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Reduced GHG emissions due to compost production and compost use in Egypt

Comparing two scenarios

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Preface

This study was carried out by B. Luske, a representative of The Louis Bolk Institute, on request of Soil and More International BV (SMI).

SMI is specialized in the field of composting as an emission reduction methodology and carbon footprint calculations of products. SMI is often asked by costumers to clarify the emission reduction potential of its composting projects in various developing countries. Furthermore, costumers are interested in the emission reduction which can be reached by substituting chemical fertilizers with compost. SMI requested for a science based study where these two topics are clarified with a case study, which resulted in this document.

Contents

Summary

Composting has been acknowledged as an emission reduction methodology by the UNFCCC. The emission reduction reached by a composting project is determined by comparing the composting scenario with the applicable baseline scenario. The objective of this study was on the one hand to clarify the emission reduction methodology of a composting facility in Egypt and on the other hand to extend this methodology with an example to illustrate the effect of compost use on greenhouse gas emissions. In this study, the emissions in a scenario where compost originating from a compost facility near Alexandria is used on a citrus farm in Egypt, were compared with a hypothetical baseline scenario where organic waste is not recycled and chemical fertilizer is used on the farm. The results show that the composting scenario causes significant lower emissions than the baseline scenario. This is mainly due to the avoidance of methane emissions from organic waste dumping, but also emissions due to chemical fertilizer production are avoided. The third reason for lower emission in the composting scenario is soil carbon sequestration. The composting scenario on the other hand also causes extra emissions due the transportation of biomass and fuel use for windrow turning. Although not showed in this study, it must be mentioned that compost has other beneficial effects, like improving soil fertility, improving the buffering capacity and reducing the risk for pathogens.

1 Introduction

1.1 Compost and climate

Composting is acknowledged by the UNFCCC as one of the few emission reduction methodologies related to agriculture (methodology number AM0025, www.unfccc.int/methodologies/PAmethodologies/index.html). The methodology stimulates recycling of organic waste. By composting, organic matter originating from multiple waste streams is going through a process which kills pathogens. It results in compost which contains stable organic material which is useful for agricultural fields as a soil conditioner. Soil fertility, structure, water holding capacity and buffering capacity are all improved by this means.

Composting is only acknowledged as an emission reduction project if the “baseline scenario” in a specific country causes significant greenhouse gas emissions (UNFCCC/CCNUCC, 2008). This is for instance the case in Egypt, where most of the waste is land filled or illegally dumped. When organic waste is land filled, a fermentation or rotting process will start due to a lack of oxygen. During fermentation microbes will emit methane, a greenhouse gas which is ca 25 times stronger than carbon dioxide. The new composting scenario, “avoids” the emission of methane for a substantial part, but on the other hand causes more emissions due to the transport of biomass and fuel use on the composting facility. The emissions of N_2O due to microbial activities may also be higher during composting than during fermentation, which were taken into account in the study.

1.2 Research objective

The objective of the study was to clarify the emission reduction methodology of composting projects and to extend this method with compost usage in a case study. Both reduced and increased emissions are taken into account in the assessments.

1.3 Research questions

The following research questions were distinguished:

1. How is the emission reduction of a composting facility calculated?
2. What is the carbon footprint of 1 ton of compost at farm gate?
3. How does the carbon footprint of citrus look like in two different scenarios: one with and one without compost?

2 Methods

2.1 Approach

To illustrate the beneficial effect of composting on climate, the greenhouse gas emissions of two different situations were compared:

1. a baseline scenario where organic waste is land filled and agriculture uses chemical nitrogen fertilizer
2. a second scenario where different organic waste materials are processed into compost which is used for organic farming.

In the baseline scenario, organic waste is not used for recycling, but is transported to a landfill, or illegally dumped. Furthermore, the agricultural fields are fertilized with ammonium nitrate in the baseline scenario.

In the second scenario, waste materials included in the baseline scenario are used for composting at a composting facility near Alexandria. This composting facility is founded by Soil & More International and is acknowledged as an emission reduction project by TUEV-Nord.

In the comparison, the compost and the chemical fertilizer are used on a hypothetical citrus farm, located in the southern desert of Egypt (near Minia).

2.2 System boundaries

In both scenarios the organic waste fractions are taken into consideration. In the baseline the waste fraction is dumped and land filled where anaerobe fermentation takes place and methane is emitted. In the second scenario, organic waste is transported to the composting facility and composted in windrows according to the Controlled Microbial Composting (CMC) method.

