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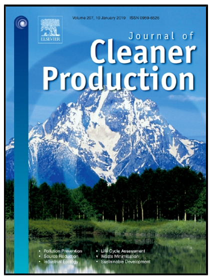

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Implementation of material flow cost accounting (MFCA) in soybean production

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Implementation of material flow cost accounting (MFCA) in soybean production

Abstract

Reducing waste is a significant strategy for reducing the negative environmental effects of agricultural production. Material flow cost accounting (MFCA) is an environmental management tool that can assist farmers to better understand the financial and environmental consequences of the use of materials and energy and provide opportunities for achieving financial and environmental sustainability of agricultural activities by providing solutions. The objective of MFCA for soybean production is to quantify and identify agricultural inputs/energy waste to improve management of residue, waste and energy at different stages of crop production. Analysis of the economic and environmental performance of soybean production was performed using an MFCA for the first time. Current economic and cost analysis using MFCA was compared and a new method was used for incorporating material waste into classic energy and cost analysis. The results shows that the total energy consumption and production cost for 2701 kg of soybean seed were 52064.63 MJ and 1408 USD, respectively. The economic indices of gross production value, gross return and the benefit/cost ratio were evaluated for conventional and MFCA cases. The MFCA results indicate that gross production value, gross return and the benefit/cost ratio were 2103 USD ha^{-1} and 695 USD ha^{-1} and 1.49, respectively. These values for conventional calculations were 1781 and 373 USD ha^{-1} and 1.26, respectively. The gross income in conventional mode showed a difference of 322 USD with MFCA, which is equivalent to the cost of material waste. The benefit/cost ratio was higher by 0.22 because of the calculation of the cost of material waste in MFCA. The efficiency of the use of energy and energy productivity were calculated based on the equivalent input and output energy. The energy use efficiency of soybean production in MFCA-based and conventional calculations were 1.04 and 1.29, respectively. In this case, energy use efficiency decreased by 0.25 compared to conventional calculations. When calculating net energy, the input energy was obtained from the total energy of the negative (with negative sign) and positive products. The net energy in MFCA-based and conventional calculations was 2436.42 and 15460.36 MJ ha^{-1}, respectively. As seen, the net energy in MFCA accounting is 13023.94 MJ ha^{-1} less than conventional mode. Energy and cost analysis based on MFCA was efficient for soybean production. This approach helps to better understand the relationship between economic factors and the environment through a comprehensive energy and cost assessment.

Keywords: Environmental impacts, energy use efficiency, benefit/cost ratio, negative products, cost assessment.

1. Introduction

After the service sector, agriculture is the largest economic sector in Iran and accounts for 21% of Iran's GDP, 75% of the food requirements and 13% of non-oil exports (Statistics, 2014). Iran ranks first to tenth globally in production of 15 field crops and 25 orchard crops.Iran ranks 32nd globally in soybean production at 145,000 tons/year. Ardabil province produces 53% of soybeans in the country (Statistics, 2014; Najafi et al., 2009; Taghizadeh-Alisaraei, 2017a). Because a large portion of Iran's seed oil currently is imported, this is a strategic crop for the country. Agricultural crop waste in Iran reaches 30%, with a value of USD 5 billion. This is six times the world average and equals 25% of the country's oil revenue (Najafi et al., 2009; Taghizadeh-Alisaraei, 2017 b).

Considering the rapid population growth in Iran and the consequent the demand for food, increasing productivity in this sector should be seriously considered. In recent years, as global energy costs rise, efforts have been made to focus on the optimal use of resources in all sectors, including the agricultural sector. Moreover, environmental considerations require consideration about decreasing waste and the use of inputs (in specific energy inputs) (Khan et al., 2009; Pahlavan et al., 2012).

The most significant reason for the irregular growth of energy consumption and other inputs in the agricultural sector has been the distribution of subsidies (Pishgar-Komleh et al., 2012). This practice leads to inefficient use of scarce energy resources, increases government spending and also has negative environmental impacts (Khoshnevisan et al., 2014; Pishgar-Komleh et al., 2012). Cost and energy flow have been adopted as a method of evaluating sustainable agriculture development in recent years (Ozturk, 2017; Wasiak, 2017). It is important to become familiar with energy and cost allocation methods for the various components involved in farming and in the development and management of farms.

Reducing waste or finding uses for waste is a significant strategy for developing environmentally friendly agricultural production. Different strategies have been developed for the use of waste (Taghizadeh-Alisaraei, 2017a b); however, most energy and cost calculation approaches often overlook the hidden costs of waste at different stages of production. Several studies have measured energy efficiency and cost in agriculture (Shamshirband et al., 2015; Buus, 2017; Khoshnevisan et al., 2014; Pishgar-Komleh et al., 2011; Mohammadi, 2010), but all of them have calculated energy efficiency based on the final product and have not considered the waste of materials.

MFCA is an environmental management tool that can assist farmers in better understanding the financial and environmental consequences of efficient use of materials and energy and provide opportunities for achieving financial and environmental sustainability of agricultural activities by providing solutions (Kokubu & Kitada, 2015; Mahmoudi et al., 2017). MFCA provides transparency about the use of materials and energy through the development of a material flow model (ISO, 2011; Schmidt et al., 2013). It compares the costs pertaining to crop production and costs pertaining to the waste of inputs. Most farmers are not aware of the impact of the cost of material waste, as collecting data on cost and material waste from available statistics is not easy. MFCA can provide an opportunity to reduce the use of materials and/or waste of materials, improve the efficiency of the use of materials and energy and reduce environmental degradation (ISO, 2011).

