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Enabiling Activities for Preparation of Syria's Initial National Communication to UNFCCC

Mitigation of greenhouse gas emissions within the Agriculture Sector

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Assess the potential Mitigation of greenhouse gas emissions within the agriculture sector in Syria

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This report has been approved unanimously by the technical committee, during the Technical Workshop which took place on 28.2.2010, in Samiramis Hotel, Damascus.

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1. Introduction

Utilizing natural resources by unsustainable and improper human activities is the major factor for eco-systems degradation and the imbalance in the natural emission of gases by their bio-activities, which increased the emission of GHG (CH_4 , CO_2, CO, N_2O, N_x O_x) and their concentration in the atmosphere. In addition, the massive and continuous increase in fuel use (the main source of energy) substantially increased GHG emissions and is the main contributor to increasing the concentration of these gases in the atmosphere. The increase has induced a change in climate with adverse impacts affecting the globe, especially in dry areas. Scientific information indicate that the world has to keep concentration of GHG in the atmosphere below 350-450 part per million (ppm) of CO_{2e} in year 2050, to have a 50% chance of preventing a dangerous climate change [1]. To achieve that these accumulated gases in the atmosphere have to be redeposit in terrestrial eco-systems and oceans. Effective sequestration for mitigating the concentration of GHG gases in the atmosphere requires integrated management for all emitting and sequestering sectors, and would need a balance sheet for carbon equivalent (CO_{2e}) across all emitting and sequestering sectors. Clean technology may provide 50% of the solution, improving fuel efficiency provide 25% and improving land management provide 25%.

Land degradation including forests is the second contributor to increasing GHG emissions and their concentration in the atmosphere [2]. Inappropriate agriculture practices are approximately responsible for 15% of global GHG, and land use change is approximately responsible for 17% of the emissions. In Syria, however, total GHG from land and fertilization, land use change and forests, and domestic animals contributes 48% of all the emissions of GHG in year 2005, whereas the contribution of emissions by energy use in the agriculture sector is 3.4% only [3,4 and 5]. Therefore, mitigating GHG emissions by agriculture activities and their energy use needs reconsidering the present conventional farming systems and the activities of land use change and energy use, with respect to the society' present and future food security requirements, and other needs of agriculture commodities. The challenge ahead developing countries including Syria, is how to balance between the requirements for development and mitigating the emissions of GHG and their adverse impacts on human life.

This report will present the development of the sources emitting GHG in the agriculture sector in Syria until year 2007, and the expectations of development in year 2030. In addition, it will present actions and proposals for mitigating the emissions in agriculture without affecting the requirements for development and food security in Syria and the region.

2. Agriculture development in Syria and expectations for year 2030

The agriculture sector in Syria, like anywhere else is developing by increasing agriculture production and consequently the used energy with no attention to the adverse impacts that might incur by the applied means and methods. Resources are degraded and their GHG emissions increased and have affected climate change and the livelihood of people in Syria. These conditions require studies and suggestions to overcome the incurred damages and mitigate GHG emissions in the agriculture sector with all considerations to the needs of food security in Syria and the Arab region.

2.1. Development of agriculture activities in Syria and the expectation for year 2030

Agriculture activities include utilization of land, land use change and forests and rangelands, and production of domestic animals.

2.1.1. Development of cultivated land and farm animals in Syria

Plans and activities for developing agriculture increased the area of rainfed and irrigated agriculture within the arable land, and by cultivating rangelands and changing forests into annual crops and fruit trees (Figure 1) [6]. This was accompanied with increasing the number and depth of cultivations for all rainfed and irrigated crops. The number and capacity of tractors and combine harvesters increased (Figure 2) and other transport machinery such as trucks and trains increased [6]. In addition, the number of irrigation water pumps and the related electric generators and motors increased (Figure 2) [6]. The increases in year 2000 than in 1994 were; 16% for tractors more than 50 horses; 38% for tractors less than 50 horses; 38% for pumps more than 65 horses; and 11% for pumps more than 65 horses, whereas the number of combine harvesters decreased by 9%. In year 2007 the increases than year 2000 were; 9% for tractors more than 50 horses; 16% for tractors less than 50 horses; 6% for pumps more than 65 horses; 38% for pumps less than 65 horses; and 11%of combine harvesters. Nitrogen fertilizers also increased by 9% in year 2000 than in year 1994, and by 5% in year 2007 than in year 2000 (Figure 3) [6]. The increase in poultry production in year 2000 was 41% than in year 1994, and was 64% more in year 2007 than in year 2000 (Figure 4) [6]. Green houses increased by 66% in 2007 than in year 2000(Figure 5) [6]. Besides, related services to agriculture production increased along with agriculture development and have increased the use of energy.

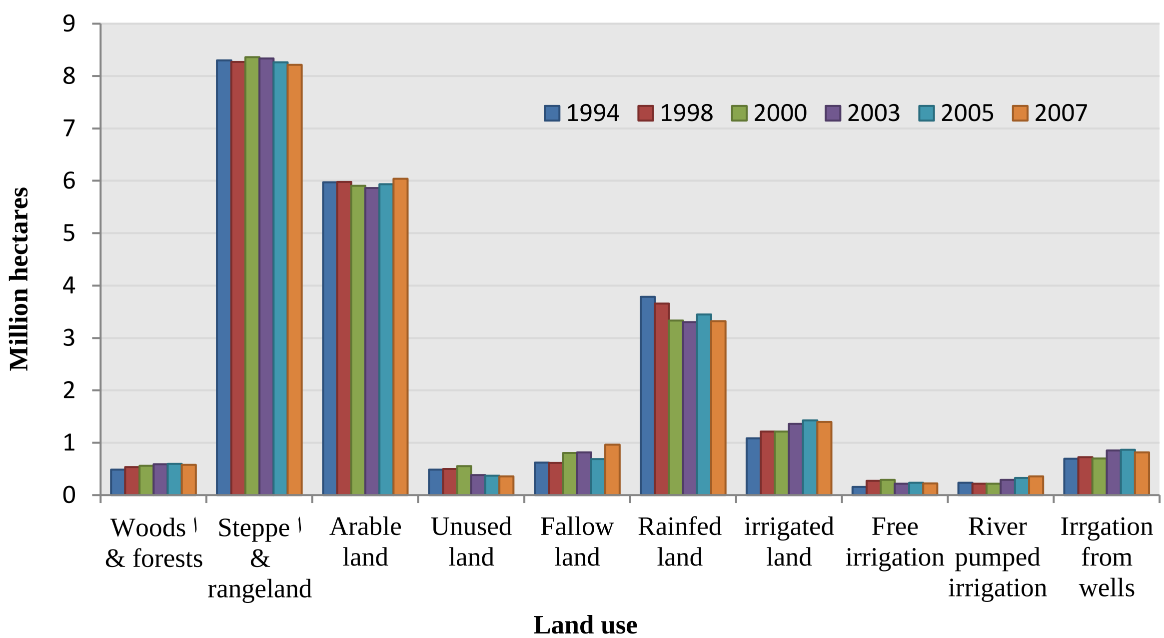
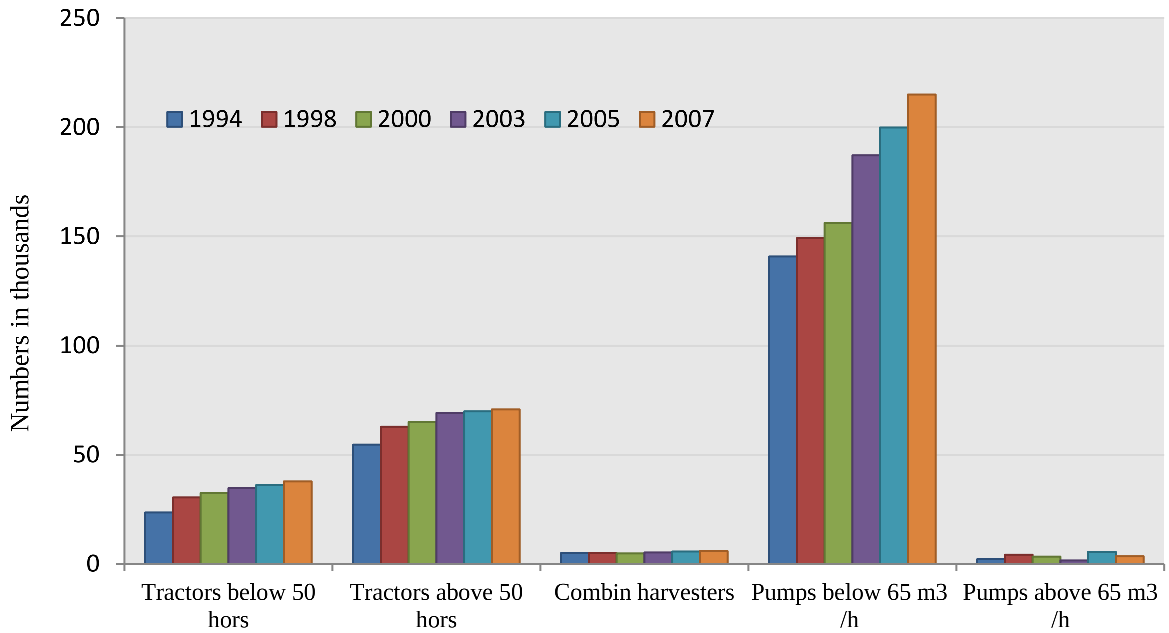


Figure 1. Land use change in Syria for 1994-2007.



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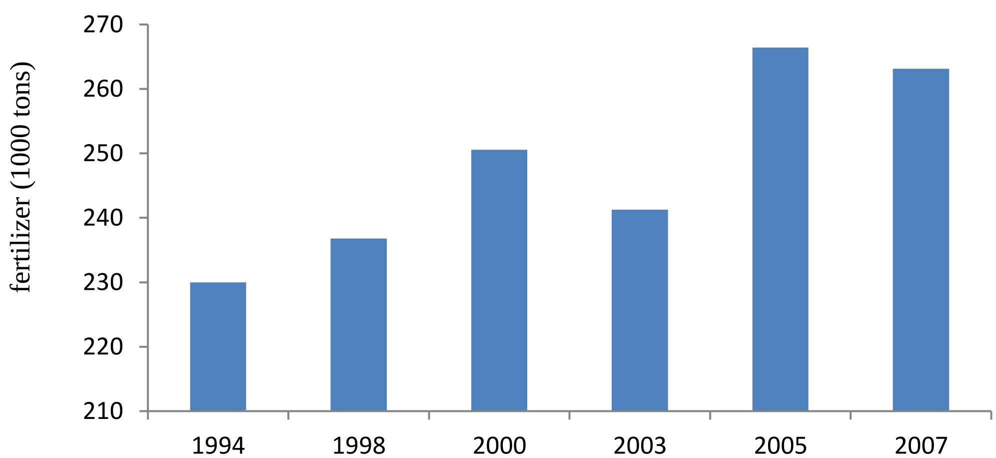

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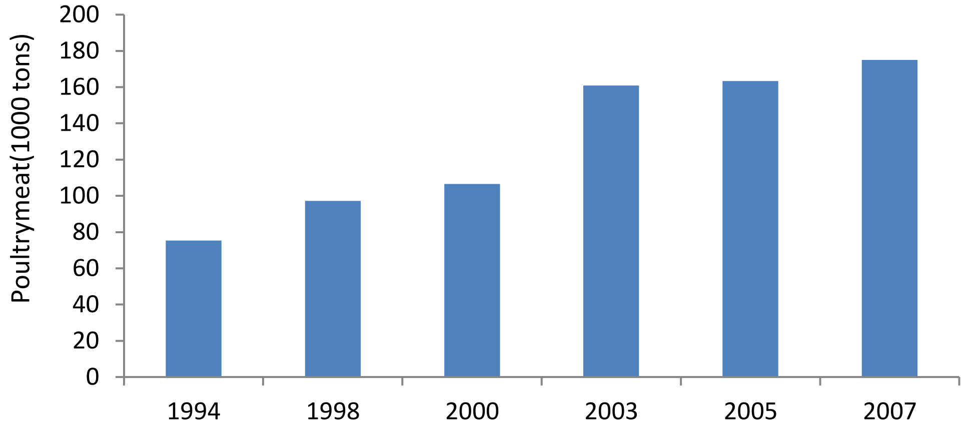

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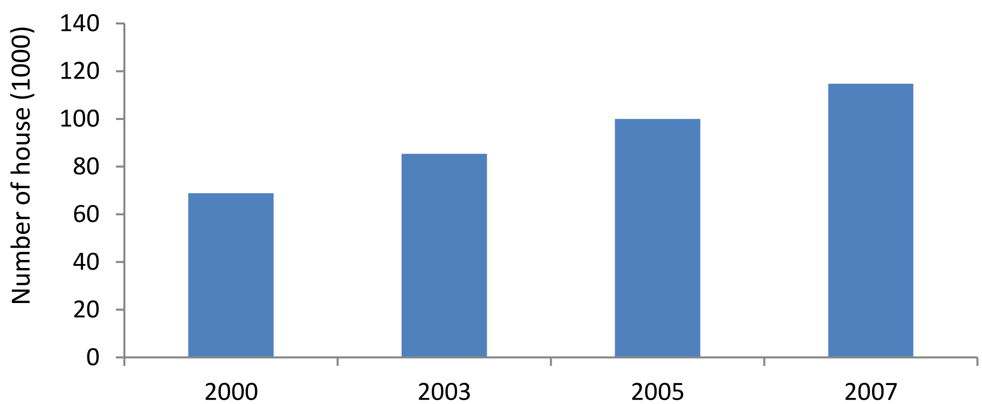

Figure 5. Change of green houses numbers in Syria for 1994-2007.

The number of domestic animals increased in year 2000 than year 1994 in a range of 0.3% for horses and 116% for camels, whereas the number of horses, mules and donkeys decreased in year 2006 than year 2000, and all other domestic animals increased in a range of 1.7% for non- dairy cows and 114% for camels (Table 1).

Table 1. Change of farm animals' numbers (1000 animal) in Syria for 1994-2000 [6]

Animals	2000	1994	2006
Dairy cows	469	320	597
Nondairy cows	515	405	524
Sheep	13505	11160	21380
Goats	1050	1028	1420
Camels	13.4	6.2	28.7
Mules & Donkeys	229	214	118
Horses	27.1	27	14
Hens	21629	18115	30946
Buffaloes	2.8	1	4

2.1.2. Development of forests and rangelands in Syria

Forests and rangelands over the last decades exhibited severe degradation by intensive woodcutting, and early and heavy grazing, where plant cover density, diversity and area deteriorated. In addition, fires have damaged around 20 thousand hectares over the last 2 decades [7]. Besides, the cultivated rangeland in the Syrian Badia summed up to 0.55 million hectares [8].

Forest degradation reduced trees cover down to 2-3% in some parts, 30- 60% in others, and in few parts it may be 80%. The forest area dropped drastically and is not more than 2.71% of the country' area. Old forests form 47% of the forest area and 53% are new plantations, a part of the forestation strategy of the government [9]. The area of heavily degraded forest and has no longer the forest form is 25% of the natural forest area, and thus the actual portion of the old natural forest is not more than 0.944% of The country' area. However, despite forest degradation annual forest plantations increased the total forest area by 14% in year 2000 than the 486900 hectares area in 1994. The area increased to 576008 hectares In year 2007, a 3% more than in year 2000 (Figure 1).

