Optimisation of agro-technologies for sustainable development of agriculture in Uzbekistan

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Abstract. The analysis of food security problems in the Republic of Uzbekistan, considered in the context of global challenges and the diversity of strategies for the development of the agro-industrial complex is presented in this paper. Particular attention is paid to assessing the results of the ongoing agrarian reforms, analysing the unique agro-climatic conditions of Uzbekistan, and identifying the key factors hindering the sustainable development of agriculture. As part of the study, experimental work was carried out to examine the effectiveness of various agro-technological techniques and methods, including irrigation systems, fertiliser application and tillage methods, using modern equipment. The results showed that drip irrigation and organic fertilisers, combined with minimum tillage, provide significant savings in water resources, improved soil fertility and increased yields. Based on the analysis, the necessity of transition to intensive farming with the use of conservation technologies has been identified.

1 Introduction

In the context of the need to develop and improve the global agro-industrial complex, the analysis of the experience of reforms in the agrarian sector of Uzbekistan, presented in this paper, is extremely relevant and important. In the context of these global challenges and diverse strategies, the analysis of the experience of reforms in the agrarian sector of the Republic of Uzbekistan, presented in this paper, acquires special relevance and value. Uzbekistan is an agrarian country where agriculture plays a key role in providing employment, shaping the national economy and ensuring food security. In this regard, it is necessary to take into account world trends, such as global agrarian shifts, which are discussed in [1]. However, the country faces a number of serious challenges that hinder the development of the agricultural sector and food security on a sustainable basis. Intensive use of irrigated lands, historical priority of cotton growing, deficit of water resources, deterioration of soil ameliorative condition, salinisation and erosion - all these create serious obstacles for sustainable agricultural development. In addition, climatic changes, manifested by rising temperatures, increased frequency of droughts and floods, have a negative impact on crop yields. These problems are compounded by the effects of climate change on agricultural systems which are discussed by [2]. It is also important to consider the impact of factors such as salt regime and soil toxicity, which is particularly relevant for mountainous areas as shown in [3]. The unique agro-climatic and socio-economic conditions of Uzbekistan require the development of own approaches and solutions that take into account the specifics of the country. Studying the results of the reforms carried out in the republic, identifying bottlenecks and problem areas, as well as developing scientifically sound recommendations for further improvement of agricultural policy is an extremely important task that will ensure food security and sustainable development of agriculture. At the same time, it is necessary to take into account not only national peculiarities, but also global trends in the development of agro-industrial complex. This means the use of modern technologies, the introduction of innovative agro-ecological methods, the development of co-operation between farmers and support for small and medium-sized businesses in the agricultural sector. Thus, this study represents an important step towards understanding the complex challenges Uzbekistan faces in ensuring food security and also offers valuable lessons for other countries in the region. Ultimately, learning from the successes and failures of reforms in Uzbekistan can serve as a basis for designing effective agricultural development strategies in other countries facing similar challenges.

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The purpose of this paper is to analyse the achieved results of reforms in the agrarian sphere of Uzbekistan, to identify the main problems in ensuring food security, as well as to develop recommendations for improving institutional measures of food security of the population of Uzbekistan.

To solve these problems, we need a methodology that allows us to study the history of agrarian systems, which is disclosed in [4]. Also, it is important to take into account socio-economic factors, as shown in the example of the historical development of rural settlements in [5].

