Int. J. Environ. Eng. Nat. Resour.
Volume 1, Number 4, 2014, pp. 197-202
Received: July 25, 2014; Published: October 30, 2014

International Journal of
Environmental Engineering
and Natural Resources

New Principles for the Atmosphere Drought Classification

Yuriy V. Petrov[1], Bakhtiyar M. Kholmatjanov[2] and Khamrakul T. Egamberdiev[3]

1. Department of Astronomy and Physics of Atmosphere, Faculty of Physics, National University of Uzbekistan, 17 Beshchinor Str., Tashkent 100031, Uzbekistan

2. Department of Astronomy and Physics of Atmosphere, Faculty of Physics, National University of Uzbekistan, 4a Massiv Qoraqamish2/5 Apt. 21, Tashkent 100176, Uzbekistan

3. Department of Astronomy and Physics of Atmosphere, Faculty of Physics, National University of Uzbekistan, 17 Qayirma-5 Str., Tashkent 100176, Uzbekistan

Corresponding author: Yuriy V. Petrov (yuvpet@mail.ru)

Abstract: The atmospheric drought as hazardous atmospheric phenomenon leads to significant loss in the economic sectors of many countries of the world including Central Asia. The purpose of the research is to develop new criteria corresponding to pessimum of crops condition. As such a parameter one has been chosen that takes into account the air temperature and humidity. The parameter has been named thermohygrometric factor of air dryness (THF). New direction of fundamental and applied sciece-ecological qualimetry is a methodological toolkit of the research. Besides, the methods of correlation regression analysis are widely used. The present day analysis of the air temperature and humidity on various crops showed that at K within 76-90‰ at any air temperatures relative air humidity is 24-26%, which corresponds to law intensity atmospheric drought (AD). From independent sources it is known that weak AD is observed at the relative humidity less than 30%. From the same sources it is known that at more intensive drought (moderate drought) relative humidity is in the range of 15-20%. In our calculation, K within 89-92‰ corresponds to this relative humidity. Relative humidity 10-20% corresponds to strong AD. At these values of relative humidity, K falls within 103-106‰. At very strong drought, relative humidity is less than 10%, and K is higher than 120‰. Necessary and sufficient conditions for AD of any intensity to emerge have been defined. The dependence between air temperature and water vapor pressure is sustainable and reliable. The results obtained cam be applied for AD study in other regions of the world.

Key words: Atmosphere drought, atmosphere drought classification, termohygrometric factor of air aridity, qualimetry, impact on crops.

1. Introduction

The atmosphere drought as hazardous atmospheric phenomenon leads to significant losses in the economic sectors of many countries including Central Asia. As many climate scientists evaluate the situation may aggravate in connection with the global climate change. In order to minimize impact of the atmosphere drought on productivity it is necessary to develop methods of its forecast and monitoring as well as development measures for preventing its consequences.

The atmosphere drought (AD) is one of the most hazardous natural phenomena. It is because AD entails enormous losses to the economies of various countries as it spreads to large territories and may last long time. Iguo Dai, the researcher from the National Meteorological Service of the USA based of analysis of ensemble of 22 climatic models, arrived to the conclusion that the United States of America and many other densely populated countries may run into AD within the closes decades to come. This problem will touch, in particular, the Central Asian countries, too [1]. Further Day's calculations show that Turkmenistan, Uzbekistan, Tajikistan, and Kyrgyzstan as well as small part of the southernmost regions of Kazakhstan by the middle of the current century will be struck by large drought and by 2099 the region will become even more drought.

Due to enormous impact of the AD on all the aspects of human activities the problem of its forecast and monitoring emerges. First of all the problem needs solution for raising efficiency of agriculture based of the recent hi-tech including utilization of fundamental research in the area of ecological qualimetry [2, 3]. It is obvious that increase of food production must be based both on theoretical studies, and development of new technologies and methods of evaluation of environmental and meteorological factors impact on production of crops. Evaluation of these impacts at present stage is possible only on basis of new approaches to classification of objective criteria, indices, and other quantitative parameters taking into account the current climate change trends.

The purpose of the article is to develop new criteria corresponding to the pessimum condition of these crops on the basis of the recent data on response of some agriculture crops (on the example of Uzbekistan) to extreme weather conditions including the AD.

