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# A Case Study of Energy Ratio in Agro-Forestry Systems (Date Palm and Wheat)

**Barabadi, S. A.*** **and Pourjafar, M.**

Higher Educational Complex of Saravan, Department of Agricultural Extension and Education, Saravan, Iran.

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**Abstract** Agroforestry system has good ecological, social and economic benefits in comparison with traditional forestry. Some of these benefits incloude savings in energy consumption. The aim of this study was to evaluate the energy efficiency in agroforestry systems of date and wheat. Statistical sample of this study was 132 gardens of date which have the date and wheat agroforestry that selected randomly in the province of Sistan and Baluchestan. The data related to the input and output pertinent to the agricultural year of 2011-2012 were obtained from the farmers by structured questionnaires. The results showed that in the system of agroforestry of date and wheat, the total energy inputs are 53262.36 MJ ha and the total energy outputs are 129614.05 MJ ha. Therefore, the energy ratio was calculated 2.43 in agroforestry system and 4.20 in the date monoculture system. This may be due to the use of chemical fertilizers in the wheat farming. The results also revealed that in date and wheat agroforestry, a cycle between human, livestock and plant is created while the rise in biodiversity and the farmers' income. In addition to provide part of the required forage, it reduces the waste.

**Keywords:** Agroforestry system, energy ratio, date palm, wheat, Sistan and Baluchestan

## Introduction

In the current era that productivity and efficiency issues are very important, and according to the conditions in Iran, planting of date palms (*Phoenix dactylifera* L.) alone may not be affordabe. Therefore, planting crops such as wheat in row spacing of dates in agroforestry systemcan help supply some of the nutritional needs, biodiversity, prevent of pests and disease, and also increase input use efficiency.Agroforestry is multifunctional, environmentally sustainable, and required minimum cultivating operations.Agroforestry increases the crop production through a combination of annual agricultural plants with perennial woody plants or livestock on a piece of land as well as economic, cultural, environmental and cultural profits. Nautiyal *et al.* (1998) have a study about agroforestry in India. This study was

* **Corresponding author**: Barabadi, S. A.; **Email:** barabadi.a@gmail.com

done in different types of forestry systems and the results showed that per ha annual energy input in simultaneousagroforestry system was 305267 MJ compared to 279 MJ in sequential agroforestry and 27047MJ in home garden. In monetary terms, highest per ha annual output was obtained fromsimultaneous agroforestry (Rs 25370, Rs 35 = US$1) followed by home garden (Rs 18200) andsequential agroforestry (Rs 9426).Energy output/input ratio of simultaneous agroforestry systems were 0.63.

Thevathasan *et al.* (2004), report that tree-based intercroppingwith soybean, corn, and either winter wheat or barley, can transfer nitrogen (N) from fall-shed leaves to adjacent crops with enhanced soil nitrificationapproximately 5 kg $ha^{-1}$. They showed major changes in the flow of energy within the trophic structure identified with intercropping systems. Gordon and Newman (1997) and James *et al*. (1995), observed in several experiments that in dry condition, Leucaenatree competes well in mixed cultivation with plants such as millet, sorghum, peanuts and corn.

Tuomisto *et al.* (2012) in their study compared energy and greenhouse gas (GHG) balances and biodiversity impacts of different farming systems by using life cycle assessment (LCA) accompanied by an assessment of alternative land uses. Farm area and food product output were set equal across all of the farm models, and any land remaining available after the food crop production requirement had been met was assumed to be used for other purposes. Three different management options for that land area were compared: *Miscanthus* energy crop production, managed forest and natural forest. The results illustrated the significance of taking into account the alternative land use options and suggest that integrated farming systems have potential to improve the energy and GHG balances and biodiversity compared to both organic and conventional systems. Sensitivity analysis shows that the models are most sensitive for crop and biogas yields and for the nitrous oxide emission factors.

Jianbo (2006) reported in his study of two types of agroforestry with Paulownia Tree (Pauliwaniaelongta S. Y.HU) in the north of China and Tea (Camellia sinensis) in the southof China, it was observed that the ratio of energy input to output and the economic income in agroforestry of Paulownia, increased 9.45 and 7.56 respectively, compared with the system in which there is no tree. Also the energy input to output ratio and the economic income in agroforestry of Tea had been increased 18.7 and 64.29 percent respectively, compared to the traditional system (without the system of agricultural forest).

