Modelling of grassland yields in consideration of drought

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Abstract

Grassland with its different characteristics covers an area of 1.61 million hectares, which represents more than 50 % of the Austrian agriculturally used area. Grassland is managed by 115,000 grassland and cattle farmers, mostly running small structured enterprises. Over the past years, the global climate change has affected parts of Austria by the occurrence of intensive drought periods, which caused heavy drought damages on agricultural areas. Grassland yield, which is influenced by many factors, can be estimated by different models, mapping certain natural processes in a simplified way. The prerequisite for a state-wide analysis of grassland yield is the integration of these models into a Geographic Information System (GIS). The soil water balance is the basis for the simulation of growing processes. The precipitation is compared with the potential evapo-transpiration and the soil water balance model is developed according to the FAO method, considering the field capacity. The growth and yield model is based on the data of the soil water balance and results in a multiple regression in order to calculate the quantity of grassland yield. The results of this work will be the fundamentals of an insurance model for drought damages on grassland and will therefore help to protect the existence of grassland and cattle farmers in drought endangered regions.

Keywords: drought, GIS, grassland, water balance, yield.

Introduction

Grassland yield, which is influenced by many factors, can be estimated by different models, mapping certain natural processes in a simplified way. The prerequisite for a state-wide analysis of grassland yield is the integration of these models into a Geographic Information System (GIS), since the model parameters have a well-defined spatial reference.

Grasslands of different types cover an area of 1.61 million hectares, which is more than 50 % of the Austrian agricultural land. They are managed by 115,000 grassland and cattle farmers, mostly running small to medium size enterprises that depend on the stability of the fodder production. (BMLFUW, 2004).

Over the past years, the global climate change has affected parts of Austria by the occurrence of intensive drought periods, which caused heavy drought damages on agricultural areas, especially in the Northeast, East and Southeast of Austria (Figure 1). In the year 2003, the drought damages on grassland amounted to about 300 million Euros. An appropriate insurance against drought damages on grassland is not yet available, because qualified, scientifically based models do not exist so far.

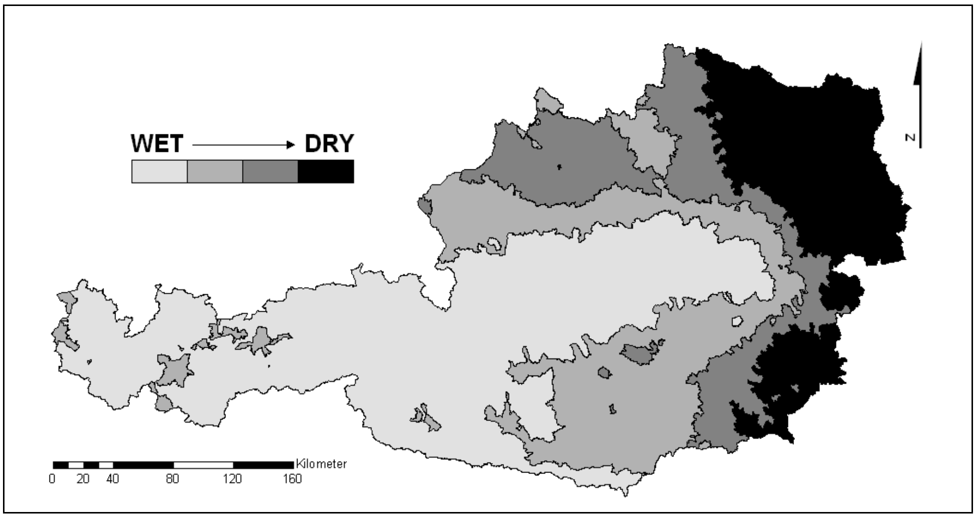

Figure 1. Spatial distribution of droughty endangered areas in Austria.

The Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management (BMLFUW) reacted on that situation and charged the Federal Research and Education Centre for Agriculture Raumberg-Gumpenstein (HBLFA) with the development of a model aiming at the determination of drought damages on grassland. The Institute of Meteorology at the University of Natural Resources and Applied Life Sciences in Vienna (BOKU) developed a growth and yield model and provides the necessary model equations, whose coefficients are being harmonized with the results of grassland field trials (Trnka *et al.*, 2005). The results of this work will be the fundamentals of an insurance model for drought damages on grassland.

