Mobile installation of a low-pressure drip irrigation system with photovoltaic panels

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Abstract: *Currently Uzbekistan has widely adopted drip irrigation systems on large-scale agricultural lands (1-100 hectares or more), and smaller plots cultivated by households and individuals for essential food production often lack this technology. To address this disparity, a novel mobile drip irrigation system incorporating photovoltaic panels has been engineered. This integrated solution is self-sufficient, requiring no external power source, and offers versatility suitable for both rural and urban settings. Its mobility allows for easy deployment on small plots (up to 1 hectare) commonly used for household gardens, suburban areas, and greenhouses. The integration of photovoltaic panel complexes with low-pressure mobile drip irrigation systems holds significant potential for ensuring a dependable water supply to agricultural crops. This innovative technology is particularly well-suited for regions facing water scarcity, such as Uzbekistan, Central Asia, and other arid zones globally, enabling sustainable agriculture practices even in the context of climate change.*
KEYWORDS: *AGRICULTURE, WATER-SAVING TECHNOLOGIES, DRIP IRRIGATION, PHOTOVOLTAIC SYSTEMS, MOBILE INSTALLATIONS.*

1. Introduction

Central Asian nations face a growing challenge in satisfying their agricultural water needs. This issue stems from a confluence of factors including population growth, expanding irrigated farmland, the impacts of climate change, and the depletion of glaciers, which are crucial sources of freshwater. Projections indicate that by 2030-2050, Central Asian glaciers could shrink by as much as 50%. This reduction in glacial meltwater, combined with other factors, is expected to lead to a significant decline in water availability: a 10-15% decrease in the Amudarya River basin and a 6-10% reduction in the Sirdarya basin. Concurrently, agricultural water demand is projected to rise by 5% by 2030, with further increases of 5-10% by 2050 and 12-16% by 2080 [1]. This growing disparity between water supply and demand poses a serious threat to food security and access to safe drinking water for the region's population. Implementing water-saving technologies in agriculture is crucial for mitigating this impending water deficit and ensuring sustainable agricultural practices.

Household agriculture plays a crucial role in ensuring food security for the Republic of Uzbekistan. These farms not only provide sustenance for their own families but also contribute significantly to the national food supply, even exporting excess produce [2, 3]. Currently, over 692,200 families engage in farming across 1,043,700 plots of land, cultivating a variety of crops and raising livestock. Their contribution is substantial: they account for 84% of potato production, 71% of vegetables, 55-60% of plums, grapes, and other fruits, and over 94% of livestock products [4]. However, challenges remain in remote mountainous areas where access to essential infrastructure such as electricity is limited. These regions often feature complex soil types unsuitable for conventional farming methods. Utilizing solar-powered pumping devices could unlock the agricultural potential of these underutilized lands, enabling higher yields and contributing further to Uzbekistan's food security.

The implementation of water-saving technologies, particularly drip irrigation systems, has significantly increased in large agricultural areas within the country. However, the adoption of such systems remains limited in smaller plots (ranging from 0.01 to 1.0 hectares), including field courtyards and greenhouses. Furthermore, there is a lack of research regarding optimal drip irrigation practices for different hydromodule zones. This includes determining the frequency of watering and water consumption per irrigation cycle for both large-scale agricultural lands and smaller plots such as citizen gardens and greenhouses.

Traditional irrigation methods, such as furrow watering, remain prevalent in agricultural settings despite their inherent inefficiencies. This approach leads to significant wastage of both water resources and mineral fertilizers. In contrast, drip irrigation delivers water and nutrients directly to plant roots, minimizing resource waste. Implementing water-conserving technologies like drip irrigation, coupled with renewable energy sources like solar power, can enhance crop yields on arid lands even during periods of water scarcity. This approach promotes sustainable agricultural practices while maximizing productivity.

2. Materials and methods

The research team "Suvchi" has developed a novel, low-pressure mobile drip irrigation system for small plots of land (ranging from 0.01 to 1.0 hectares) (Fig.1). This innovative system incorporates photoelectric panels and is designed specifically for efficient irrigation in limited areas. Its primary components include:

- low pressure drip irrigation system;
- photoelectric solar panels;
- pumping device;
- four-wheel carriage with metal construction;
- automated control system.

3. Results and discussions

3.1. Low pressure drip irrigation system.

The drip irrigation system can be tubular or ribbon. The tubular system is rigid and resistant to high pressure. The belt system is soft and is used in low-pressure drip irrigation systems. There are many types of ribbon drip irrigation systems [6]. Labyrinth, ribbon and emitter drip irrigation pipes are low-pressure and they are very easy to install and assemble on irrigated land. Ribbon pipes are very cheap and when filled with water they take on a round shape.

