Energy Efficiency Analysis of Wheat Crop under Different Climate- and Soil-Based Irrigation Schedules †

Rubina Ansari 1,*, Muhammad Usman Liaqat 1, Hafiz Ihsan Khan 2 and Sumra Mushtaq 1

1 Department of Irrigation and Drainage, University of Agriculture, Faisalabad 38000, Pakistan; usmanliaqat0321@gmail.com (M.U.L.); sumra.mushtaq449@gmail.com (S.M.)
2 Department of Structure and Environmental Engineering, University of Agriculture, Faisalabad 38000, Pakistan; ihsankhanuaf@gmail.com
* Correspondence: rubina.ansari67@yahoo.com; Tel.: +92-33-5691-0116
† Presented at the 2nd International Electronic Conference on Water Sciences, 16–30 November 2017; Available online: http://sciforum.net/conference/ecws-2.

Published: 16 November 2017

Abstract: Use of energy in the agriculture sector has directly or indirectly been intensified to increase crop production to fulfill the food demand of the growing population. Considering the energy and water scarcity in Pakistan, the present study was carried out to assess wheat production efficiency with regard to energy consumption. For this purpose, a field experiment was conducted at the Water Management Research Centre (WMRC), University of Agriculture Faisalabad, to compare two irrigation scheduling techniques (climatic- and soil moisture-based) and farmers’ practice. All the inputs, except volume of irrigation water, were the same for all treatments. Energy equivalents (extracted from a scientific source) were used to calculate the energy balance and indices (energy use efficiency, energy productivity (kg MJ⁻¹), specific energy (MJ kg⁻¹), net energy (MJ ha⁻¹) and water productivity (kg m⁻³)). The results show that soil moisture-based treatment (at 30% management allowable depletion (MAD)) gave 7.94% and 27.94% more yield compared to climate-based treatments (20 mm cumulative pan evaporation (CPE)) and farmers’ practice respectively. Pumping water for irrigation was the highest energy consumption input for wheat production after chemical fertilizers. T1 = 30% MAD and T4 = 20 mm CPE treatments saved 33.71% and 35.72% energy, respectively, compared to farmers’ practice, due to water being saved. T1 and T4 treatments increased energy output by 11.40% and 6.38%, respectively, compared to farmers’ practice, in terms of grain yield and biological yield. The highest net energy (155,557.95 MJ ha⁻¹), energy use efficiency (7.478), energy productivity (0.181 kg MJ⁻¹) and water productivity (1.875 kg m⁻³) were achieved with T1 (30% MAD); however, the highest specific energy (8.148 MJ kg⁻¹) was achieved with farmers’ practice. The results thus obtained help the farmers, stakeholder agencies and researchers to make informed decisions when choosing different treatments.

Keywords: energy; water; climate; soil moisture

1. Introduction

Pakistan is a water- and energy-scarce country and both are important in agricultural production. Agriculture is considered as the backbone of the country’s economy, contributing 21% to its GDP, accounting for nearly 43.7% of its work force and providing a livelihood to more than 67% of its population. Water and energy conservation plans are directly related to poverty reduction and the living standard [1].
Wheat is the biggest grain crop grown and chief staple food in Pakistan. Wheat production in the country for the preceding economic year (2013) was 24.21 million tons, covering an area of 8.66 million hectares (state bank of Pakistan, 2013) and it contributes 2.2% to the national GDP and 10.1% to value added agriculture [2]. In 2030, Pakistan will require over 33 million tons of wheat to meet its domestic needs [3].

Use of energy in the agriculture sector has directly or indirectly been intensified to increase crop production to fulfill the food demand of the rapidly growing population and improve the living standard with a limited supply of arable land. These factors have encouraged the use of energy to obtain the maximum yield but the maximum yield may not bring maximum profit due to the higher cost of production. Besides the high production cost, the intensive use of energy inputs can cause environmental distortion and result in the excessive use of natural resources. Energy is directly used in land preparation, tillage operations, sowing, irrigation, harvesting; and indirectly used in inputs such as seed, pesticides, fertilizers, and plant protection agrochemicals. Irrigation water was the highest energy consumption input for wheat production after chemical fertilizers. The output energy is obtained in the form of feed, fodder, fruits, vegetables, seed and grain.

