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Future scenarios of biomass dynamics under pastoral conditions and regional water balance aspects for the Drâa catchment in south-eastern Morocco

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Summary

The process-oriented and spatial explicit ecosystem model SAVANNA (Coughenour 1993) is used to assess biomass dynamics in rangeland landscapes in south-eastern Morocco. The model was first calibrated for a characteristic rangeland area of 200 km^2 of the northern Drâa river catchment at Taoujgalt (1900 m a.s.l.), located at the southern slope of the High Atlas mountains. The dominant perennial species are *Artemisia herba-alba/-mesatlantica*, *Teucrium mideltense*, *Adenocarpus baquie* and *Stipa ct. parviflora*, being the basic nourishment of trespassing nomadic and sedentary herds. Multiple ten year simulation runs with 'no grazing' and 'grazing' conditions for calibration and sensitivity analysis with three basic SAVANNA vegetation types: herbaceous, shrub and woody has been carried out.

Keywords: Ecosystem modelling, biomass dynamics, herd dynamics, transhumance, Morocco

Résumé

Une analyse de la dynamique de la biomasse des terres pastorales de la vallée du Drâa s'est effectué avec le model d'écosystème SAVANNA. Le modèle a été calibré pour la plaine steppique de Taoujgalt (env. 1900m d'altitude) sur le versant sud du Haute Atlas. Les steppes sont dominées par des espèces pérennes *Artemisia herba-alba, A. mesatlantica, Teucrium mideltense*, *Adenocarpus bacquei* et *Stipa cf. parviflora*. Ces espèces sont le fourrage principale des troupeaux sédentaires et nomadiques que pâturent sur la plaine. On a mis en cours des multiples simulations de dix années pour le calibrage et les analyses de sensibilité du modèle, toujours avec deux types des conditions, 'sans pâturage' et 'pâturage'. Le modelage de SAVANNA se base sur trois groupes fonctionnelles de plantes, des plantes herbacées, des chamaephytes et des nanophanérophytes.

Introduction

This study is part of the IMPETUS project (**I**ntegratives **M**anagement **P**rojekt für einen **t**ragfähigen **U**mgang mit **S**üßwasser) an interdisciplinary research initiative of the universities Cologne and Bonn/ Germany. The Taoujgalt plain, one of our thirteen research test sites in the Drâa catchment, has been spatially explicit examined for model parameterisation. SAVANNA has been parameterized and calibrated by transpiration studies and biomass determination measurements (Gresens 2003). Since spring 2004, measurements of biomass (kg/ha) and plant component parameters (g/m^2 DWT, Dry Weight Matter) of many saharan, iranoturanean and oromediterranean species as well as soil data were assembled in a database for further calibration and validation purposes. Other model input parameters were derived from the IMPETUS database, where all subprojects of IMPETUS continuously contribute data for calibration and validation purposes of our model family.

Material and Methods – SAVANNA Initial conditions

SAVANNA is the model best suited for the purpose of the study as it is capable of running comprehensive simulations of primary production, decomposition and nutrient cycling, site hydrology, herbivores, and predators, all in a dynamic spatial framework (Coughenour 2005). This process-oriented, spatially explicit ecosystem model was calibrated with maps of species and herds distribution and their parameterisation in *. txt program files. Additional maps of soils, soil fertility, distance to water, digital elevation maps, slope and aspect are needed to set up the SAVANNA Model (Roth, Gresens 2004). The program accepts raster GIS files as ASCII grids derived from programs such as ArcGIS, IDRISI or ERDAS Imagine. The specified grid-cell size determines the spatial resolution, ranging from 100m up to 1km. Each grid-cell consists of fractions of facets or patch types of areas dominated by herbs, shrubs, or trees. Within each patch-type, multiple species or functional groups of plants may be represented as specified through the plant parameter files. SAVANNA simulates variation of vegetation patterns in space and time by using a look-up table to specify the species or functional group composition for each patch type of vegetation type on the vegetation map. In our case three dominant plant species are simulated for model calibration purposes: herbaceous *Stipa ct. parviflora*, shrub *Artemisia herba-alba* and tree *Juniperus phonecia*. Parameter files then describe the physiology and physiometry of each simulated plant species or functional group (see above). The model is actually running at a spatial resolution of 145m, but will be upscaled in subsequent work to 1km for regionalisation scenarios of the whole Drâa catchment.

