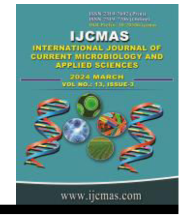
EXCELLENT PUBLISHERS

Int.J.Curr.Microbiol.App.Sci (2024) *13*(03): 276-286

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 13 Number 3 (2024)**
Journal homepage: http://www.ijcmas.com



Original Research Article https://doi.org/10.20546/ijcmas.2024.1303.027

Assessment of Energy Consumption and Production in Surface, Sprinkler, and Tape Irrigation Systems for Potato Farming

Rahim Alimohammadi Nafchi*

Agricultural Engineering Research Department, Chaharmahal and Bakhtiari Agricultural and Natural Resources Research and Education center, AREEO, Shahrekord, Iran
**Corresponding author*

ABSTRACT

Keywords

Different Irrigation Systems, Direct and Indirect Energy, Energy and Water Use Efficiency, Potatoes, Renewable and Non-renewable Energies

Article Info

Received:
01 February 2024
Accepted:
05 March 2024
Available Online:
10 March 2024

This study aimed to evaluate and conserve energy consumption for both input and output per unit area in Shahrekord, Iran, focusing on sustainable potato production. A questionnaire was developed and administered at various stages of potato production, covering planting, growing, and harvesting operations across three different irrigation systems: Surface, Sprinkler, and Tape. Equivalence equations were used to convert the energy consumption metrics per unit area. The average energy consumption and production per unit area were 137089 and 149085 MJ ha^{-1}, respectively. In the surface irrigation system, the values were 95103 and 119118; in the sprinkler irrigation system, they were 141302 and 149273; and in tape irrigation systems, they were 91428 and 156600 MJ ha^{-1}. The mean energy use efficiency index was 1.14 overall, with values of 1.18, 1.06, and 1.71 for surface, sprinkler, and tape irrigation systems, respectively. The average water use efficiency was 5.1 kg per cubic meter, with values of 3.74, 6.25, and 10.6 kg m^{-3} in the respective irrigation systems. Only 0.406, 0.338, and 0.585 kg of potato crop were produced for each megajoule of nonrenewable energy utilized in the mentioned irrigation systems. These results indicate that energy and water use efficiency were high in the tape irrigation system.

Introduction

Increased per capita energy consumption to ensure food security in the community, limited energy resources, failure to address environmental concerns, and future generations' rights have consistently posed challenges. Today, with technological advancements and specific cultural conditions shaping society, the use of non-renewable energy is significantly important. Conversely, agricultural products possess their energy (Esengun, 2007), often experiencing inefficiencies and low energy utilization in this sector due to poor management, stemming from economic, productivity, and utilization issues, traditional and non-specialized functions, and land fragmentation. The potato has substantial food value (in terms of food security) in the world, ranking just after wheat, rice, corn, and barley. It is sensitive to water stress and is crucial in ensuring food security. With limited water resources and population growth, there is an increasing need for optimal water resource management, particularly in the agricultural sector (Djaman *et al.*, 2021). Despite the rising energy consumption in food production systems across various countries, energy consumption has decreased by over 18% due to improved energy efficiency. The food industry in developing countries and agricultural production in developed countries showed the highest productivity (Bajan *et al.*, 2020). Future global challenges include food security, rising demand for food and energy, climate change, and the per capita reduction of water and land resources, necessitating more serious efforts and research (Kannan and Anandhi, 2020). Najafi conducted a study comparing surface and subsurface drip irrigation systems for the Marfona potato variety, finding that the subsurface drip irrigation system at a depth of 15 cm resulted in a maximum yield of 13.15 kg per cubic meter of water consumption, with a significant difference observed at the 5 percent Duncan test (Najafi, 2006).

The subsidy significantly contributes to low productivity in using inputs (such as energy or water resources) within the community. The average water consumption for potato production in Iran is reported as 11603 and 7635 cubic meters per hectare for surface and tape irrigation, with recent systems showing water use efficiency ratings of 1.11 and 2.9 kg per cubic meter of consumed water (Balali, 2008). In assessing potato fields with traditional and mechanized cultivation methods in East Azerbaijan, Iran, the total energy consumption for traditional cultivation was estimated at 60783 MJ per hectare, comprising 44.43 percent direct energies and 55.57 percent indirect energies. Additionally, 46.96 percent of the energy was renewable, while 53.04 percent was non-renewable. The output energy was calculated as 148268 MJ ha-1. The energy efficiency levels in traditional and mechanized systems were determined to be 2.44 and 4.43, respectively. The primary energy inputs in traditional irrigation systems were 24.9 percent for irrigation, 22.36 percent for nitrogen fertilizer, and 19.72 percent for potato seed. In contrast, mechanized irrigation systems used 32.21 percent for irrigation, 19.32 percent for nitrogen fertilizer, and 15.27 percent for machinery (Izadkhah Shishvani, 2010). Another study conducted across various provinces in Iran reported the water use efficiency (WUE) for potatoes as 2.18 kg of product per cubic meter of water utilized (Heydari, 2011), which showed a significant difference from the other treatments at the 5% level (Baghani, 2011). Ebrahimipak in Shahrekord, Iran, calculated the highest potato yield in the treatment by providing 100% water (944 mm) at the rate of 43416 kg ha-1 (Ebrahimipak, 2014). A study conducted in potato fields in Ghoochan, Iran concluded that 22 percent of the potato farmers were at high and good levels regarding optimum energy use. However, most of the inputs are provided in the form of quota which is prices lower than the actual costs. Fertilizers, machinery, seed, and labor accounted for 56%, 19%, 12%, 11%, and 1% of total energy consumption, and their role in production costs are 18%, 6%, 7%, 32%, and 35% (Zare, 2015). In Fariman, Mashhad, Iran, a comparison of soil depths at 10 and 20 cm using surface tapes revealed that surface treatments yielded significantly higher results than other treatments, with a 5% difference (Baghani, 2011). Ebrahimipak in Shahrekord, Iran, found that providing 100% water (944 mm) resulted in the highest potato yield at 43416 kg ha-1 (Ebrahimipak, 2014).

