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Investigation of Tape Line Drip Irrigation Systems in the Eastern Faryab Plain: Technical Assessment and Solutions

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Abstract

Today, by field evaluating modern irrigation systems and monitoring their status, we can identify their strengths and weaknesses, thereby facilitating better utilization through amendments and the adoption of new management practices. In this study, 30 experimental farms managed by farmers in 2024, equipped with tape drip irrigation systems, were selected in the Faryab region, where potatoes and onions were cultivated. To evaluate the irrigation systems, a main pipe was randomly selected, and four lateral pipes located at the beginning, one-third, two-thirds, and the end of the main pipe were considered. The flow rate from the emitters and the pressure at the beginning and end of the tested pipes were measured. The system's performance was evaluated based on the Christiansen's Uniformity Coefficient (CU), Distribution Uniformity (DU), Coefficient of Variation (Cv), Emitter Uniformity (EU), flow variation (qvar), application efficiency (Ea), Actual Lower Quartile Distribution Efficiency (AELQ) (AELQ), and Potential Lower Quartile Application Efficiency (PELQ). The results showed that the average CU, DU, Cv, and EU in the evaluated designs were 77.6%, 69.8%, 0.29, and 59.5%, respectively. Furthermore, the average flow variation (qvar), application efficiency (Ea), actual lower quartile application efficiency (AELQ), and potential lower quartile application efficiency (PELQ) were 58.2%, 61.5%, 59.8%, and 53.8%, respectively. The results indicated that the average volume of water consumed, yield, and water productivity index (WPI) for onions were 8340 $m^3\ ha^{-1}$, 41 $t\ ha^{-1}$, and 5.86 $kg\ m^{-3}$, respectively, while these values for potatoes were 7710 $m^3\ ha^{-1}$, 39.5 $t\ ha^{-1}$, and 5.98 $kg\ m^{-3}$.

Keywords: Distribution Uniformity, Field Evaluation, Yield, Water Productivity Index.

Introduction

The increasing depletion of available water resources and rising consumption in drinking, industry, and agriculture have led agricultural officials to adopt systems that enhance irrigation efficiency. One such method that significantly impacts this issue is drip irrigation (Kandelous and Simunek, 2010). The success of a drip irrigation system is ensured by precise design and proper implementation. Often, the simultaneous establishment of these two conditions does not occur, and the system fails to deliver its full potential. Therefore, periodically field evaluating these systems and monitoring their status can reveal their strengths and weaknesses, enabling better utilization through amendments and new management practices (Ahmadaali, 2017). Generally, the delivery of any irrigation system based on measurements in real conditions during the system's normal operation is termed evaluation (Merriam and Keller, 1978). Today, the uniformity of water distribution on the land surface is accepted as a key criterion for assessing irrigation system yield. Managing irrigation systems to increase their efficiency under water scarcity conditions poses a significant challenge for agricultural specialists and irrigation engineers (Qureshi et al., 2015).

Evaluations and investigations of issues and problems in drip irrigation systems have been reported by many researchers in recent years (Acar et al., 2010; Pannunzio et al., 2016; Farah et al., 2024; Umara et al., 2011).
Research by Ortega et al. (2004) evaluated the yield of localized irrigation systems in the semi-arid Castilla region of Spain. The results showed that the distribution uniformity under the experimental unit was 84% and 82% for the entire system. A significant portion of the problems in the systems was reported due to low operational pressure. This issue arises from various reasons, the most important of which are low efficiency at distribution network stations, lack of filter cleaning, and high losses. Ella et al. (2009) reported that the coefficient of uniformity (CU) and distribution uniformity (DU) in drip irrigation systems, especially under sloped conditions and low operational pressure, were not suitable. They recommended using pressure-regulated emitters to improve water distribution uniformity. Hezarjribi et al. (2008) showed that the discharge of the used emitters was affected by operational pressure, and the nominal flow provided by the manufacturer for design purposes is not reliable. Ahmadaali et al. (2017) obtained DU, PELQ, and AELQ values for drip irrigation systems of 53.9%, 45.3%, and 53.9%, respectively. They cited the low values of AELQ and PELQ compared to standard values as indicators of poor management and operation of drip irrigation systems and the type of emitters used in them. Noushadi and Ghaemi (2013) examined the technical and hydraulic performance of drip irrigation systems in Fars Province. Their results showed that the values of CU, DU, EU, AELQ, PELQ, and CV in the studied designs ranged from 61-97%, 50-95%, 43-93%, 34-93%, 30-84%, and 5-52%, with averages of 86%, 80%, 75%, 72%, 65%, and 18%, respectively. Their findings indicated that the status of drip irrigation systems in Fars Province regarding AELQ, PELQ, EU, CU, and DU efficiencies was good to relatively good, but the emitters coefficient of variation was not suitable, and in some cases, the CV values were very high. Gupta and Singh (1983) concluded from a comparison of furrow and drip irrigation systems on potato crops that the yield of potatoes increased by 50 to 65% when using drip irrigation. Ghadami Firouzabadi et al. (2004) examined the productivity of potato crops under various irrigation systems. The water productivity in the studied farms varied from 1 to 1.4 kilograms per cubic meter. The average water productivity in surface, sprinkler, and drip irrigation systems of tape line was estimated at 1.4, 2.5, and 2.9 kilograms per cubic meter, respectively. Saxena et al. (2019) evaluated the hydraulic yield of a subsurface drip irrigation system installed at two depths of 15 and 20 centimeters. In this study, the uniformity efficiency and Christiansen uniformity coefficient for the 15-centimeter depth were 93% and 95%, and for the 20-centimeter depth, they were 92% and 87%, respectively. They reported the irrigation system yield as excellent. Hakiruwizera et al. (2024) conducted a technical evaluation of a drip irrigation system inside a smart greenhouse located in the Ngoma sector. In this study, the average flow rate of the emitters was measured to determine the Coefficient of Uniformity (CU) and assess the Distribution Uniformity (DU). The results showed that the average flow rate of the emitters was 3.98 liters per hour. The Coefficient of Uniformity was found to be 99.96%, and the Distribution Uniformity was 57.72%. Overall, the results of the research indicated that the drip irrigation systems yield is excellent. However, the method of water distribution in all systems was weak. Ghamarnia et al. (2023) evaluated five drip irrigation systems in the Thalas Babajani County of Kermanshah Province based on the guidelines of the U.S. Soil Conservation Service (SCS) and the methods of Merriam and Keller. Their results showed that the minimum

