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Calculation of fossil energy application

Storing and preparation of organic manure

The methods for energy balancing in plant production could be complemented through a suggestion for balancing fossil energy input in the processing and storing of slurry and solid manure. Compared on area and product associated bases, the calculation of fossil energy applied in the barn in a slurry dairy cow housing system leads to lower values compared with those from the mineral fertilising of fields alone or fertilising with solid manure.

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Literatur

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The material and energy economy is an important area for the determination of environmentally supportive agricultural management systems. Weak points of currently available models for the calculation of complete management systems are differentiated applications for energy inputs in livestock and crop production systems. Two factors are argued about in the case of organic manures in the livestock production sector: regarding them as waste or as a product of animal production [1] and the application of an NPK substitute value as energy input [2] instead of the (difficult to quantify on a farm basis) application of fossil energy. The right direction here would therefore seem to be a start in calculation of fossil energy inputs in the storage and preparation of organic manure.

Calculation

For solving the problem the required direct energy input for diesel and electricity required in the storage and preparation of organic manure and the indirect energy input in investment in four loose housing dairy cow barns has to be calculated (*tables 1 and 2*). Main methodical bases here are the investigation results for energy equivalents for investment material [5]. With solid dung housing annual input is between 1480 and 1610 MJ/cow. The increase in larger herds is caused through the extra labour for dung removal [3] and additionally DK use (*table 1*). The annual primary input per cow is a little greater in the case of slurry systems (*table 2*).

The use of organic fertiliser is calculated for a model farm (AF: 900 ha) with a field area ratio which represents the situation in the state of Brandenburg when one leaves out fallow and pasture areas [9]. Stocking is 0.4 GV/ha, a little less than the average in that state [9]. On an area of 540 ha mineral fertilising alone takes place; on 180 ha combined slurry and mineral fertilising and on another 180 ha combined solid manure and mineral fertilising with, in each case, 1 GV/ha.

It is assumed that nitrogen (*table 3*) in the application year is used for 30% of requirements with solid dung and for 50% with slurry, with P to 100% because of the effect of the following crop and K to 80% because of expected losses on sandy soils [10, 11]. As basic yield for areas receiving mineral fertiliser only, and for nutrient requirements, data from Brandenburg state is used [12]. On using solid manure in combination with mineral fertilising yield increases of up to 10% have been recorded in many trial locations [10, 13]. In this report yield increases of 10% were assumed for solid dung application and 5% for slurry application.

For energy balances based on cropping, the PC model REPRO was applied [14, 15]

Table 1: Fossil energy input for the storage and processing of solid manure from loose dairy cattle houses

Item	Unit	Number of animals			
		60	120	180	240
DK-use[1)]	$l\ a^{-1}$	681	1647	2994	4499
Machinery[2)]	$kg\ a^{-1}$	2133	3145	4566	6204
Midden[3)]	$GJ\ a^{-1}$	24.6	45.9	66.6	87.1
Slurry pit[4)]	$GJ\ a^{-1}$	23.6	38.6	48.7	66.0
Total	$GJ\ a^{-1}$	94.2	177.7	274.4	386.2
Energy input	$MJ\ GV^{-1}\ a^{-1}$	**1570**	**1481**	**1524**	**1609**
Energy input	$MJ\ t^{-1}FM$	**157**	**148**	**152**	**161**

1) Working time for littering and mucking according to [3], tractor 35 kW, 1 l DK equals 39.4 MJ primary energy [4]
2) Writing off primary energy for tractor, slurry blade, dung spreader, 1 kg equals 9 MJ [5]
3) Area requirement per cow and 6 months 3.6 m^2 according to [6], retaining wall, energy equivalent according to [5]
4) Container requirement according to [6], slurry pit according to [7] with concrete flooring and lid and steel container walls.

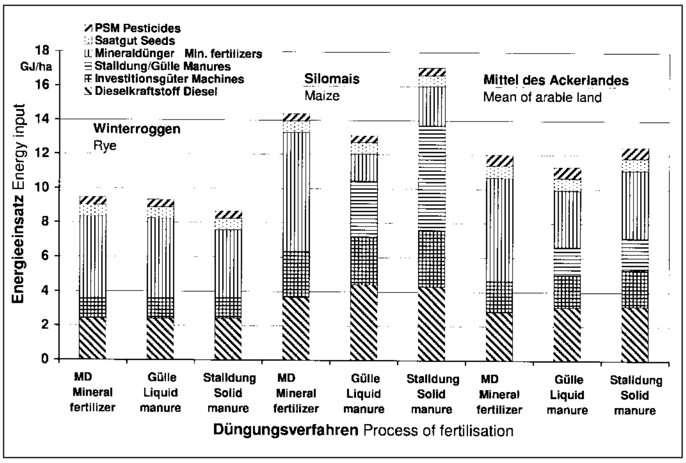

Fig. 1: Energy input for different fertilisation applications in various crops

Table 2: Fossil energy input for the storage and processing of liquid manure from loose dairy cattle houses

