ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS
SBORNÍK MENDELOVY ZEMĚDĚLSKÉ A LESNICKÉ UNIVERZITY V BRNĚ

Ročník LIII 14 Číslo 4, 2005

ENERGY ANALYSIS OF VARIOUS GRASSLAND UTILISATION SYSTEMS

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Received: February 23, 2005

Abstract

RŽONCA, J., MITRUŠKOVÁ, M., POZDÍŠEK, J., POSPIŠIL, R., MIČOVÁ, P., ŠTÝBNAROVÁ, M., SVOZILOVÁ, M.: *Energy analysis of various grassland utilisation systems*. Acta univ. agric. et silvic. Mendel. Brun., 2005, LIII, No. 4, pp. 117-126

In 2003 and 2004 was carried out the energy analysis of the different types of permanent grassland utilization on the Hrubý Jeseník locality. There were estimated values of the particular entrances of additional energy. Energy entrances moved according to the pratotechnologies from 2.17 GJ. ha^{-1} to 22.70 GJ.ha^{-1}. The biggest share on energy entrances had fertilizers. It was 84.93% by the nitrogen fertilisation. The most energy benefit of brutto and nettoenergy was marked by the low intensive utilisation (33.40 GJ.ha^{-1} NEL and 32.40 GJ.ha^{-1} NEV on average). The highest value of energy efficiency (13.23%) was marked by the low intensive utilization of permanent grassland. By using of higher doses of industrial fertilizers has energy efficiency decreased. From view of energy benefit and intensiveness on energy entrances it appears the most available utilisation of permanent grassland with three cuts per year (first cut on May 31st at the latest, every next after 60 days) or two cuts per year (first cut on July 15th, next cuts after 90 days).

nettoenergy, energy benefit, fertilization, pratotechnology, production of phytomass

Withdrawal from the intensive plant production to sustainable management has fallout mainly on energy management, ecological carrying capacity and economical efficiency of the new technologies. Agriculture as every other productive activity is process of the energetic transformation of raw materials and of the effective change of their attributes. It differs from the other branches of human activities by the eminent transformation of the solar radiation and by its purposeful accumulation to the final production (POSPIŠIL, VILČEK; 2000).

Agriculture is complex system that is able to change inorganic substances on important organic compounds due to solar radiation. Production system is affected by various factors such as weather conditions, nutrition and fertilisation, physical and agrochemical characteristics of the soil or natural characteristics of grown plants. This whole process is very complicated and it is practicable due to additional energy forms. Basic problem of the energetic balances in plant production is influence extent of the production process by the direct and indirect energy contribution and their total efficiency on the formation of biomass or economic valuable product expressed by the yield (KOSTREJ, DANKO; 1996).

Chemical energy transformation in agricultural system must be done by its gradual capping, i.e. by the chemical substances entrance limitation and by the acceleration of their circulation inside the agricultural system after the compensating reactions. In these specifications the system became stable and economically effective, as well, together with accomplishment of the requirements of the landscape area progressive development (POSPIŠIL, VILČEK; 2000). KU-

DRNA, ŠINDELÁŘOVÁ (2002) had a try at quantitative evaluation of the closed agriculture system.

There are various points of view at energy balance of grown plants. Most of studies about energy balance is engaged in plants grown on the arable land. It is evaluated fertilizer's effectiveness, efficiency of pesticides and various ways of soil tilling or energetic influence of preceding crops, varieties and various agro-ecological conditions. KOVÁČ (1998), RISOUD, BOCHU (2002), POSPIŠIL (2002), DZIENIA, WERESZCZAKA (2002), RŽONCA, POSPIŠIL (2003) and KOTOROVÁ et al. (2004).

The aim of this study was to analyse and to quantify energy-material's entrances and outputs in production process of permanent grassland on the basis of various methods of its utilization and fertilization and subsequently to carry out balance from the viewpoint of additional energy sources for their optimal level assessment.

MATERIALS AND METHODS

We have carried out the observation in 2003–2004 on VÚCHS Rapotín holdings. The locality is situated in 390–402 m above sea level and it comes under the geomorphologic division Hrubý Jeseník. Geomorphologic subgrade is deeper diluvium of mica schist. The soil is sandy-loam, type cambisol (horizons Ad-Bv-B/C-C). From July to October was average temperature 14.9 °C and total rainfall 420 mm. The precipitations and the temperatures for years 2003–2004 are in table I.

