Erasmus Plus for Organic Sector

Problem solving project in organic food chain

Jasmin Lehtinen & Veera Naukkarinen

How to use the residues of bioenergy production process as fertilizer

Introduction

This report is part of the Problem solving project in the organic food production chain course in the University of Helsinki. The aim of the report is to find out the answers to these questions:

- How usable are residues of bioenergy production as fertilizer in organic farming?
- Can those be used as only fertilizer and what is the effect of fertilization on yield and quality?
- What is the optimal fertilization system that is sustainable and profitable for ecological symbiosis?
    - Crop rotation
    - Distances and transportation
    - Amount of biomass

Materials and methods

We interviewed Jukka Kivelä and Kari Koppelmäki who are both involved to this project. Kari Koppelmäki is the coordinator of the project. We visited at Knehtilä farm and interviewed Markus Eerola who is the owner of Knehtilä farm. We also stopped at Mäntymäki egg production farm and posed questions to the owner Virva Latostenmaa. All the interviews have been used as sources of this project report. Also a big amount of this report is based on literature.

Our aim is to find out the answers to the questions mentioned in the introductory chapter. Palopuro project is not yet operating in its entirety, so it seems to be challenging to get right answers to all the questions.

Mid-course project plan

After the week 8, we still need to find out:

- Evaluation of optimal crop rotation. We are still lacking the geographical information of the fields of the Palopuro project. Thus we have been unable to evaluate crop rotation, distances between fields and transportation possibilities. This question is difficult to answer when we do not know the locations of the fields.
- Analysis of fertilization effects of the residues of bioenergy production. We are lacking information of nutrient contents of some biomasses planned to use in biogas production. We are going to make tables of nutrient contents after having more detailed information.

- If we have enough time we will look up some information about agricultural subsidies that Knehtilä farm is already having and is there some possibilities to have better subsidies if they make some changes.

Case Palopuro

Palopuro agroecological symbiosis is a cooperative network of several organic farms and other actors. The symbiosis is surrounded by Knehtilä farm which is the main driver of the project. The purpose of this symbiosis is to develop energy- and nutrient self-sufficient model of organic food production which can be multiplied. Knehtilä farm is located in Hyvinkää and it has been selected as the most environmentally friendly farm of Baltic region in 2015. Palopuro Agroecological Symbiosis has funded by the Ministry of Environment's RAKI programme. The purpose of RAKI programme is to improve cycling of nutrients in agriculture, especially phosphorus and nitrogen (Ministry of the Environment).

Drivers of symbiosis:

- Knehtilä Organic Farm (cereals, legumes and green manure)
- Samsara Bakery
- Mäntymäki Organic Farm (organic eggs)
- Joentausta Organic Strawberry Farm
- Lehtokumpu Organic Farm (vegetables)
- Department of Agricultural Sciences, University of Helsinki
- Natural Resource Institute Finland (LUKE)

The formula and the goal of the symbiosis

The formula consist on the Knehtilä farm that have field areas for greenmanure 100ha, 200ha cereals and legumes, 50ha stable grass. The farm produces the cereals for the bakery, farm shop, fodder for chickens and the green manure to the biogas production. It is also the place where the biogas plant, the new Samsara bakery and the mill will be located. The new chicken house which has started operating on February 2016 is about 2 kilometers from the Knehtilä farm. Eerola is taking care of the fields of the chicken farm. Manure and litter go to the tube and in the future to the biogas production.

