Climate change effects on irrigated agriculture: perspectives from agricultural producers in eastern Uzbekistan

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Abstract. Sustainability of irrigated agricultural development has been severely impacted by global climate change in recent decades, which is among the main environmental and economic problems facing the world community. The article presents the results of the research conducted in selected areas of irrigated agriculture in eastern Uzbekistan to study the impact of climate change on agricultural production and the agricultural producer's perspective and awareness. Major factors affecting agricultural producers' behavior under climate change and their current practices and skills for adapting to climate change were studied. The field study has been conducted in 9 districts located in two regions of the Ferghana valley. The respondents-representatives of agricultural producers selected from the list of Farmer's Associations members taking their location relative to irrigation water sources into account. Quantitative analysis of data carried out with the use of SPSS-22 software. As the research results show, the impact of climate change on irrigated agriculture has become incredibly tangible in the last decade. It affected the situation with losses in yields of up to 16% and decreasing the quality of agricultural products. The rural population's vulnerability factors include low income from agriculture, acute dependence on irrigation in conditions of increasing water scarcity, low level of applied technologies, adaptation measures, low yields, land degradation, etc. Analysis of the research results, and other related studies on this issue, allows us to indicate directions for improving adaptation measures in the short, medium, and long-term periods.

Keywords: Impact of Climate Change, Irrigated Agriculture, Awareness, Adaptation

1. Introduction

The ongoing changes in global climate parameters that have sped up for the last 10-20 years have become significant challenges of sustainable development globally and in different continents [1,2,3]. Issues related to the effects of climate change on water resources potential and agriculture in conditions of Central Asia remain not well studied in detail and unpredicted. There is a strong interrelation between climate, freshwater, biophysical, and socio-economic systems where a change in any of these systems can severely impact one another. Specifically, anthropogenic causes add significant challenges in the sustainable development of countries already facing difficulties in using freshwater resources under conditions of limited water resources. In situations of Uzbekistan located in the lower reaches of main rivers and experiencing problems of ongoing water scarcity and continuing deterioration of water quality, the timely studying and taking the climate change impacts into account in the country's strategic

sustainable development play a crucial role. Factors of freshwater in the scientific literature indicated one of the major ones defining territories vulnerability [4,5,6].

Unexpected changes in hydrological regimes of rivers and tributaries exacerbated by the impact of climate change severely harm the pace of the country's development, provision of essential demands, and sustainable use of natural resources. Today, Central Asian countries under the condition to find effective ways and means to solve the problem of minimizing and, if possible, to prevent the water problems and, above all, mitigating water scarcity. The studies conducted in different parts of the Aral Sea basin show that the changes in the climate parameters occurs in some phases of the hydrometeorological cycle. According to the studies, trends in increasing the evaporation means, decrease in snowpack (its thickness, coverage, and standing period) and reduction in glaciation in the mountainous territories. All these changes are interconnected with growth in the variability of multiyear hydrometeorological data and information [7,8,9]. A review of scientific literature shows [7,10] noticeable changes in average means of highest and lowest temperatures for the last decades. Particularly average rate of such changes in Uzbekistan for the period between 1951 and 2018 accordingly was 0.22-degree and 0.30 degrees. The highest rates in increasing of maximum temperatures observed in the Prearal zones and mainly during the fall seasons. According to analyses, the climate warming parameters observed in Uzbekistan are two times higher compared to the global average means. The number of scorching days (with the temperature above 40 degrees) increased, and it is now more in the Prearal territories. It was high by 10-12 percent in the foothills and between 32 and 70 percent in the other parts of the country. According to scenarios of projection for the period till 2030, the Aral Sea basin will have about the same amount of water resources as it does nowadays. But in the case of the extreme scenario, it projects a significant reduction in runoff. For example, some models show that in the case of doubled CO_2 concentration, it can reduce the flow of the Amu Darya river by more third and, accordingly, the flow of the Syr Darya river by one-fifth. Current regimes of Central Asian river flows are suitable for irrigated agriculture (in terms of the natural distribution of runoff over the seasons). In many rivers, including the Amu Darya River, the peak of the flood occurs in July. An increase in winter runoff and a decrease in summer runoff expected under conditions of warming. Such a redistribution of runoff will result from the melting of mountain glaciers and an increase in the liquid part of precipitation (rain). Glaciers of the Aral Sea river basins for the period 1957-1980 lost almost 20% of ice reserves, and by 2015, the loss amounted to another 16% [10, 11].

