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Energy balance in the production of mountain coffee ☆

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ABSTRACT

Coffee culture is highly relevant in Brazilian agriculture in socioeconomic terms. The energy balance of production systems results from the subtraction of the consumed energy (MJ ha^{-1}) from the produced energy (MJ ha^{-1}), in any culture or system. Produced energy is understood as the transformation resulting from the production of grains or fruits, or dry matter, into energy. Consumed energy or cultural energy (MJ ha^{-1}) is understood as the sum of the energy coefficients related to the fertilizers, seeds, fungicides, herbicides, insecticides, incident solar energy during the cycle and operations related to sowing, fertilization, application of products and manual harvesting. Post-harvest is considered to be the sum of the energy coefficients spent in the pre-processing and processing operations used in each treatment. The present work aimed at evaluating the energy balance in a mountain coffee production system with emphasis on production, harvest and post-harvest. It was concluded that plants and their individual components take little advantage from the amount of energy aggregated in the energy balance (less than 0.3%).

Contents

1. Introduction

According to Conab [7], the Brazilian production of green coffee Arabica in the 2013 harvest was 38.28 million bags of 60 kilos.

Consumption of energy in a system of production is one of the most worrying things in agricultural activity. Accordingly, the calculation of the energy balance is one of the most important tools when you want to assess the sustainability of agroecosystems.

In terms of energy, an agricultural production system can be interpreted as a converter of solar energy into food energy, with the intervention of water, carbon dioxide and semi-manufactured products, such as fuels, fertilizers, pesticides and seeds, among others [9].

The energy balance of production systems results from subtracting the consumed energy (MJ ha^{-1}) from the produced energy (MJ ha^{-1}), in any culture or system. Produced energy is regarded as the transformation resulting from the production of grains or fruits, or dry matter into energy. The consumed energy, or cultural energy

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($MJ\ ha^{-1}$), corresponds to the sum of the plots related to fertilizers, seeds, fungicides, herbicides, insecticides, incident solar energy during the cycle and the operations related to sowing, fertilization, application of products and harvest. Post-harvest energy is considered to be the sum of the energy coefficients spent in the pre-processing and processing operations used in each treatment.

The energy value of tractors, trucks and implements, according to Doering et al. [8], is calculated according their weight, multiplied by the energy value of the material used in their making, with the addition of 858 $MJ\ kgf^{-1}$ (20.5 $Mcal\ kgf^{-1}$) for tires and 5% of the total energy for repairs and maintenance.

According to the BEN [3], Balanço Energético Nacional (National Energy Balance), the calorific Power of the fuels used for gasoline is 10.400 $kcal\ L^{-1}$ and for diesel oil is 10.100 $kcal\ L^{-1}$.

Pimentel and Hall [17] used the values of 271.713, 363.805 and 418.223 $kJ\ kg^{-1}$ (64.910, 86.910 and 99.910 $kcal\ kg^{-1}$) for fungicides, insecticides and herbicides, respectively.

Sartori and Basta [18] and Serra et al. [19] adopted the energy indicators from the American economy, which are: for nitrogen (N), 58.081 $kJ\ kg^{-1}$ (13.875 $kcal\ kg^{-1}$); for phosphorus (P_2O_5), 6.969,6 $kJ\ kg^{-1}$ (1.665 $kcal\ kg^{-1}$); for potassium (K_2O), 4.646,5 $kJ\ kg^{-1}$ (1.110 $kcal\ kg^{-1}$) and for limestone, 167,4 $kJ\ kg^{-1}$ (40 $kcal\ kg^{-1}$). In the fertilization with lime, Pimentel et al. [16] reported the value of 1.318,6 $kJ\ kg^{-1}$ (315 $kcal\ kg^{-1}$).

To calculate the photosynthetically active radiation (PAR), it is necessary to consider that plants grow because of the radiant energy (light), photosynthesis process (visible range of radiation between 0.4–0.7 μm.) and the capacity to absorb light by the canopy.

