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Assessment of the economic value of cattle slurry and biogas digestate used on grassland

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Abstract. Concentration of dairy production and development of manure handling technologies has led to large amounts of cattle slurry produced as a by-product. Slurry can be used directly for fertilisation or input for biogas production. As a result of added organic materials, the nutrient content of the by-product of anaerobic digestion (biogas digestate) differs from nutrient content of slurry. The data from the 2012 to 2014 field experiment designed to evaluate the use of local organic fertilisers on grassland were used for the current study. The objective of this research is to present an approach for the fair reflection of the economic value of organic fertilisers. The approach is based on substitution relationships between mineral and organic fertilisation on a certain yield level of grass dry matter production. The economic value was assessed based on the nutrient content of cattle slurry and biogas digestate, application costs, and the cost of mineral fertilisation. Two categories of economic value were calculated: the total and the actually realised value. The total economic value shows the potential value of nutrients available for plant production. The actual realised value is formed through the nutrient usage by plants. The economic value of the biogas digestate used in the experiments appeared to be higher than the value of slurry, due to the equal application of ammonium nitrogen (NH_4-N), the higher content of potassium and lower application rates.

Key words: cattle slurry, biogas digestate, economic value, grassland.

INTRODUCTION

Several aspects of fertilisation with organic fertilisers are gaining importance, such as the emission of atmospheric gases (Webb et al., 2010; Rodhe et al., 2015), minimisation of transportation and application costs (Tamm & Vettik, 2011; Tamm & Vettik, 2012) and the fertiliser value of liquid manure and biogas digestate (Schröder et al., 2007; Alburquerque et al., 2012; Möller & Müller, 2012; Tampere & Viiralt, 2014).

In line with the development of technologies in animal husbandry and biogas production, as well as with the shift of animal production from smaller production units to larger ones, the need for consideration of the economic value of by-products has arisen. Farmers and biogas producers often consider animal manure and biogas digestate as wastes that create disposal costs (Keplinger & Hauck, 2006; Alburquerque et al., 2012). In the periods of economic recession, the fertiliser value of organic fertilisers is clearly perceived, but the marketing distance of these goods is limited by high transportation costs.

The economic value of products is formed through market transactions. In European markets, animal slurry and biogas digestates are valued differently, based on the local needs for plant nutrients and availability and prices of mineral fertilisers. In Estonia, the value of animal manures has been treated in multiple ways: accounting with zero value (Koik et al., 2009; Rebane, 2015) or considering the value of manure nutrients equal to the mineral fertiliser nutrients (Vettik & Tamm, 2013). To date, the market for cattle slurry and biogas digestate is still limited in Estonia. Thus, the value of liquid organic fertilisers has to be obtained through an alternative way – using the component prices and associating costs for application and transport (Kässi et al., 2013; Naglis-Liepa, 2013). Disposal prices of biogas digestate for biogas producers can vary from negative to positive, depending on the regional nutrient availability, season, feedstock and other factors (Dahlin et al., 2015).

The agronomic and economic value of organic fertilisers depends on several factors, including ammonia volatilisation, which is affected by the application method (Rodhe et al., 2015). The farm survey titled ´The main production resource efficiency of agriculture in Estonia´ in 2013, reviewed the main technologies in agriculture. It was found that 33 % of dairy farmers who had liquid manure system at their farm used trailing hose application; 24.7% indicated usage of broadcasting with mixing into soil. Within larger dairy farm (>100 cows) groups, in addition to injection technologies, the share of trailing hose and broadcasting systems used is still quite large (Fig. 1). Among other factors, the choice of fertilising machinery depends on the dry matter (DM) content in the liquid manure, where the trailing hose and trailing shoe application are suitable for grassland application of manure DM content in between 6 to 9 % (Vettik &Tamm, 2013).