and maximum values of Christiansen's uniformity coefficient in the examined systems (EUs) were determined to be 29.49% and 62.56%, respectively. Generally, the poor yield of the systems was attributed to various reasons, including the absence of a central control station or an appropriate filtration system, insufficient wetted area, inappropriate type and number of emitters, clogging of emitters, pressure differences in the systems, unsuitable pressure, and uneven distribution, inappropriate irrigation frequency and duration, and ultimately poor operational management. Shaheen et al. (2022), in their study on potato cultivation, evaluated drip irrigation uniformity and application efficiency under different water application strategies. The research showed that precisely matching the irrigation schedule to crop needs and soil water-holding capacity is crucial for achieving high CU and DU. This ensures uniform water distribution. Furthermore, optimizing AELQ is essential to prevent water waste, as both over- and under-irrigation lead to either deep percolation or plant stress, respectively.

Overall, the results of the research indicate that the evaluations conducted reveal problems in drip irrigation systems. Therefore, the objective of the present study is to technically investigate the problems of tape line drip irrigation systems used for cultivating potatoes and onions in the Eastern Faryab region.

Materials and Methods

Study Area

The "Eastern Faryab " plain is a study area in the southwest of the Jiroft plain in Kerman Province. The Eastern Faryab plain covers an area of 1,741 square kilometers, of which 502 square kilometers is plain and 1,239 square kilometers is mountainous (Figure 1).

The hydrograph of this aquifer shows two main trends: the statistical period from 1994 to 1997 indicates an increasing trend in the water level, while the period from 1998 to 1999 shows a general decreasing trend with a continuous decline. Overall, it can be said that during this 25-year period, the groundwater level has decreased by 12.75 meters, with an average annual decline of 0.51 meters. The maximum water level depth is 71.98 meters, related to the Eastern Kohan well, while the minimum water level depth is 3.41 meters, corresponding to the Tajabad well.

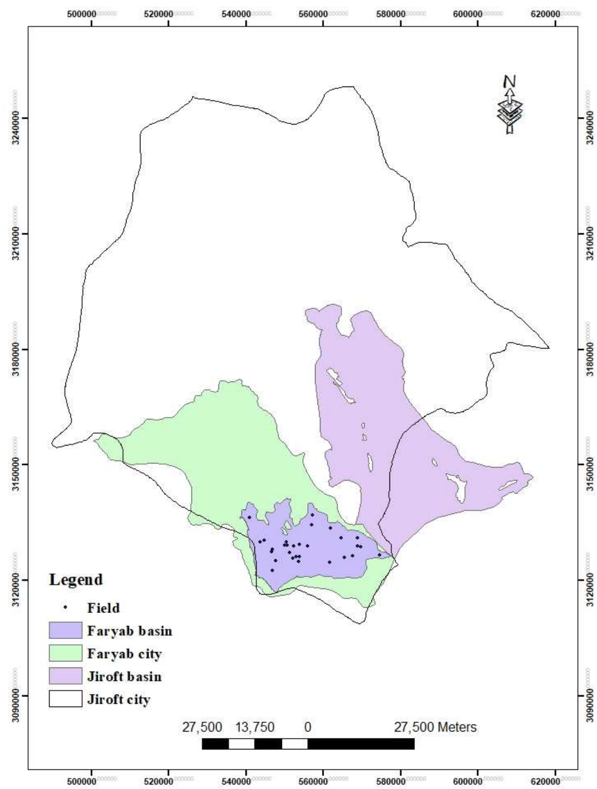


Fig. 1 Location of drip irrigation systems in the study area

Measurement of Field Parameters

To collect the necessary information for the technical evaluation of the tape line drip irrigation systems, Merriam-Keller method was used. Thirty experimental farms equipped with drip irrigation systems and dedicated to potato and onion cultivation were randomly selected in 2024. According to the standard, a working main pipe was randomly selected, and four lateral pipes were marked at the beginning, one-third from the beginning, two-thirds from the beginning, and at the end (Merriam and Keller, 1978; Keller and Blizner, 2000). To measure the flow rate of the emitters, one-meter containers were placed under each of the four tape line emitters for one minute (Figure 2). Measurements were taken after the system had been turned on and stabilized. The farmer was asked to turn on the risers that were irrigated simultaneously according to the irrigation plan and to close the other risers. After ensuring that the other risers were closed, measurements were taken. In total, 16 samples were collected from the working riser. Additionally, using a pressure gauge, the pressure at the beginning and end of the four selected lateral pipes was measured. The tape lines used in the region for potato and onion cultivation are mostly spaced 20 centimeters apart. After conducting the tests, information from the farmer regarding irrigation time, irrigation frequency, yield, cultivated area, and length of tape lines was recorded in a questionnaire (Table 1). The status of the central control system was examined through field visits. Soil texture was determined in the laboratory using the hydrometer method. After collecting data from the farm evaluations, the parameters of Christiansen's Uniformity Coefficient (CU), Distribution

Uniformity (DU), Coefficient of Variation (Cv), Emitter Uniformity (EU), statistical uniformity (Us), Discharge Variation (qvar), application efficiency (Ea), Actual Lower Quartile Distribution Efficiency (AELQ), and potential lower quartile application efficiency (PELQ) were calculated to determine the systems yield and the method of water distribution in the farms.

