Energy balance of chosen crops and their potential to saturate energy consumption in Slovakia

Energetická bilancia vybraných plodín a ich potenciál pre zabezpečenie potreby energie na Slovensku

Katarína HRČKOVÁ[1*], Štefan POLLÁK[2], Norbert BRITAŇÁK[3] and Roman HAŠANA[1]

[1] Plant Production Research Institute, National Agricultural and Food Centre Slovakia, Bratislavská cesta 122, 921 68 Piešťany, Slovakia

[2] Grassland and Mountain Agriculture Research Institute, National Agricultural and Food Centre Slovakia, Mládežnícka 36, 974 21 Banská Bystrica, Slovakia

[3] Grassland and Mountain Agriculture Research Institute, National Agricultural and Food Centre Slovakia, Research Station Poprad SNP 2, 058 01 Poprad, Slovakia

*correspondence: hrckova@vurv.sk

Abstract

The aim of the present work was to assess and compare energy inputs and outputs of various crop managements in 2011–2012. Two main crops on arable land and three permanent grasslands were investigated. Silage maize (*Zea mays* L.) and winter wheat (*Triticum aestivum* L.) were grown on lowland, whilst two semi-natural grasslands and grassland infested by tufted hair-grass (*Deschampsia caespitose* (L.) P. Beauv) were located in mountainous regions of Slovakia. In these crops and grasslands the dry matter yield was measured and subsequently the supplementary energy, energy gain and unifying energy value – tonne of oil equivalent (TOE) – were calculated. Silage maize with 233.37 GJ*ha^{-1} has provided the highest energy gain. In the group of grasslands, grassland infested by tufted hair-grass has offered the highest energy gain (59.77 GJ*ha^{-1}). And this grassland had the lowest requirement on the supplementary energy (3.66 GJ*ha^{-1}), contrary to silage maize with highest one (12.37 GJ*ha^{-1}). The total energy potential of the crop biomasses was confronted with energy consumption in Slovakia. Winter wheat has the biggest energy potential, but it could cover only 19.6% and 11.3% total consumption of electricity or natural gas, respectively. Large area of permanent grasslands and their spatial location make them an important energy reservoir for bioenergy production. But, it is not possible to replace all consumed fossil fuels by bioenergy from these tested renewable energy sources.

Keywords: energy potential, grassland, maize, renewable energy, tonne of oil equivalent, tufted hair-grass, winter wheat

Abstrakt

Cieľom predkladanej štúdie bolo zhodnotiť a porovnať vstupy a výstupy energie pre pestovateľské technológie silážnej kukurice (*Zea mays* L.) a pšenice letnej (*Triticum aestivum* L.) v nížinnej oblasti a troch trvalých trávnych porastov (dva poloprírodné a porast osídlený metlicou trstnatou, *Deschampsia caespitose* (L.) P. Beauv) v horských oblastiach Slovenska počas obdobia 2011-2012. Plodiny boli porovnávané z hľadiska úrod sušiny, dodatkovej energie a energetického zisku prevedením na zjednocujúcu energetickú veličinu - tona ropného ekvivalentu (TOE). Najvyšší energetický zisk bol dosiahnutý pri silážnej kukurici (233.37 GJ*ha^{-1}). V skupine trvalých trávnych porastov dominoval porast osídlený metlicou trstnatou so ziskom energie (59.77 GJ*ha^{-1}). Tento trávny porast vyžadoval na svoju prevádzku veľmi nízky vklad dodatkovej energie (3.66 GJ*ha^{-1}) v porovnaní so silážnou kukuricou (12.37 GJ*ha^{-1}). Celkový potenciál rastlinnej biomasy bol konfrontovaný so spotrebou energie na Slovensku. Najpriaznivejší energetický potenciál poskytla pšenica, ale aj napriek tomu by dokázala pokryť iba 19,6% spotreby elektrickej energie a 11,3% spotreby zemného plynu. Vysoká výmera plôch trvalých trávnych porastov a oblasti kde sa nachádzajú, sú dôvodom, prečo sa pokladajú za významný rezervoár bioenergie. Nie je však možné nahradiť spotrebu fosílnych palív energiou biomasy testovaných plodín.