Degradation in the rangeland decreased the total area to 8214112 hectares in 2007 a 1.7% less than the area in year 2000 (Figure 1). In addition the productivity decreased by 350%, plant cover decreased by 85% and species number decreased by 200% [10].

2.1.3. Expectations for the development of agriculture activities in Syria

Expectations of population growth for year 2030 indicate that the population in Syria shall increase from 19.1 million people in year 2005 up to 30.6 million people in year 2030, an increase of 60% [11]. The growth will increase the demand for commodities especially the essential agriculture products of food and clothing, and require developing all agriculture activities and increasing production during that period. The expected changes by 2030 are the following (Table 2): 1) Cultivating the remaining unutilized 0.6 million hectares of the arable land, 2) increasing the number of green houses by 125%, 3) increasing the forested area by 10.8%, 4) decreasing the rangeland area by 5.7%, 5) increasing the number of combine harvesters and tractors, 6) increasing the number of fishing boats by 6.3%, 7) increasing poultry production by 128%, 8) increasing the stored agriculture products by 60%,

9) increasing the use of N fertilizers by 6.3%, 10) increasing the number of domestic animals in a range of 6.9% for nondairy cows and 213.2% for camels, except horses, mules and donkeys which shall decrease by 95%.

Table 2. Expected development of the agriculture sector in Syria for 2030

Changes in agriculture activities from 2007[1]			Changes in the number of farm animals from 2006[1]		
Activities and machinery	Change amount	Change (%)	Animal type	Change amount (1000 animals)	Change (%)
Utilized land	+ 0.36 Million hectare	6.3	Dairy cows	+ 511.92	85.7
No. of green houses	143152 +	125	Non dairy cows	+ 36	6.9
Woods and forests	+ 0.06 Million hectare	10.8	sheep	+ 31500	147.3
Steppe & rangeland	− 0.47 Million hectare	− 5.7	Goats	+ 1480	104.2
Irrigated land	0	0	Camels	+ 61.2	213.2
Combine harvesters	368 +	6.3 [2]	Mules & donkeys	− 112.1	− 95[4]
Tractors	+ 6831	6.3 [2]	horses	− 13.3	− 95[4]
Fishing boats	−	60 [3]	Poultry	+ 37267.9236	120.4
Poultry meat	+ 224503 ton	128	Buffalos	+ 4.8	120
N fertilizer use	+16576.4ton	6.3 [5]	-	−	−
Stored agriculture products	−	60[3]	-	−	−

[1]calculated from the annual change rate between year 2000 and 2006 or 2007(AASA 2007). [2] this percent was used because the expected increase in tractors and combine harvesters will be proportional to the increase in utilized land. [3] because no information is available on the changing rate of fishing boats and stored agriculture products, this percent is used on the bases that food demand would increase proportional to population growth.
[4] the 95% decrease from the number in 2006 is used because when using the annual decreasing rate there will be none of these animals, which is not practical. [5] This percent is used because fertilizer use was hectic and it is expected to increase its use proportional to the increase in the utilized land..

2.2. Development of energy use in the agriculture sector in Syria and the expectations for year 2030

Agriculture development, as described before, over the last 3 decades in Syria drastically increased the use of diesel fuel by agriculture machinery "excluding fishing boats" (Figure 6) [6]. Energy use increased up to 1044167 tons diesel in year 2000, an increase of 19.7% than in 1994. In year 2007 energy use was 1160370.7 tons diesel an 11% increase than in year 2000. Around 81-83% of the total energy used by agriculture machinery (excluding fishing boats) is used by tractors for cultivations during that period. There were increases in tractors used energy by 23% in year 2000 than in 1994, and by 10% in year 2007 than in 2000. The increase in energy use by tractors, however, is not due to the increase in the cultivated area because the cultivated area in year 1994 was (4.9 million hectares) more than the area in year 2000 (4.5 million hectares) and year 2007 (4.7 million hectares), and the bare fallow area was increasing from 0.62 million hectares in 1994 to 0.8 million hectares in year 2000 and to 0.96 million hectares in 2007 (Figure 1). This may suggest that the increases in the used energy by tractors could be due to intensifying cultivations and to the low efficiency of using diesel by tractors. In addition, services related to cultivations and are provided by tractors have increased in a similar proportion to cultivations, the dependency on tractors for transportation in the countryside increased, and the area of land reclamation increased. The fuel used by combine harvesters had different trend and was in year 2000 8% less than in 1994, and have increased by 23% in 2007 than in year 2000 (Figure 6).

Energy use of diesel fuel and coke for heating poultry barns doubled in 2007 than the use in year 1994. The total used energy was 118718.5 tones diesel equivalent in year 2007 a 64.1% increase than the amount in 2000, and the used amount in year 2000 was 72346 tones diesel equivalent an increase of 41.6% than the used amount in 1994 (figure 7) [6]. The used energy for heating green houses in year 2007 increased by 66% than in year 2000 and was 227646 tones diesel equivalent (Figure 8) [6]. These high rates of increases in the use of energy in poultry barns and green houses is attributed to provide the increasing demand for food products by population growth, change of consuming patterns in Syria, and to the inefficient heat isolation and fuel burning in poultry barns and green houses.

The used diesel fuel by fishing boats in year 2007 was 3510 tones, and cooling stored agriculture products used 3034 tones diesel to produce the needed 35989 Mw/hour of electrical energy (Figure 9) [6]. Providing the needed water for irrigation agriculture in year 2007 used 4681.8 Mw/hour of electricity in addition to134701.1 tones diesel, summing up to 135095.8tones of diesel equivalent (Figure 9). Other uses of energy in the agriculture sector (offices heating) in 2007 are estimated by 10000 tons of diesel fuel/year, however, it will not be included in the calculations here as it is considered human use.

The integrated information in year 2007 show that the total energy use by the different agriculture activities (tractors “Cultivations and other works”, combine harvesters, poultry barns, green houses, irrigated agriculture, fishing boats, and cooling stored agriculture products) in Syria was 1648374.6 tons diesel equivalent (Figure 9). Tractors used 64.2% of the energy for cultivations and other works. Whereas, green houses used 14%, agriculture irrigation 8.2%, poultry barns 7.2%, combine harvesters 6%, fishing boats 0.2%, and cooling stored agriculture products 0.2% (Figure 10)[6].

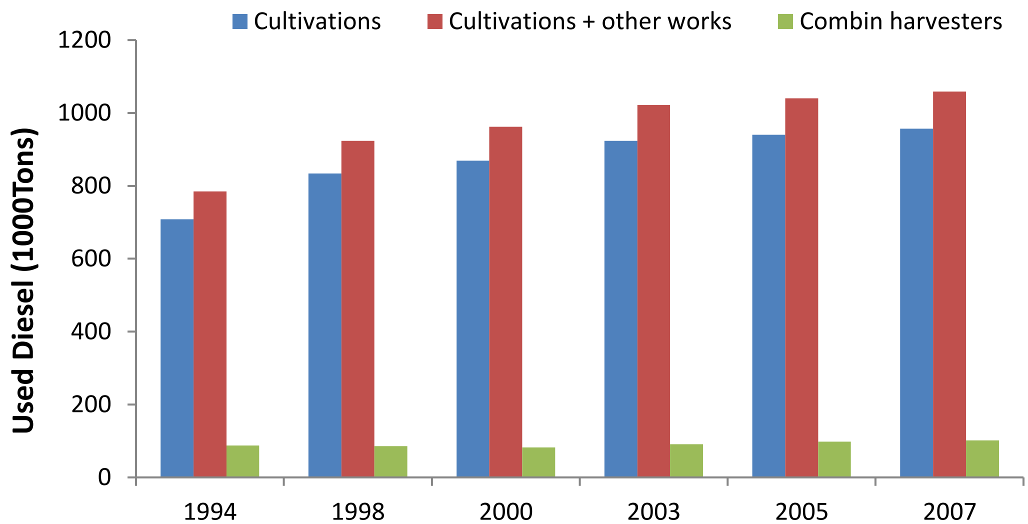

Figure 6. Change of diesel use by agriculture machinery in Syria for 1994-2007.

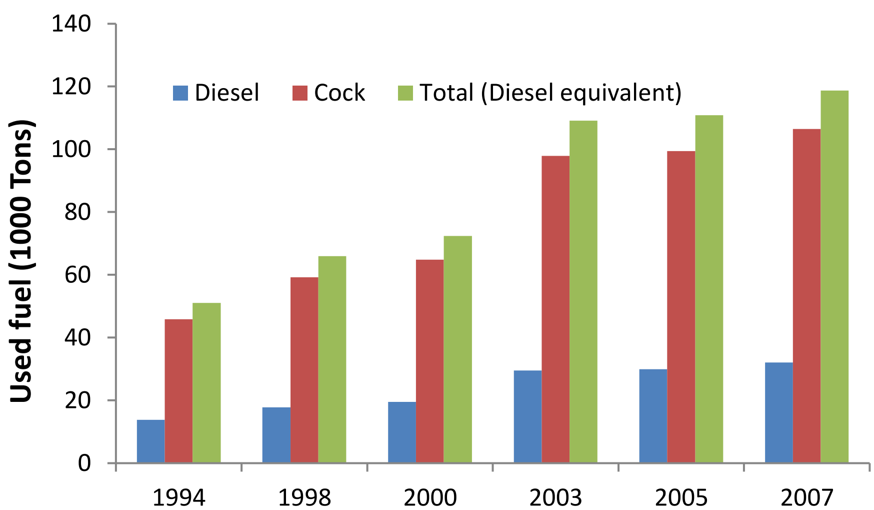

Figure 7. Change of fuel use for poultry barns heating in Syria for 1994-2007.

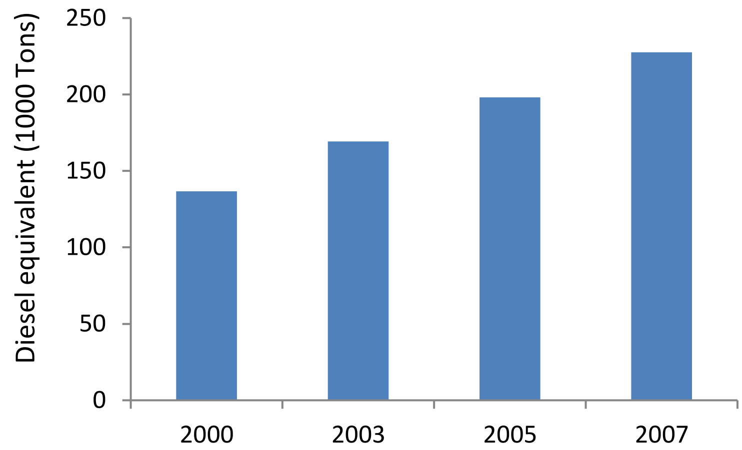

Figure 8. Fuel use for heating Green houses in Syria for 1994-2007.

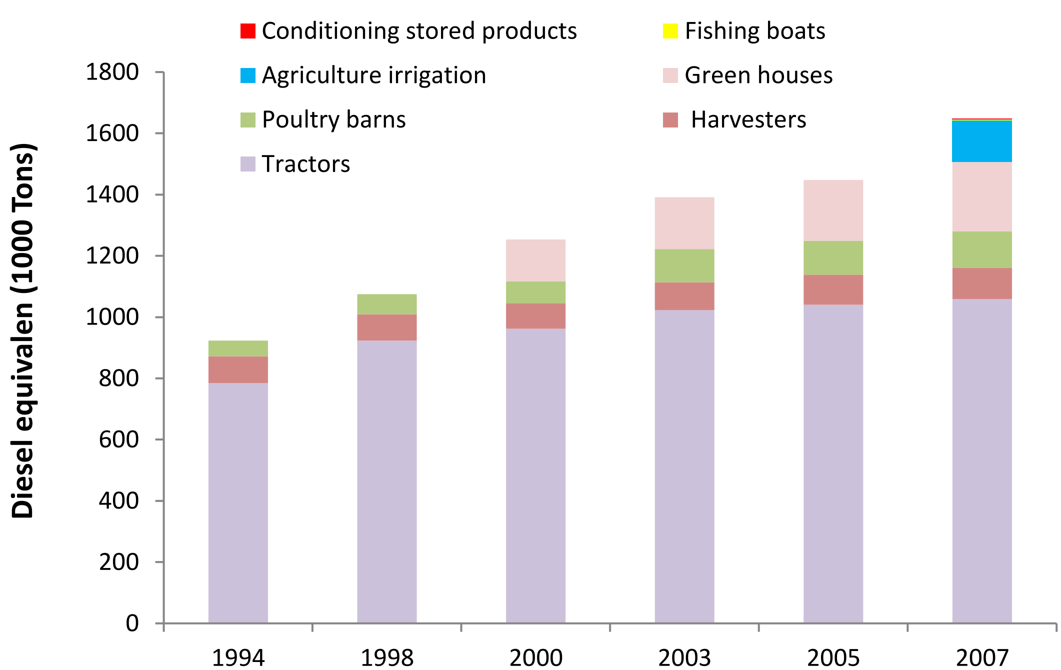

Figure 9. Change of energy by agriculture activities in Syria for 1994-2007.

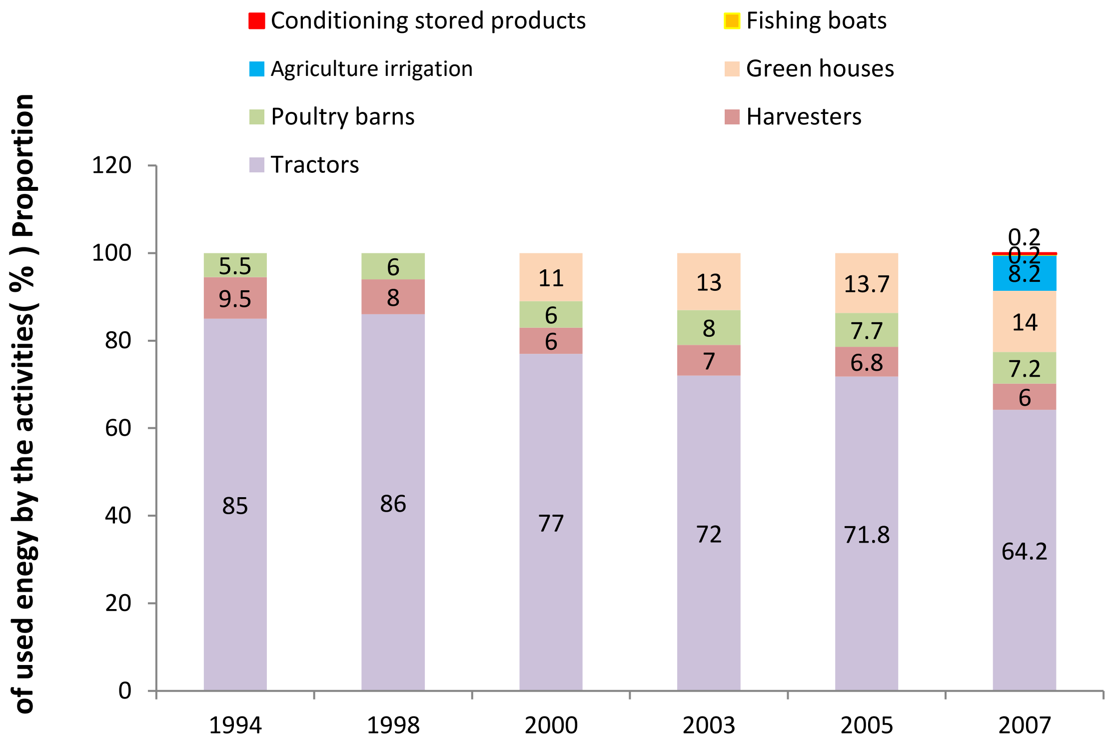

Figure 10. Contributions of agriculture activities in energy use in the agriculture sector for 1994-2007.

