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Determination of Energy Indices for Banana Production and Presenting a Solution for Agriculture Development using AHP

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ABSTRACT: This study was done in Sistan and Baluchistan Province of Iran in 2013-2014 and level of energy use efficiency, energy productivity, specific energy and net energy were calculated for banana. In this study random sampling was used and 10 farms were completed through field operation and interviews with farmers. The results of study showed that the total average input energy was calculated as 49535.68 MJ per hectare and the maximum share of energy consumption was related to fertilizer energies of nitrogen with 47 percent and diesel fuel with 41 percent and the minimum is related to the energies of human labor and animal fertilizers. Energy use efficiency, energy productivity, specific energy and net energy for total were achieved 0.251, 0.86 kg MJ^{-1}, 1.18 MJ $kg^{-1}$and -49413.26 MJ ha^{-1}, respectively. The shares for direct and indirect energy were 42% and 58%, respectively. Four farms were assessed and analyzed randomly and by using AHP, that 80% energy and 20% yield were effective, and farm F1 had minimum energy consumption with 68% and maximum yield with 0.583. The incompatibility rate was zero for all the parameters, so the criteria were compatible with aims and options.

Keywords: AHP, Banana, Energy use efficiency, Energy productivity, Specific energy.

INTRODUCTION

Today, agriculture section is very much dependent on energy consumption in order to provide the required food for population around the world. Regarding the limited natural resources and adverse effects of using different energy resources inappropriately on human health and natural environment, it becomes vital to study energy consumption patterns in agriculture section (Hatirli *et al*, 2005). With regard to energy crisis and greenhouse gas emissions due to indiscriminate use of fossil fuels, all the efforts are aimed at reducing energy consumption. Agriculture section is not excluded from this issue. Most developed and developing countries study energy input in surface unit for producing different agricultural products and tried to optimize their agriculture system by calculating energy use efficiency index (Nassiri *et al.*, 2009). Efficient use of energy is one of the needs of dynamic agriculture. Energy use in agriculture in response to population increase, limited lands for cultivation and tendency to better life standards have increased. Increased demand for food caused an increase in chemical fertilizer use, pesticides, machineries and other natural resources. Increased energy consumption in recent years caused some problems in human health and environmental issues.

Efficient use of energy in agriculture reduces environmental issues and prevents degradation of natural resources and develops dynamic agriculture as an economical production system (Erdal *et al*, 2007). Today by using more inputs, energy consumption and limitations of ecologic system have increased and if this continues, we will reach unstable system that troubles future generations. Banana is a tropical fruit that is implanted at latitude 30 degrees north and south. This fruit is special for tropical and damp areas of the world, in a way that in areas with 10 to 40 degrees and average of 27 degrees grows well. Its growth declines in areas more than 35 degrees and less than 20 degrees. The rate of banana production around the world is 145.4 million tons and India with 29.6 million tons (20%) and Uganda with 11.1 million tons (8%) have the maximum rate of banana production in the world (FAO, 2011). In Iran, cultivation and farming of banana in southern areas of Sistan and Baluchistan with 4500 hectares under cultivation and annual yield of 135 thousand tons is considered as the first pole of banana production in Iran. Energy analysis can be a way for energy reduction input and increasing of energy productivity (Kaltsas *et al.*, 2007). A study of input and output energy for banana production and determining maximum energy operation consumption in Turkey showed that all input and output energy were 51560.05 and 98024.88 MJ per hectare.

Electricity had the maximum energy input with 27.55 percent of total energy and energy use efficiency, specific energy, energy productivity and net energy were 1.90, 0.99 kg MJ^{-1}, 1 MJ kg^{-1}, and 46464.83 MJ kg^{-1}, respectively (Akcaoz, 2011). Many researchers have used AHP for a variety of purposes that some of them like Ahadi (2012) for selecting the best supplier of Rolling Stock, Kahraman *et al* (2003) used phased AHP for selecting the best supplier in Turkish White factory. Decision makers could determine preference according to importance of each criteria. Chan *et al.* (2007) used one of the phased AHP methods like Kahraman to select a supplier. In this method phased triangular numbers and a developmental analysis were used to analyze paired comparisons and extract different weights and criteria. Kilincci and Onal (2011) used a phased AHP method to choose a supplier. This choice was more inclined towards client's satisfaction.

