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ON INTENSITY AND RECURRENCE OF DROUGHTS IN THE FOREST-STEPPE AND STEPPE ZONES

Abstract: Presented are the general estimates of the crop water supply which are determined by the value of the ratio ET/ETO, where ET is the actual transpiration, and ETO is the potential transpiration. The evapotranspiration model with standard meteorological data and leaf area index are used to obtain the crop water supply. The crop water supply was analyzed for large scale spatial trends over many years for the spring wheat fields represented by 45 agrometeorological stations in the forest-steppe and steppe zones of the former Soviet Union. For 6 agrometeorological stations the crop water supply for individual years within a period over 20 years was examined. The calculation showed that the droughts are uniformly distributed in the forest-steppe and steppe zones of the former Soviet Union and differ only in intensity for different areas of the zones in question.

Key words: agriculture, crop water supply, evapotranspiration, drought, yield.

1. Method

The foundation of the present approach to estimate intensity and recurrence of droughts is the calculation of the quantitative consumption of water by agroecosystems during their growth and development. The real regularities of the formation of the soil-hydrology conditions with their from year to year variability are considered, too. The crop water supply (Budagovsky, Shumova 1976) is determined by the value of the ratio of actual transpiration to potential transpiration (transpiration corresponding to the optimal soil water storage)

$$WSP=ET/ETO \qquad (1)$$

were:

WSP - water supply parameter,

ET - actual transpiration,
ETO - potential (optimal) transpiration.

The crop water supply parameter *WSP* shows to what extent soil water provides the development of the vegetation cover. If the parameter *WSP* is equal to 1, it indicates, that plants are well provided with water. If the parameter *WSP* is below 1, it indicates that the drought takes place.

The water supply deficit in absolute values is transpiration deficit and can be determined as the difference between optimal and actual transpiration

$$dET = ETO - ET \quad (2)$$

where:
dET - transpiration deficit.

The evapotranspiration model (Budagovsky 1964) with standard observational data of agrometeorological stations (air temperature, air humidity deficit, net radiation, wind speed, precipitation, initial soil water storage) and leaf area index (Shumova 1994) are used for actual and potential transpiration calculations.

2. Results and Discussion

Average many years values of *ET* and *ETO*, with ten-day time step for 45 agrometeorological stations of the forest-steppe and steppe zones (and partially outside their ranges) of the European territory of the former Soviet Union for the spring wheat crops have been obtained (Fig. 1). Among these, for 6 agrometeorological stations which reflected best the variety of natural conditions of the forest-steppe and steppe zones, *ET* and *ETO* values were determined for individual years within a period of over 20 years. These data have been used for obtaining the water supply parameter *WSP*.

The spring wheat water supply parameter *WSP* varies from 0.8 to 0.3 (Fig. 2). These values indicate a rather low natural spring wheat water supply in the forest-steppe and steppe zones. The droughts are uniformly distributed in the forest-steppe and steppe zones and differ only in intensity for different areas of the zones in question. Figure 3 presents probability curves of the crop water supply parameter. From Figure 3 we can see that spring wheat water supply parameter *WSP* reached 1 in 5 of 24 years even for the more favourable conditions of Mironovka, in 3 of 22 for Kamennaya Step, and in 1 of 24 for Gigant. The spring wheat water supply parameter never reached 1 for Bezenchuk, Ershov and Odessa. In other words in Bezenchuk, Ershov and Odessa every year the drought took place. Occasionally droughts have catastrophic character. The average squared deviation of the spring wheat water supply parameter varies from 0.15 to 0.20 The variation coefficient changes within a range of 0.20 to 0.38.

