GREENHOUSE GAS MITIGATION ANALYSIS

AGRICULTURE

Lebanon's Second National Communication

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1. AGRICULTURE

1.1. BACKGROUND

The greenhouse gas emissions inventory for Lebanon shows that the agricultural sector is among the sectors that contribute least to emissions. These emissions mainly originate from agricultural soils, manure management (mainly emitting N_2O) and enteric fermentation (mainly emitting CH_4). The total emissions in CO_2 equivalent did not constitute more than 3.7% of the national total emissions between 2000 and 2004. The 2004 total emissions from the agriculture sector amounted to 685 tCO_2-eq, distributed as follows: 131 tCO_2-eq from enteric fermentation; 127 tCO_2-eq from manure management; 426 tCO_2-eq from agricultural soils; and 1 tCO_2-eq from field burning of agricultural residues.

1.2. BASELINE SCENARIO

Many agricultural activities known to generate GHG emissions are not practiced in Lebanon (forest burning, rice cultivation, intensive fodder and leguminous species cultivation, intensive animal husbandry, etc.). Limited development in agricultural practices and activities could be seen as an advantage for Lebanon in terms of limiting GHG emissions from the agriculture sector.

The number of animals in the farming sector has not considerably increased over the past years, except for poultry, and the trend is expected to remain stable by 2030 (MoA, 2000, 2005, 2006, 2007) as shown in Table 1-1.

Table 1-1 Poultry and livestock head numbers per year

	2000	2004	2006	2007	2030
Dairy cows	38,900	43,850	36,500	45,300	55,719
Other cattle	38,100	36,550	36,500	40,100	45,634
Poultry*	10,898,630	13,200,000	13,389,534	12,676,712	18,508,000
Sheep and goat	591,575	732,000	854,800	759,100	950,000

* Number of birds per year is adjusted from an average bird life cycle of 38 days.

Source: MoA, 2000, 2005, 2007, 2007

The expected rise in emissions from the animal husbandry sub-sector is expected to be alleviated by ***improved breeding and feeding management***, and thus higher food conversion efficiency that lowers emissions from manure (Smith et al., 2007). Calculations for the livestock sector in Lebanon show that improved breeding and feeding management can reduce up to 32% of tCO_2-eq emissions from the livestock sector – dairy cows, other cattle and poultry – as shown in

Table 1-2. However, such measures are not likely to be applicable for the traditional rearing of small ruminants (sheep and goat) from which emissions are not expected to change, and would be difficult to mitigate, since manure is mostly daily spread in rangeland, and small ruminants are mostly dependent on natural seasonal pastures. Small ruminants are mostly local breeds, and put in small scale traditional shelters. Their manure is stocked and then sold to farmers to be used as organic fertilizer.

Table 1-2 GHG emissions from manure and enteric fermentation for major animal husbandry activities for the baseline year, 2004, and 2030, with and without mitigation measures

	CH_4 (GG)			N_2O (GG)			TOTAL CO_2-EQ. (GG)	
	2004	2030 WITHOUT MITIGATION	2030 WITH MITIGATION	2004	2030 WITHOUT MITIGATION	2030 WITH MITIGATION	2030 WITHOUT MITIGATION	2030 WITH MITIGATION
Dairy cows	1.666	2.117	1.906	0.082	0.104	0.100	76.764	33.196
Other cattle	1.206	1.506	1.431	0.052	0.065	0.062	51.631	20.562
Poultry	0.238	0.333	0.293	0.249	0.350	0.335	115.189	111.194
Total	3.110	3.956	3.629	0.383	0.518	0.497	243.584	164.953

Emissions from agricultural soils and field burning of agricultural residues are not expected to increase either, given the forecast that total agricultural area will fluctuate (increasing or decreasing) at the expense of other land uses (construction, land reclamation, forests) that vary with time. As a matter of fact, between 2006 and 2007, the MoA's Census showed that the total agriculture area contracted by 2% while calculations made following the IPCC manual for N_2O emissions, show a decrease of 3.5% in N_2O emissions which are mainly from N-fertilizers' application, N-fixing crops and field burning. The national GHG emissions inventory showed that between 2004 and 2006, N_2O emissions from agricultural soils dropped from 2.145 Gg to 1.373 Gg. On the other hand, the IPCC report on mitigation measures in agriculture (Smith et al., 2007) calculated a potential of 0 to 10% annual decrease in N_2O emissions in warm dry climates. Since such reductions can be easily obtained from annual variability in cropping patterns and yields in Lebanon, we estimate that an average annual decrease of 3.5% of N_2O, NOx and CH_4 emissions from agriculture soils is feasible under different scenarios, even if there is no clear policy for GHG reduction from the agriculture sector. Hence, by 2030, GHG emissions from agriculture soils could be at 60% less than the emissions in the baseline year, without taking into consideration CO_2 emissions or sequestration.

