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FULL-LENGTH RESEARCH ARTICLE

Evaluation of Climate Change in the Rice-Growing Zone of Ukraine and Ways of Adaptation to the Predicted Changes

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Abstract The article presents the results of the analysis of the current state of weather and climatic conditions and evaluation of their predicted changes for immediate and distant prospects in the rice-growing zone of Ukraine. Studies were performed on the example of the Danube rice irrigation systems (RIS) in Odessa region with a total area of 13,678 ha, which are located in lands prone to salinization. The following major meteorological characteristics were investigated: air temperature, precipitation, relative humidity and air humidity deficit, as well as derivatives: photosynthetically active radiation and water availability coefficient (precipitation/evapotranspiration ratio). Retrospective analysis and forecast of meteorological regimes by typical groups were done (estimated years) of vegetation periods of target years in view of general heat and moisture provision: *very wet*—*p* = 10%, *wet*—*p* = 30%, *middle*—*p* = 50%, *dry*—*p* = 70%, *very dry*—*p* = 90%. The basis of forecast calculations is the results of studies of possible changes of air temperature by the models of Canadian Climate Center “CCCM” and of the United Kingdom Met Office “UKMO” which foresee an increase in average annual temperature up to 4 °C and 6 °C relatively—provided that the doubling CO_2 in atmosphere occurs. The main trends in changes of meteorological characteristics and their possible effect on the conditions of functioning rice irrigation systems as well as on the natural and ameliorative state of irrigated areas were identified. The most significant influence on the condition of fonctioning of RIS is air temperature, which directly effects duration of maturation and total value of water consumption of rice crops. It is established that in the last decades a significant increase in the average value of air temperature for the growing season happened (April–October): 1981–1990—16.9 °C, 1991–2000—17.5 °C, 2001–2010—18.1 °C, 2011–2017—17.7 °C. It is determined that at the existing rates and levels of weather and climatic changes, we should expect a significant deterioration of functioning conditions of RIS and natural reclamation state of irrigated land. In this regard, were examined core measures regarding the adaptive potential enhancement and development of the rice-growing zone under the conditions of climate change.

Keywords Evaluation · Climate change · Rice-growing zone · Ways of adaptation

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Introduction

Global warming is one of the numerous ecological, social and economic problems, which humans started to face at the end of the last century. Current climate change may have significant natural, economic and social aftermath [1, 2, 7].

Climate change is a real concern for the sustainable development of agriculture. Although agriculture is a complex and highly evolved sector, it is still directly dependent on climate, since heat, sunlight and water are the main drivers of crop growth. While some aspects of climate change such as longer growing seasons and warmer temperatures may bring benefits, there will also be a range of adverse impacts, including reduced water availability and more frequent extreme weather phenomena. These impacts may put agricultural activities, certainly at the level of individual land managers and farm estates, at significant risk [6, 7, 12].

Ukraine also belongs to the number of regions influenced by ongoing climate change that is rather essential. In view of the changes in climate conditions taking place even today, the forecasting of possible climate change in the future and solving a number of crucial and complicated tasks play an important part. These tasks are related to the development and implementation of the strategies of farther humanity survival both on a worldwide basis and at a regional level. Therefore, today a need of predicted evaluation of climate change and development of relevant adaptive decisions has arisen [3, 4, 8, 10, 17–19, 21].

On the basis of numerous meteorological factors and indexes, the domestic scientists (climate researchers) come to the point that for the last 10–25 years there has been forming a new climate over the territory of Ukraine [2]. Such climate change is already noticeable and affects all spheres of human activity, including agricultural production and conditions of water management and both ameliorative objects and complexes.

The climate has a decisive role in shaping the agroecological conditions of agricultural production. One of the biggest challenges that lie in this study is the need for knowledge about what kind of agricultural crops are profitable to grow in a certain area, how the climate affects the soils on which these crops are growing, what technologies are best to use. Climate is one of the important factors affecting soil formation, vegetation and plant capacity [5].

Absorbed by the soil, solar energy is spent on processes such as heating, evaporation, transpiration, photosynthesis, humus synthesis and others. The sum of active temperatures is used for agronomic and soil evaluation of the territorial thermal regime. Increasing the average annual temperature and the sum of active temperatures per year affects the increase in intensity of evaporation, synthesis of organic mass, activation of vital activity of animals and microorganisms, increase in intensity of soil-forming processes. One of the basic processes of soil formation is the evaporation of soil moisture, which depends on temperature. Evaporation leads to increase in soil solution concentration and precipitation of salts, which causes the formation of secondary minerals and salt accumulation in soils [19].

These changes are very tangible in the rice-growing zone of Ukraine where the irrigated lands are instrumental for the country's economic development and provision of food security.