Expectations of agriculture development in Syria for year 2030 indicate increases in all activities except irrigated agriculture because of limited water resources and the drastic increases of human and industrial demand for water. The development of activities will be accompanied with similar increases in energy use (Table 2, and figures 6, 7, 8, 9, and 10). The expected increases in energy use (Tone diesel equivalent) by the activities are (Table 3): 53803 by tractors, 6388 by combine harvesters, 2106 by fishing boats, 1820 by cooling stored agriculture products, 284557 by heating green houses, and 151960 by heating poultry barns. The total expected increases in the used energy between year 2007 and 2030 in the agriculture sector in Syria would sum up to 500634 tons diesel equivalent (Table 3).

Table 3. Expectations of the increase in energy use and its GHG emissions in the agriculture sector in Syria in 2030 than in year 2007

Agriculture Activity	**energy use increases in Diesel equivalent (Tons)**	**Emission increase CO_{2e} (Gg)**	**Increase percent (%)**
Tractors	53803	191.13	6.3
Comb. harvesters	6388	18.28	6.3
Fishing boats	2106	6.06	60
Agric. Irrigation	0	0	0

Cooling stored agric. Products	1820	5.22	60
Green houses	284557	815	125
Poultry production	151960	432.13	128
Total	**500634**	**1467.82**	**31**

3. GHG emissions in the agriculture sector in Syria and the expectation for year 2030

The quantities of GHG emissions in the agriculture sector vary with the different emitting sources, and the major source of emissions is land use change. Burning savanna and crop residues, forest fires, N fertilization, farm animals, and energy use by the different agriculture activities would increase the emissions.

3.1. GHG emissions from energy use in the agriculture sector in Syria and the expectations for year 2030

Energy use increases in the different agriculture activities (Figure 10), have been accompanied with increases in GHG emissions. The calculations are based on the Syrian conversion factors of Caloric content (C C) and carbon emission factors (CEF) are used in the calculations (appendix table 5[12]). The aggregated emission factors (EF) of CH_4 and N_2O resulted from using the IPCC factors for each energy source used in the agriculture sector [5, 13, 14) are used in the calculations for the total used energy in diesel equivalent by the different agriculture activities (Appendix table 6).

The total emissions of CH_4 and N_2O are 0.1% of the total GHG emissions (CH_4, N_2O, CO2), a negligible contribution compared to the 99.9% of CO_2 (Appendix table 7). However, the effective contribution of CH_4 and N_2O gases in GWP is higher when converted to CO_2 equivalents (CH_4 values are multiplied by a factor of 21 and N_2O values are multiplied by a factor of 310 [13]). The CO_2 equivalents (CO_{2e}) for CH_4 and N_2O gases is 2.7% of the total GHG emissions as CO_{2e}, a value still very small compared to the 97.3% of CO_2.The proportion of the two gases in the emissions were constant over the years between 1994 and 2007 (Appendix table 7).

The amounts of emitted GHG (CO_2, CH_4, N_2O) by tractors in 1994 were 2185.7Gg CO_2 and 2.1 Gg N_2O + CH_4 (60.8 Gg CO_{2e}), summing up to 2246.5 Gg CO_{2e}. These gases increased by 23% in year 2000 and they were in year 2007 2950.9 Gg CO_2, and 3033.9 Gg CO_{2e}, an increase of 10% than in the year 2000 (Figure 11, and appendix table 7). The emissions from the used energy by combine harvesters also increased by 6% in year 2000 than in year 1994, and they were in 2007 about 282.5 Gg CO_2, and 290.2 Gg CO_2e, a 23% increase than in year 2000 (Figure 12 and Appendix table 7). The percent of increases in gases emissions from the used energy in Green houses was higher than other activities, and the emissions in year 2007 were 634.3 Gg CO_2 and 652 Gg CO_{2e}, a 67% increase than in 2000 (Figure 13 and Appendix table 7). The increases in gases emissions were also high from the used energy for heating poultry barns, and emissions were 42% higher in year 2000 than in 1994 and 64%

higher in 2007 than in year 2000, and the emissions in 2007 were 330.8 Gg CO_2 and 337.6 Gg CO_{2e} (Figure 14 and Appendix table 7). GHG emissions from the used energy for agriculture irrigation in 2007 were 386.9 Gg CO_{2e}, of which 376.4 Gg is CO_2 (Appendix table 7). The emissions in 2007 from energy use for cooling stored agriculture products were 8.7 Gg CO_{2e} of which 8.4 Gg CO_2, and from the used energy by fishing boats the emissions were 10.1Gg CO_{2e} of which 9.8Gg CO_2 (Appendix table 7).

The above mentioned estimates of GHG emissions from the used energy in the different agriculture activities in 2007 show that the total emissions were 4721.2 Gg CO_{2e} of which 4593.1Gg CO_2, 90.3 Gg CO_2 equivalent to CH_4 and 37.8 Gg CO_2 equivalent to N_2O (Figure 15 and Appendix table 7). The highest contribution to the emissions comes from the energy used by tractors and was 66% of the total emissions of CO_{2e} from the use d energy in the agriculture sector in 2007 (Figures 16 and 17, and Appendix table 7). The contribution of the other activities to the emissions of CO_{2e} were as follows; 14% from heating green houses; 8.4 % from agriculture irrigation; 7.3 from heating poultry barns, 6.3% from combine harvesters, 0.2% from fishing boats, and 0.2% from cooling stored agriculture products (Figure17).

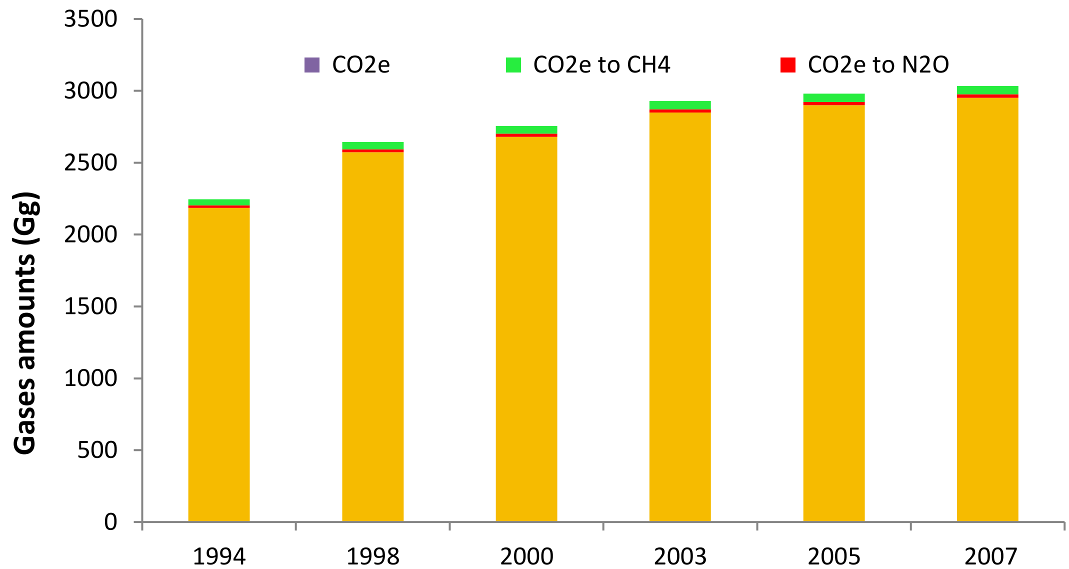

Figure 11. GHG emissions by tractors used fuel for 1994-2007.

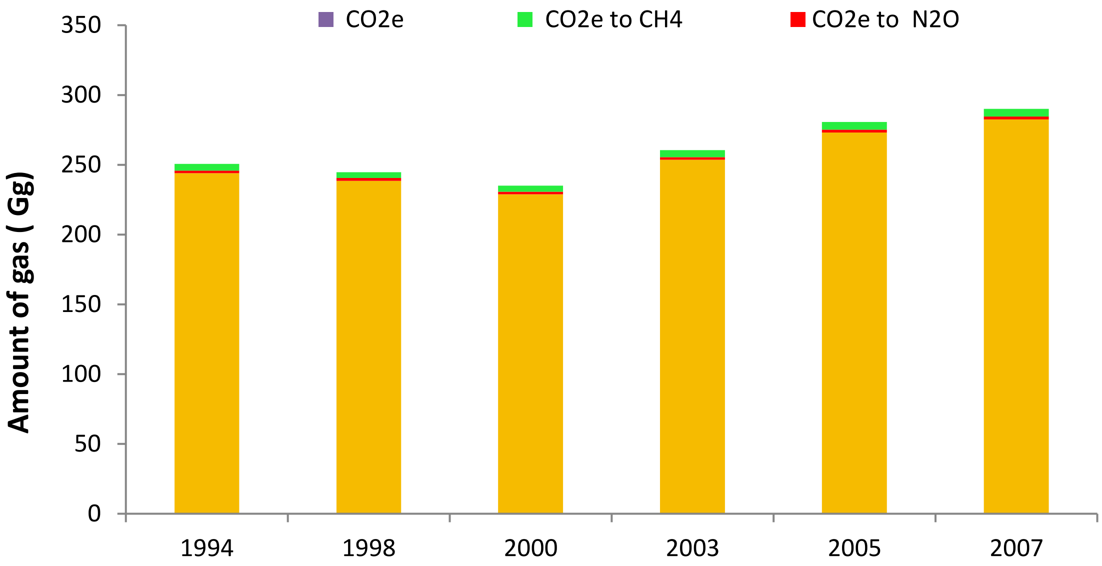

Figure 12. GHG emissions by combine harvesters used fuel for 1994-2007.

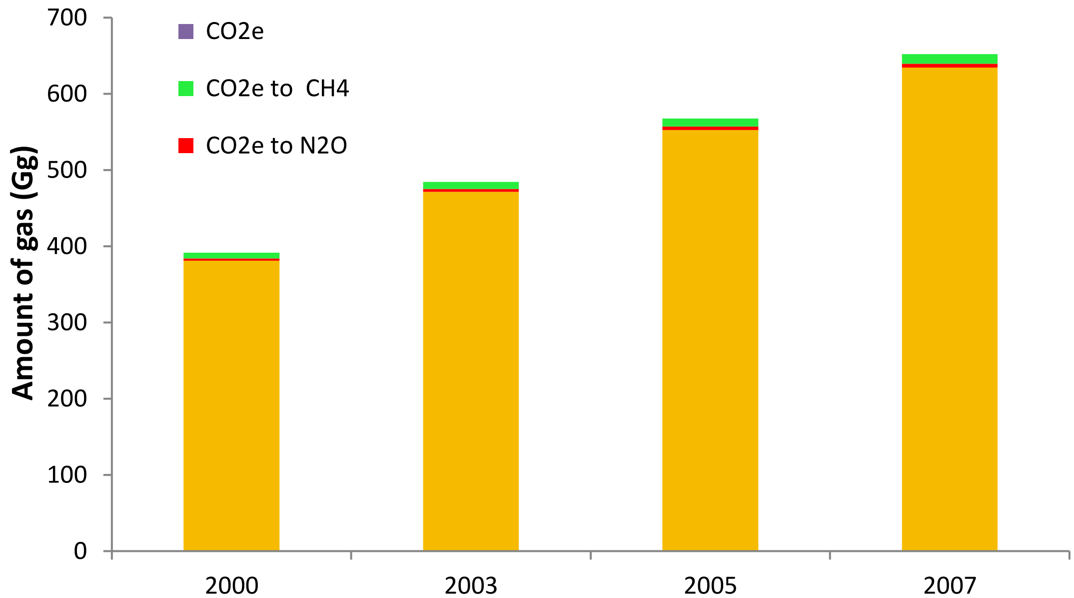

Figure 13. GHG emissions by heating green houses fuel for1994-2007.

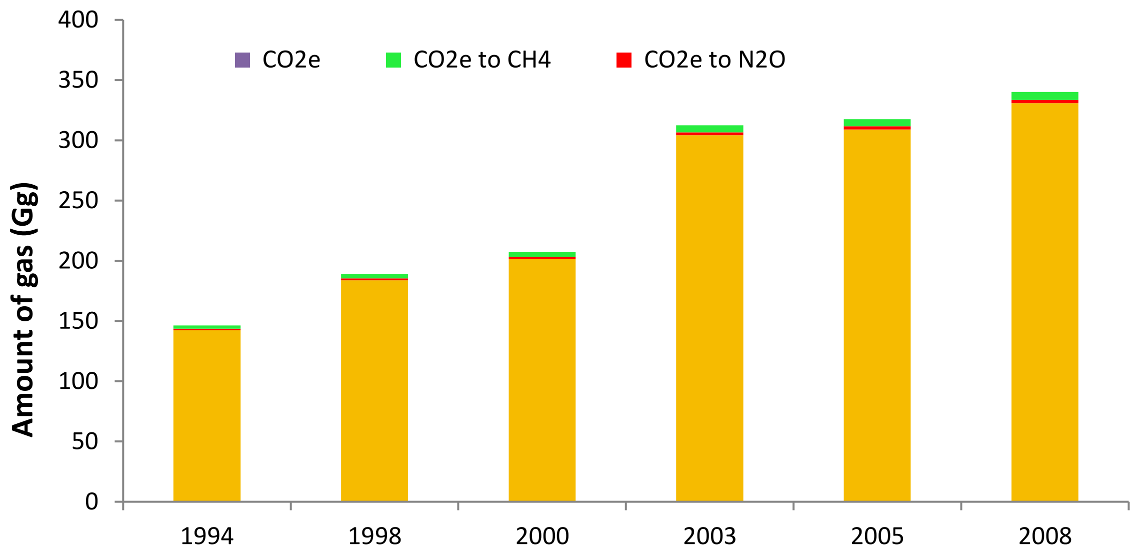

Figure 14. GHG emissions by heating poultry barns fuel for1994-2007.