2. Materials and Methods

One of the most often used currently definitions of the AD is as follows: according to that definition the AD is observed while effective precipitation (more than 5 mm/day) in the vegetation period not less than 30 day in raw at maximum temperature over 25 °C (in the Southern regions-over 30 °C). Such a situation leads to sharp increase of plant transpiration and evaporation from the surface. The AD sets in when stable blocking anticyclones develop in the atmosphere over synoptic region [4].

The AD is a consequence of certain weather conditions characterized first of all by the air temperature, moisture deficiency, and precipitation. Various combinations of the listed values may serve as drought indicators. As main indices of the AD D.A.Ped and Palmer's index are usually applied [5]. Common feature for all the indices is that, firstly, they diagnose the droughts as phenomenon for the periods of time of one month and more. Secondly, the criteria are insufficiently substantiated of various levels of AD by its impact on development of plants in the state of pessimum. In the agrometeorological practice, Selianinov's hydrothermic factor (HTF) is normally applied [6]. It is defined as the ratio of precipitation sums (mm) for the period with average daily air temperature over 10 °C to the sum of temperatures for the same period. The factor allows separate natural zones by the level of their aridity. HTF within the range of 0.44 to 1.3 characterises the arid zone, HTF equal to 0.4 to 0.7 characterises the arid subzone etc.

This index, as well, holds the same shortcomings as the previous ones. Besides, it is a dimensional index, which limits its potential in simulation studies.

L.N. Babushkin established the following criteria of atmospheric draught. In the conditions of arid climate of Central Asia, he classified the AD by the air moist deficiency at noon. Total of 4 types of the AD had been separated based on its intensity: weak (humidity deficiency 50 to 60 HPa), moderate (61 to 70 HPa), strong (71-80 HPa), very strong (more than 80 HPa) [7].

In the same paper, L.N. Babushkin recommended to use the air temperature for efficiently to establish drought criteria. Thermohygrometric factor (THF) of air dryness is the parameter that takes into account both meteorological values [8].

$$K = \frac{T - \tau}{T} \quad (1)$$

where τ-dew point temperature, T-air temperature in Kelvins. The value is measured in per mille (‰).

Potential of using this factor in addressing agrometeorological problems has been shown in the papers [8-10].

In order achieve the goals, the data of standard meteorological observations of about 20 meteorological stations of Uzbekistan for the period 1961 to 2011 have been used.

A new area of fundamental and applied sciences-ecological qualimetry is a methodological apparatus of the study [11]. Besides, the methods of correlation regression analysis have been applied widely. x paragraphs must be indented. All paragraphs must be justified, i.e. both left-justified and right-justified.

3. Results and Discussion

The territory of Uzbekistan includes various climatic zones. The significant part of them falls into areas of instable agriculture, where deficiency of precipitation, high summer temperature, salinity of soil, etc. are typical. With this regard, difficulties and certain problems emerge with cultivation of some crops.

Analysis of the literature sources in the area of agrometeorology revealed some fundamental peculiarities of various crops response to regimen of the air temperature and its humidity in the periods of formation and accumulation of the harvest. For many kinds of cabbage (Brassica), temperature above 25 °C negatively impacts growth of heads. Tissues grow thick, lower leaves drop down, heads crack. All this leads to decrease in yield and the formation of small non-standard cabbages. Long-term high temperatures, especially during droughts, inhibit growth and development of the cabbage. It such a case, the plants scale down their size (leaves, heads) forming higher external stalks. For potato (Solánum tuberósum), increase of temperature to 30 °C and higher breaks the plant's growth. Raise of temperature to 23-25 °C hampers tuber weight gain, and at 29-30 °C tuber development stops practically. At the temperature 42 °C and higher tops development stops because more products of assimilation are spent for the plant breathing than the leaves accumulate in the process of photosynthesis. For cucumbers (Cucumis sativus), the best temperature for growth is 22-28 °C, and when temperature raises to 30 °C, cucumber growth stops [12]. For tomatoes (Solánum lycopérsicum), sudden sharp changes of temperature, moreover during the long period of time, harmfully impact the plant development, especially in the period of their budding. The leaves turn yellow with bluish tone, and buds may lapse then. Temperature above 35 °C impacts tomatoes especially negatively. Consumption of matters for breathing increases sharply exceeding gain from assimilation, which results in ruin of the plants of hunger.