A study in Ghoochan, Iran, indicated that 22% of potato farmers effectively utilized energy, with most inputs acquired below market price. Fertilizers, machinery, seed, and labor accounted for 56%, 19%, 12%, and 11% of total energy consumption, respectively, contributing to 18%, 6%, 7%, and 32% of production costs (Zare, 2015). At the Isfahan University of Technology, it has been confirmed that the total energy utilized in the potato production system is 33648 MJ ha-1, with 65.4% direct energies, 34.7% indirect energies, 33.9% renewable energies, and 66.1% non-renewable energies. The estimated energy output is also 719911 MJ ha-1 (Zahedi, 2015). The primary energy inputs in potato production are diesel fuel at 33.7%, irrigation water at 41.3%, nitrogen fertilizer at 41.1%, and potato seed at 31.2%. Concerning energy production, potatoes yield the highest energy output per hectare, second only to cabbage in terms of produced proteins (Horton and Fano, 1985). Agriculture is the process that produces live energy through the composition and use of various energies (renewable and non-renewable, direct and indirect) (Alam *et al.*, 2005). The utilization of different energies to improve crop productivity, water productivity, and the overall competitiveness of agricultural production was crucial (Khan *et al.*, 2009). In a study evaluating potato farms in Hamedan province, two groups were compared: A) farmers with cultivation machinery and a large cultivated area, and B) farmers without machinery and a small cultivated area. The researchers concluded that the energy consumed by groups A and B is 153071.4 and 157151.2 MJ ha-1, respectively, and the pure energy is 4110.4 and 2242.9 MJ ha-1. The benefit-cost ratios for groups A and B were 1.09 and 0.96, respectively (Zangeneh *et al.*, 2010). In a study conducted in Kerman province (Iran), it was found that the highest potato yield per hectare is 3.93 tons/ha, with a water use efficiency of 19.16 kg m-3 using the tape irrigation system.

Conversely, the lowest yield per hectare is 19.16 Tons/ha, with a water use efficiency of 1.2 kg m-3 using the surface irrigation system (Ghasemi-Sahebi *et al*., 2013). Additionally, Rahbari *et al*. (2013) Reported in Isfahan province that the total energy consumed per hectare of potatoes was 8,936,680 MJ. The energy of the diesel fuel used to provide the required water was maximal and significantly different from the other energy sources at 1 percent (Rahbari, *et al.,* 2013). In Spain, researchers found that supplying 80 percent of the water requirement resulted in a maximum water use efficiency of 11.6 kg m-3, while supplying 60 percent led to a minimum water use efficiency of 7.1 kg m-3 (Camargo *et al*., 2015). In Northern Ethiopia, it was concluded that meeting the water needs for potatoes resulted in a yield and water use efficiency of 18770 kg ha-1 and 2.79 kg m-3, respectively. When 75 percent of the water demand was supplied, the yield and water use efficiency reached 14440 kg ha-1 and 2.86 kg m-3, with the water use efficiency being higher in the second treatment (Kifle and Gebretsadikan, 2016). In Turkey, an analysis of water and energy input in potato irrigation using a drip irrigation system in the Anatolia region estimated the total energy consumption in potato cultivation to be 63222 MJ ha-1, with 62 percent being indirect energies (seeds, fertilizers, machinery, and polyethylene tubes) and 38 percent being positive energies. Irrigation accounted for 43.8 percent of the total energy consumption, with 65 percent being direct energy (Yavuz *et al*., 2016).

Potato is a key and widely used product in terms of input usage. Assessing sustainable agricultural development using energy is an effective method for better planning and economic assessment. Therefore, being informed about energy and water use, as well as energy efficiency, and implementing various programs (short-term, medium-term, and long-term) can help manage product supply while increasing production per unit area through efficient input usage.