I: *Climatic factors for estimated period*

Year		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
2003	Precipitation [mm]	74.6	18.7	30.9	25.8	80.8	32.1	59.8	25.9	23.7	70.2	24.8	76.3
	Temperature [°C]	–6.0	–14.3	–3.8	6.7	15.5	18.4	18.3	19.2	12.2	5.1	5.2	–4.77
2004	Precipitation [mm]	96.9	31.8	11.9	34.3	20.9	65.4	51.5	59.3	41.0	49.8	114.1	40.9
	Temperature [°C]	–9.7	–1.4	2.2	8.93	11.6	15.4	16.93	17.5	12.1	9.4	3.43	1.1

On the permanent grassland are dominant these species:

1. Taraxacum sect. Ruderalia 27%
2. Dactylis glomerata 7%
3. Lolium perenae 5%
4. Poa pratensis 27%
5. Trifolium repens 13%
6. Rest 21%.

Intensity of utilization:

1. Extensive – 2 cuts per year (1st cut on June 30th at the latest, 2nd cut after 90 days)
2. Low intensive – 2 cuts per year (1st cut on June 15th at the latest, 2nd cut after 90 days)
3. Medium intensive – 3 cuts per year (1st cut on May 31st at the latest, every next after 60 days)
4. Intensive – 4 cuts per year (1st cut on May 15th at the latest, every next after 45 days)

Nutrition and fertilization:

A – no fertilization
B – P:K 30:60 kg.ha^{-1}
C – N:P:K 90:30:60 kg.ha^{-1}
D – N:P:K 180:30:60 kg.ha^{-1}.

It was used ammonium nitrate with pulverized limestone as nitrogen fertilizer, superphosphate as phosphorus fertilizer and potassium chloride as potassium fertilizer.

For the phytomass bruttoenergy evaluation it was used energy equivalent 17.64 GJ.t^{-1} of dry matter. The value of the dry matter in particular cuts was multiplied by the value of the NEL and NEV energy concentration, that was ascertained for the concrete growth stage from the table values in the catalogue of feedstuffs (ZEMAN et al., 1995). By means of these values was calculated the total nettoenergy production.

The energy contribution quantification, the used energy equivalents and methods of the calculations were realized according to the PREININGER's method (1987). For the energy balance evaluation there were included these factors to the additional energy entrances:

1. used industrial and organic fertilisers in pure nutrients NPK [kg.ha^{-1}]
2. energy in machines [GJ.ha^{-1}]
3. fuel consumption [l.ha^{-1}]
4. amount of the human labour [h.ha^{-1}].

On the basis of these energy values it was counted:

- energy benefit: EZ [GJ.ha^{-1}] = energy of phytomass – entrances of the additional energy
- coefficient of the energy efficiency: KeU [%] = energy of phytomass / entrances of the additional energy.

The obtained data were processed by the statistical program Statgraphics 5.0 (analysis of variance, multiple range tests).

RESULTS AND DISCUSSION

Table II shows the values of the brutto and netto energy outputs. We have noticed the highest value of energy production by the low intensive (2.) and medium intensive (3.) grassland utilization. The lowest energy production was noticed by the intensive utilization (4.). Phytomass and energy production had increased by the fertilization.