Explicit animal diet- and plant preference data, for sheep, goats and dromedares, being the most abundant animals in this area, were provided by pastoralists and zoologists from the OSS/ ROSELT program at the Office Regional de Mise en Valeur Agricole (ORMVAO) (Benidir 2005, Ramdane 2005). The important roles of trespassing nomadic people and their herds, were taken into account by processing different herd compositions and sizes. These herds are composed of local goat breeds *Rhali* and sheep breeds *D´Man*, *Saghro* and *Siroua*. In our case herds of ‘shoats’ had been designed. ‘Shoats’ is the term for aggregated herds of sheep and goats, as are commonly found in the project area. Sizes of nomadic herds are in general bigger than sedentary ones. For that reason we initially designed preset herd numbers for the starting year 2002: for nomadic herds: 15000 head, sedentary herds: 5000 head. The number of goats in both types of herds largely exceeds sheep numbers. This is due to the capability of local goat species to handle arid environments and highly variable terrains. Trespassing herds were represented by having specified numbers of shoats enter and leave the simulation at certain time steps at defined areas. Harvesting of plant biomass by humans totalling 500 t/ha/a (El Moudden 2005) will be represented in the scenarios by treating humans as a third ‘consumer’ species (in addition to sheep and goats).

Results

Calibration of SAVANNA showed the sensitivities of herbaceous plants and shrubs in terms of plant growth, root water uptake and reproduction rates, to the variable and stressful climate of the semi-arid environment. High mortality rates were initially predicted in response to high irradiation and temperature values and resultant water stress during summer. This was a consequence of using parameter values from N. American species that are less adapted to water stress. After re-parameterizing the model for species and conditions in Morocco, we simulated two treatments, called ‘grazing’ and ‘no grazing’. *A*nnual *n*et *p*rimary *p*roduction (ANNP) for ‘grazing’ conditions was similar among years. This was due to a constant number of shoats which were present in the simulations in all years. ANPP in the ‘no grazing’ simulation was less than in the grazing simulation (figures 1,2). Woody biomass (trees) was not represented in these simulations.. These outcomes demonstrate the high potential for plant regrowth under grazing even under drought conditions (Roth, 2005).