Materials and Methods

This study took place in Iran (Chahrmahal and Bakhtiari province) in 2016 for one year. The meteorological data from the synoptic station in Shahrekord, located at an altitude of 2066m above sea level, was utilized. Chaharmahal and Bakhtiari province, with its specific geographical and topographical characteristics, exhibits diverse climate patterns. Rainfall is largely influenced by the Mediterranean and low-pressure systems entering the West and South West zones, impacting the area for 8 months. The Zagros Mountains, perpendicular to the direction of these flows, enhance cyclonic activity and bring intense, heavy rains to the region. The mean annual precipitation is 323 mm, with temperatures ranging from a maximum of 42°C to a minimum of -35°C on the warmest and coldest days of the year. The dry period lasts about six months, with an average relative humidity of 34 percent and an annual evaporation rate of 2575 mm. Shahrekord's climate is classified as semi-arid by the Demartini method, mild cold by the Koppen method with hot and dry summers, and semi-humid with mild summers and very cold winters by the Karimi method. Due to these conditions, most farmers are compelled to rely on underground sources, resulting in significant energy consumption. On the other hand, developing and producing all inputs, both direct and indirect, as well as both renewable and nonrenewable energies, is required. Consequently, all inputs are analyzed by standardizing energy in terms of MJ. Following the observations, 19 farms at varying levels with different irrigation systems (and a willingness to collaborate) are selected, and a composite soil sample depths of 0 to 30 and 30 to 60 cm is taken from the chosen fields to determine the texture, field capacity, and soil wilting point, before being sent to the laboratory. In the fields, the input flow rate to the systems is measured, and the required water is calculated using FAO publications 24 and 56. Throughout the planting-to-harvesting period, a questionnaire containing all planting, growing, and harvesting operations, as well as the consumption of inputs for each farm, is completed with the cooperation of farmers under the measurements and supervision (as much as possible). The following equations and tables convert all operations and inputs to energy equivalents. The energy equivalent of human resources is determined based on completed questionnaires, the number of workers, or the required amount for each stage of planting, growing, and harvesting. Table (1) is then used to calculate the equivalent energy. The measurement indices are then calculated to evaluate the data.

The net energy index indicates the net energy output from the field. A positive index shows that the output energy exceeds the input or consumed energy, while a negative index indicates that the input energy surpasses the output energy, resulting in a lack of energy efficiency.

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

Input energy includes various forms of energy such as plow, disc, seed, irrigation water, electricity, fertilizers, pesticides, necessary machinery, hygroscope, harvesting, transportation, and implementation of irrigation systems, needed human resources, and fossil fuels. These are determined through questionnaires, measurements, and calculations presented in Table 1. The energy output relates to the specific crop being studied, which in this case is potatoes, and the energy equivalence is established using Table 4.

Energy efficiency shows the harvested energy per MJ of energy consumed per hectare. The ratio of this index is higher than 1, indicating higher energy efficiency in the agricultural sector (Sartori *et al.*, 2005).

$$\text{Energy Use Efficiency} = \frac{\text{Energy output}}{\text{Energy input}} = \frac{Mjha^{-1}}{Mjha^{-1}} \quad (2)$$

Economists consider productivity the ratio of outputs to inputs. In other words, productivity is the ability to transform inputs into outputs. The productivity index reflects the output obtained per MJ ha-1 of energy consumption. A larger ratio indicates higher productivity of total energy consumption.

$$\text{Energy Productivity Index} = \frac{\text{Potato output}}{\text{Energy input}} = \frac{Kgha^{-1}}{Mjha^{-1}} = \frac{Kg}{Mj} \quad (3)$$

Specific Energy

$$\text{Specific energy} = \frac{\text{Energy input}}{Yield} = \frac{Mjha^{-1}}{Kgha^{-1}} = \frac{\text{MJ}}{\text{kg}} \quad (4)$$

$$h.p = \frac{\gamma Qh}{75\times e} \quad (5)$$

$h.p$ Power Required to Pump Water (horsepower)

γ Water specific gravity (kg m-3)

h Manometric height (m)

e Pump efficiency (decimal value)

Direct energies equal energies (human labor + diesel fuel + water irrigation). (6)

Indirect energies equal energies (seeds + chemical materials + farmyard manure + machinery). (7)

Renewable energy = equal energies (human labor + seeds + farmyard manure). (8)

Nonrenewable energy = equal energies (diesel fuel + chemical materials and fertilizer + water irrigation + machinery). (9)

Table.1 Input and output equivalent energies in agricultural production

Particulars	unit	Equal energy (MJ ha^{-1})	References
Human labor	h	1.96	(Singh and Mittal, 1992)
Machinery	h	62.7	(Singh and Mittal, 1992)
Diesel fuel	lit	56.31	(Singh and Mittal, 1992)
Chemical fertilizers			
Nitrogen	kg	66.14	(Yilmaz *et al.*, 2005)
Phosphate	kg	12.44	(Yilmaz *et al.*, 2005)
Potassium	kg	11.15	(Yilmaz *et al.*, 2005)
Sulphur	kg	1.12	(Esengun, 2007)
Micronutrients	kg	120	(Strapatsa *et al.*, 2006)
Farmyard manure	kg	0.3	(Demircan *et al.*, 2006)
Poisons			
Herbicide	kg	238	(Ozkan *et al.*, 2007)
Fungicides	kg	92	(Ozkan *et al.*, 2007)
Pesticides	kg	199	(Ozkan *et al.*, 2007)
Water irrigation	M^3	1.02	(Esengun, 2007)
Seeds	kg	3.6	(Esengun, 2007)
Power	kwh	11.93	(Singh and Mittal, 1992)
Polyethylene Pipes			
With D (90 mm)	m	43.6	(Guzman and Alonso, 2008)
With D (63 mm)	m	21.5	(Guzman and Alonso, 2008)
With D (16 mm)	m	3.9	(Guzman and Alonso, 2008)

*The useful life of polyethylene pipes is 10 years.

