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MANURE MANAGEMENT PLAN IN LIVESTOCK FARMS IN LEBANON: CASE OF BEKAA AND BAALBEK-HERMEL GOVERNORATES

by

SARA IBRAHIM HTEIT

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SARA IBRAHIM HTEIT

Approved by:

Dr. Darine Salam, Assistant Professor — Advisor
Department of Civil and Environmental Engineering
American University of Beirut

Dr. Makram Suidan, Professor — Member of Committee
Department of Civil and Environmental Engineering
American University of Beirut

Dr. Isam Bashour, Professor — Member of Committee
Department of Agricultural Sciences
American University of Beirut

Dr. Rana Bilbeisi, Assistant Professor — Member of Committee
Department of Civil and Environmental Engineering
American University of Beirut

Dr. Naji Chamieh, Managing Partner — Member of Committee
Sustainable Environmental Solutions s.a.l

Date of thesis/dissertation defense: April 24, 2019

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AN ABSTRACT OF THE THESIS OF

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Title: Manure Management Plan in Livestock Farms in Lebanon: Case of Bekaa and Baalbek-Hermel Governorates

The improper management of animal manure has significant impacts on the environment and human health due to soil and groundwater pollution, and malodourous emissions. Several physical and biological methods are used to treat manure before being disposed or reused, of which composting and anaerobic digestion (AD) are widely applied. This study assesses the current management of manure in the Bekaa and Baalbek-Hermel Governorates and proposes a plan for its future management. 30 farms were visited in the study area where livestock production is concentrated. It was found that farmers either add manure to their lands without prior treatment as a means of soil amendment, or sell manure to other farmers to be used for the same purpose. Manure and soil samples were collected from the visited farms and analyzed for their nutrient content (N, P and K). A nutrient management plan was proposed for the two mostly planted crops in the Bekaa and Baalbek-Hermel regions which are wheat and potatoes. The analysis showed that in some sites manure should not be added since the concentration of P available for crops exceeds the requirements. This leads to the generation of excess manure that could not be used directly as fertilizer. Knowing that raw manure may contain pathogenic bacteria and antibiotics which should be mitigated before the manure is disposed of, the study recommends to install a centralized integrated AD and composting plant in Baalbek-Hermel governorate. This will lead to the generation of biogas and composted digested material that can be used as fertilizers. As for the Bekaa governorate, the study recommends to upgrade the existing composting facility in Terbol so that it can treat most of the manure that is generated from small and medium farms in that area. These facilities can benefit from the subsidized environmental loans. Both solutions were found to be economically feasible. Moreover, in some farms that have the available space, it is feasible to carry out onsite windrow composting, as this would not entail further cost on the farmers.

Keywords: animal manure, anaerobic digestion, composting, nutrient management plan

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CHAPTER I

INTRODUCTION

There is a variety of livestock farms in Lebanon that raise poultry, cattle, goats, ovine and pigs. According to a study conducted by the Ministry of Agriculture in 2010, there are around 76,900 cattle, 78,000,000 poultry, 494,700 goats, 337,300 sheep and 10,000 pigs (UNDP/CEDRO, 2012). The distribution of livestock heads differs across Governorates in Lebanon with the Bekaa Governorate having the highest number of cattle, sheep and goats, and South Lebanon and Nabatieh Governorates together having the highest number of poultry (Figure 1). These farms generate large quantities of manure and other agricultural wastes (feed waste, straw, wood chips, etc.) that are probably not managed properly. Most farms in Lebanon use manure as a soil amendment in their farms or sell it to other farmers to be used for the same purpose without any pretreatment. Untreated manure may contain antibiotics, hormones, phosphorous, nitrogen, microorganism (such as bacteria, viruses, prions, pathogens i.e. Escherichia coli and parasites), metals, etc. (IFC, 2007), and its direct application as soil amendment could lead to soil and groundwater pollution which may consequently impact human, terrestrial, and aquatic animals’ health. Therefore, it is very important to treat the manure before its disposal or use.

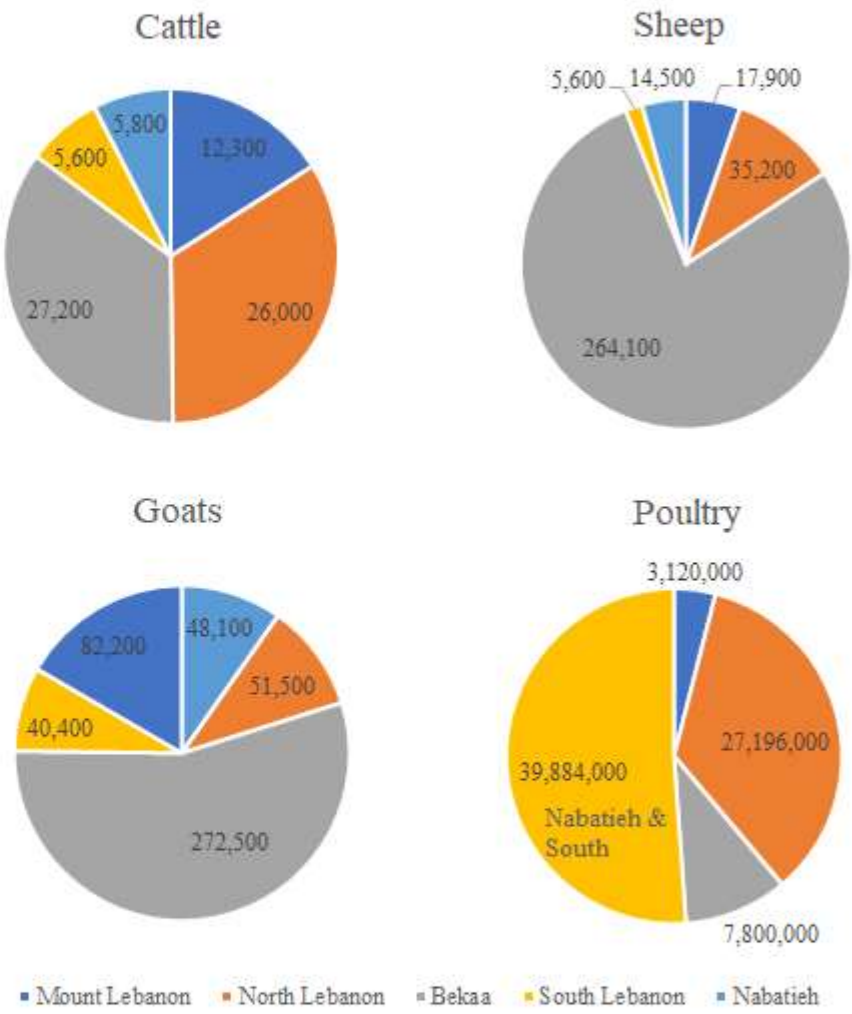

Figure 1. Distribution of livestock heads per governorate (UNDP/CEDRO, 2012).

The proper application of manure to agricultural lands improves soil quality through reducing erosion and runoff of soil, reducing leaching of nitrates, and increasing carbon and phosphorous content. These are attributed to the increase in the soil water retention, decrease in its bulk density, and improvement of its hydraulic properties (Mikha et al., 2017). The organic nitrogen that is found in manure "is slowly released as soil warms", which coincides with the crops' need and thus reduces the leaching of nitrogen (USDA, N.D.). Moreover, manure increases the soil's cation exchange capacity and the water holding capacity (FAO, 1996). However, the improper addition of manure to soil leads to the diffusion of nutrient pollution to surface water, ground water, and air. The over application of manure that exceeds the holding capacity of the soil and the nutrient needs of the planted crop will lead to the leaching of the nutrients. In addition to nutrient pollution, manure may contain pathogens, trace metals, antibiotics, and growth hormones. The US Environmental Protection Agency has identified the agricultural production sector as the largest contributor to surface water pollution (USDA, N.D.). Therefore, it is important to develop a nutrient management plan that reduces the environmental impacts and increases the benefits of manure application.

There are various methods that are adopted internationally to treat manure. The most commonly used methods include: composting, anaerobic digestion (AD) for the production of biogas, pelletizing under high pressure and temperature, and aerobic trickling biofiltration. In order to improve the handling of manure, solid manure is separated from liquid manure using the solid-liquid separation method. The solid manure can either be used on-site as an organic fertilizer after testing its quality, or transported to other farms, or further treated (composted, pelletized, etc.) to be reused. Moreover, liquid manure can either be discharged into a wastewater treatment sewer or used to irrigate special crops after testing its quality (nitrogen, phosphorous, hormones, microbiological characteristics, etc.) (Flotats et al., 2011; IAEA, 2008).

The most commonly used treatment technologies are: composting and AD. More information about the composting and digestion processes, factors affecting them, and their applications in Lebanon are presented below.

A. Composting

Composting is an aerobic treatment process through which organic matter is decomposed. The composting process produces carbon dioxide (CO_2), ammonia, water, heat and humus (FAO, 2003). The composting process is composed of four phases according to temperature conditions: latent phase (22°C), growth phase (22-40°C), thermophilic phase

(40-65°C), and maturation phase (40°C -ambient temperature). The increase in temperature to 55-65°C for a minimum of one week will lead to the evaporation of water and destruction of pathogens and weed seeds, and consequently produce hygienic compost. Compost increases the concentration of organic matter in the soil, supplies nutrients (N and P) and humus, and provides a porous medium that helps in retaining nutrients in the soil (USEPA, 2002).

There are many factors that affect the composting process such as concentration of oxygen (O_2), pH, temperature, moisture content, nutrients (carbon, nitrogen (C:N ratio), phosphorous, and potassium), lignin, and polyphenols. These factors should be well controlled in order to be able to produce compost of good quality. Several types of composting systems are used of which windrow, static pile, and in-vessel composting are the most commonly adopted (IAEA, 2008).

According to the country profile of solid waste management in Lebanon, around 15% of the Municipal Solid Waste (MSW) is composted (SWEEP-NET, 2014). There are around nine operational composting plants, three constructed but non-operational, and three under construction (SWEEP-NET, 2014). Table 1 presents the existing composting facilities and their corresponding capacities and locations. Most of these plants are financed by the European Union (EU) and constructed by the Office of the Minister of State for Administrative Reform (OMSAR). Only one facility, GreenCo, deals with the composting of manure, and is located in Terbol, Bekaa. GreenCo collects cow and chicken manure from the farms and composts them using the windrow system to produce compost. On average, it composts around 20,000-25,000 tons/year.

Table 1. Existing Composting plants in Lebanon (SWEEP-NET, 2014)

Status	Number of Plants	Location	Capacity (tons/day)
Under Construction	3	Baalbeck Mishmish Nabatiyeh	60 10 120
Constructed/non-operational	3	Jbeil Minieh Shouf Swayjani	80 60 26
Operational	9	Ain Baal Ain Ebel Ansar Aytaroun Bint Jbeil Bourj Hammoud Kherbet Selem Khiam Qabrikha	150 20 10 15 50 300 15 10 15

B. Anaerobic Digestion

In contrast to aerobic processes, biodegradation of the organic material using anaerobic digestion takes place in the complete absence of oxygen. Anaerobic digestion is a “complex process carried out by a consortium of several different microorganisms, which in the case of manure are naturally present in the animal intestine” that leads to the decomposition of the organic material (Carotenuto et al, 2016). This process leads to the generation of biogas which is mainly formed of methane and CO_2 in addition to traces of organic acids and other gases. The formation of biogas is a result of metabolic pathway that is composed of four phases: “hydrolysis, acidogenesis, acetogenesis and methanogenesis” each one having its own group of microorganisms (Carotenuto et al, 2016). There are several factors that affect the production of methane in AD, such as type of biomass used (animal manure, sewage sludge, organic municipal solid waste, and agricultural waste), pH (optimal 7-7.2), temperature in the digester (cryophilic (12- 24°C), mesophilic (22-40°C) or thermophilic (50-60°C)) (Vintila et al., 2010), retention period, moisture content, loading rate, and agitation. AD takes place in a biogas digester which is found in various capacities depending on the quantities of manure that are being treated. The size can vary from a small-scale unit (fixed dome plant, floating drum plant and balloon/bag digester) for households use, to a large-scale plant for industrial and communal use (IRENA, 2016). There are several types of AD systems classified into wet and dry systems, each of which is divided into continuous and batch system. The main difference between wet and dry systems is the concentration of total solids. In wet systems, water is added to the slurry, and the total solid concentration is less than 15%. Dry systems, on the contrary, have higher total solid concentration (between 20-40%) and do not require the addition of water. However, dry systems are considered more flexible than wet systems due to lower water consumption, better energy balance, and better market acceptability of the digestate (Angelonidi and Smith, 2015).