Emissions due to transport, production of ammonium nitrate, methane emission during anaerobe fermentation and composting, nitrous oxide emissions during composting, direct and indirect emissions due to fertilizer application and soil carbon sequestration are all taken into account. The system boundaries are illustrated in figure 1.

2.3 Functional unit

The functional unit is 1 ton of citrus at farm gate produced at a hypothetical desert farm in Egypt.

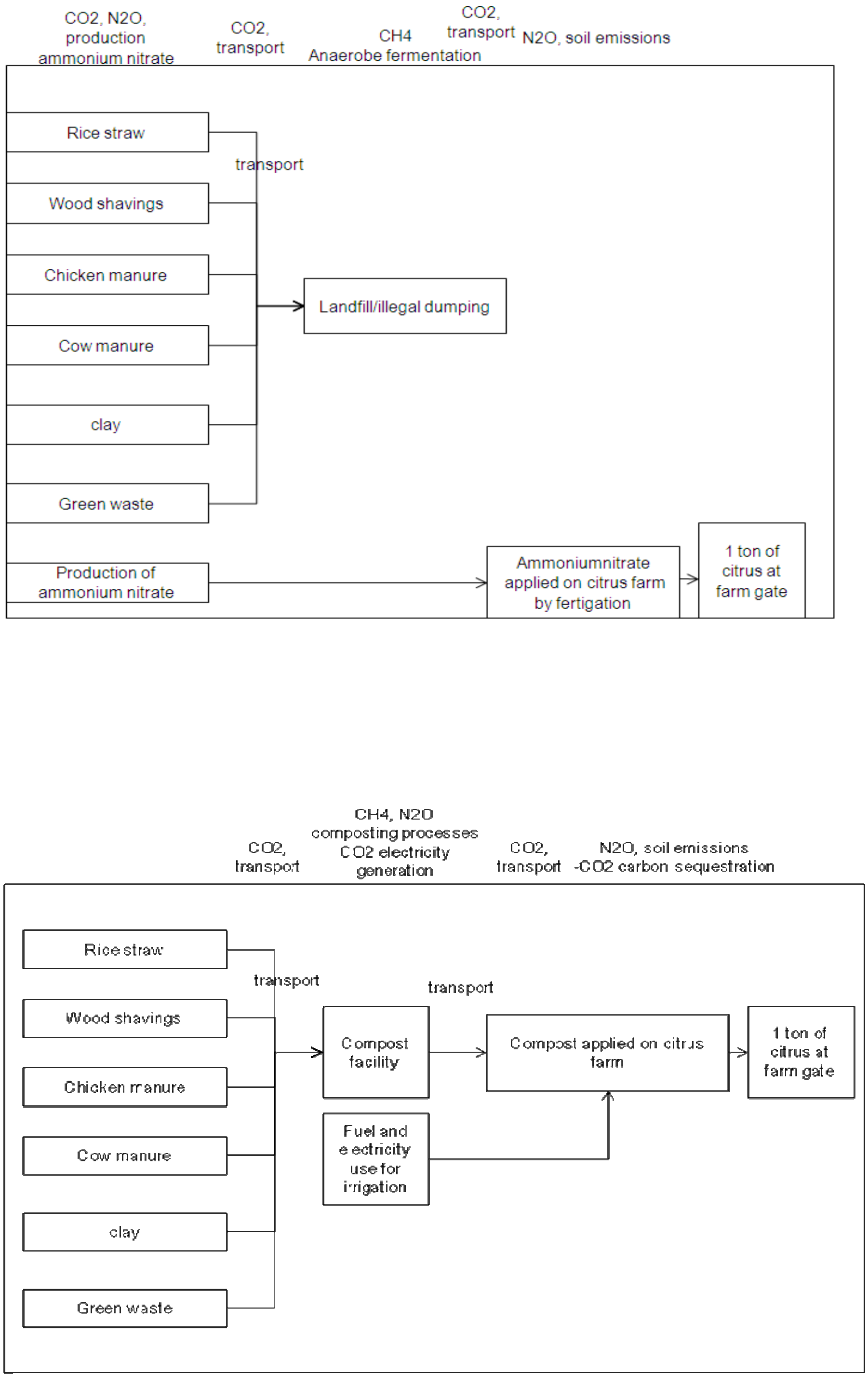

Figure 1. System boundaries for the baseline (upper) and the composting scenario (lower).