Water use efficiency

Since the province's water resources are primarily groundwater and direct electricity is needed to access and supply the necessary pressure for irrigation systems, it is possible to save energy by reducing water consumption and improving water use efficiency. The equation for water use efficiency is based on water consumption and yield.

$$Water\ use\ Efficiency = \frac{Yield\ (kg)}{Consumption\ water\ (m^3)} \quad (10)$$

According to equations and tables derived from questionnaires and field measurements, all operations and inputs are converted into energy. The energy from human resources is calculated based on completed questionnaires and the force required for planting, growing, and harvesting, while utilizing tables (3 and 4) to determine equivalent energy.

Statistical calculations

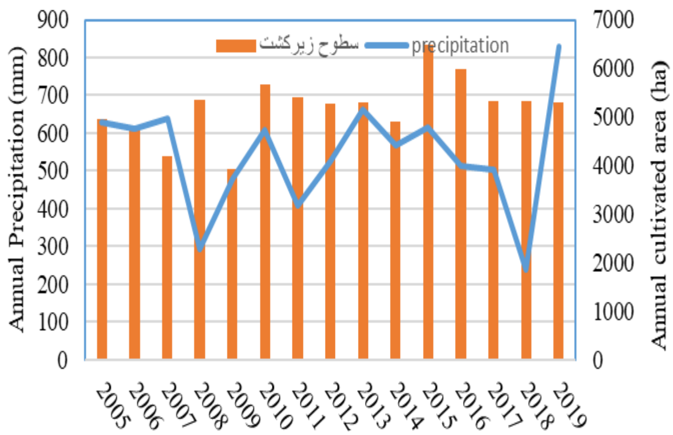
Graphs are plotted by Excel, tables are prepared by Word, and statistical analysis is conducted by SPSS.

Results and Discussion

The area for potato cultivation has not kept up with the annual rainfall due to groundwater use (Figure 1). Last year's market price dictates the acreage for the following year, with little influence from rainfall and water supply. This indicates that farmers in this region are not involved in a specific program. The small size of their plots, weak agricultural trade organizations, lack of consultants and experts, and reliance on traditional practices have contributed to this situation. Furthermore, allocating water to farmers without a plan, purpose, and at no cost is another significant factor in this context.

The estimated annual irrigation requirement for potatoes in the Shahrekord region is 555 and 544 mm according to Cropwat and Netwat software. This amount will vary depending on the efficiency of water transport and distribution in the network. Taking into account irrigation efficiency for surface (water transmission lines by pipes or short concrete channels), sprinkler, and tape systems at 58, 69, and 88 percent, the water requirements for potatoes during the growing season in the Shahrekord region for surface, sprinkler, and tape systems are 957, 804, and 631 mm per year, respectively. The results indicate that the most efficient forms of equivalent energy are linked to electricity consumption, fertilizers, and seed, leading to a revision of all plans based on their usage. Water use varies across surface, sprinkler, and tape systems, with surface irrigation generally consuming the most water, while sprinkler and tape systems require the least. Water consumption also varies within each system and typically depends on topography and water availability. The average energy consumption for water in surface, sprinkler, and tape systems is 9617, 6864, and 4184 MJ ha-1. Most plans use underground water, but the annual decline in water level leads to higher electricity consumption. Pressurized irrigation systems also contribute to increased energy usage. Table 2 shows that electricity consumption accounts for 53.8% of the total, with surface, sprinkler, and tape systems representing 30.3%, 55.2%, and 32.4% respectively. Chemical fertilizers rank second at 15.2 percent, compared to 18.4, 14.9, and 21.2 percent for irrigation systems. While all farmers use chemical fertilizers, some also use manure alongside them. However, the energy equivalent of manure is only 65 percent of the total equivalent energy of the applied fertilizers. In surface, sprinkler, and tape systems, seed equivalent energy accounts for 20.2, 12.7, and 17.9 percent of the energy consumption in each irrigation system. The amount of seed required depends on factors such as soil type (texture and structure), soil nutrient levels, climate, and seed quality. The variation in energy levels of seeds reflects changes in seed density per unit area, ranging from 4500 to 5800 kg ha-1. Fossil fuels and water usage are also significant factors. The substantial use of electricity and chemical fertilizers serves as a cautionary signal for agricultural planners, highlighting the need to provide these inputs to farmers at subsidized rates, particularly electricity at a significantly reduced cost. Failure to address this issue could severely impact the agricultural sector. Energy consumption per unit area is 47.7% and 54.68% higher for sprinkler systems compared to surface and tape systems, respectively. Surface systems use 4.2% more energy than tape systems. However, tape irrigation systems consume 35.35% and 3.86% less energy than sprinkler and surface systems, respectively. Pesticide usage varies, with greater usage in larger areas. The equivalent energy of applied pesticides accounts for approximately 1% of total energy usage. Fossil fuels contribute 9.5% of total energy due to fragmented lands and frequent machine operations. The energy ratio for surface, sprinkler, and tape irrigation systems is 18.6%, 9.3%, and 11.8%, respectively (Table 2).