The anaerobic digestion of organic matter does not only generate biogas but also post-digestion matter that is of solid and liquid form. The solid can be separated from the liquid digestate and used directly as a fertilizer due to its valuable composition. The digestate contains mineral elements, such as phosphorous, potassium, and nitrogen that are fundamental nutrients for plants. Moreover, the liquid can be returned to the AD plant (Koszel and Lorencowicz, 2015).

There are only two anaerobic digesters in Lebanon that are operated by the private sector, namely AUB/AREC in Haush-Sneid-Bekaa and IBC Inc. in Saida. AREC is currently upgrading its existing biogas plant to treat the manure generated from cows and chickens.

The digester is still non-operational and it has a total volume of 96m^3. With respect to IBC plant, it started operating in November 2012 and it only treats municipal solid waste from 16 municipalities in the Caza of Saida. IBC plant has a capacity of 550 tons/day. It is the only AD plant in Lebanon that treats municipal solid waste. The plant receives mixed waste, and sorts them to recover the recyclables and separate the organics that are being treated anaerobically. The plant generates around 2,000 kWh of electricity and 2,000 kWh of heat (IBC, n.d.). However, the plant is being operated over capacity which lead to the accumulation of waste on the coastline and the generation of foul odors.

According to a study that was developed by the United Nations Development Programme (UNDP) through the Country Energy Efficiency and Renewable Energy Demonstration Project for the recovery of Lebanon (CEDRO) in 2012 which assesses the energy potential of manure in Lebanon, the primary energy potential ranges from 26,100 GJ to 3,012,750 GJ (UNDP/CEDRO, 2012). This was estimated based on various factors, such as the animal type, quantities of manure produced, and net calorific value of the manure. Table 2 presents the findings of the study.

Table 2. Assumptions for theoretical biogas production potential from animal manure (UNDP/CEDRO, 2012)

	Livestock (Heads)	Manure quantities (Kg/year/ animal)	Moisture content (%)	Manure quantities (Tons/year)	Manure quantities (Tons of dry matter/year)	Calorific value (MJ/Kg Dry Matter)	Methane potential (m^3/ ton of dry matter)	Primary energy potential (GJ)
Cattle	76,900	6000	92	461,400	36,912	17.5	15	645,960
Horses	23,000	5000	72	115,000	32,200	16.2	19	521,640
Sheep/Goats	832,000	800	72.5	665,600	183,040	11.08	16	848,108
Pigs	10,000	3000	94	30,000	1,800	14.5	14	26,100
Chickens	78,000,000	25	89.7	1,950,000	200,850	15	18	3,012,750

Adapted from “UNDP/CEDRO. 2012. National Bioenergy Strategy for Lebanon”.

In 2016, UNDP, through the CEDRO project, implemented a project “Nationwide, Intensive and Rapid Survey on Potential Sources for Small to Medium Scale Biogas Plants in Lebanon” to encourage the development of anaerobic digestion in Lebanon. Sustainable Environmental Solutions (SES) that was contracted by CEDRO surveyed several sites (farms, slaughterhouses, dairy industries, vegetable markets, olive mills and municipal solid waste sorting plants) for potential implementation of biogas systems. At the end of this project, only five sites were selected as they have suitable conditions for the implementation of a biogas plant. These include Taanayel Farms, Domain Taanayel, Bi Clean (municipal solid waste sorting facility), Gout Blanc (goat farm), and Al Tayeb cow farm. Technical and financial proposals for the development of onsite biogas plants for each site were developed.

The main objective of this paper is to assess the management of manure in the Bekaa and Baalbek governorates where cattle production is concentrated and propose a plan for the manure management in order to mitigate negative impacts of its direct use without pretreatment. To achieve this objective, 30 farms in the Bekaa and Baalbek-Hermel governorates were surveyed, and manure and soil samples from each farm were collected and analyzed for their nutrient contents (N, P, and K). A nutrient management plan was assessed through considering the nutrient needs of the main two crops planted in the study area (wheat and potatoes), and was used besides other factors in defining a proper manure management in the studied governorates.

CHAPTER II

NATIONAL AND INTERNATIONAL LEGISLATIONS

A. National Legislations

There are four national legislations that address livestock farms: Decree No. 4917/94, Decree No. 8633/2012, Decision No. 9/1, and Decision No. 16/1. Decree No. 4917/94 classifies cattle farms under article 68 into three classes taking into consideration the location of the farm (inside or outside cities and summer villages) and the number of cattle in each farm. Table 3 below presents the three classes.

Table 3. Cattle Farm Classification (MoE, 2016)

Location	Number of cattle	Class
Inside Cities and Summer Villages	≤ 3	3
	> 3 and ≤ 10	2
	> 10	1
Outside Cities and Summer Villages	< 3	3
	> 3	2

On March 3, 2001, the Ministry of Environment (MoE) issued Decision No. 16/1, which sets the environmental conditions for the construction and operation of cattle and poultry farms. This decision defines the environmental impacts of farms, which includes generation of solid waste and wastewater, consumption of water, air pollution, generation of noise, and bacterial contamination. Moreover, this decision identifies the required mitigation measures to be adopted by farmers. With respect to wastewater generation, the MoE forbids the discharge of wastewater into sewer networks, rivers or artesian wells. It also forces each farm to install a wastewater treatment unit in order to treat the wastewater before its discharge. As for manure and other organic wastes, the decision forces the farms either to transfer organic wastes into feed or organic fertilizers or to send them to specialized facilities to be treated.

On December 2, 2004, the MoE issued Decision No. 9/1, which sets the minimum setback distances for all types of farms (including cattle) from residential areas in un-classified zones. This decision takes into consideration the number of Animal Unit (AU) and the class of the farm. One cow is equal to one AU. Table 4 outlines the minimum distance allowed for the construction of cattle farms with reference to closed residential agglomerations (minimum five houses or apartments).

Table 4. Minimum Distance Requirement in Unclassified Areas according to the Number of Animal Units. (MoE, 2016)

Total Number of Animal Units	Minimum Distance Requirement (m)
≤50	350
51-100	400
101-150	450
151-200	500
201-250	550
251-300	600
301-350	650
351-400	700
401-450	800
451-500	900
501-550	1,000
551-600	1,000
≥600	1,000

Finally, annex 2 of Decree No. 8633/2012 declares that all new class 1 and 2 farms must develop an Initial Environmental Examination (IEE) study in order to acquire a construction permit. The IEE must be developed by national environmental consultancies that are registered in the Council for Development and Reconstruction (CDR). The IEE identifies and assesses the potential environmental impacts of the farm's operation on the environment, and develops an environmental management plan to mitigate the consequent impacts.

B. International Legislations

European Commission (EC) issued several regulations related to livestock farms. These include European Union (EU) Nitrate Directive, Integrated Pollution Prevention and Control (IPPC), and Environmental Impact Assessment Directive. With respect to the nitrate directive, the most relevant directive is 91/676 that elaborates on the "protection of waters against pollution caused by nitrate from agricultural sources" (Martinez and Burton, 2003). The directive also requires the members to develop and implement action programs in order to protect surface water and groundwater from nitrate pollution. The action programs should include measures to limit livestock manure annual application to 170 Kg N/Hectare of land (Martinez and Burton, 2003).

The aim of the IPPC is to control and reduce the emissions of substances from agricultural and industrial activities to the environment which might impact human health and pollute the environment. However, IPPC scope includes only raising of production pigs and poultry and does not include cattle farms.

As for the Environmental Impact Assessment (EIA) directive, it states that all kinds of animal farms that may have a negative impact on the environment must undertake EIA studies prior to acquiring a development permit.

CHAPTER III

MATERIALS AND METHODS

A. Farms' Visits

According to the Food and Agriculture Organization of the United Nations (FAO), cattle farms are classified into three classes: small farms having less than 10 cattle, medium farms having between 21 to 50 cattle and large farms having more than 50 cattle (FAO, 2003). This classification was adopted in this study.

Since the Bekaa and Baalbek-Hermel Governorates have the highest number of cattle in Lebanon, the two were selected in order to assess manure management in Lebanese farms. According to the Ministry of Agriculture (Department of Animal Production and Breeding), medium and large cattle farms are concentrated in the northern area of the Bekaa Governorate and southern area of the Baalbek-Hermel Governorate (MoA, 2017). Hence, 18 farms were visited in northern Bekaa and twelve farms were visited in southern Baalbek-Hermel (Figure 2).