In the Table 1 general specifications of the evaluated designs, including soil texture, crop type, well operating permit flow rate, manifold length, tape line length, shift area, number of irrigations, irrigation frequency, and duration. The water source for all projects is a deep well. The operational status of the regional projects is either communal or private. In communal projects, a multi-user irrigation system is used, and usually, the communal head is responsible for dividing water and adhering to irrigation timing. Projects operated communally face more problems than private projects, including the lack of fertilizer tanks, low pressure in the systems, issues related to water division, etc. The manifold length in most projects that are irrigated unidirectionally is 50 meters. In the Faryab region, due to the use of direct pumping, the lengths of agricultural parcels are considered shorter to maintain pressure; thus, the lateral lengths are less than 100 meters.

Fig. 2 Measurement of field parameters

Hydraulic Parameters:

Christiansen's Uniformity Coefficient (CU)

In a drip irrigation system, there is often a significant difference between the actual emitters discharge. Some specialists have proposed design methods based on the Christiansen Uniformity Coefficient (CU). The range of flow variation of the emitters discharge can be determined using the following equation (Christiansen, 1942):

$$CU = 100\left(1 - \frac{\sum_{i-1}^{n} |qi - \bar{q}|}{\bar{q} \times n}\right) \tag{1}$$

where CU is the Christiansen Uniformity Coefficient (Percentage), $\bar{q}$ is the mean emitters discharge, and n is the number of emitters from which each plant receives water.

Emitter Uniformity (EU)

The Christiansen's uniformity coefficient, calculated as the ratio between the minimum and mean discharge in the emitters, was proposed by Keller and Karmeli (1974):

$$EU = 100(\frac{q_n}{q_a}) \quad (2)$$

where: EU is the Emitter Uniformity (Percentage), q_n:is the average discharge in the emitter's lower quartile (liters per hour), q_a is the average emitter discharge (liters per hour).

$$EU=[1 - 1.27 \quad \frac{Cv}{N^{0.5}}]\frac{q_n}{q_a} \quad (3)$$

$$Cv = \frac{Sd}{q_a} \quad (4)$$

$$Sd=\frac{\sqrt{((q1^2+q2^2+\cdots+qn^2-nq^2))}}{qn} \quad (5)$$

where: Cv: is the manufacturing coefficient of variation, derived from equation (4), N is the number of emitters evaluated, q_n : is the average discharge in the emitters lower quartile (liters per hour), q_a : is the average emitter discharge (liters per hour).

Emitter Flow Coefficient of Variation (q_{var})

Another method for examining flow coefficient of variation in emitters is by comparing the maximum and minimum flow among them, which can be used as a criterion for selecting emitters and is calculated as follows:

$$q_{var}=100(1-(\frac{q_{min}}{q_{max}})) \quad (6)$$

where: q_{var} is the emitter flow coefficient of variation (in percent), q_{max} : is the maximum discharge in the emitters (liters per hour), q_{min} : is the minimum flow in the emitters (liters per hour). The emitter flow coefficient of variation should not be less than or exceed 15% (Keller and Karmeli, 1974).

Application Efficiency (Ea)

$$Ea = 100 \times (\frac{q_{min}}{q_a}) \quad (7)$$

where: q_{min}: is the minimum flow in the emitters (liters per hour), q_a : is the average flow in the emitters (liters per hour).