Energy input and output are the two main factors for determining the energy efficiency and environmental impact of crop production. Energy utilization and output differ depending on the crop, production system and intensity of management practices. Considerable research has been conducted on the energy use pattern of field crops under different management practices throughout the world. Most of the work is related to the energy use pattern for different crops such as sugarcane [4], wheat [5–7], cotton [8], garlic [9], tomatoes [10,11], and cucumber [12]. Very little effort has been made to explore the relationship among water, energy and the yield in Pakistan. Hence, the primary goal of this study was to investigate the consumption pattern with regard to energy and water in wheat production under different irrigation schedules and evaluate the differences in different energy and water indices between all irrigation schedules. The second objective of this study was to develop an economic analysis to select the optimum irrigation management practices for wheat crop.

2. Materials and Methods

The study was carried out at the Water Management Research Center (WMRC) Faisalabad, Pakistan (31°38.74 N, 73°01.29 E) and at an elevation of 184 m above the mean sea level, during winter 2014–2015 on wheat crop. Lower Chenab canal, diverted from Chenab River at Khanki headwork, is the main source of irrigation water for Faisalabad region. Faisalabad lies in a semi-arid environment and experiences extreme maximum and minimum summer and winter temperatures of 50 °C and –2 °C, respectively, with a mean annual rainfall of 350 mm, most of which falls during a monsoon in the form of high intensity rainfall. The topography of the study area is flat and the soil is sandy loam textured throughout the area.

Six irrigation schedules based on the management allowable depletion (MAD) and cumulative pan evaporation (CPE) were studied: T1 = 30% MAD, T2 = 45% MAD, T3 = 60% MAD, T4 = 20 mm CPE, T5 = 30 mm CPE, T6 = 40 mm CPE and farmers’ practice. Data were collected related to water use, fertilizer, chemicals used for plant protection, and energy consumed in land preparation, pumping water, machinery operations etc. All inputs except volume of irrigation water were the same for all treatments. The amount of first irrigation water was the same for all treatments to obtain better emergence. Energy equivalents (extracted from a scientific source) were used to calculate the energy input and output. The energy equivalents used in this study are shown in Table 1.
Table 1. Energy equivalents of inputs and outputs in agricultural production.

| Energy       | Unit     | Energy Equivalent (MJ unit⁻¹) | References |
|--------------|----------|-------------------------------|------------|
| Inputs       |          |                               |            |
| 1. Human Labor | h        | 1.96                          | [13]       |
| 2. Machinery | h        | 62.7                          | [13]       |
| 3. Diesel Fuel | L        | 56.31                         | [13]       |
| 4. Chemical Fertilizers | kg |                               |            |
| (a) Nitrogen |           | 66.14                         | [13]       |
| (b) Phosphorous |          | 12.44                         | [13]       |
| (c) Potassium |          | 11.15                         | [13]       |
| 5. Herbicides | kg       | 238                           | [14]       |
| 6. Water     | m³       | 1.02                          | [13]       |
| 7. Electricity | kWh     | 11.93                         | [15]       |
| 8. Seeds     | kg       | 14.7                          | [16]       |
| Outputs      |          |                               |            |
| 1. Wheat Grain Yield | kg | 14.7                          | [16]       |
| 2. Wheat Straw Yield | kg | 12.5                          | [16]       |

Based on these energy equivalents given in Table 1, energy indices include energy use efficiency, energy productivity (kg MJ⁻¹), specific energy (MJ kg⁻¹), net energy (MJ ha⁻¹) and water productivity (kg m⁻³) [17].

\[
\text{Energy Efficiency} = \frac{\text{Energy Output (MJ ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{1}
\]

\[
\text{Specific Energy} = \frac{\text{Energy Input (MJ ha}^{-1})}{\text{Grain Output (kg ha}^{-1})} \tag{2}
\]

\[
\text{Energy Productivity} = \frac{\text{Grain Output (kg ha}^{-1})}{\text{Energy Input (MJ ha}^{-1})} \tag{3}
\]

\[
\text{Net Energy} = \text{Energy Output (MJ ha}^{-1}) - \text{Energy Output (MJ ha}^{-1}) \tag{4}
\]

\[
\text{Water Productivity} = \frac{\text{Grain Yield (kg ha}^{-1})}{\text{Water Applied (m}^3\text{ha}^{-1})} \tag{5}
\]