In the systems of agricultural forest, each tree has had a significant impact on ecosystem inanimate condition due to its size, rooting depth and permanent nature and involves in many interactions between organisms. Furthermore, the tree limits the water and wind erosion, provides shade and branches for the livestock, forms micorizaee community, moderates the soil temperature and reduces evaporation and transpiration. The mixture of species and the difference in the time of flowering and ripening of the fruits, cause that the cropalways exists for harvesting all the year and also food resources and income are guaranteed for the entire year.

As one of the most important gardening crops in more than 30 countries around the world, the date is produced more than 4/5 million tons per year. Iran is one of the major countries in date production and produces more than 900 thousand tons of date annually (Mazloumzadeh *et al.*, 2010). The role and importance of date in the industry is noteworthy, so that in the division of agricultural products, the date is often placed among industrial plants. In Sistan and Baluchestan Province, the date annual production is over than 140 thousand tons. Farmers in the regions of Sistan and Baluchestan usually consider the spaces in the cultivation of date trees about six meters; this matter causes that the light does not reach to the lower layers.Wheat is the most important source of carbohydrate in a majority of countries, and is the primary food staple in North Africa and the Middle East, with growing popularity in Asia. In the Central and West Asia and North Africa (CWANA) region, per capita annual human wheat consumption is the highest in the world globally, wheat is the leading source of vegetable protein in human food, having higher protein content than either maize or rice, the other major cereals.Wheat is also planted to a limited extent as a forage crop for livestock, and its straw can be used as a construction material for roofing thatch.It also increases the use efficiency of inputs and the farmers' income and results in the higher resistance of the production ecosystems in these regions. So this research was done with the aim of the calculation of energy flow in a production system of date and wheat agroforestry in the region of Baluchestan.

## Materials and methods

### *GeoghraphicCharacteristics of the Location under Study*

This study was donein Sistan and Baluchestan Province of Iran.This province is the largest in Iran, with an area of 187502 $km^2$and a population of 2.4 million. It is in the southeast of the country, and located in a distance of 25 to 31 degrees north and 58 to 63 degrees east.

The dominant climate is desert and semi-desert, the average annual rainfall is between 110 to 120 mm and the average annual temperature is between 22 and 37 degrees centigrade.

### *Data Collecting and the Calculation Methods*

The data using in this research were collected from the gardens of dates and wheat in some important cities of Sistan and Baluchestan. So 132 date gardens which have the date and wheat agroforestry were chosen randomly in these areas.The data related to input and output wheat pertinent to the agricultural year 2011-12 were obtained in the form of questionnaires from the farmers. The data related to the type of inputs and the energy equivalents are shown for each group of inputs in Table 1.

**Table 1.** Energy equivalents of different input and output values used in low input system in date palm production

| Particulars | Unit | Energy equivalents (MJ/ unit) |
|---|---|---|
| **A. Input** | | |
| **Human labor** | H | 1.96 |
| **Machinery** | H | 62.70 |
| **Chemical fertilizers** | | |
| **Nitrogen** | Kg | 60.60 |
| **Phosphorus** | Kg | 11.10 |
| **Potassium** | Kg | 6.70 |
| **Manure** | Kg | 0.3 |
| **Pesticides** | Kg | 199 |
| **Fungicides** | L | 92 |
| **Herbicides** | Kg | 238 |
| **Diesel-oil** | L | 56.31 |
| **Water for irrigation** | $m^3$ | 0.63 |
| | | |
| **B. Output** | | |
| **Date palm** | kg | 18.76 |

The amount of energy consumption in each group of inputs was calculated from the multiplication of the amount of the input use and its energy equivalent per unit (extracted from scientific sources). Then on the basis of input and output energy, the amounts of the energy use efficiency, energy productivity, specific energy and net energy were obtained according to the following equations:

1) Energy use efficiency = energy output ($MJ.ha^{-1}$) / Energy input ($MJ.ha^{-1}$)

2) Energy productivity = yield of wheat ($kg.ha^{-1}$) / Energy input ($MJ.ha^{-1}$)

3) Specific energy = energy input ($MJ.ha^{-1}$) / Yield of wheat ($kg.ha^{-1}$)

4) Net energy = energy output ($MJ.ha^{-1}$) – Energy input ($MJ.ha^{-1}$)

Also the share of direct energies (including human power, fossil fuels, and irrigation water), indirect (including seed, consumer chemicals, and machinery), renewable energies (man power and seed), non-renewable (fossil fuels, fertilizers and chemicals, water and machinery) was calculated (Beheshti Tabar *et al*., 2010; Ozkan *et al.*, 2004; Lin *et al*., 2013).

