	35.00	12,965.75
1998	36.32	51.15	350.00	466.34	0.46	4.00	22.60	34.00	13,812.33
1999	38.43	55.40	378.05	435.97	0.45	4.00	21.80	28.00	14,308.22
2000	38.90	56.40	354.00	417.00	0.45	3.58	19.78	26.00	15,198.63
2001	39.58	53.76	328.58	399.18	0.44	3.58	19.78	23.00	15,760.27
2002	43.82	63.13	297.83	408.93	0.44	3.58	19.78	21.00	16,136.99
2003	47.46	57.00	302.51	428.04	0.44	3.58	19.78	14.00	16,232.88
2004	43.86	53.79	305.36	432.16	0.44	3.58	19.78	12.50	16,793.15
2005	43.80	48.17	337.30	494.70	0.44	3.58	19.78	11.00	16,235.62
2006	43.90	49.22	370.40	484.40	0.44	3.58	19.78	10.00	17,072.60
2007	45.30	47.55	324.40	434.70	0.44	3.58	19.78	9.00	17,468.49
2008	55.00	34.22	330.00	450.00	0.45	3.58	20.00	8.50	17,696.68
2009	40.80	49.55	372.10	430.10	0.45	3.58	20.00	8.00	17,058.90
2010	40.16	44.06	265.35	403.86	0.45	3.58	20.00	7.74	16,662.15
2011	40.16	41.51	255.00	400.00	0.45	3.60	20.00	7.65	16,919.87
2012	42.00	36.90	258.00	398.00	0.45	3.65	20.00	7.80	17,166.45

* Includes average annual population of imported beef (days alive = 60 days)

** See Annex I-2

Annex I-2: Average annual population of poultry in 1994-2012 (head)

Year	Laying hens	Broilers	Broilers (AAP)*	Traditional chicken	Total
1994	2,599,000	51,800,000	8,515,068	676,190	11,790,258
1995	2,500,000	50,500,000	8,301,370	779,047	11,580,417
1996	2,725,000	50,350,000	8,276,712	881,904	11,883,616
1997	2,800,000	58,800,000	9,665,753	500,000	12,965,753
1998	3,000,000	60,300,000	9,912,329	900,000	13,812,329
1999	3,200,000	62,100,000	10,208,219	900,000	14,308,219
2000	3,200,000	66,300,000	10,898,630	1,100,000	15,198,630
2001	3,300,000	68,500,000	11,260,274	1,200,000	15,760,274
2002	3,400,000	71,400,000	11,736,986	1,000,000	16,136,986
2003	3,500,000	73,200,000	12,032,877	700,000	16,232,877
2004	3,600,000	76,000,000	12,493,151	700,000	16,793,151
2005	3,700,000	72,000,000	11,835,616	700,000	16,235,616
2006	3,600,000	77,700,000	12,772,603	700,000	17,072,603
2007	3,700,000	79,500,000	13,068,493	700,000	17,468,493
2008	3,846,000	80,000,000	13,150,685	700,000	17,696,685
2009	3,800,000	76,400,000	12,558,904	700,000	17,058,904
2010	3,757,000	76,000,000	12,493,151	412,000	16,662,151
2011	3,757,000	77,000,000	12,657,534	505,333	16,919,867
2012	3,800,000	78,000,000	12,821,918	544,533	17,166,451

* AAP of broilers based on days alive = 60 days

Annex I-3: Total population and average annual population for imported beef in 1994-2012

Year	Total imported beef	AAP
1994	220,179	18,097
1995	218,059	17,923
1996	215,940	17,749
1997	213,872	17,579
1998	185,988	15,287
1999	218,481	17,957
2000	222,634	18,299
2001	185,036	15,208
2002	227,982	18,738
2003	222,382	18,278
2004	210,571	17,307
2005	183,297	15,066
2006	196,074	16,116
2007	187,917	15,445
2008	149,950	12,325
2009	187,992	15,451
2010	190,462	15,654
2011	202,862	16,674
2012	181,314	14,903

Annex II

Annex II-1: Emissions of methane (Gg CH_4) and nitrous oxide (Gg N_2O) in 1994-2012

	Methane emissions/Gg CH_4			Nitrous oxide emissions/Gg N_2O		
Year	Enteric fermentation	Manure management	Total Gg CH_4	Manure management	Agricultural soils	Total Gg N_2O
1994	11.02	2.27	**13.29**	0.46	1.99	**2.45**
1995	10.29	1.99	**12.28**	0.43	1.95	**2.38**
1996	11.19	2.10	**13.29**	0.45	1.99	**2.44**
1997	10.39	1.97	**12.36**	0.46	1.94	**2.40**
1998	10.52	2.00	**12.52**	0.48	1.89	**2.37**
1999	10.91	2.06	**12.97**	0.49	1.84	**2.33**
2000	10.76	2.08	**12.84**	0.50	1.86	**2.36**
2001	10.48	2.04	**12.52**	0.50	1.94	**2.44**
2002	11.25	2.23	**13.48**	0.53	1.61	**2.14**
2003	11.43	2.18	**13.61**	0.53	1.84	**2.37**
2004	10.95	2.07	**13.02**	0.52	1.88	**2.40**
2005	11.15	1.99	**13.14**	0.52	1.56	**2.08**
2006	11.32	2.02	**13.34**	0.54	1.39	**1.93**
2007	10.90	2.00	**12.9**	0.53	1.51	**2.04**
2008	11.34	2.02	**13.36**	0.54	1.42	**1.96**
2009	10.76	1.94	**12.70**	0.53	1.54	**2.07**
2010	9.77	1.82	**11.59**	0.49	1.51	**2.00**
2011	9.58	1.79	**11.37**	0.49	1.55	**2.04**
2012	9.55	1.77	**11.32**	0.49	1.57	**2.06**