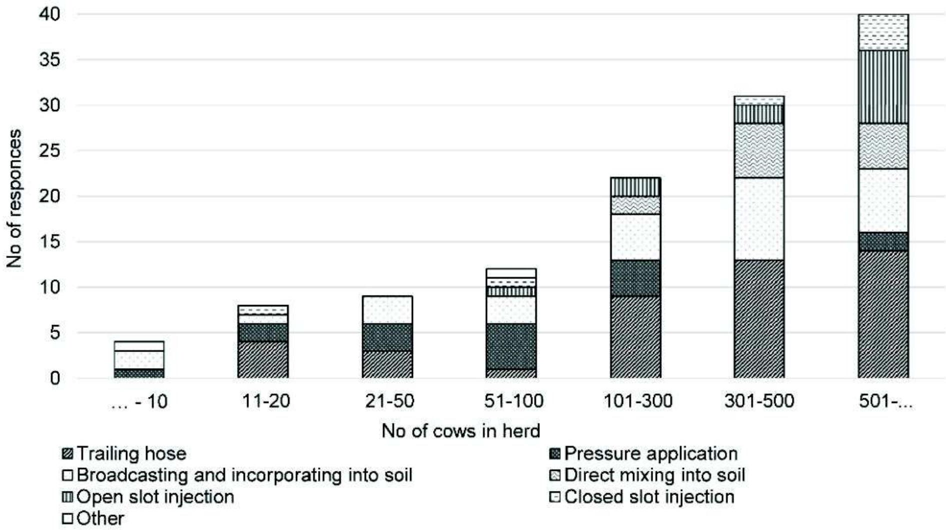

Figure 1. Liquid fertiliser application technologies at Estonian Dairy Farms in 2012 (The main…, 2013).

The application of liquid organic fertilisers on grassland allows reduction of the aggregate emission from storage and application of fertilisers during the summer period due to high temperatures (Rodhe et al., 2015). The timing and choice of application machinery for grassland fertilisation in the vegetation period is still limited because of the risk of grass contamination and crop damages (Laws et al., 2002; Rodhe & Halling, 2014), especially in case of shallow injection systems.

In practice, organic fertilisation is necessary to compensate the amounts of nutrients carried away with grass yield, since the farm financial budget constraints often limit the usage of mineral P and K on grassland. While the official statistics (EN17) shows the negative balance of phosphorus (P) per hectare of total agricultural land in Estonia, no official information about the balance of potassium (K) is available. In terms of global resource supply, it is pointed out that the scarcity of phosphorus and potassium is increasing (Kässi et al., 2013; Vaneeckhaute et al., 2013); thus, appropriate usage of organic fertilisers should help to balance the usage of these nutrients. Therefore, it is necessary to analyse the contents of organic fertilisers; however, not often done by farms.

The aim of the current study is to evaluate the economic value of biogas digestate and cattle slurry on the example of their use as organic fertilisers on grassland (consistent of grass species only). Analysis is based on field experiment data from 2012 to 2014.

MATERIALS AND METHODS

Field experiment data

The data for the assessment of the economic value of cattle slurry and biogas digestate originate from a field experiment conducted at the Erika Experimental station, Estonian University of Life Sciences (58°23`32``N, 26°41`31``E). Experiments were conducted in four replicates in a randomised complete block design. In 2012–2014, the grass sward consisted of smooth meadow grass (*Poa pratensis*) and red fescue (*Festuca rybra L.*), previously also perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*), which had disappeared during unfavourable winters (Tampere & Viiralt 2014).

The primary objective of the trial was to investigate the yield effect and grass silage quality under fertilisation with cattle slurry and biogas digestate (composed of cattle slurry and agricultural residues). These fertilisers were compared to barely mineral nitrogen applied to grass-only mixtures, which is a common practice in Estonia. Grass yield, dry matter (DM) and nutrient content of grass were measured and several measurements of silage content made.

The fertiliser rates in trial were set up to meet NH_4-N levels of 180 kg ha^{-1} for all fertilised treatments (Table 1), divided into three applications. The total amounts of nitrogen (N_{tot}) reached the level of 300 kg ha^{-1} at the treatments with organic fertilisers, containing 26% (digestate in 2012) to 40% (slurry in 2012, digestate in 2013) of nitrogen in organic form. One third of organic nitrogen is estimated to be released in the year of application, the rest during the following years.

