- Optimization of heat recovery/upgrade clinker cooler;
- Using efficient transport system (mechanical transport instead of pneumatic transport);
- Establishment of annual targets for GHG emissions reduction in cement factories;
- Support to increase the flow of CDM revenues to encourage costly mitigation measures in the cement sector;
- Creation of a dialogue platform between the government and the cement factories management representatives.

3.3. Agriculture

The total GHG emissions from the agricultural sector do not constitute more than 3.7% of the national total emissions. The main GHGs are N_2O and CH_4, generated from agricultural soils, manure management and enteric fermentation. 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.

3.3.1. 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.). Therefore, the 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 as shown in Table 3-10. 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).

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 at the expense of other land uses (construction, land reclamation, forests) that vary with time. The national GHG emissions inventory shows a decrease of 3.5% in N_2O emissions between 2004 and 2006, while the IPCC report on mitigation measures in agriculture (Smith et al., 2007) estimates 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, it is estimated that N_2O, CH_4 and NO_x emissions from agriculture soils will decrease by 3.5% annually 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 (Table 3-11) 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 add value to the NAP's contribution.

3.3.2. Mitigation scenarios

It is to be noted that the mitigation scenarios developed hereafter are to be considered as complementary.

Mitigation scenario 1: Field level measures

Improve Manure management: Large modern farms need to better manage their manure and other agricultural

Table 3-10 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.

Table 3-11 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

wastes by producing compost or biogas which would reduce GHG emissions considerably. Compost can be restituted to the soil as an organic fertilizer, which would increase water conservation and soil fertility (FAO, 2009b). Biogas could be used as an autonomous energy source for farms generating it, thus reducing their energy import from non-renewable sources. For instance, 1.7 cubic meters of biogas is equivalent to one liter of gasoline, thus 1 kg of cow manure will 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).

Manure management is an essential practice in minimizing GHG emissions caused by microbial activities during manure decomposition. 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 3-12.

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 3-13. 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 mainly local breeds, put in small scale traditional shelters and their manure is stocked and sold to farmers to be used as organic fertilizer.

Plowed agricultural soils 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 such as purpose of plowing (land reclamation, tubers harvesting, etc.) and type of soil (plowing soil with excessive nitrogen fertilization or soils previously planted with legumes emits N_2O) and

Table 3-12 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

Source: IFAD, 2009; Berg and Pazsiczki, 2006; AAFRD & UoA, 2003

Table 3-13 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

geographic area (soil texture in semi-arid areas is easily degraded). Mitigation measures include encouraging organic farming, with appropriate crop rotation, intercropping, the use of compost and green cover fertilization instead of chemical fertilizers, and 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).

Use efficient irrigation system: 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 through reduced plowing, reduced use of herbicides, pesticides and fertilizers and reduced water pumping.

Mitigation scenario 2: Research, education, assistance, infrastructure, and institutional measures

Research measures: Agricultural research institutions and programs in Lebanon should be strengthened and enhanced to elaborate research programs in fields related to adaptation to climate change. The existing governmental research institutions (LARI, NCSR, etc.) should join venture with local universities and regional institutions with long past experience in arid and semi-arid areas (ICARDA, ACSAD). Ultimately, a network of research institutions that address research on agriculture and climate change in Mediterranean countries could provide invaluable insight and direction on critical areas for action. Some topics to be studied include:

- Identifying 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;
- Modifying animal nutrition in order to cope with changing cropping patterns for fodder species, and minimize nitrogen losses in manure;
- Analyzing the economic feasibility for newly adopted agricultural systems.

Educational and assistance measures: Educational measures should be targeted at owners and employees of major modern farms, farmers in semi-arid areas, veterinarians, agricultural engineers, and technicians.

Infrastructure measures: The major infrastructure changes to be undertaken are among the private sector, and include the use of units for composting and/or recovering biogas manure in modern poultry and animal husbandry farms, the improvement of irrigation systems and the use of appropriate machinery for conservation agriculture techniques (for seeding, harvesting in no-till agriculture, etc.).

