APPLICATION OF CROP WATER PRODUCTIVITY MODELS FOR BETTER UTILIZATION OF WATER RESOURCES IN UZBEKISTAN

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Abstract

In a number of world regions, agriculture consumes a large part of the available water for irrigating crops. Therefore, there is a need to estimate and model crop water requirements and irrigation amounts in order not only to improve water management but also to study scenarios and provide basis for discussion with the stakeholders. This paper focuses on the arid ecosystems located in the southern part of Uzbekistan. With the help of the soil water balance model BUDGET, an assessment was made of the region's potential productivity for different kind of rainfall regimes. BUDGET is a robust simulation tool, and only requires a minimum of input data, which is readily available or can easily be collected. A local meteorological station in Tim delivered most of the required climatic data, while most of the crop and soil related parameters were found in literature or were estimated by common sense. Once a renewed dataset is available, the BUDGET model can be calibrated and validated, and more specific results on the biomass production in the region can be expected.

1. Introduction

Most of Uzbekistan lies between the two largest rivers in Central Asia, the Amu Darya and Syr Darya (Figure 1). These two roughly parallel rivers both have their headwaters in the mountains east of Uzbekistan, and follow northwesterly courses toward the Aral Sea, a saltwater lake straddling the border between Uzbekistan and Kazakhstan. Since the early 1960s, the Aral Sea has shrunk to less than half its former size, and dry land has separated the remaining bodies of water into two main lakes. Uzbekistan's largest river is the Amu Darya. This river is formed by the confluence of the Panj and Vakhsh rivers on the extreme southwestern border of Tajikistan, near the southeastern tip of Uzbekistan. The Amu Darya traverses a course generally parallel to, and at times, part of Uzbekistan's southern borders with Afghanistan and Turkmenistan, and then heads due north through

Uzbekistan's Karakalpak Autonomous Republic toward the southern section of the Aral Sea. The Syr Darya is formed in the fertile Fergana (Farghona) Valley by the convergence of two rivers flowing from the east, the Naryn and Koradaryo. The Syr Darya then flows westward through this valley and northern Tajikistan, turns north to cut through Uzbekistan, and enters Kazakhstan, eventually reaching the northern section of the Aral Sea.

Figure 1: Map of Uzbekistan (source: GRID-Arendal, 1998).

Another important river is the Zaravshon, which flows westward from the mountains of Tajikistan through east-central Uzbekistan. Before it began to be tapped for irrigation, the Zaravshon was the Amu Darya's largest tributary; but now it evaporates in the Kyzylkum desert near the city of Bukhara (Bukhoro). Uzbekistan has thousands of small streams that expire in the desert, many having been emptied by irrigation.

Extensive canal systems, such as the Amu-Bukhara canal and many others built during the Soviet period, have greatly altered water-flow patterns. Artificial lakes and reservoirs have been created, many of which are fed by irrigation runoff. The largest freshwater lake is Aydarkul, in northeastern Uzbekistan.

2. Main drivers of climate and environmental changes in the region

The world as well as a region of Central Asia is changing rapidly. There are several basic drivers of climate and environmental change such as population and economic growth, urbanization, human investment patterns, family structure and education, social stability, land use/land cover change etc.

Population growth is the main problem of environmental change. By the end of XIX, there were some 7-8 million people in the region. Irrigated land amounted to about 3.4 million hectares and was equipped by an irrigated network. To-date, the regional population has increased by 7 times, and irrigated areas have broadened twice up to 7.5-7.7 million hectares.

Population growth is also one of the main reasons of reducing sources of existence in the region. Annual population growth in Kyrgyzstan is 1.5%, in Tajikistan-2.5%, in Turkmenistan-2.4%, in Uzbekistan-2.3%. Although slowing, population growth is still rising and the highest rates are in those countries, which are least able to sustain them.