The proposed low-pressure ribbon labyrinth drip irrigation system was developed at the National Research University Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (NRU TIIAME) [7, 8, 9]. The main working part of the complex low-pressure drip irrigation system is a polyethylene pipe for drip irrigation. The distance between the droppers holes in the oval tube may vary. In currently manufactured hoses, the distance between the droppers is 20, 40 and 50 cm. On request, the distance between the droppers holes can be changed. A drip irrigation pipe made of inelastic plastic consists of a main pipe and a small pipe made of it as a single unit. With a diameter of a drip polyethylene pipe of 25 mm, the height of the oval pipe receiving water from the main pipeline is 3÷5 mm, and the width is 6 mm. The oval-shaped pipe receives water every 20 cm through holes opened in the main pipe. Water, passing through the openings in the pipe, through droppers located every 20 cm, gets to the base of the plants (Fig. 2).

One of the main elements of the system is the hydraulic resistance elements in the oval-shaped pipe. The resistance elements are arranged along the length of the oval pipe wall in opposite directions and at the same distance from each other. These hydraulic resistances ensure the same number of drops at both the beginning and the end of the pipes, regardless of their length. For example, if 1 liter of water flows out of an elastic pipe dropper at the beginning of a 500 m long field in 1 hour, then the same amount of water flows out of the dropper at the end of the field [10].

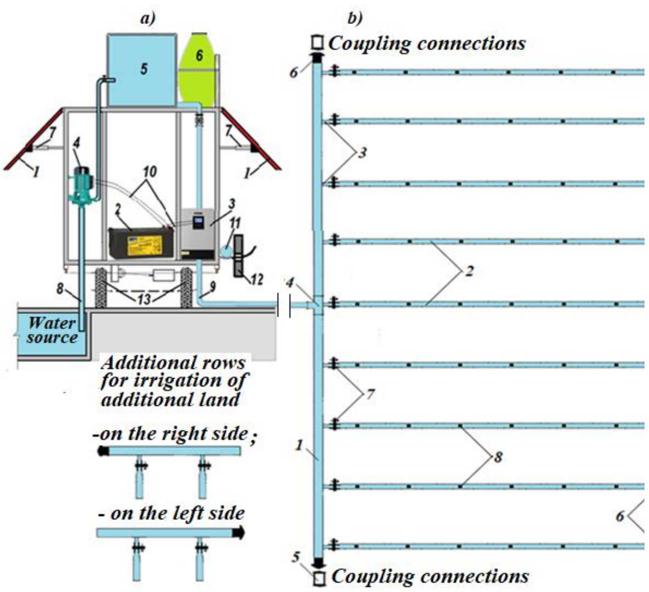

Figure 1. *The design scheme of the mobile integrated low-pressure drip irrigation system with photovoltaic panels:*
a - the general scheme of the mobile drip irrigation installation: 1-photovoltaic panels with a capacity of 0.55 kWh; 2-batteries; 3-an inverter with a built-in controller; 4-a pumping unit; 5 - a water tank with a volume of 2.0 m^3; 6-a tank for liquid mineral fertilizers with a volume of 0.1 m^3; 7-a device for changing positions of the photovoltaic panel; 8-suction pipe of the pumping unit; 9-tube for connecting water to the drip irrigation system; 10-connecting wires; 11-mounted drip irrigation system; 12-a coil of polyethylene pipes for drip irrigation; 13- wheels from a passenger car (4 pcs).
b-the scheme of the low–pressure drip irrigation system: 1-main polymer pipes, D=50, 75 mm; 2-low-pressure polyethylene pipes with droppers; 3-connecting pipes, D=20 mm; 4-triple coupling; 5-connecting couplings; 6-plugs; 7-gaskets.

Drip irrigation pipes made of flexible polyethylene material with a thickness of 100 microns are very light, do not take up much space, and it is very convenient to take them with you to hard-to-reach places. A 6 cm wide coil of ribbon pipes can range from several hundred meters to several kilometers. Figure 3 shows coils of various sizes, Table 1 shows the dimensions of the coils, and Table 2 shows the technical characteristics of a flexible polyethylene pipe with droppers. For a low-pressure drip irrigation system, a 2.0 m^3 water tank and a 0.1 m^3 liquid fertilizer tank are installed.