Materials and methods

In the year 2002, an integrated project has been started with the installation of exact grassland field trials with randomised blocks and triplicate replication on 27 different sites throughout Austria. On every field trial site there are three different types of fertilization and standardised utilisation. The data from these grassland trials, particularly yield and forage quality, are the main basis for growth and yield modelling. 80 % of the yield data were used randomised to calibrate the model and the rest for validation.

The soil water balance is the basis for the simulation of growing processes. The precipitation is compared with the potential evapo-transpiration and the soil water balance model is developed according to Penman-Montheith (Allen *et al.*, 1998), considering the field capacity. First of all the potential evapo-transpiration for grass surfaces was determined on a daily basis for the entire country. The most important parameters of this model are the global radiation, respectively the daily radiation balance, the saturation deficit based on temperature and relative humidity as well as the wind. For this project, the weather measurements from 274 official stations of the Central Institute for Meteorology and Geodynamics (ZAMG) were available for the year 2003, providing the basis of all meteorological analyses.

The calculation result of the potential evapo-transpiration was included into the soil water balance model. Together with the field capacity the soil water ratio and the effective evapo-transpiration of three different soil layers from 0 to 40 cm could be determined in this way. The change of soil water balance compared with that of the day before was included as well as the possible drainage of the soil layers located above. The precipitation considering the interception was integrated into the balance calculation. In order to identify drought, it is necessary to examine a longer period and not only a cutoff date. Hence

the accumulation of results of the soil water balance calculation for a certain period is an important pre-condition to simulate growth.
Another important parameter for the soil water balance is the plant factor, which indicates the development status of plants. The plant factor is used for the calculation of interception and transpiration and describes a linear increase of biomass production from the beginning of the vegetation period to the first utilisation and in the same way from the next to the following utilisation. The basic requirement for this calculation is the exact determination of the vegetation period with its temperature-sensitive and elevation-dependent begin and end as well as the elevation-dependent duration of growth stages for the several utilisations (Schaumberger, 2005).
The growth and yield model is based on the data of the soil water balance and results in a multiple regression in order to calculate the quantity of grassland yield (Trnka *et al.*, 2005). For that purpose it is necessary to calculate a growth factor, which is generated from long-term and short-term water stress factors and from the resultant water availability factor. The model also considers the cultivation intensity concerning fertilisation. Using the Integrated Administration and Control System (IACS) data, the stocking rate in livestock units (LU) per hectare was calculated and used for the estimation of the N-fertilisation as another parameter of the yield equation.

Results and discussion

The results refer to data of the year 2003. The yield was on a very low level in the eastern part of Austria and in many areas with total yield loss of the following growths. In areas of enough rainfall the yield was above-average due to the higher temperature of this year. Of course, the results of a GIS implementation can not be visualised satisfactory without maps. These results with coloured and detailed maps for every step of the model are published in Schaumberger (2005). The model results were verified on sites of the exact grassland field trials and show good correlation with a coefficient of determination about 0.7. Qualified interpolations of weather data as well as the very simplified modelling of utilisation frequency and N-fertilisation are the big challenges and also the weak points of the model. All calculations are based on the grid data model and were performed as local grid operations in ESRI ArcGIS programs. Most of the intermediate and particularly the final results had to be generated in a resolution of 50 meters. These state-wide operations with a high resolution scale on a daily basis resulted in a geodata set of more than 1.5 TByte with intensive and long computing time.

References

Allen G.A, Pereira L.S, Raes D. and Smith M. (1998) *Crop Evapotranspiration – guidelines for Computing Crop Water Requirements.* FAO Irrigation and Drainage Paper 56. FAO, Rome, Italy, pp. 78-86.
BMLFUW. (2004) *Grüner Bericht 2004. Bericht über die Situation der österreichischen Land- und Forstwirtschaft im Jahr 2003.* Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, Abteilung II 5, Wien, pp. 78, 179.
Schaumberger A. (2005) *Ertragsanalyse im österreichischen Grünland mittels GIS unter besonderer Berücksichtigung klimatischer Veränderungen.* Veröffentlichungen der HBLFA Raumberg-Gumpenstein, A-8952 Irdning, Heft 42, pp. 66.
Trnka M., Eitzinger J., Gruszczynski G., Buchgraber K., Resch R. and Schaumberger A. (2006) Simple Method for predicting permanent grassland yields in Austria. *Grass and Forage Science,* in print.