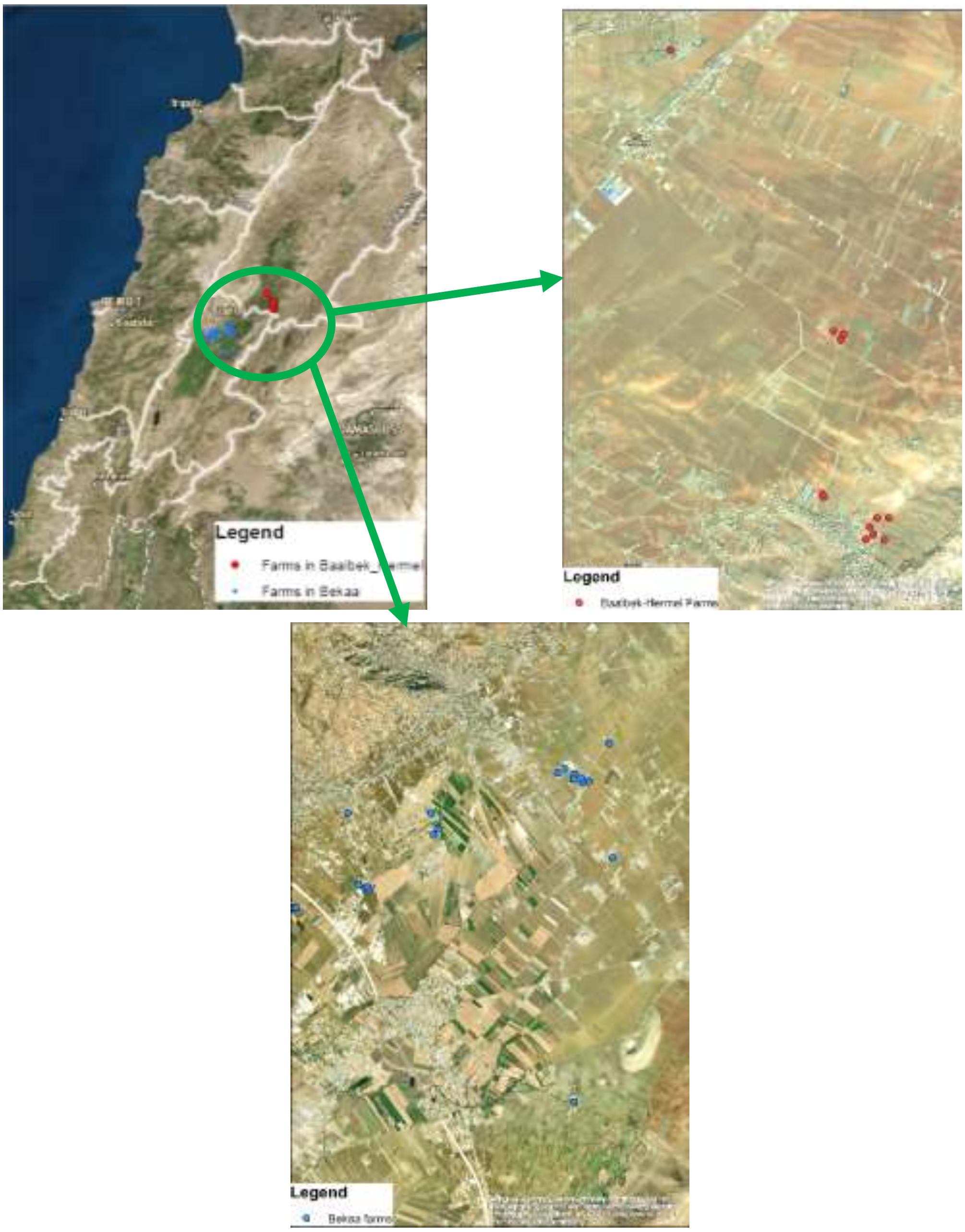

Figure 2. Location of visited farms

A survey was conducted in each of the 30 farms (copy of the survey form in Appendix). The farmers were asked several questions on the capacity of their farms, current manure management processes, the generation of other organic wastes, land availability, energy consumption, their knowledge about international manure management practices and their willingness to treat manure or send it to a centralized treatment facility. Table 5 presents general information about the visited farms.

Table 5. General Information about the surveyed farms

Site #	Owner	Address	No. of cattle	Class*	Estimated farm area (m^2)
1	Domaine Taanayel	Taanayel	92	Large	230,000,000
2	Nour Eldine Lotfi Eltilyani	Bar Elias	70	Large	Unknown
3	Khaled Ali Obeid	Saadnayel	40	Medium	5,000
4	Taanayel Farm	Zahleh	1000	Large	93,000
5	Skaff Farm	Zahleh	250	Large	20,000
6	Abou Jihad Neiaimy	Zahleh	40	Medium	40,468
7	Fattoush Farm	Zahleh	100	Large	24,281
8	Joseph Touma Touma	Zahleh	30	Medium	60,000
9	Khoury Farm	Zahleh	1500	Large	120,000
10	Ibrahim Azar	Zahleh	100	Large	Unknown
11	Shawki Fawzi Nabhan	Zahleh	80	Large	Unknown
12	George Bou Lawz	Zahleh	400	Large	56,656
13	Aziz ElMor	Zahleh	100	Large	89,031
14	Fadia Hrouk	Zahleh	20	Small	8,094
15	Nadim Mahmoud Elzmar	Taanayel	55	Large	4,900
16	Mohamad Obeid	Taanayel	22	Medium	4,900
17	Ahmad Hussein Beiruti	Taalbaya	90	Large	5,000
18	Ali Hussein Haidar Ahmad	ElMaalaka	50	Medium	60,703
19	Moufid Hammoud Abdallah	Saraain ElFawka	44	Medium	485,623
20	Abbass Hammoud Abdallah	Saraain ElFawka	29	Medium	404,686
21	Mohammad Hussein Chouman	Saraain ElFawka	50	Medium	40,469
22	Ali Mahmoud	Saraain ElFawka	30	Medium	1,400
23	Morshid Hajj Hussein	Saraain ElFawka	15	Small	8,094
24	Hamza Chouman	Saraain ElFawka	20	Small	20,234
25	Ali Mkheiber Chouman	Saraain ElFawka	25	Medium	20,234

26	Youssef Mkheiber Chouman	Saraain ElFawka	13	Small	20,234
27	Hizzaa Shokor	Nabi Chit	35	Medium	28,328
28	Ibrahim Hazzaa	Nabi Chit	20	Small	40,469
29	Ibrahim Chokor	Nabi Chit	12	Small	40,469
30	AREC	Haoush Sneid	3	Small	954,079

* Classification based on FAO

B. Collection of Manure and Soil Samples

With respect to soil samples, soil samples were collected from selected locations in virgin lands (areas that are neither planted nor affected by manure or fertilizers) in each farm in order to test the nutrient requirements of the land. Five samples from each farm were collected from surface layer down to a depth of 15-20 cm. The five samples were thoroughly mixed and a composite sample was prepared from the mixture. Soil samples were then placed in zip-locked bags that were sealed after pushing the excess air out. Samples were then placed in a refrigerator during transportation, and were then spread on plastic sheets for 24 hours before testing to allow for air-drying.

As for manure samples, five samples of equal amount were randomly collected from each barn to the depth necessary for the manure to be removed. The five samples were thoroughly mixed and a representative composite sample was made from the mixture. In some farms where manure was already collected from the barn, samples were collected from a stockpiled manure. 10 samples were collected from different locations of each pile at a depth of around 45cm from the surface to avoid losses by leaching and volatilization. Similarly, the 10 samples were thoroughly mixed and a composite sample was made from the mixture. The subsample from each farm was placed into a zip-locked bag that was sealed after pushing the excess air out. Only two-thirds of the bag was filled to allow for gas expansion. Manure samples were then placed in an ice cooled refrigerator to reduce biological activity during transportation, and were then spread on plastic sheets for 24 hours to allow for air- drying.

C. Analysis of Soil and Manure Samples

After air-drying, manure samples were placed in an oven at 60°C for 48 hours. In order to obtain a homogenized sample, the manure samples were ground (UC Davis, 2010). Furthermore, manure samples were analyzed for total nitrogen (TN), total phosphorous (TP) and water extractable (soluble) potassium (K) according to standard methods listed below.

Manure samples were extracted with deionized water for the testing of water-soluble N (manure: water ratio is 20:1) and P (manure: water ratio is 2:1) available for the crops. The Persulfate Digestion Test 'N Tube method having a range of 2 to 150 mg/L N was used (Hach Method 10072) to test N, and Molybdovanadate Method with Acid Persulfate Digestion having a range of 1.0 to 100.0 mg/L PO_4^{3-} was used (Hach Method 10127) to test TP. As for the water extractable K, manure samples (0.75g) were first extracted with 30 ml of milli-Q water and then filtered using 1.5 µm filter paper. Then, water extractable K was tested using BWB flame photometer.

As for soil samples, they were ground and then sieved using sieve mesh No. 10 (2 mm pore size). Then, the samples were analyzed for water extractable N, P and K according to standard methods listed below. Water extractable N and P are measured instead of TN and TP since they constitute an immediate source of nutrient uptake by crops.

In order to test for water extractable N, soil samples (5g) were first extracted with 50ml of milli-Q water and then filtered using Whatman Grade 42 filter paper (pore size = 2.5µm). A NitraVer 5 powder pillow was then added to the extract and tested using the spectrophotometer. As for water extractable P, a similar procedure was used whereby soil samples (2 g) were first extracted with 40ml of milli-Q water and then filtered (Whatman Grade 42 filter paper). A PhosVer 3 powder pillow was then added to the extracts and tested using the spectrophotometer. As for the water extractable K, soil samples (1g) were first extracted with 25 ml of milli-Q water and then filtered using 1.5 µm filter paper. Then, water extractable K was tested using BWB flame photometer.

N, P and K are tested in both soil and manure samples due to their important role in the plant metabolic processes. N is an important constituent of protoplasm, nucleic acids, chlorophyll and amino acids knowing that the latter is crucial for protein synthesis. It also promotes the rapid development and growth of "all living tissues and improves the quality of leafy vegetables and fodders" (FAO, 2006). P, on the other hand, is involved in several metabolic processes such as photosynthesis, respiration, glycolysis, and synthesis of fatty acids. It is also involved in the production of amino acids through the activation of coenzymes. As for K, it activates enzymes that are responsible for metabolism of carbohydrates and controls many "metabolic processes required for growth of fruit and seed development" (FAO, 2006).

CHAPTER IV

RESULTS AND DISCUSSION

A. Survey's Findings

In this study, the three farm classes were considered in order to examine the management of manure in all farms. Accordingly, seven small farms, 11 medium farms and 12 large farms were visited.

Out of the 30 visited farms, various procedures pertaining to manure management are undertaken:

- Five farms store the manure in an external area and wait until the dry season (spring and summer) to spread it on their own lands.

- One large (Domain Taanayel) composts the manure and use it on its lands. Domain Taanayel were thinking of installing a biogas plant but found that the current treatment method is much cheaper.

- 21 farms irrespective of their class sell the manure to other farmers to be used as a soil amendment.

- One large farm, Taanayel Farm, separates the solid from the liquid manure and sells both to a composting facility (GreenCo). This farm is currently studying the feasibility of installing a biogas plant onsite.

- One large farm, Khoury farm, separates the solid from the liquid manure (Figure 3) and sells solid manure to farmers then treats the liquid manure by an onsite wastewater treatment plant. The treated effluent is then discharged into the sewer network.

Therefore, out of the 30 farms, only two farms located in the Bekaa Governorate pretreat their manure by separating the liquid from the solid fraction, and one farm located in the Bekaa composts the collected manure. Moreover, one farm in Baalbek-Hermel Governorate (AREC) has built a small-scale biogas plant (Figure 4) but is still non-operational.

Figure 3. Solid-Liquid separator in Khoury farm

Figure 4. Small scale biogas plant at AREC

On the contrary, eight farms in Saraain El Fawqa, three farms in Nabi Chit and two farms in Taanayel were found to drain the manure into a pit or open area in front of their farms and store it there until the manure dries (Figures 5, 6 and 7). This measure poses a threat to soil and groundwater quality.

Figure 5. Storage of manure in a farm in Saraain El-Fawqa

Figure 6. Storage of manure in a farm in Taanayel

Figure 7. Storage of manure in a farm in Nabi Chit

As for the generation of other organic residues from the farm, a key finding is that 15 farms do not generate any other organic waste, 10 farms generate sawdust, four generate straw, and one sawdust and straw. Sawdust and straw are discharged with the manure.

With respect to energy supply and consumption, farmers mainly consume energy to provide hot water to clean the milking parlors and to power the workers' houses. It was found that seven farms do not have generators and rely solely on the electricity supplied by Electricité du Liban (EDL), a public establishment "responsible for the generation, transmission, and distribution of electrical energy in Lebanon" (EDL, 2017), or Electricité de Zahlé (EDZ), a private electric utility that provides Zahle municipality and 15 surrounding localities with electricity "under a concession agreement with the Lebanese government and EDL" (EDZ, N.D.). The remaining farms have electric generators to compensate for the gap in electricity provision. Four of the farms that have generators are located in Zahle and do not use generators anymore since they are provided with 24-hour electricity supply by EDZ.

As for the farmers' knowledge on the impacts of mismanagement of manure, 26 farmers believed that the addition of manure has positive impacts on soil quality. As for the remaining farmers, one farmer said that it has a negative impact on soil and groundwater quality, two farmers mentioned that the bacteria in the manure impact the soil, and one farmer believed that it increases the ammonia in soil. As for the international technologies used to treat manure, 22 farmers had no knowledge of any technology, whereas the remaining farmers identified anaerobic digestion, composting, shredding, and drying as means of treating manure.

Finally, when asked whether the farmers are willing to start treating manure onsite, on the one hand, 15 farmers refused to treat their manure for various reasons.