Table 1 General characteristics of the evaluated projects

Number Field	Region	Operation type	**Soil texture**	Cultivation pattern	Qp Lit/sec	M m	L m	A ha	n	T day	t hr
Field1	Ahovan	joint	Loamy sand	Onion	35	50	75	1.5	32	3	5
Field 2	Bagher abad	joint	Sandy Loam	Onion	40	50	60	1.5	85	2	3
Field3	Hosseinabad dehdar	Personal	Loamy sand	Potato	30	40	70	2.5	32	3	6
Field4	Tohan	joint	Sandy Loam	Onion	60	55	70	4	42	3	3
Field5	Zavarhlke	Personal	Sand	Onion	20	50	60	3	58	3	2
Field6	Band sraji	Personal	Loamy sand	Onion	10	50	50	0.75	24	3	3
Field7	Bagher abad	joint	Sandy Loam	Potato	35	50	70	1.5	23	5	4
Field8	Khaton abad	Personal	Sandy Loam	Onion	30	50	60	1.5	77	3	3
Field9	Hosseinabad dehdar	joint	Loam	Onion	15	50	45	0.25	47	5	8
Field10	Dehsheikh	Personal	Loam	Onion	18	50	50	0.25	22	6	3
Field11	Jangalabad	Personal	Loamy sand	Potato	16	50	46	0.5	32	4	2
Field12	Tohan	Personal	Sandy Loam	Onion	25	50	70	1	48	3	2
Field13	Jamtan	joint	Silt loam	Potato	21.64	35	70	0.75	52	2	1
Field14	Paghaleh	Personal	Sandy Loam	Potato	31	35	100	1	18	7	5
Field15	Dehnoamlak	Personal	Loam	Potato	37.5	35	40	0.7	55	2	1
Field16	Saghari	Personal	Silt loam	Potato	40	50	75	2.5	27	3	2
Field17	Tohan	Personal	Sandy Loam	Potato	40	50	65	1.5	51	2	4
Field18	Zavar	joint	Sandy Loam	Potato	36	50	70	2	40	2	4
Field19	Aliabad	Personal	Silt loam	Onion	38	50	70	1.5	45	4	2
Field20	Narjo	Personal	Sandy clay loam	Potato	16.5	50	50	2	32	5	6
Field21	Tarj	Personal	Sandy Loam	Onion	35.64	60	100	1.5	74	4	2
Field22	Hokerd	Personal	Loamy sand	Onion	37.5	35	40	0.7	55	2	1
Field23	Khaton abad	Personal	Loam	Onion	52	50	70	0.27	54	2	2
Field24	Sharifabad	joint	Silt loam	Potato	19	50	50	1	52	2	1
Field25	Romarz	joint	Sandy clay loam	Onion	19	50	50	1	47	2	1
Field26	Baghboieh	Personal	Sand	Onion	45	50	45	1	21	5	2
Field27	Badijan	Personal	Loamy sand	Onion	34	50	70	1.5	60	2	2
Field28	Temgavan	Personal	Sandy Loam	Onion	18.5	50	50	0.5	65	2	1.5
Field29	Dehno	joint	Loamy sand	Onion	35	50	75	1.5	32	4	5
Field30	Dehno fath	joint	Loam	Onion	15	50	45	0.25	47	3	2

Table 2 Classification of the Coefficient of Distribution Uniformity (EU)

Classification	EU (%)
Excellent	90-100
Good	80-90
Acceptable	70-80
low	<80

Potential Lower Quartile Application Efficiency (PELQ)

In the evaluation of drip irrigation systems, the concept of PELQ must be transformed, as in this method only a portion of the soil area is wetted, and the minimum irrigation depth is zero. Additionally, in drip irrigation, since only part of the soil volume is wetted, the Soil Moisture Deficit (SMD) must be continuously compensated. However, estimating SMD is somewhat challenging because part of the wetted soil remains at field capacity, even if the interval between irrigations extends to several days. In systems where irrigation is conducted daily, estimating SMD is nearly impossible; thus, it should be estimated from meteorological data or evaporation meters.

Since this estimation will certainly have some error and measuring this amount is impractical, a type of reliability factor must be applied. As a general rule, areas of land that receive the least water should be irrigated with approximately 10% more than the estimated evaporation-transpiration or SMD (Noshadi and Ghaemi, 2013). Consequently, for drip irrigation systems, PELQ is defined as:

$$\mathrm{PELQ} = 0.9 \times \mathrm{EU} \tag{8}$$

Actual Lower Quartile Distribution Efficiency (AELQ)

To better define the concept of distribution uniformity, a combination of uniformity, distribution uniformity, and losses must be included. This concept is expressed as the actual lower quartile application efficiency of water, which is the average of one-fourth of the least amount of water infiltrated and stored in the root zone, relative to the average water used, expressed as a percentage (Merriam and Keller, 1978). When the average depth of water infiltrated in the soil is less than one-fourth of the samples compared to the deficit in soil moisture (SMD), AELQ can be expressed as:

$$\mathrm{AELQ}=\mathrm{SMD}/\ \textit{mean irrigation water depth} \tag{9}$$

A low AELQ value indicates management issues and how the system is applied. In drip irrigation, the concept of AELQ must be transformed since only part of the soil surface is wetted. The effectiveness of a drip irrigation system is determined by the amount of water stored in the root zone. Given that in drip irrigation, in areas that receive the least water, there is no reason for water to be lost through evaporation and deep infiltration, the actual lower quartile application efficiency of water is defined as:

$$AELQ = \mathrm{ERF} \times \mathrm{EU} \tag{10}$$

$$\mathrm{ERF} = (1.5 \times \mathrm{P_{end}} + \mathrm{P_{ave}})/(2.5 \times \mathrm{P_{ave}}) \tag{11}$$

where: ERF: uniformity reduction factor, P_{end} : is the pressure at the end of the pipe (meters), P_{ave} : is the average pressure in the pipe.

Water Productivity Index (WPI)

The Water Productivity Index (WPI) is the amount of product produced per unit area relative to the amount of water applied per unit area, calculated from:

$$\mathrm{WPI}=\frac{\mathrm{Yield}\ (\frac{kg}{ha})}{\mathrm{I}\ (\frac{m3}{ha})} \tag{12}$$

Where Yield: is the crop yield in kilograms per hectare, and I: is the amount of irrigation water during the growing period in cubic meters per hectare.

