American-Eurasian J. Agric. & Environ. Sci., 4 (2): 165-171, 2008
ISSN 1818-6769

Energy Analysis of Sugarcane Production in Plant Farms A Case Study in Debel Khazai Agro-industry in Iran

M. Karimi, A. Rajabi Pour, A. Tabatabaeefar and A. Borghei

Department of Agricultural Machinery, Faculty of Biosystems Engineering, Tehran University, Karaj, Iran

Abstract: The aim of this study was to examine direct and indirect input energy in per hectare in sugarcane production alone in plant farms. The study was performed in Debel khazai Agro-Industry situated in southern region of Iran. Total energy expenditures were 148.02 GJ ha^{-1} and energy output was 112.22 GJ ha^{-1} in plant farms. The output/input energy ratio was 0.76. The energy intensity lies about 1.59 MJ kg^{-1} and is one of the highest among sugarcane producing countries. Irrigation is the most energy consuming operation with about 43% of total energy inputs. Electricity, fertilizers, fuel and machinery are the main energy inputs. The influence of the different inputs is discussed and practical measures for energy saving and environmental conservation based on energy analysis are discussed.

Key words: Energy analysis · Energy ratio · Energy intensity · Environment · Sugarcane · Sustainable agriculture

INTRODUCTION

Sugarcane is known to be much more efficient in photosynthetic efficiency than other crops because more solar energy is harvested as crop. In recent years, in Brazil and other countries, it has assumed importance as a source of alcohol production, which can be used as a commercial replacement for petroleum products. Sugarcane has been suggested as an energy crop for the production of liquid fuels and other chemicals [1, 2]. Man's inputs of energy are usually a small fraction of that derived from the sun. However even this fractional input is causing concern.

Sugarcane is an intensive crop in Iran requiring high inputs of natural resources especially fossil energy and irrigation water.

Earlier studies showed that major energy inputs on farms were derived through farm machinery and equipment, use of petroleum products (directly as diesel or indirectly through fertilizers), tube well irrigation using electricity, as well as animal-and man-power and plant nutrients [supplied as farm yard manure (FYM) and as chemical fertilizers] [3-6].

The relation between agriculture and energy is very close. Agriculture itself is an energy user and energy supplier in the form of bio-energy [7, 8]. Energy use in agriculture has developed in response to increasing populations, limited supply of arable land and desire for an increasing standard of living. In all societies, these factors have encouraged an increase in energy inputs to maximize yields, minimize labor-intensive practices, or both [9]. Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution Reduction [10]. Application of integrated production methods are recently considered as a means to reduce production costs, to efficiently use human labor and other inputs and to protect the environment (often in conjunction with high numbers of tourists present in the area). Energy budgets for agricultural production can be used as building blocks for life-cycle assessments that include agricultural products and can also serve as a first step towards identifying crop production processes that benefit most from increased efficiency [11]. Many researchers have studied energy and economic analysis to determine the energy efficiency of plant production, such as sugarcane in Morocco [12], wheat, maize, sugar beet, sunflower, grape, olive, almond, barley, oat, rye, orange, lemon, apple, pear, peach, apricot and plum in Italy [13], rice in Malaysia [14], sweet cherry, citrus, apricot, tomato, cotton, sugar beet, greenhouse vegetable, some field crops and vegetable in turkey [15,16], soybean, maize and wheat in Italy [17], soybean based production system, potato in India [18,19], wheat, maize, sorghum in

Corresponding Author: M. Karimi, Department of Agricultural Machinery, Faculty of Biosystems Engineering, Tehran University, Karaj, Iran

United States [20], cotton, sunflower in Greece [21] oilseed rape in Germany [22].

The scarcity of natural resources as well as the impact of intensive agriculture on the environment is raising ecological concern as to the sustainability of Iran agriculture. To investigate possible practical measures to improve the sustainability of agriculture, an identification of the actual flow of the various inputs in sugarcane production and sugar output is necessary.