The most urgent and important issue of climate change impacts on the functioning RIS is the water factor. As we know, the rice industry is one of the most water-intensive branches of agricultural production. The annual intake from the Danube in the rice systems was 250 million m^3 in the early 1970s and now it has reached 90 million m^3. According to the traditional rice cultivation technology by surface flooding and the necessity of a maintenance of washing water regime on saline-prone lands of the Ukrainian rice-growing zone, the demand for irrigation water is on average 25 m^3/ha. In the face of climate change, in particular, increase in air temperature, one should expect a significant reduction in the natural moisture supply of the territory, increase in the amount of total evaporation and corresponding increase in the demand for irrigation water for cultivation of flooded rice culture. In case of noncompliance with the recommended soil washing water regime on the rice systems will be restored the secondary salinization processes and the deterioration of the overall natural reclamation state of irrigated lands and adjacent territories [22, 23].

With a large volume of water supply is also associated a significant amount of unproductive technological discharges (50% of total water supply volume). Demand for irrigation water for rice cultivation depends on many factors: weather and climatic conditions of the territory, irrigation regime, water-physical properties of soil, designs of rice systems, etc.

Considering the abovementioned facts, *the hypothesis of this work* is that climate change in the rice-growing zone of Ukraine can lead to a significant decrease in the natural water availability of the territory, the magnitude of which will primarily affect the volume of water supply RIS for rice cultivation and worsen the conditions of their functioning.

Thus, *the objective of this work* is to estimate the forecasted changes of weather and climatic factors in conditions of climate change and their influence on the conditions of the functioning of rice systems, in particular, on the value of irrigation water demand for the cultivation of flooded rice culture and natural reclamation state of irrigated land. The obtained results should be the basis for the development of adaptation measures, aimed at mitigating the negative effects of climate change on the conditions of rice systems functioning and industry productivity in general.

Materials and Methods

To solve the task of estimation of the changes in weather and climatic factors in conditions of climate change were planned and performed a large-scale computer experiment

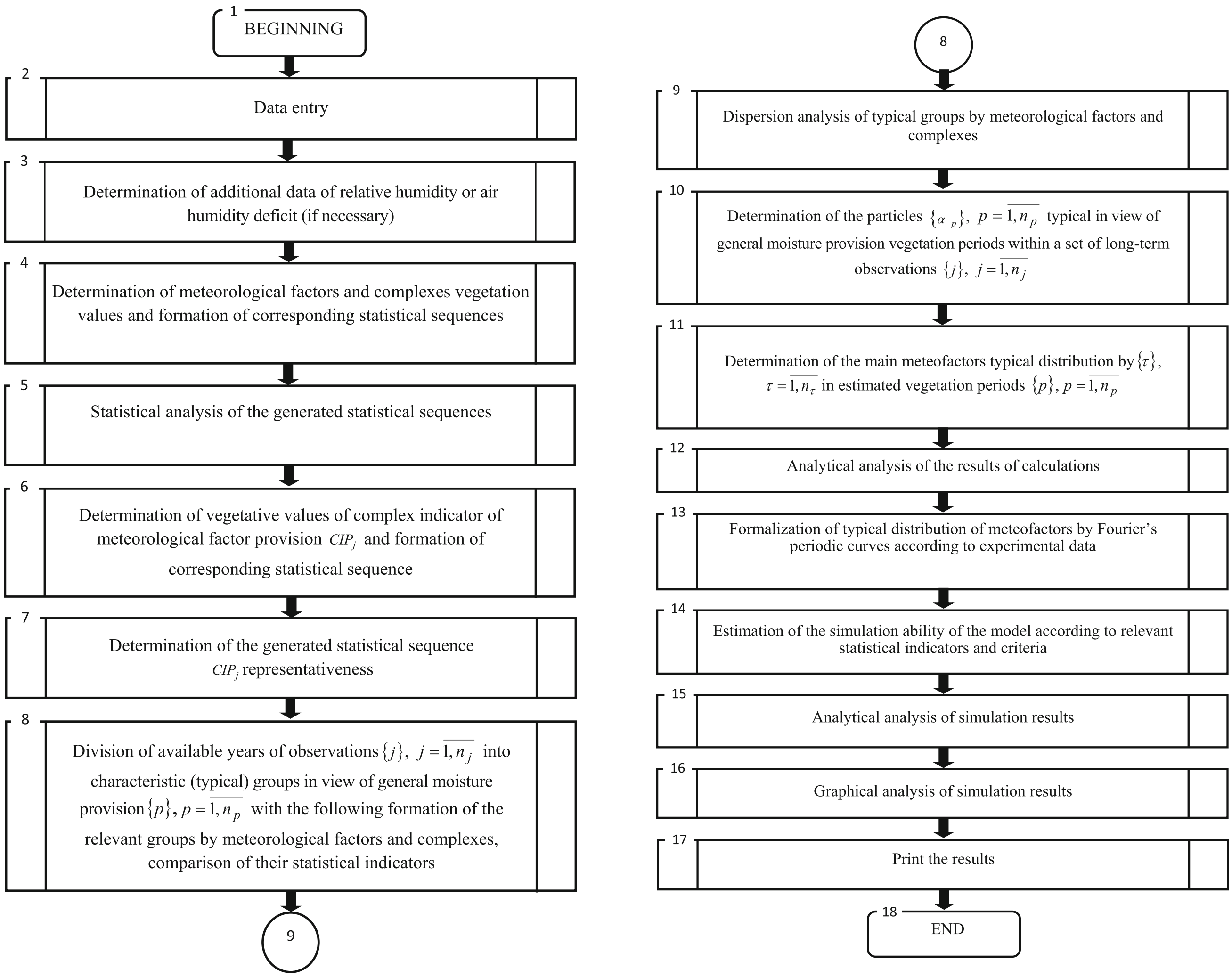

Fig. 1 The generalized block scheme of stages of implementation the model of typical distribution of meteofactors in the case of availability of long-term database

based on long-term retrospective (1891–1964) and current observational data (1981–2017) obtained in the rice-growing zone of Ukraine (Odessa region).