Agriculture namely irrigated agriculture characterized by its vulnerability under conditions of ongoing climate change [12,13,14,]. Studies conducted in a different part of the world show strong adverse trends and special features of the impact of climate change under conditions of large, smallholder, and subsistence agriculture [15,16,17]. Irrigated agriculture is an important branch of economy that makes essential contributions to the sustainable development of Uzbekistan. Agricultural producers include agrarian corporations, different size farms, and dehkan farms and firms producing agricultural products [18,19].

According to the State Committee of the Republic of Uzbekistan on Statistics [20], the agricultural sector employs a significant share of the population. About 50% of the population of Uzbekistan lives in rural territories and 27% of the working-age population is employed in agriculture. There is a noticeable tendency to reduce the share of agriculture in the growing GDP of Uzbekistan. Nevertheless, agriculture remains vital in the country's economy. According to the official statistics, the percentage of agriculture in the GDP of the country was about 17% in 2017. Agriculture in Uzbekistan is an essential source for providing food and industrial safety to the country and the region. The agricultural industry produces 90% of the country's food products. At the same time, according to estimates by the International Food Policy Research Institute (IFPRI) (Asian Development Bank, 2009) and the World Bank (2009), Uzbekistan is significantly vulnerable to climate change because of high sensitivity of arid arable land, high population density, and high-water demand to meet the needs of a growing population and preserve ecosystems [21-22]. In this regard, on time evaluation of the climate change impacts on agricultural production, the development and implementation of effective adaptation measures are

among the urgent problems of ensuring the sustainable development of agriculture in Uzbekistan and countries in similar arid climate.

2. Research methodology

We have developed a study to obtain data characterizing the practical knowledge of agricultural producers about climate change and its impacts on agricultural production on example of selected pilot districts. An essential task of the study was to collect and analyze the unique information based on perspective from agricultural producers in Eastern Uzbekistan to determine the direction of further development of the reasonable recommendations. We conducted the studies in 9 districts in the Namangan and Fergana regions of Uzbekistan. The study used a questionnaire developed by the research team for quantitative analysis. We ran the interviews with 79 (Fergana - 37, Namangan - 42) respondents from selected farms, household plots, and other agricultural organizations.

The questionnaire included the following components:

- information associated with characteristics of each respondent and his household, farm;
- general awareness on climate change, the availability of necessary information;
- assessment of climate change impact on agriculture and agricultural producers' awareness and knowledge on it;
- respondent's behavior and abilities to adapt to climate change;
- respondent's perspectives on improving the efficiency of adaptation measures to climate change.

Neighbourhoods and study participants

When laying the field research in the field, we selected nine districts in two regions as representative ones. Specifics of natural and economic conditions, regional specialization, and the geographical location of the districts were taken into account.

We selected respondents representing agricultural producers from the list of members of the farmers ' Association (including private farms). We also took into account the respondents ' conditions regarding water sources when selecting respondents. The quantitative data collected during the study were processed and analyzed using the SPSS-22 data processing software.

3. Results and discussion

As the survey has shown, the median age of respondents in the project area was 47 years. In the regions, the age deviations were insignificant (figure 1). Respondents were younger in the Ferghana region - 45 years old and older - in the Namangan region - 49 years. The percentage distribution in the two regions was as follows:

27% of all respondents were younger than 40 years old,

32% were in the age range between 41 and 50 years old,

42% were older than 51 years old. The share of female respondents to the survey was small, as was the proportion of managers and chief specialists of agricultural enterprises in the region. Three of the women who took part in the survey were over 55, and three other women were between the ages of 40 and 43. All women who participated in the survey were managers of farms whose main specialization is the production of cotton and wheat.