To propagate sugarcane, stem cuttings are planted. The first crop, called plant cane, is harvested after 12-16 months. The underground buds on the stool develop to give a second crop called ratoon. The first ratoon crop is harvested after 10-12 months and five to six ratoon crops are commonly found in Iran sugarcane farming.

The objective of the present investigation is to make an input-output energy analysis of sugarcane production alone in plant farms in Debel khazai Agro-Industry situated in southern region of Iran and identify the major energy flows in this system.

MATERIALS AND METHODS

The study was performed in Khouzestan province where all sugarcane production is concentrated. Debel khazai Agro-Industry covers an area of approximately 8243 ha and is situated in the south of Khouzestan province. In 2006-7, plant farm area was about 1269 ha that covers about 15 percent of the total Agro-Industry area.

Field Operations in Plant Farms: Land preparation for planting sugarcane takes during late summer or early fall (August-September) and consists generally in a deep tillage (30-35 cm) intended to remove the stools of the previous crop using reversible plows. Subsoiling operation is performed after that. In farms, with small tractors, a 15-25 cm tillage is performed using a furrow or disc plow. Crossed passes of disc harrows alleviate soil compaction. The number of passes depends on soil condition (moisture, clods size . . .). Generally two to three passes are practiced.

Fertilizing consists in mechanically applying of 123 kg ha^{-1} nitrogen and 188 kg ha^{-1} of phosphorus in the opened furrows. No potassium is applied to sugarcane since the soils of Khouzestan province area are rich in this element. Also, because of the high alkalinity of the soils, no lime is added. Organic fertilizing with manures isn't used in the Agro-Industry area.

Sugarcane stem cuttings are planted manually in the fertilized furrows, before first rain falls. Sugarcane cuttings are covered either manually using hand hoes, or mechanically using a modified ridger. About 10 tons of cuttings are used for planting a hectare but these quantities may vary from 8 to 12 t ha^{-1}. Replanting is sometimes necessary where problems of buds sprouting occur.

A first irrigation of 60-120mm is applied right after planting the cuttings to initiate germination and to benefit from the fall warm weather.

Weed control is done manually, chemically and through mechanical cultivation. Chemical weeding using herbicides is used in most farms with a dose of 8 L ha^{-1} of a mixture of 41% Atrazine and 14% Glyphosate. For dicotyledon weeds, 1-2 L ha^{-1} of 2, 4, D is applied. Spraying is done using either a tractor mounted sprayer or a knapsack sprayer.

Maintenance operations include cultivation, manual weeding and nitrogen fertilizing. For the latter, about 75 kg ha^{-1} of nitrogen as urea are applied during elongation stage and another 75 kg ha^{-1} of nitrogen are applied during the active growth phase.

Irrigation is applied generally twice a month during the dry periods. Irrigation water is applied at 1400-1600 m^3/ha. The total water applied may vary from 35000 to over 45000 m^3/ha per crop.

Sugarcane harvest is carried out mechanically using Sugarcane harvesters. Sugarcane yields in Iran usually are more than 85 t ha^{-1} in most of the plantations.

Energy Analysis: The assessment took place starting the 2006-7 agricultural season and included 1269 ha plant cane. Data recorded included the duration of each operation and the quantities of each input (machinery, fuel, fertilizers, chemicals, irrigation water, labor, etc . . .). To calculate the energy involved in the production of sugarcane, the energy analysis technique was used. The energetic efficiency of the agricultural system has been evaluated by the energy ratio between output and input. Human labor, machinery, diesel oil, fertilizer, pesticides and Sugarcane stem cutting amounts and output yield values of Sugarcane crops have been used to estimate the energy ratio. All inputs were converted to energy units using the energy coefficients reported on Table 1. These coefficients were adapted from several literature sources that best fit the Iran conditions.

The mechanical energy was computed on the basis of total fuel consumption (L ha^{-1}) in different operations.