Results and Discussion

Hydraulic Status of the Systems

The hydraulic characteristics of the evaluated designs, including the number of hydrocyclones, sand filters, screen filters, the status of screen filters, pump operating hours, minimum pressure, maximum pressure, average pressure in the manifold, average discharge from the emitters, and lower quartile discharge, are presented in Table 3. Out of the evaluated designs, 10 designs (33%) lacked hydrocyclones. Hydrocyclones are essential in designs using direct pumping to prevent the entry of sand particles and clogging of emitters. Due to the absence of a reservoir in the region, most designs lack sand filters. Of all the designs evaluated, 20 designs (67%) do not have sand filters. (Table 6) All designs equipped with a central control system had screen filters, but in most designs, especially those operated communally, the screen filters were removed due to low pressure (66%). One of the issues arising from the absence of screen filters in the system is the continuous clogging of emitters. However, since the tape lines in the region are single-use and are collected at the end of the growing season without being reused, farmers are reluctant to replace the screens in crop cultivations such as potatoes and onions.

The pressure in the evaluated designs varied between 0.2 to 5.7 meters. The average pressure in the operating manifolds (MLIPave) was found to be 2.04 meters. The non-uniform distribution of pressure at different points in the system is one of the main issues in most designs in the region. The average discharge from the measured tape lines ranged from 1.7 to 15.23 liters per hour. The overall average discharge across all designs was 7.64 liters per hour.

Coefficient of Uniformity (CU) and Distribution Uniformity (DU)

The CU values for all evaluated designs were above 73 percent, varying between 73 and 93 percent. The average CU across all designs was 83 percent, classifying them as good according to the classification by Mistry et al. (2017). The average CU for potato and onion crops was equal (83 percent), with CU values for potatoes ranging from 77 to 90 percent and for onions from 73 to 93 percent (Tables 4 and 5).

DU indicates the extent of uniformity in the system. Low DU values, provided adequate irrigation is applied, indicate water loss due to deep percolation. DU values fluctuated between 51 and 91 percent, with an average DU of 74 percent across the evaluated designs. Values below 67 percent are generally considered unacceptable. Since achieving high uniformity often incurs increased costs, lower uniformities are somewhat acceptable as long as they are economically justified (Noshadi and Ghaemi, 2013). Nevertheless, the status of the region regarding the DU index is also satisfactory. Hakiruwizera et al. (2024) reported CU and DU values of 99.96 and 57.72 percent, respectively, in designs they evaluated, which aligns with the current study's results. Noshadi and ghaemi. (2013) showed that CU and DU values for the Fars province counties ranged from 80 to 94% and 69 to 91%, respectively.

Table 3 Hydraulic Characteristics of Evaluated Designs

	HF	SF	MF	MF-S	Pump lighting	P_{min}	P_{max}	$MLIP_{ave}$	qave	q1/4
					h	m	m	m	Lit/h	Lit/h
Field1	1	2	1	2	21	0.5	2	1.13	1.70	1.13
Field 2	1	2	1	2	18	2	4.5	3.13	6.86	5.73
Field3	2	2	2	2	22	2	4.5	3.13	12.64	8.64
Field4	1	2	1	2	19	0.5	2	1.13	4.53	3.22
Field5	1	2	1	1	20	1	3	2.13	7.24	6.60
Field6	2	1	1	2	20	2	5	3.13	13.61	8.85
Field7	1	2	1	2	20	1	3.5	2.31	7.13	5.64
Field8	2	2	2	2	24	0.5	4	2.19	7.35	4.58
Field9	2	1	1	2	21	0.5	4	1.44	4.44	3.13
Field10	1	2	1	1	20	4	5	4.50	6.59	4.44
Field11	1	1	1	2	20	3	4.5	3.38	8.07	6.90
Field12	1	2	1	2	22	0.5	2	1.28	6.94	5.85
Field13	1	2	1	1	22	0.5	2.5	1.34	6.79	5.55
Field14	1	2	1	2	18	0.5	2.75	1.41	6.83	5.93
Field15	2	1	1	1	21	0.5	2	1.19	10.22	8.25
Field16	1	2	1	2	20	0.5	1.75	1.03	3.36	2.48
Field17	2	1	1	1	24	0.2	2.5	1.31	5.70	4.20
Field18	1	2	1	2	20	0.3	2	0.95	8.04	6.08
Field19	1	2	1	1	20	1	7.5	2.75	6.17	3.83
Field20	1	2	1	2	24	1	3	2.25	9.83	5.40
Field21	1	2	1	2	24	0.8	2	1.20	5.76	2.93
Field22	2	1	1	1	21	0.5	2.5	1.38	15.23	12.00
Field23	2	1	1	1	20	3.5	5	4.13	12.06	10.50
Field24	1	1	1	2	18	2.2	3.5	2.84	12.04	9.00
Field25	1	1	1	2	18	2.5	3	2.84	7.39	4.20
Field26	1	2	1	2	20	0.5	2	1.22	7.39	5.63
Field27	2	1	1	1	20	1	3	1.88	4.73	3.71
Field28	1	2	1	1	20	1.5	3	1.88	8.93	7.65
Field29	1	2	1	2	21	0.5	2.5	1.25	3.85	3.05
Field30	2	1	1	2	21	0.5	4	1.44	7.70	6.15

P_{min}: Minimum pressure in lateral (m), P_{max}: Minimum pressure in lateral (m), P_{ave}: Average pressure in the manifold (m), q_{ave}: Average flow rate in emitters (L/h), Hydrocyclone filter (1: Yes, 2: No), Sand filter (1: Yes, 2: No), Mesh filter (1: Yes, 2: No), Mesh filter status (1: intact, 2: no lace).