Annex II-2: Emissions of methane and nitrous oxide (Gg CO_2eq.) in 1994-2012

	Enteric fermentation	Manure management		Agricultural soils	
Year	CH_4 emissions enteric fermentation Gg CO_2eq.	CH_4 emissions manure management Gg CO_2eq.	N_2O emissions manure management Gg CO_2eq.	N_2O emissions agricultural soils Gg CO_2eq.	Total emissions from agriculture Gg CO_2eq.
1994	231.49	47.75	141.91	616.06	**1,037.13**
1995	216.19	41.86	131.77	603.13	**992.95**
1996	235.00	44.06	140.73	617.12	**1,036.91**
1997	218.12	41.35	143.62	600.18	**1,003.27**
1998	220.97	42.10	148.31	585.72	**997.10**
1999	229.13	43.38	153.04	569.21	**994.76**
2000	225.98	43.68	156.12	575.76	**1,001.54**
2001	220.13	42.85	155.82	600.87	**1,019.67**
2002	236.24	46.88	163.56	497.62	**944.30**
2003	240.06	45.75	163.09	568.90	**1,017.80**
2004	229.96	43.45	162.16	581.77	**1,017.34**
2005	234.05	41.79	163.24	483.19	**922.28**
2006	237.70	42.36	168.56	430.14	**878.75**
2007	228.88	42.14	166.72	467.21	**904.94**
2008	238.06	42.46	168.38	438.98	**887.88**
2009	226.01	40.06	164.33	478.21	**908.61**
2010	205.17	38.34	154.17	467.67	**865.35**
2011	201.11	37.68	153.59	479.77	**872.16**
2012	200.46	37.27	153.42	485.36	**876.51**

Annex II-3: Emissions of methane from enteric fermentation in 1994-2012 (Gg CH_4 and CO_2eq.)

Year	Dairy cattle	Non-dairy cattle	Sheep	Goats	Camels	Horses	Mules and asses	Swine	Total CH_4	Total CO_2eq.
1994	5.16	2.09	1.21	2.09	0.02	0.12	0.27	0.05	**11.02**	**231.49**
1995	5.20	1.23	1.25	2.19	0.02	0.10	0.26	0.05	**10.29**	**216.19**
1996	5.06	1.78	1.56	2.41	0.02	0.09	0.23	0.04	**11.19**	**235.00**
1997	3.42	2.49	1.61	2.48	0.02	0.09	0.24	0.04	**10.39**	**218.12**
1998	3.63	2.45	1.75	2.33	0.02	0.07	0.23	0.03	**10.52**	**220.97**
1999	3.84	2.66	1.89	2.18	0.02	0.07	0.22	0.03	**10.91**	**229.13**
2000	3.89	2.71	1.77	2.09	0.02	0.06	0.20	0.03	**10.76**	**225.98**
2001	3.96	2.58	1.64	2.00	0.02	0.06	0.20	0.02	**10.48**	**220.13**
2002	4.38	3.03	1.49	2.04	0.02	0.06	0.20	0.02	**11.25**	**236.24**
2003	4.75	2.74	1.51	2.14	0.02	0.06	0.20	0.01	**11.43**	**240.06**
2004	4.39	2.58	1.53	2.16	0.02	0.06	0.20	0.01	**10.95**	**229.96**
2005	4.38	2.31	1.69	2.47	0.02	0.06	0.20	0.01	**11.15**	**234.05**
2006	4.39	2.36	1.85	2.42	0.02	0.06	0.20	0.01	**11.32**	**237.70**
2007	4.53	2.28	1.62	2.17	0.02	0.06	0.20	0.01	**10.90**	**228.88**
2008	5.50	1.64	1.65	2.25	0.02	0.06	0.20	0.01	**11.34**	**238.06**
2009	4.08	2.38	1.86	2.15	0.02	0.06	0.20	0.01	**10.76**	**226.01**
2010	4.02	2.11	1.33	2.02	0.02	0.06	0.20	0.01	**9.77**	**205.17**
2011	4.02	1.99	1.28	2.00	0.02	0.06	0.20	0.01	**9.58**	**201.11**
2012	4.20	1.77	1.29	1.99	0.02	0.07	0.20	0.01	**9.55**	**200.46**

Annex II-4: Emissions of methane and nitrous oxide from manure management and CO_2eq. (1994-2012)

Year	CH_4 (Gg)	CO_2eq. (Gg)	N_2O (Gg)	CO_2eq. (Gg)	Total CO_2eq. (Gg)
1994	2.27	**47.75**	0.46	**141.91**	**189.67**
1995	1.99	**41.86**	0.43	**131.77**	**173.62**
1996	2.10	**44.06**	0.45	**140.73**	**184.79**
1997	1.97	**41.35**	0.46	**143.62**	**184.79**
1998	2.00	**42.10**	0.48	**148.31**	**190.41**
1999	2.06	**43.38**	0.49	**153.04**	**196.42**
2000	2.08	**43.68**	0.50	**156.12**	**199.80**
2001	2.04	**42.85**	0.50	**155.82**	**198.67**
2002	2.23	**46.88**	0.53	**163.56**	**210.45**
2003	2.18	**45.75**	0.53	**163.09**	**208.84**
2004	2.07	**43.45**	0.52	**162.16**	**205.62**
2005	1.99	**41.79**	0.52	**163.24**	**205.03**
2006	2.02	**42.36**	0.54	**168.59**	**210.92**
2007	2.00	**42.14**	0.53	**166.72**	**208.86**
2008	2.02	**42.46**	0.54	**168.38**	**210.84**
2009	1.94	**40.06**	0.53	**164.33**	**204.36**
2010	1.82	**38.34**	0.49	**154.17**	**192.51**
2011	1.79	**37.68**	0.49	**153.59**	**191.27**
2012	1.77	**37.28**	0.49	**153.42**	**190.70**

Annex II-5: Emissions of methane from manure management by animal species in 1994-2012 (Gg CH_4) and total CO_2eq.