Table 1: Energy equivalent of inputs in sugarcane production

Inputs and ouputs	Unit	MJ/Unit	References
Fuel			
Diesel	L	47.7	[23]
Lubricant	kg	81.1	[24]
Electricity	kWh	12.7	[25], [26]
Fertilizer			
Nitrogen	kg	75.4	[26]
Phosphorus	kg	10.9	[26]
Chemicals			
Herbicides	g activ. in	418	[27], [28], [29]
Insecticide	g activ. in	363.6	[27], [28], [29]
Insecticides	g activ. in	310.6	[27], [28], [29]
Traction			
Tractor 100 hp	h	57.8	[24], [25], [26]
Tractor 75 hp	h	42.5	[24], [25], [26]
Field machinery			
Machinery	h	62.7	[30], [31], [32]
Transportation			
Truck	h	29.8	[24], [25], [26]
Wagon	h	29.8	[24], [25], [26]
Irrigation water			
Electricity for irrigation	kWh	12.7	[24], [25], [26]
Irrigation indirect	MJ/ha/year	3787	[33]
Labor			
Human labor	h	1.96	[30]
Sugarcane			
Seed cuttings and stalks	kg	1.2	[34]

Therefore, the energy consumed was calculated using conversion factors and expressed in MJ ha^{-1}.

Basic information on energy inputs and Sugarcane yields were entered into Excel spreadsheets, SPSS 15 spreadsheets. Based on the energy equivalents of the inputs and output (Table 1), the energy ratio (energy use efficiency), energy productivity and the specific energy were calculated [15, 17].

Energy use efficiency =
Energy Output (MJ ha^{-1})/Energy Input (MJ ha^{-1}) (1)

Energy productivity =
Grain output (kg ha^{-1})/Energy Input (MJ ha^{-1}) (2)

Specific energy =
Energy input (MJ ha^{-1})/Grain output (kg ha^{-1}) (3)

Net energy gain =
Energy Output (MJ ha^{-1})-Energy Input (MJ ha^{-1}) (4)

For the growth and development, energy demand in agriculture can be divided into direct and indirect, renewable and non-renewable energies [8]. Indirect energy included energy embodied in Sugarcane stem cuttings, fertilizers, chemicals, machinery while direct energy covered human labor and diesel used in the Sugarcane production. Nonrenewable energy includes diesel, chemical, fertilizers and machinery and renewable energy consists of human labor, Sugarcane stem cuttings.

RESULTS AND DISCUSSION

Figure 1 shows the energy requirements to grow and transport sugarcane to the sugar mill for plant cane crop in Debel khazai Agro-Industry. Figure 2 gives the energy distribution by inputs.

Total energy uses to grow 1 ha of sugarcane were 148.02 for plant cane. The share of indirect energy is about one-third of total energy inputs (32%). Electricity is the main energy input accounting for 43% in the plant cane. The second single largest energy input in plant cane is diesel fuel used in the farm machinery and transport accounting for 23.0% (34.04 GJ), followed by nitrogen fertilizer 14.4% (21.32 GJ), sugarcane cuttings 8.3% (12.25 GJ) and machinery 6.0% (8.93 GJ). Chemicals are the smallest of all inputs with 1.3% (1.92 GJ). A total of 1225 h of labor were used in the plant cane.

Energy outputs in Agro-Industry farms with 93.5 ton/ha yield were 112.22 GJ ha^{-1} for plant cane. The output to input energy ratio was calculated as 0.76. Energy productivity, Specific energy and Net energy gain were 0.63 kg/MJ, 1.59 MJ kg^{-1} and-35.8 GJ ha^{-1}, respectively.

Obviously, the major energy inputs are electricity, fuel, nitrogen and machinery as well as cuttings. It is a

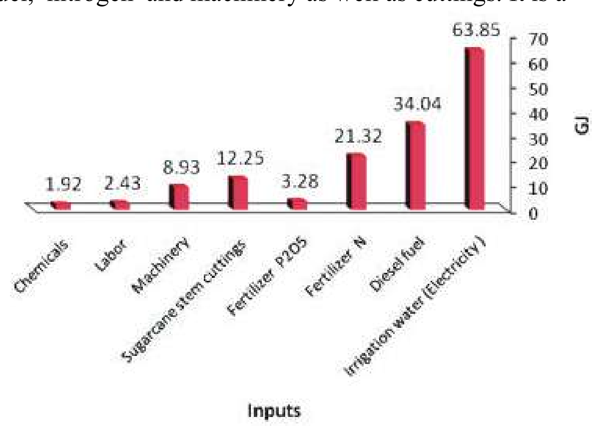

Fig 1: Energy inputs in sugarcane production in Debel khazai Agro-Industry (plant cane)