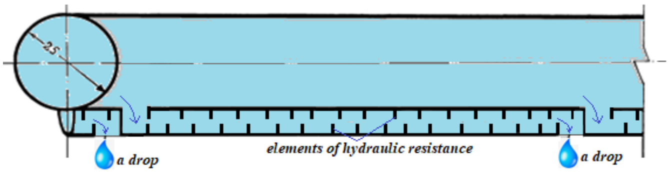

Figure 2. *Scheme of the drip polyethylene pipe.*

Table 1. Dimensions of polyethylene pipe coils

No	Coils parameters:		
	diameter, sm	length, m	weight, kg
1	23	243	2,4
2	35	622	6,2
3	48	1220	**12,2**

Figure3. *View of the coils.*

The drip irrigation system developed by NRU "TIIAME" has the following advantages [7, 8]:

1. Droppers are capable of passing not only colloidal particles and microorganisms in the water, but also sand and silt up to 0.5 mm in diameter.
2. The ability to operate at a low pressure of 1.5-2.0 m (without a pumping unit producing a pressure of 20-30 m).
3. Low cost, simple design, the possibility of its installation and operation, repair and dismantling by any water user.
4. Production of necessary raw materials and equipment for the system in Uzbekistan.

Table 2. *Technical characteristics of flexible polyethylene pipe for drip irrigation*

No.	Characteristics	Unit of measurement	Quantity
1	Diameter	mm	25
2	Type of droppers	лабиринтли-тиркишли	
3	Water consumption of each dropper (relative to pressure)	l/s	1-4
4	Distance between drops	sm	20, miscellaneous
5	Drip inequality: - in 500 m - in 1000 m	% %	10 15
6	The water pressure required to the system work	m	1.5 – 2.0
7	Minimum furrow length	m	250
8	Optimal slope of the field		0.003- 0.006
9	Working period	year	1-2
10	Working period of trunk plastic pipes	year	12 - 15

3.2. Photoelectric panels

The photovoltaic system of the low-pressure mobile drip irrigation installation consists of: 2 photovoltaic panels with a capacity of N=0.55 kWh each (with a total capacity of N= 1.1 kWh); a 100 Ah battery; an inverter with an integrated controller; a position regulator for photovoltaic panels and connecting wires.

For the period of hot summer days (t = 40-50°C), in order to ensure high efficiency of the solar panels, a water cooling system was installed behind the panels (Fig. 4). In order for the photovoltaic panels to work with a high efficiency, it is necessary that the temperature on the does not exceed t= 25-27^{0}C. Compared with non-cooling panels, the power of cooled panels increases up to 2 times [11, 12].

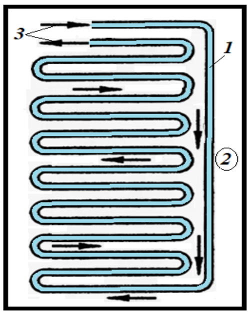

Figure 4. *Photoelectric panel cooling system:*
1-photoelectric panel cooling system; 2-photoelectric panel; 3-movement of coolant.

The mobile complex low-pressure drip irrigation system with a photovoltaic device allows pumping irrigation water from pools and wells, rivers, canals, lakes, springs, aqueducts, and even accumulated rainwater using its own small pumping unit. Scientific innovations obtained during the development of the installation include the following:

- possibility of introducing drip irrigation in small areas (ω = 0.01 – 1.0 ha) in agriculture, on household plots, as well as in greenhouses;
- its mobility allows it to be used on 3-5 consumer lands.;
- the possibility of using renewable energy sources (solar);
- cooling of photoelectric panels during hot periods of the year (t = 40-50^{0}C);
- low cost of the system, simplicity of construction;
- possibility of using the energy generated by a photovoltaic installation during the non-vegetation season (autumn-winter) for various other purposes (power supply of electrical equipment in small industrial enterprises of farms, lighting, heating and cooling of residential premises, shops, hairdressers, slaughterhouses, workshops, offices and other consumer facilities, in the preparation of livestock feed on livestock and poultry farms, etc.);
- preparation of all parts from domestic raw materials;
- operation of the water carrying pump device at the expense of solar energy;
- compact water tank instead of water intake pool as well as application of mineral fertilizer tank;
- qualified specialists are not required for exploitation;
- simplicity of installation and operation, repair and dismantling and storage work;
- possibility of developing an irrigation regime for irrigation crops that are planted in small areas.