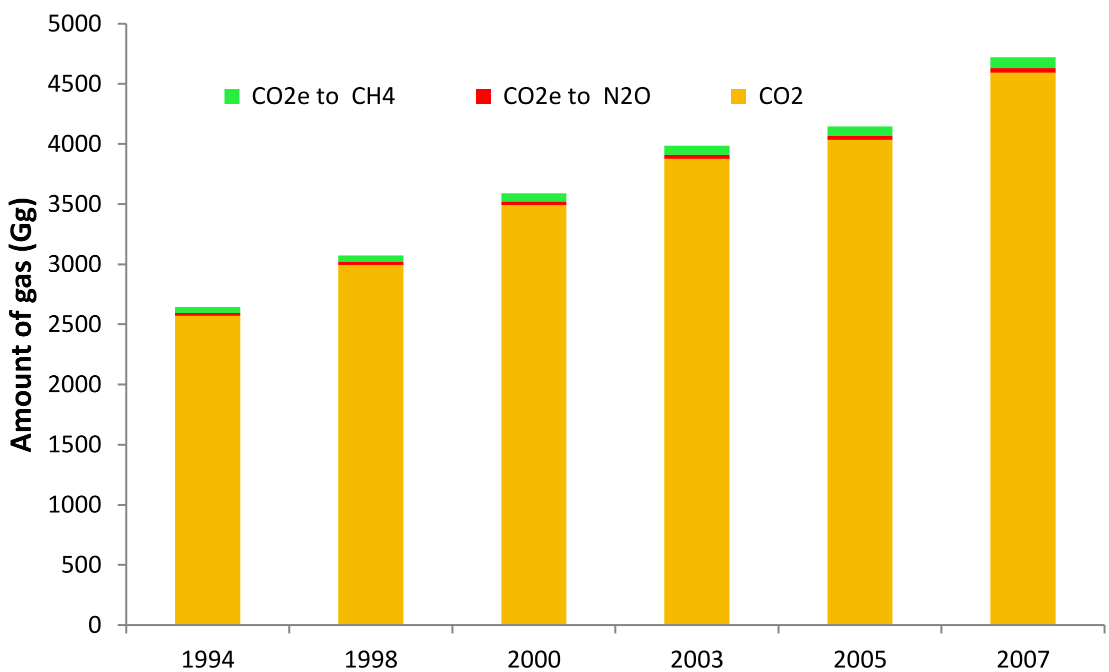

Figure 15. Total and forms of GHG emissions by energy use in agriculture for 1994-2007.

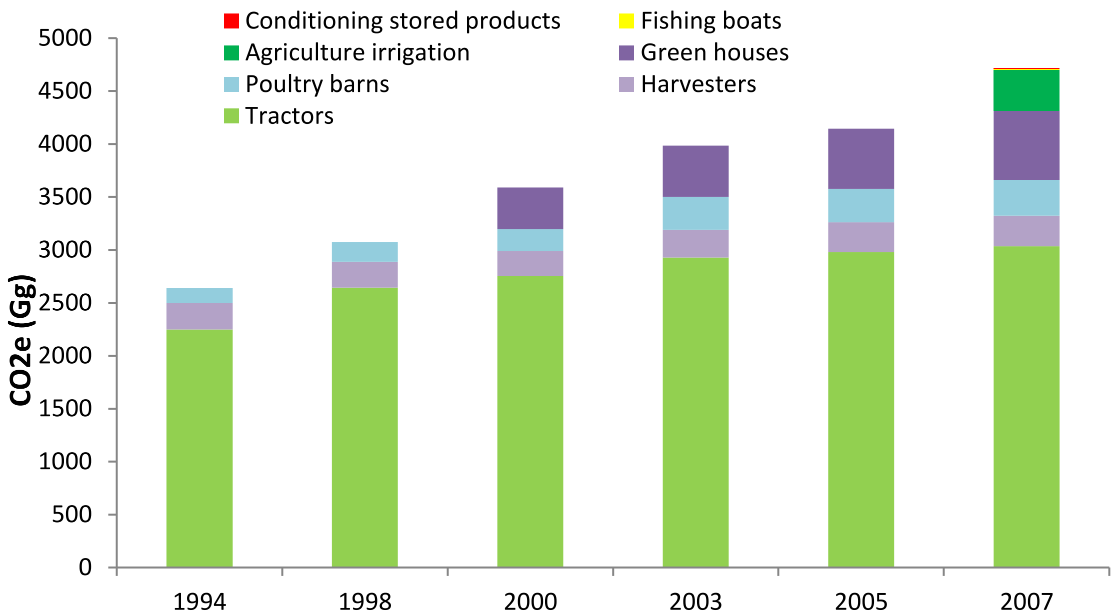

Figure 16. Change of GHG emissions by energy use in agriculture activities for 1994- 2007.

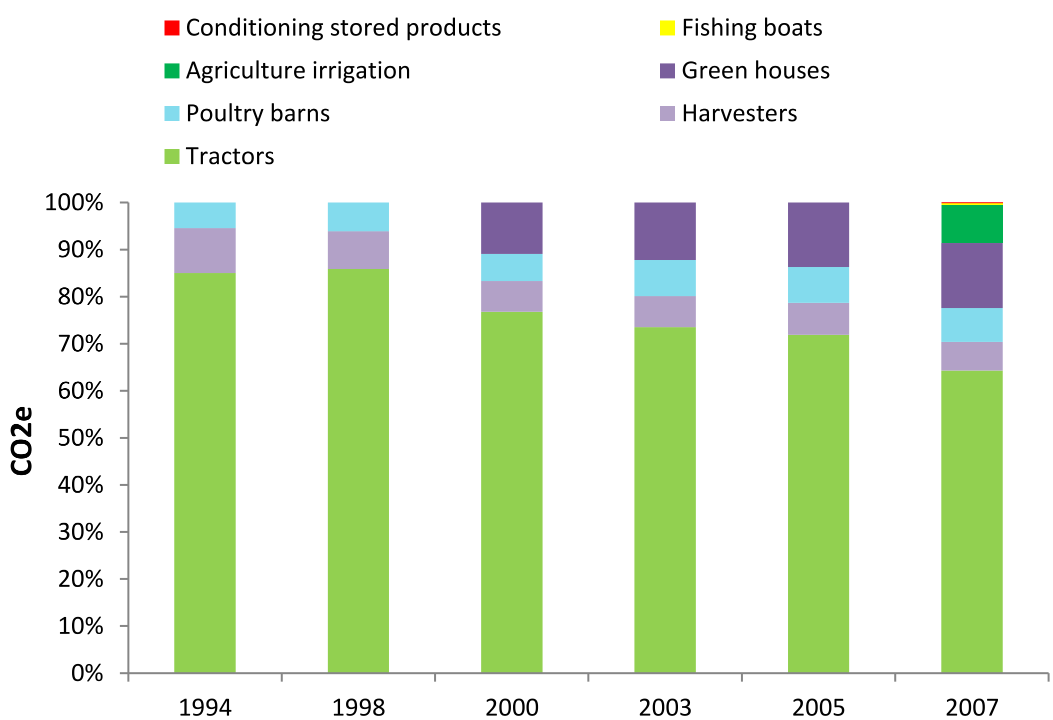

Figure 17. Contributions of agriculture activities to GHG emissions for 1994-2007.

Increases in GHG emissions will also accompany the expected increases in the use of energy in agriculture activities in 2030, and the percent of increases in emissions would be similar to the increases in energy use in the different activities (Table 2). The expected increases in GHG emissions in Gg CO_{2e} are (Table 3): 191.13 by tractors, 18.28 by combine harvesters, 6.06 by fishing boats, 5.22 by cooling stored agriculture products, 815 by heating green houses, and 432.13 by heating poultry barns. These emission increases in 2030 sum up to 1467.82 Gg CO_{2e}, and is equal to 31% of the emissions from the used energy in the year 2007.

3.2. GHG emissions from agriculture forests and rangelands in Syria and the expectations for year 2030

GHG emission studies in Syria [4] reported that the total emissions in agriculture, forests and rangelands were 58561.2 Gg CO_{2e} in year 2006 of which; 42343 Gg CO_{2e} by forest fires and conversion to steppe or cropping land; 227.6 G g CO_{2e} by burning savanna; 1322 Gg CO_{2e} by burning crops residues; 11178.6 Gg CO_{2e} from soil and N fertilization and 3490 Gg CO_{2e} by farm animals and its waste. The emission of GHG is expected to increase in year 2030 by 110112 Gg CO_{2e} than in year 2006 (based on the rate of increase between years 2000 and 2006). In addition, the expected increase of 6.3% in the area of cultivated land and in the use of N fertilizer will increase emissions by 704.2 Gg CO_{2e}. The emissions by farm animals will also increase by 4945.91 Gg CO_{2e} in year 2030 than it was in year 2006, a consequence of the expected increasing numbers of farm animals (Tables 2 and 4). The GHG emissions from other sources are not expected to increase because the area of burning savanna and crops residues as well as forest fires are not expected to increase due to the actions implemented by the concerned parties to protect and develop forests and rangelands, and to prevent burning crops residues. The total increase in GHG emissions from forest, rangelands, and agriculture in year 2030 than in 2006 will sum up to 16661.3 Gg CO_{2e}.

Table 4. Emissions of CH_4, N_2O, and CO_2e by the expected increase of farm animals in year 2030 in Syria.

Animals	Increase of animal numbers[1] (1000 animals)	Total emissions of CH_4 Gg/year	Total emissions of N_2O Gg/year	Total emissions CO_2e Gg/year
Dairy cows	511.92	19.45	0.024	415.9
Nondairy cows	36	1.19	0.0004	756.1
Sheep	31500	162.54	0.119	3450.2
Goats	1480	7.65	0.019	166.5
Camels	61.2	2.93	0.0008	61.8
Mules & Donkeys	− 112.1	− 1.22	− 0.0014	26 −
Horses	− 13.3	− 0.26	− 0.0002	5.5 −
Hens	37267.92	5.03	0.049	120.82
Buffaloes	4.8	0.29	0.00006	6.11
Total	−	197.6	0.21066	4945.91
[1]Calculated using the annual changing rate between years 2000 and 2006 [4].				

3.3. Total GHG emissions in the agriculture sector in Syria and the expectations for 2030

It is agreed to consider year 2006 as the base year for calculating the total emissions of GHG in the agriculture sector, and therefore the values of GHG emissions from the used energy in agriculture in 2007 are recalculated for the year 2006 to integrate with the emissions in agriculture and forests. The available rates of emissions between years 2000 and 2007 are used, whereas the same emission values in 2007 for cooling stored agriculture products and fishing boats are used because no other information is available and a change of one year in this case could be negligible (Appendix table 7). The emissions from energy use in agriculture irrigation in 2006 are calculated by using the average annual increase percent of irrigation pumps between year 2000 and 2007 (figure 2). Accordingly the annual increase of emissions from agriculture irrigation equals 124.4 Gg CO_{2e}, and by Subtracting this value from the emissions in 2007 the emissions in 2006 would be 4595.01 Gg CO_{2e} (Table 5). In addition, the increase in GHG emissions from the expected increase in energy use between years 2007 and 2030 is modified to be for the period between 2006 and 2030 by adding the increase of emissions from the annual increase of energy use between 2000 and 2007 to the expected increase in emissions between 2007 and 2030 (Tables 3 and 5).

Based on the above considerations the total GHG emissions in the agriculture sector in year 2006 equals 63156.21 GgCO_{2e} of which 7.3% is by energy use and the rest are the emissions by agriculture, forests and rangelands. Expectations for year 2030 indicate that GHG emissions will increase by 18253.52 GgCO_{2e} that equals 28.9% of the emissions in year 2006. Only 8.7% is due to the increase in energy use, and 91.3% is due to increases in agriculture activities. These proportions suggest that the percent increase of emissions by energy use is more than the percent increase by agriculture activities.

Table 5. GHG emissions by energy use in the agriculture sector in year2006 and by the expected increase in year 2030 than in 2006

Agriculture Activity	Rate of emission change CO_2e (Gg/year) 2007-2030	Emissions CO_2e (Gg) In 2006	Emission increase CO_2e (Gg) In 2030 than 2006
Tractors	38.8	2995.1	229.93
Comb. harvesters	7.87	282.33	26.15
Fishing boats	Not available	10.1	6.06
Agric. irrigation	21.67	365.23	21.67
Cooling stored agric. Products	Not available	8.7	5.22
Green houses	37.23	614.77	852.23
Poultry production	18.82	318.78	450.95
Total	124.39	4595.01	1592.21

4. Actions to rationalize and mitigate energy use and its GHG emissions in the agriculture sector in Syria and the expectations for the year 2030.

Estimates and expectation showed that GHG emissions by energy use in the agriculture sector would increase by 35% in year 2030 than in 2006. Therefore, it is wise to search for all the means, methods and actions that would help to rationalize and mitigate the use of energy in agriculture activities especially the used by tractors and has contributed up to 65% of the gas emissions by the used energy in year 2006.

4.1. Developing the present agriculture systems and the expectations for the year 2030.

The calculated values of GHG emissions by energy use in the different agriculture activities show that, the major portion of the emissions is by the locomotive energy particularly by tractors (Figure 17) for the conventional intensive and deep cultivations. Therefore, we need to replace the present farming systems by systems that limit or abandon cultivations, promote agriculture development, sustain and increase production to provide the growing needs of the society in quantity and quality. Conservation Agriculture has been developing over the last 8 decades to improve and sustain soil productivity, prevent soil degradation and erosion, combat desertification, and mitigating climate change on earth especially in dry and semi dry regions characterized with harsh ecosystems and limited resources.

Scientific validation of Conservation Agriculture (CA) showed that the system could reduce; the number of tractors needed for work, energy use by 60-70%, working hours of machinery by 65%, working hours by 60% and irrigation water by 42% for rice and 26% for wheat [15]. In addition, CA increases the annual accumulation of soil organic matter by 0.1-0.2% until saturation, increases carbon sequestration in soil by 74%, improves soil structure and texture and soil biological activity and the biomass, improves soil water holding capacity, reduces water runoff (by 90%) and evaporation, and improves soil fertility (which reduces fertilizers use especially chemical fertilizers), and on the long run it reduces the use of herbicides. Application of CA will also prevent burning crops residues, which in turn reduces GHG emissions and protects soil microorganisms and improves their activity.

Conservation Agriculture has 3 basic rules [16]: 1) Direct drilling or no till, 2) Soil cover, and 3) Crop rotation. Direct drilling (No Till) excludes cultivations and plants the seeds directly in the soil at a depth of 6-8 cm through a thin Till made in the soil by a special machine pulled by tractors. Fertilizers could be added at the same time by the same machine. Different Direct Drillers are available for the different crops including root and tuber crops… etc. The soil is covered either by leaving 20-30% of crops stand over the soil when harvesting crops, or by growing cover crops during the intervals between the main crops then mow it and leave the residues on the top of soil, or the cover crops might be grazed moderately leaving 20-30% of the stand over the soil. Crop rotations include legume crops to improve the quality of soil organic matter and soil fertility. Besides, rotations may also include crops that would control weeds, which reduces the use of herbicides or on the long run dispense with it.

Implementing Conservation Agriculture in Syria started two years ago on small areas of land with few farmers in collaboration with the Syrian Ministry of Agriculture, the Arab Center ACSAD, and the German Agency for Technical Cooperation GTZ. The preliminary results are good, however, the data could not be authenticated for less than 5 years, and because it does not cover all the mentioned subjects. Therefore, the international data is used in the calculations for reductions in energy use and the resulting reduction in GHG emissions bearing in mind that these reductions might be more or less under local conditions.

