SIMULATION OF GRAZED GRASSLAND PRODUCTIVITY IN ETHIOPIAN HIGHLANDS

SIMULAZIONE DELLA PRODUTTIVITÀ DEI PRATI DA PASCOLO DEGLI ALTOPIANI ETIOPI

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Abstract
This study simulates the dynamics of vegetation biomass in a site of the Ethiopian highlands which are the main livestock grazing area of the Ethiopia. Ethiopian highlands are characterized by a monsoon climate with mild daily temperature and precipitation mainly centred in the June-September period (main rainy season). In such conditions the major limitations to grassland productivity are represented by soil water and nutrients shortage. The mechanistic model Sim_PP is used to describe biomass dynamics in these grassland systems. Model run has been performed based on the Addis Ababa airport meteorological time series, providing productivity data compatible with data in literature. Potential biomass productivity might be much higher if plant nutrition could be satisfied (especially nitrogen), which represents an agronomic challenge for the future.

Keywords: productivity model, Ethiopian highland, pastures, monsoon climate, livestock.
Parole chiave: modello di produttività, altopiano etiope, pascoli, clima monsonico, bestiame.

Introduction

Global food security is strictly related to the rational management of agricultural lands (1.4 billion of ha arable soils and 3.4 billions of ha of pastures). A key question for the management of these lands in the developing countries is given by the low productivity due to obsoleted crop genetics or agro-techniques. These aspects has been adressed by the authors with reference to paddy rice productivity in Nepal (Parisi et al., 2011). Hereafter a similar problem has been faced with reference to Ethiopian highland grasslands.

Thanks to the mild climate due to an altitude ranging from 1500 to 3000 m a.s.l., Ethiopian Highlands vegetation is constituted by forest, shrub and grassland. The latter is an indispensable source for livestock feed. The main grass species belongs to the genus: *Andropogon*, *Avena*, *Eragrostis*, *Eleusine*, *Cynodon*, *Cyperus*, *Digitaria*, *Hyparrhenia*, *Pennisetum*, *Setaria*, *Trifolium* and *Medicago* (Zewdu, 2005). The Ethiopian climate is characterized by three main seasons: Spring rainy season (march-april) due to the migrating InterTropical Convergence Zone (ITCZ), summer rainy season (June-September) due to the Indian Ocean monsoon, and winter dry season (October-February) due to dry trade winds (Gilioli & Mariani 2011, Holton 2004, Mukabana & Pielke 1996).

Materials and Methods

Sim_PP is the modelling tool adopted to describe the Ethiopian Highland grassland system (Mariani and Maugeri, 2002). Sim_PP is a mechanistic dynamical model which simulates the cascade of matter in plants triggered by solar energy until re-partition among plant organs (leaves, stems, roots and reproductive organs). Sim_PP uses a basic daily time step and an hourly fast loop describing temperature limitation.

L.A.I. is obtained applying a specific leaf weight (1500 g m^2 per L.A.I. unit), and light interception is described with the Lambert Beer law. Gross ASSimilation (GASS) values from photosynthesis process are simulated with Goudrian and van Laar approach (1993). Thermal limitation is described with a response curve applied to hourly temperatures and parameterized with minimum cardinal temperature of 12°C, optimal in the range 22/28°C and maximum at 35°C. Water limitation is approached with a water balance based on the mass conservation equation applied to the soil reservoir (AWC=150 mm), with a reference crop evapotranspiration as in the Hargeaves and Samani model and a suitable response curve applied to daily water content to obtain water limitation due to both shortage or excess.

A suitable Harvest index (0.7) is adopted to partition the final dry matter between above and below ground fractions.

The green matter senescence, crucial for the Highland environment, has been simulated with the two stages approach proposed by Romera et al. (2010) which considers both a gradual senescence and an acute senescence.

Addis Ababa airport temperature and precipitation daily data have been retrieved from NOAA GSOD dataset. The data consistency is low, so three sub-periods with higher data consistency (1981-1988; 1990-1996; 2006-2011) have been taken into consideration for model calibration and validation.

Results and Discussion

Results of the model are summarized in Fig. 1 where average and maximum production is presented while yearly totals are shown in Fig. 2.

Results show the extreme inter-annual variability of the grassland productivity which represents a strong limitation for livestock production in this area (milk and meat).