The purpose of this study is to determine the share of each consumption input in terms of energy consumption in banana production, energy indices (energy use efficiency, energy productivity, specific energy and net energy) in the area, and direct and indirect energy share for this product.

MATERIALS AND METHODS

A. Data collection and processing

This study was done in an area of 3825 square kilometer in Sistan and Baluchistan Province in Konarak town. As mentioned earlier, this province is considered as the first pole of banana production in Iran and banana production is about 76/47% in this town. There were some interview done with farms throughout this area randomly. For this purpose the following formula was used which is called Cochran formula (Nabavi-Pelesaraei *et al*, 2013):

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

where *n* is the required sample size; *s*, the standard deviation; *t*, the value at 95% confidence limit (1.96); *N*, the number of holding in target population and *d*, the acceptable error (permissible error 5%). For the calculation of sample size, criteria of 5% deviation from population mean and 95% confidence level were used.

B. Energy indices

To analyze and assess accurately production system with a view towards energy, different indexes are considered that makes it possible to compare energy consumption in different sections of a system and also makes it possible to assess different systems with each other. The most important indexes are as follows (Nabavi-Pelesaraei *et al.*, 2014a).

Energy use efficiency: This index is calculated by dividing output energy (yield) from mail product and or mail product and by-product by input energy (consumption) and a number without unit.

$$\text{Energy use efficiency} = \frac{\text{Output energy (MJ ha}^{-1})}{\text{Input energy (MJ ha}^{-1})} \quad \ldots(2)$$

Energy productivity: This index shows the product in each energy unit and is calculated by dividing the product by input energy and is in terms of kg per MJ. This index shows that for each MJ energy how much product is produced in terms of kg.

$$\text{Energy productivity} = \frac{\text{Banana yield (kg ha}^{-1})}{\text{Input energy (MJ ha}^{-1})} \ldots(3)$$

Specific energy: This index is the reverse of energy productivity index and shows the consumed energy for each product unit and is in terms of MJ per kg.

$$\text{Specific energy} = \frac{\text{Energy output (MJ ha}^{-1})}{\text{Banana yield (kg ha}^{-1})} \ldots(4)$$

Net energy: It refers to the amount of overall output energy (yield) minus overall input energy (consumption), and its unit is MJ per hectare. Like energy use efficiency index, this index is also better when it is higher.

$$\text{Net energy} = \text{Output energy (MJ ha}^{-1}) - \text{Input energy(MJ ha}^{-1}) \ldots(5)$$

Overall consumed energy is calculated by the sum of consumed energy in machinery, fuel, fertilizer and worker sections, the used energies in this study are presented in Table 1. In this study equivalent and energy formulas were used to analyze and calculate existent energy in different inputs and operations. For example, fertilizer consumed energy is calculated by determining type and amount of consumed fertilizer per hectare in terms of kg ha^{-1} and multiplying the effective amount in its equivalent energy in terms of MJ kg^{-1}, the amount consumed energy in terms in this section in terms of MJ ha^{-1} (Almassi, 2008). Direct and indirect energy are other classifications for energy that its direct type includes human labor and diesel fuel and indirect energy includes chemical fertilizers, farmyard manure and machinery. In other classification in renewable and non-renewable, human labor and chemical fertilizers are renewable and machinery, diesel fuel and chemical fertilizers are non-renewable (Tabatabaeefar *et al*, 2009).

Table 1: Equivalent comparison of different inputs.

Items	Units	Energy equivalent (MJ unit^{-1})	References
A. Inputs			
1. Human labor	h	0.27	(Kitani, 1999)
2. Machinery	h	62.7	(Nabavi-Pelesaraei *et al.*, 2014b)
3. Diesel fuel	L	47.8	(Kitani, 1999)
4. Chemical fertilizers	kg		
(a) Nitrogen		12.6	(Kitani, 1999)
(b) Phosphate (P_2O_5)		10	(Kitani, 1999)
(c) Potassium		9	(Kitani, 1999)
5. Farmyard manure	ton	7.9	(Mobtaker et al., 2010)
B. Output			
1. Banana	kg	10.33	(Anon, 2011)

RESULTS AND DISCUSSION

A. Input and output energy in banana production

In this study, the researchers analyzed the energy required for all farms with regard to five inputs, farmyard manure, chemical fertilizers, diesel fuel, machinery and human labor and banana production as only output, that average of total input energy were found as 49535.68 MJ per hectare and output energy was 122.42 MJ ha^{-1}. As it is shown in Fig. 1, the amounts of nitrogen and fuel with 47% and 41% had the maximum share among all input energy used in banana production, respectively. The minimum amounts were for human labor and farmyard manure. These indices require input control for achieving optimized level from consumed input.