The National Action Plan (NAP) for Combating Desertification (MoA, 2003) developed by the Ministry of Agriculture is expected to help reduce GHG emissions from agricultural soils through the promotion of sustainable agriculture, improved rangeland management, and soil conservation practices. The implementation of the NAP for Combating Desertification could therefore count GHG emission reduction as a co-benefit, provided that more detailed and structured calculations are provided to value the NAP's contribution.

1.3. MITIGATION MEASURES

Even though agriculture is a minor contributor to GHG emissions in Lebanon, mitigation measures are suggested and coupled in most cases with the adaptation measures suggested for the sector. The agricultural sector in Lebanon can potentially become a carbon neutral sector. The mitigation measures are divided into two major groups (UNFCCC, 2007):

1.3.1.1. Field level measures

These measures apply to three major agricultural systems:

- Modern poultry and animal husbandry (dairy and meat production) farms which emit a notable proportion of CH4 and N2O gases;
- Plowed agricultural soils in areas prone to desertification and land degradation;
- Surface irrigated crops.

Modern animal production farms

Large modern farms need to better manage their manure and other agricultural wastes by producing compost or biogas which would reduce GHG emissions considerably. Manure management is an essential practice in minimizing GHG emissions caused by microbial activities during manure decomposition. The major gas emitted is methane (CH_4). The amount of gas emitted varies with: (1) the amount of manure, which depends on the number of animals and amount of feed consumed; (2) animal type, particularly the condition of the digestive tract, quality of feed consumed, etc., which in Lebanon consists of cattle and poultry; (3) manure handling method through solid or liquid disposal methods; and (4) environmental conditions such as temperature and moisture.

Common mitigation measures for manure management are summarized in Table 1-3 (IFAD, 2009; Berg & Pazsiczki, 2006; AAFRD & UoA, 2003).

Table 1-3 Common mitigation measures for manure management

GENERAL MANAGEMENT PRACTICES	FEED MANAGEMENT	MANURE STORAGE, HANDLING AND TREATMENT TECHNOLOGIES
▪ Avoid adding straw to manure as it acts as a food source for anaerobic bacteria ▪ Avoid manure application on extremely wet soil ▪ 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	▪ Select livestock to genetically improve food conversion efficiency ▪ Increase the digestibility of feed by mechanical, chemical or biological processing ▪ Feed less frequently ▪ Feed cattle additives (ionophores) that act to inhibit methane production by rumen bacteria ▪ Add edible oils that reduce methane emissions by rumen	▪ Covered lagoons: covers on the surface of the manure reduce the transfer of GHGs to the atmosphere. Methane under the cover is either flared and the emissions are released to the atmosphere, or burned in a generator to produce electricity. Methane emissions can be reduced by 80% ▪ Digesters: wastes are fermented under anaerobic conditions to produce methane, generating heat and electricity as an alternative energy source ▪ Filtering of exhaust from animal houses for GHG removal (still under research) ▪ Composting of manure

Compost can be restituted to the soil as an organic fertilizer, which would increase water conservation and soil fertility. Consequently, productivity of plants and removal of CO_2 are enhanced (FAO, 2009).

Biogas could be used as an autonomous energy source for farms generating it. Thus, their energy import from non-renewable sources is reduced, which in turn reduces their GHG emissions. For instance, 1.7 cubic meters of biogas is equivalent to one liter of gasoline, thus 1 kg of cow manure will thus generate 388 watt-hour at 28°C. For a cow dung generation rate of around 25 kg per day, energy production can reach around 20 kilowatt-hours daily (Singh, 1971; Reidhead, 2010).