Emitter Uniformity (EU)

The uniformity of water discharge from emitters is one of the important indicators in drip irrigation systems. The EU values in the region varied between 41 and 86 percent, with an average EU of 65 percent. The results indicated that in 54%, 33%, and 13% of the designs, the EU was less than 70%, between 70-80%, and greater than 80%, respectively (Tables 5 and 6). The lowest and highest EU values were recorded in onion crops. The results suggest that the uniformity of water discharge from the tape lines in the region is not satisfactory, attributed to factors such as emitter clogging and low system pressure.

Table 4 Values of Various Evaluation Indices for Onion Crop

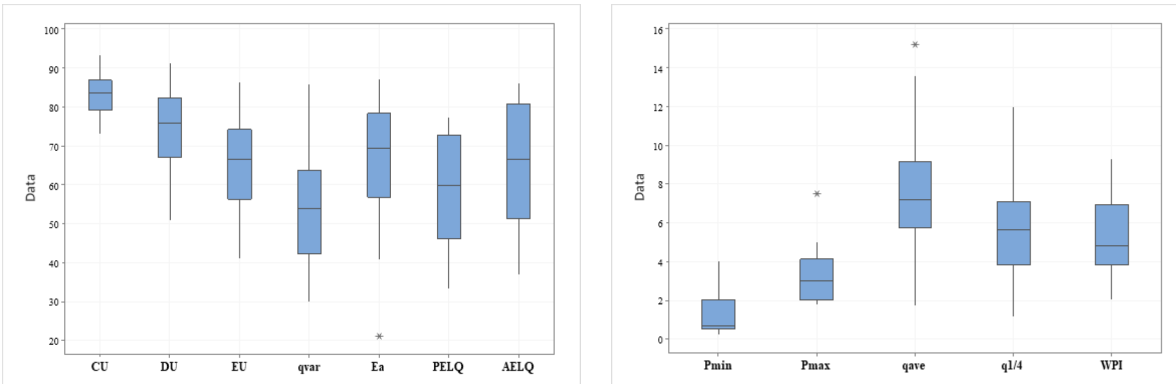
	CU	DU	cv	EU	Classification	qvar	Ea	PELQ	AELQ	V	Yield	WPI
	%	%	%	%		%	%	%	%	m^3	Ton	kg/m^3
Field 1	80	66	0.26	56	Low	62.50	53	47	53	9517	30	3.15
Field 2	88	84	0.15	76	Acceptable	45.89	75	74	82	6166	25	4.05
Field 4	73	71	0.38	56	Low	66.67	66	47	52	6804	50	7.35
Field 5	93	91	0.09	86	Good	30.00	87	75	83	6720	50	7.44
Field 6	76	65	0.31	53	Low	72.97	44	38	42	7250	50	6.90
Field 8	80	62	0.26	53	Low	58.82	57	65	72	11088	50	4.51
Field 9	77	70	0.31	58	Low	59.46	68	43	48	10152	40	3.94
Field 10	80	67	0.25	58	Low	56.67	59	47	52	11232	30	2.67
Field 12	86	84	0.16	76	Acceptable	32.14	82	73	81	8640	50	5.79
Field 19	77	62	0.30	51	Low	66.67	49	39	43	9210	50	5.43
Field 21	75	51	0.34	41	Low	85.71	21	33	37	12481	40	3.20
Field 22	88	79	0.18	71	Acceptable	56.76	63	67	75	12131	40	3.30
Field 23	91	87	0.11	81	Good	30.61	85	77	86	4921	40	8.13
Field 25	78	57	0.29	47	Low	68.75	41	37	41	6725	50	7.43
Field 26	84	76	0.21	67	Low	52.78	69	76	85	4275	27	6.32
Field 27	85	78	0.17	71	Acceptable	40.00	76	66	73	9344	40	4.28
Field 28	84	86	0.20	76	Acceptable	42.86	81	60	67	9457	45	4.76
Field 29	89	79	0.14	73	Acceptable	33.33	78	61	68	9517	30	3.15
Field 30	86	80	0.21	70	Acceptable	57.35	71	52	57	10152	40	3.94
MIN	73	51	0.09	41		30.00	21	33	37	4275	25	2.67
MAX	93	91	0.38	86		85.71	87	77	86	12481	50	8.13
AVE	83	73	0.23	64		53.68	64	57	63	8725	41	5.04

Table 5 Values of Various Evaluation Indices for Potato Crop

	CU	DU	cv	EU	Classification	qvar	Ea	PELQ	AELQ	V	Yield	WPI
	%	%	%	%		%	%	%	%	m^3	Ton	kg/m^3
Field 3	80	68	0.30	57	Low	68.62	56	60	66	8207	40	4.87
Field 7	86	79	0.19	71	Acceptable	47.47	76	59	65	7789	30	3.85
Field 11	90	85	0.12	80	Good	31.25	82	67	74	11057	45	4.07
Field 13	86	82	0.18	73	Acceptable	46.67	71	77	85	5401	50	9.26
Field 14	89	87	0.14	80	Good	36.67	84	60	66	10044	50	4.98
Field 15	82	81	0.24	70	Acceptable	52.63	79	72	81	12375	25	2.02
Field 16	84	74	0.19	66	Low	42.86	72	75	84	8164	30	3.67
Field 17	84	74	0.24	64	Low	60.00	63	70	77	6297	40	6.35
Field 18	80	76	0.25	65	Low	55.00	67	34	38	6250	35	5.60
Field 20	77	55	0.29	46	Low	68.89	43	44	49	5702	40	7.02
Field 24	81	75	0.25	64	Low	51.72	70	50	56	5525	50	9.05
MIN	77	55	0.12	46		31.25	43	34	38	5401	25	2.02
MAX	90	87	0.30	80		68.89	84	77	85	12375	50	9.26
AVE	83	76	0.22	67		51.07	69	61	67	7892	40	5.52

Variations in Emitter Discharge and Application Efficiency

As previously mentioned, the average discharge from the tape lines across all evaluated designs was 7.64 liters per hour (Table 3). The percentage variation in discharge (qvar) in the region varied between 30 and 83 percent, with an average of 53 percent, indicating a significant variation in discharge among the evaluated designs. Additionally, the variation in application efficiency ranged from 21 to 87 percent, with an average of 66 percent. As shown in the boxplot diagram (Figure 3), the efficiency has an outlier (21 percent), and by removing it, the average application efficiency in the region increases to 68 percent.