## Results and discussion

Agroforestry is the most important system of date production in the region of Sistan and Baluchestan. Farmers of this area often use annual plants such as wheat, barley and vegetables like lettuce under the palm tree for farming. The use of chemical fertilizers in the date production is not common in this area and mostly livestock manure is used. There just moldboard plow is used for earthwork operations and other cultivation operations and garden construction is done traditionally and in fighting with weeds also revertible plow is often used. Though mozafati date is valuable economically, but due to the fairly good resistance of this kind of date against diseases, the use of fungicides is not common. The most important pest of this region is the date weevil and the farmers force to use toxins to fight with this pest.

Table 2 showed the amounts of inputs, date performance andtheir energy equivalents. The total amount of inputs for the date production was about 20524.35 MJ ha in a year. On the contrary to the other production systems, the energy obtained from the chemical fertilizers was zero in this system. The amount of used livestock manure was about 12 percent of the total energy inputs. Machinery and fossil fuels was about 47 percent of the total energy inputs which was more used for earthwork operations, the transportation of livestock manure and the products in the farm. The consumed water was about 30.70 percent and the manpower 7.91 percent that devoted about 3.20 of the total energy inputs according to the harvest by hand and other common operations in the garden was about 4.71 percent. Machinery was 1.83 percent and meanwhile the land preparation operations devoted the most amount of energy.

And eventually to combat with date weevil, the use of pesticides includes 1.17 percent of the total energy inputs. The average date performance and the total energy inputs were 4600 kg ha and 20524.35 MJ ha respectively. The amount of total energy output was 86296 MJ ha and the energy use efficiency was 4.20 in this production system.

**Table 2**. Energy consumption and energy input-output relationship for date palm production

| Energy | Unit | Quantity per unit area (ha) | Energy equivalent (MJ/unit) | Total energy equivalent (MJ) | Percentage of total energy input or output (%) |
|---|---|---|---|---|---|
| **A. Input** | | | | | |
| **Human labor** | H | 828 | 1.96 | 1622.88 | 7.91 |
| **a.Land preparation** | H | 104 | 1.96 | 203.84 | 0.99 |
| **b.Cultural practices** | H | 389 | 1.96 | 762.44 | 3.72 |
| **c. Harvesting** | H | 335 | 1.96 | 656.60 | 3.20 |
| **Machinery** | H | 5.99 | 62.70 | 375.58 | 1.83 |
| **a.Land preparation** | H | 2.55 | 62.70 | 159.89 | 0.78 |
| **b.Cultural practices** | H | 1.54 | 62.70 | 96.56 | 0.47 |
| **c. Transportation** | H | 1.90 | 62.70 | 119.13 | 0.58 |
| **Chemical fertilizers** | H | | | | |
| **Nitrogen** | Kg | - | 60.60 | - | - |
| **Phosphorus** | Kg | - | 11.10 | - | - |
| **Potassium** | kg | - | 6.70 | - | - |
| **Manure** | Kg | 8200 | 0.30 | 2460 | 11.99 |
| **Pesticides** | L | 1.2 | 199.00 | 238.80 | 1.17 |
| **Fungicides** | Kg | - | 92.00 | - | - |
| **Herbicides** | L | - | 238.00 | - | - |
| **Diesel-oil** | L | 169.19 | 56.31 | 9527.09 | 45.43 |
| **Waterfor irrigation** | $m^3$ | 10000 | 0.63 | 6300 | 30.70 |
| **Total energy input** | MJ | | | 20524.35 | |
| **B. Output** | | | | | |
| **Date palm** | kg | 4600 | 18.76 | 86296 | 100 |
| **Energy input-output ratio** | | | | 4.20 | |

The most amount of input use in wheat cultivation was related to chemical fertilizers, devoted 30.9 percent of the total energy input. Ziaei *et al.*(2013) also obtained similar results pertinent to the share of chemical fertilizers in Sistan and Baluchestan. The most amount of consumed energy in chemical fertilizer was related to Nitrogen (26.64 percent) and phosphorus fertilizer includes 2.54 percent and potassium fertilizer includes 1.72 percent of the total energy input. Also Fossil fuels include 25.65 percent, seed 18.11 percent, livestock manure 10 percent and work force 1.32 percent of energy input. The total energy inputs and energy outputs were respectively 32738.01 MJ ha and 43345.05 MJ ha and the energy use efficiency was estimated 1.32 (Table 3).