With watermelons, melons and gourds, at the temperature above 40 °C seed-buds do not conceive totally or conceive partially, fruits do not set. The temperature above 40 °C impacts badly blooming: mainly male flowers bloom, and roundish fruits set [13]. For wheat, at the temperature 35-36 °C assimilation processes slow down, the plant began to fade [14].

Actually, the above extreme temperatures for agricultural crops may be considered criteria of the AD of various intensity. As, by definition, the AD draught comes at the maximum air temperature above 25° C, this temperature may be considered beginning of the weak AD.

Calculation data made for the meteorological stations in Uzbekistan located in its various climatic zones displayed fair correlation between K and the maximum air temperature and water vapour partial pressure at noon (Fig. 1).

It is seen from Fig. 1 that while the air temperature increases and partial pressure decreases dryness factor increases. And additional calculations have shown that while K is equal 76-90‰ relative humidity equals 24-26% at any air temperature. It is known from the above literature sources that at weak AD the relative air humidity is less than 30%. Thus, magnitude of K equal to 75-76‰ can be considered lower criterion of weak atmospheric draught to set. The same sources tell that at more intensive draught (moderate drought) the relative humidity is between 15 and 20%. In our calculation this relative humidity represents K equal 89-92‰. Furthermore, relative humidity 10-20% represents strong atmospheric draught. According to our calculations at these magnitudes of the relative humidity K falls in the range 103-106‰. And finally, at very strong draught the relative humidity is below 10%, and K is above 120‰.

The proposed criteria of the AD intensity include the drought classification by L.N. Babushkin [6] in that its part where the air temperature is above 35 °C. It is because L.N. Babushkin classified the AD in relation to cotton, for which unfavorable meteorological conditions take place at high air temperatures.

For each level of the AD the following regression equations have been obtained:

$y = 0.0015x^3 - 0.1204x^2 + 3.8094x - 36.297$-weak drought;

$y = -0.0002x^3 + 0.0324x^2 - 0.9824x + 11.686$-strong drought;

$y = 0.0021x^3 - 0.2421x^2 + 9.5903x - 124.64$-very strong drought, that connect the air temperature and water vapor pressure. The respective correlation coefficients lay within 0.89 and 0.92, which tells about strong enough connection between the values.

It should be pointed out that at the same air temperature the AD intensity may vary within the wide range (Fig. 1).

Thus for instance at the temperature 40 °C in the case of weak AD the water vapor pressure is 13-17 HPa, at moderate one the pressure is 9-13 HPa, at strong one—7-9 HPa, and at very strong the pressure is less than 7 HPa.

Thus, it can be accepted that the water vapor pressure is the necessary condition for the AD of some intensity to ser. The air temperature is the sufficient condition for emergence of the AD of different intensity.

Let's estimate significance of the obtained relations for the meteorological stations of Uzbekistan situating in various physical geographical areas (Table 1).