MFCA is a tool of Environmental Management Accounting (EMA) which can be used throughout the supply chain of agricultural products. In MFCA, the flow and type of material are tracked in physical units on the farm and the costs associated with the flow can be evaluated (ISO, 2011). Environmental management systems such as ISO 14001 have been effective in reducing environmental damage, but they do not increase farmer income and, in fact, even incur additional costs to the farmer. MFCA can yield significant outcomes for farmers in the form of increased energy and material efficiency by creating a balance between the environment and the economy. The objective of MFCA in soybean production is to quantify and identify agricultural input/energy waste and provide solutions to better management of residue, waste and energy at different stages of crop production. All inputs, including agricultural products and waste, at the different stages of production are calculated and measured in this method.

MFCA has not been implemented thus far in agriculture despite the need for increasing production efficiency from the economic and energy consumption standpoints. The current study aimed to use this new approach for economic and energy consumption analysis of soybean farms in Ardebil province. The goal is to augment planning and policy-making in order to optimize the production of agricultural products.

2. Methodology

2.1. Questionnaire and survey

This field study was conducted on the soybean farms of Ardabil province in 2014 to 2015. Data was collected using questionnaires containing information on agronomic activities such as land preparation, seed consumption rate, irrigation water, fertilizer use, chemical pesticide use, required human labor and diesel fuel consumption. Additional data on the cultivated area, yield per unit area, crop yield and the number of farmers producing the products were obtained from the Agricultural Jihad Organization of the province. The required number of farms for sampling each product was determined using the following equation (Madow, 1968; Mousavi-Avval et al., 2011):

$$n = \frac{N \times S^2 \times t^2}{(N-1)d^2 + (S^2 \times t^2)} \quad (1)$$

where:

n: the required sample size

N: the number of soybean farmers

S: the standard deviation in the pre-tested data,

t: the t value at 95% confidence limit (1.96)

d: the acceptable error

Accordingly, the number of fields examined for soybean production was estimated to be 44.The primary and final inventory data was obtained in two stages. The primary stage involved a survey of 100 fields based on field size. The fields had varying social, technical and economic features. The next stage was to conduct a deep survey of 44 fields to complete the inventories and validate the primary data, particularly about machinery, irrigation systems, fuel consumption and other agricultural inputs and outputs. These 44 fields are located in the cities of Bilshavar and Parsabad.

The active ingredients in one liter of herbicide and pesticide were also assessed. The medium values for the inputs and outputs were measured as the arithmetic averages of the farmer responses. Agricultural experts from the Agriculture Faculty of the University of Mohaghegh Ardabili, as well as technical literature, were used to validate all the data. Primary information on energy consumed and generated and soybean yield were recorded in SPSS16 and Excel software and the mean of the data was calculated. The mean of the data was expressed using the relevant formulas and the amount of energy per input unit (MJ).

2.2. Implementation steps of MFCA

2.2.1. Goal

MFCA is one of the best accounting tools for environmental management (ISO, 2011). This method, in addition to considering the waste and emissions to the environment, takes into account the actual costs associated with them; thus, it shows the importance of reducing waste and environmental emissions to the producers in tangible terms. A significant advantage of MFCA compared to other tools is that it can assist farmers in estimating material and energy waste during crop production and could help them to improve crop productivity. In this study, the two steps are taken to achieve these objectives were examination of the current soybean production process through assessmentof monetary and material loss and identification of material and energy hotspots to offer of the best practicable betterment options. The goal of this study was to increase the transparency of material flow, energy use patterns and reduce the environmental impact and cost of soybean production (ISO, 2011).

2.2.2. Principles

The products are classified into both positive and negative categories according to ISO 14051 standards. Positive products were those expected to be gained from the process and negative products included the waste and emissions generated during production. MFCA has different stages. It can provide significant information at various stages of the plan-do-check-act (PDCA) continuous improvement cycle. Figure 1 provides an overall outline of MFCA implementation based on the PDCA cycle.