Kľúčové slová: energetický potenciál, kukurica, metlica trstnatá, obnoviteľná energia, pšenica letná, tona ropného ekvivatentu, trvalý trávny porast

Detailný abstrakt

Cieľom štúdie bolo zhodnotiť a porovnať vstupy a výstupy energie pre pestovateľské technológie dvoch hlavných plodín pestovaných na ornej pôde v nížinných oblastiach – silážnej kukurice a pšenice letnej a trvalých trávnych porastov v horskej oblasti Slovenska. Boli spracované výsledky poľných pokusov z výskumných staníc v lokalitách Borovce, Tajov, Suchý vrch a Liptovská Teplička z rokov 2011-2012. Kukurica, pšenica a trvalý trávny porast s nulovou úrovňou dusíkatého hnojenia boli porovnávané z hľadiska úrod sušiny, dodatkovej energie a energetického zisku prevedením na zjednocujúcu energetickú veličinu - tona ropného ekvivalentu (TOE). Najvyšší energetický zisk bol dosiahnutý pri silážnej kukurici (233.37 GJ*ha^{-1}). V skupine trvalých trávnych porastov dominoval porast osídlený metlicou trstnatou so ziskom energie (59.77 GJ*ha^{-1}). Tento trávny porast vyžadoval na svoju prevádzku veľmi nízky vklad dodatkovej energie v porovnaní so silážnou kukuricou (12.37 GJ*ha^{-1}). Vysoká úroda i špecifické vlastnosti metlice trstnatej z lokality Liptovská Teplička a nízke vstupy dodatkovej energie zabezpečili vyšší energetický zisk napriek najnepriaznivejším pôdno-ekologickým podmienkam zo všetkých skúmaných lokalít trvalých trávnych porastov. Najnižší energetický zisk bol dosiahnutý v prípade trvalého trávneho porastu z podhorských oblastí Tajov a Suchý vrch. Celkový potenciál rastlinnej biomasy bol konfrontovaný so spotrebou energie na Slovensku. Najpriaznivejším energetickým potenciálom disponuje pšenica, ale aj napriek tomu by dokázala pokryť iba 19,6% spotreby elektrickej energie a 11,3% spotreby zemného plynu. Vysoká výmera plôch trvalých trávnych porastov a oblastí kde sa nachádzajú, sú dôvodom, prečo sa pokladajú za významný rezervoár bioenergie. Nie je však možné nahradiť spotrebu fosílnych palív energiou biomasy testovaných plodín.

Introduction

Agricultural inputs are mostly expressed in monetary unit. Financial balance is a question of existence for farmer and this is the reason that economic point of view is fundamental. But it is also possible to express inputs in energy units. Input and output of energy are two the most important factors for determination of energy and ecology effectiveness of agricultural productivity (Rathke and Diepenbrock, 2006). There are various forms of energy which entry into agricultural system. Natural inputs mainly depend on solar energy and its solar constant. Thereafter they are modified by soil and environmental characteristics of site. Additional inputs are characterized by supplementary energy – seeds, pesticides, fertilizers, machinery, human labour and fuels. It is necessary to ensure the consistency amongst them to achieve high effectiveness of crop management, because the genetic potential of crops should be supported by sufficient additional sources of supplementary energy, which they are adapted to (Pospišil and Vilček, 2000).

In general opinion, supplementary energy input is highly specified for crops and sites. Low-input systems in some parts of Africa reach only 1 GJ*ha^{-1}. It is great contrast with Western Europe with amount of 30 GJ*ha^{-1} of supplementary energy (Hülsbergen et al., 2001). Current global trend is moving towards increasing in agrosystem inputs via the usage of heavy machinery and high doses of fertilizers and pesticides. The situation in Slovakia is significantly affected by the economic circumstances of farmers. Official sources talks about 6.92 GJ*ha^{-1} – 35.78 GJ*ha^{-1} of supplementary energy for various crops in different parts of Slovakia (Pospišil and Vilček, 2000). The most relevant energy crops in Slovakia are silage maize, permanent grassland and woody plants. Situation in Belgium is similar - the most utilized are extensive permanent grassland and silage maize (Gerin et al., 2008).

The aim of this study was to assess energy inputs and outputs of various crops and to calculate their energy potential in energy industry.