**Table 3.** Energy consumption and energy input-output relationship in wheat production

| Energy | Unit | Quantity per unit area (ha) | Energy equivalent (MJ unit -1) | Total energy equivalent (MJ) | Percentage of total energy input or output (%) |
|---|---|---|---|---|---|
| **A. Inputs** | | | | | |
| **Human labor** | H | 220.40 | 1.96 | 431.98 | 1.32 |
| **Machinery** | H | 40.53 | 62.70 | 2541.23 | 7.76 |
| **Diesel fuel** | L | 167.20 | 50.23 | 8398.46 | 25.65 |
| **Chemical fertilizers** | kg | | | | |
| **Nitrogen (N)** | kg | 115.57 | 75.46 | 8720.91 | 26.64 |
| **Phosphate (P2O5)** | kg | 63.54 | 13.07 | 830.47 | 2.54 |
| **Potassium (K2O)** | kg | 50.56 | 11.15 | 563.74 | 1.72 |
| **Herbicide** | L | 2.08 | 238 | 495.04 | 1.51 |
| **Pesticide** | L | 1.50 | 280.44 | 421.35 | 1.29 |
| **Fungicide** | kg | 0.33 | 181.90 | 60.03 | 0.19 |
| **Water for irrigation** | m3 | 4260.10 | 1.02 | 4345.30 | 13.27 |
| **Seeds (wheat)** | kg | 295.40 | 20.10 | 5929.50 | 18.11 |
| **Total energy input** | MJ | - | - | 32738.01 | |
| **B. Outputs** | | | | | |
| **Wheat grain yield** | kg | 2487.41 | 14.48 | 36017.70 | 83.09 |
| **Wheat straw yield** | kg | 3256.60 | 2.25 | 7327.35 | 16.91 |
| **Total energy output** | MJ | - | - | 43345.05 | |
| **Energy input-output ratio** | | | | 1.32 | |

In date andwheat agroforestry the total energy inputs was equal to 53262.36 MJ ha and the total energy outputs was estimated 129614.05 MJ ha and the energy use efficiency was determined 2.43. It is considered that according to the entering of wheat, the energy use efficiency fell due to the using of chemical fertilizers in wheat production in this region. It was observed in other studies that the most important energy challenge in the discussion of wheat production is the using of chemical fertilizers especially Nitrogen fertilizers. Like the results of this study, it was also demonstrated in the research of Hossein Panahi *et al*. (2012) and Ghorbani *et al.* (2011) that the Nitrogen fertilizer devoted the most amount of energy consumption among chemicals. Though Nitrogen fertilizer has a vital role in the growth and function of the plants, but has always been considered as a serious challenge in relation to energy consumption in agriculture. According to above issues it can be inferred that though the energy use efficiency fell about twounit with the wheat enters into date production system, but in return, it increased the biodiversity and created a cyclic system between human, livestock and plant in addition to the increase in the operation and farmers' income. This matter reduces the waste while provided part of the required forage.

The rate of energy productivity in date and wheat agroforestry was obtained 0.13 (table 4). This means that per unit energy consumption in this production system, 0.13 operation unit is obtained. The amount of energy efficiency for different plants was reported 0.06 in the resources, 0.10 for wheat, 0.19 for barley, 1 for tomato, 0.06 for cotton and 1.53 for sugar beet. Energy productivity is almost a much more suitable parameter for the comparison of two different regions from the viewpoint of the plant production compared to energy use efficiency, because the difference in the rate of energy efficiency can be due to both the difference in energy input and function and this makes the judgment bit difficult, but the energy productivity index calculates the ratio of production operation per kilogram into energy consumption and demonstrates the difference between two areas much better.