They either believed that they are not doing something wrong, or they lacked the required space onsite, or due to financial constraints. 13 farmers expressed their willingness to treat onsite, and the remaining two are already treating the manure (composting onsite). On the other hand, when asked whether they are willing to send the manure to a centralized treatment facility, 16 farmers agreed with no conditions, eight farmers agreed under the condition that the treatment is free of charge, two farmers would agree in exchange for financial incentives, while four farmers refused since they are benefitting from the manure either on their own lands or by selling them to other farmers.

The survey results are presented in Table 6 below.

Table 6. Survey results

Site #	Class	Management of Manure	Generation of other Organic waste	Energy consumption	Willingness to treat manure onsite
1	Large	Composting	Straw	EDZ + generator	Treatment applied
2	Large	Sold to farmers to be spread on lands	Straw	EDZ + generator	Yes
3	Medium	Sold to farmers to be spread on lands	Nothing	EDZ + generator	No
4	Large	Solid-liquid separation	Nothing	Generators	Yes
5	Large	Land spreading	Straw	EDZ	Yes, if this is required by the municipality
6	Medium	Sold to farmers to be spread on lands	Nothing	EDZ	No
7	Large	Sold to farmers to be spread on lands	Sawdust	EDZ	Yes
8	Medium	Land spreading	Nothing	EDZ	Yes
9	Large	Solid-Liquid separation	Straw	EDZ	Yes
10	Large	Sold to farmers to be spread on lands	Sawdust	EDZ + generator	No
11	Large	Sold to farmers to be spread on lands	Sawdust	EDZ	No
12	Large	Sold to farmers to be spread on lands	Nothing	EDZ	No
13	Large	Sold to farmers to be spread on lands	Nothing	EDZ	No
14	Small	Sold to farmers to be spread on lands	Nothing	EDZ	Yes
15	Large	Sold to farmers to be spread on lands	Sawdust	EDZ + generator	Yes, with the government support
16	Medium	Sold to farmers to be spread on lands	Nothing	EDZ	No
17	Large	Sold to farmers to be spread on lands	Sawdust + straw	EDZ + generator	Yes
18	Medium	Land spreading	Sawdust	EDZ + generator	Yes

19	Medium	Land spreading	Sawdust	EDL + generator	Yes
20	Medium	Land spreading	Sawdust	EDL + generator	Yes
21	Medium	Sold to farmers to be spread on lands	Nothing	EDL+ generator	No
22	Medium	Sold to farmers to be spread on lands	Sawdust	EDL + generator	No
23	Small	Sold to farmers to be spread on lands	Nothing	EDL + generator	No
24	Small	Sold to farmers to be spread on lands	Sawdust	EDL + generator	No
25	Medium	Sold to farmers to be spread on lands	Nothing	EDL+ generator	No
26	Small	Sold to farmers to be spread on lands	Nothing	EDL + generator	No
27	Medium	Sold to farmers to be spread on lands	Sawdust	EDL+ generator	Yes
28	Small	Sold to farmers to be spread on lands	Nothing	EDL + generator	No
29	Small	Sold to farmers to be spread on lands	Nothing	EDL	No
30	Small	Composting	Nothing	EDL+ generator	Treatment applied

B. Nutrient Content

The nutrient content of the manure (N, P & K) varied tremendously between farms. On a dry mass basis, water extractable TN ranged from 0.2 to 2.87 % N (average 0.9), water extractable TP ranged from 0.17 to 1.62 % P (average: 0.66%) and water extractable K ranged from 0.12 to 1.83 % (average 0.69%) (Table 7). The variation in nutrient content is attributed to several factors, mainly to the cattle's diet, method used to store manure, type and quantity of bedding, and quantity of water used in the barn that might reach the manure. The cattle's diet has a great impact on the nutrient content of the manure. For instance, cows fed with corn silage release manure with intermediate level of fiber nitrogen, whereas cows fed with alfalfa silage release manure with lower concentrations of fiber nitrogen (Powell and Bocher, 2011). Moreover, the variation in the nutrient content could be attributed to the fact that some samples were taken from a stockpile of manure whereas other samples were taken from the barn (fresh). Stockpiling helps in concentrating the nutrients (Ackerman et al, 2010). This variation in the nutrient content of manure is also shown in the literature. According to a study which tested around 34 samples of dairy manure in Ohio, TN averaged 2.9%±0.6, P averaged 0.452%±0.04, and K 2.7% on dry weight basis (Michel et al., 2004). Another study done in Zimbabwe reported lower percentages of cattle manure nutrients whereby N averaged 1.5%, P 0.15%, and K 0.78% on dry weight basis (Giller and Mapfumo, 2001). Moreover, a study done in Kenya on cattle manure reported different averages whereby TN averaged 1.12%, P 0.3%, and K 2.4 % on dry weight basis (Lekasi et al., 2003).

With respect to the nutrient content of the soil samples collected from the 30 farms, the water extractable N ranged from 1.23 to 140.12 mg N/Kg, water extractable P ranged from 1.61 to 13.04 mg P/Kg and water extractable K ranged from 8.39 to 657.15 mg K/Kg (Table 7). These results indicate that the water extractable N in the soil of 30 farms differs tremendously as it ranges from very low to very high (Bashour, 2001). Table 8 presents the classification of NO_3-N levels in soils. Even though farmers mentioned that the land from which the soil samples were collected was not fertilized, the big variation in N between the sites indicates that the sites with high N concentrations were fertilized before the collection of samples. Moreover, the high values of N in sites 7, 10, 16, 20, 22, 26, and 27 could be attributed to the storage of manure in an open pit until its drying. This leads to the leaching of nutrients from the manure into the soil and its contamination.

Table 7. Nutrient content in manure and soil (dry weight basis)

Site	Manure			Soil		
	TN (%)	TP (% P)	Water extractable K (%)	Water extractable N (mg N/Kg)	Water extractable P (mg P/Kg)	Water extractable K (mg/Kg)
1	0.54±0.08	0.42±0.02	0.8±0.05	26.71±1.75	6.59±0.53	174.44±1.65
2	2.12±0.49	1.52±0.03	1.83±0.01	23.68±2.49	2.29±0.46	8.39±1.68
3	2.28±0.02	0.51±0.21	1.05±0.00	18.59±0.16	8.89±0.73	108.37±0.98
4	0.23±0.05	0.35±0.02	0.48±0.10	2.05±0.32	9.41±1.25	8.56±1.7
5	0.51±0.2	0.51±0.12	1.05±0.01	8.46±0.48	6.21±1.4	175.93±1.76
6	0.39±0.26	0.28±0.06	0.36±0.02	17.14±1.79	8.8±0.27	64.78±1.6
7	0.35±0.31	0.65±0.07	0.35±0.00	42.85±3.19	10.99±1.58	62.4±1.49
8	0.85±0.15	1.00±0.10	1.13±0.23	5.08±0.8	4.48±0.46	64.64±2.16
9	0.63±0.02	0.45±0.00	0.49±0.06	9.24±0.64	3.81±1.15	188.46±3.94
10	0.88±0.01	0.52±0.26	0.84±0.02	32.96±3.51	11.98±0.59	464.42±12.34
11	0.88±0.03	1.13±0.77	0.74±0.11	2.03±0.32	6.5±1.66	61.7±2.62
12	0.6±0.01	0.85±0.15	0.8±0.08	18.5±3.78	12.01±0.09	317.34±0.48
13	0.62±0.04	1.15±0.26	1.55±0.06	5.12±0.8	2.16±0.81	17.09±2.99
14	0.55±0.28	0.45±0.05	0.35±0.02	11.85±2.39	1.65±0.54	30.10±0.63
15	0.34±0.17	0.73±0.31	0.16±0.00	11.04±2.23	3.03±0.51	39.62±3.02
16	0.58±0.09	0.17±0.04	0.16±0.02	59.68±1.74	2.71±0.18	59.67±5.08
17	0.67±0.15	0.63±0.19	0.75±0.07	16.55±2.39	2.36±1.14	9.62±0.45
18	0.31±0.15	0.32±0.08	0.12±0.00	20.24±4.96	5.61±1.2	20.61±0.12
19	0.2±0.05	0.48±0.15	0.21±0.01	26.09±0.95	5.47±0.14	112.41±6.52
20	0.76±0.03	0.51±0.05	0.6±0.08	30.47±2.55	3.41±0.18	86.30±5.15
21	0.69±0.1	0.32±0.08	0.35±0.01	10.38±0.32	1.61±0.18	39.64±0.83
22	0.97±0.02	0.35±0.0.3	0.8±0.04	43.83±2.6	1.87±0.27	39.00±1.10
23	2.87±0.01	0.52±0.17	0.75±0.13	5.45±0.16	13.04±2.41	274.11±6.01
24	2.33±0.03	0.64±0.03	1.32±0.01	1.23±0.16	3.54±0.23	58.81±0.96
25	2.04±0.03	1.62±0.06	0.7±0.01	4.03±3.17	12.61±1.05	225.21±4.75
26	0.67±0.01	1.13±0.06	1.06±0.04	140.12±3.02	9.8±0.37	657.15±8.69
27	0.98±0.03	0.28±0.02	0.2±0.01	34.92±2.55	2.18±0.91	27.04±1.38
28	0.86±0.02	0.64±0.06	0.63±0.01	11.36±0.8	8.83±0.05	57.43±3.14

29	0.74±0.01	0.93±0.03	0.56±0.01	13.54±1.11	12.59±4.11	36.98±0.38
30	0.68±0.2	0.67±0.08	0.48±0.00	6.07±2.22	1.82±0.18	30.03±3.04

Table 8. Available Nutrient range in soils in mg/Kg (Bashour, 2001)

Nutrient	Very Low	Low	Medium	High	Very High
NO_3-N	0-5	5-15	15-30	30-40	>40

In order to know the nutrient content of the composted manure, several samples were taken from composted cow manure from Domain Taanayel farm and a composting facility, GreenCo. Domain Taanayel uses windrow composting that requires around three months to get the final product. Moreover, they recently started using drum composting method that was developed by a team of Saint Joseph University (USJ) professors and environmental experts in arcenciel. Based on the team in the farm, each batch of manure needs 8 hours only to be composted. Straw, woodchips, and leaves are mixed with manure. Samples were taken from four compost windrows and sent to Lebanese Agricultural Research Institute (LARI) labs. The results are presented in Table 9. It was found that the average N is 1.46%, P is 0.65%, and K is 1.52%.

GreenCo, on the other hand, collects cow and chicken manure from farms in the Bekaa area and composts them using the windrow system to produce two types of compost: chicken and cow compost. The manure is mixed with straw, grass clippings, and wood chips. The composting process lasts for a minimum of three months in an outdoor area without protection from rain. During those three months, the piles are turned on a weekly basis. Then, the compost is screened and tested. The nutrient content for three batches is presented in Table 9. It was found that the average TN is 2.39%, TP is 1.2%, and K is 2.95%. In a study that compared dairy manure compost amended with sawdust to that amended with straw, it was found that the average percentages of TN, P and K in that amended with sawdust were 2.1%, 0.31%, and 1.88% respectively whereas the average percentages in compost amended with straw were 2.85%, 0.56%, and 3.95% respectively (Michel et al., 2004). Another study presented much lower percentages whereby the average TN of a dairy manure compost was found to be 0.64%, P 0.12%, and K 0.74% (Sommer, 2001).