3. Results and Discussion

3.1. Effect of Irrigation Schedules on Wheat Grain Yield and Biological Yield

The effects of different irrigation schedules on the grain yield and biological yield of wheat crop are investigated, as shown in Figure 1. The result shows that the highest grain yield was observed in the T1 treatment whereas the minimum grain yield was observed in farmers’ practice. The T1 treatment gave 7.94% and 27.94% more yield compared to T4 and farmers’ practice respectively. The highest biological yield was also obtained with T1 and the minimum biological yield was obtained with the T6 treatment. The T1 treatment gave 3.1% and 4.1% more biological yield compared to T4 and farmers’ practice respectively. The statistical analysis was carried out on water use, grain yield and biological yield using ANOVA with a comparison of the mean of all treatments using the Least Significant Difference (LSD) test at the 5% significance level. Significant differences were observed for grain yield and biological yield. However, water use under all schedules varies non-significantly. Treatments based on the percentage of MAD (T1, T2 and T3) significantly increased wheat grain yields over CPE-based treatments (T5 and T6) and a non-significant increase was observed with T4. The results of this research are similar to the findings of [18].
Figure 1. Graphical representation of grain yield, biological yield and water use.

3.2. Energy Balance Analysis

The quantity of inputs used and output obtained in wheat production, their energy equivalents and energy indices (energy ratio, energy productivity, specific energy and net energy) are described in Tables 2–4, respectively. Table 2 indicates that about 85 h human labor, 20 h machinery power and 50-liter diesel fuel per hectare is required for wheat production in the experimental area. The amount of total fertilizers and herbicides used was 445 kg (including 104 kg nitrogen, 212 kg phosphorus and 129 kg potassium) and 1.5 kg per hectare respectively. The total amount of water and electricity used for pumping was different for all treatments.

Table 2. Quantity of inputs and outputs per unit hectare in wheat production.

| Energy       | Input/Output | Energy Equivalent (MJ unit⁻¹) | Farmer | T1  | T2  | T3  | T4  | T5  | T6  |
|--------------|--------------|-------------------------------|--------|-----|-----|-----|-----|-----|-----|
| Inputs       | Human Labor  | h                             | 1.96   | 85  | 85  | 85  | 85  | 85  | 85  |
|              | Machinery    | h                             | 62.7   | 20  | 20  | 20  | 20  | 20  | 20  |
|              | Diesel Fuel  | L                             | 56.31  | 50  | 50  | 50  | 50  | 50  | 50  |
|              | Chemical Fertilizers (a) Nitrogen | kg                  | 66.14  | 104 | 104 | 104 | 104 | 104 | 104 |
|              |              | (b) Phosphorous               | 12.44  | 212 | 212 | 212 | 212 | 212 | 212 |
|              |              | (c) Potassium                 | 11.15  | 129 | 129 | 129 | 129 | 129 | 129 |
|              | Herbicides   | kg                            | 238    | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
|              | Water        | m³                            | 1.02   | 3500| 2320| 2270| 2120| 2250| 2150|
|              | Electricity  | kWh                           | 11.93  | 618.136| 409.712| 400.882| 374.392| 397.35| 397.35|
|              | Seeds        | kg                            | 14.7   | 125 | 125 | 125 | 125 | 125 | 125 |
| Outputs      | Wheat Grain Yield | kg                        | 14.7   | 3400| 4350| 4240| 3940| 4030| 3670|
|              | Wheat Straw Yield | kg                     | 9.25   | 12,010| 12,500| 12,280| 12,050| 12,120| 11,810| 11,550|

As can be seen in Table 3, the total amount of energy consumed directly or indirectly in wheat production was in the range of 21,224.29 MJ/ha–24,132.15 MJ/ha. Pumping water for irrigation was the highest energy consumption input for wheat production after chemical fertilizers. T1 (30% MAD) and T4 (20 mm CPE) treatments saved 33.72% and 35.72% energy, respectively, compared to farmers’
practice, due to water being saved. T1 and T4 treatments increased energy output by 11.40% and 6.38% respectively, compared to farmers’ practice, in terms of grain yield and biological yield.