3.3. Pump unit

To fill a tank with a volume of W=2.0 m^3 located at a height of 2.0 m above the irrigated land in the mobile low-pressure drip irrigation system, there was selected an EVN-130-4 pump from EPA, founded in China in 2009 [13]. The main characteristics of the EVN-130-4 pump are shown in Table 3.

Table 3. *Characteristics of the EVN-130-4 pump*

1	Mains voltage, V	220
2	Power consumption, W	370
3	Insulation class	23
4	Warranty, month	12
5	Outlet diameter, mm	25
6	Flow rate, l/min	90
7	Rotation speed, rpm	2850
8	Frequency, Hz	50

Figure 5. *EV-130-4 pumping unit*

3.4. Four-wheel carriage with metal construction

The low-pressure drip irrigation system, reservoirs for water and mineral fertilizers, main pipes of a low-pressure drip irrigation system and flexible polyethylene drip pipes, photovoltaic panels, a battery, an inverter (together with a controller), a device for installing photovoltaic panels at a different angle, electrical wires, a pump for supplying water to a drip irrigation system, its suction and pressure pipes are mounted on a mobile four-wheeled metal trolley (Fig.1).

3.5. Automated control system

The automated control system allows the pumping device to operate automatically depending on the water level in the water intake source and the water tank [14]. In addition, given that crops are mostly watered at night, the developed program allows the plant owner to remotely start and stop a complex irrigation system. This, in turn, makes it convenient for farmers who live far from irrigated land.

3.6. Production of environmentally cleared energy

The developed mobile low-pressure drip irrigation system has advantages such as low cost, simplicity of design, manufacture of all parts of local raw materials, use of renewable solar energy, no need for qualified specialists for operation and ease of repair work. The electricity generated by photovoltaic panels on a mobile drip irrigation system is environmentally friendly energy that does not pollute the environment. Its use leads to the purification of the environment, as well as to the saving of organic fuels. Below we will look at how much gas fuel can be saved due to the energy produced, as well as conventional fuel (Table 4). The calculations took into account the burning of 0.15 m^3 of gas fuel to produce 1 kWh of electricity [15], as well as savings of 0.122835 conditional fuel [16]. According to the data shown in Table 4, the energy generated in 1 year by one device in the amount of E =7,920 per 1 kWh can save 1,188 m^3 of gas fuel, 973 g of conventional fuel, which also makes it possible to benefit 7,920 thousand sums. In the future, it is planned to massively introduce this installation on all dehkan farms, courtyard plots and greenhouses with an irrigation area of up to 1 hectare.

***Table 4**. The amount of gas and conditional fuel economy at the expense of electroenergy, which produces one unit of mobile photovoltaic device*

Photovoltaic panels' operation period (sunny 300 days)	Produced electroenergy, kWh·H	Economy:		Economic benefits, kVt/sum (US dollar)*
		gas, m^3	conditional fuel	
In 1 hour	1,1	0,165	0,13512	1 100 (0,0848)
In 1 day	26,4	3,96	3,243	26 400 (2,0354)
In 1 year (300 days)	7 920	1 188	973,0	7 920 000 (610,61)

Note: 1.0 kWh of electricity costs 1,000 soums (equivalent to 0.077 US dollars)

Conclusions

1. Mobile complex low-pressure drip irrigation system with photovoltaic panels:

- in conditions of water scarcity, it reliably provides crops on small areas (ω = 0.01 - 1.0 ha);
- it provides water pumping to the drip irrigation system by a pumping unit using environmentally cleared electricity generated by solar energy;
- gives possibility of using the energy generated by a photovoltaic installation during the non-vegetation season (autumn-winter) for various other purposes (power supply of electrical equipment in small industrial enterprises of farms, lighting, heating and cooling of residential premises, shops, hairdressers, slaughterhouses, workshops, offices and other consumer facilities, in the preparation of livestock feed on livestock and poultry farms, etc.);
- it makes it possible to develop an irrigation regime for irrigation crops that are planted in small areas.

2. The integration of photovoltaic panel complexes with low-pressure mobile drip irrigation systems holds significant potential for ensuring a dependable water supply to agricultural crops. This innovative technology is particularly well-suited for regions facing water scarcity, such as Uzbekistan, Central Asia, and other arid zones globally, enabling sustainable agriculture practices even in the context of climate change.

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Gratitude: we are grateful for the support of scientific research to the REP-24112021/32 project "Automated drip irrigation system for agricultural crops using renewable energy sources", funded by the World Bank.

Financing: this study was prepared on the basis of materials from the REP-24112021/32 project "Automated drip irrigation system for agricultural crops using renewable energy sources", funded by the World Bank.