Assuming that implementing Direct Drilling in Syrian agriculture will reduce the used fuel by 65% (Mean percent of reduction by CA), then emissions of CO_{2e} from the used fuel by tractors in year 2007 will decrease by the same percent, that is equal to 1972 Gg CO_{2e}. Another assumption is that implementing CA in Syria will reduce the amount of irrigation water (present systems) for wheat by 26%, and then the used energy in agriculture irrigation will decrease by the same percent hence emissions of CO_{2e} will decrease by the same percent which equals 100.6 GgCO_{2e} in year 2007. In addition implementing modern irrigation systems and techniques will reduce the used diesel equivalent fuel in agriculture irrigation by 6.5% “as well as about 20-35% of irrigation water” [17], then emissions of CO_{2e} from the used energy in agriculture irrigation will further decrease by the same percent which equals 25.1Gg CO_{2e} in year 2007. The total decrease in CO_{2e} emissions by energy use in the agriculture sector induced by implementing CA and modern irrigation techniques would sum up to around 2097.7 GgCO_{2e} /year that is equal to 44.4% of the total (4719.4 GgCO_{2e}) GHG emissions by the used energy in the agriculture sector in year 2007.

Implementing CA will further reduce GHG emissions resulting from the increase in energy use by tractors when expanding the area of cultivated land as expected by year 2030, and the reduction equals 124.2 GgCO_{2e} (Table 3). Therefore, the total reduction in GHG emissions that might be induced by implementing CA and modern irrigation techniques equals around 2221.9 GgCO_{2e} in year 2030.

4.2. Production of biogas (CH_4) from livestock waste as energy source and the expectations for the year 2030

Biogas CH_4 could be produced in Syria from the waste of farm animals’ in barns (dairy and nondairy cows, Buffalos, sheep an hens) as a source of energy (Before it is used as organic fertilizers to improve soil fertility). Only animals raised in barns are considered because collecting animals’ solid waste is easy and cost effective. The estimated amount of biogas that could be produced by anaerobic fermentation unit if the entire solid wastes of farm animals in barns (dairy and nondairy cows, Buffalos, 20% of sheep, and hens) are used, equals 13.34Gg CH_4 in year 2006 (Appendix table 10). The estimated production of CH_4 could increase several folds by improving the efficiency of the anaerobic fermentation.

The produced biogas from the waste of farm animals would reduce GHG emissions in the agriculture sector by two ways:

A- The produced energy from CH4 would reduce the used amounts of other energy sources by an equal amount of energy and the GHG emissions incurred by that amount from other sources. The Caloric contents of 1Kg CH4 equals 54.8 MJ [14], and the total heat energy of the estimated produced Methane in year 2006 (13.34Gg CH_4) would equal 731.032 GJ. Therefore, the reduced amount of diesel equivalent fuel equals 18.27Gg (Appendix table 6), and the reduced amount of GHG emissions would equal 840.7 $GgCO_{2e}$, which is equal to 17.8% of the total emissions (4719.4 $GgCO_{2e}$) from the used energy in the agriculture sector in year 2007.

B- The produced amount of Methane (13.34 $GgCH_4$ = 280.14$GgCO_{2e}$) from the solid waste of farm animals for heating energy would equally reduce CH_4 emissions in the agriculture sector. However, burning the Methane gas will emit 36.68 $GgCO_2$ (75% of CH_4 is C and will be converted to CO_2), therefore the net reduction in CH_4 emission from the agriculture sector would be 243.46 $GgCO_2$ (280.14 $GgCO_2$ - 36.68 $GgCO_2$).

Expectation for developments in the numbers of farm animals indicate large increases by year 2030, for example there will be 37.3 million hens and 31.5 million sheep than there were in year2006 (Table 2). That is in response to the increasing demand of society with population growth and the changing style and patterns of people's life. These large increases provide more solid waste to produce biogas as energy source and reduce GHG emissions in the agriculture sector.

Appendix table (10) indicates that an amount of 27.49 $GgCH_4$ could be produced (by anaerobic fermentation in the digester) from the solid waste of farm animals in barns in the year 2030. This will reduce GHG emissions in the agriculture sector by 2234.5 $GgCO_{2e}$ that is double the reduced amount in year 2006 (See the above section B).

4.3. Total mitigation of GHG emissions by reducing energy use in the agriculture sector and by using biogas in the year 2006 and expectations for the year 2030.

The information in the above section (4.2.) show that implementing CA, using modern irrigation technologies and using the biogas produced from the solid wastes of farm animals, will reduce GHG emissions in the agriculture sector by 3150 $GgCO_{2e}$ in year 2006, and is expected to increase by 75% in 2030 (Table 6). Implementing CA contributes about 65% of the total reduction in emissions in year 2006, and will only contribute 6.5% of the expected increase in the reduction (2392.4 $GgCO_{2e}$) of GHG emissions in year 2030 (Table 6). Using the biogas contributes around 34% of the total reduction in the emissions in year 2006 and will contribute up to 93% of the

expected increase in the reduction of emissions in year 2030 (Table 6). In conclusion the total reduction in GHG emissions in year 2006 equals 68% of the total GHG emissions by the used energy in the agriculture sector in that year. In year 2030 the total expected increase in the reduction of GHG emissions 1.5 times of the expected increase of the emissions of CO_{2e} in year 2030 (Tables 5 and 6). However, the numbers of farm animals will increase by time, and the production of biogas from the solid waste of farm animals shall increase and its contribution to the reduction of GHG emission will increase too.

Table 6. Contributions of energy use reduction and biogas production in mitigating emissions (Gg) of CO_2e in the agriculture sector in year2006 and the expected increase in year 2030

Applications	2006	2030	
	reduction of emissions	Increases of emissions reduction than 2006	Total reduction of emissions
Conservation Agric.	2041.8	156.5	2198.3
Modern irrigation techniques	23.7	1.4	25.1
Use of Biogas	1084.2	2234.5	3318.7
Total	3149.7	2392.4	5542.1

4.4. Indirect actions to mitigate energy use and its GHG emissions

Mitigation of CO_{2e} emissions by other productive activities could be done by implementing actions that reduces energy use. For example, improving heat insulation and distribution as well as the burning efficiency of fuel in green houses and poultry barns could reduce their energy use. Fishing boats too are old and need improvement to increase their efficiency in fishing and energy use. These actions, however, require studies to collect the needed data and information to take the proper actions to improve the efficiency of energy use and to save it in those activities.

5. Actions to increase C sequestration, reduce C and N emissions, and reduce fertilizer use in the agriculture sector in Syria

The lands in Syria are highly vulnerable to human activities and change of land use. Around 94% of the land is dry and semi-dry, with 95-97% is vulnerable to degradation, and 94% will be impacted by climate change [18]. Unsustainable utilization systems for land resources and encroachments on forests and rangelands degraded 18% of the total area of Syria [19]. These conditions increased emissions of C and N from lands and they form 94% of the total emissions by agriculture activities, and are 87% of the total emissions in the agriculture sector in year 2006 (Table 7). GHG emissions, however, are expected to increase by agriculture activities and their energy use in year 2030, and it equals around 18253.5 $GgCO_{2e}$ that is 29% of the total emissions in year 2006 (Table 7). The increases of emissions from land and fertilization are 64% of the total increase in GHG emissions in year 2030, whereas the emission increases by farm animals contributes around 27%, and the emission increases by energy use contributes 9% (Table 7). Burning savanna and crops residues is expected to

seize due to prohibiting actions and laws implemented by the concerned parties in addition to peoples collaboration. On the other hand, burning and converting forests to cropping land will not increase.

Carbon (C) sequestration by forests in Syria is estimates by 170438.1 $GgCO_{2e}$ in year 2006(Table 7), and despite forest degradation it is expected to increase at a rate of 3089 $GgCO_{2e}$ /year (based on the average increase between years 2006 and 2030) due to the annual growth of forest plants and the annual increases in afforested areas. Increases of the sequestered C by forests in year 2030 is estimated by 74136 $GgCO_{2e}$, an increase of 43% than the than the forest C in year 2006 (Table 7).

The carbon balance in the agriculture sector in Syria show that the net values of sequestered C (CO_2) and emissions and reductions of GHG leave an excess amount of the sequestered C in forests equals 107282 GgCO_2 in year 2006 and shall increase in year 2030 by an amount of 60776 GgCO_2. Therefore the total net amount of the sequestered forest C in year 2030 is equal to 168058 GgCO_2 (Table).

The C balance in Table (7) show that GHG emissions would be around 81410 GgCO_{2e} in year 2030 with no consideration to any mitigation actions. The amount, however, will decrease to 76517 GgCO_{2e} due to the mitigation actions implemented by the government and the production of biogas from the solid wastes of farm animals and its use as energy source (Table 7). Therefore, the net increase in GHG emissions in year 2030 than the emissions in 2006 is 21%. Despite the fact that C sequestration by forests is far more than Increases in GHG emissions, mitigation actions are required to reduce the emissions from land and fertilization, and energy use along with increasing production to provide the increasing needs of society for food and other agriculture commodities. In addition, efforts for increasing C sequestration should be intensified to mitigate the present and expected increases in GHG emissions in the agriculture sector and other sectors.

The Syrian government has put great efforts over the last decade to combat degradation and desertification of land, and mitigate emissions of C and N as well as climate change through forestation projects, restoration of rangelands and prohibiting its cultivation, stabilizing sand dunes, planting green belts and wind breaks, enhancing drip and sprinklers irrigation net works and other modern irrigation techniques, introducing sustainable agriculture systems such as Conservation agriculture, and ratifying laws and regulations for protecting rangelands, forests, and arable land. The effort yet are short compared to the size and threats of the expected adverse impacts, and are confined to projects here and there that covers small parts of the degraded land, lands vulnerable to degradation, and non-agricultural lands[19 and 20]. In the energy domain, the efforts are still incapable of providing the requirements for development and controlling the increases of GHG emissions. Overcoming these, conditions require implementing several actions and means for improving agriculture systems, forests and rangelands, and energy use to increase C sequestration and mitigate the emissions of C and N along with providing the needs for development.

Table 7. The balance of emission, sequestration, and mitigation of GHG in the agriculture sector in 2006 and the expectations for 2030 as based on present activities

Agriculture activities	2006[1]	2030[1,2,3]	
	Emissions (+) & Sequestration (−) Gg CO_{2e}	Increases from 2006 Emissions (+) & Sequestration (−) Gg CO_{2e}	Mitigation of emissions Gg CO_{2e}
Cultivated land and fertilization	+ 11178.6	11715.4 +	0
Burning & converting forest & rangeland for cropping	42343 +	0	0
Burning savanna	227.6 +	0	−227.6
Burning crop residues	1322 +	0	−1322

land management sum	+ 55071.2	+ 11715.4	−1549.6
Farm animals	+ 3490	+ 4945.9	0
Agriculture activities sum	+ 58561.2	+ 16661.3	−1549.6
Energy	+ 4595	1592.2+	−25.1[5]
Carbon emissions sum	+ 63156.2	+ 18253.5	0
Biogas use	0	0	−3318.7 [6]
(−) Mitigation sum	0	0	−4893.4
Net mitigation (−) & emission (+)	63156.2 +	13360.1 +	
Forest (C) sequestration[4]	170438.1 −	− 74136.0	
Net mitigation (−) & sequestration (−) & emission (+)	−107281.9	60775.9 −	
[1]values from section (3.2., [4]) and table (4). [2] Agriculture values from table (4). [3]Energy values from table (5). [4]Source: [4] . [5]Mitigation by developing irrigation methods and techniques. [6]the value is due to mitigating 2588 Gg CO_2 e from energy emissions and the rest from animal emissions.			

5.1. Actions to increase C sequestration

Developing natural vegetation cover in forests and rangelands is the main factor for increasing C sequestration and decreasing C concentration in the atmosphere. The second important factor is developing agriculture systems for increasing C sequestration. That is because the amount of soil C is (1580 Gt) double the C in the atmosphere and is approximately 3 times the C in the vegetation cover [21]. Therefore, all actions and means should be implemented to develop forests and rangelands.

5.1.1. Developing forests and increasing forested area

Forests and woods are the smallest form of land use in Syria covering an area of 0.502 Million hectares. Old natural forests cover 0.233 Million hectares, and new forests planted in accordance with the forestation plan of the government cover 0.269 Million hectares [7]. Deciduous trees cover 75.5% of the forests area and conifers cover 24.5%. Quercus trees alone cover 58% of the forests area; Pin trees 27%, Pistacia Atlantica 8%, and the rest are divers species [9]. The conditions of the natural forests are characterized under 3 groups; 1) Climax or pre-climax forest with complete or semi- complete vegetation cover forms 25% of the natural forests area, 2) Maqui stage forests form 50% of the area, 3) Heavily degraded areas and don't have a form of forest population and is 25% of the area. However, despite increases in forests area the area per capita decreased by 40% in year 2006 [18].

Forests are the main terrestrial store for carbon, and the annual rate of C sequestration per hectare in Syria equals 2.25 tons C/ hectare/year, which equals 8.25 tons CO_2/ hectare/year. Deciduous trees sequester around 28% and conifers sequester 72%. This indicates that conifers sequester C 2.6 times more than deciduous trees, because its growth rate is higher than deciduous trees by this ratio [7]. Therefore, it is necessary to increase the proportion of conifers in the forestation programs to sequester more Carbon.

Sequestered C in forests is distributed as follows: 44% in the giving mass above the ground, 6% in the dead wood, 4% in the forest floor, and 46% in the top 30 cm of soil [7]. It is therefore preventing soil erosion is an added main forests eco-service to carbon sequestration. In addition, the economic value of forests in Syria is mainly envisaged by soil and water conservation and carbon sequestration. The total direct income is estimated by 7.6 million €/year, and the indirect income (Based on the cost of damage incurred by floods and soil erosion occurring when forests are degraded ore converted to cropping land) is estimated by 45.1 million €/year [22]. The direct income value is attributed to the following resources: 45% as wood growth; 26% as fruits of Chestnut, laurus, and Rhus, and Thymus leaves; 19% as medicinal and aromatic plants; 3.5% as manufacturing wood ; 2.3% as honey, 2.2% grazing value, and 2% as wood fuel and as licensed and illegal charcoal production. The value of soil conservation and preventing flood damages is 94% of the indirect income of forests and the remaining 6% is the value of carbon sequestration.

In conclusion, the following actions are required for developing forests:

- Extending forestation projects to include reclaimed land for fruit trees plantations because the environmental revenues from carbon sequestration, soil and water conservation, preventing degradation and mitigating the adverse impacts of climate change are more important than the unsustainable production of fruit trees. In addition, the income from fruit trees plantations is compensated by the direct sources of income forests provide (see above paragraph).

- Increasing the proportion of conifers and reducing deciduous trees in forest plantation areas.

- Reforestation of degrade and burnt areas in forests.

- Introducing new trees that are tolerant to the local climatic conditions and of higher production efficiency for all selected sites and areas in a short term plan.

- Prohibiting the industrial utilization of forest wood for sustaining and developing the productivity and diversity of the vegetation cover, as the economic value of soil conservation and flood prevention is 150 times more than the value of trees wood. Also, the total income from the fruits and leaves of some trees and shrubs, honey, and medicinal and aromatic plants is 14 times more than the value of trees wood. However, if industrial utilization of forest wood is necessary, then it should be controlled by regulations and action plan for cutting the trees and replanting the utilized areas by the same type of trees.