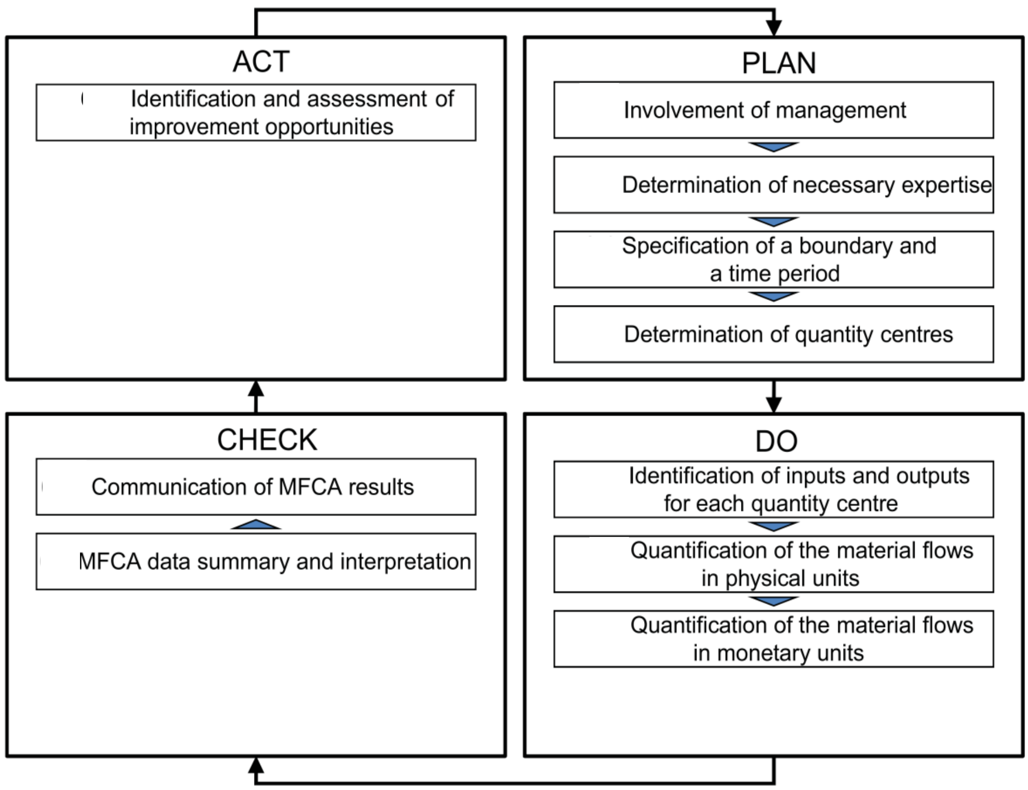

Figure 1: PDCA cycle for MFCA implementation in soybean production (ISO, 2011)

2.2.3. Agricultural Quantity Centres

In the current study, a quantity center (QC) served as a separate part of a process for which inputs (material and energy) and outputs (positive and negative products) are computed in monetary and physical units (ISO, 2011). A QC is the foundation for data gathering in MFCA. For each QC, energy use and material flow are quantified and the energy and material costs are quantified (Figure 2).

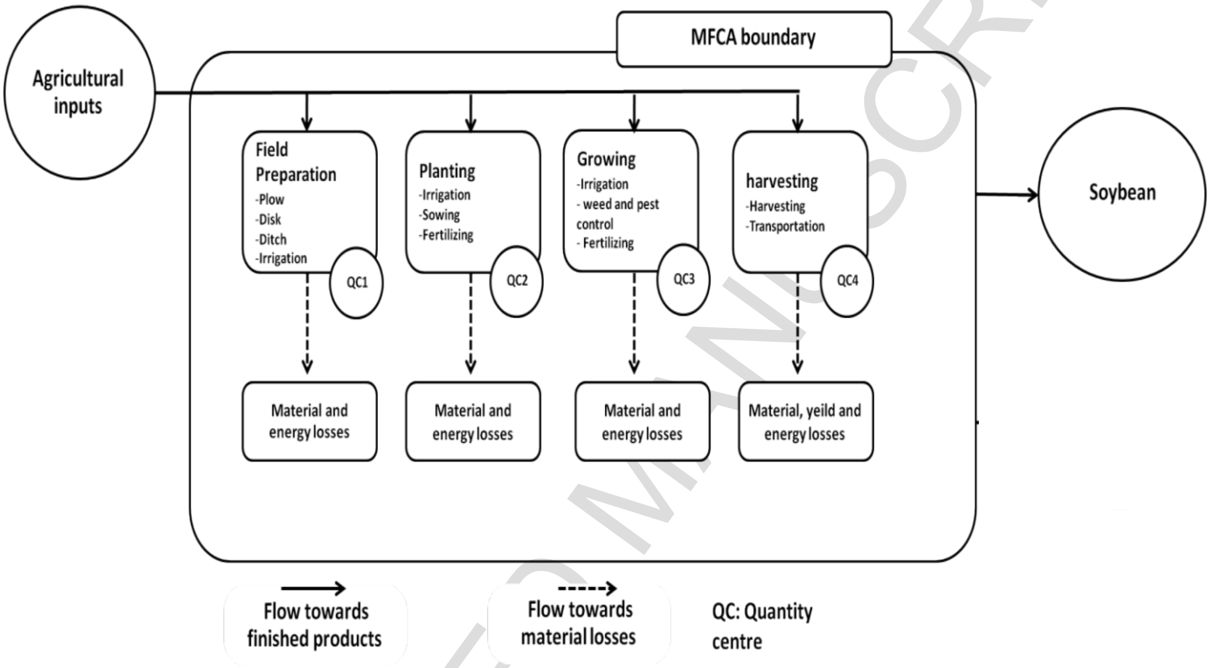

Figure (2): Material flow model for soybean production within the MFCA boundary

Processes such as pre-planting, planting, growing and harvesting were included as QCs in this study. For each QC within the MFCA boundary, the inputs and outputs were identified. The study inputs were agricultural and energy inputs and the outputs were soybeans, emissions and waste. After identifying the inputs and outputs for each QC, the data was combined and evaluated for the entire system under study. For each QC, the input and output values were determined based on their specific physical units. Then all physical units used as inputs and outputs were converted into a single cost unit, such that the cost balance for each QC could be determined. In the cost balance, the total value of the outputs, taking into account any energy change within the QC, should be equal to the total amount of inputs consumed.

2.2.4. Calculation and attributing energy/costs to material losses

Energy or materials that enter a QC finally leave it in the form of energy/material loss or product(s). The total costs associated with input (energy and material) losses was assessed as practicably and accurately as possible and costs then were attributed to energy or material losses (negative products) that generated environmental impacts and costs (and not as positive products) (ISO, 2011). In the present study, for each QC, the cost of materials as inputs and outputs was determined as MJ of energy consumption. Subsequently, the material costs were determined for each input and output flow according to ISO standards by multiplying the physical quantities of the material flow by the unit cost of the material during the relevant time period of the agricultural season.