The main meteorological characteristics that were investigated are: air temperature, T, °C; precipitation, P, mm; relative air humidity, H, %; air humidity deficit, D, mm; and their derivatives: photosynthetically active radiation, PAR, MJ/m^2; water availability coefficient (precipitation/evapotranspiration ratio), K_w.

Scientific and methodological basics of machine experiment are the approaches and models for forecasting of typical meteorological regimes on a long-term basis, the use of which are regulated by the relevant industry standards [13]. The generalized block scheme of stages of implementing the model of the typical distribution of meteofactors in the case of availability of long-term database is presented in Fig. 1.

To study the changes in weather and climate conditions (from the retrospective to the recent conditions and perspective) were implemented the following variants of study for the average conditions of the Danube RIS in Odessa region on the example of the Kilia RIS [15, 22, 23]:

- *variant 1—"Base"* characterization of the meteorological characteristics over a period of vegetation (months 4–10), obtained on the base of long-term retrospective data (1891–1964) [Hydrometioizdat 1990];
- *variant 2—"Recent"* characterization of the dynamics and standardized average long-term values of the variables of basic meteorological characteristics and their distribution over the vegetation period, obtained under recent conditions over the years of 1981-2017;
- *variant 3a—"CCCM" and variant 3b—"UKMO"* characterization of standardized average long-term values of the variables of basic meteorological

characteristics and their distribution over the vegetation period, obtained in view of current and predicted climate change, in accordance with the recommendations [19], by the models of Canadian Climate Center "CCCM"—as a more favorable forecast, and of the United Kingdom Met Office "UKMO"—as a less favorable forecast, which foresee an increase in average annual temperature up to 4 °C and 6 °C relatively—provided that the doubling CO_2 in atmosphere occurs [19, 20].

Practicability of the application of "CCCM" and "UKMO" models is proved by their capabilities to involve both less and more critical scenarios of changing weather patterns, and they perfectly comply with the predictive estimate of the rationing of basic meteorological characteristics in the long-term and one-year vegetation context [14].

As a base variant of the study were taken the retrospective long-term data (1891–1964 years) according to official reference data [9], because in this period the climate of the studied region had a pronounced stable character. In addition, the weather and climatic conditions of this period occurred during the design and construction of the Danube.

Performing of forecast regime calculations on the long-term basis with sufficient accuracy for engineering practice, we consider it appropriate to divide available statistical sequences of meteorological values into the five typical groups (estimated years) of vegetation periods in view of general heat and moisture provision by exceeding probability of exceeding (p, %) their average vegetation values (item 8 in Fig. 1). Schematically, they can be represented as the following set $P = \{p\}$, $p = \overline{1, n_p}$ ($n_p = 5$) taking into account the natural change in the provision of meteorological factors in the typical groups according to Table 1.

Thus, the estimation and forecast of the weather and climatic condition's changes were made by:

- Four variants of study: *Base, Recent, CCCM, UKMO*;
- Six meteorological characteristics: *air temperature, precipitation, relative humidity and air humidity deficit, photosynthetically active radiation (PAR) and water availability coefficient (precipitation/evapotranspiration ratio)*;
- Five typical groups (estimated years) of vegetation periods of target years in view of general heat and moisture provision: *very wet*—p = 10%, *wet*—p = 30%, *middle*—p = 50%, *dry*—p = 70%, *very dry*—p = 90%.

The general scheme of the study presented in Fig. 2.

Table 1 Estimated provision of meteorological factors according to typical groups (estimated years) of vegetation periods in view of general heat and moisture provision

Provision p(%) by P_j, $\bar{H}_j$	Typical groups (estimated years) $P = \{p_j\}$, $p = \overline{1, n_p}$ (n_p= 5)	Provision p (%) by $\bar{T}_j$, $\bar{D}_j$
0–20%	p = 1, very wet	80–100%
20–40%	p = 2, wet	60–80%
40–60%	p = 3, middle	40–60%
60–80%	p = 4, dry	20–40%
80–100%	p = 5, very dry	0–20%

Results

The summarized results of the calculation of the values of basic meteorological characteristics (precipitation, temperature, air humidity deficit and relative air humidity) and their derivative characteristics (PAR, water availability coefficient) over the target years presented in Table 2, as the percentage change in normalized vegetation values of the basic meteorological characteristics by the variants of study («Recent», «CCCM», «UKMO») relative to their baseline values («Base»).