Table 1. Amounts of plant nutrients applied with fertilisers and measured in yield

Year	Treatment	Fertilisation, kg ha^{-1}					Yield in DM* t ha^{-1}	Nutrients in cut grass, kg ha^{-1}		
		N_{tot}	NH_4-N	NO_3-N /org-N	P	K		N_{tot}	P	K
2012	Control	0	0	0	0	0	7.52^{1}	122	n.m	n.m
	NH_4NO_3	180	90	90/0	0	0	8.76^{2}	203	n.m	n.m
	Digestate	247	183	0/64	44	131	10.59^{3}	210	n.m	n.m
	Slurry	308	180	0/128	55	150	11.61^{3}	222	n.m	n.m
2013	Control	0	0	0	0	0	4.70^{1}	93	13	104
	NH_4NO_3	180	90	90/0	0	0	5.52^{2}	147	18	131
	Digestate	312	181	0/131	57	252	6.44^{3}	137	19	152
	Slurry	299	180	0/119	51	199	7.08^{4}	140	20	159
2014	Control	0	0	0	0	0	5.09^{1}	109	14	55
	NH_4NO_3	180	90	90/0	0	0	8.22^{2}	246	29	108
	Digestate	288	182	0/106	51	176	11.20^{3}	243	35	164
	Slurry	294	180	0/114	53	162	11.05^{3}	219	33	143
Mean	Control	0	0	0	0	0	5.76^{1}	108	14	80
	NH_4NO_3	180	90	90/0	0	0	7.50^{2}	199	24	120
	Digestate	282	182	0/100	54	214	9.41^{3}	197	27	158
	Slurry	300	180	0/120	52	180	9.92^{3}	194	26	151

* DM – dry matter; indexes express significant difference in yield ($P < 0.05$); n.m – not measured; N_{tot} – total amount of nitrogen; org-N – nitrogen bound in organic matter.

Factors of the economic value of organic fertilisers

To assess the economic value of organic fertilisers, several factors have to be taken into account that are connected to the machine technologies used, the plant need for nutrients in the year of application and the following years in crop rotation, soil nutrient content, availability of the land, etc. (Fig. 2).

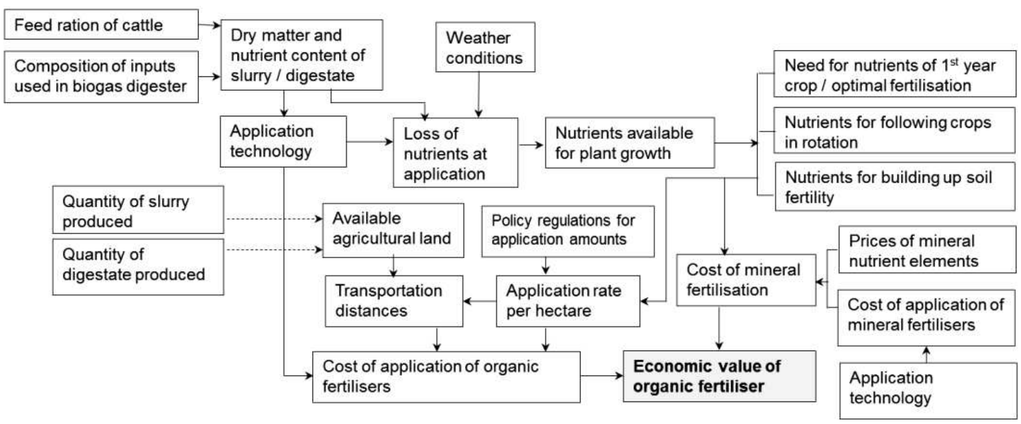

Figure 2. Factors influencing the economic value of cattle slurry/ biogas digestate.

The value of organic fertilisers is not based on the total nutrient content but rather on the amount of nutrients that become available for plants when applied to the soil. Loss of nutrients during and directly after application depends on the application machine technology (Webb et al., 2010), weather conditions and dry matter content of the fertiliser. The higher the temperature and the higher the DM content, the higher is the total ammonia emission from the fertiliser (Sommer & Hutchings, 2001).

Crop needs for nutrients and nutrient availability in an organic fertiliser determine the upper limit for application rates per hectare that has an effect on the application costs. At low soil nutrient content and at crop rotation, where the following crops use the carry-over effect of fertiliser nutrients, higher rates of potassium and phosphorus than the need of the first year crop are reasonable. The very low application rates typically reflect the shortage of fertilisers that cause an inefficient use of labour, machinery and materials (fuels) and the high cost of application.

