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ИҚЛИМ ЎЗГАРИШИ ШАРОИТИДА СУВ ТЕЖОВЧИ СУҒОРИШ ТЕХНОЛОГИЯЛАРНИНГ САМАРАДОРЛИГИНИ ОШИРИШ ВА ҚИШЛОҚ ХЎЖАЛИГИДА СУВ РЕСУРСЛАРИДАН ОҚИЛОНА ФОЙДАЛАНИШНИНГ ИЛМИЙ АСОСЛАРИ

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Аннотация: Иқлим ўзгариши глобал миқёсда қишлоқ хўжалигига жиддий таъсир кўрсатиб, сув ресурслари танқислиги, об-ҳаво ўзгарувчанлиги ва экстремал иқлим ҳодисаларининг кучайиши каби муаммоларни келтириб чиқармоқда. Ушбу мақола Ўзбекистон каби қурук ва ярим қуруқ иқлим зоналарида сув тежовчи суғориш технологияларининг самарадорлигини ошириш ва қишлоқ хўжалигида сув ресурсларидан оқилона фойдаланишнинг илмий асосларига бағишланади. Мақолада томчилатиб суғориш, ёмғирлатиб суғориш, лазерли текислаш каби замонавий технологияларнинг афзалликлари, амалий қўлланиши ва уларнинг иқлим ўзгаришига мослашувдаги роли таҳлил қилинади. Шунингдек, географик ахборот тизимлари (GIS), сенсор технологиялари, масофавий зондлаш ва математik моделлаш воситалари орқали сув бошқарувини оптималлаштириш масалалари кўриб чиқилади. Иқтисодий, экологик ва ижтимоий омилларни инобатга олган ҳолда, маҳаллий шароитларга мослашган интеграциялашган ёндашувларнинг муҳимлиги таъкидланади. Тадқиқот натижалари қишлоқ хўжалигининг барқарор ривожланишини таъминлаш ва иқлим ўзгаришига мослашиш учун амалий тавсиялар беради.

Калит сўзлар: иқлим ўзгариши, сув тежовчи суғориш, томчилатиб суғориш, ёмғирлатиб суғориш, лазерли текислаш, сув ресурсларини бошқариш, қишлоқ хўжалиги, барқарор ривожланиш, географик ахборот тизимлари, математik моделлаш, масофавий зондлаш.

НАУЧНЫЕ ОСНОВЫ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ВОДОСБЕРЕГАЮЩИХ ТЕХНОЛОГИЙ ОРОШЕНИЯ И РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ ВОДНЫХ РЕСУРСОВ В СЕЛЬСКОМ ХОЗЯЙСТВЕ В УСЛОВИЯХ ИЗМЕНЕНИЯ КЛИМАТА

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Аннотация: Изменение климата оказывает серьёзное влияние на сельское хозяйство в глобальном масштабе, вызывая такие проблемы, как дефицит водных ресурсов, изменчивость погоды и учащение экстремальных климатических явлений. Статья посвящена научным основам повышения эффективности водосберегающих технологий орошения и рационального использования водных ресурсов в сельском хозяйстве в засушливых и полузасушливых климатических зонах, таких как Узбекистан. В статье анализируются преимущества современных технологий, таких как капельное орошение, дождевание и лазерная планировка, их практическое применение и роль в адаптации к изменению климата. Также рассматривается оптимизация управления водными ресурсами с использованием геоинформационных систем (ГИС), сенсорных технологий, дистанционного зондирования и инструментов математического моделирования. Подчеркивается важность комплексных подходов, адаптированных к местным условиям, с учетом экономических, экологических и социальных

факторов. Результаты исследования дают практические рекомендации по обеспечению устойчивого развития сельского хозяйства и адаптации к изменению климата.
Ключевые слова: изменение климата, водосберегающее орошение, капельное орошение, дождевание, лазерная планировка, управление водными ресурсами, сельское хозяйство, устойчивое развитие, геоинформационные системы, математическое моделирование, дистанционное зондирование.