Year	Dairy cattle	Non-dairy cattle	Sheep	Goats	Horses	Mules and asses	Swine	Poultry	Total Gg CH_4	Total Gg CO_2eq.
1994	0.98	0.57	0.04	0.07	0.01	0.02	0.37	0.21	**2.27**	**47.68**
1995	0.99	0.33	0.04	0.07	0.01	0.02	0.32	0.21	**1.99**	**41.80**
1996	0.96	0.48	0.05	0.08	0.01	0.02	0.28	0.21	**2.10**	**44.02**
1997	0.65	0.67	0.05	0.08	0.01	0.02	0.25	0.23	**1.97**	**41.27**
1998	0.69	0.66	0.06	0.08	0.01	0.02	0.24	0.24	**2.00**	**42.02**
1999	0.73	0.72	0.06	0.07	0.01	0.02	0.20	0.26	**2.06**	**43.33**
2000	0.74	0.73	0.06	0.07	0.01	0.02	0.18	0.27	**2.08**	**43.64**
2001	0.75	0.70	0.05	0.07	0.01	0.02	0.16	0.28	**2.04**	**42.83**
2002	0.83	0.82	0.05	0.07	0.01	0.02	0.15	0.29	**2.23**	**46.84**
2003	0.90	0.74	0.05	0.07	0.01	0.02	0.10	0.29	**2.18**	**45.72**
2004	0.83	0.70	0.05	0.07	0.01	0.02	0.09	0.30	**2.07**	**43.41**
2005	0.83	0.63	0.05	0.08	0.01	0.02	0.08	0.29	**1.99**	**41.75**
2006	0.83	0.64	0.06	0.08	0.01	0.02	0.07	0.31	**2.02**	**42.33**
2007	0.86	0.62	0.05	0.07	0.01	0.02	0.06	0.31	**2.00**	**42.09**
2008	1.05	0.44	0.05	0.08	0.01	0.02	0.06	0.32	**2.02**	**42.41**
2009	0.78	0.64	0.06	0.07	0.01	0.02	0.06	0.30	**1.94**	**40.69**
2010	0.76	0.57	0.04	0.07	0.01	0.02	0.05	0.30	**1.82**	**38.28**
2011	0.76	0.54	0.04	0.07	0.01	0.02	0.05	0.30	**1.79**	**37.62**
2012	0.80	0.48	0.04	0.07	0.01	0.02	0.05	0.31	**1.77**	**37.27**

Annex III

Annex III-1: Summary of emissions of nitrous oxide from agricultural soils in 1994-2012 (Gg N_2O)

	Total direct N_2O emissions (Gg)		Total indirect N_2O emissions (Gg)		N_2O emissions from PRP animal grazing (Gg)		Total N_2O emissions (Gg)
Year	Gg N_2O	% total	Gg N_2O	% total	Gg N_2O	% total	Gg N_2O
1994	1.01	51%	0.76	38%	0.23	12%	**1.99**
1995	0.99	51%	0.73	37%	0.23	12%	**1.95**
1996	0.99	50%	0.74	37%	0.26	13%	**1.99**
1997	0.90	46%	0.76	39%	0.26	13%	**1.94**
1998	0.90	48%	0.74	39%	0.26	14%	**1.89**
1999	0.86	47%	0.72	39%	0.26	14%	**1.84**
2000	0.90	48%	0.72	39%	0.24	13%	**1.86**
2001	0.95	49%	0.76	39%	0.23	12%	**1.94**
2002	0.85	53%	0.62	39%	0.14	9%	**1.61**
2003	0.89	48%	0.71	39%	0.24	13%	**1.84**
2004	0.91	48%	0.72	38%	0.24	13%	**1.88**
2005	0.71	46%	0.59	38%	0.26	17%	**1.56**
2006	0.60	43%	0.53	38%	0.26	19%	**1.39**
2007	0.70	46%	0.57	38%	0.24	16%	**1.51**
2008	0.64	45%	0.53	37%	0.24	17%	**1.42**
2009	0.70	45%	0.59	38%	0.25	16%	**1.54**
2010	0.71	47%	0.59	39%	0.21	14%	**1.51**
2011	0.73	47%	0.60	39%	0.21	14%	**1.55**
2012	0.75	48%	0.61	39%	0.21	13%	**1.57**

Annex III-2: Direct nitrous oxide emissions from agricultural soils by subcategory in 1994-2012 (Gg N_2O)

Year	Synthetic fertilizer Gg N_2O	Animal waste Gg N_2O	N fixing crops Gg N_2O	Crop residues Gg N_2O	Total direct emissions Gg N_2O
1994	0.55	0.22	0.09	0.14	**1.01**
1995	0.53	0.20	0.09	0.16	**0.99**
1996	0.52	0.22	0.11	0.16	**0.99**
1997	0.52	0.22	0.05	0.11	**0.90**
1998	0.49	0.24	0.06	0.13	**0.90**
1999	0.46	0.24	0.06	0.11	**0.86**
2000	0.46	0.24	0.06	0.14	**0.90**
2001	0.50	0.25	0.06	0.13	**0.95**
2002	0.38	0.27	0.06	0.14	**0.85**
2003	0.44	0.27	0.05	0.14	**0.89**
2004	0.46	0.25	0.05	0.17	**0.91**
2005	0.27	0.25	0.03	0.16	**0.71**
2006	0.17	0.27	0.03	0.13	**0.60**
2007	0.24	0.27	0.03	0.17	**0.70**
2008	0.17	0.27	0.03	0.17	**0.64**
2009	0.27	0.25	0.03	0.14	**0.70**
2010	0.30	0.25	0.05	0.11	**0.71**
2011	0.33	0.25	0.05	0.11	**0.73**
2012	0.33	0.25	0.05	0.11	**0.75**