Table 9. Nutrient content of composted manure (dry weight basis) *

Site	N (%)	P_2O_5 (%)	K_2O (%)
Domain Taanayel			
Pile 1	1.00	0.55	1.66
Pile 2	1.99	0.84	1.75
Pile 3	1.74	0.72	1.38
Pile 4	1.09	0.50	1.28
GreenCo			
1	2.80	1.35	3.15
2	2.30	1.35	3.15
3	2.06	0.89	2.56

* Samples were tested by Lebanese Agricultural Research Institute (LARI)

CHAPTER V

MANURE MANAGEMENT PLAN

A. Nutrient Management Plan

Developing a nutrient management plan is essential to prevent negative impacts of manure on the environment. The key elements of a successful plan are testing the nutrient content of manure and soil, determining the quantities of generated manure, and identifying the crops' needs. Accordingly, manure application rates should be based on the manure nutrient content and the requirements of the crops to plant.

Since wheat and potato are the most planted crops in the studied area, a nutrient management plan will be developed for these two crops. Table 10 presents the required nutrient application rates for rainfed wheat based on soil fertility in the near east area, while Table 11 presents nutrient requirements by potato crop.

Table 10. Required nutrient application rates for rainfed wheat based on soil fertility in the near east area (IFA, 1992)

Soil Fertility class	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
Low	100	75	50
Medium	75	50	-
High	50	-	-
Very High	25	-	-

Table 11. Nutrient requirement by potato crop in the near east area (IFA, 1992)

Tuber yield (tons/ha)	N (Kg/ha)	P_2O_5 (Kg/ha)	K_2O (Kg/ha)
50	242	63	314
37	113	45	196

25	96	31	129

Manure application is based on the nitrogen requirement by the crop. With respect to the quantities of manure to be added to the 30 sites to produce 25 tons of potatoes/ha in each site, it varies from around 3.32-46.44 tons depending on the nutrient content of the soil and manure (Table 12). The calculation was based on quantities of water extractable N found in a hectare of soil, amount of TN found in manure, and N requirement to produce 25 tons of potatoes/ha. The weight of soil in one hectare was based on the bulk density of clay soil (1,330 Kg/m^3) which is the dominant type of soil in the target area (Darwish et al. 2001) in addition to the depth of potato roots that is around 0.3m taking into account that the roots occupy around 3% of the soil volume only. An example is presented below to elaborate on how to calculate the amount of manure needed:

- First, the amount of N found in one Ha of soil was calculated by multiplying the concentration of N in soil by the weight of soil (26.71 mg N/Kg *119,700 Kg=3,197,187 mg which is equivalent to 3.2 Kg N/Ha).

- Second, quantity of N needed to plant 25 t/ha was calculated by subtracting N requirement to produce 25 tons of potatoes/ha from the obtained quantity above (96-3.2=92.8 Kg)

- Finally, quantity of manure needed was calculated by dividing the quantity of N needed to plant 25 t/ha by the concentration of N in the manure (92.8*100/0.54=17,185 kg which is equivalent to 17 tons)

As for the quantities of manure to be added to the 30 sites to grow 1-2 tons of wheat/ha, it varies from around 3.43-46.10 tons depending on the nutrient content of the soil and manure (Table 12). Similar to potatoes, the calculation was based on quantities of water extractable N found in a hectare of soil, amount of TN found in manure, and N requirement to produce 1-2 tons of wheat/ha. The depth of wheat roots is between 0.5-1m but an average of 0.75m was used taking into account that the roots occupy around 3% of the soil volume only.

Table 12. Required amount of manure that must be added to produce 25 tons of potatoes/ha and 1-2 tons of wheat/ha

Site	TN in Manure (%)	Water extractable N in Soil (mg P/Kg)	Quantity of Manure (ton/ha) to produce 25 tons of potato/ha	Quantity of Manure (ton/ha) to produce 1-2 tons of wheat/ha
1	0.54	26.71	17.10	16.96
2	2.12	23.68	4.39	4.38
3	2.28	18.59	4.11	4.14
4	0.23	2.05	41.17	42.73
5	0.51	8.46	18.49	18.98
6	0.39	17.14	23.91	24.14
7	0.35	42.85	25.87	24.82
8	0.85	5.08	11.25	11.62
9	0.63	9.24	15.18	15.56
10	0.88	32.96	10.50	10.28
11	0.88	2.03	10.83	11.24
12	0.60	18.5	15.53	15.64
13	0.62	5.12	15.42	15.92
14	0.55	11.85	17.13	17.47
15	0.34	11.04	27.77	28.36
16	0.58	59.68	15.22	14.07
17	0.67	16.55	14.13	14.28
18	0.31	20.24	30.19	30.30
19	0.20	26.09	46.44	46.10

20	0.76	30.47	12.15	11.96
21	0.69	10.38	13.73	14.04
22	0.97	43.83	9.36	8.96
23	2.87	5.45	3.32	3.43
24	2.33	1.23	4.11	4.28
25	2.04	4.03	4.68	4.84
26	0.67	140.12	11.83	8.67
27	0.98	34.92	9.37	9.14
28	0.86	11.36	11.00	11.23
29	0.74	13.54	12.75	12.97
30	0.68	6.07	14.01	14.44

Even though nutrient management plan reduces the impacts of improper application of manure, there are some challenges that face the use of raw manure in agricultural production. These include the imbalance between the manure nutrient content and crop requirements, the variability of nutrient content in manure, insufficiency of lands in farms to apply manure which will oblige farmers to either store manure or transport it to other farmers in need, low nutrient content in comparison to chemical fertilizers, and the presence of “pathogens and pharmaceutically active compounds (PAC)” (Leytem et al, 2014).

Therefore, it is advisable to treat the manure before its use for agricultural purposes. As mentioned before, there are various technologies for the management of manure. However, composting and AD are the only technologies with “documented record of cost-effective” reduction of pathogens and antibiotics in manure (Leytem at al., 2014). The sections below elaborate on the chemical and microbiological composition of manure compost and digestate.

B. Composting

With respect to macronutrient composition, composting stabilizes nutrients in manure and therefore slows their release when applied to soil (Larney et al., 2006). Studies show that composting decreases TN and K content and increases P (Sommer, 2001). The increase in P is due to the decrease in the volume and weight of the manure and precipitation of P into salts that do not dissolve easily which makes it hard to leach and consequently be lost (Petersen et al., 1998; Sommer, 2001). As for the decrease in N, as mentioned previously, it is attributed to nitrification and denitrification processes that convert nitrogen into N_2O and N_2, ammonia volatilization, and degradation of nitrogen into ammonium (Maeda et al., 2011; Larney et al., 2006). The decrease in K is attributed to its precipitation into highly mobile salts that easily dissolve in water. However, compaction and covering of the piles can decrease the loss of K from around 14-16% to around 8-11% (Sommer, 2001).

As for the impact of composting on pathogens, studies found that composting of manure mixed with sawdust or straw at 55°C for 3 days can remove *Salmonella, E. coli and Listeria* (Grewal et al, 2006). Other studies reported that windrow composting can inactivate more than 99.99% of *E. coli* and fecal coliforms found in cattle manure within seven days (Larney et al., 2003) and 99.99-100% of *Salmonella* spp. during 20 days (Sunar et al., 2010).

In addition, studies found that composting systems significantly reduce the level of antibiotics. Different studies had demonstrated the efficiency of composting in significantly reducing the levels of 16 different antibiotics found in livestock manure (Youngquist et al., 2016).

C. Anaerobic Digestion

In addition to biogas production, AD generates digestate that is used as fertilizer in European and other countries. The digestate composition depends on the substrate (cattle manure, poultry manure, crop residues, wastewater sludge, organic municipal solid waste, etc.) and on the management of the AD process (Risberg, 2015). Most of the macronutrients (N, P, K, Mg, Ca and S) and micronutrients (Cl, Fe, Cu, Ni, Zn, B, Mn, Mo) that are found in the substrate end up in the digestate. With respect to N, P and K content in digestate, K and TN content was found to remain unchanged whereas a small reduction (less than 10%) in P was reported. Even though TN remains the same, the proportion of ammonium nitrogen in TN increases due to the mineralization of organic nitrogen (Möller & Müller, 2012; Risberg, 2015). It is worth mentioning here that studies comparing the macronutrient composition of digestate and compost reported higher concentrations of N, P and K in digestate (Tambone et al., 2010; Manyi-Loh et al., 2016).

With respect to pathogens, studies showed that AD process has no impact on spore forming bacteria even if preceded by pasteurization. Studies also showed that when AD plant is operated at mesophilic phase at an operating temperature of 28°C for 24 days, *Campylobacter jejuni, Salmonella typhimurium, Listeria monocytogens and Yersinia enterocolitica were moderately reduced* (Leytem et al., 2014). However, increasing operating temperature (thermophilic process) and hydraulic retention time (HRT) increase the reduction of pathogenic bacteria (Risberg, 2015).

As for levels of antibiotics in digestate, studies showed a greater impact of thermophilic process on the reduction of antibiotics in comparison to mesophilic process (Varel at al., 2012). However, composting is more effective in reducing levels of antibiotics in comparison to AD. For example, it was found that monensin (widely used antibiotic for cattle) in manure is reduced by around 54% when using composting for 22-35 days (Turker at al., 2013) whereas it is only reduced by 3%, 8% and 27% after 28 days when using AD at 22, 38 and 55°C respectively (Varel at al., 2012).

D. Manure Management Plan

In order to develop a manure management plan, several factors must be taken into consideration which are: nutrient content of the manure, availability of agricultural lands to fertilize, analysis of applicable treatment technologies, and analysis of economic costs (Flotats et al., 2009). Even though the results demonstrated the need for manure application on agricultural lands in the Bekaa and Baalbek-Hermel Governorates, it remains necessary to manage produced manure to avoid its environmental drawbacks, namely contamination with pathogens and PAC. Assessment of manure management options through implementing centralized or on-farm treatment facilities in the studied governorates, along with an economic feasibility of the chosen option was conducted for this aim.

With respect to the choice of treatment scale, the most important factors to look at are: density of animal farms, transportation cost, availability of areas onsite to install the treatment facility, simplicity of maintaining and operating the facility, and required investment. During the field surveys, it was found that in both governorates, small and medium farms are located next to each other (i.e. Zahle in the Bekaa and Saraain El Fawqa in Baalbek-Hermel). This helps in maintaining low transportation cost. Moreover, these farms have neither the required surface area nor the financial capacity to install a treatment facility. These favor the installation of a centralized treatment facility to accept manure from small to medium farms. However, it remains feasible to carry out onsite composting in some farms where space allows, as this would not entail further cost on the farmers.

As for choosing the treatment technology, both composting and AD produce an end product that can either be used as a soil amendment or as organic fertilizer. The compost, as mentioned before, has lower NPK content and antibiotics than digestate. The production of biogas by AD plants is an added value which makes it a more attractive technology knowing that all of the country, except for Zahle, suffers from shortage in electricity supply. However, the investment cost of AD plant is higher than that of a composting plant.

Therefore, it is recommended to have a centralized treatment facility in Baalbek-Hermel governorate and another one in Bekaa governorate. In Baalbek-Hermel, it is recommended to install a centralized integrated AD and composting plant. The composting plant will be used to compost the solid digestate in order to ensure higher destruction of pathogens and improve its quality so that it can be used as a fertilizer. It must be mentioned here that composting of digestate requests a shorter duration than composting of raw manure.

Assuming that 10% of the farms registered in the MoA have closed, it is estimated that the treatment facility in Baalbek-Hermel should treat manure from around 6,853 cattle heads. Based on the surveyed farms, an average of 24.3Kg/day of manure is generated from each animal. Therefore, the AD plant should be able to treat 167 tons/day which is equivalent to 708 kWe.