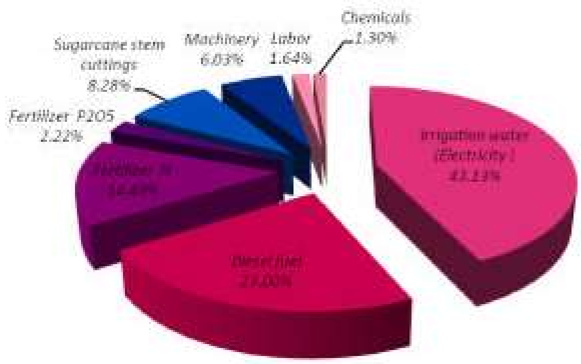

Fig. 2: Share of energy inputs in sugarcane production in Debel khazai Agro-Industry (plant cane)

normal practice in intensive large farming systems in Iran to use more irrigation water, high power machinery and more chemicals to ensure high yields. Large farming system in Debel khazai Agro-Industry uses every possible means to ensure the good establishment of the crop in the plant cane.

Although large farms use machinery and herbicides, extensively, they still require large labor inputs. This has the social advantage of providing employment in rural areas. Debel khazai Agro-Industry required 1025 h/ha in the plant cane.

Techniques for Reducing Energy Inputs in Debel Khazai Agro-Industry: In the following, techniques to reduce energy inputs for a sustainable sugarcane production are discussed. These techniques are based on the experience of other producing countries and also on research taking into consideration the local socio-economic conditions.

Irrigation: The water requirements of sugarcane in Agro-Industry have been determined experimentally to be about 40000 m^3/ha-year. Depending on the climatic conditions, irrigation may have to supply up to 75% of this water. In all cases, irrigation requires the largest amount of energy in plant cane farms compared with all other energy inputs. Large amounts of indirect energy are required with the equipment used in the pressurizing stations. In addition the surface equipment necessary to apply water to the sugarcane requires large inputs of energy and has a relatively short lifetime [35].

In addition, water is becoming a scarce resource in Iran. The nation is approaching the limits of its water availability. Competitors for water include public and industry plus other sectors of the economy. To cope with this competition, it is necessary that agriculture uses alternative and more efficient water systems. Large amounts of water are wasted due to some irrigation practices coupled with inefficient crop choice [29]. With aging irrigation systems and lack of good maintenance, irrigation efficiencies are probably lower in Iran. Furrow irrigation, plus drip irrigation and micro-irrigation and other new water-saving irrigation technologies should also be considered.

Fuel and Machinery: Fuel and machinery account for 29% of the energy inputs for sugarcane production in Debel khazai Agro-Industry. The major part of fuel consumption is associated with transport and land preparation. For transportation, good maintenance of the trucks would reduce energy use. Also, it is common practice to deliver harvested cane with large amounts of waste leaves and other extraneous matter.

About 66 kg ha^{-1} of machinery are used in Agro-Industry farms with most of the machinery used in seedbed preparation. These machinery input values are lower than those of Louisiana (72 kg ha^{-1}) [34].

Deep tillage requires the use of high powered machines, which is very energy consuming and is not always justified through a significant increase in yield [36]. Several studies investigated minimum tillage practices for sugarcane [37] and showed that minimum tillage gave better yields and was reported to have other advantages such as improved soil conservation and the prevention of the spread of diseases than conventional tillage practices. Other tillage systems have been described for a reduced tillage without compromising yields [38]. Research on optimum tillage techniques suitable for local conditions is required.