Annex IV

Direct soil emissions

Annex IV-1: Nitrogen fertilizer compounds and amount applied (tonnes) in 1994-2012

	Fertilizer Applied/tonnes of fertilizer								
Year	Urea	Ammonium sulphate	Ammonium nitrate	Sodium nitrate	Calcium nitrate	NPK	Di-ammonium phosphate	Mono-ammonium phosphate	Total
% nitrogen	-46%	-21%	-35%	-16%	-16%	-17.50%	-18%	-11%	
1994	NR*	NR	NR	NR	NR	NR	NR	NR	NR
1995	NR	NR	NR	NR	NR	NR	NR	NR	NR
1996	NR	NR	NR	NR	NR	NR	NR	NR	NR
1997	4,496.3	27,897.3	37,751.0	710.4	184.5	48,080.5	4,290.7	101.1	123,511.8
1998	1,444.7	23,454.1	42,396.5	150.9	8.3	38,943.4	2,954.3	1,345.6	110,697.8
1999	2,742.3	19,448.3	35,982.7	150.9	-	50,080.8	2,282.8	79.4	110,767.2
2000	4,962.3	22,267.5	31,313.8	215.6	-	41,432.5	3,353.5	151.5	103,696.7
2001	19,293.7	22,651.7	22,420.2	172.6	-	39,512.0	3,852.3	333.3	108,235.9
2002	6,252.8	23,540.1	18,351.7	147.7	-	38,071.4	1,660.7	513.6	88,538.1
2003	8,978.2	25,951.5	19,674.1	3.0	-	42,758.8	4,007.5	762.0	102,135.2
2004	10,329.5	24,476.0	22,089.6	54.2	91.2	43,353.2	1,811.0	1,315.4	103,520.0
2005	4,554.0	19,753.1	5,683.7	108.4	102.7	33,904.5	3,131.0	1,241.9	68,479.3
2006	299.9	17,867.0	969.7	272.5	45.6	25,552.7	3,692.6	1,210.7	49,910.8
2007	561.5	25,278.1	999.0	152.7	828.4	37,833.0	2,790.5	1,304.6	69,747.8
2008	45.0	18,908.7	342.4	282.5	68.5	31,482.7	220.8	220.7	51,571.2
2009	3,457.0	34,729.0	1,156.0	72.0	806.0	27,499.0	3,635.5	150.5	71,505.0
2010	4,090.0	29,744.0	4,496.5	49.0	4,276.5	33,976.0	3,281.0	781.0	80,694.0
2011	7,937.0	26,954.0	3,475.0	10.0	3,095.0	40,000.0	1,816.5	545.5	83,833.0
2012	4,961.0	34,253.0	9,556.0	7.0	7,634.0	23,174.0	5,048.0	699.0	85,332.0

*NR = Not Reported. Values were estimated based on extrapolation.

Annex IV-2: Total nitrogen fertilizers consumed (tonnes) and corresponding average N content (tonnes of N)

Year	Total nitrogenous fertilizers (tonnes)	Nitrogen content (tonnes of N)
1994	122,614*	31,016*
1995	119,343*	29,991*
1996	116,071*	28,965*
1997	123,512	29,914
1998	110,698	27,313
1999	110,767	26,608
2000	103,697	25,354
2001	108,236	28,815
2002	88,538	21,009
2003	102,135	24,459
2004	103,520	25,372
2005	68,479	14,814
2006	49,911	9,535
2007	69,748	13,325
2008	51,571	9,736
2009	71,505	14,894
2010	80,694	16,948
2011	83,833	18,359
2012	85,332	18,940

*Values for 1994-1996 were obtained by extrapolation of total nitrogenous fertilizers and of nitrogen content.

Annex IV-3: Calculation of $Frac_{PRP}$: fraction of manure deposited from PRP (1994-2012)

Year	Nitrogen excretion from PRP (kg)	Total nitrogen excretion from all animal MMS (kg)	$Frac_{PRP}$
1994	7,327,199.42	23,182,843.22	0.32
1995	7,445,401.31	22,219,397.31	0.34
1996	8,172,610.54	23,868,853.52	0.34
1997	8,292,017.72	24,311,529.89	0.34
1998	8,231,529.45	24,809,829.62	0.33
1999	8,207,101.86	25,311,318.55	0.32
2000	7,788,307.12	25,282,512.27	0.31
2001	7,458,492.06	24,967,470.78	0.30
2002	4,444,805.19	22,791,859.01	0.20
2003	7,547,442.96	25,854,580.79	0.29
2004	7,591,672.34	25,837,736.83	0.29
2005	8,092,254.79	26,327,645.00	0.31
2006	8,295,794.47	27,146,945.26	0.31
2007	7,648,812.84	26,234,557.47	0.29
2008	7,734,120.44	26,636,443.87	0.29
2009	7,877,421.70	26,284,512.28	0.30
2010	6,797,733.26	24,127,063.10	0.28
2011	6,690,452.94	23,981,987.89	0.28
2012	6,709,035.82	23,996,165.20	0.28