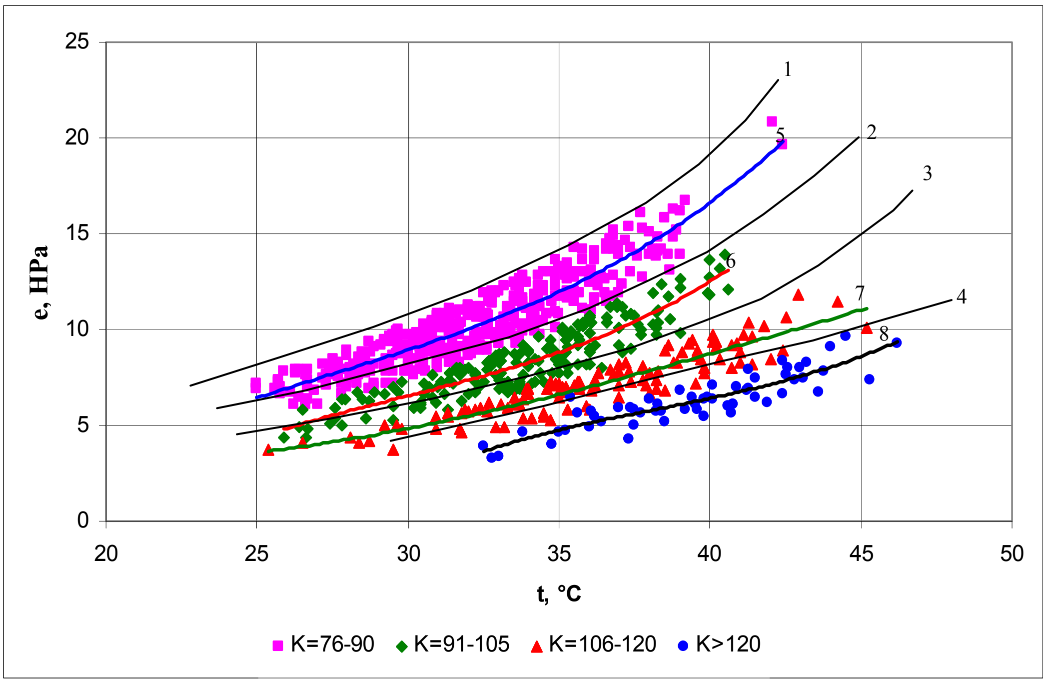

Fig. 1 Correlation of the THF of air dryness (‰) with the maximum values of air temperature and pressure of water vapour (1-*K*=75‰, 2-*K*= 90‰, 3-*K*=105‰, 4-*K*=120‰, 5-8-lines of polynomial regression for respective levels of the AD).

The stations Urgench and Termez are located in the area of irrigated agriculture belonging to the Northern and Southern parts of Uzbekistan territory. The other stations are located in various parts of semi-desert and desert zones. It is seen from Table 1 that no significant differences between values of the given parameters have been observed. The significance of relation coefficient for all the levels of AD is very high and exceeds 4-5 units. Based on the values of this coefficient one can conclude that significance of the relation exceeds 98% [15]. Thus the dependence between the air temperature and water vapor pressure we have obtained are stable and reliable.

The significance coefficient is defined by the formula:

$$D = \frac{y_2 - y_1}{\sigma} \quad (2)$$

where y_1 is the minimum value of water vapor pressure, y_2 is the maximum value of water vapor pressure, σ-standard deviation.

4. Conclusion

The classification of AD intensity is complicated enough task. Therefore, there is a certain share of subjectivity in the classification we have proposed. New research methodological approaches have been used in the research. First, a new parameter: thermohygrometric factor of air dryness has been used as quantitative characteristics of AD.

Second, the classification of AD is based on a new scientific direction-ecological qualimetry.

Based on the listed approaches the following results have been obtained. First, a new classification the quantitatively expressing the AD intensity has been substantiated. Second, the necessary and sufficient conditions for AD of various intensity to set in based on strong and significant relation between the air temperature and water vapour pressure have been formulated. The obtained results may be used in the studies of AD in other regions of the world.

Table 1 Calculation of significance level of relations between the air temperature and water vapor pressure for various physical geographical areas of Uzbekistan.

Station	Drought classification	Regression equation	R	$\Delta y = y_2 - y_1$	σ	D
Karakalpakistan	Strong	$y = 0.001x^3 - 0.191x^2 + 6.796x - 77.84$	0.92	9	1.61	5.5
Urgench		$y = 0.000x^3 - 0.067x^2 + 2.747x - 34.46$	0.92	7	1.52	4.5
Tamdy		$y = 0.000x^3 - 0.062x^2 + 2.171x - 22.90$	0.93	11.4	1.93	5.9
Jangeldi		$y = 7E\text{-}05x^3 + 0.000x^2 + 0.138x - 2.378$	0.93	9.4	1.91	4.9
Akbaytal		$y = -0.000x^3 + 0.041x^2 - 1.433x + 18.18$	0.92	9.5	1.77	5.3
Termez		$y = 0.001x^3 - 0.191x^2 + 7.405x - 93.34$	0.88	8.3	1.65	5.0
Karakalpakistan	Moderate	$y = 0.001x^3 - 0.124x^2 + 4.053x - 41.10$	0.91	10	2.22	4.4
Urgench		$y = -0.003x^3 + 0.387x^2 - 13.50x + 158.7$	0.90	8	1.71	4.5
Tamdy		$y = 0.000x^3 - 0.027x^2 + 1.179x - 13.48$	0.98	11.6	2.23	5.1
Jangeldi		$y = -0.000x^3 + 0.051x^2 - 1.747x + 21.57$	0.94	12.4	2.17	5.7
Akbaytal		$y = 0.000x^3 - 0.024x^2 + 0.983x - 10.23$	0.96	9.1	2.02	4.4
Termez		$y = 0.000x^3 - 0.079x^2 + 3.034x - 36.28$	0.98	8.6	1.78	4.8
Karakalpakistan	Weak	$y = 0.000x^3 - 0.030x^2 + 1.251x - 12.30$	0.97	15.5	1.69	5.8
Urgench		$y = -0.000x^3 + 0.041x^2 - 1.591x + 23.81$	0.99	12	2.60	4.6
Tamdy		$y = 0.000x^3 - 0.046x^2 + 1.719x - 17.33$	0.98	15.6	2.92	5.3
Jangeldi		$y = -0.000x^3 + 0.056x^2 - 1.882x + 24.68$	0.99	12.6	2.87	4.3
Akbaytal		$y = 0.000x^3 - 0.035x^2 + 1.397x - 14.41$	0.98	12	2.66	4.5
Termez		$y = 0.001x^3 - 0.167x^2 + 6.136x - 69.89$	0.99	11.4	2.51	4.5