2.4 Emission calculations

2.4.1 Baseline scenario

It is assumed that a part of the organic waste materials were not recycled in the baseline scenario. Most of the waste materials in Egypt are land filled or illegally dumped. It was assumed that the waste was transported over 10 km (one way) by truck with a diesel consumption of 0,3 l per km and a truckload of 15 ton. The emissions due to transport amount to 0,22 kg CO_2/ton waste. Due to anaerobical decomposition of the organic waste, methane is emitted. The UNFCCC published a methodology to calculate the greenhouse gas emissions from solid waste disposal sites, based on a research of Oonk et al., 1994 (www.unfccc.int). The methodology differentiates the fraction degradable organic (DOC) carbon for different organic waste types. Per waste type the percentage of waste which is land filled or dumped is multiplied with the fraction degradable carbon. Together with the waste type quantities, the amount of carbon dumped was calculated (table 1).

Table 1. Waste materials parameters in the baseline scenario.

Material type	Waste type quantities (ton)	% to landfill or illegally dumped	Degradable Organic Carbon (DOC)	DOC in waste
Rice Straw	1.324	55%	0,3	218,46
Wood shavings	785	60%	0,3	141,30
Chicken manure	2.389	50%	0,17	203,07
Cow manure	20.028	80%	0,17	2.723,81
Clay	11.916	0%	0	-
Green waste	5.211	80%	0,17	708,70
Total	41.653			3.995,33

It was determined that 77% of the organic carbon present in the waste which was land filled decomposes anaerobically. The fraction of methane in the emission to air amounted 50%. The landfills and illegal dumping sites near Alexandria are relatively shallow, with depth less than 5 meters. Therefore the methane correction factor (MCF) for these type of landfills is 0,4 (IPCC, 2006). The total greenhouse gas emission of the baseline scenario was calculated by multiplying the amount of degradable carbon and the warming potential of 25[1] for methane and the values displayed in table 2. In total the greenhouse gas emissions of the baseline scenario amounted to 20.509 ton CO_2e.

[1] The IPCC also reported a global warming potential of 21 over a time horizon of 100 years.

Table 2. Degradable carbon in organic waste and methane emissions due to land filling in the baseline scenario.

DOC in all waste types	fraction DOC which can decompose (DOCf)	Fraction of methane in gas	Correction factor	Global warming potential methane	Methane correction factor shallow, unmanaged land fills	Emission ton CO_2e
3.995,33	0,77	0,5	16/12	25	0,4	20.509,4

In total, 41.653 tons of waste was composted at the facility. This means that for the baseline scenario that if one ton of waste was illegally dumped or fermented at landfills the emission would have been 492 kg CO_2e/ton waste.

In literature different emission factors for the production of ammonium nitrate have been published and are in between 3,0 and 7,0 kg CO_2e/kg N (Davis & Hacklund, 1999; Kongshaug 1998; Kramer 1999; Elsayed, 2003; Kuesters & Jenssen 1998; Wood & Cowie, 2004). In this research the most conservative value is used.
It was assumed that the production of ammonium nitrate took place within Egypt and was transported by truck over 400 km (one way), with a fuel use of 0,3 l diesel per km and a truckload of 20 tons. Ammonium nitrate consists for 34% out of pure N. The emission factor for diesel amount to 2,68 kg CO_2/l diesel. The emission due to transportation of 1 kg of ammonium nitrate to the farm amounts therefore 0,9 kg CO_2e/kg N[2].
It was assumed that fertilizers are applied by fertigation, where fertilizers are applied together with the irrigation water. This is often the case in Egypt. It was assumed that 150 l diesel and 230 kWh per hectare was used for this purpose. The emission factor used for electricity on the Egyptian grid amounted to 0,467 kg CO_2/kWh (www.iea.org). The average application rate for the production of citrus 200 kg N/ha (El Kadi & Kamh, 2004) with an average yield of 14,7 ton/ha (www.faostat.com).
Soil nitrous oxide emissions were calculated according to the Tier 1 method defined by the IPCC (see annex 1). For the baseline scenario no other soil effects were assumed that relate to greenhouse gas emissions.

2.4.2 Compost scenario

The compost facility in Alexandria composted 41.653 tons of organic waste in the period November 2008 until September 2009. The total amount of compost produced during this period was 17.560 tons, this means that 42% of the input material was eventually turned into compost.
The input materials are put into windrows of two meters high and 3 meters wide. In total the composting process takes 6 weeks, and the rows are turned several times. For irrigation and turning purposes, the facility uses diesel, which amounted to 60.308 liters during November 2008 until September 2009.