Annex IV-4a: Crop production of N-fixing crops (tonnes) in 1994-2012

Year	Beans, dry	Beans, green	Broad beans, horse beans, dry	Chick peas	Alfalfa	Lentils	Lupins	Peas, dry	Peas, green	Vetches
1994	4,726	30,000	1,950	9,700	27,200	13,000	1,170	1,986	12,800	5,000
1995	5,000	34,000	2,200	11,000	28,000	13,500	1,140	1,990	13,500	4,900
1996	5,124	36,836	2,409	11,056	28,400	13,810	1,150	2,425	15,437	4,999
1997	1,400	11,698	2,729	7,789	28,800	3,932	1,180	2,420	8,393	5,000
1998	400	27,400	1,000	4,100	29,000	1,600	1,147	2,410	8,500	5,100
1999	500	26,600	300	3,200	29,200	1,400	1,140	2,400	8,700	4,067
2000	100	45,900	300	2,200	30,000	800	1,150	2,450	4,400	5,250
2001	100	41,600	300	1,900	30,400	500	1,200	2,500	4,400	5,350
2002	736	28,829	0	3,189	30,000	1,822	1,150	2,400	4,562	5,250
2003	300	20,700	800	1,900	30,000	1,500	1,000	2,400	5,400	5,000
2004	400	18,300	300	1,500	30,000	600	820	2,400	4,600	4,000
2005	200	12,600	400	1,300	29,200	800	580	2,400	4,600	3,600
2006	200	12,700	300	1,200	30,000	600	450	2,400	2,900	3,150
2007	200	14,200	200	1,400	30,000	1,400	300	2,400	5,200	2,800
2008	400	16,000	300	1,300	30,000	800	220	2,400	6,000	2,000
2009	200	15,900	100	1,200	30,000	1,600	150	2,500	4,900	1,300
2010	750	27,000	170	2,650	30,000	1,900	100	2,433	6,000	700
2011	831	25,000	152	2,911	30,000	2,106	103	2,614	5,950	720
2012	950	25,000	160	3,000	30,000	2,200	110	3,000	6,200	800

Annex IV-4b: Crop production of non N-fixing crops (tonnes) in 1994-2012

Year	Barley	Maize	Oats	Sorghum	Wheat	Carrots and turnips	Garlic	Onions, dry	Potatoes
1994	20,185	4,086	510	1,653	52,675	32,620	35,000	70,789	321,767
1995	33,410	4,670	520	1,780	60,005	33,000	40,000	76,000	340,730
1996	28,423	4,772	530	1,729	58,342	38,420	46,890	81,097	352,121
1997	26,043	2,800	700	1,720	58,394	36,941	13,800	75,782	288,948
1998	15,000	5,000	540	1,703	80,600	15,100	21,400	48,400	302,000
1999	13,900	4,000	500	1,600	73,000	16,300	19,900	64,100	281,600
2000	9,400	3,500	400	1,400	108,100	8,200	11,000	157,600	275,000
2001	8,100	3,800	350	1,200	139,500	10,800	11,000	144,200	257,000
2002	17,100	2,744	300	1,000	119,000	34,600	9,200	72,623	397,100
2003	25,000	3,300	312	1,041	116,300	30,100	5,100	62,500	416,400
2004	23,800	3,300	200	1,180	136,800	9,000	3,800	52,000	499,000
2005	29,000	3,400	190	950	143,700	10,800	3,300	50,900	511,400
2006	31,800	3,100	240	860	153,400	5,800	3,100	45,000	398,000
2007	33,100	3,100	200	770	116,200	7,100	3,300	45,900	514,600
2008	29,000	3,400	210	690	143,700	7,100	3,300	50,900	514,600
2009	29,700	4,700	220	580	111,400	5,700	2,800	86,500	425,000
2010	23,500	4,500	164	440	83,000	3,600	3,400	90,000	260,000
2011	30,000	3,000	225	450	125,000	3,650	3,650	90,800	275,000
2012	35,000	3,000	235	460	150,000	4,000	4,000	95,000	280,000

Annex V

Annex V-1: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2005

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	200	1.00	2	0.03	12.0
Beans, green	12,600	0.85	2	0.03	642.6
Broad beans, horse beans, dry	400	1.00	2	0.03	24.0
Chick peas	1,300	1.00	2	0.03	78.0
Alfalfa	29,200	0.50	1	0.03	438.0
Lentils	800	1.00	2	0.03	48.0
Lupins	580	1.00	2	0.03	34.8
Peas, dry	2,400	1.00	2	0.03	144.0
Peas, green	4,600	0.85	2	0.03	234.6
Vetches	3,600	0.90	1	0.03	97.2
Total					1,753.2

Annex V-2: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2006

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	200	1.00	2	0.03	12.0
Beans, green	12,600	0.85	2	0.03	642.6
Broad beans, horse beans, dry	400	1.00	2	0.03	24.0
Chick peas	1,300	1.00	2	0.03	78.0
Alfalfa	29,200	0.50	1	0.03	438.0
Lentils	800	1.00	2	0.03	48.0
Lupins	580	1.00	2	0.03	34.8
Peas, dry	2,400	1.00	2	0.03	144.0
Peas, green	4,600	0.85	2	0.03	234.6
Vetches	3,600	0.90	1	0.03	97.2
Total					1,753.2

Annex V-3: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2007

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	200	1.00	2	0.03	12.0
Beans, green	14,200	0.85	2	0.03	724.2
Broad beans, horse beans, dry	200	1.00	2	0.03	12.0
Chick peas	1,400	1.00	2	0.03	84.0
Alfalfa	30,000	0.50	1	0.03	450.0
Lentils	1,400	1.00	2	0.03	84.0
Lupins	300	1.00	2	0.03	18.0
Peas, dry	2,400	1.00	2	0.03	144.0
Peas, green	5,200	0.85	2	0.03	265.2
Vetches	2,800	0.90	1	0.03	75.6
Total					1,869.0