II: *Energy production (average of 2003–2004)*

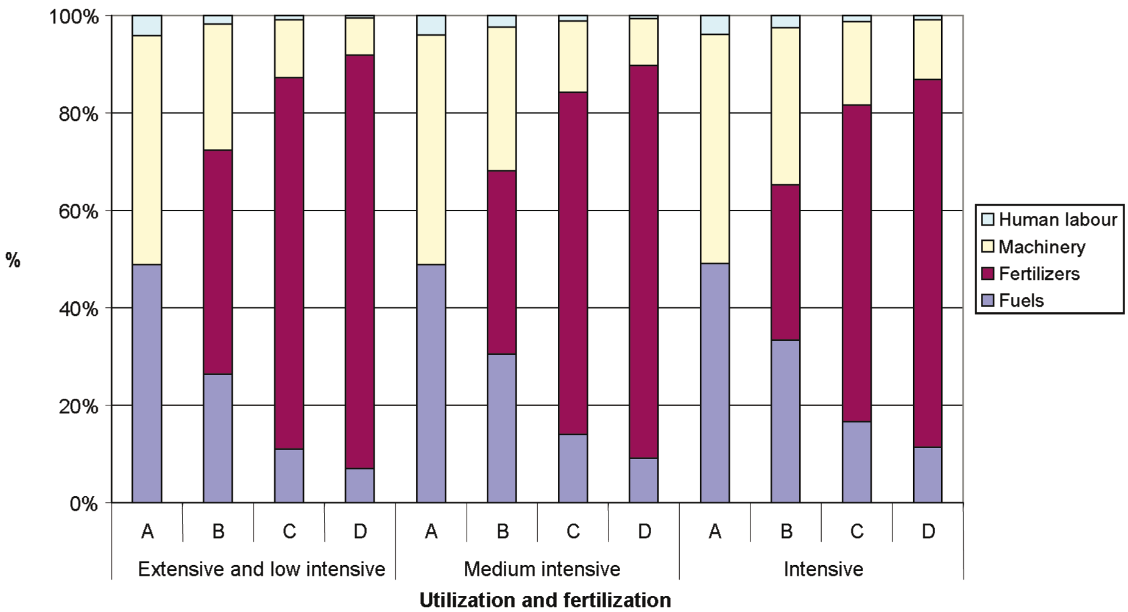
Utilization	*Fertilization*	*Phytomass [t.ha^{-1}]*	*Bruttoenegy [GJ.ha^{-1}]*	*NEL [GJ.ha^{-1}]*	*NEV [GJ.ha^{-1}]*
1. Extensive	A	5.72	100.95	32.97	32.18
	B	5.70	100.45	32.74	31.94
	C	7.41	130.66	42.60	41.57
	D	8.08	142.52	46.19	45.02
	x	**6.73**	**118.64**	**38.62**	**37.68**
2. Low intensive	A	6.05	106.79	35.25	34.48
	B	6.71	118.40	39.00	38.14
	C	8.00	141.08	46.17	45.09
	D	9.24	163.02	53.19	51.91
	x	**7.50**	**132.32**	**43.40**	**42.41**
3. Medium intensive	A	6.41	113.09	33.87	32.28
	B	6.98	123.10	36.86	35.14
	C	8.25	145.55	43.57	41.54
	D	8.18	144.23	43.17	41.16
	x	**7.45**	**131.49**	**39.37**	**37.53**
4. Intensive	A	5.72	100.95	30.24	28.82
	B	6.03	106.42	31.87	30.38
	C	7.35	129.65	38.81	37.00
	D	7.59	133.88	40.07	38.20
	x	**6.67**	**117.72**	**35.25**	**33.60**

In table III there are mentioned the energy entrances according to the particular types of utilisation and fertilisation of the permanent grasslands. Contribution of additional energy moved from 2.17 GJ. ha^{-1} to 22.70 GJ.ha^{-1}. Similar values were found out also by MAJERNÍK, ZMETÁKOVÁ and PROKSOVÁ (2002) study of the permanent grassland. The most demanding on energy entrances was the intensive grassland utilization (x = 12.26 GJ.ha^{-1}), less demanding was the medium intensive (x = 11.08 GJ.ha^{-1})

and the least demanding was the low intensive and the extensive (x = 10.00 GJ.ha^{-1}) grassland utilization. Energy contributions increased along with the fertilization intensity. Graph I shows percentage of the additional energy contributions for the particular components. The values for fossil fuels energy entrances moved on average from 16.52% (by the medium intensive utilisation) to 19.49% (by the intensive utilisation). Fertilisers partook the most in the energy contribution. Their share achieved up to 84.93% (1.D) by the intensive nitrogen fertilisation (dose of 180 kg N.ha^{-1}). Values for the human labour moved on average from 1.55% (utilization 4.) to 1.00% (utilisation 1. and 2.).