Materials and methods

The most often cultivated silage maize hybrids (PR39F58, Karacho, Luciana and Graneros), two winter wheat hybrids (Hymack and Hybnos), two winter wheat cultivars (Ignis and Pavlína) and three permanent grasslands were used in study. Field experiments focused on silage maize (*Zea mays* L.) and winter wheat (*Triticum aestivum* L.) were established in 2011–2012 in Research Station Borovce, National Agricultural and Food Centre Slovakia. Experimental site is situated in a maize growing region of Slovakia. The soil is Chernozem degraded on loess, with pH 6.35. Soil is characterised by good content of available potassium, middle content of phosphorus and high content of magnesium. Depth of humus horizon is 0.4 – 0.5 m and humus content ranges for 1.8 to 2.0%. Additional data are shown in Table 1.

Conventional soil tillage cultivation involved autumn ploughing (into depth of 0.2 m), sowing bed preparation and fertilization. Sowing rate was 90 000 maize plants per hectare. Hybrids and cultivars of winter wheat were (the same depth of ploughing, sowing bed preparation and fertilization) sown in sowing rate of 4.5 millions of germinated seeds per hectare. Both field trials were conducted in conditions without irrigation. Phosphorus and potassium were applied before sowing in dose of 45 $kg*ha^{-1}$ and 120 $kg*ha^{-1}$, respectively. Nitrogen fertilization was not applied, to attain connection to unfertilized permanent grasslands in mountain region. Whole aboveground biomass of maize and winter wheat was harvested, oven dried and taken into account for the next energy evaluation.

Table 1. Basic characteristics of experimental sites

Tabuľka 1. Základná charakteristika pokusných lokalít

Characteristic	Borovce	Suchý vrch	Tajov	Liptovská Teplička
Longitude (λ)	17°43′45″ N	19°06′13″ E	19°02′06″ E	20°03′33″ E
Latitude (φ)	48°34′43″ E	48°43′05″ N	48°45′05″ N	48°56′01″ N
Altitude (m)	167	480	748	1400
Precipitation per year (mm) *	595	853	850	950
Precipitation per GP (mm)*	359	441	500	525
Air temperature per year(°C)*	9.2	7.7	6.2	3.5
Air temperature per GP (°C)*	15.5	13.6	12.9	9.5
Agro-climatic region	mostly hot	mildly warm	mildly warm	mostly cold
Growing region	maize	mountain	mountain	mountain
Slope	0	1-7°	1-10°	0-5°
Exposition	–	NE	N-NE	N-NE

*long-term average, data were measured directly in the experimental localities of NPPC, GP – growing period

Experimental site Suchý vrch is situated in mountain area which belongs to region Kremnica Mountains. The soil group and soil type at the research site was Leptic Cambisol and loamy soil, respectively, with pH 6.09. Soil was slightly acidic, with a suitable content of available phosphorus and potassium and very high magnesium content. On the former arable land, after 30 to 40 years of cutting and grazing management a grassland community with dominance of *Trisetum flavescens* has developed. Based on the floristic composition of this species it can be classified into *Arrhenatherion* community and detailed phytocoenologic classification is difficult. Primary production of dry matter was determined as a sum of three haymaking per growing period.

Research area Tajov belongs to municipal boundary Tajov and it is located in the foothills Kremnica Mountains. Soil is defined as Cambisol created on andesite. Soil is loam clay. Agrochemical soil analyses showed following results: C_{OX} 44.60 $g*kg^{-1}$, humus 76.89 $g*kg^{-1}$, N 4.76 $g*kg^{-1}$, P 14.36 $mg*kg^{-1}$, K 122.06 $mg*kg^{-1}$, Mg 150.18 $mg*kg^{-1}$. Soil reaction was extremely acidic (pH 3.5).In term of syntaxonomical classification the grassland belong to community *Cynosurion cristati* R.Tx. 1947 and sub-community *Lolio-Cynosuretum* Jurko1974. There were three cuttings per growing period in Tajov natural grassland.

Experimental site Panská hoľa is located in the cadastre of Liptovská Teplička village. The soil group and soil type at the research site was Leptosol and loam clay, respectively. Agrochemical soil characteristic was following: C_{OX} 53.20 g*kg^{-1}, humus 91.73 g*kg^{-1}, N 5.47 g*kg^{-1}, P 1.71 mg*kg^{-1}, K 147.03 mg*kg^{-1}, Mg 516.73 mg*kg^{-1} Hanzes (2008). Soil reaction was acidic (pH 4.72). Due to selective grazing of sheep herds this previously once a year mowed meadow (*Nardo-Agrostion tenuis* Sillinger 1933) was infested by tufted hair-grass (*Deschampsia caespitosa* (L.) P. Beauv. It has created a monoculture. There was just single cutting per growing period in October.