- Developing the sources of sustainable direct income of forests, such as medicinal and aromatic plants, the fruits and leaves of some trees and bushes, and honey production, to provide income options to local populations and encourage them to protect and develop forests.

5.1.2. Developing natural rangelands

Rangelands are the main form of land use in Syria extending on 44% of the country area, and their degradation decreased the vegetation cover by 90% and plant production by 230Kg dry matter /hectare. These vegetation losses indicate a drastic reduction in carbon sequestration (By the plant cover after rationalized grazing), and regaining developing rangelands productivity would increase carbon sequestration by a minimum of 2folds the present sequestered amount. These developments require the following actions:

- Vast increases in the rehabilitation and plantation projects of the rangelands to cover all needy areas in a 5 or 10 years plan.

- Introducing new plants with high productive efficiency and are tolerant to the local climatic conditions in the rehabilitation and plantation projects.

- Vast increases in the protected areas in the Badia to regain the biodiversity and use it in rehabilitating degraded areas.

- Prohibit woodcutting in the Badia for sustaining and developing the diversity and productivity of the vegetation cover.

- Control grazing to avoid budding and flowering periods, and to rationalize stock rating and grazing duration. This would conserve, sustain and improve the quality and productivity of the plant cover.

- Develop genetic engineering programs to make use of indigenous and international plant species for producing more drought tolerant and more productive plants under local dry conditions.

- Disseminating biogas production technique from the solid waste of farm animals as a source of energy among the settled and nomad population of the Badia to reduce their reliance on cutting the wood that sequester carbon.

5.1.3. Dissemination and application of Conservation Agriculture in farmland

Introducing Conservation Agriculture (See section 4) to replace the present systems in farmland would increase carbon sequestration in soil by 74% as follows :

- Increases soil organic matter by 0.1-0.2% per year until saturation.

- Increases soil biomass and its activity.

5.2. Actions to mitigate emissions of C and N in the agriculture sector in Syria

Reducing the concentration of CO_{2e} in the atmosphere cannot be achieved by increasing C sequestration without controlling the continuous increases in GHG emissions. Therefore, actions and means that mitigate GHG emissions should be implemented along with all that increases C sequestration. Section 4 suggests the implementation of the following actions and means to mitigate C and N emissions:

5.2.1. Application and dissemination of Conservation Agriculture in Farmland

Implementing Conservation agriculture rather than the present systems in farm and mitigate C and N emissions as follows:

- Reducing emissions of CO_{2e} in year 2030 by 3% by reducing energy use in cultivations and agriculture irrigation (Tables 6 and 7).

- Increasing soil biomass and its activity, including N fixing micro- organisms whose N fixation increases by the increase of C sequestration.

- Reducing soil surface temperature, by mulching, and this reduces the rate of organic matter degradation and consequently the emissions of C and N.

- Enriching soil with nitrogen by including legumes (that fixes atmospheric N) in the rotations, a pillar of Conservation Agriculture, and this will indirectly reduce soil N emissions.

5.2.2. Production and use of biogas

Estimations of biogas (CH_4) production from the solid waste of farm animals and its use as fuel indicate that it would reduce emissions of CO_{2e} by 4% in year 2030, and this contribution would increase by improving the efficiency of its production and use and by increasing the amount of waste that could be utilized for its production (Table 7). In addition, its production and use by the population in the Badia would reduce C and N emissions from the wastes of their farm animals.

5.2.3. Improving the efficient use of fuel by agriculture machinery

Good fuel use efficiency by machines directly reduces GHG emissions by good combustion, and indirectly by saving energy. This could be achieved by the following:

- Provide the required routine maintenance for tractors.

- Renew agriculture machinery.

5.3. Reducing the use of fertilizers in Syria

Nitrogen fertilizers increase soil N emissions by decomposing and releasing N to the atmosphere during worm periods, and when applying high rates. This requires reducing fertilizer requirements and ore improving methods of application.

5.3.1. Application and dissemination of Conservation Agriculture in farmland

Implementing Conservation Agriculture rather than present systems in farmland would reduce fertilizer use by the following:

- Preventing losses of soil nutrients with soil erosion by reducing 90% of water runoff, and by reducing its leaching with water due to improving soil texture and structure and increasing soil organic matter.

- Improving contents of soil N by including legumes in crop rotations (A pillar of CA) to enrich soils with fixed N from the atmosphere.

5.3.2. Using more efficient methods for the application of fertilizers

There are several methods for applying fertilizers and reduce N emissions to the atmosphere, but there no available information to N emission in our conditions. International science, however, reported that good fertilization would reduce emission of N_2O by 30-40% of the conventional emissions. The main important methods are:

- Subsoil application of fertilizers.

- Add fertilizers with irrigation water.

- Apply appropriate rates of fertilizers.

- Use the least volatilizing N fertilizers.

- Split fertilizer application for more than additions.

5.3.3. Introducing livestock into the farming system

This system introduces forage crops including forage legumes. Forage legumes fixes nitrogen during the crop rotation and are grazed by farm animals, which fertilize the soil by their waste, or they might be mowed and stored to feed animals in their barns, excluding the direct fertilization by the grazing animals. In both cases, fertilizer requirements will decrease.

Estimates suggest that farm animals while grazing forage crops will drop their excretions on the soil adding an amount of 137 tones N/ year[Calculated on the basis that the number of animals introduced in the system are only 20% of the dairy and nondairy cows, and 5% of sheep in year 2030 (appendix tables 8 and 10)]. This would reduce the requirements of chemical N fertilizers, and would reduce N emissions compared the emissions by chemical N fertilizers. However, there is no available local information to estimate the incurred reduction in N.

5.4. Possible scenarios to mitigate GHG emissions, reduce fertilizers use and increase C sequestration, in the agriculture sector in Syria for 2006 – 2030

The presented information suggest 3 main scenarios to what may happen for carbon sequestration, mitigation of GHG emissions, and reduction of fertilizers use in the agriculture sector in Syria.

5.4.1. First scenario: Continue with the present conditions and produce biogas

Dissemination of biogas production continues with the implementation of present agriculture systems and the actions for preventing land degradation and mitigating of GHG emissions in the agriculture sector. These could be summarized as follows:

- Fallowing around 0.62- 0.96 million hectares of the farmland.

- Implement the present several and deep cultivations.

- Increase the number of tractors without routine maintenance.

- The present policies and programs for the management of agriculture irrigation, and the dissemination and implementation of modern irrigation techniques, improving conventional irrigation methods, that will reduce GHG emissions by 25 $GgCO_{2e}$ in year 2030 (Table 6).

- Increase sheep and poultry production.

- cultivating the same crops in the same sequence.

- Increasing green houses.

- Implementing forestation and land restoration plans.

- Early and heavy grazing and woodcutting in the rangelands continues.

- Wood cutting in forests without strict implementation of protection laws and regulation.

- Free applications of Fertilizers.

- Prohibiting burning crops residues and savanna would reduce GHG emissions by 1550 $GgCO_{2e}$ (Table 7).

- Production of biogas for energy use would reduce GHG emissions by 3319 $GgCO_{2e}$ in year 2030(Table 6).

The reduction in GHG emissions by this scenario would total to around 4894 $GgCO_{2e}$ in year 2030.

5.4.2. Second scenario: Adopting and implementing Conservation Agriculture in the arable land only and introducing livestock into the farming system to replace the present systems, this will need 5-10 years

This scenario will add to the present actions for prohibiting burning savanna and crops residues, implementing modern means and techniques in agriculture irrigation, and biogas production the following actions to mitigate GHG in the agriculture sector:

- Implementing conservation agriculture will further reduce GHG emissions from energy use in agriculture by about 2198 $GgCO_{2e}$ in year 2030 (Table 6).

- Introducing livestock production within the farming system will reduce the amount of applied fertilizers by no less than 13.7 Ton N/Year (See section 5.3.3.). However, there are no available national measurements for estimating reductions of N emissions from added chemical fertilizers.

- Implementing Conservation agriculture will also reduce the amounts of fertilizer use by improving soil fertility. However, there are no available national measurements for estimating reductions in applications and mitigation of N emissions from added chemical fertilizers.

Therefore, mitigation of GHG emissions in 2030 will increase with this scenario by about 7092 $GgCO_{2e}$ (Excluding the reduction due to reduced applications of fertilizers) than the mitigation of emissions in scenario one.

On the other hand implementing Conservation agriculture will increase C sequestration in farmland by 74%. However, there are no available measurements in our conditions for estimating this increasing amount of C sequestration.

5.4.3. Adopting and implementing Conservation Agriculture in the arable land, forest and rangelands, and introducing livestock into the farming system to replace the present systems, this will need 5-10 years

This scenario will add to the present actions for prohibiting burning savanna and crops residues, implementing modern means and techniques in agriculture irrigation, and biogas production the following actions to mitigate GHG in the agriculture sector:

- The mitigating actions implemented in the second scenario, which reduces emissions by about 2198$GgCO_{2e}$, and the reduction (not estimated) due to the decrease in fertilization by an amount of 13.4 Ton N/ year.

- The mitigation resulted from preventing changing burnt forests and rangelands into farmland, and is determined by subtracting the GHG emissions from burning from the total emissions resulted from burning forests and rangelands and conversion into farmland. The estimates of GHG emissions from burning forests are about 15 $GgCO_{2e}$ (Mahmud 2009). Thus preventing forests and rangeland conversion into farmland will reduce emissions by 42328 $GgCO_{2e}$ (Table 7).

-Reduction resulted from disseminating biogas production by herders and the inhabitants of the Badia. The estimated increase in biogas production is 1.45 Gg CH_4 will reduce GHG emissions by 118 $GgCO_{2e}$ (see production of biogas section 4.2.). This increase of biogas production resulted from using the solid waste of grazing sheep and goat herds in the Badia excreted during their rest intervals and is approximately equal 20% of their total solid waste.

Therefore, this scenario will further reduce GHG emissions in year 2030 by 44644 $GgCO_{2e}$ than scenario one and thus the total mitigation by this scenario will sum up to 49538 $GgCO_{2e}$.

Implementing Conservation Agriculture in forests and rangelands as part of this scenario will also increase C sequestration because it includes rehabilitation of degraded forests and rangelands and burnt areas. However, the sequestered C is not estimated because there are no available local measurements.

5.4.4. Comparison of GHG mitigation by the 3 scenarios

The 3 scenarios show that the first scenario will mitigate GHG emissions by only 4894 $GgCO_{2e}$, the second scenario would increase the mitigation to be 7092 $GgCO_{2e}$ and the third scenario would further increase the mitigation to be 49538 $GgCO_{2e}$. The mentioned amounts of mitigation for scenarios one and two do not include the contribution of reducing fertilizers use.

There are huge differences between scenarios, and the second scenario mitigation is 1.5 folds of the first whereas, the third scenario mitigates emissions approximately 10 times the first scenario and 7 times the second scenario. The reduced amount of GHG emissions by each scenario mitigate a percent of the increase in GHG emissions in year 2030 equals; 27% by the first scenario; 39% by the second scenario and 271% by the third scenario. This indicates the significance of implementing the third scenario.

5.5. Economical, climatic and environmental impacts of the actions

These actions will have positive impacts on the economy, climate and environment in Syria especially on the agriculture sector. That is because it develops and improves all the activities in the agriculture sector, which will directly affect the agriculture working force and indirectly all working forces in other sectors.

5.5.1. Economical impacts

- The reduce of energy in crops' production by such a high percent (65%) while sustaining or increasing production rates will reduce production cost and consequently producers profit will increase and improves his purchasing capability. In addition reducing production cost of agriculture commodities may reduce prices, enabling their accessibility to larger slices of the society and improve their nutritional conditions.

- Improving soil fertility and replacing chemical fertilizers with solid waste of farm animals, while grazing forage crops, would reduce fertilizers applications and reduces production cost, adding another tip to farmers' income.

- Improving soil water holding capacity and preventing water runoff will increase the amount of water available to crops and increases crops production without cost increases. This will increase producers' income and may reduce commodities prices enabling their accessibility to larger slices of the society.

- Reducing irrigation requirements for crops will reduce production cost as well as saving water for other uses such as increasing irrigated farmland or increasing crops per year. This will increase farmers' income and may reduce commodities prices increasing their accessibility to larger slices of the society.

- Producing biogas from the solid waste of farm animals in farms and in the Badia as a source of energy will reduce the cost of the needed energy increasing the income of farmers and herders.

- Rehabilitation of degraded forests and increasing forested area will provide potential sustainable opportunities for utilizing medicinal and aromatic plants, fruits and leaves of some trees and shrubs, and bee rearing in forests, improving the income of neighboring population and their accessibility to their needed commodities.

- Rehabilitation of degraded forests and rangelands will prevent soil erosion and floods, reducing the incurred damages in farmers' fields and the infrastructure of public services.

5.5.2. Climatic and environmental impacts

-Developing rangelands and forests increase water conservation and c sequestration, and that would mitigate summer heat and winter cold, which improve the production in surrounding lands. In addition, atmospheric humidity and annual precipitation relatively improve.

- Developing rangelands and forests also preserve biodiversity.

- Developing farmland increases C sequestration and reduces GHG emissions, which consequently mitigates the adverse impacts of climate change.

- Developing farmland also reduces ground water pollution especially percolation of nitrogen oxides, and prevent land degradation and desertification.

5.6. Obstacles before mitigation of GHG in the agriculture sector in Syria

There are several obstacles prevent implementing the appropriate actions for mitigating GHG emissions in the agriculture sector in Syria, and the main obstacles are:

- Centralized governance and administration.

- Single oriented approach for resolving problematic issues especially environmental issues.

- Scarcity of expertise in all fields especially those of the environment.

- Inactive role of modern science in the management and development of resources, and define plans and programs to confront the challenges for food security, environmental degradation and the adverse impacts of climate change.

- Limited and inadequate budgets allocated for protecting natural resources and developing ways for sustainable utilization of these resources.

- Inadequate awareness of the critical importance of the environment as the cradle to human life and development, as well as to all human activities rather than as a part of those activities, and that the survival and wellbeing of human societies is dependant its sustainability and development.

6. Conclusions

Inappropriate and unsustainable management of farmland in terms of the number and depth of cultivations, fertilization, types of crops, unsuitable crop rotations, fallowing and burning crops' residues, is the main source for GHG emissions in the agriculture sector. Forests and rangelands fires and conversion into farmland is the second main source for GHG emissions in the agriculture sector. Burning crops' residues and savanna, however, will stop and the induced emissions of GHG will stop too. On the other hand, emissions from farmland and fertilization will increase due to expanding utilization of agriculture lands. Forests and rangelands fires and conversion to farmland will continue to induce similar amounts of GHG emissions.

Energy use in agriculture sector induces a small proportion of the GHG emissions in the sector. Inappropriate cultivations (caused substantial land degradation) are the major consumer of energy in agriculture and induce the main proportion of the emitted GHG from that energy. Low efficiency of agriculture irrigation as well as low efficiency of heat insulations in poultry barns, green houses and the conditioned stores of agriculture commodities, and the low efficiency of the engines of combine harvesters and fishing boats would further increase GHG emissions. Use of energy will increase with increasing and developing these activities, and consequently GHG emissions will increase. Agriculture irrigation in expected not to increase because of the limited resources and the increasing demand for human and industrial use, therefore will not be increases in energy use and emissions by this activity.