The project is now open so that they have not decided the size, right place, between wet or dry process, to separate or not, how much manures is going to be used, can the tube process be left a side, who is the manufacturer of the biogas plant and how much and which distances the green manure should be used or it is profitable to use. Mäntymäki farm is not also sure how much chickens will be profitable to keep. Now there are 2700 chickens and the maximum amount that could be kept is 5400 birds. So the exact amount of chicken manure is not known for a year or two. Eerola is now taking only the manure of 20-30 horses which is about 240-360m^3 of horse manure. He is thinking to take more when the process is working. The estimate of the amount is about 100 horses from stables close to Knehtilä. The amount of manure that is required is 1 000 000 kg which means about 170- 210 horses manure. The main thing that is controlling the amount of horse manure is the tube process which need a lot work. When doing the tube requires it three tractors to be working at the same time. If these can be left a side the amount of horse manure could be bigger. Eerola thinks that it cannot be left aside without building a different kind of manure managing system.

There is also the possibility that this biogas plant will not be build at all.

There are six different biogas plant producers that have given their own succession about the biogas plant that should be building but there is now decision made yet. One of the biogas plant producers is Methator, which promises that the residue that comes out of the biogas plant is dry like wanted. Eerola do not want the process that needs the separation between the wet and dry material because it requires more work and investments. He also requires the biogas plant that needs only one man's job.

There is also possibility to use wet process when the decomposition residue is wet and have to use the wet manure spreading machine.

Table 1. Biomasses that will be used for bioenergy. Sources: Mäntymäki farm, 2016, Eerola, 2016, Kivelä, 2016, Airaksinen, 2006, Kauppinen, 2005.

	Current situation	Goal situation
	Units	
Chickens	2700 pc	5400 pc
Chicken manure	40 500 kg	80000 kg
Horses	20- 30 pc	170- 240 pc
Horse manure	84 000-180 000 kg	714 000- 1 440 000 kg
Green manure	900000 kg	1000000 kg

Table 2. Edited from the source:

Animal	Manure kg/a	Biogas m^3/a
Chicken	10,95	2,0- 2,5
Horse	9125	700

Calculations:

Chicken manure (based on literature):

2700*10,95kg/a= 29 565 kg/a   29 565 kg/v* 0,382= 11 293,82kg ts/a

5400*10,95kg/a= 59 130 kg/a   59 130 kg/v*0,382= 22 587,66 kg ts/a

Chicken manure (based on estimated amounts by Palopuro Symbiosis)

(2700pc) 40 500kg/a*0,382= 15 471 kg ts/a

(5400pc) 81 000kg/a*0,382= 30 942 kg ts/a

Amount of litter (based on literature and the estimation of the Mäntymäki Farm)

Hemp: 280 kg or 560 kg

Wood chips: 250 kg or 500 kg

Horse manure (based on literature)

20*9125kg/a=182 500 kg/a	182 500 kg/a* 0,27=49 275kg ts/a
30*9125kg/a= 271 750 kg/a	271 705kg/a*0,27= 73 360,35 kg ts/a
100* 9125kg/a= 912 500 kg/a	912 500kg/a* 0,27= 246 375 kg ts/a
110*9125kg/a= 1003 750kg/a	1003 750 kg/a* 0,27= 271 012,5 kg ts/a

Or

Calculation is done by using 350- 500kg/m^3 weight of horse manure and 12m^3/ horse/year. It is between 8m^3-12m^3 depending on the size of the horse (Kauppinen, 2005)

20-30pc (12m^3): 84 000-180 000 kg/a	22 680-48 600 kg ts/a
20-30pc (8m^3): 56 000-120 000 kg/a	15 120-32 400 kg ts/a
100pc (12m^3): 420 000-600 000 kg/a	113 400-162 000 kg ts/a
100pc (8m^3): 280 000- 400 000kg/a	75 600- 108 000 kg ts/a

These two calculations differ because of the amount of litter and which litter it is (wood chips, peat, hemp, straw etc.). Also the size of the horses is one thing that has influence to the amount of manure and litter, because the little ponies produce less manure and need less litter than bigger ones. We counted the amount of the manure with the big horses produced amount of manure 12m^3/ horse/year but used the 350-500kg/m^3

Horse manure (based on estimated amounts by Palopuro Symbiosis)

1000 000kg fresh manure

1000 000kg * 0,27= 270 000kg ts/a

Green manure (based on literature)