Plowed agricultural soils (mainly in areas prone to land degradation)

Most agricultural soils in Lebanon are plowed. Even though plowing releases GHGs (N_2O, CO_2); these emissions vary according to several criteria. Deep plowing for land reclamation and for tubers harvesting are the most critical. Plowing soils with excessive nitrogen fertilization and soils previously planted with legumes increases N_2O emissions. Soil texture in semi-arid areas is easily degraded when plowed, and releases GHG gases. Mitigation measures to be proposed are linked to adaptation measures:

- Encouraging organic farming, with appropriate crop rotation, intercropping, the use of compost and green cover fertilization instead of chemical fertilizers.
- Encouraging no-till or conservation agriculture techniques that would reduce gas emission from soils by 40% and conserve soil fertility in semi-arid areas (GTZ/CoDeL, 2009).

Surface irrigated crops

Agricultural cropping patterns that are irrigated using surface techniques suffer from low water efficiency and low production. This irrigation method boosts weed proliferation and requires plowing and soil management. As a result, the use of herbicides, pesticides and fertilizers increases as well. The adoption of localized efficient irrigation systems (e.g., drip irrigation) is a win-win solution where productivity, and thus carbon uptake, increase, water efficiency is enhanced, and GHG emissions are reduced. Higher water efficiency would reduce pumping from the water table, and consequently reduce GHG emissions.

1.3.1.2. *Research, education, assistance, infrastructure, and institutional measures*

These measures follow the same approach as for adaptation measures, to which they should be coupled. They are summarized as follows:

Research measures

- Empirical studies that study the appropriate agricultural practices (till, no-till, weed control, irrigation methods, etc.) and agricultural production systems (organic farming, conservation agriculture, crop rotations, etc.) which can lead to reduction in GHG emissions from soils.
- Adapting agricultural machinery to no-till practices.
- Studies engaging in animal nutrition in order to cope with changing cropping patterns for fodder species, and in order to minimize nitrogen losses in manure.
- Economic feasibility studies for newly adopted agricultural systems.

Educational and assistance measures

Since mitigation field measures were subdivided into three categories, educational measures should be targeted at the following groups:

- Owners and employees of major modern farms
- Farmers and farmers' groups in semi-arid areas
- Farmers and water users' associations using surface water for irrigation
- Veterinarians, agricultural engineers, and technicians

Infrastructure measures

Infrastructure measures need to be undertaken in order to mitigate GHG emissions. The major infrastructure changes to be undertaken are among the private sector, specifically within the target groups mentioned above. These include:

- Units for composting manure in moderni poultry and animal husbandry farms.
- Units for recovering biogas and producing clean energy from fermentation in modern farms.
- Water efficient irrigation systems at the farm level.
- Appropriate machinery for conservation agriculture techniques (for seeding, harvesting in no-till agriculture, etc.).

Institutional measures

Monitoring GHG emissions and proposals of adequate measures for mitigation are essentially mandated to the Ministry of Environment. The Ministry of Agriculture is responsible for the implementation of an eventual national action plan or governmental decisions relating to GHG emissions reduction from the agriculture sector. Such measures should be taken into consideration in the Ministry's agricultural strategies. Since most of the measures for adaptation and mitigation are linked, the major administrative institutions and departments to be reinforced are almost the same:

- The directorate of Animal Resources on manure management and fodder issues (as part of new legislation on organic agriculture)
- The directorates of Plant Resources and of Rural Development and Natural Resources on soil management and grazing/ rangeland management as well as organic farming
- Research institutes; to achieve the research measures to be addressed
- Green Plan; to implement the infrastructural mitigation/adaptation measures related to water
- Extension services; to disseminate information to farmers

Some of these major directorates and institutions, namely research and extension services, could be delegated or implemented in joint venture with the private sector (input and service providers, universities, etc.) and NGOs. Some international organizations are already involved in such measures (UNDP, GTZ, FAO, etc.). Financial incentives (such subsidies and loans) are crucial for all measures.

1.4. COST OF MITIGATION MEASURES

Field and infrastructure measures could only be addressed at the level of individual, major poultry and animal husbandry farms. This is the case because cost varies with the number of animals, and with the technologies used. Case studies could be undertaken in order to estimate the cost of ***processing the manure into compost***, or for the ***production of biogas and then energy at the farm level***.