Based on the price level of mineral fertilisers used at the farm, the monetary value of nutrients in manure and digestate can be calculated. Since the application costs of an organic fertiliser exceed substantially the spreading costs of a mineral fertiliser, the value of the organic fertiliser must be adjusted.

Weather conditions

The utilisation of nutrients is dependent on weather conditions. In 2013, plant growth was influenced by unfavourable weather conditions at the experimental area. The precipitation during the period from May to September (294.4 mm) was 22% lower than long term average (376.9 mm). In the second fertilisation period of the experiment plots in 2013, the precipitation was only 2.2 mm, average temperature 19.5 °C (Table 2). In such conditions, the infiltration of fertilisers into soil is slow and ammonia volatilisation rates are high (Huijsmans et al., 2001). In some cases, conversely NH_3 losses increase if infiltration is reduced by a high water content (Sommer & Hutchings, 2001). The precipitation at the field trial site was above the long term average at the second fertiliser application in 2012 and 2014 (35.6 mm and 44.6 mm, respectively), which improved the infiltration of nutrients, but also increased the risk of losses through leaching (Tampere et al., 2014).

Table 2. Weather conditions on the fertiliser application decades (I, II and III application)

Indicator	Period	2012	2013	2014
Average temperature, °C	I	9.9	6.1	7.3
	II	12.2	19.5	12
	III	14.1	17.9	21.9
	April – September	12.6	13.7	13.3
Precipitation, mm	I	9.8	15.2	7.8
	II	35.6	2.2	44.6
	III	24	27.2	15.2
	April – September	443	294.4	407.2

Ammonia emission from surface-applied slurry at the temperatures of 9–10 °C is presumably at the level of 10% (slurry dry matter content 8%), at the temperature 20 °C, emission can reach 20–30%, at the temperature 30 °C up to 50% (Sommer & Hutchings, 2001; Huijsmans et al., 2001). The trailing hose application allows up to 51% reduction in emission compared to splach plate application technique (Häni et al., 2016). Different factors, like dry matter content, soil infiltration rate, air temperatures, rainfall etc. with varying relative importance, affect the nitrogen emission, therefore the actual emission rates are not predictable (Sommer & Hutchings, 2001).

Nutrient content of organic fertilisers in the experiment

Nutrient content of slurry varies considerably, depending on the nutrient content of raw manure, type of slurry storage system, time since excretion etc. The content of biogas digestate depends on the input ingredients, the speed and anaerobic fermentation process in the digester.

The exact chemical content of cattle slurry and biogas digestate was analysed at the Laboratory of Plant Biochemistry of the Estonian University of Life Sciences (Tampere & Viiralt, 2014). Dry matter content of biogas digestate was 3.5% in 2012 (Table 3), since the input to the digester was cattle slurry with no considerable added organic material. Additional input of organic material led to higher dry matter levels of the digestate in 2013 and 2014. The higher content of NH_4-N in biogas digestate (mean value of three years 2.8 kg t^{-1} compared to 2.56 kg t^{-1} in cattle slurry) determined the lower average application rates per hectare compared to cattle slurry. The high share of ammonium nitrogen in the digestate increases the potential volatilisation of total nitrogen as compared to undigested cattle slurry.

Table 3. Data for the calculation of the economic value of organic fertilisers used in the experiment

Factor	Cattle slurry				Digestate (digested cattle slurry)			
	2012	2013	2014	**Mean**	2012	2013	2014	**Mean**
Quantity applied. t ha^{-1}	67.1	76.0	68.3	**70.5**	57.3	71.8	68.2	**65.8**
Application cost € t^{-1}	2.98	2.84	2.98	**2.93**	3.14	2.90	2.96	**2.99**
DM yield. t ha^{-1}	11.61	7.08	11.05	**9.91**	10.59	6.44	11.2	**9.41**
DM and nutrient content measured in fertilisers								
DM. %	8.3	8.2	8.8	**8.4**	3.5	8.1	6.8	**6.2**
N_{tot}. kg t^{-1}	4.60	3.93	4.30	**4.28**	4.31	4.32	4.23	**4.29**
NH_4-N. kg t^{-1}	2.68	2.36	2.63	**2.56**	3.20	2.51	2.68	**2.80**
P. kg t^{-1}	0.83	0.68	0.79	**0.77**	0.76	0.79	0.76	**0.77**
K. kg t^{-1}	2.23	2.60	2.37	**2.40**	2.28	3.48	2.59	**2.78**
Amount of nutrients reached into yield*								
N_{tot}. kg t^{-1}	3.31	1.84	3.21	**2.75**	3.66	1.91	3.56	**2.99**
P. kg t^{-1}	0.49	0.27	0.48	**0.41**	0.52	0.26	0.51	**0.43**
K. kg t^{-1}	2.25	2.09	2.09	**2.14**	2.13	2.12	2.40	**2.22**