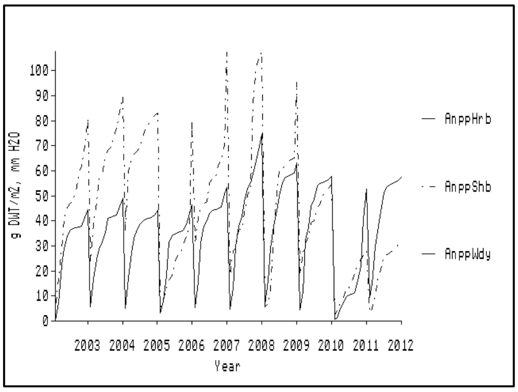

Fig. 1: ANPP g (DWT)/m^2 ’grazing’ conditions

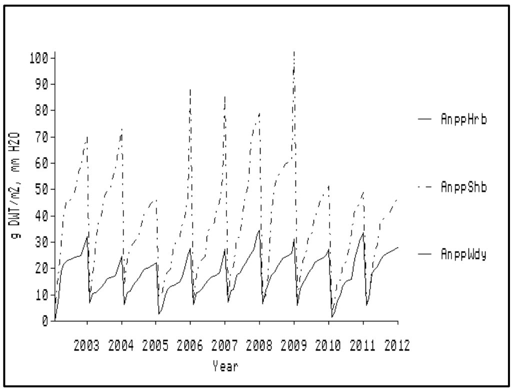

Fig. 2: ANPP g(DWT)/m^2 ‘no grazing’ conditions

Simulated standing biomass corresponded to the ANPP results. Results for total herbaceous-, shrub- and woody biomass in DWT g m^{-2} are presented in figures 3 and 4. Herbaceous biomass rests stable at equal amounts, even in dry years under both grazed and ungrazed conditions. However, in the ‘grazing’ conditions run there were larger intra-annual fluxes due to grazing removal . Shrub biomass showed higher sensibility to drought under ‘grazing’ than ‘no grazing’ conditions. It declined in 2005 due to drought but recovered, and then it dropped again in years of drought. In the ‘no grazing’ run shrub biomass declined in 2005 to levels below the starting point, and recovered in 2012 to the initial level of 70 g DWT /m^2.

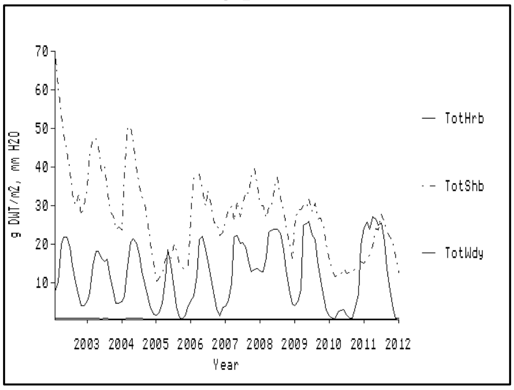

Fig. 3: Total biomass g DWT/m^2
‘grazing conditions’

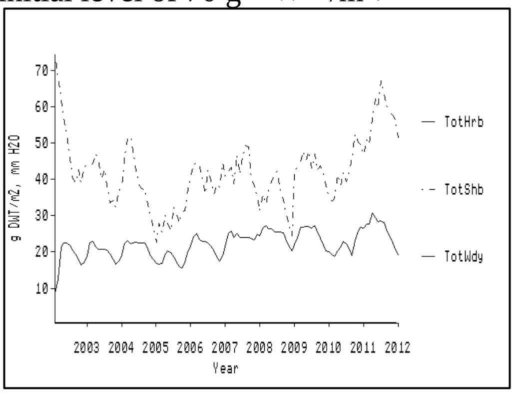

Fig. 4: Total biomass g DWT/m^2
‘no grazing’ conditions

More detailed plant growth components in terms of root, leaf and dead g DWT /m^2 results of herbaceous plant (*Stipa cf. parviflora*) indicated higher amounts and fluxes of herbaceous leaves under ‘grazing’ than under ‘no grazing’ model runs. Herbaceous root dynamics were similar under grazing and no-grazing conditions. Dead herbaceous biomass carried over from year to year under ‘no grazing’ conditions. However under ’grazing’ conditions, dead biomass carried over in smaller quantities, as it declined to low amounts at the end of the growing seasons due to herbivory. Animal grazing stimulated growth rates in some time steps and reduced transfers to standing dead during the dry season.

Discussion and Conclusions

The results presented here reflected conditions in a balanced producer-consumer system. Model analysis showed the high plant sensitivity to irradiation and temperature, along with low precipitation (~200 mm in 2002) in this semi-arid climate. Refined plant parameterisation corrected these excessive sensitivities to this specific environment. Thus, the model has been successfully calibrated to represent a single plant-environment system. Further work is required, however, to improve the simulations of dead biomass dynamics. Multiple North African, Saharan and Oromediterranean species will be added to SAVANNA in order to enlarge the plant database and provide realistic simulations of the Drâa catchment. Species that must be added include *Hamada sc.*, *Covolvulus trab.*, *Genista* and *Facecia* species. Explicit animal diet specific preference and composition data will then have to be included. Upscaling to the whole Drâa catchment area is in progress.

Our overall aim is to determine regional influences of herd populations on vegetation cover, species composition and distribution in order to assess their influence on the local/regional water cycle. Model scenario results with a prospective to 2020 will be used to integrate scientific with local and regional knowledge. This should allow local and regional decision makers to take appropriate measures for environmental preservation, which will allow future populations to engage in sustainable livelihoods which provide ample income while minimizing the negative impacts of recurrent water shortages.

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