The obtained results on the comparative assessment of changes in current and predicted values of basic meteorological characteristics over the target years and on the average for the years enable to make the following conclusions:

- *On precipitation* in recent conditions ("Recent") compared with the retrospective ("Base"), there is a decrease in the amount of precipitation for all considered target years, which is an average of 14.7%. The largest decrease for precipitation is observed in the "wet" (p = 30%)—21.4% and "dry" (p = 70%)—21.7% target years.
  Accordingly the forecasting variants also expected to decrease the amount of precipitation in relation to their average long-term norms ("Base"), which is on average on the model "CCCM"—18.3% and "UKMO"—7.8%. At the same time, the value of the forecasted deviations is gradually reduced for the marginal "very humid" (p = 10%) and "very dry" (p = 90%) target years;
- *On air temperature* already in recent conditions ("Recent") compared with the retrospective ("Base"), there is a pronounced increase in air temperature, which is an average of 2.3%; deviation increases with the transition from "middle" (p = 50%) to "very dry" (p = 90%) and "very wet" (p = 10%) target years. According to forecasts variants, "CCCM" and "UKMO" predicted a significant increase in air temperature with respect to

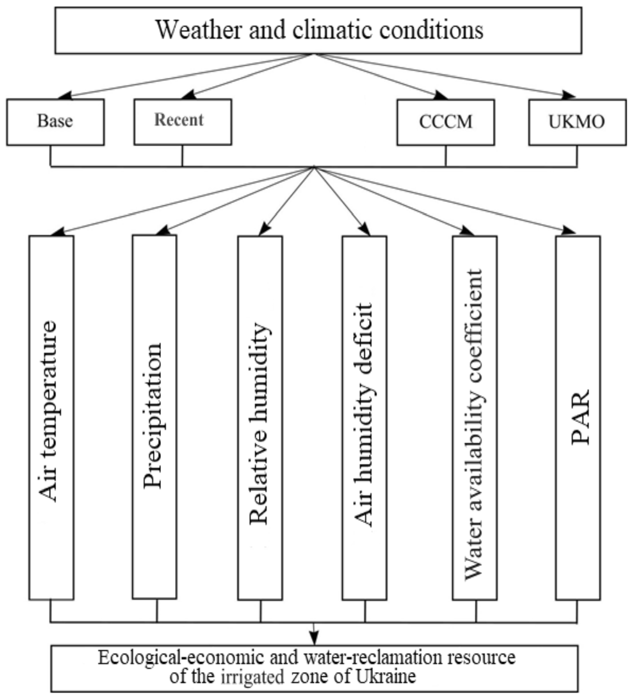

Fig. 2 Diagram of weather and climate characteristics assessment under retrospective («Base»), recent («Recent») and forecasted («CCCM», «UKMO») conditions

the data of "Base" variant on 22.0% and 26.9%, respectively;

- *On air humidity deficit* the change of this indicator is similar to changing of the air temperature with some deviations in a target years and a somewhat larger change in the forecast variants—for «CCCM» increase is 24.5% and for «UKMO»—29.1%;
- *On atmosphere relative humidity* in recent conditions ("Recent"), there is a slight increase, which is from 4.0 to 4.9% in "dry" and "very dry" years, other values in all variants differ insignificantly— ± 1…3%;
- *On PAR* the change in this indicator is completely similar to changing of the air temperature with some deviations in target years and a somewhat lesser change in the forecast variants—for «CCCM» increase is 15.5% and for «UKMO»—18.9%;
- *On water availability coefficient* the change of this indicator is completely similar to changing of the precipitation in target years. At the same time, according to the forecast variants, it significantly decreases—for «CCCM» decrease is 34.4% and for «UKMO»—29.6%.

Table 2 Comparative assessment of changes in the values of basic meteorological characteristics by the variants of study for the conditions in the area of the Danube RIS location (%)