The present work aimed at evaluating the energy balance in a mountain coffee production system. The specific goal was to evaluate: (a) the energy balance in the production stage, (b) the energy balance in the harvest stage and, (c) the energy balance in the post-harvest stage.

2. Material and methods

The experiment was carried out in an agricultural property, located at 20° 52′ latitude south, 43° 10′ longitude west and at 702 m average altitude. The climate is tropical of average altitude [13].

Inside the cultivated area of 60 ha, an experimental area of 14,25 ha was randomly selected and divided into four plots. The species cultivated was Coffea arabica, cultivar Catuaí-Vermelho, lineage MG-44, at initial age of 2.5 years, planted with the spacing of 2.5 m between lines and 0.8 m between plants. Table 1 presents the characteristics of the crop.

All the agronomical operations necessary to the coffee productive process and the different treatments for the fertilization of the plots selected were considered, according to the technical recommendations of the Empresa de Pesquisa Agropecuária do Estado de Minas Gerais (EPAMIG). The needs of phosphorus and potassium were calculated and recommended according to the remaining content of the respective soil elements, content of clay and the productivity expected in the plots evaluated.

Potassium was provided in three applications during each phenological year. The needs of nitrogen were calculated according to the remaining content of nitrogen found by the results of the leaf analyses and by the productivity expected in the period evaluated. The calculations to determine of the needs of liming and gypsum

Table 1
Characteristics of the crop and harvest procedures.

Item	Plots					
	1	2	3	4	5–13	14
Spacing (m)	2.5 × 0.8					
Number of plants	17.761	20.094	19.734	13.650	203.750	25.000
Area (ha)	3.55	4.02	3.95	2.73	40.75	5.00
Harvest in cloth	Semi-selective	Semi-selective	Semi-selective	Semi-selective	Harvesting	

Note: the population of plants, in each plot, was achieved with the collection and counting of one leaf of each plant, in the respective plots.

Table 2
Characterization of the lots of coffee, in the phenological years of 2003/2004 and 2004/2005.

Plots	Area (ha)	Number of plants	Productivity (bags ha^{-1})	
			2003/2004	2004/2005
01	3.55	17.761	29.4	36.6
02	4.02	20.094	34.4	41.3
03	3.95	19.734	30.1	39.2
04	2.73	13.650	23.2	34.2

Table 3
Energy values of machines and implements used in the production systems of mountain coffee.

Machines and implements	Manufacturer/model	Mass (kg)	Energy	
			10^3 ($MJ\ t^{-1}$)	10^3 (MJ)
Tractor Number 1	Massey Ferguson—Mod. 275	3.759	[b]93.05	349.74
Tractor Number 2	New Holand—Mod. TL75E	3.500	[b]93.05	325.75
Truck	Mercedes Benz—Mod. 710P	5.300	[c]64.67	342.80
Sprayer[a]	Jacto—Mod. 2000	1.650	[b]45.21	74.64
Cart Number 1	Agric. Machinery—3.5 × 2.0 × 0.6	0.830	–	–
Cart Number 2	Agric. Machinery—4.0 × 2.0 × 0.6	0.800	–	–

Source
[a] system with ten sprinklers and a 2.000 L tank.
[b] Pimentel et al. [16]
[c] Doering et al. [8].

Table 4
Energy values inherent to inputs used in mountain coffee production systems.

Inputs	Embodied energy ($MJ\ kg^{-1}$)			Average
	Pimentel	Stout	Doering	($MJ\ kg^{-1}$)
Nitrogen (NH_2)	61.59	58.66	58.14	59.46
Phosphate (P_2O_5)	12.57	16.32	6.98	11.96
Potassium (K_2O)	6.70	6.31	4.65	5.89
Limestone	–	–	0.17	0.17
Gypsum	–	–	0.18	0.18
Pesticides	306.96	–	–	306.96

Source: Pimentel [17], Stout [20] and Doering et al. [8].