III: *Share of particular components on energy contribution [GJ.ha^{-1}]*

Utilization	*Fertilization*	*Fuels*	*Human labour*	*Fertilisers*	*Machinery*	*Total*
Extensive and low intensive	A	1.06	0.09	0.00	1.02	2.17
	B	1.30	0.09	2.27	1.27	4.94
	C	1.41	0.11	9.69	1.52	12.73
	D	1.41	0.11	17.12	1.52	20.16
	x	**1.30**	**0.10**	**7.27**	**1.33**	**10.00**
Medium intensive	A	1.59	0.13	0.00	1.53	3.25
	B	1.84	0.14	2.27	1.78	6.02
	C	1.94	0.15	9.69	2.03	13.82
	D	1.94	0.15	17.12	2.03	21.24
	x	**1.83**	**0.14**	**7.27**	**1.84**	**11.08**
Intensive	A	2.13	0.17	0.00	2.04	4.34
	B	2.37	0.18	2.27	2.29	7.10
	C	2.47	0.19	9.69	2.54	14.90
	D	2.58	0.21	17.12	2.79	22.70
	x	**2.39**	**0.19**	**7.27**	**2.42**	**12.26**



1: *Share of particular components on energy contribution in %*

On the basis of these markers we have counted the energy balance. Value of the energy benefit and coefficients of the energy efficiency are shown in table IV.

The most important factor for the energy balance is ratio: agricultural yield energy entrance / entrance of the additional energy to production process. Coefficients of energy efficiency (counted from the BE) moved from 5.9 (4.D) to 49.21 (2.A). The energy effectiveness has decreased by using of the higher doses of the industrial fertilisers.

IV: *Markers of the energy balance (average of 2003–2004)*

Utilization	*Fertilization*	*Energy benefit [GJ.ha⁻¹]*			*Coefficient of energy efficiency [%]*		
		BE	NEL	NEV	BE	NEL	NEV
1. Extensive	A	98.78	31.65	30.80	46.52	15.19	14.83
	B	95.51	28.09	27.80	20.33	6.63	6.47
	C	117.93	29.05	29.87	10.26	3.35	3.27
	D	122.36	29.90	26.03	7.07	2.29	2.23
	x	**108.64**	**28.62**	**27.68**	**11.86**	**3.86**	**3.77**
2. Low intensive	A	104.62	33.17	33.08	49.21	16.24	15.89
	B	113.46	31.78	34.06	23.97	7.89	7.72
	C	128.35	33.20	33.44	11.08	3.63	3.54
	D	142.86	37.95	33.03	8.09	2.64	2.57
	x	**122.32**	**33.40**	**32.40**	**13.23**	**4.34**	**4.24**
3. Medium intensive	A	109.84	32.30	30.62	34.80	10.42	9.93
	B	117.08	29.29	30.84	20.45	6.12	5.84
	C	131.73	27.36	29.75	10.53	3.15	3.01
	D	122.99	24.21	21.93	6.79	2.03	1.94
	x	**120.41**	**28.28**	**26.45**	**11.87**	**3.55**	**3.39**
4. Intensive	A	96.61	23.38	25.90	23.26	6.97	6.64
	B	99.32	24.70	24.77	14.99	4.49	4.28
	C	114.75	23.98	23.91	8.70	2.60	2.48
	D	111.18	16.42	17.37	5.90	1.77	1.68
	x	**105.46**	**22.99**	**21.34**	**9.60**	**2.88**	**2.74**

The highest average value of brutto and netto energy benefit was noticed by the low intensive utilization (x = 122.32 GJ.ha^{-1} BE; eventually 33.40 GJ.ha^{-1} NEL and 32.40 GJ.ha^{-1} NEV). From the viewpoint of bruttoenergy it was noticed the second highest energy benefit by the medium intensive utilisation (120.41 GJ.ha^{-1}) and the third by the extensive utilisation (108.64 GJ.ha^{-1}). When we have expressed energy benefit by NEL and NEV values, sequence of 2nd and 3rd type of utilisation has changed. These differences were not statistically significant.

By the intensive and medium intensive type of grassland utilisation energy benefit (counted by bruttoenergy benefit) increased along with fertilization intensity. This trend did not prove true by the energy benefit expressed by nettoenergy. By the medium intensive and the intensive type of utilisation energy benefit increased up to dose of the nitrogen fertilizer 90 kg.ha^{-1}, but it was lower by dose of 180 kg.ha^{-1}.