Meteorological parameters and additional data of individual sites are shown in Table1. Inputs of solar energy, human labour, energy for drying, storage, and biomass transport from the farm to the customers were not taken into account (Hülsbergen et al., 2001). Direct and indirect inputs included energy of fuels, machines, seeds, pesticides, and potassium and phosphorus fertilizers. Gross energy, i.e. brutto energy (BE) was specified according to Petrikovič (2000) and it is defined as a caloric value of produced biomass. Inputs of supplementary energy (DE) were calculated according to Preininger (1987). Based on these data, following energy parameters were determined (Pospišil and Ržonca, 2010) energy gain: BE – DE (GJ*ha^{-1}), energy consumption per 1 ton of final product: DE / dry matter yield (GJ*t^{-1}), energy efficiency ratio: BE / DE. Tonne of oil equivalent (TOE) is generally used for the crop energy valuation. It is used mostly in energy industry and it expresses energy potential of wide range of resources which can be utilized by energy industry. It has more meaningful relevance for perspective implementation of second generation biofuels. From the energy point of view the equation definition is following: 1 TOE = 42.1 GJ = 7.4 barrels = 1270 m^3 of natural gas = 11.63 MW = 2.3 tons of coal. To make the tables more comfortable, unit kTOE was used (1000 TOE =1 kTOE).

Experimental data were assessed by non-parametric Kruskal-Wallis test of ANOVA in Statit Custom QC 5.4.0 software package.

Results

Based on different cropping systems, the need of supplementary energy ranged between 3.66 (tufted hair-grass grassland) and 12.37 GJ*ha^{-1} (maize hybrids) (Table 2). Figure shows proportional distribution of components of supplementary energy. Grubb's test was used to identify any outlier in tested systems and no significant differences among these crops (P = 0.076) were found out. Silage maize provided the highest values of supplementary energy. Maize's important volume (46.3%) of supplementary energy is represented by fuel energy needed for all cultivation operations, which means sowing, application of herbicidal treatment, phosphorus and potassium fertilization and harvest. Efficacy of supplementary energy depended on the selected genotype of maize. On contrary to silage maize, the lowest supplementary energy of haymaking on tufted hair grass grassland consists of machinery and fuel only. And consumption of fuels in grasslands utilization is approximately two-thirds of supplementary energy.

Table 2. Energy parameters of involved agricultural crops in field experiments

Tabuľka 2. Energetické parametre poľnohospodárskych plodín v poľných pokusoch

Crop	Site	EV	DMY	EVal	GE	NG	C	TOE	SE	EG	ER	EC
			$t*ha^{-1}$	$MJ*kg^{-1}$	$GJ*ha^{-1}$	m^3	ME	–	$GJ*ha^{-1}$	$GJ*ha^{-1}$	–	$GJ*t^{-1}$
M	BO	PR39F58	13.33	17.41	232.08	7 040	64.47	5.543	12.37	219.71	18.76	0.93
	BO	Karacho	12.18	17.41	212.05	6 432	58.90	5.065	12.37	199.68	17.14	1.02
	BO	Luciana	14.49	17.41	252.27	7 652	70.08	6.025	12.37	239.90	20.39	0.85
	BO	Graneros	16.46	17.41	286.57	8 693	79.60	6.845	12.37	274.20	23.17	0.75
	Average of maize		14.12	17.41	245.74	7 454	68.26	5.870	12.37	233.37	19.87	1.18
WW	BO	Hymack	12.85	15.60	200.46	6 081	55.68	4.788	11.22	189.24	17.87	0.87
	BO	Hybnos	12.87	15.60	200.77	6 090	55.77	4.795	11.22	189.55	17.89	0.87
	Average of hybrids		12.86	15.60	200.61	6 086	55.73	4.792	11.22	189.40	17.88	0.87
	BO	Ignis	10.46	15.60	163.18	4 950	45.33	3.897	11.22	151.96	14.54	1.07
	BO	Pavlína	11.57	15.60	180.49	5 475	50.14	4.311	11.22	169.27	16.09	0.97
	Average of cultivars		11.02	15.60	171.84	5 213	47.74	4.104	11.22	160.62	15.32	1.02
	Average of w.wheat		11.94	15.60	186.23	5 650	51.73	4.448	11.22	175.01	16.60	0.95
PG	SV	Hay	3.19	13.71	43.75	1 327	12.15	1.045	10.52	33.23	4.16	3.30
	Tajov	Hay	4.00	16.51	66.05	2 004	18.35	1.578	10.52	55.53	6.28	2.63
	Aver.of p.grassland		3.60	15.11	54.90	1 666	15.25	1.312	10.52	44.38	5,22	2.97
	LT.	HTHG	3.60	17.62	63.43	1 924	17.62	1.515	3.66	59.77	17.33	1.02