Annex V-4: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2008

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	400	1.00	2	0.03	24.0
Beans, green	16,000	0.85	2	0.03	816.0
Broad beans, horse beans, dry	300	1.00	2	0.03	18.0
Chick peas	1,300	1.00	2	0.03	78.0
Alfalfa	30,000	0.50	1	0.03	450.0
Lentils	800	1.00	2	0.03	48.0
Lupins	220	1.00	2	0.03	13.2
Peas, dry	2,400	1.00	2	0.03	144.0
Peas, green	6,000	0.85	2	0.03	306.0
Vetches	2,000	0.90	1	0.03	54.0
Total					1,951.2

Annex V-5: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2009

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	200	1.00	2	0.03	12.0
Beans, green	15,900	0.85	2	0.03	810.9
Broad beans, horse beans, dry	100	1.00	2	0.03	6.0
Chick peas	1,200	1.00	2	0.03	72.0
Alfalfa	30,000	0.50	1	0.03	450.0
Lentils	1,600	1.00	2	0.03	96.0
Lupins	150	1.00	2	0.03	9.0
Peas, dry	2,500	1.00	2	0.03	150.0
Peas, green	4,900	0.85	2	0.03	249.9
Vetches	1,300	0.90	1	0.03	35.1
Total					1,890.9

Annex V-6: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2010

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	750	1.00	2	0.03	45.00
Beans, green	27,000	0.85	2	0.03	1,377.00
Broad beans, horse beans, dry	170	1.00	2	0.03	10.20
Chick peas	2,650	1.00	2	0.03	159.00
Alfalfa	30,000	0.50	1	0.03	450.00
Lentils	1,900	1.00	2	0.03	114.00
Lupins	100	1.00	2	0.03	6.00
Peas, dry	2,433	1.00	2	0.03	145.98
Peas, green	6,000	0.85	2	0.03	306.00
Vetches	700	0.90	1	0.03	18.90
Total					2,632.08

Annex V-7: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2011

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	831	1.00	2	0.03	49.86
Beans, green	25,000	0.85	2	0.03	1,275.00
Broad beans, horse beans, dry	152	1.00	2	0.03	9.12
Chick peas	2,911	1.00	2	0.03	174.66
Alfalfa	30,000	0.50	1	0.03	450.00
Lentils	2,106	1.00	2	0.03	126.36
Lupins	103	1.00	2	0.03	6.18
Peas, dry	2,614	1.00	2	0.03	156.84
Peas, green	5,950	0.85	2	0.03	303.45
Vetches	720	0.90	1	0.03	19.44
Total					2,570.91

Annex V-8: Calculation of F_{BN} (equation 4.25, GPG 2000) for 2012

Crop	Fresh weight (t)	DM	Factor	$Frac_{NCRBF}$	F_{BN}
Beans, dry	831	1.00	2	0.03	49.86
Beans, green	25,000	0.85	2	0.03	1,275.00
Broad beans, horse beans, dry	152	1.00	2	0.03	9.12
Chick peas	2,911	1.00	2	0.03	174.66
Alfalfa	30,000	0.50	1	0.03	450.00
Lentils	2,106	1.00	2	0.03	126.36
Lupins	103	1.00	2	0.03	6.18
Peas, dry	2,614	1.00	2	0.03	156.84
Peas, green	5,950	0.85	2	0.03	303.45
Vetches	720	0.90	1	0.03	19.44
Total					2,570.91

Annex VI

F_{CR} tables for years 2005-2012

Annex VI-1: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2005

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	200	0.0300	0.9	0	1.20
Beans, green	10,710	0.0300	0.2	0	514.08
Broad beans, dry	400	0.0300	0.8	0	4.80
Chick peas	1,300	0.0300	0.9	0	7.80
Alfalfa	14,600	0.0300	0.7	0	262.80
Lentils	800	0.0300	0.9	0	4.80
Lupins	580	0.0300	0.9	0	3.48
Peas, dry	2,400	0.0300	0.9	0	14.40
Peas, green	3,910	0.0300	0.2	0	187.68
Vetches	3,240	0.0300	0.8	0	38.88
Barley	25,520	0.0043	0.8	0	43.89
Carrots/turnips	1,296	0.0150	0.8	0	7.78
Garlic	1,155	0.0150	0.7	0	10.40
Maize	2,992	0.0081	0.7	0	14.54
Oats	167	0.0070	0.7	0	0.70
Onions, dry	7,126	0.0150	0.2	0	171.02
Potatoes	230,130	0.0150	0.0	0	6,903.90
Sorghum	836	0.0108	0.7	0	5.42
Wheat	126,456	0.0028	0.8	0	141.63
Total					8,339.20

Annex VI-2: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2006

Crop	Dry weight (t)	$Frac_{NCRBF}$\ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	200.0	0.0300	0.9	0	1.20
Beans, green	10,795.0	0.0300	0.2	0	518.16
Broad beans, dry	300.0	0.0300	0.8	0	3.60
Chick peas	1,200.0	0.0300	0.9	0	7.20
Alfalfa	15,000.0	0.0300	0.7	0	270.00
Lentils	600.0	0.0300	0.9	0	3.60
Lupins	450.0	0.0300	0.9	0	2.70
Peas, dry	2,400.0	0.0300	0.9	0	14.40
Peas, green	2,465.0	0.0300	0.2	0	118.32
Vetches	2,835.0	0.0300	0.8	0	34.02
Barley	27,984.0	0.0043	0.8	0	48.13
Carrots/turnips	696.0	0.0150	0.8	0	4.18
Garlic	1,085.0	0.0150	0.7	0	9.77
Maize	2,728.0	0.0081	0.7	0	13.26
Oats	211.0	0.0070	0.7	0	0.89
Onions, dry	6,300.0	0.0150	0.2	0	151.20
Potatoes	179,100.0	0.0150	0.0	0	5,373.00
Sorghum	756.8	0.0108	0.7	0	4.90
Wheat	134,992.0	0.0028	0.8	0	151.19
Total					6,729.71