The cost of each mitigation option can be estimated according to carbon price (USD per tCO_2-eq. per year). For instance, livestock feeding and nutrient management costs 60 USD and 5 USD/tCO_2-eq per year respectively, while animal breeding costs 50 USD/tCO_2-eq. per year (Smith et al., 2008).

Assuming that improved livestock feeding and animal breeding are implemented and have an equal impact on emission reduction, the cost per tCO_2-eq. per year will be the mean of two values, i.e. 55 USD/tCO_2-eq per year. Thus, for the year 2030 for example, 78,631 tCO_2-eq. reduced from animal husbandry would cost around 4.33 million USD (Table 1-4).

Improved nutrient management practices are expected to result in a reduction of 60% of baseline N_2O emissions. At an assumed cost of 5 USD/tCO_2-eq per year(Smith et al, 2008), the total cost of emission reduction from nutrient application would amount to 2 million USD (Table 1-4).

Table 1-4 Emission Reduction Potential and cost of mitigation from the proposed measures

	MITIGATION OPTION 1: IMPROVED BREEDING & FEEDING MANAGEMENT	MITIGATION OPTION 2: NUTRIENT MANAGEMENT
Emission Reduction (in tCO_2-eq)by 2030	78,631	399,000
Cost ($/$tCO_2$-eq)	55	5
Total Cost (in million USD)	4.33	2.0

The same approach could be used in order to estimate the cost of conversion of exploitations from conventional agriculture (for selected vulnerable crops like potato, tomato, wheat or olive) to conservation agriculture adopting no-till practices and eventual drip irrigation systems. In many cases, measures are almost costless. For example, the cost of converting an olive orchard to a no-till production system is around 88 USD/hectare in Syria (FAO, 2009). FAO sources estimate the cost of adopting no-till agriculture at 600 USD/hectare in Morocco. Other measures would be more expensive. For example, the cost of shifting from surface to drip irrigation is around 3,500 USD/hectare in Lebanon. Subsequently, in order to convert, by 2030, 30,000 ha of cereals, legumes, and fruit orchards in Baalback-Hermel area to no-till agriculture, a budget of 18 million USD is needed, excluding the cost of machinery (i.e., seeders for cereals and legumes). Hence, to convert 30,000 ha of fruit orchards and vegetables to drip irrigation until 2030 we will roughly need 105 million USD, without counting head units, and common water canalization. The lack of information on the sequestration of CO_2 by soils in Lebanon limits the analysis of the sequestration potential from the shift to drip irrigation, and the calculation of the cost of this measure per tonne of CO_2-eq.

Since many adaptation and mitigation measures are coupled together, it should be noted that costs should not be double counted (e.g., the cost of irrigation systems).

Table 1-5 and Table 1-6 present the mitigation strategy for the Agriculture sector as well as gaps and constraints associated with its implementation.

Table 1-5 Mitigation Strategy for the Agriculture Sector

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
Reduction of GHG emissions from animal husbandry	Reduce GHG emission by 32% from modern poultry and bovine farms by 2030 by reducing/ recovering methane gas generated during anaerobic fermentation of manure disposed in ponds	- Survey farms and farmers then propose according to each case the following measures: (a) Improve manure management through better storage, handling and treatment technologies (including methane recovery) (b) Improve feeding practices by selecting additives or by choosing high feed conversion animal breeds (c) Improve pasture management and avoid manure storage and mixture with straw (d) Training for farmers	- Farmers/coops -MoA (extension) - Municipalities - Unions of municipalities -Universities (research) - Private sector (study/implementation) - MoE (monitoring)	MT-LT	USD38.33/t CO_2 eq./yr or the equivalent of USD 3 million for the year 2030 as an estimation.	Farmers, municipalities, unions of municipalities, GEF, GTZ, EFL, UNDP, FAO and NGOs/enterprises dealing with carbon trade, etc
Reduction of GHG from agricultural soils	Promote Good Agricultural Practices (GAP), no-till (conservation) agriculture and good agricultural practices especially in areas vulnerable to land degradation. GHG emissions reduction could reach up to 40% in such soils.	- Identify ongoing projects and join efforts to promote the adopted strategy for potential crops (rain fed crops, irrigated cereals ,fruit orchards and potato) - Identify the suitable measure for each crop/area - Follow up the implementation with farmers and introduce the necessary technology/practices	-Farmers/coops -MoA (extension, quality control, accreditation) -Universities (research) - Private sector (study/implementation) -NGOs (implementation/follow up, marketing)	MT-LT	USD88-600/ha according to the selected measure and crop without adding neither the cost of labeling and certification nor the managerial cost.	Farmers associations, GEF, GTZ, EFL, UNDP, FAO, and NGOs/enterprises dealing with carbon trade, etc.