M – maize, WW – winter wheat, PG – permanent grasslands, BO – Borovce, SV – Suchý Vrch, LT – Liptovská Teplička, EV – energy vector, HTHG – hay of tufted hair-grass, DMY – dry matter yield, EVal – energy value, GE – gross energy, NG – conversion to natural gas, C – conversion to MW, TOE – tonne of oil equivalent , SE – supplementary energy, EG – energy gain, ER – energy ratio, EC – energy consumption per 1 tonne of final product

Energy efficiency ratio must be greater than 1. If this condition is satisfied then one can say any agroecosystem produces more energy than it consumes in process of biomass production. The given condition was fulfilled within all tested agroecosystems. The efficiency ratio values were different in individual systems, but there were not statistical differences among agroecosystems. The highest energy efficiency ratio has achieved in silage maize. According to the plant genotypes, this parameter has varied between 17.14 and 23.17 (Table 2). In mountainous region, similar value was reached in grassland dominated by tufted hair grass. The relatively high value of this index was caused by very low energy input to the system. On the other side, the high energy efficiency ratio of silage maize biomass is primary caused by high dry matter production, consequently, which influenced other energy parameters in energy balance. The lowest variation in energy efficiency coefficient was detected in winter wheat hybrids and cultivars (14.54 – 17.89).

Energy consumption is another energy parameter which was used. It defines the amount of (supplementary) energy inputs to dry matter production. It is strongly depended on conditions of environments. For example, haymaking was the most difficult process in mountainous region of Slovakia. Its supplementary energy is higher than silage maize and winter wheat without inclusion of fertilizers, pesticides and seeds (Figure 1). Due to environmental and climatic conditions grasslands under investigation produced only limited amount of dry matter. Their production was only the quarter of silage maize dry matter yield. Comparing dry matter production of cultivated grasslands and tufted hair-grass one, it is possible and even desirable to produce the same production using the supplementary energy lowered approximately about 65%.