In this study, for each QC, the input and output costs of the system were determined for each input. In MFCA calculations, the total input, production yield and amount of waste were determined. The cost of materials for each input flow was determined by multiplying the amount of material at its unit cost during the period of 2015-2016. In MFCA computing, the sum of input energy/materials, quantity of positive product and quantity of emission and energy losses are denoted as $M_{pi,wi(in)}$, $M_{pi(in)}$ and $M_{wi(in)}$, respectively (Wan et al., 2015; Mahmoudi et al., 2017).

$$\sum M_{pi.wi(in)} = \sum_{i=1}^{p} M_{pi(in)} + \sum_{i=1}^{w} M_{wi(in)} \tag{2}$$

The energy and costs of different QC is determined by 3.

$$Cost_i^{SP} = Cost_i^{M} + Cost_i^{ENGY} + Cost_i^{SYS} \tag{3}$$

where;

$Cost_i^{SP}$: total cost/energy of soybean production process i

$Cost_i^{M}$: the cost/energy of raw material m that is needed in process i

$Cost_i^{M}$ is computed via:

$$Cost_i^{MAT} = \sum_{m=1}^{M} Cost_{i.m} M_{i.m} \tag{4}$$

where:

$Cost_{i,m}$: The unit cost/energy of raw material m

$M_{i,m}$: The required amount of raw material m in process i

Similarly, $Cost_i^{ENGY}$ is determined by Equation (5):

$$Cost_{i}^{ENGY} = \sum_{e=1}^{E} Cost_{i.e} E_{i.e} \quad (5)$$

where:

$Cost_{i,e}$: the unit cost of energy types *e*

$E_{i,e}$: the amount of energy type *e* required in process i

Human labor cost is taken as $Cost_i^{SYM}$ and it determined by Equation (6):

$$Cost_{i}^{SYS} = \sum_{l=1}^{L} Cost_{i.l} L_{i.l} \quad (6)$$

Direct and indirect input energy/costs included irrigation water, human labor, machinery, diesel fuel, pesticides, manure, electricity, fertilizers and seed. Soybeans (as a positive product) and material and energy losses (as negative products) were calculated as output costs/energy. The energy/cost equivalent coefficients were used to convert inputs and outputs into energy/cost equivalents. The various methods were used to calculate this aspect of input costs are summarizing below:

Human labor: The most commonly used method is to calculate the human labor hours and their associated cost for soybean cultivation and convert it to the equivalent cost by the multiplication of the cost of work per person work and the number of hours worked. The worker can be a farmer or a hired laborer. The cost of labor was determined as the hours worked by the hourly wage.

Electricity: Electricity is a significant component of input energy to agricultural systems. It accounts for a significant share of input energy to soybean farms. Electricity energy is often used to power water pumps and transfer water from wells into the irrigation system. To determine the electrical energy, the number of hours of operation of the pump is multiplied by the amount of energy consumed by the pump. The cost per kilowatt hour was considered to be 0.0047 USD.

Agricultural equipment cost: The agricultural equipment cost (high-powered tractors with 150 HP) is calculated at 4.74 USD per hour per tractor. Some farmers lack all agricultural equipment; thus they must pay the cost of for renting tractors belonging to other farmers. The number of hours of use of the tractor is multiplied by the price of fuel per liter and fuel consumption rate to achieve the fuel consumption of the machinery. The price per liter of diesel fuel at the time of the research was 0.14 USD (Equation 7).

$$FP\ (l/QC) = FC\ (l/h) \times Operation\ time\ h\ (h/QC) \times Diesel\ price\ (USD) \quad (7)$$

Fertilizers: Fertilizer is one of the most significant energy inputs to soybean systems and account for a large share of energy input. The values of different types of fertilizer were differentiated were based on the percentage of components multiplied by their cost and energy equivalents. The amount of input was determined for each fertilizer source. In the present study, it was assumed that 30% of nitrogen fertilizer is lost through nitrate leaching. Organic fertilizer was the most valuable sources of agricultural production. Because of the valuable energy they store, they are often used in soybean cultivation to improve the physical condition of the land. The cost per ton equivalent of manure is 1.42 USD. It is determined by multiplying the amount of fertilizer consumed per farm and its equivalent cost.

Pesticides: Another source of input energy is that consumed by the use of pesticides. In addition to the high consumption of energy and the cost of production, pesticides also pose significant environmental risk. Different types of pesticides with different active substances are used in the region depending upon the application and the pressure caused by the pest. After determining the amounts and types of pesticides consumed, each pesticide was multiplied by its equivalent cost and the amount of energy was determined. Because the subjects, equipment and study area were the same for all types of pesticide, 50% waste (due to spray drift and volatilization) was considered for all pesticides (Van den Berg and Ashmore 2008).

Irrigation: The region uses furrow irrigation. By multiplying pump hours worked during the growth season in the pump flow, the amount of water consumed during the crop season was calculated and multiplied by the cost per cubic meter of water to calculate the equivalent cost of the water used in irrigation. In the present study, the mean cost estimation method was used to estimate the cost per cubic meter of well water in the study area. To this aim, after identifying all items related to the costs of extraction and distribution of well water, the costs were calculated. In order to obtain the price of each component of the irrigation costs, information was obtained from the Agricultural Jihad and the costs were calculated using the engineering economics formulas for one year. The mean cost per cubic meter of water was calculated by dividing the cost spent during one year by the volume of water consumed in that year (derived from the water organization information) as (Equation 8):

$$P = \frac{\sum(C * A) + O\&M}{V} \tag{8}$$

where P is the unit cost per cubic meter of well water, C is the initial cost associated with the well and its facilities, O and M are the current and well repair costs and facilities, respectively, V is a water flow of 3.6 h of well operation, A is the capital recovery agent for estimation of equal uniform costs($\frac{i(1+i)^n}{i(1+i)^n-1}$), n is the useful life, and I is the interest rate and was considered to be 15% (Brouwer, 1989).