(b) (a)

Fig. 3 Boxplot of Evaluation Indices

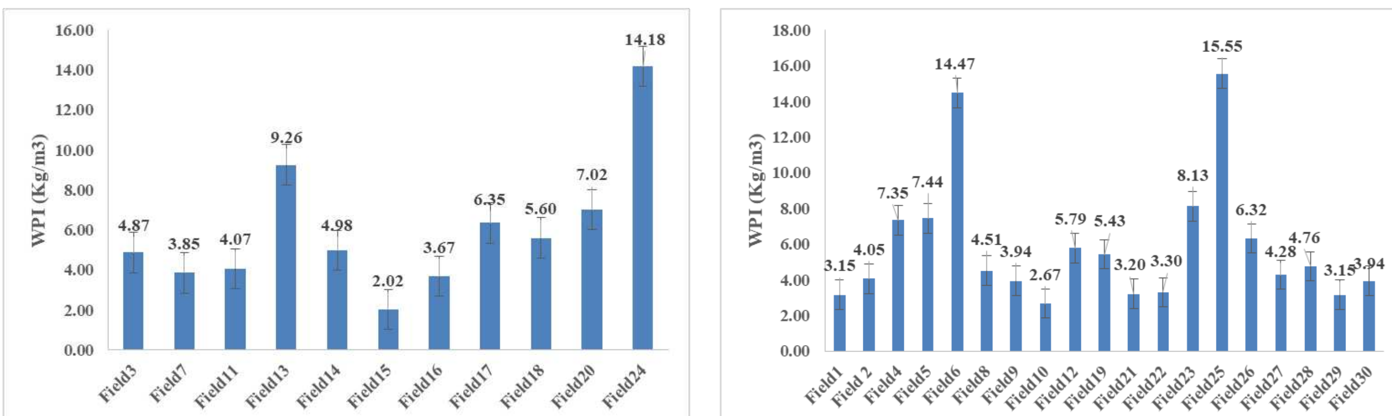
AELQ and PELQ Indices

The AELQ values in the evaluated designs varied between 37 and 86 percent, with an average of 63 percent. In 23 percent of the designs, the AELQ was less than 50 percent, in 33 percent between 50-70 percent, and in 44 percent greater than 70 percent. The PELQ values ranged from 33 to 77 percent, with an average of 58 percent. The variations in AELQ and PELQ indices are clearly visible in Figure 2. The main reasons for the low values of these indices may include significant pressure fluctuations, especially low system pressures (in communal designs), insufficient knowledge of farmers in managing operation and maintenance of the system, improper use of the central control system, lack of filter cleaning, and the use of low-quality and inexpensive tape lines.

Water Productivity Index (WPI)

The calculated irrigation water volumes based on the discharge from the emitters (Vq) and the yield and water productivity for onion and potato crops are presented in Tables 5 and 6. The average irrigation volume for onion and potato crops in the region was calculated to be 8725 and 7892 cubic meters, respectively. The minimum and maximum yields for onion and potato crops were reported as 25 and 50 tons per hectare, respectively. The average yields for onion and potato were 41 and 40 tons per hectare, respectively. The average water productivity index (WPI) for onion and potato crops in the Faryab plain was found to be 5.04 and 5.52 kilograms per cubic meter, respectively. The variations in the water productivity index for different onion and potato fields are presented in Figure 3. The results of the research by Shahrokhnia and Baghani. (2021) showed that the minimum and maximum yields for onion were 36 and 80 tons per hectare, respectively. Additionally, the water productivity of onion in the drip irrigation systems of Fars province was reported as 2.12 and 5.49 kilograms per cubic meter. Karimizadeh et al. (2016) reported the water requirement for onion in Khorasan Razavi province as 11293 cubic meters per hectare and its productivity as 7.11 kilograms per cubic meter. Geries et al. (2020) in a study in Ethiopia showed that the maximum and minimum yields for onion in drip and surface irrigation were 41.76 and 34.48 tons per hectare, respectively, with productivities of 13.05 and 6.84 kilograms per cubic meter, respectively.

The research by Joleini et al. (2022) on potato productivity in Khorasan Razavi province, which utilized drip irrigation with tape line systems, showed that the average volume of applied water and potato yield in the fields were 11,885 cubic meters and 40 tons per hectare, respectively. Additionally, water productivity varied from 2.22 to 2.55 kilograms per cubic meter. Shahrokhnia and Baghani. (2021) conducted a study in 15 potato fields across three counties: Abadeh, Eqlid, and Khorramabad in Fars province, managed by farmers. The average amount of applied water in the potato fields was found to be 9,420 cubic meters per hectare. The yield and water productivity were 43.4 tons per hectare and 4.87 kilograms per cubic meter, respectively. Ghadami Firouzabadi et al. (2019) studied water productivity in potato crops under various irrigation systems in the Qahavand plain in Hamadan province. The water productivity in the studied fields varied from 1 to 1.4 kilograms of product per cubic meter of water. The average water productivity for surface, sprinkler, and tape line drip irrigation systems was estimated at 1.4, 2.5, and 2.9 kilograms per cubic meter, respectively. Overall, a review of other research and the results of the current study indicate that the irrigation water productivity in the Faryab region is in good condition (Figure 4).