TARGET	PROPOSED MITIGATION STRATEGY	ACTIVITIES	RESPONSIBILITY	PRIORITY (ST/ MT/ LT)	INDICATIVE BUDGET (USD)	SOURCES OF FINANCING/ IMPLEMENTATION PARTNERS
	30,000 ha could be converted by 2030.	- Ensure the certification of the products and promote their marketing - Train farmers	- Certification bodies (certification) - Traders (marketing) -MoE (monitoring)			

N.B: Refer to adaptation measures for irrigation and rangeland which can be also considered as mitigation measures in agriculture and natural ecosystems.

Table 1-6 Constraints to the implementation of mitigation measures

MITIGATION STRATEGY	CONSTRAINTS/ GAPS				
	LEGAL	INSTITUTIONAL	TECHNOLOGICAL	CAPACITY AND AWARENESS	DATA/ INFORMATION GAPS
Reduction of GHG emissions from animal husbandry	None	Limited specialized staff in relevant areas	- Lack of local breeding technology. - Lack of anaerobic digestion technology. - Lack of relevant expertise.	Essential to train farmers all the practices required for feed and pasture management	All data can be found or estimated and information can be imported when necessary.
Reduction of GHG from agriculture soils	- Constraints related to the import of biological material - Constraints related to accreditation and certification of products	Lack of staff in private enterprises. Constraints related to quality control and traceability	- Absence of insectariums and local providers of traps, pheromones, biological pesticides and natural enemies in Lebanon. - Absence of local technologies for the machinery required in no-till agriculture (seeders, harvesters, etc.) - Limited funds for the promotion of mitigation measures.	Essential to train engineers and farmers on conservation agriculture, good agriculture practices and organic farming practices (soil management, composting, etc.)	- Lack of data on the actual cropping pattern and actual agriculture practices in potential areas for conversion. - Lack of information about the quantity of reduction of GHG per crop, per region and per type of measure

APPENDIX A

Table 1 Principles advocated by the National Action Plan for Combating Desertification that contribute to the reduction of GHG emissions

Sustainable agriculture	Rangeland management	Soil conservation
▪ Implementation of a comprehensive land use plan. ▪ Development of a decision support system for farmers on trends and production techniques (including organic farming and low external inputs for sustainable agriculture - LEISA). ▪ Adoption of a system approach to improve agricultural productivity and to identify needed interventions in terms of provision of necessary infrastructure, credit, training, post-harvest and marketing. ▪ Development and adoption of integrated and sustainable agriculture practices including certification programs and procedures.	▪ Development of a comprehensive legislative and policy framework with the active participation of all rangeland users. ▪ Development of a national rangeland strategy. ▪ Provision of support for the establishment of proper land tenure systems so that users have long-term stake in sustainable use. ▪ Enhancement of biomass and vegetative cover of rangelands. ▪ Support for sustainable livestock production through the introduction of improved stock, animal husbandry, stock management, alternative feed resources and health programs; through the initiation of relevant pilot activities; and through the implementation of a participatory model for rangeland management in a pilot area. ▪ Support of research to develop a better understanding of rangeland dynamics, rehabilitation and management techniques. ▪ Support for technical trainings and efficient extension services for rangeland management, rehabilitation and sustainable livestock production.	▪ Protection of prime agricultural lands from further misuse through the establishment of a proper land use planning and zoning system. ▪ Development and enforcement of a comprehensive legislative framework for sustainable agricultural production. ▪ Promotion of soil conservation practices. ▪ Development of a proper extension service. ▪ Development of a strategy for relevant applied research in soil conservation and management issues. ▪ Mainstreaming of soil conservation and management topics in the curricula of agricultural schools and relevant departments at universities.

Source: MoA, 2003

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