* the amount of nutrients in cut grass, kg ha^{-1} (Table 1) divided by the applied amount of slurry / digestate, t ha^{-1}.

The amounts of nutrients that reached the yield were measured in cut grass and were in accordance with the fertilisation recommendations in Estonia at acquired grass yield. The average amounts of total nitrogen (N_{tot}) in 2012–2014 measured in cut grass were 64.3% of N_{tot} applied with slurry and 69.7% of N_{tot} applied with biogas digestate (Table 3).

Calculation of the economic value of organic fertilisers

In order to establish the relations between the factors of economic value of cattle slurry and biogas digestate, a model was built up by using Lindo™ software for linear programming. The value of an organic fertiliser is expressed as a shadow price through the substitute relationship between organic and mineral fertilisation. It is dependent on the available amounts of nutrients in cattle slurry (X_S) and digestate (X_D), the costs of application of the organic fertiliser (C_S, C_D) and the alternative costs of fertilisation: with mineral fertilisers. The cost of mineral fertilisation (C_{NPK}) includes the purchase and application costs of mineral fertilisers (€ kg^{-1}). Both the organic and mineral fertiliser amounts have to meet the requirement of nutrients (R_{NY}, R_{PY}, R_{KY}; kg ha^{-1}) by the crop grown at an expected yield level (Q_Y, t ha^{-1}). The value (shadow price) of organic fertilisers is expressed through the following relation:

$$Min\ \ C_N * Q_N + C_P * Q_P + C_K * Q_K + C_S * Q_S + C_D * Q_D - P_Y * Q_Y$$

Subject to

$$R_{NY} - - X_{SN} * Q_S - X_{DN} * Q_D < 0$$
$$R_{PY} - Q_P - X_{SP} * Q_S - X_{DP} * Q_D < 0$$
$$R_{KY} - Q_K - X_{SK} * Q_S - X_{DK} * Q_D < 0$$

$$Q_S < A_S$$
$$Q_D < A_D$$

where: Q_{NPK} – quantity of nutrient elements in mineral fertilisers (kg ha^{-1}); Q_S , Q_D – quantity of organic fertilisers (t ha^{-1}); P_Y – value of grass dry matter yield (€ t^{-1}); Q_Y – amount of grass dry matter produced (t ha^{-1}); A_S, A_D – availability of slurry/digestate (t).

Characteristics of the calculation

To calculate alternative costs of mineral fertilisation, the plant requirement for nutrient elements (NPK) per hectare of fertilised area was taken into account. The 2012–2014 average prices of mineral nutrient elements were N 0.94 € kg^{-1}, P 0.96 € kg^{-1} and K 0.91 € kg^{-1}. The average cost of three applications of mineral NPK per kilogram of nutrient (depending on loading, transportation and application of mineral fertilisers) ranged from 0.10 € kg^{-1} to 0.12 € kg^{-1} according to the total amount of nutrients applied. The cut grass was ensilaged, thus the price of grass dry matter yield (74.29 € t^{-1}) was obtained through the market price of a ton of grass silage.

The cost of cattle slurry and digestate application (Table 3) was calculated according to the machine technology implemented in field trials, using machinery cost calculation algorithms from Estonian Crop Research Institute (Machinery cost …). The slurry and digestate were spread to the field with 20 cm spacing, implicating the trailing hose application technology. The transportation distance for the application costs shown in Table 3 was assumed to be 1 km, performed by application equipment. The total application cost of three applications was divided by the quantity of the applied organic fertiliser. For transportation beyond two kilometres from storage facilities, it is economical to involve a separate tank (Tamm & Vettik, 2012).

