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IMPROVING IRRIGATION EFFICIENCY AND SOIL MOISTURE DISTRIBUTION ON TERRACED SLOPES OF ADYR LANDS IN THE FERGANA VALLEY

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ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ ОРОШЕНИЯ И РАВНОМЕРНОСТИ УВЛАЖНЕНИЯ ПОЧВЫ НА ТЕРРАСИРОВАННЫХ СКЛОНАХ АДЫРОВЫХ ЗЕМЕЛЬ ФЕРГАНСКОЙ ДОЛИНЫ

Annotation: The article explores methods to enhance irrigation efficiency and soil moisture distribution on terraced adyr lands in the Fergana Valley. A low-pressure irrigation network was developed to adapt to complex terrain, reduce water loss, and prevent soil erosion. Field experiments confirmed improved irrigation performance, labor productivity, and water savings up to 2200 m³/ha per season.

Keywords): adyr lands, terraced slopes, surface irrigation, furrow irrigation, low-pressure irrigation network, soil erosion control, water use efficiency, hydraulic modeling, slope agriculture.

Аннотация: В статье рассматриваются методы повышения эффективности орошения и равномерности увлажнения почвы на террасированных адыровых землях Ферганской долины. Разработана низконапорная оросительная сеть, адаптированная к сложному рельефу, позволяющая снизить потери воды и предотвратить водную эрозию почвы.

Полевые эксперименты подтвердили повышение эффективности орошения, производительности труда и экономию оросительной воды до 2200 м³/га за сезон.

Ключевые слова: адыровые земли, террасированные склоны, поверхностное орошение, бороздковое орошение, низконапорная оросительная сеть, борьба с эрозией почвы, эффективность использования воды, гидравлическое моделирование, сельское хозяйство на склонах.

The cultivation and irrigation of agricultural crops on complex adyr lands—characterized by steep and sloping hillsides—poses a significant risk of water-induced soil erosion and creates serious difficulties in the mechanization of fieldwork operations.

Adyrs are sharply elevated landforms that rise above the surrounding plains in the form of elongated ridges. They are marked by their fragmented contours and scattered distribution.

The lack of conveniently cultivable land areas has necessitated extensive efforts to develop the adyr regions of the Fergana Valley in the Republic of Uzbekistan. The climate of the Fergana Valley is dry, sharply continental, and has a long frost-free period. The high accumulated temperature levels allow for the cultivation of cotton and the development of subtropical crops, horticulture, viticulture, and melon growing.

Part of the adyr lands, characterized by steep slopes, has been developed through the construction of step terraces.

In our study, the level of potential for applying economically efficient irrigation methods in these areas was assessed through scientific and methodological analysis, taking into account the specific characteristics of regions with complex topography.

Many researchers (Kostiakov, 1960; Krivovyaz, 1966; Surin, 1982) consider drip irrigation to be ineffective under certain conditions, particularly:

it must be acknowledged that it is not suitable for areas with complex terrain and small, scattered land plots.

The objective of the research work was to increase the operational efficiency and productivity of terraced slopes on the adyr lands of the Fergana Valley by improving the on-farm irrigation network and surface irrigation technology using furrows.

As a result of the studies, the patterns of soil water regime formation on terraced slopes under conditions of distributed water application along the length of furrows were identified, as well as the hydraulic regime in the elements of the piped irrigation network with above-ground irrigation pipelines. Based on this, a design for a low-pressure irrigation network was developed (Surin, Sabitov, et al., 1991), along with new irrigation technologies and design methodologies for the irrigation network aimed at conserving irrigation water and protecting soil from degradation.

The high pressure naturally generated by the slope's terrain is reduced and maintained at a stable low pressure—ranging from 0.9 to 1.0 meters—with the help of devices installed for each row of plantings. The excess water volume, which exceeds the needs of the plants on the terraces, is transferred to the lower part of the slope through a distribution network.

The water flow delivered by these devices is distributed as an equal number of irrigation streams along the length of the furrows through holes of varying diameters, which are uniformly opened along the length of the irrigation pipes. The number and discharge of irrigation streams, as well as the spacing between the holes, are determined using special calculation methods based on the row length and its longitudinal slope. As a result, the irrigation process can be completed in a short period with a high level of quality.

This irrigation technique, which we recommend for use in intensive orchards or vineyards on adyr slopes, ensures that the water is evenly distributed over very short distances (1.5–4.0 meters) from the beginning to the end along the plant rows [1]. At the same time, the one-time irrigation rate is completed before ¾ to ⅘ of the furrow depth is filled with water.

The relationship between water level (H) in the furrow and specific water discharge (q_1) was established. Scientists (Kostiakov, 1960; Surin, 1982) have identified the following patterns of furrow irrigation:

$$\upsilon = (\upsilon_n - \upsilon_u)\, \mathbf{e}^{\mathbf{kt}} + \upsilon_u ;$$

Where: υ – infiltration rate of water into the soil, m/hour;

υ_n – initial infiltration rate of water into the soil, m/hour;

υ_u – steady-state infiltration rate of water into the soil, m/hour;

e – base of the natural logarithm;

k – proportionality coefficient of water movement along the furrow, 1/hour;

t – duration of water application into the furrow, hours.

The distance X that the irrigation stream travels is given by:

$$X = L_0 (1 - B\, e^{kt}) ;$$

Where: X – distance the irrigation stream reaches, m;

L_0 – maximum reach distance of the irrigation stream, m;

B – dimensionless parameter.

The maximum reach distance of the irrigation stream (**L_0**) is determined by the formula:

$$L_0 = 3.6 q_б / \mu\, \chi\, \upsilon_u ;$$

Where: $q_б$ – flow rate of water supplied into the furrow, L/s;

μ – coefficient accounting for the reduction in wetted perimeter;

χ – wetted perimeter at the beginning of the furrow, m.

Based on the above relationships, we conducted hydraulic calculations, which allowed us to describe empirical formulas for the process of water accumulation in small streams, water consumption, and water level increase over time (Shevelev, 1984).

Field experiments were conducted using different specific water flow rates ranging from 0.0016 to 0.006 L/s·m. During the experiments, the dynamics of water level changes inside the furrows were studied.

A technique was developed for conducting these experiments, which matched the non-traditional nature of the irrigation process. One of the main objectives of the field experiments was to monitor the accumulation of a specific amount of water in the field.

Based on graphical data obtained from field experiments, it can be concluded that when the specific water flow rate ranged from 0.0015 to 0.005 L/s·m, the amount of water corresponding to an irrigation norm of 800–1000 m^3/ha was equivalent to a water column height of 0.04 to 0.12 m. The water pressure was regulated using a water meter; the irrigation duration ranged from 8 to 22 hours.

Using this process, it became possible to determine the maximum specific water flow rate. An experiment conducted at 0.006 L/s·m showed that when the irrigation rate reached 75–80%, the furrow volume reached full capacity for the given soil condition.

The results of the experiments show that the proposed irrigation technique allows for safe irrigation from the standpoint of preventing irrigation-induced soil erosion, while also ensuring high-quality irrigation in a very short period on terraced plots.

Operational use of the proposed irrigation network demonstrates its reliability and high efficiency:

- Labor productivity of irrigation workers increased from 0.12 to 3–5 ha per shift compared to existing irrigation technologies;
- Irrigation water savings during the growing season amounted to 2200 m^3/ha;
- Safe irrigation and terrace stability were ensured;
- High uniformity coefficient of soil moisture along the furrow length (0.90–0.96);
- Significant reduction in irrigation duration of a modular plot (3–5 hours).

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