Hence we can conclude, that it is available to express energy markers not only by bruttoenergy adjustment but also by nettoenergy, because of the changes of the permanent grassland`s nutrient and energy values during the season.

KOVÁČ (1998) found out by growing of the clover-grass mixtures on the arable land values of energy outputs from 124.40 to 127.52 GJ.ha^{-1} and commensurate with the growing technologies was coefficient of energy efficiency 5.71–6.62. PORVAZ and JANČOVIČ (2001) were engaged in growing of lucerne. They found out energy entrances at the level of 22.27 GJ.ha^{-1}, outputs were 622.18 GJ.ha^{-1} (bruttoenergy of total phytomass) and coefficient of energy efficiency was 28.77. Comparing with our results and with results of MAJERNÍK, ZMETÁKOVÁ, PROKSOVÁ (2002) we can conclude that production of feedstuffs is more energy demanding on the arable land, assuming that nitrogen fertiliser's doses will not be higher than 100 kg. Nitrogen dose of 180 kg.ha^{-1} causes increasing of the energy intensiveness above level of cereals grown on arable land.

Thence it follows, that the most participate in energy entrances and in energy benefit are industrial fertilisers. Machinery have indispensable share on the energy entrances. Its extent of contribution is equal as energy additioned in fuel form. Energy production increased by the fertilization with industrial fertilizers, but coefficient of energy efficiency obviously decreased. MAJERNÍK, ZMETÁKOVÁ, PROKSOVÁ (2002) arrived at the similar conclusion.

Crop and energy markers were effected by growing class, by fertilization and also by utilization of permanent grassland (see table VI–VII).

V: *Analysis of variance by the chosen indexes*

Indicator	*d.f.*	*Utilisation*	*Fertilization*	*Class*	*Residual*
		3	3	1	
Phytomass production	MS	5.3087	38.4429	14.1978	0.827
	F-ratio	6.417^{++}	46.457^{++}	17.161^{++}	
Bruttoenergy	MS	2016.925	11990.384	4417.648	230.280
	F-ratio	8.759^{++}	52.069^{++}	19.184^{++}	
NEL	MS	358.4214	1156.1067	452.5912	23.255
	F-ratio	15.413^{++}	49.715^{++}	19.462^{++}	
NEV	MS	409.9217	1086.9197	418.7980	21.913
	F-ratio	18.706^{++}	49.600^{++}	19.111^{++}	
Energy benefit (bruttoenergy)	MS	2300.5710	4122.6923	4547.3966	227.226
	F-ratio	10.125^{++}	18.144^{++}	20.013^{++}	

++ $\alpha = 0.01$

VI: *Multiple LSD-test for energy outputs comparing (α = 0.05)*

Energy output	*Observed factor*		*Average*	*Homogenous group*		
Bruttoenergy	Fertilization	A	105.44	x		
		B	112.09	x		
		C	136.74		x	
		D	145.91			x
	Utilization	4.	117.72	x		
		1.	118.64	x		
		3.	131.49		x	
		2.	132.32		x	
NEL	Fertilization	A	33.08	x		
		B	35.14	x		
		C	42.79		x	
		D	45.65		x	
	Utilization	4.	35.25	x		
		1.	38.62		x	
		3.	39.37		x	
		2.	43.40			x
NEV	Fertilization	A	31.94	x		
		B	33.90	x		
		C	41.31		x	
		D	44.13		x	
	Utilization	4.	33.60	x		
		3.	37.53		x	
		1.	37.68		x	
		2.	42.41			x

Homogenous group		
x		not significant differences
x		
x		significant differences
	x	

Data in the tables V and VI for the observed factor fertilization are the means of 2–4 cuts. LSD test confirmed that the nitrogen fertilisation has more of influence on the energy production than the phosphorus or the potassium fertilisation. There were not any significant differences between particular nitrogen doses (N 90 kg and N 180 kg) by NEV and NEL production.

