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НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

Монография в 5 томах

Том IV Оптимизация сельскохозяйственных ландшафтов

В содружестве с Академией почвенного плодородия Митчерлиха (МИТАК), Паулиненауэ, Германия

Москва 2018
NOVEL METHODS AND RESULTS OF LANDSCAPE RESEARCH IN EUROPE, CENTRAL ASIA AND SIBERIA

Monograph in 5 Volumes

Vol. IV Optimising Agricultural Landscapes

With friendly support of the Mitscherlich Academy for Soil Fertility (MITAK), Paulinenaue, Germany

Moscow 2018

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ISBN 978-5-9238-0246-7
ISBN 978-5-9238-0250-4 (Том 4)
DOI 10.25680/1479.2018.72.58.004

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Main Chapter 14.2 Water Demand and Irrigation Technologies

Chapter IV/74: ZUWABE: A MODEL FOR ESTIMATION OF SPATIAL IRRIGATION WATER DEMAND FOR AGRICULTURAL CROPS

Глава IV/74: ZUWABE: Модель для оценки региональных потребностей в воде для орошения сельскохозяйственных культур

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DOI 10.25680/1712.2018.54.77.339

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ABSTRACT. ZUWABE developed in the Leibnitz-Centre for Agricultural Landscape research (ZALF) Müncheberg, Germany and described here in a short manner is a model for spatial estimation of yearly irrigation water demand. The model is parametrized for different agricultural crops and different soil types and sites. It can be used for spatial simulation runs under past, present and future climate conditions. The model supports farmers and advisory agencies to plan new technique and scheduling systems for irrigation and gives administrative bodies the background for strategic planning of regional water balance. For the Federal State of Brandenburg, Germany results for 11 agricultural crops are presented for 1975-2075. Applications for three regions within Germany as well as for the whole Federal State of Thuringia are shown.

KEYWORDS: irrigation water demand, model, climate change, advisory system, model application

INTRODUCTION

The actual process of climate change is an ongoing process with increasing temperatures during summer and especially during winter. The average yearly precipitation amounts will decrease slowly, but the distribution of precipitation during the year will change dramatically with decreasing precipitation amounts during the main growing season of crops, i.e. during the spring and summer months. Such conditions are connected with an increase of the potential evapotranspiration rates and the climatic water balance deficit will increase. Coupled with poor soil conditions all this focuses into future problems for an effective plant production at arable land. In future the cropping risk under rain-fed conditions will increase, especially for spring crops, and the crop yields and the yield stability will decrease.

The most effective adaptation measure of agriculture to climate change is the irrigation. Three water sources are available for irrigation: ground water, surface water from rivers and lakes and cleaned waste water from settlements and from the industry. But the usage of irrigation in agriculture must be in accordance with the regional water availability and the landscape water balance. For development of
climate adaptation strategies in agriculture and for future-oriented investigations in irrigation technique and irrigation scheduling technologies and systems on regional scale better information about long-term demands in irrigation water for agricultural crops are necessary. Only a well validated model for irrigation water demand in agriculture which take into account the necessary crop, soil and climate values, gives the possibility for assessing the impact of climate change on irrigation water demand. Therefore models with an intermediate complexity are favoured which are robust and solid, and which have realistic input data demands in space and time. For this purpose the model ZUWABE (ZUsatzWAsserBEdarf – irrigation water demand) - a model for regional assessment of irrigation water demand at arable land - was developed by the Leibniz-Centre for Agricultural Landscape Research Müncheberg, Germany.

AIM OF THE METHOD
The model ZUWABE based on expert-knowledge and statistics was developed to close the methodical gab in the field of assessing the site-specific irrigation water demand of agricultural crops under present and future climate change conditions for farmers using irrigation, for planners in the field of regional water management, for developers of irrigation technique, irrigation technologies and irrigation scheduling systems as well as for administration stakeholders. The ZUWABE model also serves as a basis for determining optimal irrigation techniques and systems for future irrigation-based cropping systems, either by repairing or optimizing existing irrigation systems, or by installing new irrigation systems.

PRINCIPLE AND PROCEDURE
The ZUWABE model basis on crop- and site-specific long-term averaged irrigation water benchmarks [1, 2, 3] for East German cropping conditions. These benchmarks depend on crop-specific irrigation periods (for East German cropping conditions given in [1]), rooting depth, plant-available soil water via soil types, and the crop-specific long-term precipitation averages (period 1961-1990) for the corresponding crop-specific irrigation periods. Concerning the plant available soil water capacity in the rooting zone the soil types are grouped into four classes (low, medium, high, very high). The loess soils are grouped into the class “very high” and the poor sandy soils are grouped into the class “low”, for instance. Table 1 shows an example for the crop- and site-specific irrigation water benchmarks according to Roth [2] as a long-term average (1961-1990) valid for cropping conditions in the East German lowlands.

Table 1: Long-term averaged crop- and soil-specific irrigation water benchmarks (IWB_{CR,ST}; mm) for selected agricultural crops

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Soil water capacity class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>80</td>
</tr>
<tr>
<td>Potatoes</td>
<td>100</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>110</td>
</tr>
<tr>
<td>Winter rape</td>
<td>25</td>
</tr>
<tr>
<td>Spring barley</td>
<td>65</td>
</tr>
<tr>
<td>Silage maize</td>
<td>100</td>
</tr>
<tr>
<td>Winter barley</td>
<td>50</td>
</tr>
<tr>
<td>Triticale</td>
<td>80</td>
</tr>
</tbody>
</table>

The irrigation water benchmarks were designed to guarantee high crop yields associated with high water use efficiency, without any water percolation and nutrient leaching.