Figure.1 Changes in the cultivated areas of potatoes and annual precipitation



The mean total produced and consumed energy calculated per unit area was 137089 and 149085 MJ ha-1, indicating that the produced energies are only 8.7 percent higher than the consumed energy per unit area. These figures are (99393 and 115457) in surface irrigation, (142464 and 151167) in sprinkler irrigation, and (91428 and 156600) percent in the tape irrigation systems (Table 3). The high energy consumption is associated with non-renewable energies, with 103,941 MJ ha-1 ranking first in energy consumption, followed by 80043, 122555, and 66435 MJ ha-1 in irrigation systems for potato cultivation. The direct energies rank second with 81987 MJ ha-1, while the indirect and renewable energy consumptions are next at 42027 and 18607 MJ ha-1, respectively. In surface irrigation systems, the produced energies are 16% higher than the consumed energies.

The maximum energy consumption is associated with non-renewable energy (80043 MJ ha-1), direct energies (59818 MJ ha-1), and indirect and renewable energies at 39575 and 19344 MJ ha-1. This indicates that non-renewable energy consumption is 4.14 times higher than that of renewable energy, and direct energies are used 51.15 percent more than indirect energies (Table 3). This highlights a challenge in developing sustainable agriculture and environmental programs. Furthermore, it serves as a warning to planners in the country, suggesting that programs should be developed to avoid excessive consumption of non-renewable energy and aim to reverse the current ratio. Direct energies are used about twice as much as indirect energies per unit area (Table 3). The average yield of potato production and energy consumption (direct, indirect, renewable, and non-renewable) per square meter in surface irrigation systems is 32571 kg per hectare and 59818, 39575, 19344, and 80048 MJ ha-1, respectively. The average direct energy consumption per unit area in surface, sprinkler, and tape irrigation systems is 59818, 99477, and 44779 MJ ha-1 (Tables 3 and 4). The ratio of direct energy to total energy consumption in surface, sprinkler, and t-tape irrigation systems is 60.2, 69.7, and 49.0 percent, respectively. The ratio of indirect energy to total energy consumption in these systems is 39.7, 30.3, and 51.0 percent, respectively. In tape irrigation systems, non-renewable energy consumption is at the lowest level among all irrigation systems, accounting for 66435 MJ ha-1. It should be noted that farmers are less welcoming of this system due to the costs associated with purchasing tape pipes, challenges with implementation time, specific management requirements, and insufficient promotion. The average energy consumption of water and electricity per unit area shows a significant difference at the 1 percent level across sprinkler and tape systems.

The Duncan test indicates that the difference between surface and tape systems is less than between sprinkler systems, suggesting increased energy consumption in sprinkler systems due to the need to maintain system pressure. The average equivalent fuel consumption per unit area among irrigation systems is also significant at the 1 percent level. According to the classification from the Duncan test, surface and sprinkler systems show minimal difference, while surface irrigation systems are significantly different from the other two systems. The difference in applied manpower across irrigation systems is significant at the 5 percent level. Notably, sprinkler and tape systems fall within the same group, and surface and sprinkler systems belong to the same category. The consumed and produced energies differ significantly across surface, sprinkler, and tape systems at the 1 percent level, with consumed and produced energies in surface and tape systems being less different than in sprinkler systems, which are notably more distinct. Importantly, the average energy consumption of non-renewable energy is significantly different among surface, sprinkler, and tape systems at the 1 percent level, with sprinkler systems exhibiting greater variation than the other two systems.

Table.2 Percent of energy for each input to the total energy

Particulars	All systems	Irrigation systems		
		Surface	Sprinkler	Tape
Water	4.85	9.5	4.8	4.57
Electricity	53.8	30.3	55.2	32.4
Chemical fertilizers	15.2	18.4	14.9	21.2
Seeds	13.1	20.2	12.7	17.9
Poisons	1.01	1.17	0.96	2.05
Diesel fuel	9.5	18.6	9.3	11.8
Human labor	0.115	0.268	0.11	0.15
Output	108.7	125.0	105.6	171.3

Table.3 The average and comparison the average inputs per unit area of Irrigation systems

Equivalent Energies	Irrigation systems								
	Surface			Sprinkler			Tape		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Water	8554	12934	9617	6329	7488	6864	4182	4186	4184
Electricity	2286	3456	2570	6108	7226	6590	2483	2487	2484
Chemical fertilizers	9758	26402	17626	17388	26625	21292	14408	19407	18141
Seeds	17100	20400	19033	16200	20880	17999	16415	18000	16733
Poisons	639	1763	1002	330	1220	893	1040	1342	1280
Diesel fuel	14678	30220	19939	10987	16405	14250	10445	10816	10741
Human labor	184	797	3116	104	268	179	136	138	137
Input	83950	129813	99393	135128	153870	142646	91228	91628	91428
Output	88200	140400	115457	142200	167400	151167	156400	156800	156600
Net energy	-3813	53488	16064	-4830	22447	8521	64972	65372	65172
Direct	52622	85186	59818	94476	110025	99477	44579	44979	44779
In direct	29564	46485	39575	38117	50942	43168	46448	46848	46648
Renewable	17306	21197	19344	16391	21149	18227	17058	17098	17080
Non renewable	66644	108616	80043	113508	135555	122555	66235	66635	66435

Figure.2 The diagram of the percentage of direct and indirect energies in various projects