The data of the experiment with high rates of organic fertilisers used on permanent grassland, allow us to show the potential economic value of the used organic fertilisers and the actual value, realised through the fertilisation of particular grassland mixture with high rates on continuous years.

The contents of nutrient elements in slurry and digestate were involved in the calculations as follows:

1) **To calculate the total economic value of a fertiliser**, the total available amounts of nutrients in manure were considered after ammonia losses through emission. The estimation of potentially available nitrogen was at similar level than the nitrogen amounts reached into grass yield.

2) **To show the actual realised value of a fertiliser at the current yield level**, the amount of nutrients were used by crops in the current year. It was presumed that the possible uptake of the nutrients (in available form) from soil was compensated by the organic fertilisers through nutrient mineralisation; thus, the stock of nutrients in soil would not be reduced. In the experiment variants of control and mineral nitrogen, where the PK was not applied (Table 1), the formulation of yield was a result of decreasing the soil nutrient reserves. Carry-over (residual) effect of organic nitrogen in organic fertilisers used on grassland has cumulative nature (Schröder et al., 2007), which means that the currently applied organic nitrogen has an effect on developing the yield in the following years.

RESULTS AND DISCUSSION

The economic value of organic fertilisers depends on farm-specific conditions presented in Fig. 2. The conditions of field experiments in 2012–2014 enabled the calculation of the value of fertilisers at two levels: a) the total economic value at maximum usage of nutrients in an organic fertiliser; b) the value actually realised at the level on nutrient application to the soil (Fig. 3).

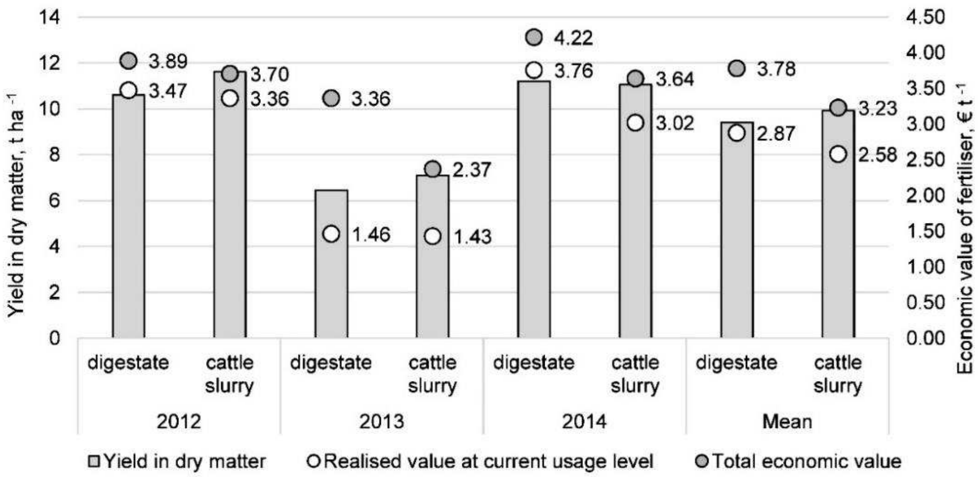

Figure 3. The economic value of cattle slurry and biogas digestate in the grassland experiment.

Since the experiment continued for several years at the equally high rates of fertilisation, the phosphorus and potassium levels exceeded the crop needs. The soil element supply at experimental plots was at high (P) and medium (K) level, thus there was no need to rebuild the soil element stock. Even if the leaching of phosphorus from grassland is marginal, potassium appears to be more mobile, especially from the grass-only mixtures (Tampere et al., 2014). Thus, it is not economical to apply excess nutrients.

The yield levels of treatments fertilised with slurry and digestate were at a comparable level in 2012 and 2014 and differed significantly ($P < 0.05$) only in dry 2013 (Table 1).

Based on the 2012–2014 average data, the total economic value of biogas digestate used at grass-only mixture was 3.78 € t^{-1}, the value of cattle slurry 3.23 € t^{-1} (Fig. 3). These levels are reachable when fertilisers are used at high application rates for a crop with high need for nutrients. The value actually realised at the current fertilisation level reached respectively 2.87 € t^{-1} and 2.58 € t^{-1}.