The benchmarks from Table 1 are corrected (1) by a factor which takes into account the precipitation differences between the specific site for which the irrigation demand is calculated and the East German lowlands, (2) by the changing amount of climatic water balance between the period 1961-1990 and the actual 30-year period for the concrete simulation period, and (3) by decreasing of transpiration by crop stands in the result of atmospheric CO$_2$-increase.

Bringing together all this, the averaged crop- and site-specific irrigation water demand is given as follows:

$$IWD_{CR,ST} = IWB_{CR,ST} \frac{Pr_{IP,LL}}{Pr_{IP,SS}} - \Delta CWB - (CO_2 - 380) \cdot F_{CO_2}$$

$$\Delta CWB = CWB_{30,SP} - CWB_{1961-1990}$$
where \( \text{IWD}_{\text{CR,ST}} \) represents the crop- and site-specific yearly irrigation water demand [mm]; \( \text{CR} \) is the agricultural crop type; \( \text{ST} \) is the site type; \( \text{IP} \) is the crop-specific irrigation period [1, 2, 3]; \( \text{IWB}_{\text{CR,ST}} \) is the crop- and site-specific irrigation water benchmark [mm] according to Roth [2]; \( \text{Pr}_{\text{IP,LL}} \) is precipitation average (1961-1990) for the East German lowlands calculated for IP [mm]; \( \text{Pr}_{\text{IP,SS}} \) is precipitation average (1961-1990) for the particular site calculated for IP [mm]; \( \text{CWB}_{1961-1990} \) is the 30-year average of climatic water balance for 1961-1990 [mm]; \( \text{CWB}_{30ySP} \) is the 30-year average of climatic water balance for concrete simulation period [mm]; \( \text{CO}_2 \) is the actual atmospheric \( \text{CO}_2 \)-content [ppm]; and \( \text{F}_{\text{CO}_2} \) is the factor for \( \text{CO}_2 \)-induced reduction of transpiration [mm]. The climatic water balance is the difference between precipitation and potential evapotranspiration which is calculated using the TURC-WENDLING approach [4]. The ZUWABE model is parameterized for the whole eastern part of Germany. A more detailed description of the method is given in [6] and [7].

RESULTS

Because water is the most limiting factor for agriculture in the Federal State of Brandenburg, Germany, some results for Brandenburg are presented here. For 11 different agricultural crops the calculated irrigation water demands as average for whole Brandenburg, i.e. over all arable land are presented in figure 1 for the time period 1975-2075. The presented irrigation water demand values are the result of a 30-year average for each case assuming the SRES-IPCC emission scenario A1B and using the climate downscaling method WETTREG 2010 [5].

In figure 2 for the time period 1975-2075 the spatial distribution of irrigation water demand for the arable land within Brandenburg is shown for winter wheat, potatoes, sugar beets and silage maize. In a spatial case study for Brandenburg with different land use scenarios a cropping scenario with irrigation to stabilize and increase yields was taken into account. Among other landscape indicators also the irrigation water demand was calculated. The results show that the spring crops (maize, sugar beet) need much more irrigation water than the winter crops (winter wheat, winter barley, winter oilseed rape). The between-district variation in irrigation water demand was related to the precipitation pattern within Brandenburg and to the soil quality-related yield potential. In any case, crop yield increases caused by irrigation were positively correlated with irrigation water demand [8]. The distribution of spatial irrigation water demand in Brandenburg calculated by the ZUWABE model is in accordance with the results taken from [9].
APPLICATION

The ZUWABE model algorithm was incorporated into the statistical-based yield estimation model YIELDSTAT for agricultural crops [10] as prerequisite for the calculation of additional yields due to irrigation. The model ZUWABE is one of the models which can be activated within the decision support system LandCaRe-DSS for projections of climate change impacts on crop production and agro-ecosystems [11]. This system can be used for finding economic and ecological suitable adaptation strategies for agricultural cropping systems to climate change. Within LandCaRe-DSS the model for calculation of irrigation water demand was practical used for three German regions, the Uckermark region (ca. 2600 km\(^2\)) located in the Federal State of Brandenburg, the Weisseritz (ca. 400 km\(^2\)) and the Dresden regions (ca. 4500 km\(^2\)) both located in the Free State of Saxony, Germany.

Additional ZUWABE has been used in practical climate scenario studies for assessing the impact of climate change on agricultural productivity and irrigation water demand up to 2050 for two Federal states of Germany: Saxony [12] and Thuringia [13].

For increasing the accuracy in estimating the irrigation water demand a further improvement of the model is necessary. For taking into account the influence of the hysteresis phenomena on irrigation water demand and irrigation rates it is planned to incorporate the approach according to Terleev et al. [14, 15, 16]. For adaptation of the method described above to other regions it is necessary to adapt the model parameters, the irrigation periods and the soil classification.

CONCLUSIONS

The ZUWABE model
1. offers to estimate the regional water demand for irrigation taking into account different agricultural crops and different soil types,
2. gives the possibility to consider different regionalized climate scenarios,
3. supports farmers and advisory agencies to plan new technique and scheduling systems for irrigation,
4. gives administrative bodies the background for strategic planning of regional water balance and
5. has potential for application and adaption to other regions, also in Russia and Central Asia.
REFERENCES