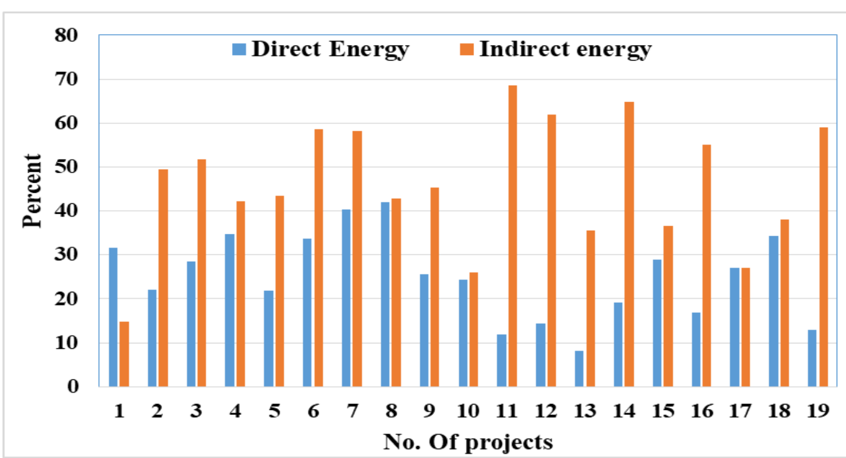
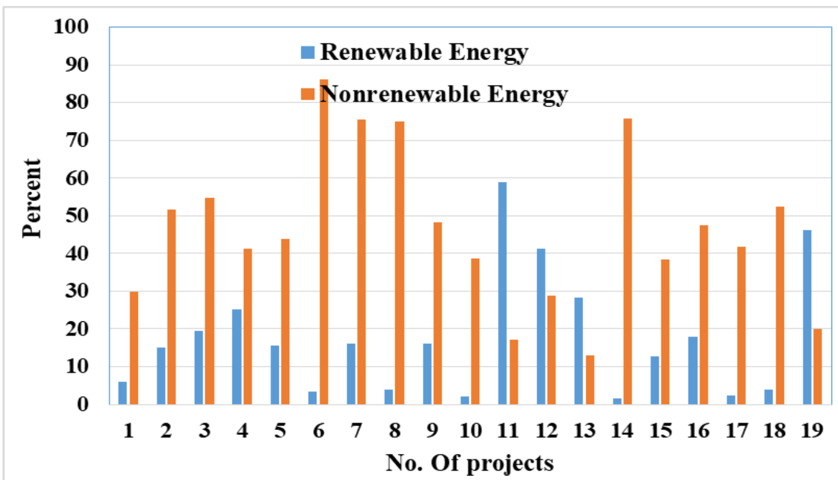


Table.4 Averages, minimum and maximum yield per unit area and some indices based on Duncan test

Equivalent Energies	Irrigation systems								
	Surface			Sprinkler			Tape		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Yield (kg ha^{-1})	28000	39000	32571	39500	46500	41990	33500	53500	43500
WUE (kg m^{-3})	2.8	4.3	3.5	5.6	6.9	6.3	8.6	12.6	10.6
WUE	1.0	1.6	1.15	1.0	1.2	1.07	1.5	1.9	1.7
Specific Energy	2.23	3.71	3.14	3.12	3.72	3.4	1.7	2.5	2.1
Energy productivity (kg MJ^{-1})	0.27	0.45	0.33	0.27	0.32	0.29	0.38	0.59	0.48

Figure.3 The diagram of the percentage of renewable and nonrenewable energies in various projects



The consumed energies and yield per unit area are 99393 and 32571 MJ ha-1 for surface, 151646 and 41990 MJ ha-1 for sprinkler, and 91428 and 43500 MJ ha-1 for tape irrigation systems (Tables 3 and 4). Water use efficiency in surface irrigation systems is 3.5 kg of potato consumption per cubic meter, with a production level of 6.3 and 10.6 kg m-3. The main reason for low water use efficiency in surface systems is fragmented lands and the lack of adherence to expert recommendations (filled questionnaire). The energy consumption efficiency index for surface, sprinkler, and tape irrigation systems is 1.18, 1.07, and 1.70, respectively, which demonstrates good performance in tape irrigation systems. The maximum rate of the energy efficiency index for surface, sprinkler, and tape irrigation systems is 0.59, 0.45, and 0.32 kg MJ-1, respectively. The specific energy index, representing the ratio of input energies to production per unit area in surface, sprinkler, and tape irrigation systems, is 3.40, 3.14, and 2.10 (Table 4).

Chemical fertilizers and fossil fuels have the greatest impact on the equivalent energy used to produce potatoes, which has doubled the necessity and importance of saving their consumption (Izadkhah Shishvani 2010, Yavuz *et al*. 2016, Rahbari *et al*. 2013, Zahedi *et al*. 2015). Surface irrigation systems use more inputs than sprinkler systems, and they utilize more inputs and energy than strip irrigation systems, which is consistent with the results and findings of (Hatrili *et al*. 2015, Kifle and Gebretsadikan 2016). The highest values of energy consumption efficiency and specific energy were estimated in surface irrigation systems, while the lowest values of the mentioned indices were estimated in strip irrigation systems (Najafi 2006, Ghasemi *et al.* 2013, Heydari, 2011, Kifle and Gebretsadikan 2016). The maximum energy consumption was associated with non-renewable energies and direct energies, which always pose serious challenges to sustainable development in the agricultural sector (Zangeneh *et al.* 2010, Khan *et al.* 2009). The consumption of electrical energy in sprinkler irrigation systems is higher than in the other two methods due to the need to maintain the required pressure for the system, which is consistent with (Yilmaz *et al.* 2005, Baghani and Faridhosseini 2012).