More specifically the passage from potential to final productivity is ruled by:

(I) a thermal limitation slowed by the mitigating effect of altitude and summer precipitation which maintain temperatures in the optimal range for long periods;

(II) a water stress which reduces crop growth and enhance the senescence process;

(III) a stress due to nitrogen limitation. Nitrogen limitation has been estimated as ratio between the potential nitrogen removal

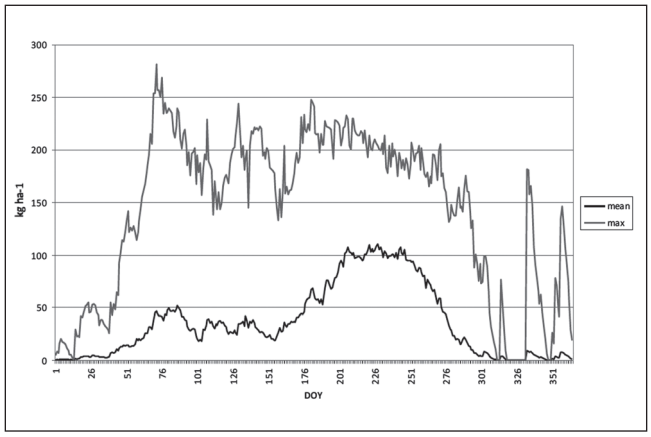

Fig. 1 - Mean and maximum daily production (21 years) [kg ha-1].
Fig. 1 - Produzione media e massima giornaliera (21 anni) [kg ha-1].

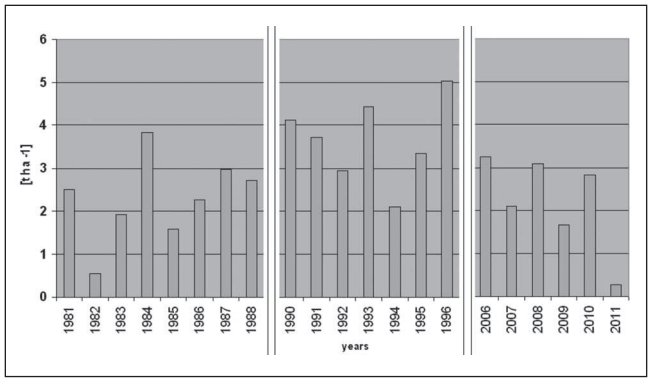

Fig. 2 - Yearly final biomass production [t ha-1].
Fig. 2 - Produzione finale annua di biomassa [t ha-1].

of a grassland without limitation (480 kg ha^{-1} $year^{-1}$) and the net nitrogen restitution due to balance among manures released by livestock (3 Tropical Livestock Units ha^{-1}), bacterial nitrogen fixation, rainfall release and volatilization/leaching losses (for a total yearly restitution of 102 kg ha^{-1}). Tab. 1 shows the strong nitrogen limitation affecting the experimental area where only 21% of the needed nitrogen is made available and leads to the adoption of a suitable multiplier (0.21). This coefficient accounts for for nitrogen limitation and is coherent with the results of the fertilization trials carried out in four pilot sites of the Ethiopian Highlands (Zewdu, 2005). In the hypothesis of complete fulfilment of nutrient demand, the production could overcome 18 t ha-1, and in general can achieve 12 t ha^{-1}. On the contrary, the nitrogen shortage lowers the production to 4 t ha^{-1}.

Conclusions

Results highlight that Ethiopian Highlands are favourable to grassland productivity for thermal resources, while production shortage is caused by irregular rainy seasons and lack of soil nutrients. The complete fulfilment of nutritional requirement could easily double the productivity respect to the current value. In the light of this evaluations it should be desirable an improvement in agrotechnical features in order to provide sufficient nutrients to the soil.
Future developments of the Ethiopian Highland productivity analysis will consider a large scale extended to the entire country. The analysis will be performed by the Sim_PP model and take into account data from 21 meteorological stations from ETHIOMET (Ethiopian National Meteorological Service) located over all Ethiopian highlands and in border lowlands area.
In this way it will be possible to run Simpp model on each station point, having a more complete framework of the variability in grassland productivity.

Tab. 1 - Estimate of nitrogen limitation factor.
Tab. 1 - Stima del fattore di limitazione dell'azoto.

YEARLY NITROGEN RESTITUTION TO THE SOIL	measures units	value
Tropical livestock units (TLU)	n ha-1	3
Weight of a TLU	kg	250
Total hectarial charge	kg ha-1	750
Yearly manure	kg per kg of livestock	27
Total manure	kg ha-1	20250
N in the manures	%	0.0059
N gross release per hectar	kg ha-1	119.5
N losses (volatilization, leaching)	%	0.2
N net release from manures	kg ha-1	95.6
N from bacteral nitrogen fixation	kg ha-1	3
N from rainfall	kg ha-1	3
N yearly restitution to soil	kg ha-1	102
POTENTIAL NITROGEN REMOVAL		
Potential dry matter production (without N limitation)	kg ha-1	20000
Protein content	%	15
Nitrogen content	%	2.4
Potential Nitrogen removal	kg ha-1	480
RATIO BETWEEN RESTITUTION AND POTENTIAL REMOVAL		
Restitution VS potential removal (=102/480)		
Multiplier to convert final production to N limited	%	21

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