The cost per cubic meter of water in the agricultural wells in the area according to formula (1) is 0.22 USD (mean of each cubic meter of water in the crop year). When the subsidies given to the agricultural sector are applied, the price per cubic meter of irrigation water is on average 0.05 USD. The irrigation efficiency in this study was considered to be 48%.

Seed: The quantity of seed used per hectare was multiplied by the cost per kilogram to obtain the total seed input cost per hectare of agricultural land. The selling price of soybean seed per kg was 1.52 USD at the time of the study. The seed emergence rate was considered to be 85% in the field.

3. Results and discussion

3.1. Energy/cost calculation

The energy coefficients/costs are used to determine the energy/cost flows in crop production. In current study, the energy coefficients/costs were multiplied by the consumption or loss rates of the input/output materials to calculate the positive and negative energies. It should be noted that a large portion of the input energy/cost is accumulated in the soybean straw. Since the study's assumption is that straw is return to soil through plowing, so the amount of energy in the straw is not mentioned in the calculations. In other words, since the energy that lies in the straw does not leave the system, then it is not included in the calculation. The energy equivalents for different inputs and outputs in soybean production are shown in Table 1.Table 2 provides the input and output costs for agriculture, including the positive and negatives products.

Table 1. Energy equivalents for different inputs/outputs in soybean production (kg ha^{-1})

Input and output flow	Unit	Energy coefficients (MJ unit^{-1})	Reference	Soybean production	Soybean production Energy (MJ ha^{-1})	Percentage (%)

Diesel fuel	l	47.8	(Kitani, 1999)	98.5	4708.3	9%
Human labor	h	1.96	(G. Erdal et al.2007)	172	337.12	1%
Machinery	h	87.63	(G. Erdal et al.2007)	41.2	3610.356	7%
Nitrogen (N)	kg	66.14	(G. Erdal et al.2007)	214	14153.96	27%
Phosphate (P_2O_5)	kg	12.44	(G. Erdal et al.2007)	156	1940.64	4%
Potassium (K_2O)	kg	11.15	(G. Erdal et al.2007)	45	501.75	1%
Herbicide	kg	238	(G. Erdal et al.2007)	3.2	761.6	1%
Insecticide	kg	101.2	(G. Erdal et al.2007)	0.75	75.9	0%
Fungicide	kg	216	(G. Erdal et al.2007)	4.2	907.2	2%
Manure	kg	0.3	(G. Erdal et al.2007)	5115	1534.5	3%
Electricity	kWh	11.93	(Mohammadi et al, 2010)	1471	17549.03	34%
Irrigation water	m^3	1.02	(G. Erdal et al.2007)	5574	5685.48	11%
Seed	kg	3.6		83	298.8	1%
Total input					**52064.636**	**100%**
Negative output						
Yield losses	kg	16.8		189.07	4726.75	36%
Seed	kg	50		12.45	43.575	0%
Irrigation water	m^3	1.02		2898.48	2956.4496	23%
Nitrogen (N)	kg	75.46		64.2	4246.188	33%
Herbicide	kg	238		1.6	380.8	3%
Insecticide	kg	101.2		0.37	37.444	0%
Fungicide	kg	216		2.1	453.6	3%
Phosphate (P_2O_5)	kg	13.07		14.4	179.136	1%
Total negative output					**13023.9426**	**100%**
Positive output						
Soybean Yield	kg			2701	**67525**	**100%**

Table 2. Material costs for agricultural process including positive and negatives products

Input and output flow	Unit	Cost (USD unit^{-1})	Soybean production	Soybean production cost (USD ha^{1})	Percentage (%)
Diesel fuel	l	0.22	98.5	22	2%
Human labor	h	3.55	172	611	43%
Machinery	h	4.73	41.2	195	14%
Nitrogen (N)	kg	0.18	214	38	3%
Phosphate (P_2O_5)	kg	0.26	156	40	3%
Potassium (K_2O)	kg	0.35	45	15	1%
Herbicide	kg	0.59	3.2	1.8	0%
Insecticide	kg	0.59	0.75	0.4	0%
Fungicide	kg	0.59	4.2	2.4	0%
Manure	kg	0.01	5115	72	5%
Electricity	kWh	0.01	1471	21	2%
Irrigation water	m^3	0.05	5574	330	23%
Seed	kg	0.65	83	54	4%

Total input				**1408.175**	**100%**
Negative output					
Yield losses	kg	0.65	189.07	125	39%
Seed	kg	0.65	12.45	8.2	3%
Irrigation water	m^3	0.05	2898	171	53%
Nitrogen (N)	kg	0.18	64.2	11.5	4%
Herbicide	kg	0.59	1.6	0.9	0%
Insecticide	kg	0.59	0.37	0.2	0%
Fungicide	kg	0.59	2.1	1.2	0%
Phosphate (P_2O_5)	kg	0.26	14.4	3.7	1%
Total negative output				**322**	**100%**
Positive output					
Soybean Yield	kg	**0.65**	**2701**	**1781.463**	**100%**

3.2. MFCA data summary and interpretation

The data generated during MFCA assessment is represented in a material flow cost diagram. Table 2 shows the total inputs and outputs, but it is necessary to identify inputs and losses in each section. Figure 3 shows the percentage of material loss in each QC.