In conclusion, Producing each crop requires several inputs with specific values. In this regard, the equivalent energy for the consumption and production inputs to grow potatoes is provided in Chaharmahal and Bakhtiari province. In this study, the total energy consumed per unit area under surface, sprinkler, and tape irrigation systems is 99393, 142646, and 91428 MJ ha^1. The energy efficiency index for tape irrigation systems is higher than for the other systems, due to optimal input use and integrated land management, with a rate of 1.7. The water use efficiency index in tape irrigation systems is 10.6 kg m^3, compared to 6.3 and 3.5 kg m^3 in sprinkler and surface irrigation systems, respectively. More importantly, the ratio of nonrenewable energies to total energy consumption is 86 percent, with specific rates of 79.5, 87.1, and 81.1 percent in surface, sprinkler, and tape irrigation systems, which indicates a serious warning to authorities and planners against producing a product under any price and any amount of input. The highest equivalent energy consumption comprises 58.3 percent electricity, 18.9 percent fertilizers, 13.0 percent seeds, and 9.5 percent machinery. The reliance on 58. 3 percent electricity suggests an overuse of groundwater, and because the current price of electricity in agriculture is subsidized and nearly free, more underground resources are extracted, leading to a neglect of water use optimization. However, the removal of subsidies on electricity will significantly impact the total cost of the product. Overall, total energy consumption in surface and tape irrigation systems is lower than that in sprinkler systems, and this difference is significant at 1 percent. Additionally, nonrenewable energies in sprinkler systems exceed those in other systems, with this difference also being significant at 1 percent. Therefore, tape irrigation systems are superior to other irrigation methods due to better energy consumption and water efficiency indices on one hand, and lower nonrenewable energy usage on the other. This suggests that adopting proposed planning and management practices while conserving inputs will enhance production and contribute to environmental protection in the future.

Acknowledgements

In light of the extensive and detailed field surveys conducted, I would like to express my appreciation and gratitude to all of my colleagues in the management of the Chaharmahal and Bakhtiari Agricultural and Natural Resources Research and Education Center, the soil, water, and technical engineering management of the provincial Agricultural Jihad Organization, as well as all potato farmers and operators for their cooperation and assistance at the provincial level.

Author Contribution

Rahim Alimohammadi Nafchi: Investigation, formal analysis, writing—original draft; Validation, methodology, Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

References

Alam, M., M. Alam, and K. Islam, 2005. Energy flow in agriculture: Bangladesh. American Journal of Environmental Sciences 1(3): 213-220. DOI: https://doi.org/10.3844/ajessp.2005.213.220

Baghani, J.A., and A. Faridhosseini, 2012. The Effect of Surface and Subsurface Drip Irrigation on Quantity and Quality Potato. Iranian Journal of lrrigation and drainage 6(3): 238-244.