In 2012, the dry matter content of digestate 3.5% and the high NH_4-N content kept the total application amounts of nitrogen lower compared to the following years, which had an effect on the application costs and on the total value of nutrients per ton of digestate.

The NH_4-N content of cattle slurry was low (2.36 kg t^{-1}) in 2013, therefore the total application amount of slurry was 76 t ha^{-1}, which increased the costs of application and decreased the total economic value of slurry (2.37 € t^{-1}). The same ground caused lower total economic value of the digestate in 2013. In addition, the phosphorus content of slurry was low in 2013.

The difference between the value actually realised and the total economic value of organic fertilisers was largest in 2013, where the uptake of nutrients was lowest due to dry weather (total precipitation 270.2 mm), and probably high ammonia emission. The actual value of fertilisers received in 2013 was respectively 1.46 € $t^{-1}$and 1.43 € t^{-1}.

As the contents of slurry and digestate were similar in 2014, the yields were at the same level. The difference in total economic value relates to the differences in the application rates of slurry between the application times. The different application quantities were caused by the variation in NH_4-N content in slurry.

The effect of fertilisation with organic fertilisers on grassland depends on the botanical composition of the grass sward. The agronomic effect of organic nitrogen is expected to be higher on swards that consist of grass mixtures compared to legume-grass mixtures. Grassland mixtures with no legumes use high amounts of nitrogen (180–220 kg ha^{-1}) (Kässi et al., 2013) that gives a higher value to manure compared to legume-grass mixtures. The effect of additional fertilisation with organic fertilisers at the legume-grass mixtures, where the need for nitrogen is covered with atmospheric fixation, compensates scarce phosphorus (P) and potassium (K) amounts. (Viiralt et al., 2015). On the other hand, the potential leaching of potassium appears to be higher at grass-only swards, depending on the precipitation and water uptake with higher yields (Tampere et al., 2014).

Policy regulation before 2014 instructed the usage of organic fertilisers through the allowed amount of 30 kg ha^{-1} phosphorus on the average of total agricultural land. That led to high volumes of slurry used on the fields near storage facilities. Current policy restricts the application rates to 25 kg ha^{-1} of phosphorus per fertilised hectare (Water Act of Estonia), thus increasing the fertilised area. Shortage of suitable land nearby storages increases the transport distances, leading to the reduction of the economic value of the fertiliser (Fig. 4). Therefore, suitable land is an important availability factor or restriction, which is farm- and site-specific.

Restricting the excess application of nutrient elements, the regulations increase the share of nutrients used for that purpose and diminish the share of nutrients lost through leaching. Adjustments in crop rotation could enhance the maximum usage of the organic fertiliser potential and decrease the dependence on mineral fertilisers.

The effect of transportation distance depends on the choice of the transportation vehicle. For our calculations, the assumption of a separate transportation tank was taken for distances over three kilometres. That enables keeping application productivity per hectare stable compared to the case of transportation with a trailing hose manure distributor. Based on the 2012–2014 average data, the total economic value of biogas digestate decreases from 3.78 € t^{-1} to 2.57 € t^{-1} reaching the 10 km distance. Similarly, the total economic value of slurry decreases from 3.23 € t^{-1} to 2.00 € t^{-1} until the 10 km distance (Fig. 4).