[2] (2,68 kg CO2e/l x 800 km x 0,3 l/km x 1/0,34)/20.000 kg = 0,09 kg CO2e/kg

Table 3. Diesel use during the different production phases of compost.

	l/ton compost
transport of input materials	6,37
diesel use composting facility	3,43
diesel use transport of compost to the farm	5,62
Total	15,42

2.4.2.1 Input materials

The input materials which are used are rice straw, wood shavings, chicken and cow manure, clay and green waste (water hyacinth from irrigation channels). The input materials are transported from different origins towards the composting facility.

- Rice straw originates from farms that are located in the Lower Nile Valley, the region where most of the Egyptian rice production takes place. This is relatively close to Alexandria. The one way distance was estimated being 25 kilometers from the rice farms towards the composting facility. The annual yield of rice and rice straw in Egypt amounts to 8,2 and 3,9 ton/ha (Ehab El Saeidy, 2004). Traditionally farmers used these farm residues as fuel for cooking and baking practices. The farmers stored the residues on the roofs of their houses or on the fields. This traditional way of handling residues caused several problems because pest infestations and the risk for destructive fires. The Egyptian Ministry of Agriculture therefore obliged famers to burn their residues immediately after harvest operations (in 1996). It resulted in severe air pollution in the region and soon (in 1999) the Ministry of Environment applied a law which prohibited the burning of residues on their fields (EEAA, 1994).
- It was estimated that the wood shavings were transported for 200 km (one way). The origin of the wood shavings is uncertain.
- It was estimated that the poultry manure was transported 25 km (one way) towards the composting facility. Poultry has been the fastest growing industry in Egypt (Hosny, 2006). Recently there has been a general trend towards more multi story and the establishment of large scale poultry production facilities. Most of the feed ingredients are imported into Egypt and chicken manure is often dumped or land filled. However, this way of manure handling can be a risk for pest and disease distribution (Axtell, 1999). By the composting process and high temperatures that are reached, possible pathogens in the manure are destroyed.
- Cow manure originates from nearby dairy farms. In Egypt, mostly buffalos and local Baladi cows are bred. The cows are kept in corrals where shade is provided. The sundried dung is collected and often dumped or used as organic fertilizer. It is estimated that the manure is transported over 25 km (one way) towards the composting facility.
- Clay used for the compost, originates from the Nile Delta. It is estimated that the clay is transported over 25 km (one way) towards the composting facility.
- The green waste in the form of water hyacinth that is used for composting originates from nearby irrigation channels. Water hyacinth is a pest that has invaded irrigated channels and lakes in Egypt. The invasive

species causes every year a significant loss of water due to evapotranspiration (Fayad et al, 2001). It also prevents the water from flowing freely. The water hyacinths are harvested and transported towards the composting facility over a distance of approximately 25 km (one way).

Table 4. Input materials of the compost facility in Alexandria.

Material	Ton	Origin	Return distance	Ton/truck
Rice Straw	1.324	Nile delta	50	12,05
Wood Shavings	785	Wood industry	400	4,72
Chicken Manure	2.389	Nile delta	50	6,53
Cow Manure	20.028	Nile delta	50	6,36
Clay	11.916	Nile delta	50	7,12
Green waste	5.211	Irrigation channels	50	6,32
Total	41.653			

2.4.2.2 Emissions during composting

During the composting process, small amounts of methane (CH_4) and nitrous oxide (N_2O) are released by microorganisms. N_2O is released during denitrification of nitrite and nitrate. Methane is released during anaerobe circumstances when organic compounds are used by microorganisms. The level of N_2O and CH_4 emissions are related with the types of organic materials that are composted, the type of composting, the amount of material and the processing circumstances (moisture, temperature and structure). Especially aeration significantly influences methane emissions (Heres et al., 2007). Apart from that there are different measuring methods (continue versus momentous measuring) which may affect the emissions which are measured.
Studies on windrow composting therefore give very different results for CH_4 and N_2O emissions. Andersen et al. (2010) measured 2,4 kg CH_4-C and 0,06 kg N_2O-N during composting of one ton garden waste, which means an emission of ca 303 kg CO_2e/ton compost. Hao et al. (2004) measured 4,8 kg CH_4-C and 0,08 N_2O-N kg per ton waste composted, which amount to a total emission of 563 kg CO_2e per ton compost. Hellebrand (1998) measured an emission of 0,08 kg CH_4-C and 0,054 kg N_2O-N per ton waste composted (0,04% of the initial carbon was emitted as CH_4 and 0,5% of the initial nitrogen was lost as N_2O-N), which amount to a total emission of 94,7 kg CO_2e/ton compost.