Item	Unit	Number of animals 60	120	180	240
DK-consumption[1)]	l a^{-1}	204	557	1079	1819
El. consumption[2)]	kWh a^{-1}	135	270	405	540
Machinery[3)]	kg a^{-1}	267	671	1270	2117
Slurry container[4)]	GJ a^{-1}	50	76	86	104
Slurry channel[5)]	GJ a^{-1}	49	97	145	192
Total	GJ a^{-1}	113	206	292	394
Energy input	MJ GV^{-1} a^{-1}	**1879**	**1716**	**1621**	**1643**
Energy input	MJ t^{-1}FM	**94**	**86**	**81**	**82**

1) See table 1; 2) Electricity consumption for pumping slurry [3], engine 15 kW, 1 kWh equals 10.41 MJ primary energy [8]; 3) Writing off of primary energy for tractor, scraper blade, slurry pump: 1 kg equals 9 or 13 MJ [4]; Slurry container and pre-pit requirements according to [6], pre-pit according to [7], energy equivalent according to [5]; 5) Slurry channel, slats grid according to [6], energy equivalent according to [5].

Table 3: Amount and contents of organic fertiliser

Item	Unit[1]	Solid manure	Urine	Slurry
Amount	t GV^{-1} a^{-1}	10	4	20
Dry matter (dm)	kg t^{-1} FM	250	30	80
Nitrogen N	kg t^{-1} FM (MDÄ)	6.3 (30)	2.5 (20)	4 (50)
Phosphate P	kg t^{-1} FM (MDÄ)	1.88 (100)	0.1 (100)	0.96 (100)
Potash K	kg t^{-1} FM (MDÄ)	8.8 (80)	5 (80)	4 (80)

1) GV = mature animal unit (cow with 500 kg lw); FM = fresh matter: MDÄ = mineral fertiliser equivalent

Table 4: Energy efficiency for different fertiliser applications

Item	Unit	Min. fertiliser	Slurry	Solid manure
Crop type			*Winter rye[2)]*	
Energy input	GJ ha^{-1}	9.46	9.33	8.67
GE-yield	GE ha^{-1}	40.4	42.4	44.4
Net energy output	GJ ha^{-1}	51.6	54.9	58.7
Energy intensity	MJ GE^{-1}	**241**	**226**	**201**
Crop type			*Forage maize[3)]*	
Energy input	GJ ha^{-1}	14.38	13.12	17.08
GE-yield	GE ha^{-1}	46.4	48.8	51.2
Net energy output	GJ ha^{-1}	145.0	154.5	158.8
Energy intensity	MJ GE^{-1}	**313**	**272**	**337**
Crop type			*Arable average[4)]*	
Energy input	GJ ha^{-1}	12.01	11.29	12.46
GE-yield	GE ha^{-1}	48.9	51.2	55.1
Net energy output	GJ ha^{-1}	73.2	78.1	104.0[1)]
Energy intensity	MJ GE^{-1}	**251**	**225**	**231**

1) Higher yield because straw harvested for littering
2) Crop type with subsequent effect of organic manure
3) Crop type with direct application of organic manure
4) Average value of cropland (9 crop types)

which was developed by the University of Halle for evaluating the sustainability of agricultural production systems. Compared with work up until now, detailed procedural and yield influences can be made more visible through this program.

Results

Because of the different Nr. fertiliser equivalents for solid manure and slurry (*table 3*), 45 ha of solid dung application area and 90 ha of slurry application area could have 40 t/ha of organic manure applied annually in the described model farm. If one applied the input of fossil energy required for dairy housing with 180 cows (tables 1 and 2) on the fertiliser areas, an energy input of 6.1 and of 3.2 GJ/ha respectively is required for the storage and preparation of organic manure in the form of solid dung and slurry. In comparison, the NPK substitution value with solid dung housing is 8.4 GJ/ha and for slurry systems 6.0 GJ/ha. The energy input per tonne of fresh crop (tables 1 and 2) differs substantially (table 3) from the values which would be calculated with mineral fertiliser equivalents (210 and 175 MJ/t fresh matter).

The inclusion of calculated energy amounts for the preparation and storage of organic dung in the balance of the total energy input for plant production gives, in the case of crop types which have had organic dung brought out to them (*fig. 1* forage maize) a low value for slurry application and with solid manure application a substantially higher value compared with mineral fertiliser application on its own. In the case of crop types affected by organic manure application (winter rye), the energy input with all three systems is almost balanced. With the solid dung variant the reduced mineral fertiliser use through the effects of the solid dung subsequently affects results with a reduced energy input despite the higher yield. Despite this reduction, the average value of cropland with nine types of crop shows a difference between slurry and application of solid dung of 1GJ/ha (fig. 1).

The higher area associated energy input with the solid dung systems could, through direct application *(table 4*, forage maize) with an assumed 10% higher yield, on a production-based basis (energy intensity), only partly balance out. With the typical Brandenburg average for crops, the energy intensity of the system with combined solid dung and mineral fertiliser is advantageous on an energy basis compared with mineral fertiliser application on its own. As far as yield-based application is concerned the slurry and solid dung systems hardly differed.

Applying the indicators energy application, net energy yield and energy intensity for the evaluation of the production system with regard to its environmental supportability, the advantageous effects of the solid dung system in the context of cropping relationships or rotations must be considered. For absolute quality evaluation humus and nutrient balances have to be incorporated. The results underline the necessity, even for livestock production, of calculating a complex strategy for the balancing of energy and for system energy evaluation.