According to Table 2 and Fig. 1, that presents the analysis of input and output energy of 10 farms in Sistan and Baluchistan Province in Iran, it could be seen that maximum consumed energy was for farm No. 8 and maximum production was for farm No. 4.

B. AHP analysis

The present study used a descriptive and analytic method of research and the type of research was applied. As the purpose of the study was energy and yields of farms of Konarak town, the findings of questionnaires were analyzed using AHP method which is a group decision making in complex environments. The basis of this method is making AHP decision making tree.

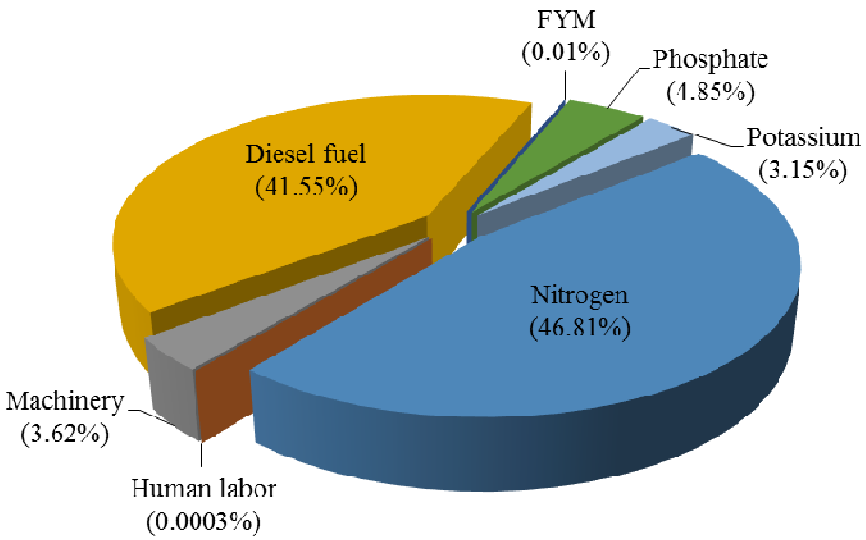

Fig. 1. The share of different inputs of farms in total input energy for banana production.

Table 2: Comparison of input and output energy of farms.

Farms No.	Energy input								
	Nitrogen	Human labor	Machinery	Diesel fuel	FYM	Phosphate	Potassium	Banana	Total input
1	23430	0.162	627.00	16730.00	3.75	1740.00	1370.00	126.0226	43900.91
2	23430	0.135	627.00	23900.00	3.00	2610.00	2055.00	117.2304	52625.14
3	23430	0.108	501.60	15296.00	2.40	1740.00	1370.00	117.2304	42340.11
4	22314.29	0.116	6270.00	27314.29	3.43	1988.57	1174.28	146.5380	59064.98
5	23430	0.162	6270.00	16730.00	3.00	2610.00	1370.00	117.2304	50413.16
6	19525	0.135	1045.00	15200.40	2.10	3480.00	685.00	114.2996	39937.64
7	23430	0.127	737.65	16491.00	3.53	2047.00	1611.76	120.6780	44321.07
8	26033.33	0.120	696.67	31866.67	3.33	2900.00	2283.33	130.5260	63783.45
9	23430	0.135	627.00	26290.00	4.50	2610.00	2055.00	117.2304	55016.64
10	23430	0.144	543.40	16013.00	3.20	2320.00	1644.00	117.2304	43953.74