Annex VI-3: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2007

Crop	Dry weight (t)	$Frac_{NCRBF}$\ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	200	0.0300	0.9	0	1.20
Beans, green	12,070	0.0300	0.2	0	579.36
Broad beans, dry	200	0.0300	0.8	0	2.40
Chick peas	1,400	0.0300	0.9	0	8.40
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	1,400	0.0300	0.9	0	8.40
Lupins	300	0.0300	0.9	0	1.80
Peas, dry	2,400	0.0300	0.9	0	14.40
Peas, green	4,420	0.0300	0.2	0	212.16
Vetches	2,520	0.0300	0.8	0	30.24
Barley	29,128	0.0043	0.8	0	50.10
Carrots/turnips	852	0.0150	0.8	0	5.11
Garlic	1,155	0.0150	0.7	0	10.40
Maize	2,728	0.0081	0.7	0	13.26
Oats	176	0.0070	0.7	0	0.74
Onions, dry	6,426	0.0150	0.2	0	154.22
Potatoes	231,570	0.0150	0.0	0	6,947.10
Sorghum	678	0.0108	0.7	0	4.39
Wheat	102,256	0.0028	0.8	0	114.53
Total					8,428.21

Annex VI-4: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2008

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	400	0.0300	0.9	0	2.40
Beans, green	13,600	0.0300	0.2	0	652.80
Broad beans, dry	300	0.0300	0.8	0	3.60
Chick peas	1,300	0.0300	0.9	0	7.80
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	800	0.0300	0.9	0	4.80
Lupins	220	0.0300	0.9	0	1.32
Peas, dry	2,400	0.0300	0.9	0	14.40
Peas, green	5,100	0.0300	0.2	0	244.80
Vetches	1,800	0.0300	0.8	0	21.60
Barley	25,520	0.0043	0.8	0	43.89
Carrots/turnips	852	0.0150	0.8	0	5.11
Garlic	1,155	0.0150	0.7	0	10.40
Maize	2,992	0.0081	0.7	0	14.54
Oats	185	0.0070	0.7	0	0.78
Onions, dry	7,126	0.0150	0.2	0	171.02
Potatoes	231,570	0.0150	0.0	0	6,947.10
Sorghum	607	0.0108	0.7	0	3.93
Wheat	126,456	0.0028	0.8	0	141.63
Total					8,561.93

Annex VI-5: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2009

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_{R}$	$Frac_{BURN}$	F_{CR}
Beans, dry	200	0.0300	0.9	0	1.20
Beans, green	13,515	0.0300	0.2	0	648.72
Broad beans, dry	100	0.0300	0.8	0	1.20
Chick peas	1,200	0.0300	0.9	0	7.20
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	1,600	0.0300	0.9	0	9.60
Lupins	150	0.0300	0.9	0	0.90
Peas, dry	2,500	0.0300	0.9	0	15.00
Peas, green	4,165	0.0300	0.2	0	199.92
Vetches	1,170	0.0300	0.8	0	14.04
Barley	26,136	0.0043	0.8	0	44.95
Carrots/turnips	684	0.0150	0.8	0	4.10
Garlic	980	0.0150	0.7	0	8.82
Maize	4,136	0.0081	0.7	0	20.10
Oats	194	0.0070	0.7	0	0.81
Onions, dry	12,110	0.0150	0.2	0	290.64
Potatoes	191,250	0.0150	0.0	0	5,737.50
Sorghum	510	0.0108	0.7	0	3.31
Wheat	98,032	0.0028	0.8	0	109.80
Total					7,387.82

Annex VI-6: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2010

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	750	0.0300	0.9	0	4.50
Beans, green	22,950	0.0300	0.2	0	1,101.60
Broad beans, dry	170	0.0300	0.8	0	2.04
Chick peas	2,650	0.0300	0.9	0	15.90
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	1,900	0.0300	0.9	0	11.40
Lupins	100	0.0300	0.9	0	0.60
Peas, dry	2,433	0.0300	0.9	0	14.60
Peas, green	5,100	0.0300	0.2	0	244.80
Vetches	630	0.0300	0.8	0	7.56
Barley	20,680	0.0043	0.8	0	35.57
Carrots/turnips	432	0.0150	0.8	0	2.59
Garlic	1,190	0.0150	0.7	0	10.71
Maize	3,960	0.0081	0.7	0	19.25
Oats	144	0.0070	0.7	0	0.61
Onions, dry	12,600	0.0150	0.2	0	302.40
Potatoes	117,000	0.0150	0.0	0	3,510.00
Sorghum	387	0.0108	0.7	0	2.51
Wheat	73,040	0.0028	0.8	0	81.80
Total					5,638.44

Annex VI-7: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2011

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	831	0.0300	0.9	0	4.99
Beans, green	21,250	0.0300	0.2	0	1,020.00
Broad beans, dry	152	0.0300	0.8	0	1.82
Chick peas	2,911	0.0300	0.9	0	17.47
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	2,106	0.0300	0.9	0	12.64
Lupins	103	0.0300	0.9	0	0.62
Peas, dry	2,614	0.0300	0.9	0	15.68
Peas, green	5,058	0.0300	0.2	0	242.76
Vetches	648	0.0300	0.8	0	7.78
Barley	26,400	0.0043	0.8	0	45.41
Carrots/turnips	438	0.0150	0.8	0	2.63
Garlic	1,278	0.0150	0.7	0	11.50
Maize	2,640	0.0081	0.7	0	12.83
Oats	198	0.0070	0.7	0	0.83
Onions, dry	12,712	0.0150	0.2	0	305.09
Potatoes	123,750	0.0150	0.0	0	3,712.50
Sorghum	396	0.0108	0.7	0	2.57
Wheat	110,000	0.0028	0.8	0	123.20
Total					5,810.30