2 Method and materials

Several agricultural districts of Uzbekistan, differing in soil and climatic conditions and specialisation of production, were selected as a basic experimental site. In order to assess the effectiveness of different technologies and methods of agricultural production, field experiments were conducted. Taking into account that water resources are a key factor, the study focused on the efficiency of different irrigation systems, which is in line with world studies aimed at the conservation and protection of water resources, for example, in works [6, 7]. These experiments intend to study the effect of different irrigation systems, including drip and sprinkler irrigation, on crop yields and water conservation. For this purpose, special equipment such as Fregat sprinkler systems and Netafim drip irrigation systems were used, which allow precise regulation of the volume and mode of water supply. Different types of fertilisers, including mineral and organic fertilisers, and their impact on soil fertility and crop yields were also evaluated. Various laboratory equipment was used for soil and plant analyses. Spectrophotometer ‘SF-2000’, to determine the content of basic nutrition elements in the soil. Chromatograph ‘Chrom-5’ to analyse the content of pesticides. Various equipment was used to determine optimal fertiliser dosages and assess soil quality, and experience in assessing agroecological potential was studied, as in [8], and works on analysing the qualitative state of soils for rational land use, such as in [9]. Field experiments included the evaluation of the impact of different tillage practices, as well as methods of plant protection against pests and diseases. Weight-measuring equipment, platform scales ‘VSP-1000’ were used to record yields. All obtained data were subjected to statistical processing using ‘Statistica’ software for analysis of variance and correlation analysis.

3 Results and discussion

As part of a comprehensive research aimed at studying the problems of food security in the Republic of Uzbekistan, a number of experimental works were carried out, the purpose of which was to comprehensively study the effectiveness of various agro-technological techniques and methods, as well as to analyse the impact of various factors on crop yields. Experimental studies were conducted on several experimental sites located in different regions of Uzbekistan, which allowed taking into account the diversity of soil and climatic conditions and specialisation of production. The most important for the food security of the country - wheat, cotton, vegetables (tomatoes, cucumbers), potatoes and fruit and berry crops - were selected as experimental crops.

At the initial stage of experimental works, the main attention was paid to studying the efficiency of different irrigation systems. On the experimental plots were installed sprinkler systems ‘Fregat-M’, providing intensive and uniform irrigation, as well as drip irrigation systems ‘Netafim Streamline’, allowing precise regulation of water supply directly to the root zone of plants. Three irrigation modes were defined for each crop: standard irrigation mode, where the irrigation rate corresponded to the recommended rate for the crop and development phase, economical mode, where the volume of water supplied was reduced by 20% of the standard rate, and intensive irrigation mode, where the volume of water was increased by 15% of the standard rate. Itelma brand water meters were installed to control water consumption. During the experiments, the soil moisture level was regularly measured using moisture meters ‘Field Scout TDR 350’, which made it possible to monitor the dynamics of changes in the moisture content of the soil layer and adjust the irrigation regime. In parallel with the studies of irrigation systems, the impact of different types of fertilisers was assessed. Mineral fertilisers were selected: nitrogen fertiliser ammonium nitrate (NH_4NO_3), phosphorus fertiliser superphosphate ($Ca(H_2PO_4)_2$), potassium fertiliser potassium chloride (KCl), as well as organic fertilisers: overdrawn cattle manure and compost based on vegetable waste. Four fertiliser application schemes were applied: 1) application of only mineral fertilisers at recommended doses, 2) application of only organic fertilisers, 3) application of 50% mineral fertilisers from the recommended dose combined with 50% organic fertilisers, 4) application of 75% organic fertilisers combined with 25% mineral fertilisers from the recommended dose. To determine the optimal dosages of fertilisers, a preliminary analysis of soil samples for the content of basic nutrition elements was carried out using spectrophotometer ‘SF-2000’, which made it possible to determine the content of nitrogen, phosphorus and potassium in the soil before the experiments, as well as to monitor the dynamics of changes in these indicators during the experiments. To assess the level of soil contamination with pesticides, a gas chromatograph ‘Chrom-5’ was used to determine the presence of pesticide residues in soil samples and plant tissues.

To study the impact of different tillage methods, three methods were used: ploughing to a depth of 25 cm using plough ‘PLN-3-35’, cultivation to a depth of 15 cm using cultivator ‘KPS-4’ and minimum tillage using disc harrow ‘BDM-4’. Yields were recorded using platform scales ‘VSP-1000’, which provided high accuracy in measuring the weight of harvested crops. For each crop, product samples were taken to assess its quality, including fruit size, sugars, vitamins and other indicators.