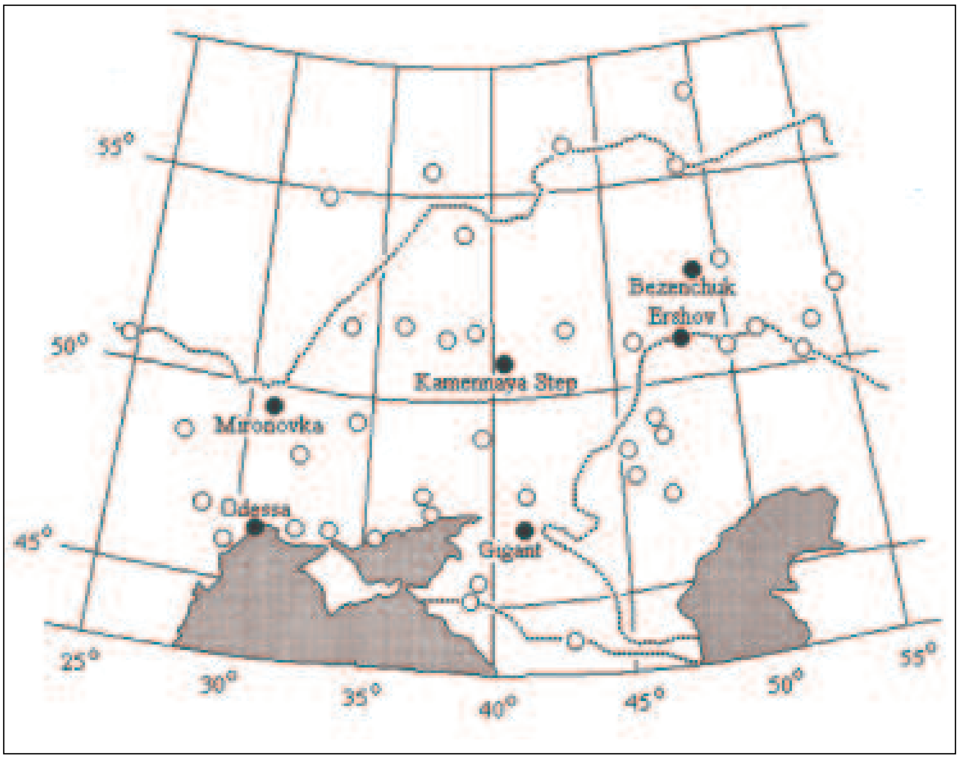

Fig. 1. Locations of the agrometeorological stations (o - average data, * - analyses for individual years). Dotted lines indicate the boundaries of the forest-steppe and steppe zones.

Figure 4 shows relationship between spring wheat water supply parameter *WSP* and transpiration deficit *dET*. Using this relationship we can estimate the intensity of drought in absolute values, too.

Figure 5 presents relationship between spring wheat water supply parameter *WSP* and grain yield obtained by Meshchaninova (1971) and Kirilicheva (1967) equations. The basis for Meshchaninova empirical relationship is growing season evapotranspiration. The foundation of Kirilicheva empirical relationship is a ratio of growing season evapotranspiration to potential evapotranspiration. The lesser scatter of the Kirilicheva equation data (empty circles) can be due to taking into account all the meteorological conditions. From Figure 5 it follows that to provide minimum spring wheat grain yield for territory under investigation water supply must be no less than 0.2. In particular, a catastrophic droughts (when spring wheat water supply parameter *WSP* less than 0.2) takes place only in Ershov in 2 of 24 years. Under optimal natural water supply conditions (when *WSP*=1) spring wheat grain yield equals