Farm animals add small amount of GHG emissions directly and by their wastes. Their emissions will increase drastically with their increasing number (except horses, donkeys and mules which will decrease) and will be 4 times the present emissions.

Disseminating biogas production is an important action adopted by the Ministry of Agriculture because it will mitigate GHG emissions by a useful amount that will increase with increases in animal numbers and by improving the efficiency of biogas production and burning processes. In addition, the great efforts of the government for mitigating GHG emissions by developing conventional irrigation methods, exploiting modern irrigation methods and techniques, prohibiting burning savanna and crops' residues will cause relatively limited but useful reduction in GHG emissions. Therefore, we should develop and implement methods or develop the ongoing agriculture systems for mitigating as much as we can GHG emissions without hampering agriculture development for national and regional food security.

Implementing Conservation Agriculture in farmland, forests and rangelands, and introducing livestock production into the agriculture system will reduce most of the GHG emissions in the agriculture sector. That is by improving soil management, reforestation of burnt sites in forests, rehabilitating degraded rangelands, reducing a major portion of the energy used for cultivations and a proportion of the energy used in agriculture irrigation, and reducing the application of chemical fertilizers. Reduction of energy use and fertilizer use will also reduce the production cost of agriculture commodities, increases farmers' income, and enable larger slices of the society to access these commodities improving their nutritional and living conditions.

Forestation strategy of the government doubled the forested area in Syria over the last 6 decades and has increased C sequestration but did not recognize the necessity of rehabilitating burnt sites in forests. Efforts should also consider increasing the annual forestation area and increasing the percent of conifers to increase C sequestration. That would help to control GHG emissions by keeping the C balance in favor of sequestration than emission for mitigating the adverse impacts of climate change.

7. Suggestions

Despite obstacles and the interactions of the basis of sustainable development, the present status of the natural resources and the adverse impacts of climate change. As well as the demands of population growth and improvement of the livelihood of people in Syria especially those related to improving and increasing agriculture production to secure food and other human needs. The following actions would resolve all those difficulties:

-Consider all actions and means for implementing governmental laws, actions and regulations for protecting and developing natural resources.

- Immediate capacity building for environmental protection and development of natural resources.

- Immediate capacity building for developing agriculture systems suitable for the different environmental zones in Syria particularly for implementing the conception and basis of Conservation Agriculture with the introduction of livestock production within the agriculture system.

- Immediate reduction of the number and depth of cultivations, and expanding the validation of Conservation Agriculture in Syria.

- Reforestation and protection of burnt forest areas, prohibiting industrial utilization of forest wood or rationalize its utilization to sustain and develop the production and diversity of the vegetation. As well as, developing forest resources that may provide direct income to neighboring population (medicinal and aromatic plants, fruits and leaves of some plants and honey production), and increasing annual forestation area and the ratio of fast growing trees.

- Improving and disseminating the use of biogas produced from the solid waste of farm animals on farms and Al Badia.

- Expanding rehabilitation of degraded rangelands, prohibiting early grazing and rationalizing grazing.

- Activation of science and providing the required funds for research and studies for improving and increasing soil biomass, introducing or developing more drought tolerant and more productive plants.

8. Summary

The total GHG emissions in the agriculture sector in Syria sum up to 63156 $GgCO_{2e}$ in year 2006 and are expected to increase up to 81410 $GgCO_{2e}$ in 2030, an increase of 29%. The main causes of these emissions are; mismanagement of lands in terms of the number and depth of cultivations, unsuitable crop rotations, fertilizers application, fallowing, burning savanna and crops residues, and burning and converting forests and rangelands into farmland. The emissions from land management in year 2006 were 87% of the total GHG emissions, 7% was from energy use, and the rest (6%) induced by farm animals.

Government actions to prevent burning savanna and crops' residues, to improve implemented irrigation methods and disseminate modern irrigation techniques, and to produce biogas will reduce GHG emissions from land management and energy use in the agriculture sector in year 2030. The GHG emissions from land management, however, will form 85% of the total emissions in year2030, the emissions from energy use will be 8% and the remaining 7% induced by farm animals.

Energy use for unsuitable conventional cultivations that have degraded farmland and induced desertification of the rangeland forms the major portion (65%) of the used energy in the agriculture sector in year 2006. In year 2030 the contribution of GHG emissions from the used energy for cultivations will be 52% of the total emissions from the used energy in agriculture. This is due to the vast increase in energy use for heating greenhouses and poultry barns.

Production of biogas from farm animals in barns will reduce GHG emissions by 1084 $GgCO_{2e}$ in year 2006 and 3319 $GgCO_{2e}$ in year 2030. Disseminating its production with herders and with the population in the Badia will further reduce GHG emissions by 117.84 $GgCO_{2e}$.

Implementing Conservation Agriculture for crops production will reduce energy use and GHG emissions by 2042 $GgCO_{2e}$ in 2006 and by 2198 $GgCO_{2e}$ in year 2030. In forests CA includes reforestation of burnt areas reducing the emissions (from burning wood and converting the land for crops production) by 42328 $GgCO_{2e}$. It will also reduce the amounts of applied fertilizers, increase C sequestration by 74%, increase soil organic matter, and will prevent 90% of surface water runoff.

Integrating livestock production in the agriculture system with CA will reduce the amount of chemical N fertilization by 13.7 Ton N/ year the amount produced by the excreted livestock waste while grazing forage crops.

Estimated sequestered C by forests in 2006 sum up to 170438 $GgCO_{2e}$ and would increase by 43% in 2030. The C balance in agriculture sector show that the net C sequestration, emission and mitigation in 2006 is 107282 $GgCO_{2e}$, and will increase up to 168058 $GgCO_{2e}$ in 2030. However, C sequestration could be increased by increasing forested area and by increasing the percent of conifers in forest plantations.

Developing the agriculture sector in Syria between years 2006 and 2030 might be according to the three following scenarios: 1) continue with the present conditions and produce biogas, 2) Adopting and implementing Conservation Agriculture in the arable land only and introducing livestock into the farming system to replace the present systems, this will need 5-10 years. 3) Adopting and implementing Conservation Agriculture in the arable land, forest and rangelands, and introducing livestock into the farming system to replace the present systems, this will need 5-10 years. The first scenario will reduce GHG emissions by an amount of 4894 $GgCO_{2e}$. Implementing the second scenario would reduce the emissions by 7092 $GgCO_{2e}$ whereas implementing the third scenario would lead to substantial reduction in emissions amounting 49538 $GgCO_{2e}$. In addition, the second and third scenarios they further reduction in emissions by reducing the use of chemical N fertilizers by no less than 13.7 Ton N/year, improving soil fertility, increasing soil organic matter, and by increasing C sequestration.

Main obstacles for sustainable development of agriculture and optimizing agriculture production in Syria are; scarcity of expertise, insufficient funding, single oriented approach for resolving problems and issues, and centralized governance. In addition, ambiguous conception of the environment status as the cradle for all human activities and life as well as it is the basis for human survival, development and the wellbeing of present and future life rather than an activity of life. However, we may overcome these obstacles by the following actions: 1) Consider all actions and means for implementing governmental laws, actions and regulations for protecting and developing natural resources. 2) Immediate capacity building for protecting the environment and developing natural resources. 3)Immediate capacity building for developing agriculture systems suitable for the different environmental zones in Syria especially for implementing the conception and basis of Conservation Agriculture and introducing livestock production within the agriculture system. 4) Reducing the number and depth of cultivations, and expanding the validation of Conservation Agriculture in Syria. 5) Reforestation and protection of burnt forest areas, prohibiting industrial utilization of forest wood or rationalize its utilization to sustain and develop the production and diversity of the vegetation. As well as, developing forest resources that may provide direct income to neighboring population (medicinal and aromatic plants, fruits and leaves of some plants and honey production), and increasing annual forestation area and the ratio of fast growing trees.

6) Improving and disseminating the use of biogas produced from the solid waste of farm animals on farms and Al Badia. 7) Expanding rehabilitation of degraded rangelands, prohibiting early grazing and rationalizing grazing. 8) Activation of science and providing sufficient funds for research and studies for improving and increasing soil biomass, introducing or developing more drought tolerant and more productive plants.

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Appendix

1. Factors used in calculating the used energy in the agriculture sector in Syria

1.1. Estimation of locomotive energy used by tractors and combine harvesters

Land restoration, cultivations, leveling, harvesting and threshing, and most of seeding operations are the main consumer of locomotive energy. The estimation of the used amounts of Diesel fuel by those activities depended on the factors provided by the Statistics and Planning Department in the Syrian Ministry of Agriculture, which are based on the following criteria: Tractors daily average working hours, annual working days, and the average fuel consumption by tractors. Factors for farmland hardness are included as follows; 0.9 for light sandy soils (20% of the land); 1.0 for silty clayi soils (65% of the land); 1.25 for shallow, gravely and stony soils (15%of the land). Land restoration, leveling, harrowing, seeding, and agriculture transportation for less than 10Km are estimated to equal 12% of the basic activities (Appendix table 1).

Appendix table 1. Factors used for calculating the used diesel fuel as locomotive energy for 1994-2007

<table>
<tr><th rowspan="2">Average power (Horse)</th><th colspan="2">Working time</th><th rowspan="2">Used fuel (L/hour/Horse)</th><th rowspan="2">Average factor of land cultivation hardness</th><th rowspan="2">Other works % of cultivations</th><th rowspan="2">Conversion factor L to Kg</th></tr>
<tr><th>Day/year</th><th>hour/day</th></tr>
<tr><td>32</td><td>150</td><td>8</td><td>0.150</td><td rowspan="3">1.12</td><td rowspan="3">12</td><td rowspan="3">0.838</td></tr>
<tr><td>70</td><td>150</td><td>8</td><td>0.135</td></tr>
<tr><td>115</td><td>90</td><td>16</td><td>0.125</td></tr>
<tr><td colspan="7">Source: [6].</td></tr>
</table>

Calculation method:

Amount of used diesel fuel as locomotive energy by tractors and combine harvesters (Ton/year) =[(Average factor of land cultivation hardness X averaged total used fuel by tractors) + fuel used by combine harvesters] L/year + (0.12X total fuel used by tractors)] L/year X Conversion factor to Kg ÷ 1000Kg.

1.2. Calculations of used fuel for heating

A- Heating of green houses

Calculations are based on factors and statistics provided by the Syrian Ministry of Agriculture for defining the distribution of green houses, the type of fuel used for heating, daily heating hours and the annual heating days in the different climatic zones (Appendix table 2).

Appendix table 2. Factors adopted for calculating the used fuel for heating green houses for 2000-2007

<table>
<tr><th>Distribution of green houses</th><th>Houses %</th><th>Heating hours/day</th><th>Heating days</th><th>Diesel fuel</th><th>*Residues of olive trees and fruits fuel</th></tr>
<tr><td>Temperate zone</td><td>95</td><td>6</td><td>60</td><td rowspan="2">75%</td><td rowspan="2">25%</td></tr>
<tr><td>Cold zones</td><td>5</td><td>14</td><td>60</td></tr>
<tr><td colspan="6">* 1ton diesel fuel = 1.3421 Ton residues of olive trees and fruits. Source: [6].</td></tr>
</table>

<u>Calculation method:</u>

- Amount of used diesel fuel in green houses (ton/year)=

(Consumption in temperate zones + Consumption in cold zones) L/year X Conversion factor to Kg ÷ 1000Kg.

- Consumption of green houses in temperate or cold zones (ton/year)=

Total number of green houses X % of houses in the zone X % of Diesel fuel X heating days X heating hours /day X L fuel/hour in the zone (Appendix table 2).

B – Heating of poultry barns

Calculations are based on factors and statistics provided by the Syrian Ministry of Agriculture for determining the heating requirements of fuel for poultry barns and the kind of fuel used for heating, daily heating hours and annual heating days for poultry flocks and barns, and the consumption of other supporting buildings (Appendix table 3).

Appendix table 3. Factors adopted for calculating the used fuel for heating poultry barns for 1994-2007

Heating requirements (hour/day) during flock rearing cycle			**Flock heating & rearing requirements**	**Annual heating period**	**Average use of diesel fuel**+	**Use of cock**	**Energy use by supporting buildings**
First 5 days	Following 10 days	Remaining 40 days	rearing days 55	110 days*	15 L/flock/ hour	80 % of fuel	5% of rearing use
24 hour/day	12 hour/day	3 hour/day	Heating hours 360	720 hours	20 % of fuel		
* Represent the 4 cold months in the year. + 1ton Diesel = 1.2289 ton cock. Source : [6].							

<u>Calculation method:</u>

Flock heating Hours = (5X24) + (12X10) +(3X4) = 360 hours

Heating continues for rearing during the 4 cold months of the year, where 2 flocks are produced that is the heating days are only 110 days/year because preparation for the next flock (Cleaning, sterilization, aeration…etc.) need 5-7 days therefore:

Heating hours for the barn = 360 heating hours/ flock X 2(number of flocks in the cold months) = 720 heating hours/year.

The overall energy use for heating poultry barns in Syria are estimated as follows:

A - Diesel fuel consumption (ton) for heating poultry barns in Syria =

Number of heated flocks/year X 360 heating hours/flock X 15 L/flock /hour X 0.2 X 0.838.

Where; 0.2 is the percent of used diesel for heating, 0.838 is the conversion factor of one liter Diesel to one Kg diesel, and that

The number of heated poultry flocks/year = the number of produced flocks/year ÷ 3 (the percent of cold months/year), and the number of produced poultry flocks/year = the number of produced chicken/year ÷ the average number of chicken (7500) in a flock. The number of chicken in a flock is usually between 7000- 8000.

- The number of produced chicken/year is calculated as follows:

Annual production of broiler÷ average weight of chicken (1.5 Kg), where chicken weight is between 1.4-1.6 Kg, and broiler chicken production sum up to 91% of poultry production in Syria.

B- Consumption of Cock and other coal for heating poultry barns in Syria = 80% of the total energy used for heating poultry barns.

The conversion factor of cock to Diesel fuel is;

1 ton of diesel fuel = 1.2289 tons of Cock

1.3. Calculations of used energy for conditioning stored agriculture products

Calculations are based on factors and statistics provided by the Syrian Ministry of Agriculture for determining requirements of electrical energy and its resources for conditioning to preserve agriculture products, daily conditioning hours and annual conditioning day. Estimates indicate a need for 3034tons of diesel fuel to provide the required power of 35989 M W hour for conditioning at least 90 days and for 6 hours a day.

1.4. Calculating used fuel for fishing

Estimates of the used fuel by fishing boats are based on data provided by the Syrian fuel corporation. Only 50% of the fuel used by fishing boats is for fishing as averaged over the year, rather than during fishing season. The other 50% is usually used for other activities such as transportation, sea tours…etc.