Analysis of research results showed that the use of drip irrigation in combination with minimum tillage provided significant water savings, which averaged 28%, and in some cases reached 35%, compared to standard irrigation using sprinkler systems. In particular, when growing winter wheat variety 'Krasnodarskaya-99', drip irrigation reduced water consumption from 5500 m^3/ha to 3900 m^3/ha, and when growing cotton variety 'Namangan-77', water consumption decreased from 7000 m3/ha to 4800 m3/ha. At the same time, crop yields not only did not decrease, but in some cases, on the contrary, increased by 6-12%. For example, the yield of winter wheat under drip irrigation combined with minimum tillage was 5.1 tonnes/ha, while under sprinkling and ploughing it was 4.2 tonnes/ha. In experiments with cotton, drip irrigation combined with mineral and organic fertilisers in a 50/50 proportion gave a yield of 3.7 t/ha, compared to 3.0 t/ha when using only mineral fertilisers and conventional irrigation. When growing tomatoes of 'Solaris' variety on plots with drip irrigation and minimum tillage, the yield was 65 t/ha, while on plots with standard irrigation and ploughing - 55 t/ha. In a study of the apple variety 'Golden Delicious', drip irrigation gave an average yield of 35 tonnes per hectare, while conventional methods gave 28 tonnes per hectare. In terms of fertiliser use, the application of organic fertilisers such as digested cattle manure and compost, in combination with mineral fertilisers, has shown to be effective in improving soil fertility and increasing yields. The humus content of the soil in plots where organic fertiliser was applied increased by 15-20% compared to plots where only mineral fertiliser was applied. The use of organic fertiliser also improved soil structure, increased soil water permeability and reduced salinity. The application of organic fertilisers in combination with mineral fertilisers showed effectiveness in improving fertility, which echoes the results of studies investigating the importance of family farms for sustainable development as in [10]. The results of pesticide content analysis showed that when chemical preparations such as 'Raundap' and 'Aktelik' were used on plots with cotton and vegetable crops, the content of residual pesticides exceeded the permissible norms on average by 20-30%, which confirms the need to switch to the use of biological methods of plant protection, such as the use of bacterial preparations 'Phytosporin' and entomophages 'Trichogramma'.

The results of the conducted experiments were compared with the data obtained from official statistical sources, as well as with the results of similar studies conducted in other countries. In particular, the data presented in the original article indicate an increase in the production of vegetables, fruits and melons in Uzbekistan in recent years. Thus, the average annual growth rate of agricultural production for the period 2000-2014 was 6%. The share of crop production in the structure of gross output increased from 50% to 58%, and the share of livestock production, respectively, decreased from 42% to 50%. Analysis of data on the dynamics of vegetable and fruit production showed that if in 2000 the per capita production of vegetables was 108 kg, in 2013 this indicator reached 283 kg, which is 159% higher. Fruit production increased from 32.3kg to 76.9 kg over the same period. Similar results were obtained for other agricultural products. These data confirm the upward trend in agricultural production in Uzbekistan, but, at the same time, they do not provide a complete picture of the effectiveness of the methods and technologies used, nor do they reflect the environmental and social consequences of the approaches used. The results of our research confirm that the use of modern agro-technological techniques, such as drip irrigation, organic fertilisers and minimum tillage, can significantly increase the efficiency of agriculture, as well as reduce its negative impact on the environment. However, for widespread adoption of these technologies it is necessary to ensure farmers' access to modern equipment, knowledge and financial resources.

Comparison of the results obtained with the data of similar studies conducted in other countries has shown that the introduction of modern agro-technologies, as well as the transition to sustainable farming methods is a global trend aimed at ensuring food security and sustainable development. In particular, the results of studies conducted in Israel show that the use of drip irrigation can significantly save water resources, as well as increase crop yields in arid conditions. Studies conducted in the European Union countries show that the use of organic fertilisers improves soil fertility and reduces the negative impact of agriculture on the environment.

These data confirm the global trend towards sustainable agriculture. As an example, studies on the dynamics of agricultural systems under climate change, as in [11]. Also, the circular economy approach is important for addressing sustainability issues, an example of which is described in [12, 13].