1000 000kg/a* 0,218= 218 000kg ts/a

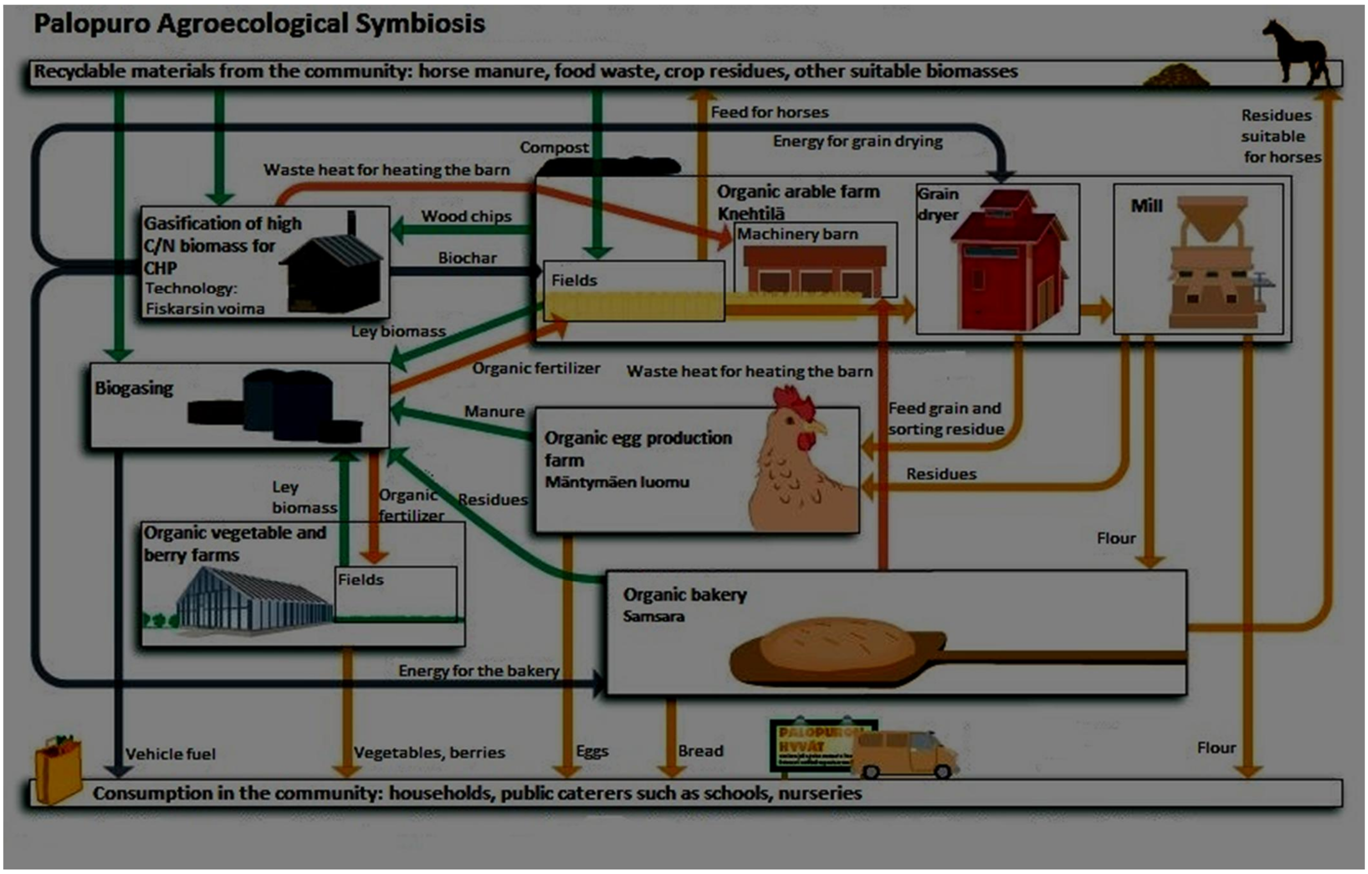
1000 000kg/a*0,278= 278 000kg ts/a

Green manure (based on estimated amounts by Palopuro Symbiosis)