Model indicators		Typical groups of target years					Average value (%)
		10%	30%	50%	70%	90%	
Precipitation (*P*)	«Recent»	− 6.3	− 21.4	− 8.8	− 21.7	− 10.5	− 14.7
	«CCCM»	− 17.1	− 17.1	− 17.2	− 18.6	− 20.8	− 18.3
	«UKMO»	− 6.5	− 6.5	− 6.4	− 8.1	− 10.5	− 7.8
Air temperature (*T*)	«Recent»	+ 4.3	+ 3.6	+ 0.6	+ 2.3	+ 1.7	+ 2.3
	«CCCM»	+ 19.8	+ 21.1	+ 22.2	+ 22.4	+ 22.7	+ 22.0
	«UKMO»	+ 23.5	+ 25.3	+ 26.9	+ 27.6	+ 28.7	+ 26.9
Air humidity deficit (*D*)	«Recent»	+ 6.3	− 2.7	− 6.4	− 7.2	− 5.5	− 4.6
	«CCCM»	+ 25.2	+ 25.2	+ 22.0	+ 25.3	+ 25.3	+ 24.5
	«UKMO»	+ 27.4	+ 28.9	+ 26.3	+ 30.6	+ 31.5	+ 29.1
Relative air humidity (*H*)	«Recent»	− 1.3	+ 1.5	+ 2.9	+ 4.9	+ 4.0	+ 3.1
	«CCCM»	0.0	− 0.3	+ 0.3	− 1.4	− 2.7	− 0.9
	«UKMO»	+ 1.1	+ 0.9	+ 1.5	− 0.3	− 1.2	+ 0.3
Photosynthetically active radiation (PAR)	«Recent»	+ 3.0	+ 2.0	+ 0.4	+ 1.4	+ 1.5	+ 1.4
	«CCCM»	+ 14.1	+ 14.7	+ 15.4	+ 15.7	+ 16.5	+ 15.5
	«UKMO»	+ 16.3	+ 17.4	+ 18.8	+ 19.4	+ 20.8	+ 18.9
Water availability coefficient (K_w)	«Recent»	− 12.5	− 19.5	− 6.3	− 17.4	− 6.3	− 12.2
	«CCCM»	− 32.1	− 31.1	− 34.4	− 34.8	− 37.5	− 34.4
	«UKMO»	− 23.2	− 24.4	− 28.1	− 30.4	− 37.5	− 29.6

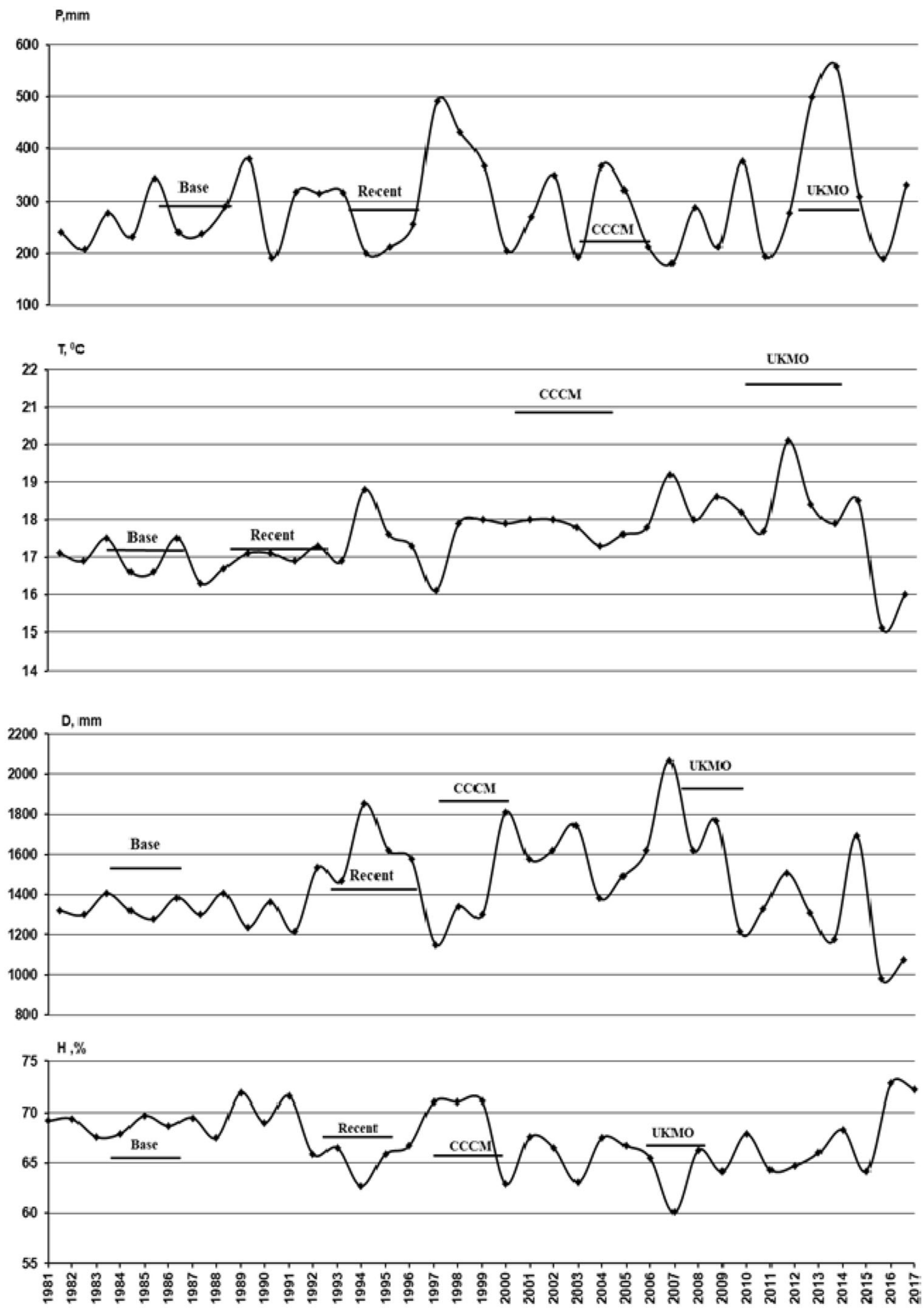

Fig. 3 Comparative assessment of normalized values of basic meteorological characteristics by the variants of study regarding the dynamics of their valid values in conditions

The given data convincingly testify that most values of meteorological characteristics, except temperature and PAR, in recent conditions are already located either in the zone or at the level of their forecasted values under conditions of climate change.