The calculations are as follows:

The amount of consumed fuel by fishing boats (ton Diesel fuel/year) =

[Average fuel consumption (Fishing + other activities) KL/month X 0.5 X 12 months] X 0.838. Where;

The average fuel consumption by boats = 410 L Diesel fuel/month,

The average fuel consumption for other activities= 288 L Diesel fuel/month,

and that: 1L Diesel fuel = 0.838 Kg Diesel fuel.

1.5. Calculations of the used energy for agriculture irrigation

Appendix table 4. Factors used for calculating the used energy in agriculture irrigation for 1994-2007

Irrigation water Million m^3/year	Average efficiency of electric generators	Efficiency of electrical motors for pumping surface water	Efficiency of average hydroelectric generator	Efficient use of electrical pumps	Efficiency of network transfer	Average upraising of water wells/ pressure
15060	0.57	0.75	0.92	0.82	0.88	100m
Source: [6].						

2. Calculations of CO_2, N_2O, and CH_4 emissions from used fuel:

- Calculations of CO_2 emissions from used fuel by the following equation:

Emissions = Amount of used fuel (GJ) X Emission factor (Kg C/GJ) X Oxidation factor (%).

Emission factor of CO_2 = 2.7866 Kg CO_2 /1 Kg Diesel

- Calculations of CH_4 emissions from used fuel by the following equation:

Emissions = Amount of used fuel (Diesel equivalent) X Calorific factor CF (0.04 GJ/1 Kg Diesel) X Emission factor (0.065 Kg CH_4 / GJ).

Therefore:

The average emission factor of CH_4 from Diesel fuel equivalent = 2.6 g CH_4/1Kg diesel.

- Calculations of N_2O emissions from used fuel by the following equation:

Emissions = Amount of used fuel (Diesel equivalent) X Calorific factor CF (0.04 GJ/1 Kg Diesel) X Average emission factor (1.845 Kg N_2O / TJ) for the overall used energy in the agriculture sector.

Therefore:

The average emission factor of N_2O from Diesel fuel equivalent = 0.074g N_2O/1Kg diesel.

- GHG emissions are expressed as CO_2 equivalent (CO_{2e}), where the amount of emissions of each gas is converted to its CO_{2e} according to its effective contribution to the global warming potential (GWP) which equals the following [14]:

CO_{2e} 21 = CH_4 and CO_{2e} 310 N_2O =

- Conversion and oxidation factors for emitted C and N [14]:

- From C to CO_2 : 12/44
- From C to CO : 12/28
- From C to CH_4 : 12/16
- From N to N_2O : 28/44
- From N to NO_2 : 14/64

Appendix table 5. Calorific and C contents of the different types of the used fuel in Syria [12]]

Fuel	Heat / Calorific Value (Gj/kg)	Carbon emission factor (kg/Gj)	IPCC default Values [11]
Syrian HF	0.0402	21.00	21.1
Diesel	0.04	19	20.2
gasoline	0.04480	18	18.9
jet kerosene	0.04459	18.5	19.5
kerosene	0.04375	19	19.6
crude oil	0.04187	21.50	20
Asphalt	0.04019	20	20.9
Petroleum coke	0.03475	28.20	27.5
wood	0.00837	26.3	26
NG (wet) (Gj/CubM)	0.037679	18.5	17.2
LPG	0.0473086	15.8	15.3

Appendix table 6. Emission factors (EF) of CO_2, CH_4 and N_2O gases for the total used energy in the different sectors in Syria [5]

Aggregated GHG emissions in relevant sectors

	A	B			C		
SOURCE AND SINK CATEGORIES	Consumption	Emissions			emission Factors		
	TJ	kton			(Ton polluant/TJ) B/C*1000		
A Fuel Consumbtion Activities		CO2	CH4	N2O	CO2	CH4	N2O
1 Energy Industries	367,399.27	26,159	1.946	0.369	71.2	0.005	1.00E-03
2 Industries and Construction	65,570.23	4,756	0.060	0.039	72.5	0.001	5.93E-04
3 Transport	185,922.93	12,457	1.722	0.139	67.0	0.009	7.45E-04
4 Other Sectors	184,213.79	12,132	12.930	0.354	65.9	0.070	1.92E-03
a Commercial/Institutional	19,757.19	1,315	0.416	0.025	66.5	0.021	1.26E-03
b Residential	99,401.93	6,381	8.281	0.208	64.2	0.083	2.09E-03
c Agriculture	65,054.67	4,437	4.233	0.120	68.2	0.065	1.85E-03

Appendix table 7. GHG emissions (Gg) by energy use as Diesel equivalent in the agriculture sector in Syria

Amounts (Gg/year) of GHG emissions by the used locomotive energy by tractors (Cultivations & other activities)						
Emitted gases	**1994**	**1998**	**2000**	**2003**	**2005**	**2007**
* CO_2	2185.7	2572.2	2680.8	2848.1	2899.6	2950.9
* N_2O	0.058	0.068	0.071	0.076	0.077	0.078
CH_4	2.04	2.4	2.5	2.7	2.7	2.8
CO_{2e} of N_2O	18.0	21.1	22.0	23.6	23.9	24.2
CO_{2e} of CH_4	42.8	50.4	52.5	56.7	56.7	58.8
CO_{2e}	2246.5	2643.7	2755.3	2928.4	2980.2	3033.9
Amounts (Gg/year) of GHG emissions by the used locomotive energy by combine harvesters						
* CO_2	243.9	238.6	228.8	253.7	273.1	282.5
* N_2O	0.006	0.006	0.006	0.006	0.007	0.007
CH_4	0 .23	0.2	0.21	0.24	0.25	0.26
CO_{2e} of N_2O	1.86	1.86	1.86	1.86	2.17	2.17
CO_{2e} of CH_4	4.8	4.2	4.4	5.0	5.3	5.5
CO_{2e}	250.6	244.7	235.1	261.2	280.6	290.2
Amounts (Gg/year) of GHG emissions by the used locomotive energy by fishing boat						
* CO_2	n a	n a	n a	n a	n a	9.8
* N_2O	n a	n a	n a	n a	n a	0.0003
CH_4	n a	n a	n a	n a	n a	0.01
CO_{2e} of N_2O	n a	n a	n a	n a	n a	0.09
CO_{2e} of CH_4	n a	n a	n a	n a	n a	0.2
CO_{2e}	n a	n a	n a	n a	n a	10.1
Total amounts (Gg/year) of GHG emissions by the used locomotive energy (Excluding fishing boats except in year 2007)						
* CO_2	**2429.6**	**2810.8**	**2909.6**	**3101.8**	**3172.7**	**3243.2**
* N_2O	**0.064**	**0.075**	**0.077**	**0.082**	**0.084**	**0.086**
CH_4	**0.27**	**2.60**	**2.71**	**2.94**	**2.95**	**3.07**
CO_{2e} of N_2O	**19.84**	**23.25**	**23.87**	**25.42**	**26.04**	**26.66**
CO_{2e} of CH_4	**47.6**	**54.6**	**56.9**	**61.7**	**62.0**	**64.5**
CO_{2e}	**2497.0**	**2888.7**	**2990.4**	**3168.9**	**3260.7**	**3334.4**
Amounts (Gg/year) of GHG emissions by the used energy for heating green houses						
* CO_2	n a	n a	380.9	471.6	552.4	634.3
* N_2O	n a	n a	0.01	0.012	0.015	0.017
CH_4	n a	n a	0.35	0.44	0.51	0.59
CO_{2e} of N_2O	n a	n a	3.1	3.7	4.6	5.3
CO_{2e} of CH_4	n a	n a	7.4	9.2	10.7	12.4
CO_{2e}	n a	n a	391.4	484.5	567.7	652.0
Amounts (Gg/year) of GHG emissions by the used energy for heating poultry barns (Broiler production)						
* CO_2	142.4	183.9	201.6	304.2	309.1	330.8
* N_2O	0.004	0.005	0.005	0.008	0.008	0.009
CH_4	0.13	0.17	0.19	0.28	0.29	0.31
CO_{2e} of N_2O	1.24	1.55	1.55	2.48	2.48	2.79

CO_{2e} of CH_4	2.7	3.6	4.0	5.9	6.1	6.5
CO_{2e}	144.9	187.7	205.8	310.4	315.5	337.6
Amounts (Gg/year) of GHG emissions by the used energy for agriculture irrigation						
* CO_2	n a	n a	n a	n a	n a	376.4
* N_2O	n a	n a	n a	n a	n a	0.01
CH_4	n a	n a	n a	n a	n a	0.35
CO_{2e} of N_2O	n a	n a	n a	n a	n a	3.1
CO_{2e} of CH_4	n a	n a	n a	n a	n a	7.4
CO_{2e}	n a	n a	n a	n a	n a	386.9
Amounts (Gg/year) of GHG emissions by the used energy for conditioning stored agriculture products						
* CO_2	n a	n a	n a	n a	n a	8.4
* N_2O	n a	n a	n a	n a	n a	0.0002
CH_4	n a	n a	n a	n a	n a	0.01
CO_{2e} of N_2O	n a	n a	n a	n a	n a	0.06
CO_{2e} of CH_4	n a	n a	n a	n a	n a	0.2
CO_{2e}	n a	n a	n a	n a	n a	8.7
Total amounts (Gg/year) of GHG emissions by the used energy in agriculture						
* CO_2	**2572**	**2994.7**	**3492.1**	**3877.6**	**4034.2**	**4593.1**
* N_2O	**0.068**	**0.079**	**0.093**	**0.103**	**0.107**	**0.122**
CH_4	2.4	2.6	3.3	3.7	3.8	4.3
CO_{2e} of N_2O	**21.1**	**24.5**	**28.8**	**31.9**	**33.2**	**37.8**
CO_{2e} of CH_4	**50.4**	**54.6**	**69.3**	**77.7**	**79.8**	**90.3**
CO_{2e}	**2643.5**	**3073.8**	**3590.2**	**3987.2**	**4147.2**	**4719.4**
*1 Kg Diesel fuel emits 2.7866 Kg CO_2, 0.074 g N_2O, and 0.074 g CH_4 [14]. n a. :Energy use is not available						

3. Calculation of CH_4 و N_2O emissions from farm animals:

Farm animals emit CH_4 gas directly and indirectly from their solid waste. Solid wastes also emit N_2O, NH_3 and NO_2 according to their management system.

3.1. Emissions of N_2O from farm animals (Appendix table 8):

Equation:

F (N_2O Gg) = [(D X E) X 28/44] ÷ 10^6

D(Kg N) = A XB X C

Note: Emissions of N from the dispersed animal waste on lands during grazing (The waste management system AWMS which is used in the estimation for farm animals raised by grazing) are in the form of **NH_3** and **NO_2** and their N product is calculated by using the emission factor **(EF3 = 0.02)** which is converted to **N_2O.**

Appendix table 8. Emissions of N_2O by the expected increase in farm animals' waste in year 2030 in Syria

Animals	[1]Number of animals (1000 animal) A	[2]Excreted N (Nex) Kg N/head/year B	[2] % of N emission by waste management system(AWMS) C	[2] N emissions Kg N/year D	[2]Waste management emission factor (EF3) Kg N_2O-N/Kg N E	[2]N_2O emissions Gg F
Dairy cow	511.92	50	3	767.88	0.02	0.024
Non dairy cow	36	70	2	50.4	0.005	0.0004
Sheep	31500	12	1	3780	0.02	0.119
Goats	1480	40	1	592	0.02	0.019
Camels	61.2	40	1	24.48	0.02	0.0008
Mules & donkeys	- 112.1	40	1	44.84 −	0.02	0.0014 −
Horses	- 13.3	40	1	5.32 −	0.02	0.0002 −
Hens	37267.9	0.6	28	6260.88	0.005	0.049
Buffalos	4.8	40	1	1.92	0.02	0.00006
Total	−	−	−	−	−	0.21066

[1] Calculated from the annual average change between years 2000 and 2006 [6]. [2] Sources: [4 &14].

3.2. Emissions of CH_4 from farm animals (Appendix table 9):

Equations:

F (Gg CH_4/year) = (C + E) ÷ 1000

C (Ton CH_4/year) = (A x B) ÷ 1000

E (Ton CH_4/year) = (A x D) ÷ 1000

Appendix table 9. Emissions of CH_4 by the expected increase of farm animals in year 2030 in Syria

Animals	[1]Number of animals (1000 head) A	[2]CH_4 emission factor from enteric fermentation (Kg/ head/ year) B	CH_4 emissions from enteric fermentation (Ton/year) C	[2]CH_4 emission factor of waste management system (Kg/head/year) D	CH_4 emissions from waste management system (Ton/year) E	CH_4 total emissions (Gg/year) F
Dairy cow	511.92	36	18429	2	1024	19.45
Non dairy cow	36	32	1152	1	36	1.19
Sheep	31500	5	157500	0.16	5040	162.54
Goats	1480	5	7400	0.17	252	7.65
Camels	61.2	46	2815	1.9	116	2.93
Mules & donkeys	- 112.1	10	1121 −	0.9	- 101	1.22 −
Horses	- 13.3	18	239 −	1.6	- 21	0.26 −
Hens	37267.9	0.117	4360	0.018	671	5.03
Buffalos	4.8	55	264	5	24	0.29
Total	−	−	190560	−	7042	197.6

[1] Calculated from the annual average change between years 2000 and 2006 [6]. [2] Sources: [4 &14].

4. Factors used for calculating biogas production (CH_4) from the solid waste of farm animals

The solid waste (VS) of farm animals raised in barns in Syria could be used for producing biogas (CH_4), because collecting the waste is practically visible (Appendix table 10).

- Calculation of the amount of biogas (CH_4) that could be produced from the solid waste of farm animals by anaerobic fermentation:

Gg CH_4/year/species =

(Number of animal species X VS species X B_0 species X MCF species X 365 days X 0.67) ÷ 1000

Appendix table 10. The amount of CH4 produced by anaerobic fermentation of the solid waste (VS) of some farm animals raised in barns and used as a bio source of energy in Syria in 2006 and 2030

£Animals	Number£ (1000)	+Waste (VS) (Kg DM/animal/day)	+Maximum CH4 production (B_0) (m^3 CH4/ Kg VS)	+CH_4 conversion factor (MCF) In the fermenter (%)	€ CH_4 produced (Gg /year)
Year 2006					
Dairy cows	579	1.9	0.13	10.0	3.5
Nondairy cows	524	1.5	0.1	10.0	1.9
Buffalos	4	3.9	0.1	10.0	0.04
*Sheep	4276	0.32	0.13	10.0	4.3
Hens	30946	0.02	0.24	10.0	3.6
Total	–	–	–	–	13.34
Year 2030					
Dairy cows	1090.92	1.9	0.13	10.0	6.589
Nondairy cows	560	1.5	0.1	10.0	2.054
Buffalos	8.8	3.9	0.1	10.0	0.084
*Sheep	10576	0.32	0.13	10.0	10.759
Hens	68213.992	0.02	0.24	10.0	8.007
Total	–	–	–	–	27.493

* The number of sheep raised in barns is estimated as 20% of the total sheep number because this is the practical number we can use their waste. + From tables A-10 (4, 5, 6, 9) [14]. X A closed big container where solid waste is mixed with water for anaerobic fermentation at a temperature of 20 °C. € 1m^3 CH_4 = 0.67 Kg CH_4. £ Source:[6].