1000 000 kg ka/a *0,30= 300 000 kg/ ts / year

Table 3. Nutrient contents. Edited from the sources: Mtt raportti 59, Keskinen et al.2014. Airaksinen. 2006, Kivelä & Parviainen. 2016

Input materials	Total solids, %	Content kg/1000kg, dry material					Total amount kg/TS /year	Content kg/100kg, dry material				Goal situation				
		Total Nitrogen	Solid Nitrogen	Total Phosphorus	Potassium			Total Nitrogen	Solid Nitrogen	Total Phosphorus	Potassium		Total Nitrogen	Solid Nitrogen	Total Phosphorus	Potassium
Chicken manure	38,2	15,6	12,8	10,5	3,1		15471,0	241,3	198,0	162,4	48,0	30560,0	476,7	391,2	320,9	94,7
Hemp							280					560				
Wood chips	96,0	3,0	0,3	0,3	1,0		250	0,75	0,075	0,075	0,25	500	1,5	0,15	0,15	0,5
Horse manure +peat, composted	27	15,5	4,2	2,7	16,5		28 350	439,43	119,07	76,55	467,78	270 000	4185,00	1134,00	729,00	4455,00
Green manure, 1year	21,8	20,3	3,63	1,3	10,5		218 000	4 425	791	283,4	2289	218 000	4425	791	283,4	2289
Green manure, 2year, yield 1	27,8	24,6	9,01	1,3	10,5		278 000	6 839	2 505	361,4	2919	278 000	6839	2 505	361,4	2919
						Total nutrients TS/ year	262 351	5106,48	3613,145	522,425	2805,03	519 620	9088,2	2316,35	1333,45	6839,2
						Total Nutriens TS/ year (2.year)	322 351	7520,48	5327,145	600,425	3435,03	579 620	11502,2	4030,35	1411,45	7469,2



Picture 1. Palopuro Agroecological Symbiosis. Edited from: http://blogs.helsinki.fi/palopuronsymbioosi/

The symbiosis is based on the idea of global warming and what are the challenges that it brings to farming in Finland. Eerola was said that the main idea to “fight against global warming and protecting our fertile croplands” was to get more leys in production in Uusimaa, but the main problem to do it, is that in Uusimaa we do not have much farm animals that can use the leys as fodder. But if we have bioenergy production we can have more leys and get energy out of it. It is said that in Finland we could use much more leys sustainable way producing bioenergy than we are doing know.

Dry decomposition process

Dry decomposition process means input material is dry and it keeps in pile. Total solids in dry process is 20-40% versus wet process where the maximum is 15%. Wanted process is working constantly. The constantly working process means regularly input and output in certain periods of time which gives us as constant biogas production as possible. The process is based on plug flow when the feed of biomass comes from the cylindrical horizontally laying reactor on the other side and biomass is moved inside the cylinder. The decomposition residue comes out from another side of the reactor. In dry process is necessary to add a lot of decomposition residue and/or liquid residue from process which recycles the needed microbes and regulate total solids. The recycled liquids in reactor should be optimized so that the nitrogen level in the process does not rise into inhibited level (Kymäläinen & Pakarinen, 2015).

The benefit of dry process is that the reactor capacity is smaller per ton of the fresh input material compared to the wet process. On the other hand, technical controlling is more difficult than in wet decomposition process. The most challenging thing is to mix the dry masses and the microbiomasses together and so ensuring efficient contact of the microbes and the input materials. Moving of the input materials is also challenging. Ensuring the release of biogas is more difficult when using dry materials. The decomposition residues of dry process can be inappropriate for fertilization use when it is not processed because it cannot be spread on field using the spreading devices that are available in the market right now. The residue can also be sticky and only partly decomposed. Its quality can be uneven and storing of residue can be challenging. (Kymäläinen ja Pakarinen, 2015). The Palopuro project drivers have requested for quotations from six different biogas manufacturers and one of them has promised so dry decomposition residues that can be spread by already existing spreading devices.