The Aral, once the world's fourth biggest inland sea, declined from a volume of about 1,000 km3 40 years ago to 110 today. The water level fell within that time from 53 meters to 28. The annual inflow in 1960 was 63-65 km^3, but now it is about 1.5. Yet 10 km^3 are needed just to keep the sea as it was, let alone to reverse its plight. The mineral content of the water is now up to seven times higher than 40 years ago, with pesticides and fertilizers combining with salt to produce "a sort of salty paste". The shoreline receded by up to 250 km, leaving toxic dry deposits. In this way, it needs to develop a agro technologies which utilize efficiently very scarce water resources available in the region. Uzbekistan has largest irrigation network in the region of Central Asia and needs more water for irrigation during summer time. Application of water saving irrigation such as sprinkling, drop irrigation, sub irrigation are promising technologies of efficient water use. Crop productivity models, as a tool for better decision making in choosing efficient crops is another option for productive and sustainable agriculture.

3. Description of BUDGET water productivity model

BUDGET is composed of a set of validated subroutines describing the various processes involved in water extraction by plant roots and water movement in the soil profile in the absence of a water table. During periods of crop water stress the resulting yield depression is estimated by means of yield response factors. By selecting appropriate time and depth criteria irrigation schedules can be generated. Climatic data, crop parameters, and soil parameters are needed as input, while initial soil water and salt conditions and irrigation data are optional.

The climatic data consists of daily, mean 10-day or monthly ETo (reference crop evapotranspiration) and rainfall observations. At run time, the 10-day and monthly data are processed to derive daily ETo and rain data. By selecting the appropriate class of crop type (annual or perennial), class of rooting depth (from shallow to very deep rooted crops), class of sensitivity to water stress (from sensitive to tolerant), and class of degree of ground cover at maximum crop canopy, and by specifying the total length of growing period, the program generates a complete set of parameters that can be displayed and adjusted if additional information is available. The soil profile may be composed of several soil layers, each with their specific characteristics. BUDGET contains a complete set of default characteristics that can be selected and adjusted for various types of soil layers.

Several validated subroutines are used in BUDGET. For example, the estimation of the amount of rainfall lost by surface runoff is based on the curve number method developed by several researchers (Rallison, 1980; Steenhuis et al., 1995; Vogeler, et al., 2000). With the help of the dual crop coefficient procedure (Allen et al., 1998) the soil evaporation rate and crop transpiration rate of a well-watered soil is calculated. For a given water stress during a specific growth stage, the resulting yield depression is estimated by means of the yield response factor Ky (Doorenbos and Kassam, 1979). And since it is highly unlikely that rainfall is homogenously distributed over all days of the 10-day period or the month, rainfall data is further processed by means of the USDA-SCS procedure (1993) to determine the part of rainfall that is stored in the top soil as effective rainfall.

With the described input and for the given initial conditions, BUDGET simulates the solute transport and water uptake in the specified climate/crop/soil environment (Raes, 2002). During the simulation, BUDGET records continuously the daily soil water and salt content in the soil profile, soil water fluxes, daily values of the various parameters of the soil water and salt balances, the daily root zone depletion and net irrigation requirement. The daily records are stored in various output files, which contents can be displayed at the end of the simulation run and saved for further analysis.

4. Practical application of BUDGET

By calculating the water and salt content in a soil profile as affected by input and withdrawal of water and salt during the simulation period, the program is suitable:

- to asses crop water stress under different environmental conditions;

- to estimate yield response to water;
- to design irrigation schedules;
- to study the building of salt in the root zone under averse irrigation conditions;
- to evaluate irrigation strategies.

This opens a lot of possibilities in case of for example croplands management. As salinization is an important problem nowadays, this phenomenon could be avoided by using a model like BUDGET. In a first step, the preferable plant species in the area of study must be identified.

In a second step, climatic data and crop/soil parameters must be assessed. Climatic data (e.g. reference evapotranspiration and rainfall) can be obtained from meteorological stations in the neighborhood of the study area or calculated from special programmes developed by different organizations (Environment and Natural Resources Service, 2005; Campbell Scientific, Inc., 1998). One can do frequency analysis on existing datasets, which must be as large as possible, in order to calculate for example average meteorological conditions for a certain period of time (decade or month). Crop parameters (e.g. rooting depth and sensitivity to water stress) can be found in literature or can be obtained by local field experiments. Soil parameters (e.g. texture and number of layers) can be derived from soil maps or by sampling the soil locally.

