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Method for accounting subsoil moisture in drip irrigation

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Abstract. The study emphasizes the critical role of irrigation in food safety, particularly in regions facing agricultural sustainability challenges. Conventional water management practices hinder a sustainable progress. The adoption of drip irrigation, delivering water directly to plant roots is proposed as a viable solution. The findings reveal a significant reduction (10-50%) in irrigation rates and increase in cotton yields. Groundwater levels impact irrigation requirements, with higher levels correlating with increased rates. Calculations highlight varying groundwater uptake and soil moisture content based on the cotton root system's depth.

1 Introduction

Irrigation plays a pivotal role in addressing the escalating food demands associated with a burgeoning global population, particularly in regions where agricultural sustainability is challenged. Investigations underscore that conventional water resource management practices constitute a primary impediment to the sustainable progression of irrigated agriculture in Uzbekistan [1, 2, 3]. A viable strategy to ameliorate this predicament involves the adoption of drip irrigation systems, characterized by the calibrated delivery of water in incremental volumes directly to the plant root zones, thereby aligning with plant requirements [4, 5, 6]. Significantly, the quantity and frequency of water provision are modulated in accordance with the specific needs of the cultivated plants.

In arid seasons, subsurface water emerges as an auxiliary water source for agricultural purposes, particularly in locales where groundwater levels permit its utilization in conjunction with surface water for irrigation [7, 8, 9, 10]. Consequently, scholarly investigations focusing on the synergistic application of drip irrigation and groundwater for crop cultivation present a prospective remedy to water scarcity challenges, a phenomenon increasingly prevalent in recent years and anticipated to exacerbate water deficit scenarios [11-13].

Presently, there is a concerted effort to integrate water-conserving irrigation technologies, such as drip irrigation and sprinkler systems, aimed at mitigating water consumption. A critical determinant in this context is the spatial configuration of agricultural fields, groundwater levels, and the establishment of irrigation norms contingent upon crop varieties.

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Attention to groundwater conditions, the presence and functionality of drainage systems, as well as meticulous consideration of soil layer parameters, water quality, crop classifications, and regional climatic nuances are imperative during the cultivation and maturation of agricultural crops.

2 Materials and methods

Field investigations were conducted to assess soil properties stratified by soil layers, with specific consideration given to the root system architecture of plants and the topsoil. Parameters investigated included soil composition, moisture content, groundwater dynamics gleaned from observational well outcomes, as well as analyses of soil and water quality, encompassing mineralization and filtration coefficients. Additionally, assessments were made of drainage flux and evaporative losses. The water-salt equilibrium within the aeration zone was quantified, with due consideration given to the dimensions of the root system contingent upon the developmental phase of the plant. For each developmental stage, irrigation norms and schedules were computed, accounting for the prevailing soil moisture reserves.

In the regions implementing drip irrigation practices for cotton and diverse agricultural crops within the Syrdarya, Saykhunabad, and Gulistan districts of the Syrdarya region, where subsurface waters exhibit proximity to the surface (at depths of 1.5-2.5 meters, salinity registering at 2-3 g/l), irrigation norms and quantities were optimized to yield water savings of 1-2 times through the adoption of subirrigation techniques (Figure 1).

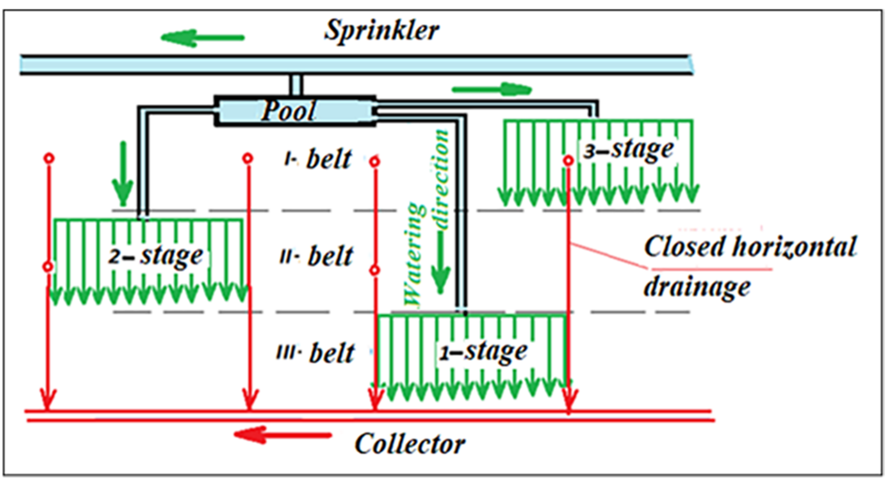

Fig. 1. Scheme of irrigation of agricultural crops.

Total water consumption for the estimated ten-day period is determined by the formula:

$$E_{b_i} = K_{l_i}\Sigma t_i \quad (1)$$

Where: K_{l_i}– biophysical coefficient (average daily water flow per 1^0C of heat); Σt_i- the sum of average daily air temperatures for a decade, ^{0}C.