ENHANCING THE EFFICIENCY OF WATER-SAVING IRRIGATION TECHNOLOGIES AND THE SCIENTIFIC FOUNDATIONS OF RATIONAL WATER RESOURCE USE IN AGRICULTURE UNDER CLIMATE CHANGE CONDITIONS

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Abstract: Climate change poses significant challenges to global agriculture, intensifying issues such as water scarcity, unpredictable weather patterns, and the increasing frequency of extreme climate events. This article focuses on enhancing the efficiency of water-saving irrigation technologies and the scientific foundations of rational water resource use in agriculture, with a particular emphasis on arid and semi-arid regions like Uzbekistan. It provides a comprehensive analysis of modern technologies, including drip irrigation, sprinkler irrigation, and laser leveling, evaluating their advantages, practical applications, and critical role in adapting to climate change. The study also explores the integration of advanced tools such as geographic information systems (GIS), sensor technologies, remote sensing, and mathematical modeling to optimize water management. By considering economic, ecological, and social factors, the article underscores the importance of tailored, integrated approaches to local conditions. The findings offer practical recommendations for promoting sustainable agricultural development, enhancing resilience to climate change, and ensuring long-term food security in water-scarce regions.

Keywords: climate change, water-saving irrigation, drip irrigation, sprinkler irrigation, laser leveling, water resource management, agriculture, sustainable development, geographic information systems, mathematical modeling, remote sensing, food security.

Climate change is a defining global challenge that profoundly impacts agriculture, threatening food security and sustainable development. Rising global temperatures, prolonged droughts, shifting precipitation patterns, and the growing frequency and intensity of extreme weather events—such as heatwaves, floods, and storms—are significantly increasing the demand for water resources. According to the Food and Agriculture Organization (FAO) of the United Nations, agriculture consumes over 70% of global freshwater resources, highlighting the urgent need for efficient water use practices. In regions like Uzbekistan, where water resources are limited, these challenges are particularly acute. The country's dependence on transboundary rivers, such as the Amu Darya and Syr Darya, combined with aging irrigation infrastructure and the adverse effects of climate-induced weather variability, creates complex water management issues. The drastic reduction of the Aral Sea, coupled with widespread soil salinization and degradation, further exacerbates the threats to agricultural sustainability. These conditions necessitate innovative approaches to water management, particularly through the adoption of water-saving irrigation technologies and scientifically grounded strategies for rational water use.

Water-saving irrigation technologies, such as drip irrigation, sprinkler irrigation, and laser leveling, are pivotal in promoting efficient water use and enhancing crop productivity. Drip irrigation, for

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instance, delivers water directly to the root zone of crops through a network of pipes and emitters, minimizing water loss due to evaporation and runoff. Research demonstrates that drip irrigation can reduce water consumption by 30-50% compared to traditional flood irrigation methods while improving crop yields by 20-40% for crops like cotton, vegetables, and fruit trees. In Uzbekistan, drip irrigation has gained traction, particularly in cotton farming, where it has significantly reduced water use while maintaining or increasing yields. This technology also mitigates soil erosion, enhances nutrient uptake through precise fertilizer application (fertigation), and reduces weed growth by limiting water distribution to non-crop areas. However, its high initial installation costs approximately 2-3 million UZS per hectare in Uzbekistan and the need for ongoing maintenance and monitoring present significant barriers, particularly for small-scale farmers. These challenges necessitate targeted financial and technical support to ensure widespread adoption. Sprinkler irrigation, another effective water-saving technology, distributes water evenly across large fields through pressurized systems, mimicking natural rainfall. This method is particularly suited for high-evapotranspiration environments and crops such as cereals, vegetables, and forage crops. Sprinkler systems promote uniform crop growth and can be adapted to various soil types and topographies. However, their efficiency is influenced by external factors such as wind direction, soil structure, and ambient weather conditions, which can lead to water loss if not properly managed. Advances in automation and sensor technologies have addressed these challenges by enabling real-time adjustments to irrigation schedules based on weather data and soil moisture levels. For example, automated sprinkler systems equipped with weather sensors can reduce water wastage by pausing irrigation during high winds or rainfall, optimizing water use and improving crop health. In Uzbekistan, sprinkler irrigation has been implemented in regions like Samarkand and Bukhara, demonstrating improved water use efficiency (WUE) in large-scale farming operations. Laser leveling technology complements these irrigation methods by ensuring a flat field surface, which prevents water pooling and runoff. By creating a uniform field gradient, laser leveling enhances water distribution efficiency, reducing consumption by 15-20%, as evidenced by studies conducted in Uzbekistan's Fergana, Andijan, and Khorezm regions. This technology is particularly valuable in areas with uneven topography or heterogeneous soil structures, where traditional irrigation methods often result in significant water loss. Laser leveling has been successfully integrated with both drip and sprinkler systems in Uzbekistan, contributing to higher yields and reduced environmental degradation. For instance, in Khorezm, laser-leveled fields have shown improved water retention and reduced soil salinization, a critical issue in the Aral Sea basin. The rational use of water resources in agriculture relies heavily on scientifically grounded approaches. Mathematical modeling, geographic information systems (GIS), and remote sensing technologies are indispensable tools for optimizing water management. Models such as CROPWAT, AquaCrop, and SWAT provide precise forecasts of crop water requirements, enabling the development of efficient irrigation schedules. These models integrate data on soil moisture, weather patterns, and crop growth stages to minimize water waste while maximizing productivity. In Uzbekistan, the AquaCrop model has been effectively used to assess the water needs of cotton and wheat, leading to tailored irrigation strategies that enhance yields under water-scarce conditions. Similarly, CROPWAT has been applied to optimize irrigation in vegetable farming, reducing water use by up to 25% in some regions.