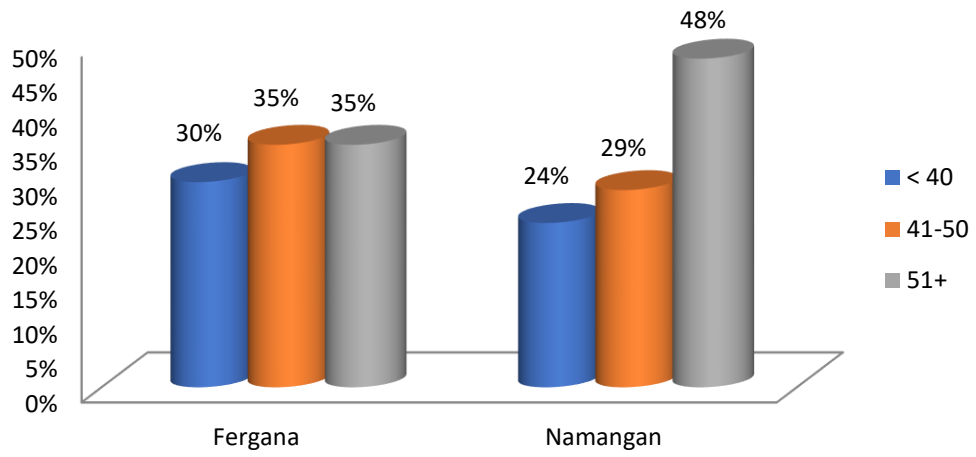

Figure 1. Distribution of respondents by age.

The distribution of respondents by education shows: respondents with a specialized secondary education (people who have a 2-year specialized college education) made up 45.6%, respondents with a higher education (people who have at list BSc degree from university)- 48.1% and only 6.3% have a secondary (people who have high school education) education. A slightly more significant proportion of those with higher education is in the Namangan region - 52.4%. A significant part of respondents has experience in agriculture and has the corresponding specialties of an agronomist, economist, accountant, etc. There are many people among agricultural producers who have no education in agriculture. They came to agricultural businesses with varied backgrounds such as driver, constructor, teacher, and many others. Most of them have more than a decade of practical experience in agriculture and have a tremendous knowledge of agricultural production.

The main types of farms surveyed were private commercial farms and remote homesteads. The majority of respondents represented farms specializing in cotton and wheat cultivation (75%) and horticulture (18%), private subsidiary farming (6%), and mulberry plantation. 67% of farmers who grow wheat and cotton also grow other crops. The size of farms varied and ranged from 22 ha to 225 ha. The dimensions of horticultural farms and homesteads varied accordingly from 1.85 ha to 150 ha, and from 0.14 ha to 0.40 ha. The total area covered by the study was about 4.95 thousand hectares.

The data analysis shows that the overall structure of cultivated areas for all farms covered by the study characterized by the following parameters of the crop plantation: cotton - 37.9%, wheat - 44.4%, orchards, and vineyards - 10.3%, corn - 1.0%, Rice - 0.2%, melons - 0.2%, and other crops - 4.8%. Farms use crop rotation and other sowings of cotton with the wheat.

Assessment of agricultural producers ' knowledge about climate change carried out using questions about their level of awareness, the impact of human activities on adaptation to climate change, the importance of problems related to climate change, the causes of differences, and sources of information.

The research results show that 97.5% of all respondents have heard about climate change. However, about a third of respondents informed that they have very little information, and 62% indicated limited knowledge. Only about 8% believe that they are thoroughly familiar with the problems associated with climate change. Figure 2 shows the distribution of respondents ' responses to the question, at what level do they consider themselves informed about climate change.

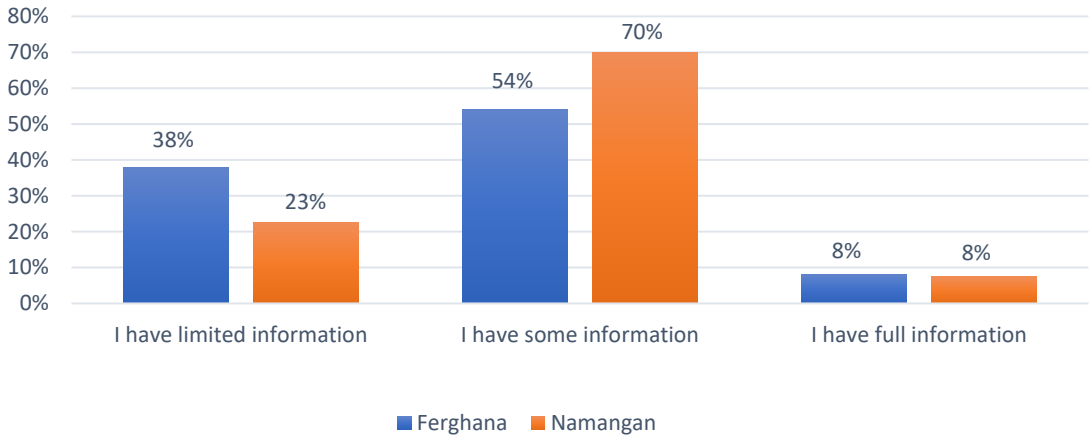

Figure 2. Climate change awareness of respondents.