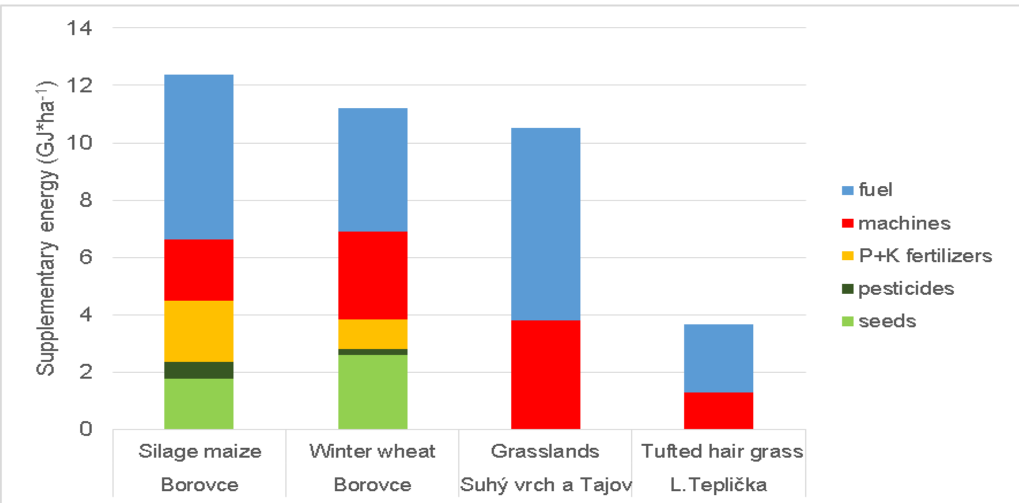

Figure 1. Distribution of supplementary energy into individual items

Obrázok 1. Distribúcia dodatkovej energie do jednotlivých vstupov

Gross energy of crops (Table 2) primary depends on dry matter amount of produced biomass. Based on non-parametric Kruskal-Wallis test of ANOVA the statistically significant differences between hybrids of silage maize and group of grasslands (χ^2 = 7.64, Df = 2, P = 0.022) were identified. From plant material tested, the silage maize hybrid Graneros produced the highest amount of gross energy and energy efficiency ratio; while its energy consumption per ton of dry matter was the lowest. On average of hybrids and cultivars, winter wheat aboveground biomass was lesser than silage maize (Table 2). But, importantly, all parameters of winter wheat hybrids were better than these for cultivars. There were no significant differences between them. Overall, crops cultivated on arable land produced more dry matter (χ^2 = 6.00, Df = 1, P = 0.014); had higher energy efficiency ratio (P = 0.066); but, they had lower energy consumption (χ^2 = 4.59, Df = 1, P = 0.032) than grasslands.

In Slovakia 2.219 million tonnes of silage maize was harvested in 2011 (Slovak Statistical Office, 2012a) and it represents energy potential of 228.23 kTOE (Table 3). Winter wheat produced 1.631 million tonnes of above-ground biomass with energy potential of 580.38 kTOE. Based on dry matter production, permanent grasslands were not as productive as these two crops on arable land but larger area ensured the higher energy potential (383.97 kTOE) than silage maize. Total energy potential of crops included in this study was 1,192.58 kTOE.

Table 3. Dry matter yield, area and energy potential of energy vectors in 2011

Tabuľka 3. Úroda sušiny, zberová plocha a energetický potenciál plodín v roku 2011

Energy vector	Harvested area ha	DM Yield t	Productivity $t*ha^{-1}$	Caloric value $MJ*kg^{-1}$	Conversion to nat.gas 1000 m^3	Conversion to energy GW	kTOE -
Silage maize	77269	2219065	28.72	4.33	289854.13	2654.33	228.23
Winter wheat	362846	1631112	4.50	14.98	737084.40	6749.84	580.38
P.grasslands	507844	1013575	2.00	15.95	487642.84	4465.58	383.97
Total amount	947959	4863752	–	–	1514581.4	13869.75	1192.6

According to Slovak Statistical Office (2013) in 2012 the area of silage maize and winter wheat increased (Table 4). In spite of lower silage maize productivity its total energy potential was higher. Due to the lower dry matter yields, winter wheat and permanent grasslands diminished their potential in compare with 2011. Total energy potential of tested crops was lower and it can be explained by unfavourable climatic conditions over growing period 2012.

Table 4. Dry matter yield, area and energy potential of energy vectors in 2012

Tabuľka 4. Úroda sušiny, zberová plocha a energetický potenciál plodín v roku 2012

Energy vector	Harvested area ha	DM Yield t	Productivity $t*ha^{-1}$	Caloric value $MJ*kg^{-1}$	Conversion to nat. gas 1000 m^3	Conversion to energy GW	kTOE -
Silage maize	85051	2276321	26.76	4.33	297332.9	2722.82	234.12
Winter wheat	388147	1275302	3.29	14.98	576297.1	5277.43	453.78
P.grasslands	507068	934775	1.84	15.95	449731.2	4118.40	354.12
Total amount	980266	4486398	–	–	1323361.2	12118.65	1042.02

According to data published by Slovak Statistical Office (2012b), the electric power consumption reached 28.8 TW and it represents 2,476.38 kTOE, and natural gas consumption was 5.3 billion Nm^3 (4,173.22 kTOE). Further comparison of electric power and natural gas consumption (Slovak Statistical Office, 2010 and 2011), and hypothetical potential of crops included in this study are given in Table 5. For better description of situation in Slovakia, the year 2010 is presented.