Table 4. Methane potentials Edited from the source: Horse Manure-hanke, 2014., Säikkö, 2014., Kalmari-Harju, 2014., Juvonen, 2014., Lehtomäki yms. 2007 & Motiva Oy. 2015.

Materials	Energy MWh/tn	m³ CH_4 / fresh tn	m³ CH_4/t VS
Horse manure	0,196	19,6	70,5
Peat	2,5		
Chicken manure		50	
Hemp	5	41,1-68	168,5- 278,8
Wood chips	3,13		
Green manure	3,3	30-150	

- According to Biokaasulaskuri the amount of biogas with these kind of input would be 168 787 m³/a, which is 101 272,2 m³ CH_4. The amount is 1 687 870 kWh. (MTT biokaasulaskuri)
- According to our own calculations, the amount of biogas is 187 880 m³/a, which is 112 728 m³ CH_4. The amount is 1 878 800 kWh.

The aim of the Palopuro Symbiosis is to achieve 100 000 m³ CH_4, which will be achieved according to our calculations.

Possible improvements

Fiber hemp

Fiber hemp is one option for replacing some of the green manure. We got the idea for this after visiting Mäntymäki egg production farm. In Mäntymäki they use hemp as a litter because it suits well for chicken houses. Hemp litter keeps eggs clean and the chicken house odorless and dust free. According to website of Hemprefine (2016), the benefits of hemp litter are antibacterial quality, absorbency, softness, mileage, ease of handling and low total costs. The hemp litter is ecological, it has good properties for fixing carbon from atmosphere and controlling global warming.

Hemp can be used in organic production because it does not need any pesticides and it is also good for controlling weeds. Hemp has a good impact on soil quality because it has deep roots and it can use the nutrients that are unavailable for most of the crops. Hemp also increases the amount of beneficial micro-organisms in the soil. It has been shown that cereals that are cultivated after hemp produce 10-20% better yields (Hemprefine, 2016). Hemp can be cultivated in the same field for 2-3 years (Norokytö, 2013). It could be a good supplement for the crop rotation of the Knehtilä Farm. The best preceding crops for hemp are green manure, fallow and red clover (Norokytö, 2013).

We think that fiber hemp could be possible part of Palopuro Symbiosis because it suits well for the image of ecological farming and the whole idea of cycling the materials. We have thought that Knehtilä farm could take care of cultivating and get the subsidies for it. When it is cultivated it could go straight to Mäntymäki and/or to horse stables nearby. Another option is to contract cultivate it to Hemprefine. Hempfrine collects the hemp and produce the litter out of it. Hyvinkää is located at the area where Hemprefrine is looking for contract farmers (Hemprefrine, 2016). They offer the seed for the price of 5-6 EUR/kg. The seed rate is about 20-30kg/hectare. They will pay the contract farmers for the baled hemp 100- 150 EUR/tn.

Hemp is suitable for dry decomposition process, where it can be used straight or cycled via the chicken house and the horse stables as litter. The spring harvested hemp can be used straight as litter and autumn harvested hemp can be decomposed. Hemp has quite good methane potential. An average yield of fiber hemp is about 6-14 tons per hectare which has energy content of 35-70 MWh (Hirvonen, 2013., Hemprefine, 2013).

Table 5. Litter consumption. Edited from the source: Juvonen, 2014.