Respondents indicate various sources received information on climate change. Television and radio (50-70%), other types of the press (45-55%), personal life experience (50-57%), Internet resources (21-26%), friends and relatives (18-20%) and other sources (up to 5%) were named as the primary sources of information on climate change. Other sources indicated during the survey were a school, a meeting with specialists, and participation in seminars.

Over 60% of respondents receive information from two or more sources. If we consider the context of the respondents, then for farms that are engaged only in gardening, the major source of information is television and radio (57%), life experience (50%) and the Internet (43%). The average age of gardeners who indicated the Internet as a source of information is 36.5 years, which is less than the total average age of gardeners (44 years). For respondents who are engaged only in growing wheat and cotton, the primary source of information is television and radio (53%) for respondents who, in parallel with growing cotton and wheat, are gardening and growing other crops (68%). As the first signs of the climate change and its consequences, the respondents indicate an increase in the average annual temperature relative to the usual one, an increase in the deficit of water resources, a delay in the onset of spring, an increase in demand for water resources and other aspects (figure 3). The responses of the respondents in the two areas are slightly different, but basically the same.

Regarding the period when climate change became noticeable, respondents almost unanimously point to the last 10-15 years. As the data analysis shows, respondents point to incorrect and irrational use of natural resources with unacceptable impact on the environment, population growth, industrial development, and other anthropogenic factors as the leading causes of climate change. However, there is a small part of respondents who believe that climate change is a natural process.

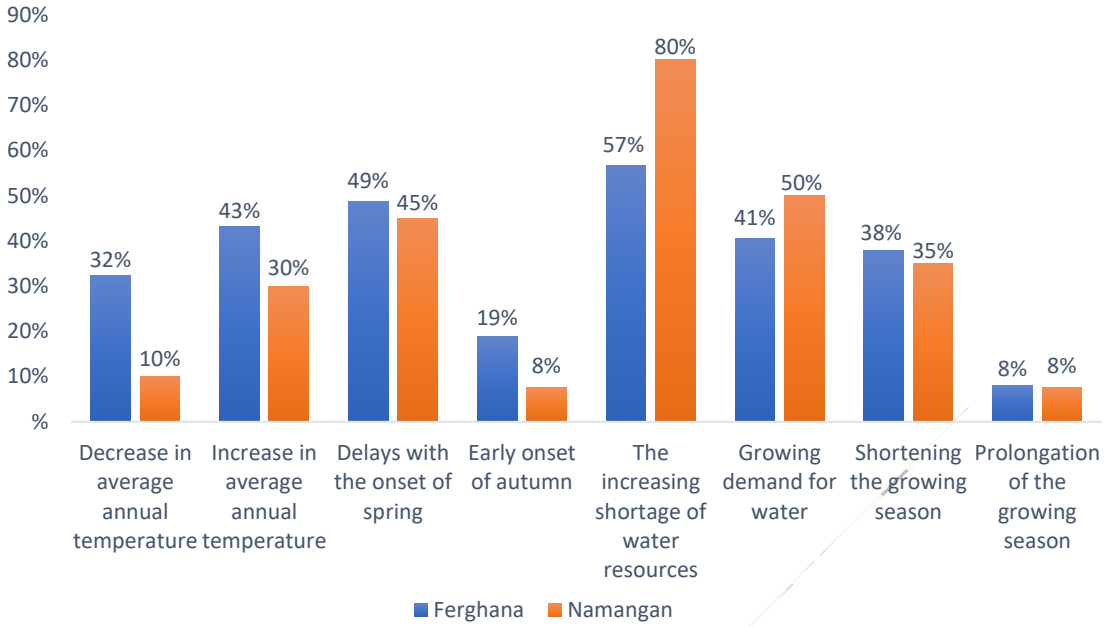

Figure 3. Signs of climate change.

More than 70% of respondents in both regions believe that climate change results from human influence.