The energy indices such as net energy, energy use efficiency, energy productivity, specific energy and water productivity for wheat production in the study area are shown in Table 4. The highest net energy (155,557.95 MJ ha⁻¹), energy use efficiency (7.478), energy productivity (0.181 kg MJ⁻¹) and water productivity (1.875 kg m⁻³) were achieved with T1 (30% MAD); however, the highest specific energy (8.148 MJ kg⁻¹) was achieved with farmers’ practice. The highest energy use efficiency (energy output to input ratio) was obtained with the T1 treatment (7.478) while the lowest energy use efficiency was obtained with farmers’ practice, showing the effective use of inputs. A study in Turkey reported the wheat output/input ratio as 2.8 [19]. Another research calculated the energy output/input ratio as 2.9, 4.0, 4.2 and 5.2 at different locations in India [20]. The highest specific energy (8.148 MJ kg⁻¹) was achieved with farmers’ practice, showing the amount of energy used to produce a unit of marketable product. The two more studies also concluded that the specific energy for wheat production as 5.24 MJ kg⁻¹ and 6.36 MJ kg⁻¹ respectively [17,19].

### Table 3. Energy consumption and production in wheat production.

| Energy          | Total Energy Equivalent (MJ/ha) |
|-----------------|---------------------------------|
| Input           | Farmer | T1  | T2  | T3  | T4  | T5  | T6  |
| 1. Human Labor  | 166.6  | 166.6| 166.6| 166.6| 166.6| 166.6| 166.6|
| 2. Machinery    | 627    | 627  | 627  | 627  | 627  | 627  | 627  |
| 3. Diesel Fuel  | 2815.5 | 2815.5| 2815.5| 2815.5| 2815.5| 2815.5| 2815.5|
| 4. Chemical Fertilizers |     | (a) Nitrogen | 6878.56 | 6878.56 | 6878.56 | 6878.56 | 6878.56 | 6878.56
|                 | (b) Phosphorous | 2637.28 | 2637.28 | 2637.28 | 2637.28 | 2637.28 | 2637.28 |
|                 | (c) Potassium   | 1438.35 | 1438.35 | 1438.35 | 1438.35 | 1438.35 | 1438.35 |
| 5. Herbicides   | 357    | 357  | 357  | 357  | 357  | 357  | 357  |
| 6. Water        | 3570   | 2366.4| 2315.4| 2162.4| 2295 | 2193 | 2295 |
| 7. Electricity  | 7374.36| 4887.864| 4782.522| 4466.497| 4740.386| 4529.702| 4740.386|
| 8. Seeds        | 1837.5 | 1837.5| 1837.5| 1837.5| 1837.5| 1837.5| 1837.5|
| **Total energy input (MJ ha⁻¹)** | 27,702.15 | 24,012.05 | 23,855.71 | 23,386.69 | 23,793.17 | 23,480.49 | 23,793.17 |

| Output          | Farmer | T1  | T2  | T3  | T4  | T5  | T6  |
|-----------------|--------|-----|-----|-----|-----|-----|-----|
| 1. Grain Yield  | 49,980 | 63,945| 62,328| 57,918| 59,241| 53,949| 48,804|
| 2. Straw Yield  | 111,092.5 | 115,625| 113,590| 111,462.5| 112,110| 109,242.5| 106,837.5|
| **Total energy output (MJ ha⁻¹)** | 161,072.5 | 179,570 | 175,918 | 169,380.5 | 171,351 | 163,191.5 | 155,641.5 |

### Table 4. Analysis of energy indices in wheat production.

| Indices         | Farmer | T1  | T2  | T3  | T4  | T5  | T6  |
|-----------------|--------|-----|-----|-----|-----|-----|-----|
| Net Energy (MJ ha⁻¹) | 133,370.35 | 155,557.95 | 152,062.29 | 145,993.81 | 147,557.82 | 139,711.01 | 131,848.32 |
| Energy Use Efficiency | 5.814 | 7.478 | 7.374 | 7.243 | 7.202 | 6.950 | 6.541 |
| Energy Productivity (kg MJ⁻¹) | 0.123 | 0.181 | 0.178 | 0.168 | 0.169 | 0.156 | 0.139 |
| Specific Energy (MJ kg⁻¹) | 8.148 | 5.520 | 5.626 | 5.936 | 5.904 | 6.398 | 7.167 |
| Water productivity (kg m⁻³) | 0.971 | 1.875 | 1.868 | 1.858 | 1.791 | 1.707 | 1.475 |

### 3.3. Economic Analysis

The energy analysis helps to plan in such a way as to reduce or increase energy productivity. Energy savings provide essential but not satisfactory economic benefits. A system of energy-saving production practices may not necessarily bring more economic benefits. A combined economic and
energy analysis of the production system may be more comprehensive and lead to the best management strategies. The economic analysis for wheat production under different irrigation schedules is shown in Table 5. The maximum benefit to cost ratio was obtained with the T1 treatment. The results illustrate that irrigation timing and amount alone create a significant difference in net returns. Therefore, decisions on when and how much to irrigate are critical, especially under water scarcity conditions.