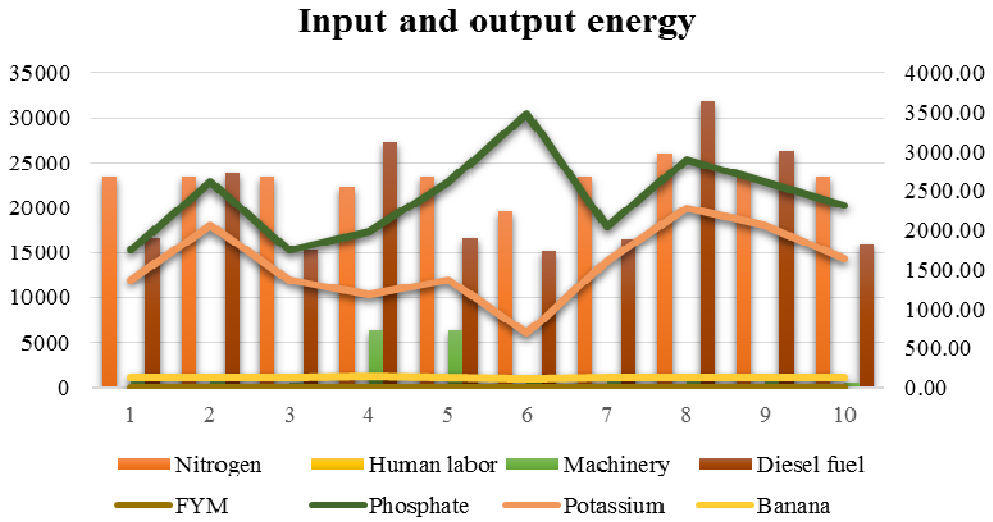

Fig. 2. Share of input and output energy of farms.

Providing AHP structure: In this study the levels of AHP decision making tree is as the following:

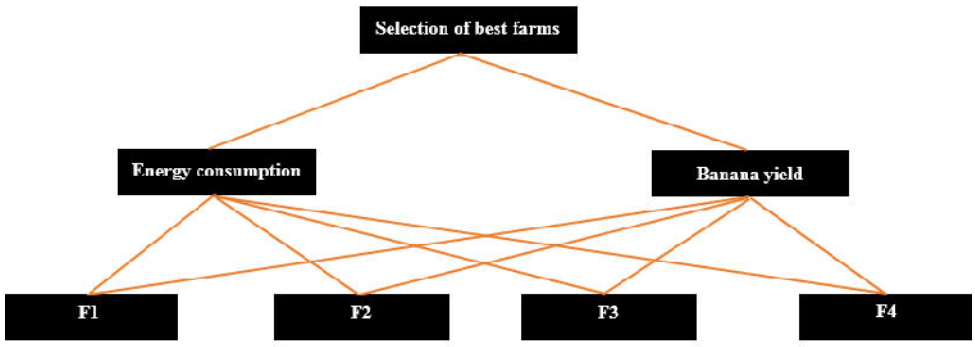

Fig. 3. Overall structure of AHP tree.

Level one includes main purpose, selecting the most suited farm. Level two includes criteria, parameters and indexes studied in farms as presented in Table 3. Final level includes farms; that in this study there was an effort to prioritize the aforementioned parameters and criteria.

Table formation of paired comparison: Comparison tables are presented based on AHP decision making tree, paired comparison are designed using on a scale between equal preference and indefinite preference (Ghodsipour, 2010).

Table 3: Criteria and indices of the study.

Criteria	Operational definition of criteria
Production performance mean	Rate of annual banana production
production consumed energy mean	Average rate of consumed energy in production year

Table 4: Preference amounts for paired comparison.

Preferences (oral judgment)	Numerical amount
Completely strong (indefinite preference)	7
Very strong	6
Strong	5
A little strong	4
Average	3
Low	2
Equal impact	1

After providing AHP tree and calculating geometric mean, for prioritizing farms, mathematical operations were done in Expert Choice 11 software. At first criteria faced a paired comparison with regard to purpose and the relative weight of each criterion was calculated with regard to the purpose. The criteria were compared two by two, which based on it and with regard to the purpose, the study of preference intensity was determined from index i to index *j*. Therefore for n index, *nn* comparison was accomplished. After determining importance coefficient of indexes, importance coefficient of options were determined. In this stage, preference for each option in relation to each index was judged and assessed.

Comparison of criteria with regard to purpose: In the first stage the criteria faced a paired comparison according to the purpose. According to Fig 4 that shows paired comparison of criteria was according to the purpose, consumed energy mean criterion with 0.800 and performance criterion with 0.200 had the maximum and minimum preferences, respectively.