In the Netherlands, the emissions of nitrous oxide and methane have been extensively monitored in several composting facilities which use different composting methodologies. Table 5 displays the maximum and minimum values that have been monitored (Heres et al., 2007).
According to Benner et al. (2007) the emissions amount to 0,2 kg methane and 0,11 kg nitrous oxide per ton organic waste, which amounts to 90 kg CO_2e/ton compost. The results from different studies displayed in table 6 illustrate that there is no golden rule to quantify the amount of greenhouse gas emissions due to composting. In this study, the

maximum values measured in Heres et al. (2007) were used. This value has been chosen, because the compost is managed actively and turning activities take place regularly. Also because of low precipitation in the region (the compost is irrigated instead), anaerobic circumstances are rare. However, it must be mentioned that no measurements on nitrous oxide and methane emissions have been carried out.

Table 5. Emissions of CH_4 and N_2O due to composting in The Netherlands (Heres et al, 2007).

Type of gas	Minimum measured (kg/ton waste)	Maximum measured (kg/ton waste)	Minimum (in kg CO_2e/ton waste)	Maximum (in kg CO_2e/ton waste)	Minimum (in kg CO_2e/ton compost)	Maximum (in kg CO_2e/ton compost)
Methane (CH_4)	0,08	0,30	2,00	7,50	4,74	17,79
Nitrous oxide (N_2O)	0,04	0,10	11,92	29,80	28,27	70,68

Table 6. Emissions due to composting in different studies.

Study	Kg CO_2e/ton compost due to methane and nitrous oxide emissions	Material
Andersen et al., 2010	303,8	Garden waste
Hao et al., 2004	563,2	Cattle manure
Hellenbrand, 1998	94,7	Grass and green waste
Benner et al., 2007	89,6	GFT
Heres et al., 2007	33-88	GFT

2.4.2.3 Compost application

In 2009 most of the compost was transported towards a new organic farm in the desert close to Minia. The average distance over which the compost was transported amounted to 880 km (one way). Due to the application of compost on reclaimed desert soils, the soil organic matter content is increased. Recent research showed that the application of 47,6 ton compost/ha/yr over 30 years on organic arable fields in Egypt, resulted in an average carbon sequestration of 0,88 ton C/ha/yr (or 3,23 ton CO_2/ha/yr) (Luske & Van der Kamp, 2009). With this information it was calculated that by the application of one ton of compost 67,79 kg CO_2 was sequestered.

In other studies values in the same order of magnitude were found; in between 0 and 22% of the applied carbon in the compost was sequestered (Saft & Kortman, 2004). It must be mentioned that the application rate, soil management, temperature, moisture level and crop types all affect this sequestration ratio. Because the circumstances in Egypt are very specific, it was decided to use the measured data in reclaimed Egyptian desert soils (Luske & Van der Kamp, 2009), although the measurements only covered a period of 30 years.

It was assumed that the farm in Minia used 20 ton of compost/ha/yr which was applied manually. While in the baseline fertigation was assumed, fuel and electricity use for irrigation were added in the composting scenario. Due to the increasing Soil Organic Matter, it was assumed that 10% less irrigation water was needed, so fuel and electricity use for irrigation practices also decreased. While organic farms often have lower yields, it was assumed that the yield per hectare was 20% lower than the baseline scenario.

3 Results

3.1 Carbon footprint of compost at farm gate

Based on the above mentioned data and assumptions, the carbon footprint of compost was calculated. For the production of one ton of compost in total 129,35 kg CO_2e were emitted (table 7). Most of the emissions actually occurred during the composting process. It must be noted however that the level of methane and nitrous oxide emissions are very dependent on management of the compost site and waste types that are used; they can be lower, but also much higher.

Table 7. Carbon footprint of compost before application.

Source of emission	Emission
transport of organic waste (kg CO_2e/ton)	17,07
diesel use composting facility (kg CO_2e/ton)	9,21
methane and nitrous oxide emissions during composting (kg CO_2e/ton)	88,00
transport to the field (kg CO_2e/ton or kg)	15,07 +
total (kg CO_2e/ton compost)	*129,35*
total nitrogen in compost[3] (kg N/ton compost)	7,27
kg CO_2e/kg N	17,79

3.2 Carbon footprint of citrus in the baseline and the compost scenario

Based on the above mentioned data and assumptions the carbon footprint of citrus was calculated for both scenarios until farm gate. Citrus fertilized with compost has a carbon footprint of 162 kg CO_2/ton. Citrus fertilized with ammonium nitrate has a much larger carbon footprint amounting to 1.813 kg CO_2e/ton (table 8, figure 3). The emissions due to fermentation of waste have the largest impact, but even if these are excluded, the carbon footprint from the compost scenario also remains lower (table 8, figure 2). If the amount of compost applied is increased to 30 ton/ha (instead of 20 ton/ha), both scenarios show equal emission levels.
When comparing the emissions per hectare, the differences are even larger.