(B) (A)

Fig. 4 Water Productivity Index Values for Crops: (**a**), Onion and (**b**), Potato

Status of the Central Control System

The central control system, which includes filters such as hydrocyclones, sand tanks, fertilizer tanks, and disc or mesh filters, is one of the main and important components of drip irrigation designs and requires proper use by the operator. In the evaluated designs, 96 percent had a central control system, while only 4 percent did not (Table 6). Given the direct pumping in the region, the use of hydrocyclones to capture sand transported from wells is essential. Observations revealed that most designs did not have a satisfactory central control system (Figure 4). Field investigations showed that although some designs had been implemented for a long time, the central control systems had suffered from rust and decay (14 percent), indicating that the materials used were of inadequate quality (21 percent).

In communal designs, fertilizer tanks are typically not used due to the possibility of other users' valves being open, which discourages farmers from using them. Additionally, the designs that included fertilizer tanks were not in good condition (Figure 5), primarily due to the poor quality of the tanks used, which rusted and decayed quickly. An important aspect of the central control system is the servicing and monitoring of operations and necessary training. Results indicated that half of the designs did not have adequate servicing, suggesting that operators require training for this purpose. Overall, given the complaints from many farmers regarding the poor quality of items used in the central control system, it is recommended that companies producing low-quality materials be identified and placed on an organizational blacklist, and that high-quality custom materials be used in areas with poor water quality.

Fig. 5 Poor Condition of the Central Control System

Table 6 Status of the Central Control System in Evaluated Designs (Percentage)

Row	Problem	Answer		
1	Is there a centralized control system for the pressurized irrigation?	YES=96%	NO=4%	
2	Hydrocyclone	YES=67%	NO=33%	
3	Sand Filter	YES=33%	NO=67%	
4	Screen or disc filtration	YES=96%	NO=4%	
5	Use of a fertilizer filter	YES=66%	NO=34%	
6	Status of Central Control System Connections	Healthy=65%	Damaged=35%	
7	Quality status of central control system accessories and connections	Suitable=65%	Not suitable=21%	It is rusty=14%
8	Foundation condition	YES=53%	NO=7%	Not suitable=40
9	Filtration service status	Suitable=47%	Not suitable=53%	
10	Is acid washing done?	YES=19%	NO=81%	

The results of the assessment of the central control system's efficiency showed that in 32 percent of the designs reviewed, the efficiency of the systems had decreased over time. According to operators, the reasons included wear and tear of central control devices (59 percent), clogging of mesh filters and rusting of filtration systems (11 percent), improper execution of designs by contractors (20 percent), lack of awareness about the system's use (7 percent), and wear and tear of emitters leading to their ineffectiveness (3 percent). While the foundational infrastructure for central control systems is present in the Eastern Faryab Plain, technical assessments reveal significant shortcomings in implementation quality, system maintenance, filtration efficiency, and routine servicing. The lack of sand filters, insufficient acid washing practices, substandard foundation construction, and deteriorated connections collectively indicate systemic weaknesses. These challenges underscore the necessity for comprehensive technical revision, capacity building among system operators, and the prompt implementation of corrective strategies aimed at enhancing the performance, reliability, and service life of pressurized irrigation systems in the region.

Discussion and Conclusion

The results of the present study indicated that the systems under review had a good status regarding the productivity index, with the minimum and maximum yields for onion and potato being 25 and 50 tons per hectare, respectively. The average yields for onion and potato were found to be 41 and 40 tons per hectare, respectively. The average water productivity index (WPI) for onion and potato in the Faryab plain was 5.04 and 5.52 kilograms per cubic meter, respectively. In 23 percent of the designs, the AELQ was less than 50 percent, in 33 percent between 50-70 percent, and in 44 percent greater than 70 percent. The PELQ values ranged from 33 to 77 percent, with an average of 58 percent. The main reasons for the low values of these indices may include significant pressure fluctuations, especially low system pressures (in communal designs), insufficient knowledge of farmers in managing operation and maintenance of the system, improper use of the central control system, lack of filter cleaning, and the use of low-quality and inexpensive tape lines.

The results indicate that the most significant problems with the systems relate to management and the lack of operator awareness regarding the proper operation of the systems, especially the central control system, insufficient pressure due to direct pumping, and the use of low-quality consumables. Another issue with irrigation designs in the region is the clogging of tape lines and emitters. In 72 percent of the evaluated designs, farmers reported that the emitters or tape lines became clogged, attributing the clogging to sediments, salts, algae from the reservoirs, sand and oil pump shaft and sheath and root crops.

Data Availability

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

Author Contributions

Mohammad Naderianfar conceived and designed the study, conducted the experiments, and drafted the manuscript. Shapour Kouhestani performed the data analysis, interpreted the results, and critically revised the manuscript. Both authors read and approved the final version of the manuscript.

Declarations

Conflict of Interest:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Ethics and Consent to Participate: Not applicable.

Consent to Publish: Not applicable.

Clinical Trial: Not applicable.

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