R-correlation coefficient, Δy-difference between maximum and minimum values of the water vapor pressure, σ-standard deviation, D-significance coefficient.

Acknowledgments

We thank very much the staff of Department of Monitoring of Agroclimatic Resoursec and Agroecology, the Center of Hydtometeorological Service, the Republic of Uzbekistan, in the person of A.K. Abdullaev for the valuable proposals and comments offered in the discussion of the paper. We will be grateful for all the experts who will read our paper.

References

[1] Apocalyptic forecast for world wide drought, [online], http://www.meteovesti.ru/news.n2?item=63423339524. (in Russian)

[2] L.N. Karlin, A.V. Dikinis, V.B. Sapunov, Criteria of ecological burden, Bulletin of RGGMU 15 (2010) 177-180. (in Russian)

[3] Dictionary of environmental terms and definitions, [Online], http://www.ecosystema.ru/07referats/slovar/10k.php. (in Russian)

[4] I.N. Rusin, Natural disasters and possibilities for their forecast, RGGMU Publishers, Saint-Petersburg, Russia, 2003, p. 140. (in Russian)

[5] D.A. Ped, On index of drought and excessive moisturiztion, Annals of Hydrometeorological Center 156 (1975) 35-125. (in Russian)

[6] M.B. Barabash, Z.L. Desiankova, On refinement of the drought criterion for Ukraine, Annals of UkrNIGMI 174 (1979) 17-21. (in Russian)

[7] L.N. Babushkin, On climatic characteristics of air drought and hot winds in cotton zone of Uzbekistan, Hot winds, their forecast and response, Tashkent, Uzbekistan, 1974, pp. 59-64. (in Russian)

[8] Yu.V. Petrov, A.K. Abdullaev, On estimation of the air dryness, Meteorology and Hydrology 10 (2010) 90-96. (in Russian)

[9] Yu.V. Petrov, A.K. Abdullaev, On utilization of new parameter for estimation of air dryness for addressing agrometeorological tasks, Annals of NIGMI 7 (252) (2006) 79-87. (in Russian)

[10] Yu.V. Petrov, S.I. Nikolaeva, A.K. Abdullaev, Desertification Process Monitoring Based on New Meteorological Parameter, World Academy of Science, Engineering and Technology, Dubai, UAE, January, 2011, pp. 1364-1365.

[11] A.I. Subetto, Noospherism, V. 1. Asterion, Saint-Peterspurg, Russia, 2001, p. 538. (in Russian)

[12] V.O. Usmanov, S.N. Nikulina, Impact of climate change on agrometeorological resources and condition of crops, in: NIGMI, 1998, pp. 119-127. (in Russian)

[13] Kh.M. Abdullaev, Sh.D. Fayziev, Estimation of hight temperature impact on development and productivity of vegetables and gourds, Annals of SANIGMI 152 (233) (1998) 74-81. (in Russian)

[14] S.R. Grupper, Evaluation of climate change impact on agrometeorological resources and productivity of winter wheat in Uzbekistan Annals of SANIGMI 160 (241) (1998) 103-120. (in Russian)

[15] Progress report to CCI on statistical WMO, TD 834 (1997) 115.