[3] A dry weight of 78% and a N% of 0,93 for compost were assumed.

Table 8. Emissions per hectare or per ton of citrus at farm gate in the two scenarios.

	Compost scenario (kg CO_2e/ha)	Baseline scenario (kg CO_2e/ha)	Compost scenario (kg CO_2e/ton citrus)	Baseline scenario (kg CO_2e/ton citrus)
production of ammonium nitrate	-	1.406,00	-	95,65
transport of organic waste	341,42	116,31	29,03	7,91
fuel use composting facility	184,17	-	15,66	-
emissions during composting	1.760,00	-	149,66	-[4]
emissions during fermentation	-	23.446,95	-	1.595,03
transport to the field	301,39	18,93	25,63	1,29
irrigation/fertigation	458,65	509,61	39,00	34,67
soil nitrous oxide emissions after application	476,79	1.147,30	18,15	78,05
soil carbon sequestration	1.355,80-	-	115,29-	-
total excl. fermentation	*2.166,61*	*3.198,15*	*161,84*	*217,56*
total incl. fermentation	*2.166,61*	*29.843,25*	*161,84*	*1.812,59*

[4] It was assumed that due to anaerobe circumstances, nitrous oxide emissions were marginal on landfills.

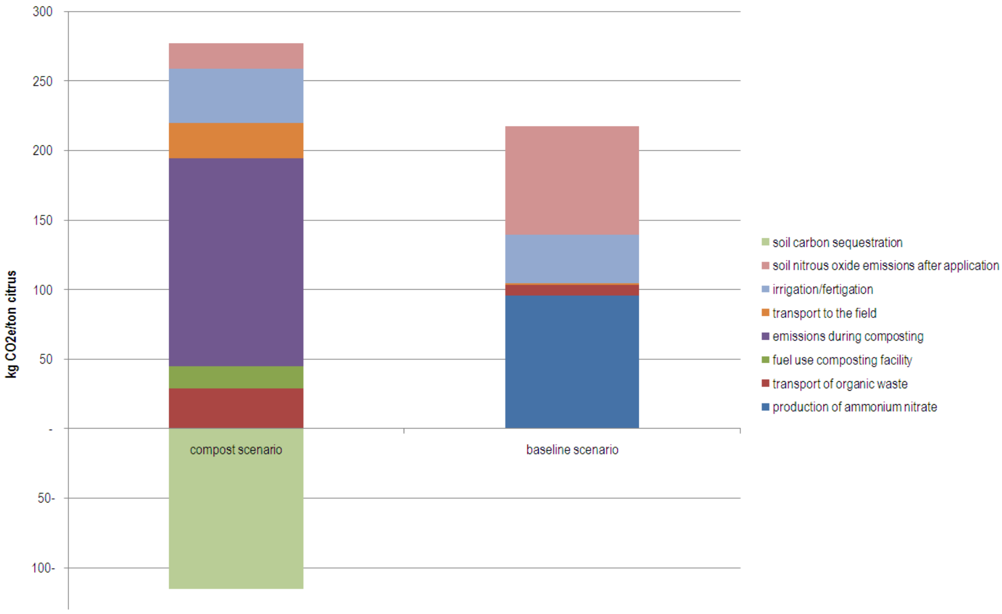

Figure 2. Greenhouse gas emissions for the production of 1 ton of citrus, when fermentation of waste on landfills is excluded from the analysis.