The timing of tillage operations is also an important factor in sugarcane production. Improved timing will help Agro-Industry managers take advantage of soil moisture remaining in the soil from the previous crop and this would reduce the number of passes over the cane field. In addition, matching the number and type of tractors to the size and task of sugarcane farming operation, plus good maintenance are keys to energy savings [28].

Fertilizers: Fertilizer inputs are very energy intensive, especially nitrogen fertilizer and research on the fertilizing of sugarcane has been investigated [39]. Note, the small increase in yield does not overcome the greater amounts of nitrogen added in surplus to the recommended levels [39].

Another investigation [40] has shown that, in fields under mono cropping of sugarcane, the loss of organic matter was about 1.5% per year. The decline in soil organic matter leads to the use of greater amounts of chemical fertilizers than normal.

In summary, some of the practically possible ways of reducing energy inputs as fertilizers include:

- The determination of the exact sugarcane nutrients needs through soil; then apply fertilizers accordingly.
- Trash management: sugarcane trash may reach 30% of the harvested yield. When it is not used to feed cattle (especially in dry years), it is burned and part of it is transported with cane to the mill. For a yield of 90 t ha^{-1}, the nutrient in sugarcane tops and leaves is estimated to be 35.5 kg ha^{-1} of N, 7.4 kg ha^{-1} of P_2O_5 and 128.3 kg ha^{-1} of K_2O [41]. These large quantities of nutrients could be restored to the field and therefore reduce chemical fertilizer input by recycling the cane trash. Meyers [37] cited several other advantages of using trash, such as reduced soil erosion and soil compaction and conserving soil organic matter. Added advantages include reduced herbicides, improved soil fertility and increased biodiversity [37, 42].
- Use of manures and cane factory by products: The use of manures and cane factory by products has been shown to have a beneficial effect on the soil structure, improved moisture holding capacity, ion exchange capacity and an increase in the potential of nitrogen release [43].
- Green manuring is another area that should be explored, because the inter-row cropping of legumes has been successful in Morocco [44]. Green manures improve soil physical and chemical conditions as well as reduce the incidence of insect, pests and diseases specific to sugarcane [37]. Garside [45] reported that following a fallow crop of soybeans there is no need to apply nitrogen fertilizer to plant cane.

CONCLUSION

Sugarcane production in Debel khazai Agro-Industry is the most energy intensive. The major energy inputs were electricity for irrigation, fuel, machinery and fertilizers. Total energy inputs are 148.02 GJ ha^{-1} in Agro-Industry farms.

A better return on energy investments could be achieved by implementing possible energy saving measures proven to be economically sound. More energy saving could be achieved with good maintenance of irrigation equipment and the introducing of more efficient irrigation systems. Energy inputs as fertilizers could be reduced if the recommended fertilizing applications were practiced. Added saving are also possible by using livestock manure and green manures, recycling trash and factory byproducts. Additional energy saving are possible by proper timing of field operations and matching the size and power of tractors and other machinery to field operations.

REFERENCES

1. Austin, R.B., G. Kingston, P.C. Longden and P.A. Donovan, 1978. Gross energy yields and the support energy requirements for the production of sugar from beet and cane; a study of four production areas. J. Agric. Sci. (Cambridge), 91: 667-675.
2. Braunack, M.V., D. McGaryy, L.R. Crees and N.V. Halpin, 1999. Strategic tillage for planting sugarcane', Proceedings of the Australian Society of Sugar Cane Technologists, 21: 101-107.
3. Fauconnier, R., 1991. Sugar cane. The Tropical Agriculturalist, Rene Coste (Ed.), London, Macmilan Press Ltd.
4. Garside, A.L., J.E. Berthelsen and C.L. Richards, 1997. Effect of fallow history on cane and sugar yield of a fallowing plant cane crop. Proc. S Aust. Soc. Sugarcane Technol., pp: 80-86.
5. Malik, R.K. and A.R. Rao, 1983. Energy utilization in sugarcane production in north india. Energy., 8(4): 291-294.
6. Malik, R.K. and A.R. Rao, 1982. Energy Inputs to Irrigation of Paddy. presented at the 19rk Annual Conu. Indian Sot. Agril. Engrs., Udaipur.
7. Karimi, M., S. Rafiee, A. Rajabi Pour, K. Khairalipour and S. Shahin, 2008. A Pattern to Distribute Tractor Power from the Viewpoint of Energy Case Study: Isfahan Province in Central Region of Iran. American-Eurasian J. Agric. Environ. Sci., 3 (4): 526-531.
8. Alam, MS., MR. Alam and KK. Islam, 2005. Energy Flow in Agriculture: Bangladesh. American J. Environ. Sci., 1(3): 213-220.
9. Esengun, K., O. Gunduz and G. Erdal, 2007. Input-output energy analysis in dry apricot production of Turkey. Energy Convers Manage., 48: 592-598.
10. Uhlin, H., 1998. Why energy productivity is increasing: An I-O analysis of Swedish agriculture. Agric Syst., 56(4): 443-465.