As for the Bekaa governorate, due to the presence of a composting facility (GreenCo) that is collecting manure from around 12 farms in Central Bekaa, it is recommended to upgrade this facility to be able to receive manure from all of the small and medium farms in the area (around 263 farms). Currently, the facility is receiving around 62 tons/day. Therefore, it should be upgraded to be able to receive around 248 tons of manure/day. However, this facility should adopt some environmental measures to prevent the contamination of the soil and groundwater especially since they are not collecting the leachate that is generated from the piles. These measures should include installing a roof in the composting area to prevent the generation of leachate from rainfall. Moreover, it is preferred to relocate the windrows to a concrete platform rather than on the soil to prevent water pollution by leachate. The leachate can be stored and reused again in the composting process.

Finally, Taanayel farms which currently have 1,000 cows and will be extended to reach 1,500 cows in the next two years and then 3,000 cows, rely solely on private diesel generators. The annual cost of electricity generation (including diesel consumption and generator maintenance) is around 350,000 USD. Therefore, it is recommended to install a biogas plant. The farm has two underground tanks having a capacity of 900m^3 each which could be transformed into digesters and thus reducing the construction cost of the plant. The AD plant can generate around 250 kW from 1,500 cows and around 500 kW from 3,000 cows. In order to install the plant, Taanayel farms could benefit from one of the low interest loans that are discussed in the following chapter.

E. Economic Assessment of the feasibility of the proposed treatment facilities

A feasibility and market study should be developed once choosing the location. The market study should indicate the number of farms that will send manure to the facility, the quantity of manure to be collected, the price of the raw manure that is currently being used by agricultural farmers and the price of the treated manure. Taking into consideration the capacity of the biogas plant and composting facility, the feasibility study should include the following:

- Costs: capital cost, operation and maintenance cost on annual basis for the whole project life (usually 20 years), transportation cost, and equipment replacement costs.

- Revenues: sale of compost/bedding, liquid digestate, energy sale, and tipping fee if available.

1. Baalbek-Hermel Governorate

To assess the feasibility of installing a centralized integrated AD and composting plant in Baalbek-Hermel Governorate, the Net Present Values (NPV) and Internal Rate of Return (IRR) of the installation was determined. The cost elements include investment cost, operation and maintenance cost, and transportation cost. Since there is no AD plant in Lebanon and in order to be able to estimate the cost of the centralized treatment facility, two biogas experts that have installed several centralized treatment facilities in Turkey and Spain were contacted. According to them and in order to install an AD plant having a capacity of 700 KWe, an investment cost of around 2,000,000 USD is estimated. As for the operation and maintenance cost, it is estimated that it will be around 140,000 USD/year. As for the transportation cost, ArcMap was used to choose the best location for installing the facility and the best route from the farms to the treatment facility. In order to select the best location for installing the facility in Baalbek-Hermel governorate, a set of criteria were used (Table 13). Several potential sites were identified (Figure 8), and in order to reduce the transportation cost, the facility was located in the middle of the governorate (Figure 9).

Table 13. Criteria for location a biogas treatment facility (Silva et al., 2014)

Criteria	Description
National ecological reserves and protected areas	Exclude areas classified as national ecological reserve or protected area
Hydrographic network	Exclude flood areas and areas which contain or are less than 150m away from water bodies.
Roads	Exclude areas which contain or are less than 70m away from motorways, regional roads, and national roads.
Slopes	Exclude areas with slopes greater than 15% or less than 2.5%.
Urban, industrial, commercial, and infrastructure	Exclude areas which contain or are less than 200 m away from urban, industrial, commercial and infrastructure areas (Airports and ports).
Residential areas	Exclude residential buildings
Electricity grid	Exclude areas whose distance to high voltage lines is less than 100m and the distance to medium voltage lines is less than 50 m.
Surface area of the land	Potential sites must have an area of at least 1 ha

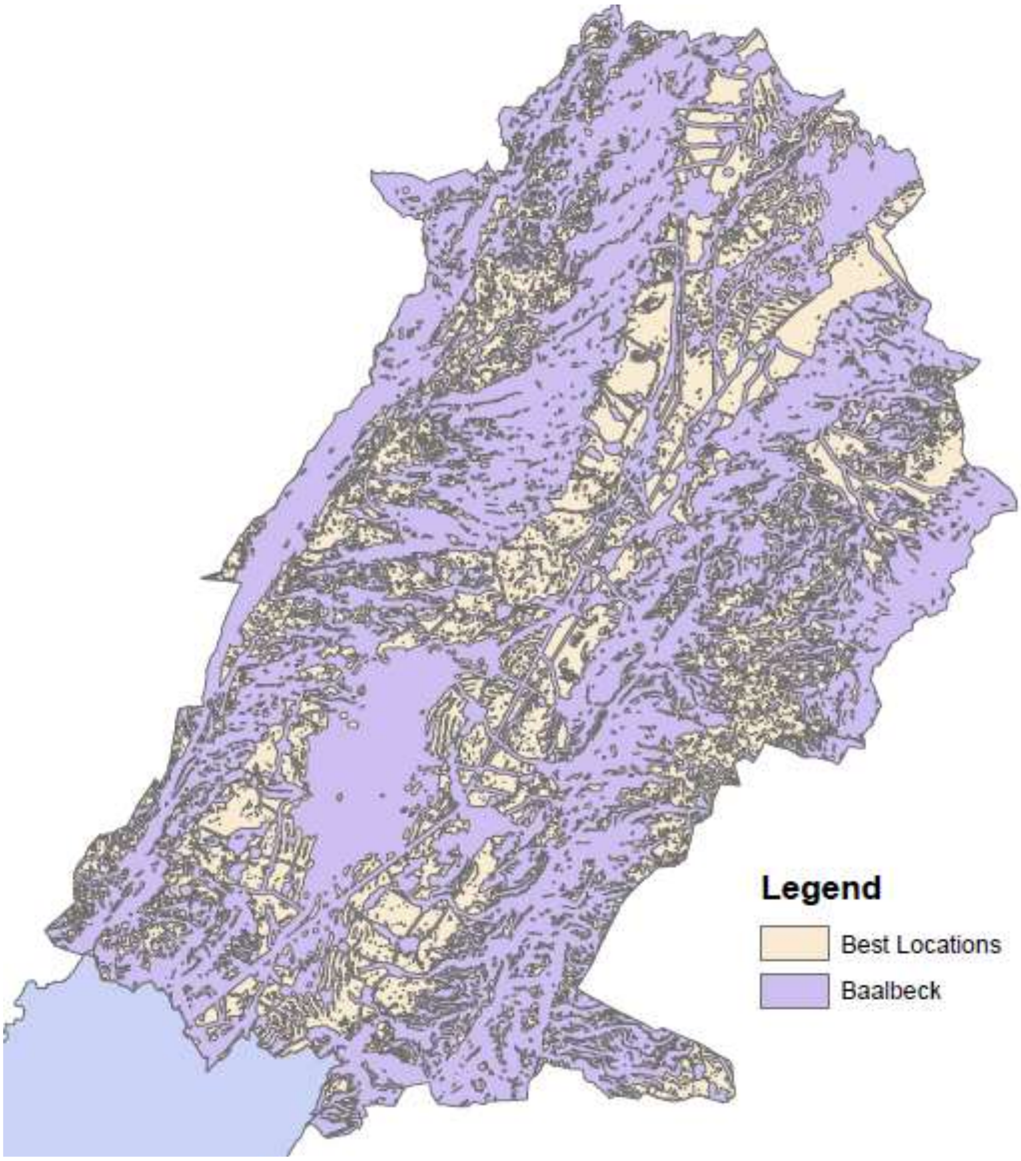

Figure 8. Suitable areas for location a centralized treatment facility

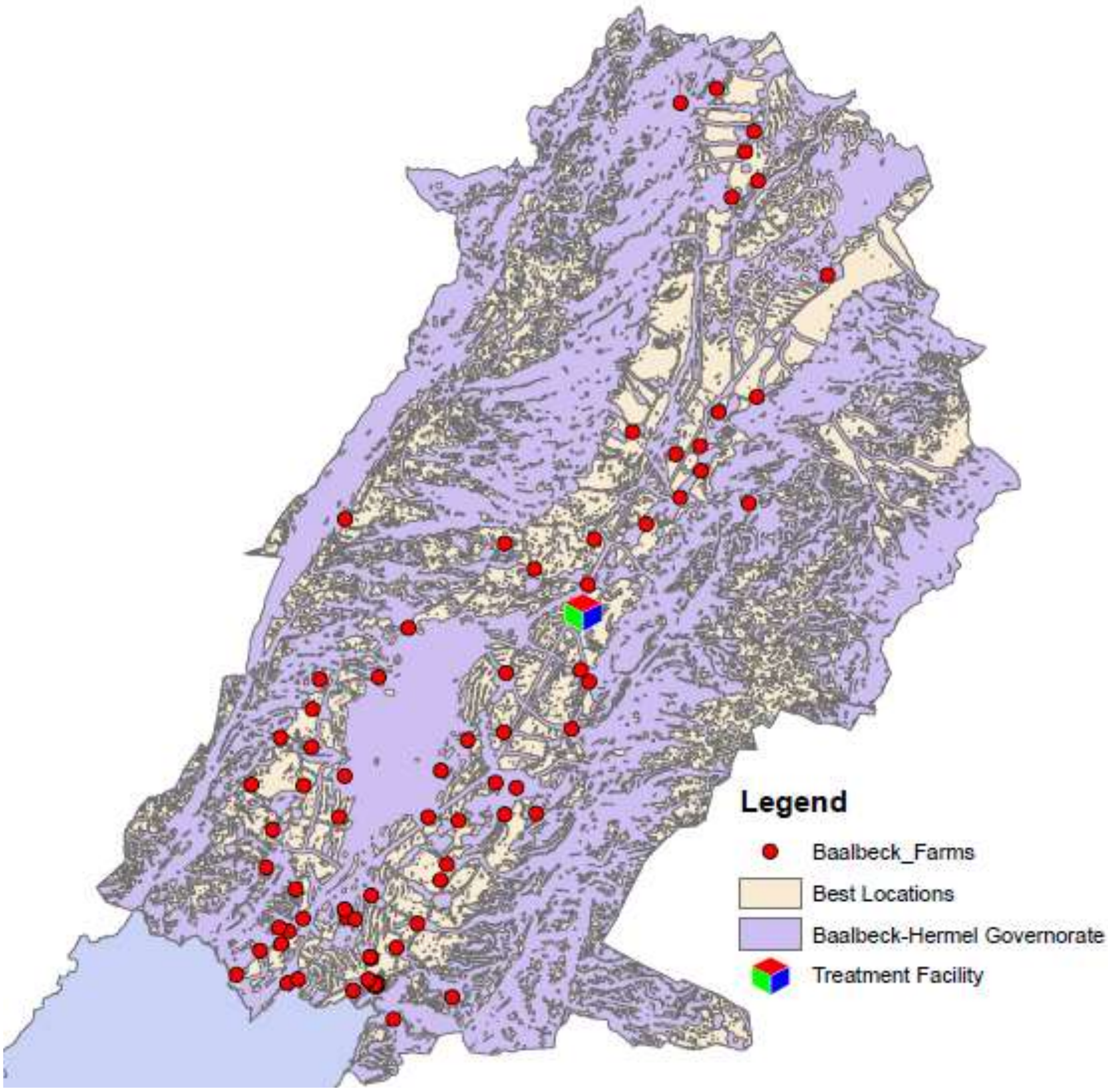

Figure 9. chosen location for the installation of the centralized treatment facility

After locating the treatment facility, the best route was chosen using the least cost path tool in Arcmap in which the slope input raster was given a high weight to avoid steep slopes. The best route was then developed (Figure 10) in order to be able to estimate the transportation cost. Assuming that the truck fuel has a fixed cost of 0.2 USD/Km and that six collection trucks having a capacity of 20 tons will be used, the average transportation cost will be around 103 USD/day. Knowing that the collection frequency is once/week, the annual transportation cost will be around 16,068 USD.