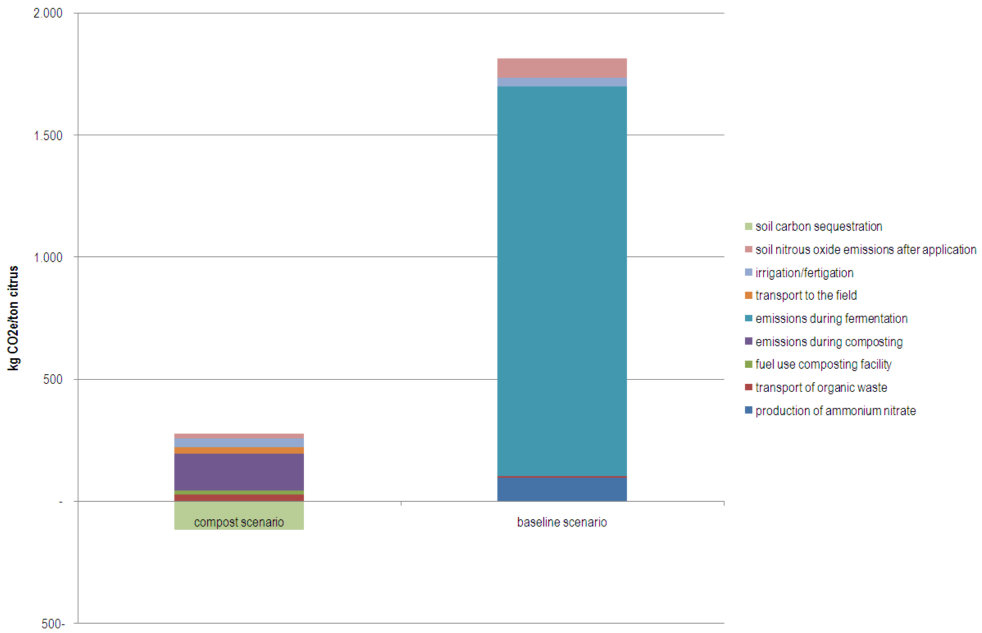

Figure 3. Greenhouse gas emissions for the production of 1 ton of citrus, when fermentation of waste on landfills is included in the analysis.

4 Conclusions and discussion

4.1 Approach taken to illustrate emission reduction

This research explains the approach for determining the emission reduction of composting projects. As displayed, the calculated emissions of a new scenario (with a composting facility) are compared with a baseline scenario. This approach is used by the UNFCCC for determination of the emission reduction which is reached by other kind of emission reduction projects. The additionality of the project and extra emission due to the project are also taken into account. Additionality and the baseline scenario of emission reduction projects are always topics of discussion, because both are hypothetical situations and cannot be checked in reality.

In this research, the same approach has been used to illustrate the climate effects of the usage of compost. For this purpose a system comparison has been done where emission due to compost production, application, transport, are compared with a hypothetical baseline scenario which has no waste recycling and uses chemical fertilizers.

4.2 Emissions due to compost use versus the baseline scenario

The result of the study show that composting of organic waste and compost usage result in a significant reduction of greenhouse gas emissions compared with the baseline scenario. The reduction is mainly reached due to avoiding methane emissions from land filling or dumping the organic waste in the baseline scenario. However, not all methane emission could be avoided. Within the windrows sometimes anaerobic circumstances can occur, which cause methane emissions. The amount of methane emitted within the windrows is highly dependent on the management of the composting process and the same accounts for the emission of nitrous oxide during composting. On the basis of literature studies it was determined that composting results in 90% less emission than the baseline scenario (149 instead of 1559 kg CO_2e/ton citrus).

In the second place, the composting scenario reduces emissions due to avoidance of nitrogen fertilizer production. Worldwide, the fertilizer industry uses a significant amount of the available fossil fuels and electricity, especially for the production of nitrate fertilizers. Often the production plants also emit nitrous oxide. Reducing the use of nitrogen fertilizers automatically reduces the emissions related to the production of chemical fertilizers.

On top of the avoidance of methane emissions and the production of chemical fertilizers, compost use reduces emission due to the sequestration of carbon in the soil. The rate of soil carbon sequestration which was used is this study was 3,23 kg CO_2e/ha, based on earlier studies in Egypt (see section 2.4.2.3). One should realize that this value is very site specific and will also be influenced by soil characteristics, climate, crops, soil management etc.

Soil nitrous oxide emissions due to fertilization are also lowered due to compost use, but it must be mentioned that this effect is uncertain. Based on literature the direct emission factor for soil nitrous oxide emissions has been determined being 0,7% instead of 1%. At this moment the specific soil microbial interactions are not well understood in relation with soil nitrous oxide emissions. There might be a trade-off between soil carbon sequestration and nitrous oxide emissions. More research is needed to draw conclusions about this topic.

Apart from lower emission in the composting scenario, some sources actually cause more emissions than the baseline scenario. For example the transportation of biomass and fuel use on the compost facility for windrow turning causes increased emissions.

The results indicate that the carbon footprint per kg N of compost (18 kg CO_2/kg N) is higher than for ammonium nitrate 3-7 kg CO_2/kg N). It must be mentioned however that compost is a very different product than chemical fertilizers. Compost use enhances soil fertility and the amount of nitrogen which needs to be applied as compost will be less than applied as chemical fertilizers (as is the case in the analysis), due to the buffering of nutrients by compost. Chemical fertilizer use will affect soil fertility in a negative way and nutrients are more easily leached.
The baseline scenario chosen in this study is relatively conservative, because a shallow landfill has been assumed with a methane correction factor of 0,4. The IPCC determined this 0,8 for landfills that are deeper, which means that the methane emissions are doubled of the baseline scenario. Furthermore it is assumed that landfills do not emit any nitrous oxide.