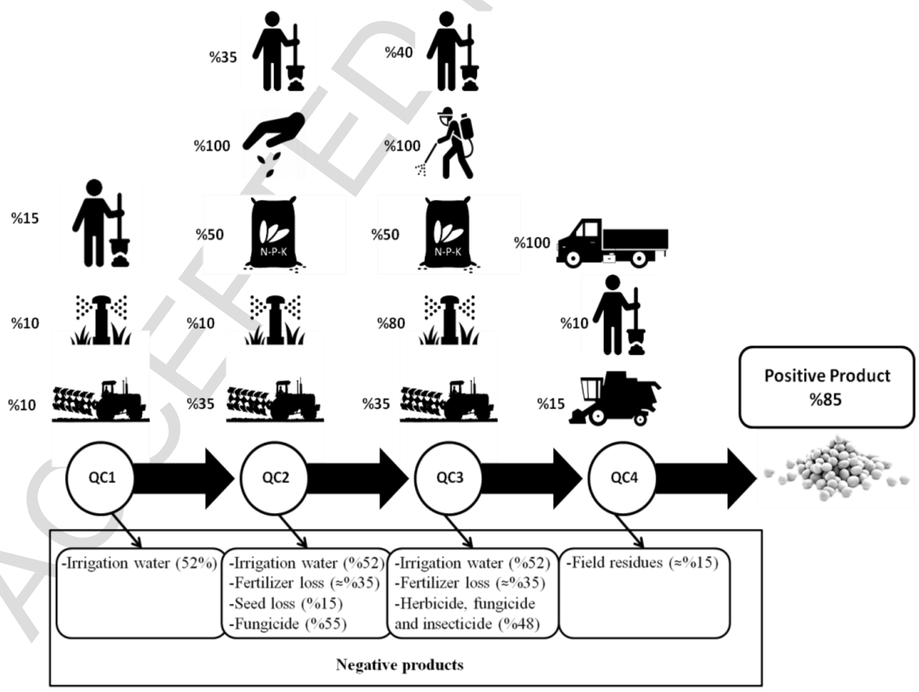

Figure (3): The results from cost allocation for positive and negative products

The balance of energy and the cost of various soybean production processes show that there are positive and negative products to which energy and cost can be allocated. The material losses in each QC were calculated as follows. For example, the cost distribution percentage in QC1 (field preparation) is 15% for human labor, 10% for irrigation and 10% for soil preparation. At the same time, 52% of the irrigation water consumed in this QC was lost.

3.3. Energy analyses

In agricultural systems, input energy is divided into operational and non-operational energy. Direct (operational) energy comprises machinery, human labor and diesel fuel, etc. Indirect (non-operational) energy comprises agro-chemicals, fertilizer, seed and manure (K.G. Mandal et al. 2002). The inputs and their equivalent energy and output energy are shown in the Table 1 as being either positive or negative. The total input energy to the system was 52064.63 MJ, the negative output energy was 13023.94 MJ and positive output energy was 67525 MJ. The highest energy consumption in soybean production system was for electricity (34%), nitrogen fertilizer (27%), irrigation water (11%) and diesel fuel (9%). The greatest percentage of energy wasted in the negative energy sector was for seed loss in QC4 (36%). The waste of inputs included nitrogen fertilizer (33%) and irrigation water (23%) are ranked after seed loss. Low irrigation efficiency (48%) caused irrigation water to be ranked as negative energy because more than half of the irrigation water was wasted. Nitrogen waste in different forms was 33% of the negative output energy of the production system. The least energy waste occurred in QC1, where the wastage of irrigation water occurred only once. It is evident that it is necessary to use effective management techniques to reduce the amount of waste so as to reduce the negative products. The entire system generated 67525 MJ of positive energy.

Conventional energy analysis calculations and MFCA assist in the understanding of energy consumption in the soybean production system. The efficiency of energy use and energy productivity were calculated based on the equivalent input and output energy. The equations 9-12 were used to analyze the energy indices of soybean farms (Ghorbani et al., 2011; Banaeian et al., 2010):

$$Energy\ use\ efficiency = \frac{energy\ output\ (MJ\ ha^{-1})}{energy\ input\ (MJ\ ha^{-1})} \quad (9)$$

$$Energy\ productivity = \frac{soybean\ output\ (kg\ ha^{-1})}{energy\ input\ (MJ\ ha^{-1})} \quad (10)$$

$$Spesific\ energy = \frac{energy\ input\ (MJ\ ha^{-1})}{soybean\ output\ (kg\ ha^{-1})} \quad (11)$$

$$Net\ energy = Energy\ output(MJ\ ha^{-1}) - Energy\ input\ (MJ\ ha^{-1}) \quad (12)$$

In MFCA-based energy accounting, in addition to the output energy of soybean yield (positive energy), other farm waste should be considered when calculating energy ratios. In MFCA-based energy accounting, the negative product is considered in the calculations. In conventional calculations, the energy efficiency is obtained by dividing the energy output by the input energy and produced relatively high energy efficiency. High energy efficiency reduces efforts to improve system performance. But when energy waste is considered as a negative product, the negative energy will be deducted from the positive energy and then divided by the input energy. In this case, the energy use efficiency decreased by 0.25 compared to the conventional calculations. When the negative products were included in the energy calculations, energy efficiency is always lower than or equal to the results of conventional calculation. Also, when calculating net energy, the input energy was obtained as the total of the negative and positive products. In this case, the net energy was 13023.94 MJ higher than for conventional calculations. In MFCA-based energy accounting, pure energy is always greater than or equal to conventional calculation. The results of two types of energy calculation approach are shown in the Table 3.