VII: *Multiple LSD-test for comparing of average energy benefit (α = 0.05)*

Energy benefit	*Observed factor*		*Average*	*Homogenous group*		
Bruttoenergy	Fertilization	A	102.46	x		
		B	106.34	x		
		C	123.19		x	
		D	124.50		x	
	Utilization	4.	105.46	x		
		1.	108.64	x		
		3.	120.41		x	
		2.	122.32		x	
NEL	Fertilization	A	24.59	x		
		B	29.21		x	
		C	29.37		x	
		D	30.10		x	
	Utilization	4.	22.99	x		
		1.	28.28		x	
		3.	28.62		x	
		2.	33.40			x
NEV	Fertilization	A	23.01	x		
		B	27.75		x	
		C	28.15		x	
		D	28.96		x	
	Utilization	4.	21.34	x		
		3.	26.45		x	
		1.	27.68		x	
		2.	32.40			x

We have noticed the highest energy benefit by the low intensive (2.) utilization and the lowest was by the intensive grassland utilization (4.). These differences were statistically significant contrary to other types of utilisation. There were not marked any statistically significant differences between the extensive and the medium extensive type of grassland utilization.

By the energy benefit expression by means of bruttoenergy we have noticed statistically significant differences only between groups 4., 1. and 3., 1. That is the reason why it is necessary to express energy outputs mainly for permanent grasslands by means of nettoenergy.

CONCLUSION

On the basis of our results we can conclude:

1. Energy outputs increased in this way: 1. (extensive) = 2. (low intensive) < 3. (medium intensive) < 4. (intensive)
2. From the viewpoint of energy benefit and of intensiveness on energy entrances it appears the most available grassland utilization by 3 cuts per year, respectively by 2 cuts per year (1st cut on June 15th at the latest, 2nd cuts after 90 days)
3. Growing of the feedstuffs on the arable land is more energy intensiveness than by means of permanent grasslands.
4. Using of the nettoenergy units NEL and NEV in energy balance of the plant production gives the new angle of view on energy efficiency of the various pratotechnologies and it is necessary to use them by the present energy evaluation.
5. Decreasing of entrances in form of the additional energy is necessary to search in decrease of fuel consumption and in rational nitrogen nutrition.

SOUHRN

Energetická analýza různých systémů využívání lučních porostů

V podmínkách Hrubého Jeseníku jsme se zabývali energetickou analýzou různých způsobů využívání TTP, v letech 2003–2004. Kvantifikace energetických vkladů, použité energetické ekvivalenty a způsoby výpočtů a vyjádření výstupů energie byly uskutečněné dle metodiky Preiningera (1987). Nettoenergii fytomasy jsme vypočítali prostřednictvím tabulkových údajů NEL a NEV pro luční porost v závislosti na stadiu sběru (ZEMAN et al., 1995). Vypočítali jsme hodnoty jednotlivých vstupů dodatkové energie. Podle jednotlivých pratotechnik se vstupy energie pohybovaly od 2,17 $GJ.ha^{-1}$ do 22,70 $GJ.ha^{-1}$. Největší částí energetických vkladů byla hnojiva, která se na nich, při intenzivním hnojení dusíkatými hnojivy, podílela až do výšky 84,93 %. Nejvyšší průměrný energetický zisk brutto i netto energie jsme zaznamenali u málo intenzivního využívání (průměr 33,40 $GJ.ha^{-1}$ NEL a 32,40 $GJ.ha^{-1}$ NEV). Nejvyšší koeficient energetické účinnosti (13,23 %) jsme zaznamenali u středně intenzivního a málo intenzivního využívání TTP. Používáním vyšších dávek průmyslových hnojiv se energetická efektivnost snižovala. Z hlediska energetického zisku a náročnosti na vstupy energie se ukazuje nejvhodnější využívání trvalých travních porostů třemi sečemi za rok (1. seč od 16. do 31. 5. další každá po 60 dnech), respektive dvě seče za rok (v termínu 1. seč do 15. 6. a 2. po 90 dnech). Pěstitelský ročník, hnojení a i využívání TTP se na úrodě i energetických ukazatelích projevil významně.

nettoenergie, energetický zisk, hnojení, pratotechnika, produkce fytomasy

Příspěvek byl zpracován v rámci řešení projektu NAZV reg. č. QF 3018 za podpory projektu MŠMT ČR 2678846201.

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