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Diesel fuel input in plant production

Energy balances are used in the evaluation of crop production systems with regard to their intensity and sustainability. A methodology problem in energy balancing is the determination of fuel consumption. Up until now, average calculation values were mainly used and the influence of work conditions and type of operation was mostly not taken account of. Regression equations were introduced based on values taken from the literature. These were presented and interpreted and the surrounding conditions defined for individual parts of a particular working operation. Data is accessible via Internet for the most important work operations.

Energy reference figures allow statements on the consumption of finite resources, on CO_2 emissions and the effect on climate and are therefore useful as agri-environmental indicators. The calculation of energy references figures for crop production requires determination of fuel consumption. As a rule, the values that are used for calculation have been arrived at without, or with not enough, consideration of operational influences. For example, the calculation takes place using figures relating to the hourly fuel consumption under average engine load, plus the operational time for the machine [1]. A more detailed operation has been worked out by Kaltschmitt and Reinhardt [2] in which the fuel consumption during different steps of engine load and the length of time of each load step in the machines used are employed. Other working conditions such as yields, farm inputs utilised, transport distances or site were not, however, taken account of.

The aim of the investigation reported here, therefore, was to establish regression equations based on data analyses for fuel consumption in crop production, and in which the operational conditions can to a great extent, taken account of.

Data basis and calculation concept

In current publications and data banks on diesel fuel (DK) consumption [3,4,5], the average calculation data which are, in the main, presented are prepared for operations and technical solutions taking place or required at that time. In order that on-farm working conditions can be taken account of, one has to use older material [6]. In this case, their transferability to current conditions has to be assessed. Following are necessary restrictions in the validity of the regression equations, and the reasons for the choice of data that was made.

Results and discussion

Data which can be accessed in Internet was used in the calculations [7, www.atb-potsdam.de/publikationen/dk-einsatz.html] with regression equations for the diesel input during the most important work operations in crop production. The linear and square re-

Table 1: Regression equations for fuel consumption in ploughing examples (according to [6])

Job Type	Implement	Soil	Regression equation	Information on operation depth l [cm]	DK-input [l/ha]	Validity area working width [m]	Regression coefficients a	b	c
Sowing-Furrow	Plough/SBB	S bis lS	DK=a+b*l	18 to 27	14,4 to 18,5	1,75 to 2,8	6,1	0,46	
	Plough/SBB	sL bis L	DK=a+b*l	18 to 27	21,0 to 26,4	1,4 to 2,8	10,2	0,60	
	Plough/SBB	L bis lT	DK=a+b*l	18 to 27	27,4 to 35,6	1,1 to 2,5	10,8	0,92	
	Plough/SBB	T	DK=a+b*l	18 to 27	29,6 to 37,8	1,1 to 2,5	13,0	0,92	
Autumn Furrow	Plough	S bis lS	DK=a+b*l	23 to 35	15,8 to 26,8	1,4 to 2,8	-5,4	0,92	
	Plough	sL bis L	DK=a+b*l	23 to 35	22,4 to 39,4	1,1 to 2,5	-10,3	1,42	
	Plough	L bis lT	$DK=a+b*l+c*l^2$	23 to 35	29,3 to 40,7	1,1 to 2,5	63,8-	3,11	0,07
	Plough	T	$DK=a+b*l+c*l^2$	23 to 35	36,5 to 52,1	0,7 to 2,1	103,2-	5,66	0,12

Table 2: Regression equations for fuel consumption in fertilizer application examples (acct. o [4, 6])

Job type	Application procedure	Regression equation	Information distance T [km]	amount M [dt/ha]	DK-input [l/ha]	Validity area load [dt]	Regression coefficients a	b	c
Slurry-fertilising	Direct	$DK=(a+b*T+c*T^2)*M/200$	0,5 - 5	150 - 400	5,7 - 64,5	35 - 50	5,275	4,515	0,175
	Direct	$DK=(a+b*T+c*T^2)*M/200$	0,5 - 5	150 - 400	4,7 - 42,1	71 - 90	4,950	2,470	0,150
	Direct	$DK=(a+b*T+c*T^2)*M/200$	0,5 - 5	150 - 400	4,4 - 41,0	111 - 130	4,725	2,025	0,225
						Working width			
Fertilising N	Direct	DK=(a+b*M)*(1+0,03*(T-6)) +0,09*M/10	1 bis 12	0,5 - 7	1,2 - 2,4	>10,5 m	1,3	0,1	
Fertilising AHL	Divided	DK=((at+bt*T)*M/200)+ $(a+b*M+c*M^2)$**	1 bis 8	0,5 - 7	1,0 - 3,0	<10 m	0,896	0,0008	7,5 E-7
Fertilising PK	Direct	DK=(a+b*M)*(1+0,03*(T-6)) +0,09*M/10	1 bis 12	0,5 - 7	1,5 - 3,3	<10 m	1,63	0,075	

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Keywords

Plant cultivation, diesel fuel input, regression equation

Literature information is available from the publishers or via Internet at http://www.landwirtschafts-verlag.com/landtech/local/fliteratur.htm

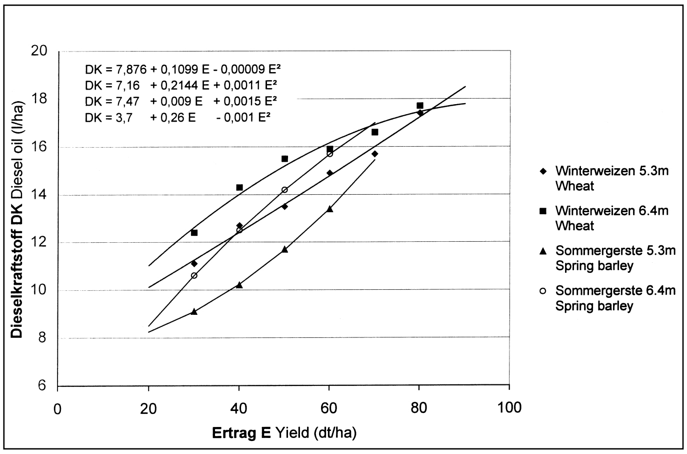

Fig. 1: Fuel consumption in combining, depending on yield, crop and working width

gression equations calculated through the minimum square method have a very high degree of accuracy [7]. Examples of the results and the choice of data are now discussed.