### Table 5. Cost analysis (PKR) for wheat crop (per hectare) for Faisalabad, Pakistan, 2014–2015.

| Treatments            | Farmer | T1   | T2   | T3   | T4   | T5   | T6   |
|-----------------------|--------|------|------|------|------|------|------|
| **INPUT:**            |        |      |      |      |      |      |      |
| 1. Seed (a)           | 2335   | 2335 | 2335 | 2335 | 2335 | 2335 | 2335 |
| 2. Fertilizers        |        |      |      |      |      |      |      |
| - Urea (b)            | 4150   | 4150 | 4150 | 4150 | 4150 | 4150 | 4150 |
| - DAP (c)             | 9880   | 9880 | 9880 | 9880 | 9880 | 9880 | 9880 |
| - MOP (c)             | 17,000 | 17,000 | 17,000 | 17,000 | 17,000 | 17,000 | 17,000 |
| 3. Spray              |        |      |      |      |      |      |      |
| - Topic               | 250    | 250  | 250  | 250  | 250  | 250  | 250  |
| - Bacterial Super     | 1350   | 1350 | 1350 | 1350 | 1350 | 1350 | 1350 |
| 4. Irrigation (Energy cost) (d) | 3300 | 2186 | 2152 | 1996 | 2120 | 2026 | 2120 |
| 5. Fuel (Bed preparation + Sowing + Threshing) (e) | 18,500 | 18,500 | 18,500 | 18,500 | 18,500 | 18,500 | 18,500 |
| 6. Labor              | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 | 15,000 |
| **Total Cost of Production** | 71,765 | 70,651 | 70,617 | 70,461 | 70,585 | 70,491 | 70,585 |
| **OUTPUT:**           |        |      |      |      |      |      |      |
| 1. Grain Yield (f)    | 110,500| 141,375 | 137,800 | 128,050 | 126,425 | 119,275 | 103,675 |
| 2. Straw Yield (g)    | 60,050 | 62,500 | 61,400 | 60,250 | 60,600 | 59,050 | 57,750 |
| **Total Value of Production** | 170,550 | 203,875 | 199,200 | 188,300 | 187,025 | 178,325 | 161,425 |
| **Net Return**        | 98,785 | 133,224 | 128,583 | 117,839 | 116,425 | 107,834 | 90,840 |
| **Benefit to Cost Ratio (--)** | 1.38 | 1.88 | 1.82 | 1.67 | 1.65 | 1.53 | 1.29 |

(a) @ PKR 33 per kg; (b) @ PKR 40 per kg; (c) @ PKR 80 per kg; (d) @ PKR 8 per kWh; (e) @ PKR 86 per liter; (f) @ PKR 1300 per mond; (g) @ PKR 200 per mond.

### 4. Conclusions

This study has illustrated trends in the consumption pattern with regard to energy and water in wheat production under different irrigation schedules based on the percent of MAD and CPE in Faisalabad, Punjab, Pakistan. The results show that the soil moisture-based treatment (at 30% MAD) gave 7.94% and 27.94% more yield compared to climate-based treatments (20 mm CPE) and farmers’ practice respectively. Pumping water for irrigation was the highest energy consumption input for wheat production after chemical fertilizers. T1 (30% MAD) and T4 (20 mm CPE) treatments saved 33.72% and 35.72% energy, respectively, compared to farmers’ practice, due to water being saved. T1 and T4 treatments increased energy output by 11.40% and 6.38%, respectively, compared to farmers’ practice, in terms of grain yield. Economic analysis also showed that the maximum benefit to cost ratio was attained with the T1 treatment (30% MAD). Energy input in terms of irrigation water is the most important energy input in arid and semi-arid regions. Overuse and mismanagement of limited water resources may raise huge concern regarding agricultural production quantity and quality. Hence, the precise application of irrigation water at the proper time can be considered as an effective and simple approach to conserve water with minimal environmental effect and less cost.