	Litter consumption tn/horse/a	Litter consumption m^3/horse/a
Peat	3,5	20,3
Hemp	1,3	11,7

Recommend horse stables to change their litter to hemp

- Longer period between emptying the manure containers
- Less transportation costs
- Maybe farm can left the tube process aside
- Better methane potential than peat has
- Suits well for horses
    - dust free

- hypoallergenic
- good absorbency
- long-lasting and economical choice
- easy to clean
- suitable bed for horses

Conclusions

It seems that the goals of the Symbiosis would be achieved when using the residues of the biogas production process as fertilizer. Our results show that the amount of the biogas would be achieved by using these kind of input materials. At the moment there is not enough input materials to get necessary amount of biogas. In the goal situation (Tables 2. & 3.) there would be sufficiently inputs for achieving the target.

The calculated nutrient contents in the goal situation are parallel to the calculations done by Kivelä & Parviainen (2016). Our calculation results are between the bottom line and the upper line of the results of the study of Kivelä and Parviainen, but closer to the bottom line. It seems that using the second year yields enhances the nutrient contents (Table 3.).

Self-evaluation

The challenge of this Problem Solving Project has been the difficulty of getting necessary information. At the beginning of the project process there was a bit of confusion about the assignment. That is the reason why we did not get the exact answers to all of the study questions mentioned in the introductory chapter.

During the process, we also learned much about the topic of the project. In its entirety, the problem solving project process was fine considering. Within the framework of the 3 ECTS wide school course, the amount of work required for that ran over remarkably. The biggest strength of this project work was our team work. We worked a lot together as a group, which made the processing of the project more efficient.

References:

Ministry of Environment. www.ym.fi

Kymäläinen, M. & Pakarinen, O. 2015. Biokaasuteknologia – Raaka-aineet, prosessointi ja lopputuotteiden hyödyntäminen https://issuu.com/hamkuas/docs/hamk_biokaasun_tuotanto_2015_ekirja

Motiva Oy. 2015. Biokaasun tuotanto maatilalla. www.motiva.fi/files/6958/Biokaasun_tuotanto_maatilalla.pdf

Juvonen, N. 2014. Kevätkuivattu kuituhamppu hevoskuivikkeen ja raaka-aineena. https://www.theseus.fi/bitstream/handle/10024/81666/Juvonen_Nina.pdf.

Tapio, E., Virkkunen, E., Heikkinen. P., Hietaranta, M. & Saastamoinen, M. 2014. Hevosenlanta tuottaa biokaasua. Horse Manure- hanke. www.smt.fi.

Säikkö, R-L. 2012. Hevosenlannan nykykäyttö ja hyödyntämismahdollisuudet energiantuotannossa Suomessa.

Kalmari-Harju, J. 2014. Elintarvikeketjun sivuvirtojen hyödyntäminen- hankkeen tuloksia. http://docplayer.fi/6972901-Johanna-kalmari-harju-20-11-2014.html.

MTT. http://portal.mtt.fi/portal/pls/portal/gas_mtt.gas_mtt_laskuri

Keskinen, R., Nikama, J., Närvänen, A., Särkijärvi, S., Myllymäki, M., Saastamoinen, M & Uusi-Kämppä, J. 2014. Hevosen lannan ravinteet talteen ja kiertoon ympäristön hyvinvoinnin vuoksi-HorseManure. http://portal.hamk.fi/portal/pls/portal/!PORTAL.wwpob_page.show?_docname=13657614.PDF

Hirvonen, K. 2013. Biomassojen energiakäytön ympäristövaikutukset Varsinais-Suomen alueella. Pure biomass –hanke. Luettu 1.3.2016.

http://www.mtt.fi/mttraportti/pdf/mttraportti21.pdf

Norokytö, N. 2013. Hamppu viljelykiertokasvina. Luettu 16.3.2016
https://www.mtk.fi/liitot/varsinaissuomi/luomuvakka/fi_FI/tapahtumat2012/_files/87025767879410082/default/noora_norokyto_hamppu.pdf

Kivelä, J. & Parviainen, T. 2016. Massataseet ja ravinnesisältö. Sähköposti 14.3.2016.