The main reasons that have led to the increased attention paid to the problem of climate change, respondents point to such reasons as the noticeable negative impact on agriculture, on economic development, on the global environmental system, and that human life remains at risk due to the impact of climate change.

3.1. Climate change impacts on agricultural productivity, crop yields, and product quality

As survey results show, over 90% of respondents believe that climate change affects agricultural productivity. Almost 96.1% of respondents agreed that climate change affects crop yields. 93.5% of respondents believe that climate change also affects the quality of agricultural products.

Respondents rated the significant effects of climate change on agricultural production upon its importance. Thus, according to respondents, the most important consequences of the negative impact of climate change on agricultural production are a decrease in crop yields, an increase in water scarcity, and an increase in the number of pests (insects, rodents, weeds) and plant diseases, a change in the growing season, and an increase in the cost of agricultural production and others (figure 4.).

According to respondents, the most important consequences of climate change in agricultural production in Namangan and Fergana regions are:

- the growing shortage of in water availability;
- growing number of agricultural pests and plant diseases;
- reduced crop yields;
- unstable and unpleasant weather conditions;
- extra expenses of resources to get a satisfactory crop yield;
- decreasing land and water resources quality;
- frequent and intensive extreme weather events.

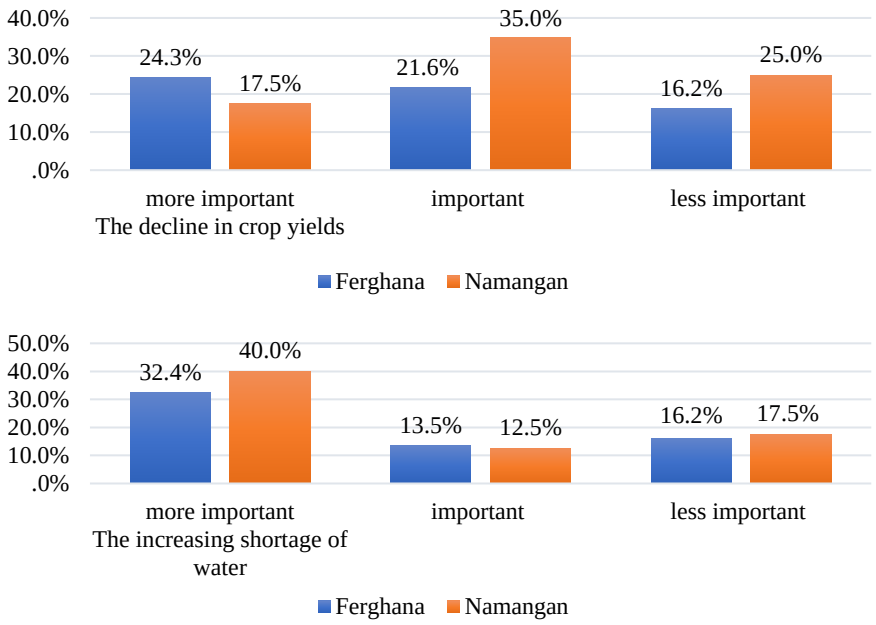

Figure 4. Assessment of the effects of climate change on agriculture.

Some respondents also indicated an increase and decrease in groundwater levels, high temperatures, deterioration in the quality and varieties of agricultural products, the inability to grow certain types of plants, and a decrease in income.

According to the data obtained during the survey, agricultural producers experience significant consequences of climate change. 74% of respondents consider the impact of climate change on their farms to be significant (impact on product quality and crop productivity).

3.2. Specific features of climate change effect

On the basis of the above discussed information, we summarized the opinions of respondents that characterize specific features of climate change impact on agricultural production in the Namangan and Fergana regions (figure 5 and table 1).