https://www.magiran.com/p1134295
Bajan, B., A. Mrowczyka-kaminska, and W. Poczta, 2020. Economic Energy Efficiency of Food Production Systems. Energies, 13(5826): 1-16. https://doi.org/10.3390/en13215826
Balali, H.K., M. Omidian, and S. Torabi Pelet Kolle, 2008. Analysis of Effects of Energy Subsidies Adjustment on groundwater Balance and Exploitation Agricultural research: water, soil and plants in agriculture 8(9): 95-106.
Camargo, D., F. Montoya, J. Ortega, and J. Coles, 2015. Potato Yield and Water Use Efficiency Responses to Irrigation in Semiarid Conditions. Agronomy Journal 107(6): 2120-2131. DOI:10.2134/agronj14.0572
Demircan, V., K. Ekinci, H. M. Keener, D. Akbolat, and C. Ekinci, 2006. Energy and economic analysis of sweet cherry production in Turkey: a case study from Isparta province. Energy Conversion and Management 47(13): 1761-1769. https://doi.org/10.1016/j.enconman.2005.10.003
Djaman, K., S. Irmak, K. Koudahe, and S. Allen, 2021. Irrigation Management in Potato (Solanum tuberosum L.) Production: A Review. Sustainability, 3(1504):1-19. https://doi.org/10.3390/su13031504
Ebrahimipak, N. A., 2010. Determination of the Potato Yield Response Factor (Ky) to Deficit Irrigation in Different Growth Stages. Journal of Irrigation & Water Engineering 1(26): 67-79. Doi: 10.22092/jsb.2010.762.
Esengun, K., O. Gunduz, and G. Erdal, 2007. Input and output energy analysis in dry apricot production of Turkey. Energy Conversion and Management 48(2): 592-598. https://doi.org/10.1016/j.enconman.2006.06.006.
Ghasemi-Sahebi, F., F. Ejlali, M. Ramezani, and I. Pourkhiz, 2012. Comparison of Tape Drip Irrigation and Furrow Irrigation Systems on Base of Water Use Efficiency and Yield of Potato in West of Iran. International Journal of Biology 5(1): 52-62. DOI:10.5539/ijb.v5n1p52.
Guzman, G. I., and A. M. Alonso, 2008. A comparison of energy use in conventional and organic olive oil production in Spain. Agricultural Systems 98(3): 167-176. https://doi.org/10.1016/j.agsy.2008.06.004
Hatirli, S. A., & Ozkan, B. and Fert, K., 2005. An econometric analysis of energy inputoutput in Turkish agriculture. Renewable and Sustainable Energy Reviews, 9: 608-623. https://doi.org/10.1016/j.rser.2004.07.001
Heydari, N., 2011. Determination and evaluation of water use efficiency of some major crops under farmers' management in Iran. Journal of Water and Irrigation Management 2, 43-58. https://jwim.ut.ac.ir/article_24582.html?lang=en
Horton, D.E., and H. Fano, 1985. Potato atlas. CIP, 135pp.
Izadkhah Shishvani, M. M., Tajbakhsh Shishvani, and A. Hassanzadeh, 2010. Evaluation and comparison of energy efficiency in both conventional and mechanized cultivation of the potato fields of East Azarbaijan Province. Iranian Journal of Field Crops Research 8(2): 284-298. https://doi.org/10.22067/gsc.v8i2.7526
Kannan, N., and A. Anandhi, 2020. Water Management for Sustainable Food Production. Water, 12(778): 1-7. DOI:10.3390/w12030778
Khan, S., M. Khan, M. Hanjra, and J. Mu, 2009. Pathways to reduce the environmental footprints of water and energy inputs in food production. Food policy 34(2): 141-149. https://doi.org/10.1016/j.foodpol.2008.11.002
Kifle, M., and T. Gebretsadikan, 2016. Yield and water use efficiency of furrow irrigated potato under regulated deficit irrigation, Atsibi-Wemberta, North Ethiopia. Agricultural Water Management 170: 133-139. https://doi.org/10.1016/j.agwat.2016.01.003
Mandal, K., K. Saha, P. Ghosh, K. Hati, and K. Bandyopadhyay, 2002. Bioenergy and economic analysis of soybean-based crop production systems in central India. Biomass and Bioenergy 23(5): 337-345. https://doi.org/10.1016/S0961-9534(02)00058-2
Najafi, P., 2006. Effect of using sub-surface drip irrigation to increasing WUE in irrigation of some crops. pajouhesh & Sazandegi, 73: 156-163.
Ozkan, B., C. Fert, and C. F. Karadeniz, 2007. Energy and cost analysis for greenhouse and open-field grape production. Energy 32(8): 1500-1504. https://doi.org/10.1016/j.energy.2006.09.010
Rahbari, H., A. Mahmoudi, and Y. Ajabshirchi, 2013. Energy consumption and application of the parametric method for tomato production in Iran. International Journal of Agriculture and Crop Sciences 5(1): 89-95. www.ijagcs.com.
Sartori, L., B. Basso, Bertocco, M., and G. Oliviero, 2005. Energy use and economic evaluation of a three-year crop rotation for conservation and

organic farming in NE Italy. Biosystems Engineering 91(2): 245-256. https://doi.org/10.1016/j.biosystemseng.2005.03.010

Singh, S., and J. Mittal, 1992. Energy in production agriculture. Mittal Publications.

Strapatsa, A. V., G. D. Nanos, and C.A. Tsatsarelis, 2006. Energy flow for integrated apple production in Greece. Agriculture, ecosystems & environment 116(3): 176-180. https://doi.org/10.1016/j.agee.2006.02.003

Yavuz, D., S. Suheri, and N. Yavuz, 2016. Energy and water use for drip irrigated potato in the Middle Anatolian region of Turkey. Environmental Progress & Sustainable Energy 35(1): 212-220. https://doi.org/10.1002/ep.12216

Yilmaz, I., H. Akcaoz, and B. Ozkan, 2005. An analysis of energy use and input costs for cotton production in Turkey. Renewable Energy 30(2): 145-155. https://doi.org/10.1016/j.renene.2004.06.001Get rights and content

Zahedi, M., H. R. Eshghizadeh, and F. Mandani, 2015. Energy efficiency and productivity in potatoes and sugar beet production systems. Journal of production and processing of agricultural and horticultural products 5(17): 181-191. DOI:10.18869/acadpub.jcpp.5.17.181

Zangeneh, M., M. Omid, and A. Akram, 2010. A comparative study on energy use and cost analysis of potato production under different farming technologies in Hamadan province of Iran. Energy 35(7): 2927-2933. https://doi.org/10.1016/j.energy.2010.03.024

Zare, Sh., and H. Muhammadi, 2015. Comparison of energy and economic efficiency of potato producers in the city Ghoochan using the interval data envelopment analysis. Agricultural Economics and development 23(91): 95-115. doi: 10.30490/aead.2015.59004

How to cite this article:

Rahim Alimohammadi Nafchi. 2024. Assessment of Energy Consumption and Production in Surface, Sprinkler, and Tape Irrigation Systems for Potato Farming. *Int.J.Curr.Microbiol.App.Sci.* 13(3): 276-286.
doi: https://doi.org/10.20546/ijcmas.2024.1303.027