Comparative assessment of the dynamics of basic meteorological characteristics of the vegetative periods for the period of 1981–2017 along with their retrospective and prospective rates is presented in Fig. 3.

The obtained results enable to make the following statements:

- *As to precipitation* there is a significant amplitude of their change for the considered period from 180 to 550 mm at the rate of 287 mm with clearly pronounced maxima in 1997 and 2014 and relatively stable changes in their values in subsequent years after 1997. The average annual rate of precipitation for the model

"Recent" is less than the average annual norm of the "Base" model;

- *As to air temperature* there is a different picture since 1981 the amplitude of changes reaches the first maximum in 1994–18.9 °C and rapidly drops to 15.9 °C in 1997; afterward there is a gradual increase in air temperature to the second maximum in 2007–19.3 °C, and the third in 2012–20.2 °C. There is a clearly pronounced trend of temperature rise over recent years, but their average annual values are much lower than their forecasted norms by the models "CCCM" and "UKMO," although the average annual rate for the model "Recent" is somewhat higher than the average annual rate for the model "Base";
- *As to air humidity deficit* the dynamics of changes in air humidity deficits, in general, reflects the characteristic features of the change for precipitation and temperature. The air humidity deficit reaches the first maximum in 1994–1850 mm with the average vegetative value of 8.69 mm, after it is similarly reduced to 1150 mm or 5.40 mm in 1997 and then gradually rises to the second and third maximums in 2000 and 2007—respectively, 1810 mm or 8.50 mm and 2150 mm or 10.1 mm. The gradual decrease in the second group of minima takes place in 2010 and 2014—respectively, 1215 mm or 5.70 mm and 1175 mm or 5.52 mm. At the same time, its average annual norm according to the model "Recent" is lower than the average annual norm for the model "Base," and its corresponding norms for models "CCCM" and "UKMO" are already within the limits of modern changes of the Danube RIS location area
- *As to air relative humidity* there is an opposite situation to the dynamics of change in the air humidity deficit, the first two maxima (about 72%) in 1989 and 1991; after which there is a rapid decrease to the first minimum of 62.9% in 1994. A similar increase to the other highs of about 72% occurs in 1996–1999 with the gradual decrease in the amplitude of changes to the second group of minima $\approx$ 63% in 2000 and 2003. Since the next minimum ($\approx$ 60%) in 2007, there has been a tendency of further increase in the air relative humidity value. At the same time, the average annual norm of air relative humidity for the model "Recent" is much higher than its average long-term norm for the model "Base," and its corresponding norms for models "CCCM" and "UKMO" are already within the limits of modern changes.

On the whole, the forecasted values of studied meteorological characteristics for the models "CCCM" and "UKMO" in the rice-growing zone of Ukraine, except air temperature, are already within the limits of modern changes and even exceed them by separate positions, which indicates a steady trend of weather and climate change in the region.

The obtained results of the comparative estimation of weather and climatic conditions in the rice-growing zone of Ukraine testify to the fact that almost all basic meteorological characteristics (except air relative humidity) are already undergoing changes. In the near future, these changes may exceed the 10% critical ecological threshold (first it concerns air temperature as the determining factor of modern climate change, as well as FAR, as its derivative), that according to N.F. Reimers will lead to corresponding irreversible changes in the environmental state of the region.

At existing rates and changes in weather and climatic conditions, we should expect the deterioration of natural meliorative conditions in the rice-growing zone of Ukraine. This is related, first, with the forecasted reduction of natural water availability of territory (an average of 32%) and corresponding increase in the demand for irrigation water for cultivation of flooded rice culture and maintenance of washing water regime on saline-prone lands of rice-growing systems. This will inevitably have a negative impact on the functioning of rice systems because of the corresponding changes in the ecological and economic resources of the region. Unfortunately, in today's economic conditions, market prices on water and electricity for the agricultural sector, such production will not be profitable in terms of high financial costs.

Therefore, the provision of favorable conditions of functioning of rice systems requires the development of adaptive technical and regime-technological measures to manage these systems through relevant comprehensive sectoral, state and interstate research and programs.

Based on the experience of European countries [11], the adaptive measures to climate change on meliorated lands should involve a range of management, operational and agro-technical, construction and project activities [16] (Table 3).