11. Piringer, G.J. and L. Steinberg, 2006. Reevaluation of Energy Use in Wheat Production in the United States. J. Indust. Ecol., 10: 149-67.
12. Mrini, M., F. Senhaji and D. Pimentel, 2001. Energy analysis of sugarcane production in Morocco. Environ. Develop. Sustainability., 3: 109-126.
13. Triolo, L., H. Unmole, A. Mariani and L. Tomarchio,1987. Energy analyses of agriculture: The Italian case study and general situation in developing countries. In: Third international symposium on mechanization and energy in agriculture, Izmir, Turkey, October 26-29, pp: 172-184.
14. Bockari-Gevao, S.M., W.I. Wan Ishak, Y. Azmi and CW. Chan, 2005. Analysis of energy consumption in lowland rice-based cropping system of Malaysia. Sci Technol., 27(4): 819-826.
15. Demircan, V., K. Ekinci., HM. Keener., D. Akbolat and C. Ekinci, 2006. Energy and economic analysis of sweet cherry production in Turkey: A case study from Isparta province. Energy Convers Manage., 47: 1761-1769.
16. Canakci, M., M. Topakci., I. Akinci and A. Ozmerzi 2005. Energy use pattern of some field crops and vegetable production: case study for Antalya region, Turkey. Energy Convers Manage., 46: 655-666.
17. Sartori, L., B. Basso., M. Bertocco and G. Oliviero, 2005. Energy Use and Economic Evaluation of a Three Year Crop Rotation for Conservation and Organic Farming in NE Italy. Biosyst. Eng., 91(2): 245-256.
18. Mandal, KG., KP. Saha., PK. Ghosh, KM. Hati and KK. Bandyopadhyay, 2002. Bioenergy and economic analysis of soybean-based crop production systems in central India. Biomass Bioenergy., 23(5): 337-345.
19. Yadav, RN., RKP. Singh and S. Prasad, 1991. An economic analysis of energy requirements in the production of potato crop in bihar sharif block of nalanda districh (Bihar). Econ Affair Kalkatta., 36: 112-119.
20. Franzluebbers, A.J. and C.A. Francis, 1995. Energy output-input ratio of maize and sorghum management systems in Eastern Nebraska. Agric. Ecosyst. Environ., 53(3): 271-278.
21. Tsatsarelis, C.A., 1991. Energy requirements for cotton production in central Greece. J. Agril. Eng. Res., 50: 239-246.
22. Rathke, G.W. and W. Diepenbrock, 2006. Energy balance of winter oilseed rape (*Brassica napus* L.) cropping as related to nitrogen supply and preceding crop. Europ. J. Agron., 24: 35-44.
23. Cervinka, V., 1980. Fuel and Energy Efficiency, Pimentel, D. (Ed.), Handbook of Energy Utilization in Agriculture, Boca Raton, FL., CRC Press, pp: 15-21.
24. Biondi, P., G. Farina and V. Panaro, 1987. 'L'analisi energetica in agricultura, Riv. di Ing. Agr., 4: 205-219.
25. Fluck, R.C., 1992. Energy for Florida sugarcane, Florida Cooperative Extension Service. Fact Sheet EES-87, University of Florida.
26. Bonnie, S., 1987. 'L'energie et sa crise de 1974 `a 1984 dans l'agriculture Franc¸aise', INRA Grignon, France.
27. Pimentel, D., 1980. Energy inputs for the production, formulation, packaging and transport of various pesticides, Pimentel, D. (Ed.), Handbook of Energy Utilization in Agriculture, Boca Raton FL., CRC Press, pp: 45-48.
28. Pimentel, D., 1991. Conserving energy for a sustainable production agriculture. Paper given before the Philadelphia Society for promoting agriculture on February 7, 1991.
29. Pimentel, D., 1998. Water resources: agriculture, the environment and ethics, Lemons, J., L. Westra and R. Goodland (Eds.), Ecological Sustainability and Integrity: Concepts and Approaches. Dordrecut, the Netherlands, Environmental Science and Technology Library. Kluwer Academic Pub.
30. Singh, H., D. Mishra and NM. Nahar, 2002. Energy use pattern in production agriculture of a typical village in Arid Zone India—Part I. Energ. Convers. Manag., 43(16): 2275-2286.
31. Erdal, G., K. Esengun, H. Erdal and O. Gunduz, 2007. Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Energy, 32: 35-41.
32. Singh, J.M., 2002. On farm energy use pattern in different cropping systems in Haryana, India. Master of Science. Germany: International Institute of Management, University of Flensburg
33. Mrini, M., 1999. Analyse energetique de la filiere sucriere au Maroc, Ph.D Thesis, IAV Hassan II, Rabat, Morocco.
34. Ricaud, R., 1980. Energy input and output for sugarcane in Louisiana, Pimentel, D. (Ed.), Handbook of Energy Utilization in Agriculture, Boca Raton, FL., CRC Press, pp: 135-136.
35. Batty, J.C. and J. Keller, 1980. Energy requirements for irrigation, Pimentel, D. (Ed.), Handbook of Energy Utilization in Agriculture, Boca Raton, FL., CRC Press, pp: 35-42.
36. Yang, S.J. and R. Quintero, 1986. The effect of the method of land preparation on the growth and yield of sugarcane in fine-textured vertisols and inceptisols in the Cauca Valley, Colombia', Proc. Internat. Soc. Sugar Cane Technol. XIX., 1: 119-129.
37. Meyer, J.H., R. Van Antwerpen and E. Meyer, 1996. A review of soil degradation and management research under intensive sugarcane cropping. Proc. S Afr. Sug. Technol. Ass., 70: 22-27.