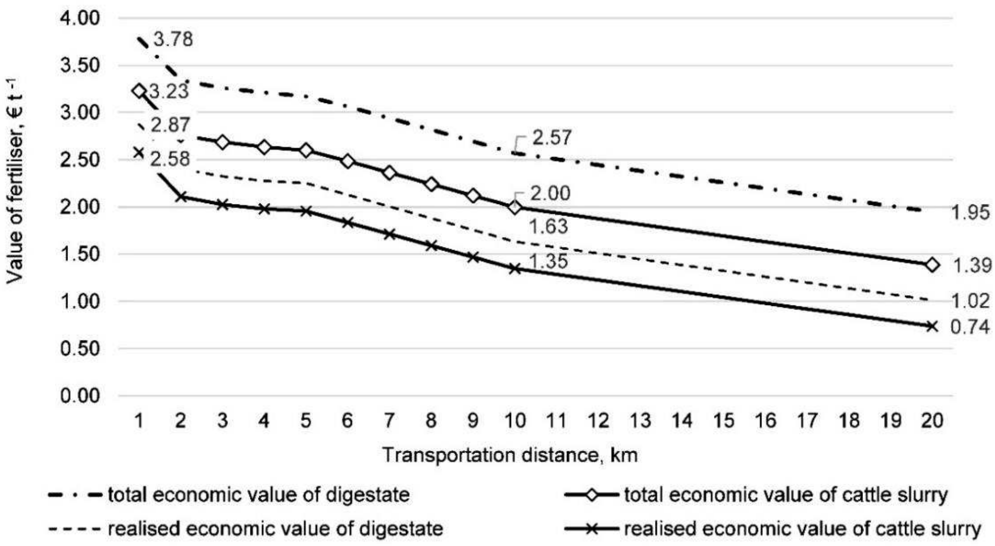

Figure 4. The 2012–2014 average total economic value (€ t^{-1}) and realised economic value (€ t^{-1}) of cattle slurry and biogas digestate depending on the transportation distance.

The total value calculated at the distance of 20 kilometres is ca 50%, actually realised value is ca 30% compared to the value at nearby fields (the other conditions remain the same). The changes in value are farm-specific, depending on the machinery used, but still give an overview of the relations between the value of the fertiliser and the distance.

The economic value of the biogas digestate used in the experiment was higher than the value of cattle slurry mainly due to the higher content of NH_4-N, thus the needed amount of digestate to reach the target nutrition level was smaller. The content of organic fertilisers varies considerably between farms, animal species, feed rations, seasons and years; therefore, the numerical results of our analyses are not extendable to different types of slurry and digestate. The results are also dependent on the value of alternative fertilisation with mineral fertilisers, which are in practise farm specific.

The estimation of production efficiency through unit production costs of grass dry matter (data not presented) shows that the three-fold application of organic fertilisers with higher total nutrient amount than plants can use increases the production costs over the market value of grass production. The surplus costs of fertilisation lead to inefficiency from the economic point of view, compared to the treatments of mineral nitrogen and controls.

The effect of advanced application technologies on the economic value of liquid organic fertilisers should be assessed in the future on the same methodological basis. Injection of the slurry or digestate to grassland with the intention to decrease ammonia losses (Webb et al., 2010; Häni et al., 2016) might result in decreased yield levels, especially in the case of spring fertilisation (Rodhe & Halling, 2014) and will increase simultaneously the costs of fertilisation.

The appraisal of the economic value of fertilisers used for forage crops should also include the quality aspects of the final product – silage. The added value of forage crops appears through milk quality and yield. The effect of the chemical and microbiological properties, metabolisable energy content of silage (MJ) and total energy production per hectare (GJ) to the performance of milk production is worth of analysing.

CONCLUSIONS

In this research, the cattle slurry and biogas digestate as organic fertilisers used on grassland were examined in order to estimate their economic value.

Based on the available nutrient content and the associating costs of fertilisation, the total economic value at a certain transportation distance on average of 2012–2014 was 3.23 € t^{-1} for cattle slurry, 3.78 € t^{-1} for biogas digestate. The actually realised value through usage of nutrients applied was respectively 2.58 € t^{-1} and 2.87 € t^{-1}, depending on the yield level and plant nutrient requirements of particular years. The difference between the total and the realised economic value is the result of the high level of fertilisation during all three experimental years, where not all of the applied nutrients were utilisable by the crop. Sources for economic values of biogas digestate higher than those to cattle slurry were the higher NH_4-N and potassium content accompanied with lower application rates.

The results of the actual economic value based on one grassland mixture (smooth meadow grass, red fescue) which uses high amounts of nutrients are not extendable to other field crops.

A general conclusion drawn from the current analysis is that attributing zero value to organic fertilisers, which is the prevalent approach in Estonia, is unjustified. The value of organic fertilisers forms through actual usage of these fertilisers at farms, depending on the nutrient requirements, range of crops fertilised and application technology.

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