The diesel input during soil preparation is mainly influenced by the type of soil; additionally, fuel consumption rises in-line with the depth of ploughing (*table 1*).The calculation of the breadth of variation for diesel input was carried out through the application of the extreme values of the application parameters in the regression equations. In that the fundamental soil preparation demands up to 40% of total plant production diesel input, the given differentiations should be taken account of in farm working energy balances. Calculated data for working areas from 5 to 20 ha [4] were used for the other implements.

For bringing out liquid manure (slurry), differences must be made according to the size of the tanker [4]. Field size and transport distance are not separated, but instead presented in combination. If one doesn't take the area as the dominating factor affecting diesel input, but the transport distance instead, one is able to calculate from the given values the diesel input in association with the transport distance [7]. In direct procedures, the diesel input varies according to the different transport distances proportional to the amount of slurry spread per hectare (*table 2*). A special approach was necessary for slurry applications of under 15 t/ha and for different sizes of slurry tanker. The influence of the tank size (load) on the diesel input is especially notable with small tankers. According to the type of operation, constant individual amounts of fuel [4] were calculated for emission-reducing manure spreading (trailing hose application 3.1 l/ha, Injection grubber 9.2 l/ha, disc injection 7.3 l/ha).

Diesel input use with farmyard manure (fym) spreading can be calculated in association with transport distance, fym amount per ha, spreader load and loading equipment utilised.

Application of artificial fertiliser was done here mainly with an agricultural truck with special fittings for the determination of the data used here [8]. In the case of direct and divided applications of nitrogen, the amount of fertiliser, the transport distance and the loading effort are of influence (example, *table 2*). In the case of divided applications, the equations receive in each case an expression for the transport and the spreading. For AHL fertilising, the values of the PSM application were used as basis whilst, with lime spreading, only the divided application was taken account of.

For sowing, further crop care and plant protection, measurement and calculation data of the KTBL were used [4,6].

Because of exemplary regression functions regarding the grain harvest according to data from [6] it is possible to present the large differentiation of fuel consumption for different types of grain and yields (*fig. 1*). While the working width of the combine used at the time of the data recording expresses that which is still normal nowadays, the engine power of the combine in the investigation (85, 168 kW) was much lower in comparison with today's [4]. Whether or not the adoption of the regression functions for the applicable working width is still practical in the light of the changed engine performance capacities requires detailed investigations.

Grain transport and straw retrieval were covered by the use of data from two literature sources [4, 6].

For the forage harvest, diesel input is very different according to working method and type of forage (*table 3*). With forage maize, as with the combine harvester, the increased power output capacity development of forage harvesters resulted in limits to the use of the older data [6], in that with higher power a higher diesel consumption, as given in *table 3*, can also be expected . In the case of forage transport, there was a difference between variants depending on whether the forage was loaded in parallel operation during the harvesting and transported to the clamp [6], or the transport operation was also parallel but transport ended at the edge of the field. In the latter case additional transport to the point of consumption or storage was taken account of in the regression equations.

With the harvest of sugar and fodder beet, the diesel input could only be calculated without yield influence [4]. The available data for the potato harvest [4] enabled yield-associated regression equations.

Conclusions

The regression equations presented allow the detailed calculation of diesel input in crop production for defined work operations with regard to the site and operational conditions. Through use of equations accessible in Internet, energy balances and economic analyses could be detailed. These data fundaments should be integrated in a practice-oriented farm balance model (REPRO [9]) in order to support process-dependent material and energy balancing.

Table 3: Regression equations for fuel consumption in forage harvesting examples (acc. to [6])

Type of job	Harvested material	Regression equation	Information distance T [km]	yield E [dt/ha]	DK-input [l/ha]	Validity area work width [m]	Regression coefficients a	b	c
Mowing	Green forage	$DK=a+b*E+c*E^2$		100 - 300	3,1 - 4,5	4,5 - 5,0	4,2	-0,017	0,000060
Chopped grass	Wilted forage	$DK=a+b*E+c*E^2$		50 - 150	16,7 - 9,6	3,5 - 4,2	5,52	-0,0214	0,000037
loading	Forage maize	$DK=a+b*E+c*E^2$		250 - 550	13,4 - 23,2	2,2 - 2,6	11,50	-0,0035	0,000045
Pick-up baling	Straw	$DK=a+b*E$		20 - 70	4,3 - 7,6	6,0 - 7,0	3	0,065	
						Load [dt]			
Pick-up loading	Hay	$DK=(a+b*T+c*T^2)*E/10$	0,5 bis 6	20 - 60	3,4 - 20,7	21 - 33	1,430	0,5246	-0,03143
Forage-transport	Baled hay	$DK=(a+b*T+c*T^2)*E/10$	0,5 bis 10	optional	3,1 - 24,8	28 - 44	1,3539	0,3928	-0,01154
Forage-transport	Maize chopped	$DK=(a+b*T+c*T^2)*E/10$	0,5 bis 5	optional	9,1 - 58,6	61 - 73	0,2250	0,2930	-0,0250