Table (3): Conventional and MFCA Energy ratios in soybean production.

Energy indices	Conventional	MFCA
Input energy	52064.63	52064.63
Output energy	67525	54501.05
Positive energy	–	67525
Negative energy	–	-13023.94
Energy use efficiency	1.29	1.04
Energy productivity	0.05	0.05
Specific energy	19.27	19.27
Net energy	15460.36	2436.42

3.4. Economic analyses

In order to increasing assessment precision, all energy/costs were computed from the data available for each QC and material flow, rather than accounted for in energy/cost allocation procedures. However, costs (system and energy costs) often are accessible only for overall soybean production and allocations are done using input/output percentages (energy and material).

In MFCA, the inputs and their equivalent cost and output costs were reported positively and negatively. The total input cost to the system was 1408 USD and the negative output cost and positive output costs were 322.37 and 1781 USD, respectively. The highest input prices in the soybean production system were for the labor force and irrigation water, respectively. The use of agricultural machinery accounted for only 14% of the input cost. The high cost of labor is related to the low level of mechanism in agriculture in the region and the availability of cheap labor. Irrigation water imposes a cost of 330 USD on farms and more than half is wasted. The largest expense for waste is related to water and seed losses.

The economic indices of gross income, gross production value, net income, and total production cost and benefit/cost ratio were evaluated for the two cases. The following equations (13-15) were used to analyze the economic indices of the soybean farms:

$$Gross\ value\ of\ production = sugar\ beet\ yeild\ \left(kgha^{-1}\right) \times sugar\ beet\ price\ \left(kgha^{-1}\right) \quad (13)$$

$$Gross\ return = gross\ value\ of\ production\ \left(USD\ ha^{-1}\right) - production\ cost\ \left(USD\ ha^{-1}\right) \quad (14)$$

$$BC\ ratio = gross\ value\ of\ production\ \left(USD\ ha^{-1}\right) / production\ cost\ \left(USD\ ha^{-1}\right) \quad (15)$$

In conventional calculations, only one product is included in the calculation. In MFCA-based accounting, the type of products is not the same; therefore, the costs of both product types are summed and form the potential yield. The effect of material waste on crop production was calculated by considering potential production instead of actual production, which shows the effect of material waste on the final outcome. The results of the two approaches are shown in Table (4).

Table 4. Economic analysis of soybean production.

Cost and return components	Unit	MFCA	Conventional
Gross value of production	USD ha^{-1}	2104	1781
Positive	USD ha^{-1}	1781	
Negative	USD ha^{-1}	322	

Gross return	USD ha^{-1}	695	373
Cost benefit ratio	–	1.49	1.26

The results show that the difference in gross income between conventional calculations and MFCA is 322 USD, which is equivalent to the cost of material waste. The benefit-cost ratio (BCR) is higher by 0.22 because the cost of material waste is included in MFCA accounting.

3.5. Identification of improvement opportunities

Reduction of material waste can substantially increase energy efficiency, yield and profits. The highest cost and energy waste was related to seeds. Soybean harvest losses and decreasing harvest waste significant affects the agricultural sector; however, controlling for grain moisture, properly adjusted equipment and timely harvest can increase the seed yield.

Irrigation water represents 36% of energy waste and 39% of the cost. This does not reduce soybean yield as it reduces water consumption. On slopes having a gradient of over 5%, sprinkler irrigation is used to reduce the amount of water used. Classic sprinkler irrigation and drip irrigation can be used instead of flood irrigation to irrigate soybeans.

The use of fertilizer by farmers has been based on trial and error. In order to reduce fertilizer waste, it is recommended that fertilizer application be based on the results of soil analysis. It is also recommended that fertilizer should be applied after thinning and weeding. A centrifugal fertilize placement machine is used before planting (instead of manual application). During weeding and thinning, linear fertilizer application is used and, to prevent fertilizer waste, it is thoroughly mixed with the soil using a disk.

Waste of seeds depends on the type of seed, the condition of the seed bed, the type and adjustment of the planter and the damage incurred by birds and insects. Determining the right cultivation time and the use of a pneumatic seeder will reduce seed waste along with the rate of damage by pests, decreasing the need for pesticides, lowering costs and environmental pollution.

4. Conclusions

MFCA was used for analysis of the economic and environmental performance of soybean production. Conventional calculation and cost analysis with MFCA were compared and a new method for incorporating material waste into classic energy and cost analysis was used. Energy use efficiency, energy productivity, specific energy and net energy of soybean production were computed for both cases. In conventional calculations, energy use efficiency was found to be higher than in the MFCA approach. Energy productivity from soybean production was same for both calculation methods.

The economic indices of gross income, gross production value, net income, total production cost and benefit/cost ratio were evaluated for both cases. The results showed that the difference in gross income between conventional calculations and MFCA was 322 USD and is equivalent to the cost of material waste. This occurred because of low soybean yield, wasteful use of inputs and high loss of materials. Efficient consumption of irrigation water, diesel fuel and chemical fertilizers would decrease the negative products and increase the positive products, allowing a decrease in production costs and increasing farmer income and environmental sustainability.