**Table 4.** Energy input-output ratio in wheat and date production

| **Items** | **Unit** | **Date palm** | **Wheat** | **Agroforestry** |
|---|---|---|---|---|
| **Energy input** | MJ $ha^{-1}$ | 20524.35 | 32738.01 | 53262.36 |
| **Energy output** | MJ $ha^{-1}$ | 86296 | 43345.05 | 129614.05 |
| **Energy use efficiency** | - | 4.20 | 1.32 | 2.43 |
| **Specific energy** | MJ $kg^{-1}$ | 4.46 | 13.16 | 7.51 |
| **Energy productivity** | kg $MJ^{-1}$ | 0.22 | 0.08 | 0.13 |
| **Net energy** | MJ $ha^{-1}$ | 65771.65 | 10607.04 | 76351.69 |

The amount of specific energy and net energy in the date and wheat agroforestry and the date pure cultivation was calculated 7.51 MJ ha and 4.46 MJ ha per kilogram of date (Table 4). Kankani *et al.* (2005) reported the amount of specific energy 5.54 for wheat, 11.24 for cotton, 3/88 for corn, 16.21 for sesame, 1.14 for tomato, 0.98 for melon and 0.97 for watermelon. The specific energy was the reversal of the energy productivity so its low rates reveal that less energy is used for the production of per unit operation.

The rate of direct, indirect, renewable and non-renewable energies in date gardens were obtained 85.02, 14.98, 38.60 and 61.40 percent respectively; for the date and wheat agroforestry, the amounts were 89.02, 65.80, 54.15 and 45.85 respectively (Table 5). These results reveal that the share of renewable energies in date production in monoculturesystem was about 15.5 percent lower than the date and wheat agroforestry that this issue reveals agriculture in Iran is too much dependent to non-renewable energies (about 87 percent) (Beheshti Tabar *et al.,* 2010).

**Table 5.** Total energy input in the form of direct, indirect, renewable and non-renewable energy for wheat and date palm

| **Types of energy** | **Date palm** (MJ ha $^{-1}$) | **%** [a] | **Wheat** (MJ ha $^{-1}$) | **%** | **Agroforestry** (MJ ha $^{-1}$) | **%** |
|---|---|---|---|---|---|---|
| **Direct energy** [b] | 17449.97 | 85.02 | 13175.74 | 40.25 | 30625.71 | 89.02 |
| **Indirect energy** [c] | 3074.38 | 14.98 | 19562.27 | 59.75 | 22636.65 | 65.80 |
| **Renewable energy** [d] | 7922.88 | 38.60 | 10706.78 | 32.70 | 18629.66 | 54.15 |
| **Non-renewable energy** [e] | 12601.47 | 61.40 | 22031.23 | 62.29 | 15772.28 | 45.85 |
| **Total energy input** | 20524.35 | | 32738.01 | | 34401.94 | |

[a]Indicate percentage of total energy input.
[b]Indicates human labor, diesel and water.
[c]Indicates seeds, chemical fertilizers (NPK), herbicide, pesticide, fungicide and machinery.
[d]Indicates human labor, seeds and water.
[e]Indicates diesel, chemical fertilizers (NPK), herbicide, pesticide, fungicide and machinery.

According to the results of other studies in Iran, the share of non-renewable energies in the common production of potato, greenhouse cucumber, sugar cane, barley, and pea has been reported 24.72 (Mohammadi *et al.,* 2008) and 78.52 (Hosseinpanahi and Kafi, 2012), 89.07 (Mohammadi and Omid, 2010), 90.08 (Karimi *et al.*, 2008), 65.61 (Mobtaker *et al.*, 2010) and 86.7 percent (Salimi and Ahmadi, 2010) respectively, which are high values.

The high consumption of non-renewable energies will reduce the energy use efficiency of the production systems because chemical production and using of machinery as the main index of common systems require high energy consumption (Pimentel, 1983). According to the report of Moore (2008) to achieve a sustainable system of food production, the amount of energy efficiency and the share of renewable energies should be increased in agricultural systems. Undoubtedly in present time to feed a growing world population is almost difficult and perhaps impossible without the use of non-renewable energies. But considering the environmental impacts of the use of chemicals and fossil fuels, agricultural experts will have no choice but to increase the sustainability in agriculture and the share of renewable energies in the production system. Resorting to decreased plow, using combined devices to reduce car traffic machinery, using natural fertilizers instead of chemical ones, returning remains and resorting to precise agriculture which is based on the exact consumption of inputs, are the ways that the authorities should consider in order to increase the agricultural sustainability.

## Conclusion

Totally the results of this study demonstrated that though the energy use efficiency in date production in the date and wheat agroforestry was less than date monoculture system, but instead it increased the biodiversity and created a cyclic system between human, livestock and plant in addition to the increase in the operation and farmers' income. In this production system the energy use efficiency can be increased and the share of non-renewable energies can be decreased while much more consumption of livestock manures in wheat production can be promoted. Moreover other plants such as alfalfa can be used in production systems with the increase in planting spaces from 6 to 8 meter.

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