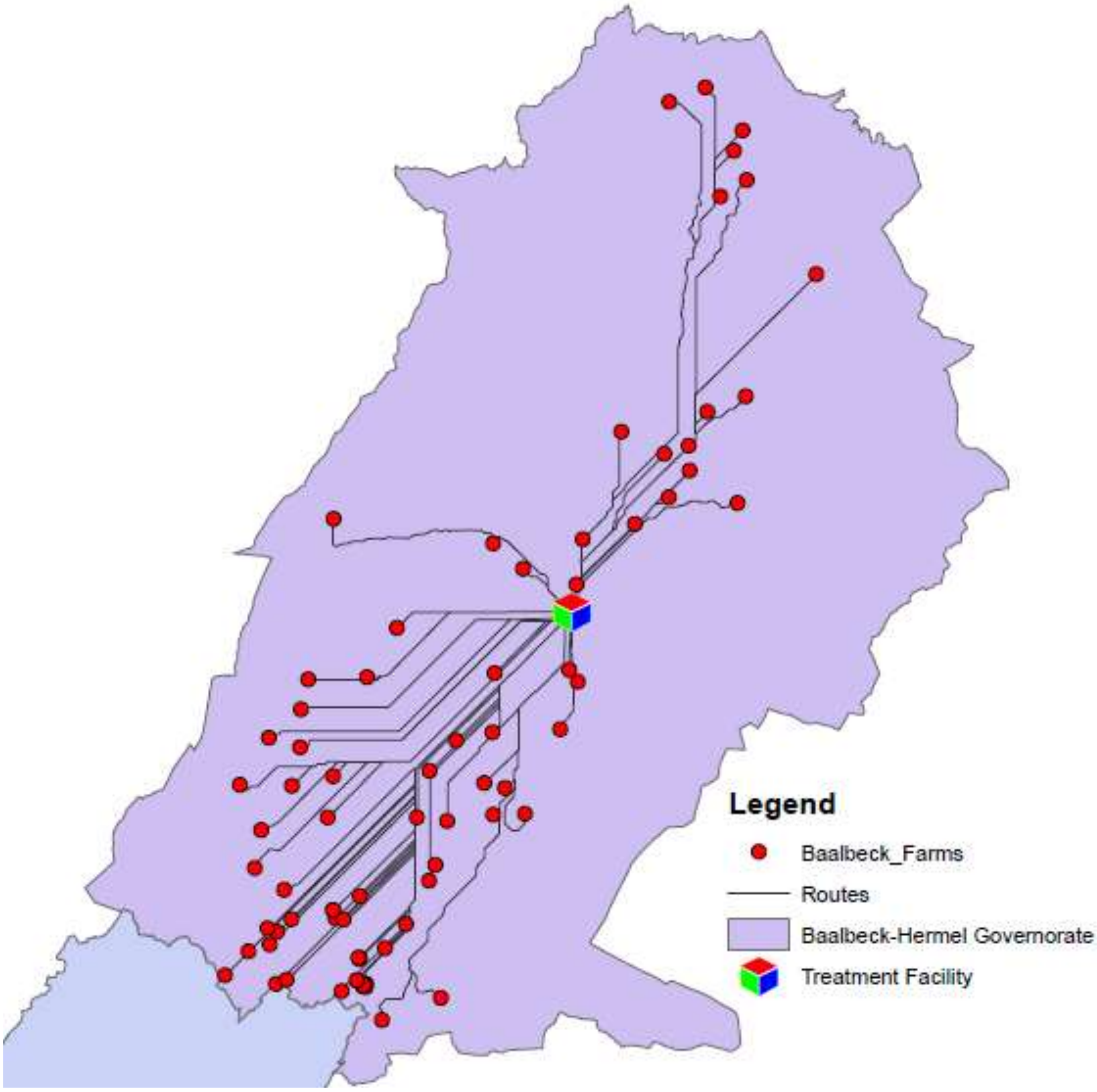

Figure 10. Best route for collection of manure in Baalbek-Hermel Governorate

Annual income was calculated according to the sale of compost and electricity. It must be noted that the biogas plant will consume around 8% of the total generated electricity. Therefore, the estimated generation of electricity is around 14,986.8 kWh. Assuming that the feed in tariff in Lebanon is 11.3 cents/kWh, it is expected that the benefit from the sale of electricity is around 618,130 USD/year. As for the sale of compost and based on the discussion with GreenCo, each ton of compost is around 100 USD. Knowing that the treatment facility will generate around 5,865 tons of compost/year, then the benefit from the sale of compost will be around 586,500 USD/year.

A cash flow table was developed for a period of 20 years which is the lifespan of the plant (Appendix B). A discounted cash flow was estimated at a discount rate of 20.5% based on risk free rate (Central Bank of Lebanon treasury notes) of 7.5%, inflation rate of 3%, and risk premium of 10%. It was found that the NPV is positive which means that “present value of incremental benefit is greater than the present value of all investment and operating costs” (Mohammed et al., 2017). Moreover, the IRR was found to be 43% with a discounted payback period of 3.62 years. Therefore, the project is economically feasible.

A table showing the output of the economic feasibility is presented in Appendix B.

2. Bekaa Governorate

To assess the feasibility of upgrading the existing composting plant in Bekaa Governorate, the cost of upgrading the facility was investigated with GreenCo. It was found that in order to be able to receive 248 tons of manure/day, around 200,000 m^2 of land is required. Based on the current prices of the nearby lands, around 140,000 USD/year is required to rent the needed surface area. In addition, two additional compost turners should be purchased with a total price of 164,000 USD.

In order to be able to estimate the transportation cost, the best route was developed (Figure 11). Assuming that the truck fuel has a fixed cost of 0.2 USD/Km and that six collection trucks having a capacity of 20 tons will be used, the average transportation cost will be around 75 USD/day. Knowing that the collection frequency is once/week, the annual transportation cost will be around 11,700 USD. Since there is only one collection truck, five new trucks should be purchased with a total price of 150,000 USD. In addition to the transportation cost, it is estimated that the annual cost of buying raw manure from the farmers is 452,000 USD, annual operation cost including labor cost is 171,000 USD, and annual maintenance cost of collection trucks and equipment is 50,000 USD. Therefore, the total annual cost is around 684,700 USD.

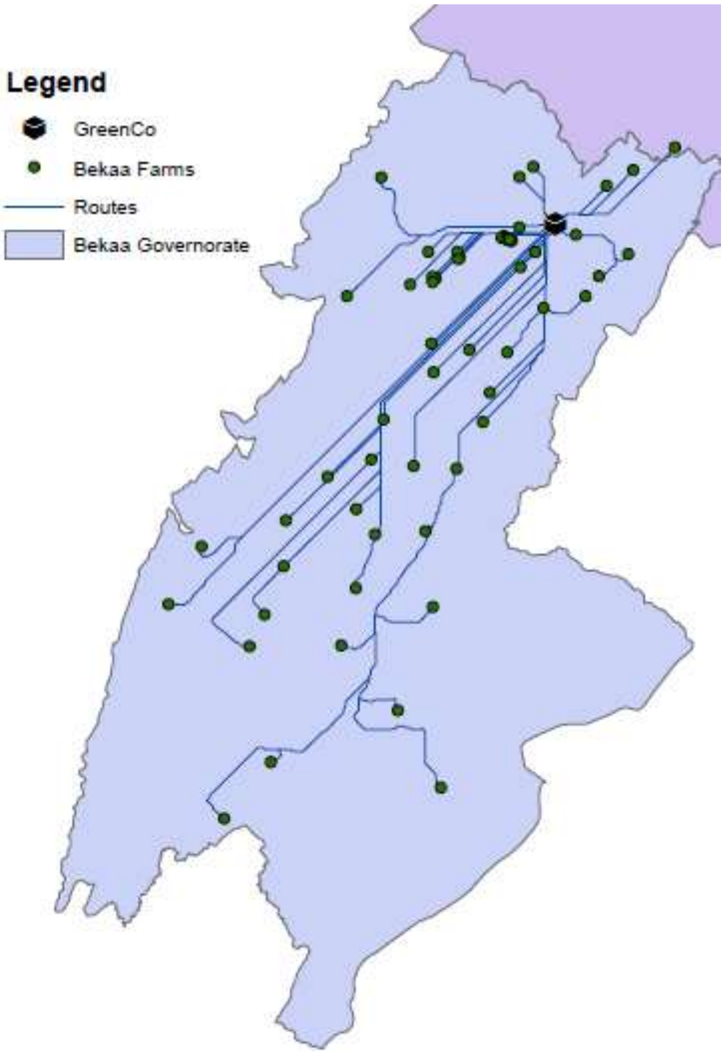

Figure 11. Best route for collection of manure in the Bekaa Governorate

Annual income was calculated according to the sale of compost only. Knowing that the treatment facility will generate around 18,081 tons of compost/year and that each ton of compost is worth 100 USD, then the benefit from the sale of compost will be around 1,808,100 USD/year.

By comparing the annual running cost to the annual benefits, one can notice that the project is highly feasible (Table 15).

Table 14. Summary of Cost-Benefit Components of Upgrading GreenCo's Composting Facility

Components	Price (USD)
Cost	
Investment cost	454,000
Buying of manure/year	452,000
Transportation cost/ year	11,700
Operation cost/ year	171,000
Maintenance cost/ year	50,000
Renting of land/ year	140,000
Total cost	1,278,700
Benefits	
Sales of compost/ year	1,808,100

CHAPTER VI

FARMERS' ACCESS TO CAPITAL

During the site visits, almost all of the farmers except for Taanayel Farm and Khoury Farm complained from the bad economic situation that they are facing now. They said that most of the dairy farms (especially small and medium farms) are closing due to the low financial return. As such, they are not capable of implementing or installing manure treatment measures on their farms. However, six of these farm owners expressed their willingness to manage their wastes if they get a fund or a low interest loan.

In Lebanon, there are several international donors that finance the provision of loans or grants to support small and medium sized enterprises (SMEs) including farms. Key donors include the EU, European Investment Bank (EIB), World Bank, and Agence Française de Développement (AFD). As such, the European Delegation to Lebanon promotes programs that reform environment, energy and agriculture sectors in addition to other sectors (social, economic, cultural, local governance, etc.). The EU usually launches call for proposals in which it specifies the sector they want to promote. They then choose the projects that they want to finance and determine the percentage of EU's contribution that usually ranges between 60 and 80%.

Moreover, Kafalat s.a.l. and the Central Bank of Lebanon (CBL) also support SMEs through the provision of subsidized loans. Both CBL and Kafalat received grants from the EU to subsidize interest rates and cover risks. CBL provides environmental loans for energy related projects and non-energy related projects (recycling, wastewater treatment, solid waste treatment, organic agriculture, ecotourism, landscaping, and any pollution abatement project). National Energy Efficiency and Renewable Energy Action (NEEREA) is one of the energy related loans that was initiated by CBL. NEEREA provides interest free long-term loans (0.6% interest rate) for new and existing projects. The maximum amount of the loan is 20 million USD for a maximum period of 14 years. Farmers wishing to install biogas plants can benefit from NEEREA. As for Kafalat s.a.l., it is a financial company that assists SMEs to get bank funding by processing loan guarantee applications. Kafalat targets SMEs that belong to agricultural, industrial, tourism, crafts and technological sectors. Kafalat Agriculture is co-financed by Kafalat s.a.l. and the EU and is executed by the Ministry of Agriculture. The maximum amount of the loan is 65 million L.L. for a maximum period of seven years at an interest rate of 0.64%.