38. Braunack, M.V., D. McGaryy, L.R. Crees and N.V. Halpin, 1999. Strategic tillage for planting sugarcane. Proceedings of the Australian Society of Sugar Cane Technologists, 21: 101-107.
39. CTCS., 1995. Rapport des experimentations du CTCS. Internal Report, CTCS/ORMVAG BP 79, Kenitra, Morocco.
40. CTCS., 1997. Resultats du Systeme de Suivi de la Canne a Sucre en grande culture. Internal Report, CTCS/ORMVAG BP 79, Kenitra, Morocco.
41. CTCS., 1991. Synthes des resultants des essays de fertilization sur canne a sucre Durant 7 annees d'experimentation. CTCS/DDA/ORMVAG BP 79, Kenitra, Morocco.
42. Abrigo, Jr. C.S., 1989. Note: Effects of organic fertilizer from cane trash on cane and sugar yield of PHIL 56-226', The Phillippine Agriculturist, 72(4): 516-521.
43. Fauconnier, R., 1991. Sugar cane. The Tropical Agriculturalist, Rene Coste (Ed.), London, Macmilan Press Ltd.
44. CTCS., 1990. Journees Scientifiques du CTCS. Conference Papers, CTCS/ORMVAG BP 79, Kenitra, Morocco.
45. Garside, A.L., J.E. Berthelsen and C.L. Richards, 1997. Effect of fallow history on cane and sugar yield of a fallowing plant cane crop. Proc. S. Aust. Soc. Sugarcane Technol., pp: 80-86.