4.3 Other effects of compost use

This research illustrates the emission reduction which can be used due to compost used. There are other benefits related to compost use that are not illustrated with this analysis, which are displayed here in a nutshell:
By improving the soil organic carbon level, at the same time the buffering capacity for water and nutrients is improved and in general soil fertility, including soil biodiversity, is increased. This will also result natural suppression of pests and diseases in the field. A good composting process reaches high temperatures which reduces the risk for pathogens. By this means regional waste streams are recycled, nutrient leaching is reduced, water use is reduced, soil fertility is maintained or improved and local living conditions are improved.

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Annex 1: Soil emissions

Direct and indirect emissions of nitrous oxide

Due to the application of fertilizers, and activities of soil microorganisms, the available nitrogen can be released into the air in the form of nitrous oxide (N_2O). Nitrous is a powerful greenhouse gas with a global warming potential of 298, being 298 times stronger as CO_2 (IPCC, 2006). In several studies it was taken into account that in the case of compost nitrous oxide emissions are lower than in the case of mineral fertilizers, due to the presence of stable soil aggregates (0,7 instead of 1%) (Saft & Kortman, 2004; Hogg et al., 2002; Vogt et al., 2002, Grant et al., 2003). According to the Intergovernmental Panel on Climate Change (IPCC) direct and indirect emissions of nitrous oxide should be taken into account.

Direct emissions take place directly from the soil due to microbial processes that are stimulated by nitrogen fertilization. Indirect emissions take place later; when volatilized nitrogen is deposited elsewhere and is released as nitrous oxide by soil microorganisms and when leached nitrogen appears in surface water and is processed into nitrous oxide also by microorganisms. While compost improves the water holding capacity of soils (Wahba, 2007; Wanas & Omran, 2006; Wesselink et al., 2009; Gerke et al, 1999), it was assumed that the run-off of nitrogen was marginalized.

The calculation methodology supplied by the IPCC is very rough and not specified for different regions or soil types. This is due to the fact that the microbial processes are very complex. Many parameters affect the microbial processes and the parameters also interfere with each other. This makes it complicated to define site specific formulas for nitrous oxide emissions. The formulas given below originate from the Good Practice Guidelines of the IPCC and are on a Tier 1 level. The default emission factors have been reviewed and changed in order to specify it for the Egyptian circumstances (table 9).

Direct emissions

The following formula is applied to calculate the direct emissions from agricultural soils:

CO_2-eq (kg/ha) =∑ Eij/ha*EFij*44/28*298

Eij=netto amount of N applied by source i on soil type j (therefore volatilized N is deducted)

EFij=emission factor of source i on soil type j

44/28= conversion factor of N_2O-N to N_2O

298= GWP value of N_2O

Indirect emissions

Indirect soil emissions are emitted due to leaching of nitrogen and deposition of volatilized ammonia.

The following formula is applied to calculate indirect soil emissions:

CO_2-eq (kg/ha)= ∑ Ei/ha*EFi*44/28*298

Ei= amount of N from source N

EFi= emission factor of source N

44/28= conversion factor of N_2O-N to N_2O

298= GWP value of N_2O

Table 9. Emission factors (EF) for direct soil emissions (IPCC, 2006) and adjusted emission factors for compost used in this study.

	EF mineral soil	Ajusted EF compost use in Egypt	Reason	Sources
Application of mineral fertilizer with nitrate (N_2O-N/kg N)	1%	0,7%	Nitrogen is stabilized in soil aggregates	Hogg, 2002; Vogt 2002, Grant 2003
Volatilization and re-deposition of NH_3-N and NO_x-N)	1%	0,7%	Nitrogen is stabilized in soil aggregates	Hogg, 2002; Vogt 2002, Grant 2003
Fraction that volatilizes of mineral fertilizers	10%		nvt	
Fraction that volatilizes of organic fertilizers	20%	20%		IPCC, 2006
Fraction that leaches (if rain or irrigation> water holding capacity)	30%	0%		Wahba, 2007; Wanas & Omran, 2006; Wesselink et al., 2009; Gerke et al, 1999
Leaching of N_2O-N	0,75%	nvt		
Crop residues (N_2O-N/kg N)	1%	Nvt		