In a third step, all this data is put together in BUDGET, and yield can be estimated under given circumstances. When more simulations are done, each time with other climatologic conditions as input (for example one can use 10% dependable rainfall/ETo in a first simulation, 90% dependable rainfall/ETo in a second simulation, and 50% dependable rainfall/ETo in a third simulation), it becomes feasible to predict yield in a wet, dry and average year.

BUDGET can also be used as a tool to evaluate bad growing conditions. Water stress and salt distribution in the soil can be found as a reason for low yield, and farmers can decide to move away or to adapt management. In case of irrigated croplands, the model can be applied to evaluate irrigation practices. Water can be saved, which is an important issue in dry areas, where most rangeland exists. So one can conclude that BUDGET is a multifunctional model that can be used for any crop species with only few parameters must be assessed.

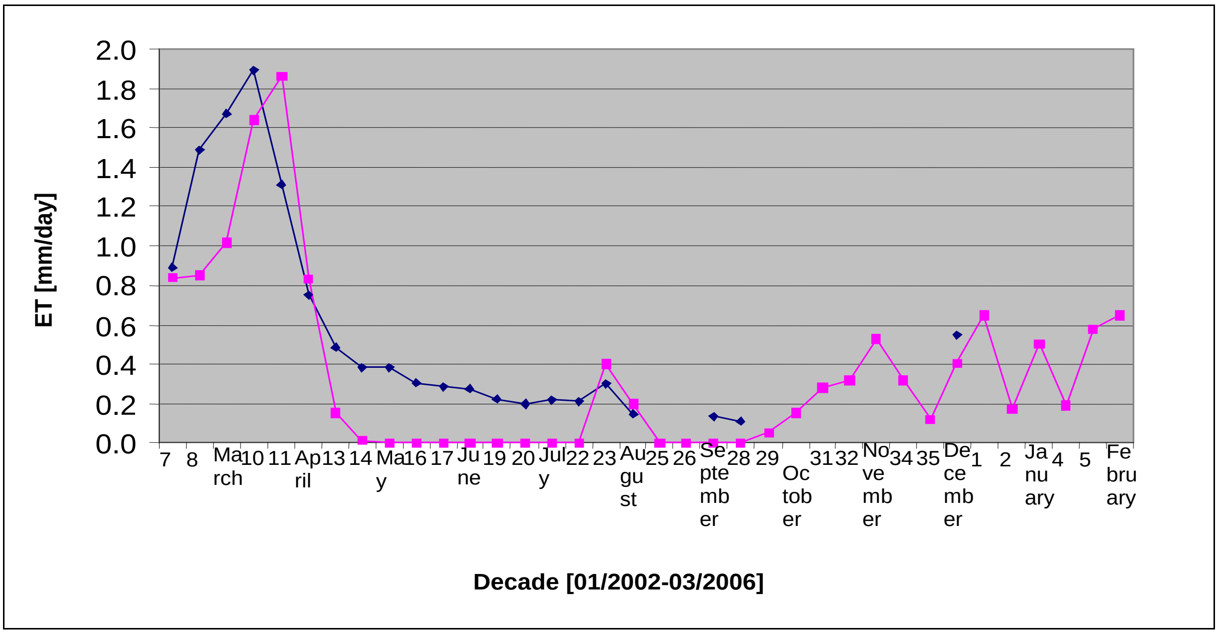

Figure 2: Comparison of simulated ET (line with squares) and measured ET (line with diamonds) after the calibration of BUDGET with 2002-2006 data. Both simulated and measured curves fit reasonable well, so far as ET measurements are available to compare with.

5. Conclusions

The BUDGET model is the right tool for simulations in various environments as the croplands of Uzbekistan, due to its robustness and its limited requirement of input data. Indicative values of the various input parameters are sufficient, as long as they stay within the right range.

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