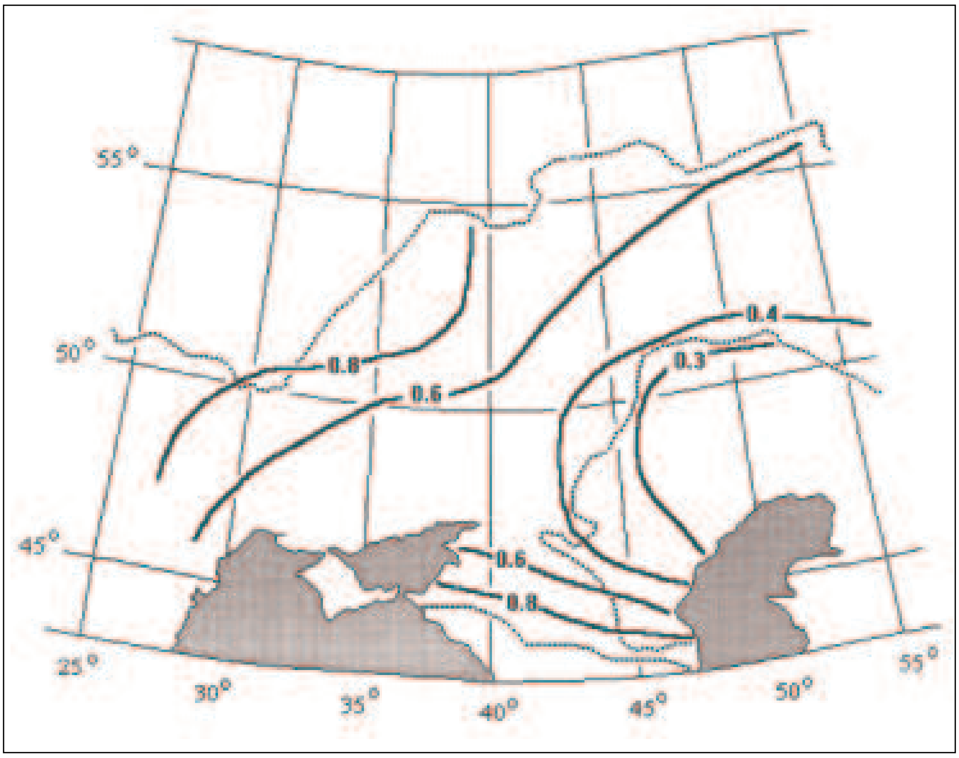

Fig. 2. The distribution of water supply parameter *WSP* for spring wheat.

to 25 metric centner/hectare. The use of the empirical relation between spring wheat water supply parameter and grain yield, which for arid regions has a practically acceptable accuracy, is possible to estimate grain yield for different values of the spring wheat water supply parameter.

3. Conclusion

The paper presents the results of the crop water supply evaluation under current climate conditions. Such approach will be available for assessment of the effectiveness of the human activity (different "dry agriculture" technique such as soil mulching, fallow, spring runoff using) in an effort to reduce the intensity and recurrence of droughts. Also the climate change impact on the crop water supply can be estimated using the climate change scenarios.