Geographic information systems (GIS) play a crucial role in mapping water resource distribution, analyzing soil properties, and assessing irrigation needs at regional and local scales. By integrating spatial data, GIS enables policymakers and farmers to identify areas prone to water scarcity or soil

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degradation, facilitating targeted interventions. For example, GIS-based mapping in Uzbekistan's Fergana Valley has identified zones with high salinization risks, guiding the implementation of drainage systems and water-saving technologies. Remote sensing technologies, including satellite imagery (e.g., Sentinel-2) and drones, provide real-time data on soil moisture, crop health, and weather conditions. These tools allow farmers to monitor fields with high precision, adjusting irrigation schedules to avoid over- or under-watering. In Uzbekistan, Sentinel-2 data have been used to assess the irrigation needs of cotton and vegetable crops, improving water use efficiency by 10-15% in pilot projects. The successful adoption of water-saving technologies depends on their economic feasibility and adaptability to local conditions. The high upfront costs of drip irrigation systems, for instance, remain a significant barrier for small-scale farmers in Uzbekistan. To address this, government subsidies, low-interest loans, and capacity-building programs are essential. In recent years, Uzbekistan's government has launched initiatives like the "Agricultural Modernization" program, which provides financial support and training to farmers adopting water-saving technologies. These programs have facilitated the installation of drip irrigation systems in regions like Kashkadarya and Surkhandarya, boosting agricultural productivity and resilience. Additionally, raising farmers' awareness through workshops and extension services is critical for ensuring the proper operation and maintenance of these technologies. Community-based approaches, such as water user associations (WUAs), further enhance water management by fostering collaboration among farmers and promoting equitable water distribution.

Integrated Water Resources Management (IWRM) principles are vital for addressing the complexities of transboundary water use in Central Asia. Uzbekistan's reliance on the Amu Darya and Syr Darya necessitates regional cooperation to ensure fair and sustainable water allocation. Agreements on water sharing and joint monitoring systems among Central Asian countries have improved water distribution efficiency, reducing conflicts and enhancing resource availability. For example, the Interstate Commission for Water Coordination (ICWC) facilitates dialogue and data sharing, enabling better management of shared water resources. Moreover, addressing ecological challenges such as soil salinization and erosion is critical for long-term sustainability. Practices like crop rotation, cover cropping, and agroecological methods can mitigate these issues while improving soil health and water retention. Climate change adaptation requires a multifaceted approach that integrates technological innovation, scientific research, and socioeconomic support. In Uzbekistan, training programs and demonstration plots have played a key role in promoting technologies like drip irrigation and laser leveling. For instance, pilot projects in the Tashkent region have showcased the benefits of combining drip irrigation with fertigation, resulting in higher yields and reduced input costs. Similarly, educational campaigns targeting smallholder farmers have increased the adoption of precision irrigation techniques, empowering communities to cope with water scarcity. The government's commitment to modernizing agriculture, coupled with international partnerships, has further accelerated the deployment of water-saving technologies.

In conclusion, enhancing the efficiency of water-saving irrigation technologies and promoting rational water use are critical for ensuring the sustainable development of agriculture in the face of climate change. Technologies such as drip irrigation, sprinkler irrigation, and laser leveling significantly reduce water consumption while boosting crop yields, making them indispensable for water-scarce regions like Uzbekistan. Scientifically grounded tools, including mathematical modeling, GIS, and remote sensing, provide the foundation for optimizing water management and improving agricultural resilience. Adapting these technologies to local conditions, addressing economic and social barriers, and fostering regional cooperation are essential for success. Government support through subsidies, affordable financing, and capacity-building programs is crucial for scaling up adoption. By implementing these measures, agriculture can adapt to the challenges of climate change, safeguard ecological sustainability, and strengthen global food security.

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