Institutional measures: The legislative framework related to agriculture and natural resources management should be reviewed and harmonized with the conventions that are ratified by the Government in relation to climate change, combating desertification, and biodiversity. The inter-linkages and conflicting mandates between different institutions should be resolved and responsibilities should be well defined and distributed. The human resources and organizational structure of the Ministry of Agriculture should be reviewed according to law amendments in order to provide the desired services related to adaptation measures.

Since most of the measures for adaptation and mitigation are linked, the major administrative institutions and departments to be reinforced are:

- 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.

3.3.3. Cost of mitigation measures

Field and infrastructure measures could only be addressed at the level of individual, major poultry and animal husbandry farms, since the 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/tCO_2eq./yr). For instance, livestock feeding and nutrient management costs USD 60 and USD 5/tCO_2 eq./yr respectively, while animal breeding costs USD 50/tCO_2 eq./yr (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./yr will be the mean of two values, i.e. USD 55/tCO2-eq/yr. Improved nutrient management practices are expected to result in a reduction of 60% of baseline N_2O emissions, at an assumed cost of USD 5 /tCO_2 eq./yr (Smith et al., 2008) (Table 3-14).

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 adopting no-till agriculture in the MENA region has been estimated to around USD 88/ha to USD 600/ha according to the country (FAO, 2009b). Other more expensive measures include shifting from surface to drip irrigation which is estimated to cost USD 3,500/ha in Lebanon. Subsequently, in order to convert by 2030, 30,000 ha of cereals, legumes, and fruit orchards in the Baalback-Hermel area to no-till agriculture, a budget of USD 18 million is needed, (excluding the

Table 3-14 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 (USD/tCO_2 eq.)	55	5
Total Cost (in USD million)	4.33	2.0

cost of machinery) while a budget of USD 105 million is needed to convert the same area to drip irrigation. 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 tCO_2 eq.

3.4. Forestry

The land and forestry sectors are regarded as sinks for GHGs where in 2004 some 605 Gg CO_2 eq. were estimated to have been sequestered. Mitigation actions are designed to increase carbon sequestration by forests and soil by maintaining and conserving existing forest carbon sinks and increasing forest cover by reforestation and afforestation.

3.4.1. Baseline scenario

The MoE's and MoA's reforestation/afforestation plan aims at increasing the forest cover from 13% of Lebanon's land surface area to 20%. The net annual emissions of GHG from the forestry sector are negative since growing trees sequester carbon from the atmosphere, while adult trees lock the carbon sequestered in the bark. Table 3-15 shows the area of forests in kha and the number of fruit trees in Lebanon for the year 2004, as well as projections under a baseline scenario with a 2030 horizon. The GHG inventory has estimated the annual total carbon uptake increment in Lebanon for the year 2004 at around 249.19 kt of carbon.

3.4.2. Mitigation options and costs

Mitigation scenario 1: Maintaining and conserving existing forest carbon sinks

Maintaining forests and nature reserves can be achieved through:

- Adopting sustainable forest management practices such as grazing, Non Wood Forest Poducts (NWFP), and harvesting of wood in forests and other wooded lands (OWL) to address the possible threats to these ecosystems and improve their status;

Table 3-15 Forest area and number of trees in the baseline scenario

<table>
<tr><th></th><th colspan="2">Total for the year 2004</th><th>Expected trend</th><th>2030 Total expected</th><th>2030 projections</th></tr>
<tr><td>Area Evergreen stands (ha)</td><td rowspan="2">139,522</td><td>134,298</td><td rowspan="2">Increase from 13% to 20% cover</td><td rowspan="2">211,836</td><td>206,612</td></tr>
<tr><td>Area Deciduous stands (ha)</td><td>5,224</td><td>5,224</td></tr>
<tr><td colspan="2">Number of non-forested evergreen fruit trees (1,000)</td><td>25,492</td><td>10% increase in number of fruit trees</td><td colspan="2">28,041</td></tr>
<tr><td colspan="2">Number of other fruit trees (1,000)</td><td>20,056</td><td>10% increase in number of fruit trees</td><td colspan="2">22,061</td></tr>
<tr><td colspan="2">Total Carbon uptake increment (kt)</td><td>249.19</td><td></td><td colspan="2">347.32</td></tr>
</table>