Paired comparison of options: In the second stage, options faced a paired comparison according to the criteria. Fig. 5 shows the weight of options according to performance mean criterion, according to this figure F1 with 0.853 and F4 with 0.077 had the maximum and minimum shares, respectively.

Fig. 6 shows the weight of options according to consumed energy mean criterion. According to this figure, farm F4 with 0.380 and farm F1 with 0.024 had the maximum and minimum preferences, respectively.

Incompatibility rate = 0.0

Fig. 4. Paired comparison of criteria according to the purpose.

Incompatibility rate = 0.0

Fig. 5. Paired comparison of options according to performance mean criterion.

Incompatibility rate =0.0

Fig. 6. Paired comparison of options according to consumed energy mean criterion.

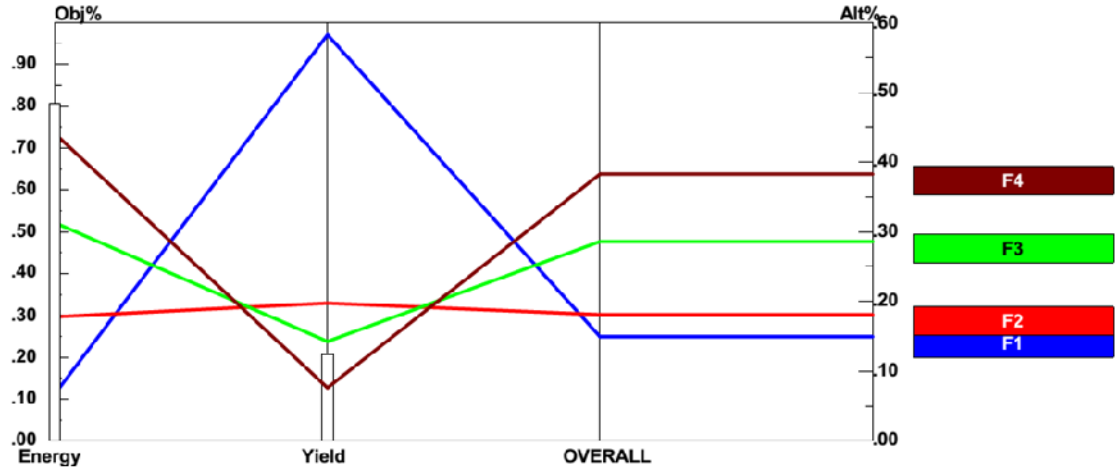

Fig. 7. Integration of options and criteria according to purpose.

Integration: Based on the findings of integration of options and criteria according to the purpose (Fig. 7), it could be concluded that among the farms of Konarak town, maximum performance and minimum consumed energy goes to F1 and minimum performance and maximum consumed energy goes to F4. The incompatibility rate for all the comparisons was zero, so the criteria are compatible with the purpose and options thoroughly.

CONCLUSION

In this study, studying and determining of energy indices for banana production and presenting a solution for agricultural development in Sistan and Baluchistan Province of Iran was accomplished. According to the results, total input energy mean for farms was 49535.68 MJ ha^{-1} and output energy mean was 122.42MJ ha^{-1}. Nitrogen and diesel fuel consumptions were 47% and 41% and has the highest share of energy among inputs. Energy use efficiency, energy productivity, specific energy and net energy were calculated as0.251, 0.86 kg MJ^{-1}, 1.18 MJ kg^{-1} and -49413.26 MJ ha^{-1}, respectively. Four farms were studied using AHP in terms of energy and performance, that energy with 80% and performance with 20% were effective. Farm F1 had minimum energy consumption with 0.068 and maximum yield with 0.583. Regarding that input energy was more than output energy, so input energy should be reduced and performance should be increased by optimization of nitrogen fertilizer and fuel reduction by reducing tractor circulations and also using high-yielding varieties suited to the area by using continuous research works and on time accomplishment of operations and management. Regarding that in 2008 an amount of 831000 tons fruit was imported in the country, in that 637000 tons (77%) was banana, and regarding that there was an intervention level in underground water, favorable weather conditions and fertile soil in Konarak town, there could be an effort to increase products and develop agriculture of the area by expanding the cultivation lands.

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