The proposed solutions and reducing negative products can produce significant cost savings because MFCA accounts for the cost of wasting energy. Unlike environmental management systems such as ISO 14001 reduce environmental damage, but do not necessarily increase farmer incomes and even incur additional costs. The implementation of MFCA produces benefits for many farms by increasing energy and material efficiency by creating a balance between the environment and the economy. MFCA allows farmers to become aware of routine waste on their farms. They can modify their processes and ensure that production costs can be reduced based on logical assessment.

References

1. Brouwer, C., Prins, K., & Heibloem, M. (1989). Irrigation water management: irrigation scheduling. Training manual, 4.
2. Buus, T. (2017). Energy efficiency and energy prices: A general mathematical framework. *Energy*, *139*, 743-754.
3. Canakci M, Topakci M, Akinci I, Ozmerzi A. Energy use pattern of some field crops and vegetable production: case study for Antalya Region, Turkey. Energy Convers Manage 2005;46:655–66.
4. Canakci, M., Topakci, M., Akinci, I., & Ozmerzi, A. (2005). Energy use pattern of some field crops and vegetable production: Case study for Antalya Region, Turkey. Energy conversion and Management, 46(4), 655-666.
5. Erdal, G., Esengün, K., Erdal, H., & Gündüz, O. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy, 32(1), 35-41.
6. Erickson JE, Cisar JL, Volin JC, Snyder GH. Comparing nitrogen runoff and leaching between alternative residential landscapes. Crop Sci 2001;41:1889–95.
7. ISO14051, I. S. O. (2011). Environmental management-Material flow cost accounting-General framework. *International Organization for Standardization, Geneva*.
8. Khan MA, Awan IU, Zafar J. Energy requirement and economic analysis of rice production in western part of Pakistan. Soil Environ 2009;28:60–7.
9. Kitani, O., & Jungbluth, T. (1999). CIGR handbook of agricultural engineering. Energy and biomass engineering, 5, 330.
10. Kokubu, K., & Kitada, H. (2015). Material flow cost accounting and existing management perspectives. *Journal of Cleaner Production*, *108*, 1279-1288.
11. Madow, W. G. (1968). Elementary sampling theory.
12. Mahmoudi, Elham, Naeimeh Jodeiri, and Esmaeil Fatehifar. "Implementation of material flow cost accounting for efficiency improvement in wastewater treatment unit of Tabriz oil refining company." *Journal of Cleaner Production* 165 (2017): 530-536.
13. Mohammadi A, Omid M. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy 2010;87(1):191e6
14. Mousavi-Avval SH, Rafiee S, Jafari A, Mohammadi A. Optimization of energy consumption for soybean production using data envelopment analysis (DEA) approach. Applied Energy 2011;88(11):3765e72.
15. Najafi, G., Ghobadian, B., Tavakoli, T., & Yusaf, T. (2009). Potential of bioethanol production from agricultural wastes in Iran. *Renewable and Sustainable Energy Reviews*, *13*(6), 1418-1427.
16. Ozturk, I. (2017). The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected Sub-Saharan African Countries. *Energy Policy*, *107*, 289-299.
17. Pahlavan R, Omid M, Rafiee S, Mousavi-Avval SH. Optimization of energy consumption for rose production in Iran. Energy for Sustainable Development 2012;16(2):236e41.
18. Pishgar-Komleh, S. H., Ghahderijani, M., & Sefeedpari, P. (2012). Energy consumption and CO 2 emissions analysis of potato production based on different farm size levels in Iran. *Journal of Cleaner production*, *33*, 183-191.
19. Rafiee S, Mousavi Avval SH, Mohammadi A. Modeling and sensitivity analysis of energy inputs for apple production in Iran. Energy 2010;35:3301–6.
20. Shamshirband, S., Khoshnevisan, B., Yousefi, M., Bolandnazar, E., Anuar, N. B., Wahab, A. W. A., & Khan, S. U. R. (2015). A multi-objective evolutionary algorithm for energy management of agricultural systems—a case study in Iran. *Renewable and Sustainable Energy Reviews*, *44*, 457-465.
21. Statistics, A. A. (2014). Ministry of Jihad-e-Agriculture of Iran.
22. Taghizadeh-Alisaraei, A., Assar, H. A., Ghobadian, B., & Motevali, A. (2017). Potential of biofuel production from pistachio waste in Iran. *Renewable and Sustainable Energy Reviews*, *72*, 510-522.
23. Taghizadeh-Alisaraei, A., Hosseini, S. H., Ghobadian, B., & Motevali, A. (2017). Biofuel production from citrus wastes: A feasibility study in Iran. *Renewable and Sustainable Energy Reviews*, *69*, 1100-1112.
24. Van den Berg LJL, Ashmore MR. Ecotoxicology: nitrogen. In: Jorgensen SE, Fath B, editors. Encyclopedia of ecology. Elsevier; 2008. p. 267–75.
25. Wan, Y. K., Ng, R. T., Ng, D. K., & Tan, R. R. (2015). Material flow cost accounting (MFCA)–based approach for prioritisation of waste recovery. *Journal of Cleaner Production*, *107*, 602-614.
26. Wasiak, A. L. (2017). Effect of biofuel production on sustainability of agriculture. *Procedia Engineering*, *182*, 739-746.

Highlights

- The economic and environmental performance of soybean production was evaluated using MFCA for the first time.
- Hidden energy and cost of soybean production was calculated.
- Using MFCA may be reducing the production energy and material waste ratio.