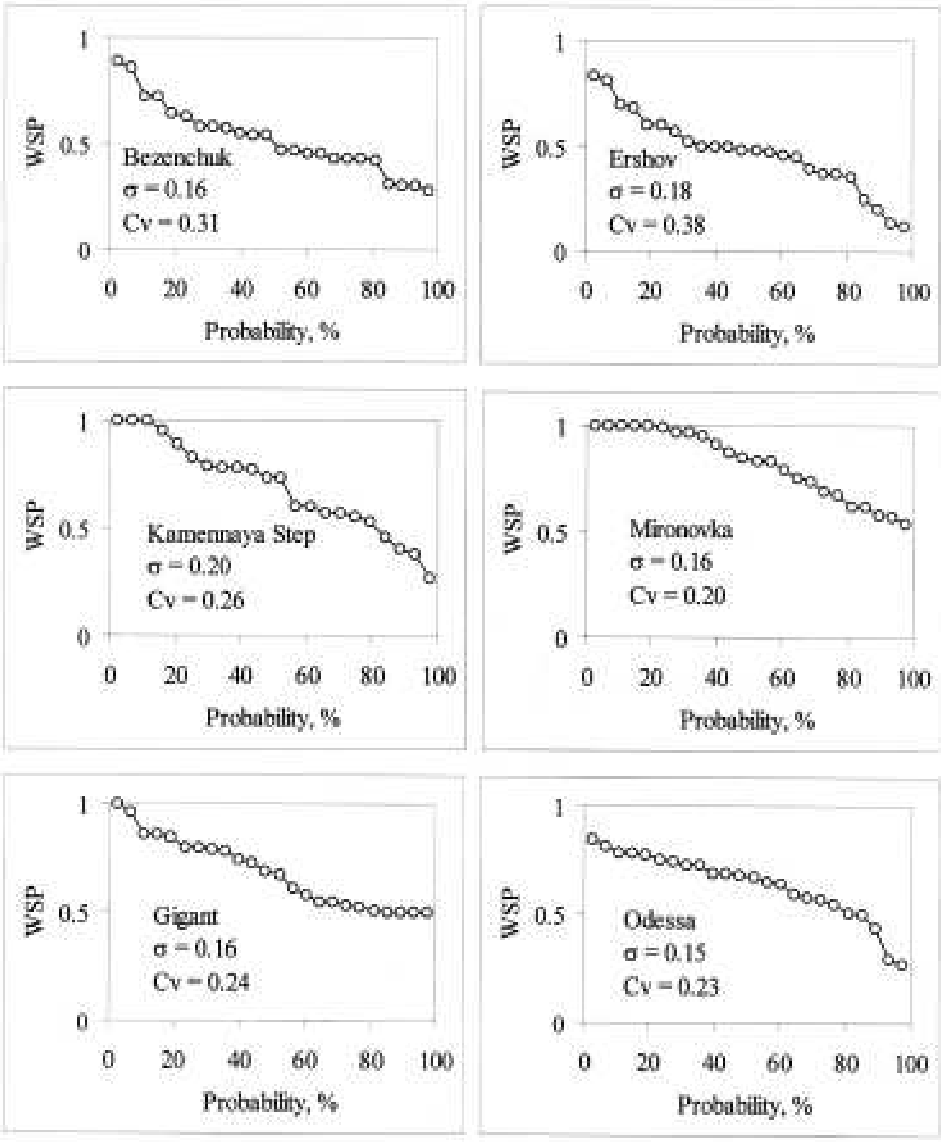

Fig. 3. Probability curves of the water supply parameter *WSP* for spring wheat. Cv - variation coefficient; σ - average squared deviation.

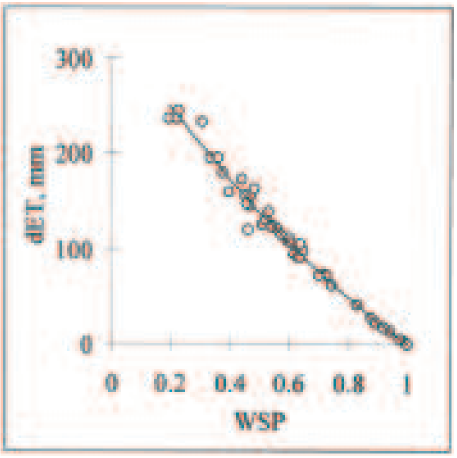

Fig. 4. Relationship between the spring wheat water supply parameter *WSP* and transpiration deficit *dET*.

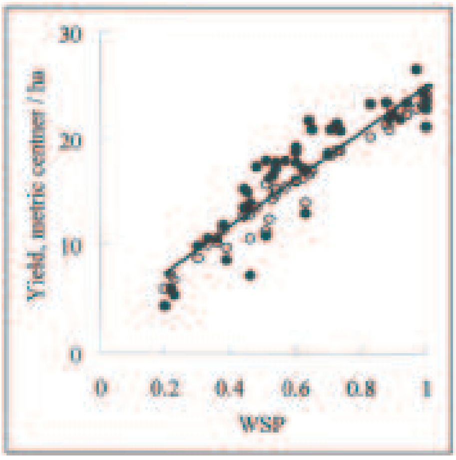

Fig. 5. Dependence of the spring wheat grain yield on the water supply parameter *WSP* (* - yield estimation by Meshchaninova equation, o - yield estimation by Kirilicheva equation).

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