Table 5. Consumption of electric energy and natural gas versus energy potential of agricultural crops in Slovakia in 2010–2012

Tabuľka 5. Spotreba elektrickej energie a zemného plynu a celkový energetický potenciál plodín na Slovensku v rokoch 2010-2012

Energy consumption	2010	2011	2012
Electric energy (GW)	28761	28862	28800
Electric energy (kTOE)	2473.001	2481.685	2476.354
Natural gas (mld.Nm^3)	5.7	5.4	5.3
Natural gas (kTOE)	4488.189	4251.969	4173.228
Silage maize (kTOE)	176.330	228.230	234.120
Winter wheat (kTOE)	421.748	580.381	453.780
Permanent grasslands (kTOE)	384.380	383.970	354.120

Utilisation of total biomass of chosen crops like a replacement for conventional energy sources is hypothetical for the purpose of this study. It could help to understand the problem of current energy consumption of human society and the possibilities of its substitution. If the finalization of whole silage maize biomass to animal husbandry was eliminated and its total energy potential was redirected into the energy sector then a demand for electric power in Slovakia would be guaranteed only 9.45% under conditions of year 2012 (Table 6).

Table 6. Replacement of natural gas and electric energy by agricultural crops (%)

Tabuľka 6. Náhrada energie zemného plynu a elektriny energiou poľnohospodárskych plodín (%)

Energy vector	Energy sector	2010	2011	2012
Silage maize	electricity	7.13	9.20	9.45
	natural gas	3.93	5.37	5.61
Winter wheat	electricity	17.05	23.39	18.32
	natural gas	9.40	13.65	10.87
P. grasslands	electricity	15.54	15.47	14.30
	natural gas	8.56	9.03	8.49

In case of natural gas replacement, the demand would be ensured as low as 5.61%. Based on experimental results, winter wheat appears to be the most favourable energy resource. It could replace up to 18.32% of electricity power consumption or 10.87% of natural gas. Permanent grasslands are also effective energy resource.

They can ensure 14.30% of electricity power demand or 8.49% of natural gas. Detailed information and recent trend is shown in Table 6. Overall, all of these crops together could cover 42.08% of electricity or 23.22% of natural gas consumption in conditions of Slovakia in 2012.

Discussion

Mechanization (as well as the fuels) and fertilizers are the main components which form the supplementary energy. In the presented article, the permanent grasslands were not fertilized by any mineral fertilizers. Consequently, it reduced supplementary energy inputs. In this situation, silage maize and winter wheat were cultivated at the lowest possible level from the point of view of the inputs into agrosystem. Silage maize is crop providing a high amount of energy in plant biomass at low energy inputs (Boehmel et al., 2008). But in the long-term period it is neither suitable, nor sustainable (Hill et al., 2006). Smyth et al. (2009) published a value 20.6 GJ*ha^{-1} of total energy consumption in the agriculture of Ireland and Britain. Experimental data from Slovakia, with absence of nitrogen fertilizer, are at level of 17.8%, 51.1%, 54.5% and 60.0% of Smyth´s value for *Deschampsia caespitosa* grassland, semi-natural grasslands, winter wheat and silage maize, respectively. As indicated the work by Boehmel et al. (2008) there is a significant change in supplementary energy components, when application of nitrogen fertilizer is included. In these cases, it highlighted nitrogen supplementary energy proportion. Winter wheat crop management needed supplementary energy as much as 11.22 GJ*ha^{-1}. There are many studies which are focused on winter wheat energy balance. In an Iranian study Soltani et al. (2013) published 12.98 GJ*ha^{-1}. It corresponds with the findings of this study. In comparison with Slovak values, however, the energy gain and energy efficiency ratio in Iran study is lower by 40.7 GJ*ha^{-1} – 78.3 GJ*ha^{-1} and 50%, respectively. Field experiment of Tabatabaeefar et al. (2009) was focused on energy balance of five different tillage technologies in winter wheat. His conventional variant is comparable to winter wheat growing technology in Slovakia and its energy input was 18.71 GJ*ha^{-1} which is higher about one third. Energy gain was significantly lower via lower dry matter productivity of winter wheat. Except for nitrogen fertilizers and their application, irrigation is one of the most demanded agricultural processes (Ziaei et al., 2015). It can increase value of energy input into agrosystem about 36 GJ*ha^{-1} (Ghorbani et al., 2011).