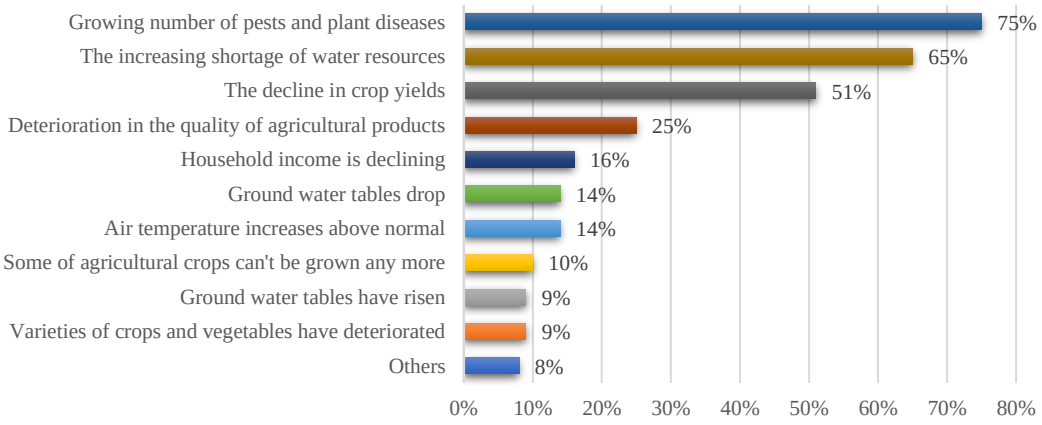

Figure 5. Negative effects of climate change on farms.

Table 1. Specific features of climate change impact on agricultural production in the Namangan and Fergana regions.

Indicators	Respondents' opinions characterizing specific features of climate change impact on agricultural production
Temperature change	– Sudden changes (sudden warming or cooling) of air temperature; especially in spring; – Frost killed the wheat; – Freezing grapes; – The onset of unexpectedly chilly weather during the flowering of fruit trees; – Sudden warming of the air temperature which caused a delay in the growth and development of wheat and cotton.
Precipitation change	– Reduced rainfall. The solid part of precipitation decreases (snow), the liquid part of precipitation increases at unusual times
Water availability change	– Water scarcity is growing
Plant diseases/pests	– Sharp increase in the number of plant diseases and agricultural pests; – Increase and distribution of the Colorado potato beetle; – The influence of pests and plant diseases has become greater; – Drying of pear trees; – Quince trees dry out for unknown reasons. Figs and its species sharply decrease; – Pomegranate seedlings dry out.
Change in the growing season, timing	– The ripening period of the crop has changed; – Ripening of a crop is delayed and its quality worsens; – Wheat yield falls; – Product quality is deteriorating; – Delay in the onset of spring. Snow falling in the spring and freezing, freezing of ears of corn; – Delay in spring, which causes additional costs of production; – Change the timing of sowing; – Late cotton planting.
Change in wind conditions	– Frequent cases of garmsil winds; – Re-crops dry up because of garmsil; – The force of the wind increases; – Unexpected wind in the summer; – Frequent powerful winds. A sharp change in temperature during the day.

4. Conclusions

1) The traditions that have historically developed over many millennia and several steps taken as part of the ongoing reforms ensure a relatively sustainable development of agriculture in both Namangan and Ferghana regions. However, over the last period, the impact of climate change has become tangible. All these changes result on significant crop losses and decline in quality of yields.

2) The agricultural producers are aware of climate change and its impact on agriculture. The majority of respondents believe that they are not sufficiently informed about the specifics of the problem, although they note some evidence of climate change impact on agricultural production. They feel direct consequences and suffer because of the adverse effects of climate change. 97.4% of respondents believe climate change affects productivity; 93.5% of respondents trust that climate change negatively affects agricultural products' quality.

3) According to respondents, the most important consequence of climate change impact on agricultural production in Namangan and Ferghana regions is:

- the growing scarcity and water resources availability;
- an increase in the numbers and varieties of pests and diseases;

- decrease in yields of agricultural crops;
- unstable and unpleasant weather conditions;
- extra expenses of resources to get a satisfactory crop yield;
- decrease in land and water resources quality;
- increase in frequent and intensive extraordinary weather conditions, etc.

4) Respondents indicated the increase in the number of agricultural pests and plants as one of the most critical and negative phenomena associated with climate change. Respondents can name the main agricultural pests and the major plant diseases that emerged with climate change.

5) Based on the generalization of respondents' opinions, specific features of climate change on agricultural production in the Namangan and Fergana regions determined that the rural population's vulnerability factors include: low incomes from agriculture, an acute dependence on irrigation and increasing water scarcity, a low level of applied technologies, adaptation measures, low productivity, land degradation, etc.

6) Analysis of the research results, and other studies on this issue, allows us to show directions for improving adaptation measures in the short, medium, and long term. The task set and its solution opens an entire range of opportunities for its successful application in the most diverse branches of science and production.

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