The following activities are relevant for the conditions of irrigated lands of the rice-growing zone of Ukraine: *Management activities* involve a range of activities, usually at the regional level: the establishment of organization and consulting centers and conducting training and seminars based on regional (administrative) consulting centers. The training should be conducted for the conditions of both existing and possible risk reduction that would provide the parameters and modes of irrigation for crops, taking into account the changing weather conditions and weather forecasts, for the optimal use of their adaptive potential. *Operational and agro-technical activities* include deep loosening of soils or other agro-technical measures for the preservation of soil moisture. Changing varieties is also

Table 3 Main activities on adaptation meliorated lands to climate changes

Activities			
Management activities	Operational and agro-technical activities	Construction activities	Project activities
Establishment of organization and consulting centers Development of reporting, planning and prospective water balance by the basin principle Modeling of river ecological conditions in view of water quality indices in agro-ecosystems	Regulation of water regime Prevention of soil degradation Improvement of plant breeding	Construction, reconstruction and renaturalization of water management and ameliorative objects and units Construction and reconstruction of flood control hydrotechnical structures	Ensuring ecological and safe conditions for environmental management Design of closed farming production cycles

relevant: introduction of varieties resistant to biotic and abiotic threats related to climate change and cultivation of hybrid varieties. *Construction activities* include the reconstruction of existing RIS or their individual components. *Project activities* include development of new and improvement in existing technologies and modes of irrigation on a resource-saving basis.

There are various activities on adaptation as applied to agriculture [11]; Paris Agreement ratified by the Law No. 1469-VIII of 14.07.2016 [21], which involves different levels of decision-making: international, national, regional and local and are aimed at both prevention and elimination of consequences. Introducing adaptive activities should be accompanied by raising awareness of public and land users.

Conclusions

Thus, at existing rates and levels of weather and climatic changes and adherence to traditional rice cultivation technologies, we should expect a significant deterioration of functioning conditions of rice irrigation systems and natural reclamation state of irrigated land. The proposed activities on adaptation meliorated lands to climate changes have their own explicit objectives, which are closely related, therefore to develop a proper program of adaptation activities the potential impacts of climate change, risks and vulnerability as its results need to be better understood. This integrative approach to solving the problems will enable to enhance and develop the adaptive capacity of the rice-growing zone of Ukraine.

Solutions of modern ecological and economic problems of the Ukraine rice industry, associated with large volumes of water supply and unproductive technological loss, are: transition to resource-saving regimes and technologies of water use; minimization of unproductive water discharges; resource-saving and environmental protection. To achieve these goals must be complete and implement a number of tasks, which includes the need to improve: design of existing rice systems; regimes and technologies of water use on the rice systems according to resource-saving requirements. These are the necessary conditions for adaptation of rice systems to the predicted changes in weather and climatic conditions of the rice-growing zone of Ukraine.

References

1. Adger W (2006) Vulnerability. Global Environ Change 16:268–281
2. Boichenko S, Voloshchuk V, Doroshenko I (2000) Hlobalne poteplinnia ta yoho naslidky na terytorii Ukrainy. Ukrainskyi heohrafichnyi zhurnal 2:59–68
3. Bours D, Mcginn C, Pringle P (2013) Monitoring & evaluation for climate change adaptation: a synthesis of tools, frameworks and approaches. SEA Change CoP, Phnom Penh and UKCIP, Oxford. https://ukcip.ouce.ox.ac.uk/wp-content/PDFs/SEA-change-UKCIP-MandE-review.pdf.
4. Dinshaw A, Fisher S, Mcgray Y, Rai N, Schaar J (2014) Monitoring and evaluation of climate change adaptation: methodological approaches. OECD Environment Working Papers No. 74. www.oecd-ilibrary.org/environment/monitoring-and-evaluation-of-climate-change-adaptation_5jxrclr0ntjd-en
5. Dudchenko V, Vozhehova R, Shpak D et al. (2008) Puti reshenia problem pri vyrashchivanii risa v ahroekosistemakh umerennoho klimata [Ways to solve the problems in rice agro-ecosystems in temperate climate]. Proceedings from Mezhdunarodnaia nauchnaia konferentsia (4-8 avhusta 2008 hoda)—International Scientific Conference. Scadovsk: UAAN, Institut risa (in Russian)
6. Espon (2007) The spatial effects and management of natural and technological hazards in Europe, ESPON 1.3.1, Executive Summary. Geological Survey of Finland, Espoo, p 309
7. FAO (2015) Climate change and food systems: global assessments and implications for food security and trade. Food Agriculture Organization of the United Nations (FAO) http://www.fao.org/3/a-i4332e.pdf
8. Flato G, Marotzke J, Abiodun B, Braconnot P, Chou SC, Collins W, Cox P, Driouech F, Emori S, Eyring V, Forest C, Gleckler P,