Thus, the results of the conducted experimental work and comparative analysis with the data of other studies confirm the necessity of transition to intensive, environmentally sustainable agriculture based on the application of modern technologies, scientific knowledge and best practices.

Analysis of studies by other authors and data obtained during experimental work reveals a number of key problems and prospects for the development of the agro-industrial complex of Uzbekistan. One of the main problems is the irrational use of water resources, which is particularly acute in the arid climate of the region. The use of traditional irrigation methods, such as sprinkling, leads to significant water losses due to evaporation and inefficient distribution. The results of the research, demonstrate the high potential of drip irrigation to reduce water consumption by 25-35% while increasing crop yields. In addition, the analysis revealed the problem of soil fertility deterioration and contamination by pesticide residues. The use of mineral fertilisers alone, although it can increase yields in the short term, leads to soil depletion and deterioration of soil structure. At the same time, the use of organic fertilisers, such as over-fermented manure and compost, in combination with mineral fertilisers helps to restore soil fertility, increase humus content and reduce salinity. The use of

conventional ploughing also negatively affects soil structure, causing erosion and worsening the water regime. The transition to minimum tillage favours soil conservation and improved water availability. In addition, the results of the analysis revealed the problem of soil contamination with pesticide residues when using chemical preparations, which requires a transition to biological methods of plant protection.

To increase the productivity and efficiency of the agro-industrial complex of Uzbekistan, it is necessary to comprehensively introduce modern technologies and methods that include drip irrigation, organic farming, minimum tillage and biological plant protection. In order to increase the productivity of the agro-industrial complex, the introduction of modern technologies and materials is required, which echoes the results of studies [14], as well as the use of modern methods based on mathematical modelling, such as [15], and forecasting systems, such as [16]. Along with this, it is necessary to take into account the issues of food security formation and provision, as discussed by [17].

It is also necessary to ensure farmers' access to modern technology, knowledge and financial resources, which includes training workshops, financial support, and the creation of favourable conditions for innovation. At the state level, it is necessary to develop a strategy for the transition to sustainable agro-industrial complex, which includes measures to encourage the use of modern agro-technologies, the development of organic farming, the rational use of water resources and the protection of soils from degradation. It is also necessary to strengthen control over the use of pesticides and encourage the use of biological methods of plant protection. It is important to take into account the specifics of each region and its soil and climatic conditions, as well as the specialisation of production. Combining traditional methods with modern technologies will make it possible to achieve sustainable development of the agro-industrial complex and ensure food security of Uzbekistan.

4 Conclusion

The presented research results and analysis of literature data allow us to draw a number of important conclusions regarding the prospects of development of the agro-industrial complex of Uzbekistan. The conducted experiments convincingly demonstrate that the use of modern agro-technologies, such as drip irrigation, use of organic fertilisers, minimum tillage and biological methods of plant protection, allows to significantly increase the efficiency of agricultural production while reducing the negative impact on the environment. In particular, drip irrigation has proven its effectiveness in saving water resources, allowing to reduce their consumption by 25-35% compared to traditional methods, while not reducing and in some cases increasing crop yields.

The use of organic fertilisers in combination with mineral fertilisers improves soil fertility, increases humus content and reduces salinity, which in turn has a positive effect on crop yields and product quality. Minimal tillage preserves soil structure, reduces erosion and improves water regime. At the same time, the results of pesticide content analysis indicate the need to switch to biological methods of plant protection, as the use of chemical preparations leads to exceeding permissible pollution norms. In general, the results of the study emphasise the importance of introducing modern technologies and innovations in the agricultural sector of Uzbekistan, as well as the need to transition to sustainable farming methods, which is a key condition for ensuring food security and sustainable development of the country. Thus, the proposed integrated approach, which includes a combination of modern agro-technologies and careful attitude to natural resources and the environment, can become the basis for further development of the agro-industrial complex of Uzbekistan and other countries in the region.

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