Annex VI-8: Calculation of F_{CR} (equation 4.28, GPG 2000) for 2012

Crop	Dry weight (t)	$Frac_{NCRBF}$ \ $Frac_{NCRO}$	$Frac_R$	$Frac_{BURN}$	F_{CR}
Beans, dry	950	0.0300	0.9	0	5.70
Beans, green	21,250	0.0300	0.2	0	1,020.00
Broad beans, dry	160	0.0300	0.8	0	1.92
Chick peas	3,000	0.0300	0.9	0	18.00
Alfalfa	15,000	0.0300	0.7	0	270.00
Lentils	2,200	0.0300	0.9	0	13.20
Lupins	110	0.0300	0.9	0	0.66
Peas, dry	3,000	0.0300	0.9	0	18.00
Peas, green	5,270	0.0300	0.2	0	252.96
Vetches	720	0.0300	0.8	0	8.64
Barley	30,800	0.0043	0.8	0	52.98
Carrots/turnips	480	0.0150	0.8	0	2.88
Garlic	1,400	0.0150	0.7	0	12.60
Maize	2,640	0.0081	0.7	0	12.83
Oats	207	0.0070	0.7	0	0.87
Onions, dry	13,300	0.0150	0.2	0	319.20
Potatoes	126,000	0.0150	0.0	0	3,780.00
Sorghum	405	0.0108	0.7	0	2.62
Wheat	132,000	0.0028	0.8	0	147.84
Total					5,940.90

Annex VII

Annex VII-1

Tier 1 uncertainty calculation and reporting			t = 2010			
A	B	C	D	E	F	G
IPCC source category	Gas	Base year emissions 1994	Year t emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty
		Input data	Input data	Input data	Input data	$\sqrt{(E^2+F^2)}$
		Gg CO_2	Gg CO_2	%	%	%
Enteric fermentation	CH_4	231.49	205.17	20%	20%	28%
Manure management	CH_4	47.75	38.34	20%	20%	28%
Manure management	N_2O	141.91	154.17	20%	100%	102%
Agricultural soils - direct	N_2O	313.10	220.10	20%	80%	82%
Agricultural soils - indirect (N deposit)	N_2O	235.60	185.11	20%	100%	102%
Agricultural soils - indirect (leaching/ runoff)	N_2O	235.60	185.11	20%	380%	381%
Agricultural soils - PRP	N_2O	71.30	68.20	20%	100%	102%
Total		15,901.00	20,299.00			

Tier 1 uncertainty calculation and reporting		t = 2010					
A	B	H	I	J	K	L	M
IPCC source category	Gas	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		(GxD)/∑D		D/∑C	IxF	JxEx√2 Note D	√(K²+L²)
		%	%	%	%	%	%
Enteric fermentation	CH_4	0%	-1%	1%	(0.001136)	0%	0%
Manure management	CH_4	0%	0%	0%	(0.000248)	0%	0%
Manure management	N_2O	1%	0%	1%	(0.001697)	0%	0%
Agricultural soils - direct	N_2O	1%	-1%	1%	(0.009034)	0%	1%
Agricultural soils - indirect (N deposit)	N_2O	1%	-1%	1%	(0.007272)	0%	1%
Agricultural soils - indirect (leaching/ runoff)	N_2O	3%	-1%	1%	(0.027635)	0%	3%
Agricultural soils - PRP	N_2O	0%	0%	0%	0.001435	0%	0%
Total		4%					**3.11%**

Tier 1 uncertainty calculation and reporting			t = 2011			
A	B	C	D	E	F	G
IPCC source category	Gas	Base year emissions 1994	Year t emissions	Activity data uncertainty	Emission factor uncertainty	Combined uncertainty
		Input data	Input data	Input data	Input data	$\sqrt{(E^2+F^2)}$
		Gg CO_2	Gg CO_2	%	%	%
Enteric fermentation	CH_4	231.49	201.11	20%	20%	28%
Manure management	CH_4	47.75	37.68	20%	20%	28%
Manure management	N_2O	141.91	153.59	20%	100%	102%
Agricultural soils - direct	N_2O	313.10	226.30	20%	80%	82%
Agricultural soils - indirect (N deposit)	N_2O	235.60	189.99	20%	100%	102%
Agricultural soils - indirect (leaching/ runoff)	N_2O	235.60	189.99	20%	380%	381%
Agricultural soils - PRP	N_2O	71.30	65.10	20%	100%	102%
Total		15,901.00	20,299.00			

Tier 1 uncertainty calculation and reporting		t = 2011					
A	B	H	I	J	K	L	M
IPCC source category	Gas	Combined uncertainty as % of total national emissions in year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
		(GxD)/∑D		D/∑C	IxF (Note C)	JxEx√2 Note D	$\sqrt{(K^2+L^2)}$
		%	%	%	%	%	%
Enteric fermentation	CH_4	0%	-1%	1%	(0.001187)	0%	0%
Manure management	CH_4	0%	0%	0%	(0.000293)	0%	0%
Manure management	N_2O	1%	0%	1%	(0.001734)	0%	0%
Agricultural soils - direct	N_2O	1%	-1%	1%	(0.008722)	0%	1%
Agricultural soils - indirect (N deposit)	N_2O	1%	-1%	1%	(0.006965)	0%	1%
Agricultural soils - indirect (leaching/ runoff)	N_2O	4%	-1%	1%	(0.026469)	0%	3%
Agricultural soils - PRP	N_2O	0%	0%	0%	(0.001630)	0%	0%
Total		4%					**2.99%**