Guilyardi E, Jakob C, Kattsov V, Reason C, Rummukainen M (2013) Evaluation of climate models. In: Stocker TF, Qin D, Plattner G-K, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V, Midgley PM (eds) Climate change 2013: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge. www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter09_FINAL.pdf
9. Gidrometeoizdat (1990) Nauchno-prykladnoi spravochnik po klimatu SSSR. Ser. 3. Mnogoletnye dannye. Chasti 1–6. Vyp. 10. Ukraynskaia SSR. Kn. 1 [Scientific and applied handbook on the climate of the USSR. Ser. 3. Perennial data. Parts 1–6. Vol. 1. The Ukrainian SSR]. Leningrad, pp 518–534
10. Gorzhyk I, Yemelyanova Z, Trofimova I, Shereshevskiy A (1998) Ukraina ta hlobalnyi parnykovyi efekt. Knyha 2. Vrazlyvist i adaptatsiia ekolohichnykh ta ekonomichnykh system do zmin klimatu [Ukraine and Global Greenhouse Effect. Book. 2. Vulnerability and adaptation of environmental and economic systems to climate change]. Kiev. Vydavnytstvo Ahentstva z ratsionalnoho vykorystannia enerhii ta ekolohii
11. Massier EE (2012) Dosvid yevropeiskoho soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini [The experience of the European Union in adapting to climate change and its application in Ukraine. OSCE Coordinator for Economic and Environmental Activities]. Biuro Koordynatora z ekonomichnoi ta dovkilnoi diialnosti OBSIE
12. Mendelsohn R, Dinar A (2003) Climate, water, and agriculture. Land economics 79(3):328–341. https://doi.org/10.2307/3147020
13. Rokochinskiy A (2010) Naukovi ta praktichni aspekti optimizacії vodoregulyuvannya osushuvanikh zemel' na ekologoekonomichnikh zasadakh: Monografiya [The scientific and practical aspects optimization of water regulation drained lands on environmental and economic grounds. Monograph]. Ed. M.I. Romashchenko. Rivne. NUVGP. ISBN 978-966-327-141-5
14. Rokochinskiy A, Halik O, Frolenkova N, Voloshchuk V, Shalai S, Zubyk YA, Bezhuk V, Zubyk L, Pokladnov YE, Savchuk T, Koptiuk R, Nesteruk L, Volk P, Kotiai L (2008) Posibnyk do DBN V.2.4-1-99 «Melioratyvni systemy ta sporudy» (Rozdil 3. Osushuvalni systemy). Meteorolohichne zabezpechennia inzhenerno-melioratyvnykh rozrakhunkiv u proektakh budivnytstva y rekonstruktsii osushuvalnykh system [Guide to DBN V.2.4-1-99 "Reclamation systems and structures" (Chapter 3. Dehumidification systems). Meteorological support of engineering and reclamation calculations in drainage systems construction and reconstruction projects]. Kiev. Vidkryte aktsionerne tovarystvo VAT «Ukrvodproekt»
15. Rokochinskiy A, Turchenyuk V, Mendus P et al (2018) Pidvyshchennia efektyvnosti funktsionuvannia Prydunaiskykh rysovykh zroshuvalnykh system: naukovo-metodychni rekomendatsii [Increasing efficiency of functioning of the Danube rice irrigation systems: scientific and methodical recommendations] Odesa-Rivne: NUVGP. ISBN 978-966-327-391-4
16. Rokochinskiy A, Volk P, Pinchuk O, Mendus S, Koptyuk R (2017) Comparative evaluation of various approaches to the foundation of parameters of agricultural drainage. J Water Land Dev 34:215–220. https://doi.org/10.1515/jwld-2017-0056.(SNIP:0.486)
17. Romashchenko M, Khvesik M, Mikhailov Y (eds) (2015) Vodna stratehiia Ukrainy na period do 2025 roku (naukovi osnovy) [Water strategy of Ukraine for the period till 2025 (scientific basis)] Kiev: IVPiM NAAN
18. Romashchenko M, Rokochinskiy A, Halik O, Savchuk T, Kolodich O (2007) Suchasni zminy klimatu ta yikh proiavy vid hlobalnoho do rehionalnoho proiaviv. Hidromelioratsiia ta hidrotekhnichne budivnytstvo 32:65–79
19. Romashchenko M, Sobko O, Savchuk D, Kulbida M (2003) Pro deiaki zavdannia ahrarnoi nauky u zviazku zi zminamy klimatu. Kiev, Instytut hidrotekhniky i melioratsii UAAN, p 46
20. Shevchuk V, Trofimova I, Trofimchuk O (2001) Problemy i stratehiia vykonannia Ukrainoiu ramkovoi konventsii OON pro zminu klimatu [Problems and strategy of Ukraine's implementation of the UN Framework Convention on Climate Change]. Kiev
21. Smit B, Skinner M (2002) Adaptation options in agriculture to climate change: a typology. Mitig Adapt Strat Glob Change 7(1):85–114
22. Stashuk V, Rokochinskiy A, Granovska L et al. (2014) Rys v Ukraini: kolektyvna monografiya [Rice in Ukraine: collective monograph]. In: Stashuk V, Rokochinskiy A, Granovska L (eds). OLDI-PLUS, Kherson
23. Stashuk V, Rokochinskiy A, Mendus P, Turchenyuk V et al (2016) Rys Prydunav'ia: kolektyvna monografiya [Rice of the Pre-Danube: collective monograph]. In: Stashuk V, Rokochinskiy A, Mendus P, Turchenyuk V (eds). Kherson. OLDI-PLUS. ISBN 978-966-930-122-2