The amount of moisture influx from groundwater was determined:

$$G_i = E_{b_i}K_i(S_i h_i) \quad (2)$$

Where S_i- granulometric (mechanical) composition of soil; h_i- depth of the soil layer.

The initial supply of moisture in soil during the period of crop seedlings:

$$W_{in} = 100 \cdot \gamma \cdot \beta_{in} \cdot h_i \quad (3)$$

γ- the volumetric mass of a meter layer of soil; β_{in}- initial average moisture content of a meter layer of soil during the period of cotton growth, %.

The moisture reserve in soil at the lowest humidity:

$$W_{res\,in} = 100 \cdot \gamma \cdot \beta_{min} \cdot h_i \quad (4)$$

Where: β_{min} is a soil moisture at the lowest moisture capacity of the dry mass, %.

The moisture reserve in the soil at the end of the estimated decade:

$$W_{res\,end} = n_i \cdot \gamma \cdot \beta_{min} \cdot h_i \quad (5)$$

Where: n_i - the pre-irrigation moisture of the soil layer.

The amount of moisture in the soil used by plants at changes the layer depth:

$$A = \frac{(h_{i+1} - h_i)W_{in}}{h} \quad (6)$$

The moisture reserve in the soil at the beginning of the first ten-day period:

$$W_{A_i} = \frac{100 \cdot \gamma \cdot \beta_{in} h_i}{h} \quad (7)$$

The irrigation rate for the crop is determined by following:

$$M = 100 \cdot h \cdot \gamma \cdot \beta_{in} \left(1 - \frac{n_i}{100}\right) K \quad (8)$$

The prescribed irrigation rates were delineated to four development phases of cotton growth: crop growth, start of budding, flowering formation and maturation. Groundwater levels were received from and documented by the Regional Hydrogeological and Reclamation Expedition.

3 Results and discussion

Table 1 encapsulates the outcomes derived from an exhaustive analysis of aeration zone moisture content in irrigated fields over the course of the growing season, juxtaposed against varying groundwater levels. The investigation facilitated the determination of requisite moisture levels essential for the developmental zones of root systems in agricultural crops. Consequently, irrigation norms and schedules were delineated for each hydro-modular region, tailoring the requirements to the specific growth phases of the plant.

Table 1. The humidity results of the aeration zone.

No	Watering date	A_0 m³/ha	*M*, m³/ha	*G* m³/ha	A_1 m³/ha	*W* m³/ha	D_G m³/ha	EU_{tr} m³/ha	*h*, m
1	05.VI	65	92	170	122	327	48	205	<0.50
2	25.VII	40	210	502	270	842	322	572	0.50
3	15.VII	36	283	1140	506	1459	634	917	1.0
4	28.VII	34	334	1255	1013	1623	242	610	1.0-2.0
5	14.VIII	15	472	1348	1620	1835	-272	215	2.5
6	05.IX	38	403	1360	2520	1801	-757	-710	3.0
7		228	1642						

During the vegetation period the temporal variations in soil moisture within the soil aeration zone was studied across distinct soil layers: 0 to 0.3 m (the arable layer), 0.3 to 1.0 m, 1.0 to 2.0 m, 2.0 to 3.0 m, and beyond 3 m (Figure 2). Prescribed irrigation rates for specific growth stages were outlined total 1642 m^3/ha for the season. Use of groundwater resources in a cotton field leads to increase in soil moisture ranging from 500 to 2500 m^3/ha at groundwater level from 1.0 m to 3.0 m. At groundwater level below 1.0 m the soil moisture content ranged from 100 to 500 m^3/ha.

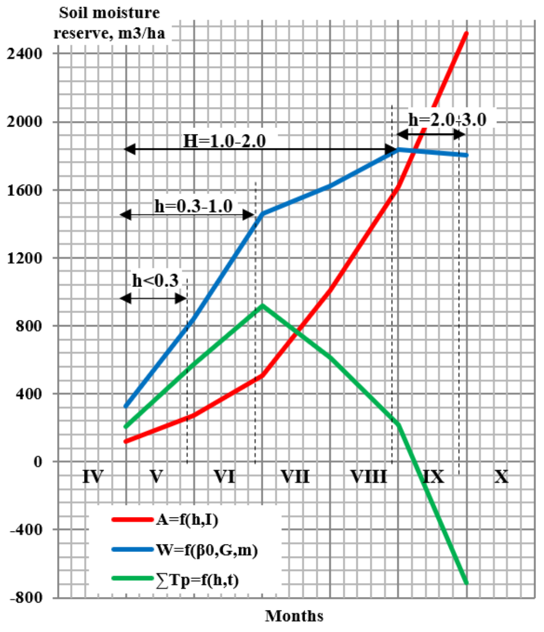

Fig. 2. Moisture exchange in the aeration zone of a cotton field: vegetation period.

The research has demonstrated that the drip irrigation provides a notable reduction in irrigation rates ranging from 10% to 50%, with an increase in cotton yields over 1.5 t/ha. Under the conditions characterized by a high groundwater level within the soil aeration zone (h < 2.0 m), where the length of the cotton root system is less than 1.0 m, irrigation requirements diminish.