In November 2018, Bank Audi signed with European Bank for Reconstruction and Development (EBRD) the first Green Economy Financing Facility (GEFF) in Lebanon. The objective of this agreement is to ensure funding for the green loans in Lebanon which in turn promotes investment in projects that mitigate climate change and improve energy efficiency (Bank Audi, 2018). People that can benefit from this loan must be eligible for a CBL subsidized loan or GEFF loan. The interest rate varies depending on whether the beneficiary has benefited from a CBL subsidized loan or not (2.2-14%). Beneficiaries who have not acquired the approval from CBL must prove that their project will improve the baseline of energy consumption by 20%. The maximum amount of the loan is 15 million USD for green projects and 10 million USD for suppliers that sell energy efficient products (solar panels, etc.).

CHAPTER VII

CONCLUSION

The absence of proper monitoring by the relevant Lebanese governmental authorities (mainly Ministry of Environment and Ministry of Agriculture) and the lack of awareness on the impacts of manure are behind the mismanagement of manure in most of the farms. Six percent of the surveyed farms are treating their manure, another 6% are pretreating it, while the remaining 88% are applying the manure on their lands directly or selling it to other farmers to be used for the same purpose, which has adverse impacts on the environment. Therefore, it is very important to improve the efficiency in using the nutrients found in the manure by developing a nutrient management plan. A nutrient management plan should be designed based on the quality of cultivable soils, nutrient content of the manure, and the nutrient requirement of the crops. However, raw manure poses a threat on the environment due to the presence of pathogens, antibiotics, and heavy metals. Therefore, it is recommended to treat the manure before its application to the land. Several technologies are widely used to treat manure such as composting and anaerobic digestion with each having its own added value. However, the farmer should not be kept alone to bear the cost of treating the manure; the government and/or private sector should help either by providing funds/loans or by encouraging the development of centralized treatment facilities that accept manure from farmers at a minimal charge. These centralized facilities could be developed and managed by the private sector though public private partnership (PPP). In Baalbek-

Hermel governorate, it is proposed to develop an integrated AD and composting centralized facility. The facility should be located in the middle of the governorate to reduce the cost of transportation. It will generate biogas that could be treated to produce electricity and the digestate should be composted to be used as a fertilizer. As for the Bekaa area, the existing composting facility in Terbol (GreenCo) could be upgraded to accept manure from small and medium farms in the area. After preliminary testing the feasibility of the recommended solutions, both options were found to be feasible.

Based on the findings of the study in both areas, it is proposed to install centralized treatment facilities (AD or composting facilities) in each governorate in Lebanon in order to reduce the environmental impacts of the mismanagement of manure and benefit from financial returns of these facilities (compost/electricity). This should be done with the support of the government that should provide the private sector with financial incentives (i.e. exemption from the payment of taxes). In addition, the government should release strict legislations that oblige farmers to either treat the manure or send it to a centralized treatment facility.

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APPENDIX A

Questionnaire

1. General Information

- Name:
- Address:
- Contact Person:
- Region:
- Telephone:
- Email:

2. Livestock

Type of Animal	Quantity	Indoor housing of animals (months/year)	Solid or liquid manure	Quantity of material (tones/year)

3. Management of Manure:

- Describe the current management of manure in wet and dry seasons:

  a) Land spreading:
  - Do you test the quality of the manure before spreading?
  - Is there a certain strategy that you follow when you spread the manure (i.e. to match crop uptake requirements)?

  b) Sold to farmers or other facilities:
  - Who?
  - What do they do with the manure?

  c) Solid -liquid separation:
  - What do you do with the solid fraction:
  - What do you do with the liquid fraction:

  d) Composting:
  - Type of system that is used:
  - Indoor/outdoor composting. In the case of outdoor composting, what do you do during wet season?
  - Quantity of manure composted/day:
  - Do you add other organic material (straw, feed waste, etc.) to the manure to be composted?
  - Do you separate solid from liquid manure before composting:
  - Do you test quality of the compost?
  - What do you do with the compost?
  - What are the problems that you are facing?

  e) Anaerobic digestion:
  - Capacity of the biogas plant:

- Type:
- What do you add to the digester other than manure?
- What do you do with the digestate (liquid and solid?)
- Do you test the quality of the digestate? If yes, what are the results?
- How much energy are you producing?
- What are you using the energy for?
- What are the problems that you are facing?

f) Other, Identify:

- Cost of current manure management system:

4. Organic Residues Other than Manure:

- Type of residue:
- Quantity (tons/year):
- Management:

5. Land availability

- Type of ownership (owned, rented or liaised):
- Area of land:

6. Current Energy Requirement

Use	Quantity	Observations (i.e. periodicity)
Governmental Electricity (KWh)		
Electricity from Generators (KVA/KWh)		
- Natural Gas (L)		
- Oil (L)		
- Biomass (Kg)		
- Diesel (L)		
Heat		
Hot water/steam		
- Natural Gas (L)		
- Oil (L)		
- Biomass (Kg)		
- Diesel (L)		

7. Stock

- Are there any existing buildings (i.e. storage silos, pits, liquid manure pits, etc.) that can be used?
- If yes, determine the area of each building:

8. Other Data

- Existence of cables or power lines on the land:
- Distance to consumption energy center:

- Existence of a heating system:
- Existence of Earthquake risk:
- Existence of high water table risk:

9. Farmer's Knowledge and Attitude

- Do you know what are the impacts of spreading manure without treatment?
- Do you know what are the different methods that are used internationally to treat manure?
- Are you willing to start treating the manure onsite? If no, why?
- If financial constraint is the reason behind not treating the waste, will you cooperate if a fund or low interest loan is ensured?

If a centralized treatment facility was developed in your area, will you contribute and send the wastes to be treated? If no, why?

APPENDIX B

Output of the Economic Feasibility for the recommended Solution in Baalbek-Hermel Governorate

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Investment Cost:																					
Biogas Setup Cost	-$2,000,000.00																				
6 collection trucks	-$180,000.00																				
Total Investment:	**-$2,180,000.00**																				
Investment breakdown listed in initial investment cost sheet																					
Biogas Plant Running Cost:																					
Operataion and Maintenance Equipment (7% of investment cost)		-$126,658.00	-$130,457.74	-$134,371.47	-$138,402.62	-$142,554.69	-$146,831.34	-$151,236.28	-$155,773.36	-$160,446.56	-$165,259.96	-$170,217.76	-$175,324.29	-$180,584.02	-$186,001.54	-$191,581.59	-$197,329.04	-$203,248.91	-$209,346.38	-$215,626.77	-$222,095.57
Assessment		-$1,660.00	-$1,709.80	-$1,761.09	-$1,813.93	-$1,868.34	-$1,924.39	-$1,982.13	-$2,041.59	-$2,102.84	-$2,165.92	-$2,230.90	-$2,297.83	-$2,366.76	-$2,437.77	-$2,510.90	-$2,586.23	-$2,663.81	-$2,743.73	-$2,826.04	-$2,910.82
Biogas Plant Insurance Cost		-$4,980.00	-$5,129.40	-$5,283.28	-$5,441.78	-$5,605.03	-$5,773.18	-$5,946.38	-$6,124.77	-$6,308.52	-$6,497.77	-$6,692.70	-$6,893.48	-$7,100.29	-$7,313.30	-$7,532.70	-$7,758.68	-$7,991.44	-$8,231.18	-$8,478.12	-$8,732.46
Transportation cost (fuel)		-$13,336.44	-$13,736.53	-$14,148.63	-$14,573.09	-$15,010.28	-$15,460.59	-$15,924.41	-$16,402.14	-$16,894.20	-$17,401.03	-$17,923.06	-$18,460.75	-$19,014.57	-$19,585.01	-$20,172.56	-$20,777.74	-$21,401.07	-$22,043.10	-$22,704.40	-$23,385.53
Maintenance of collection trucks		-$12,450.00	-$12,823.50	-$13,208.21	-$13,604.45	-$14,012.58	-$14,432.96	-$14,865.95	-$15,311.93	-$15,771.29	-$16,244.43	-$16,731.76	-$17,233.71	-$17,750.72	-$18,283.24	-$18,831.74	-$19,396.69	-$19,978.60	-$20,577.95	-$21,195.29	-$21,831.15
Total Operational Running Costs		**-$133,298.00**	**-$137,296.94**	**-$141,415.85**	**-$145,658.32**	**-$150,028.07**	**-$154,528.92**	**-$159,164.78**	**-$163,939.73**	**-$168,857.92**	**-$173,923.66**	**-$179,141.37**	**-$184,515.61**	**-$190,051.07**	**-$195,752.61**	**-$201,625.19**	**-$207,673.94**	**-$213,904.16**	**-$220,321.28**	**-$226,930.92**	**-$233,738.85**
Refer to Assumption Sheet																					
Benefits from Biogas Plant:																					
Proceeds from sale of solid compost		$486,767.86	$501,370.90	$516,412.03	$531,904.39	$547,861.52	$564,297.36	$581,226.28	$598,663.07	$616,622.97	$635,121.65	$654,175.30	$673,800.56	$694,014.58	$714,835.02	$736,280.07	$758,368.47	$781,119.52	$804,553.11	$828,689.70	$853,550.39
Income from electricity generation		$513,048.37	$528,439.82	$544,293.02	$560,621.81	$577,440.46	$594,763.67	$612,606.58	$630,984.78	$649,914.33	$669,411.75	$689,494.11	$710,178.93	$731,484.30	$753,428.83	$776,031.69	$799,312.64	$823,292.02	$847,990.78	$873,430.51	$899,633.42
Tax shields on depreciation		$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00	$18,530.00
Total Benefits		**$1,018,346.23**	**$1,048,340.72**	**$1,079,235.04**	**$1,111,056.19**	**$1,143,831.98**	**$1,177,591.04**	**$1,212,362.87**	**$1,248,177.86**	**$1,285,067.29**	**$1,323,063.41**	**$1,362,199.41**	**$1,402,509.49**	**$1,444,028.88**	**$1,486,793.85**	**$1,530,841.76**	**$1,576,211.11**	**$1,622,941.55**	**$1,671,073.89**	**$1,720,650.21**	**$1,771,713.82**
Cash Flows summary																					
Net Cash Flows	-$2,180,000.00	$885,048.23	$911,043.78	$937,819.19	$965,397.87	$993,803.91	$1,023,062.12	$1,053,198.09	$1,084,238.13	$1,116,209.37	$1,149,139.75	$1,183,058.05	$1,217,993.89	$1,253,977.80	$1,291,041.24	$1,329,216.58	$1,368,537.17	$1,409,037.39	$1,450,752.61	$1,493,719.29	$1,537,974.97
Present Value Multiplier	1.00	0.83	0.69	0.57	0.47	0.39	0.33	0.27	0.22	0.19	0.15	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.03	0.02
Discounted CFs	-$2,180,000.00	$734,479.86	$627,429.82	$535,991.59	$457,886.83	$391,169.93	$334,179.44	$285,496.46	$243,909.27	$208,382.98	$178,033.77	$152,106.77	$129,957.26	$111,034.58	$94,868.37	$81,056.91	$69,257.03	$59,175.61	$50,562.26	$43,203.12	$36,915.46

Net Present Value	**$2,645,097.31**

A positive Net Present Value is an evidence that the project is feasible at the required rate of return (ie discount rate).

Given the above extracted values, the project is financially feasible

Build-up Approach- Discount Rate Extraction:	
Risk Free Rate (BDL Treasury Notes)	7.50%
Inflation Rate (Estimated)	3.00%
Risk Premium (Country/Project)	10.00%
Discount Rate (summation)	**20.50%**
Internal Rate of Return	**43%**
Discounted PayBack Period	**3.62 years**

The above figures are all excluded from:

a. The Value added Tax