In Germany, on average of three varieties, Boehmel et al. (2008) reported 300 GJ*ha^{-1} of gross energy by (energy) maize. This amount of gross energy was grown with no nitrogen fertilization. They have tested seven plant and crop species as follow: *Brassica napus oleifera*, *Miscanthus* × *giganteus*, *Salix schwerinii* × *viminalis*, *Panicum virgatum*, *Triticum aestivum*, *Triticale* × *Triticosecale* and *Zea mays*. Silage maize grown in Slovak conditions produced, on average of four hybrids, 245.74 GJ*ha^{-1} of gross energy, only. Differences were due to environmental conditions, for example. But, the common feature of the two experiments is the highest amount of gross energy is always produced by maize. But, on marginal land in the midwest of US, Gelfand et al. (2013) found that successional old field (+ nitrogen) outperformed maize (63 GJ*ha^{-1}*year^{-1} vs. 62 GJ*ha^{-1}*year^{-1} for successional old field and maize, respectively). But, they removed all grain and straw to bioethanol production.

Smyth et al. (2009) compared the growing conditions in Ireland and other northern European countries. They published a gross energy 122.4 $GJ*ha^{-1}*year^{-1}$ for grasslands harvested twice over growing season and processed to silage with finalization to biomethane. In China, Zhou et al. (2009) presented biomass productivity of grasslands on degraded soils generally at 90 $GJ*ha^{-1}*year^{-1}$. These results document the energy output of permanent grasslands, as low-input high-diversity (LIHD) on damaged or degraded soil, is comparable to bioethanol energy gain produced by conventional grain maize on arable soil. Zhou et al. (2009) also found LIHD biofuel is more economical in comparison with traditional biofuels (e.g., maize bioethanol or soybean biodiesel). Hill et al. (2006) and Tilman et al. (2006) reached the same conclusion, too. They compared biomass ethanol, biomass electricity, and biomass synfuel versus maize bioethanol and soybean biodiesel. Moreover, Tilman et al. (2006) published higher bioenergy gain from LIHD grasslands in comparison to monoculture of plant grassland species about 238% per decade. Furthermore, biofuels derived from LIHD grasslands have negative carbon balance, because CO_2 sequestration by ecosystem (4.4 $t*ha^{-1}*year^{-1}$ of CO_2 in soil and plant roots) is higher than CO_2 production from fossil fuels during biofuel processing (0.32 $t*ha^{-1}*year^{-1}$). Additionally, on marginal land, Gelfand et al. (2013) found that successional old field (whether fertilized or with small amount of N addition) has greater potential to mitigate greenhouse gases than maize on arable land or poplar plantation. Uellendahl et al. (2008) expressed the idea that perennial crops cultivation for energy purposes are more suitable in comparison to annual crops, because they require less energy, fertilizer and pesticides and on the other side their negative environmental impact is lower.

Biofuels based on plant production are confronting with ethics and environment (e.g. Slade et al., 2014, Tilman et al., 2009) and with economics and sustainability science (e.g. Burger et al., 2012). Relationships among global demand for the food (and feed), biofuel (or bioenergy) and environmental conservation was named by Tilman et al. (2009) as the food, energy and environment trilemma. The same Slade et al. (2014) stated that biomass potential can be broadly divided into those that test the boundaries of what might be physically possible, and those that explore the boundaries of what might be socially acceptable or environmentally responsible. As it was shown above, three major crops are not able to saturate energy consumption (expressed either electricity or natural gas) in Slovakia. From the point of view of crop production finalization, the bioenergy production and subsidies becomes important competitor to animal husbandry. Food production from local sources is getting under the pressure of industry sectors, and so power engineering disrupts the continuity of primary agricultural production. Agriculture must necessarily to set some priorities in the land utilization. Soil is both important and valuable natural resource. As well, it is still natural and cultural heritage of the society and simultaneously helps to define us as a nation. Form of its appropriate utilization is a fundamental and essential base for the survival of each civilization. Harmonization of biofuel production from agricultural renewable sources and food production becomes serious problem and it will be necessary to find a reasonable sustainable compromise in the near future.

Conclusion

The most stable energy was provided by winter wheat. On arable land hybrid Graneros of silage maize was presented by the highest amount of energy gain. In mountainous area it was achieved from grassland infested by tufted hair grass. Its energy efficiency is comparable with silage maize and it is higher than both cultivars of winter wheat. Supplementary energy calculated to 1 t of production of tufted hair grass is the same as hybrid Karacho of silage maize (1.02 $GJ*ha^{-1}$). But, other grasslands are needed threefold more supplementary energy per 1 t of dry matter. Theoretically, all crops under investigation are able to meet the consumption 42.08% of electricity and 23.22% natural gas, only.

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