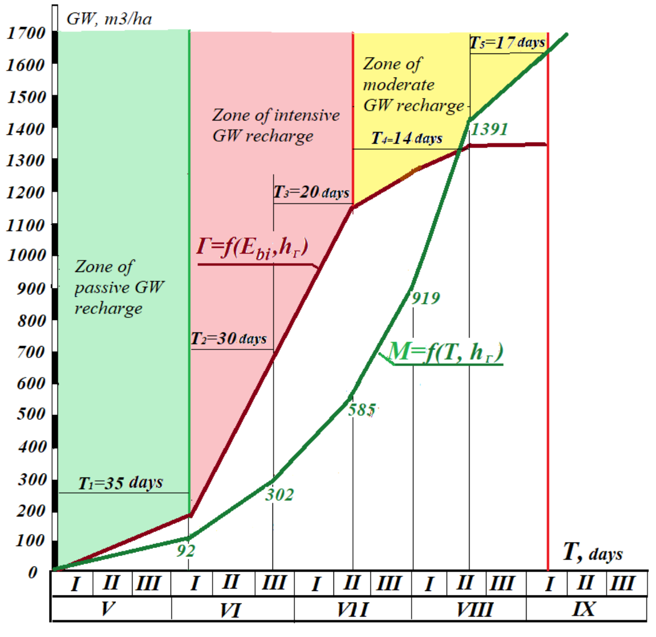

Fig. 3. Cotton water consumption schedule for the growing season in drip irrigation systems.

It has been established that irrigation rates become higher in conditions where the groundwater level and the length of the root system of crops are higher than h ≥ 2.0 m. Identified, that the temporal variations in soil moisture across different soil layers during the vegetative period, revealing pronounced increases in soil moisture from 500 to 2500 m^3/ha at using combined groundwater in cotton fields (Figure 3).

Within the 0.3 to 0.5 m layer the irrigation rate is denoted as M = 151 m^3/ha. During the flowering and seed collection period this rate increases to M = 272 m^3/ha, further escalating to M = 403 m^3/ha during the ripening stage. At the vegetation season the irrigation rate is 1642 m^3/ha in total, the number of irrigations is 6 and duration of the irrigation period is from June 5 to September 5, that is the intermediate irrigation period is from 14 to 21 days. According to study results, the volume of groundwater use by the cotton root system ranges from G_1=170 m^3/ha to G_6=1360 m^3/ha with the amount of moisture in the soil aeration zone (h_s<0.5 m) W_1=327 m^3/ha, at a depth h_s = 3.0m, W_6=1801 m^3/ha.

4 Conclusion

According to the research results there is urgent need to increase efficiency of water resources use, introduce cost-effective irrigation technologies, study the impact of groundwater levels to agricultural crops growth. The research has demonstrated that the drip irrigation provides a notable reduction in irrigation rates with an increase in cotton yields.

References

1. G. Leng, M. Huang, Q Tang, Hydrometeorology **15(3)** (2014)
2. M. Ikramova, I. Akhmedkhodjaeva, M. Otakhonov, Z. Ishpulatov, IOP Conference Series: Earth and Environmental Science **1284(1)**, 012042 (2023)
3. J. Lopez, J. Winter, J. Elliott, Earth's Future **10(1)**, e2021EF002018 (2022)
4. S. Wang, Z. Zhang, S. Wie, Journal of Hydrology **629** 130424 (2024)
5. A. Arifjanov, L. Samiev, I. Ahmedkhodjaeva, Q. Rakhimov, S. Sobirov, E3S Web of Conferences **263**, 02026 (2021)
6. B. Tulip, M. Siddik , M. Islam, A. Rahman, Agricultural Water Management **266**, 107593 (2022)
7. M. Ikramova, K. Kabilov, I. Akhmedkhodjaeva, A. Khodjiev, IOP Conference Series: Earth and Environmental Science **403(1)**, 012156 (2019)
8. A. Naloichenko, A. Atakanov, *The use of subsoil irrigation against the background of drying-humidifying horizontal drainage. (subirrigatio*n). Monograph, 261 (2009)
9. G. Akhmedzhanov, Cotton Growing **5**, 41-43 (1987)
10. M. Khamidov, S. Isaev, F. Baraev, R. Muradov, *Subirrigation is an effective technique for increasing the efficiency of use of irrigation water in irrigated areas*, in Proceedings of the conference “Modern means and technologies in agricultural production” **4(60)**, 135-142 (2015)
11. I. Aidarov, *Regulation of water-salt and nutrient regimes of irrigated lands* (M., Agropromizdat, 1985), p. 304
12. N. Khodzhibaev, *Hydrogeological reclamation zoning* (T., Fan, 1975), p. 143
13. I. Khudaev, J. Fazliev, Modern Innovations, Systems and Technologies **2(2)**, 0301–0309 (2022). https://doi.org/10.47813/2782-2818-2022-2-2-0301-0309