### References

1. Pakistan Economic Survey, 2013–2014. Agricultural Statistics. Chapter 2. Available online: http://www.finance.gov.pk/survey/chapters_14/02_Agriculture.pdf (accessed on 3 June 2014).
2. GoP. Pakistan Economic Survey 2011–2012; Ministry of Finance, Government of Pakistan: Islamabad, Pakistan, 2013; pp. 19–21.
3. Rajaram, S.; Hobbs, P.R.; Heisey, P.W. Review of Pakistan’s Wheat and Maize Research Systems; Report Submitted to PARC by a Multidisciplinary Team of CIMMYT Scientists Visited Pakistan: Palo Alto, CA, USA, 1998.
4. Shahamat, E.Z.; Asoodar, M.A.; Marzban, A.; Abdeshahi, A. Energy Efficiency Analysis of Wheat Crop under Different Climate and Soil Based Irrigation Schedules. *Int. J. Agric. Crop Sci.* 2013, 5, 249–252.

5. Shahan, S.; Jafari, A.; Mobli, H.; Rafiee, S.; Karimi, M. Energy use and Economical analysis of wheat production in Iran: A case study from Ardabil province. *J. Agric. Technol.* 2008, 4, 77–88.

6. Moghimi, M.R.; Alasti, B.M.; Drafshi, M.A.H.; Ghadim, M.A.; Taki, M. Energy consumption and assessment of econometric model between input and output for wheat production in Gove County, Kordestan Province of Iran. *Int. J. Agric. Crop Sci.* 2013, 5, 2297–2302.

7. Mirasi, A.; Mousarrezaamadi, K.E.; Taghipoor, M.B. An assessment of energy efficiency for wheat production in Iran. *Elixir Agric.* 2014, 72, 25440–25444.

8. Zahedi, M.; Eshghizadeh, H.R.; Mondani, F. Energy use efficiency and Economical analysis in cotton production system in an arid region: A case study for Isfahan Province, Iran. *Int. J. Energy Econ. Policy* 2014, 4, 43–52.

9. Samavatean, N.; Rafiee, S.; Mobli, H. An analysis of energy use and estimation of a mechanization index of garlic production in Iran. *J. Agric. Sci.* 2010, doi:10.5539/jas.v3n2p198.

10. Jadida, S.R.; Homayounifar, M.; Sabun, M.S.; Mohammadi, A. Energy analysis and optimization of inputs for wheat production in Marand region. *Indian J. Agric. Sci.* 2012, 82, 21–24.

11. Taki, M.; Abdi, R.; Akbarpour, R.; Mobtaker, H.G. Energy inputs—Yield relationship and sensitivity analysis for tomato greenhouse production in Iran. *Agric. Eng. Int. CIGR J.* 2013, 15, 59–67.

12. Mohammadi, A.; Omid, M. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. *Appl. Energy* 2010, 87, 191–196.

13. Mohammadi, A.; Tabatabaeeefar, A.; Shahin, S.; Rafiee, S.; Keyhani, A. Energy use and Economical analysis of potato production in Iran a case study: Ardabil province. *Energy Coners. Manag.* 2008, 49, 3566–3570.

14. Erdal, G.; Esengün, K.; Erdal, H.; Gündüz, O. Energy use and Economical analysis of sugar beet production in Tokat province of Turkey. *Energy* 2007, 32, 35–41.

15. Mobtaker, H.G.; Akram, A.; Keyhani, A. Energy use and sensitivity analysis of energy inputs for alfalfa production in Iran. *Energy Sustain. Dev.* 2012, 16, 84–89.

16. Singh, J.M. On Farm Use Pattern in Different Cropping Systems in Haryana, India. Master’s Thesis, International Institute of Management, University of Flensburg, Flensburg, Germany, 2002.

17. Azarpour, E. Determination of energy balance and energy indices in wheat production under watered farming in north of Iran. *ARPN J. Agric. Biol. Sci.* 2012, 7:250-255.

18. Khalilian, A.; Han, Y.; Farahani, H. *Site-Specific Irrigation Management in Coastal Plain Soils*; Clemson University: Clemson, SC, USA, 2007.

19. 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 Coners. Manag.* 2005, 46, 655–666.

20. Singh, H.; Singh, A.K.; Kushwaha, H.L.; Singh, A. Energy consumption pattern of wheat production in India. *Energy* 2007, 32, 1848–1854.

© 2018 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).