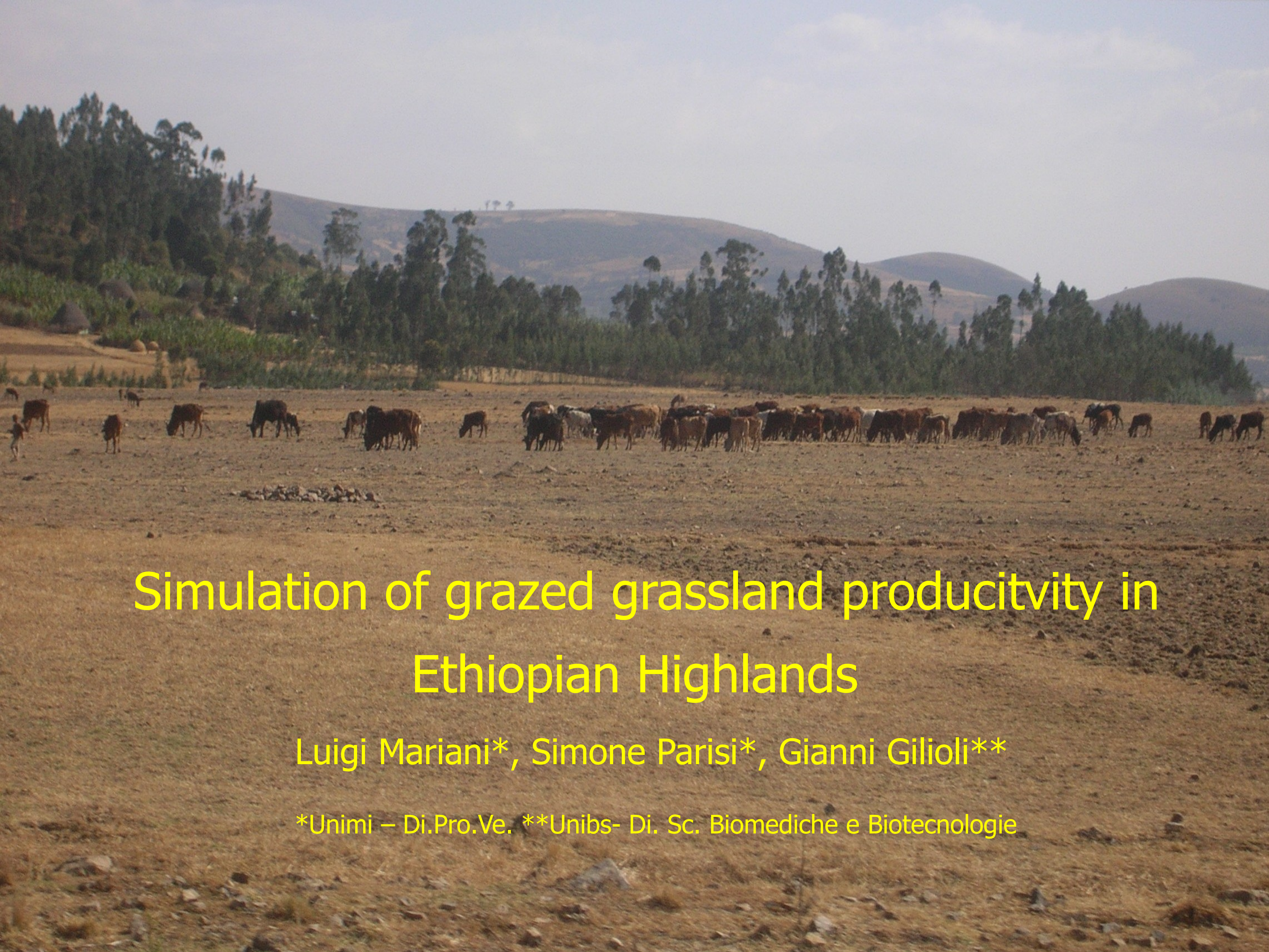

Simulation of grazed grassland producitvity in Ethiopian Highlands

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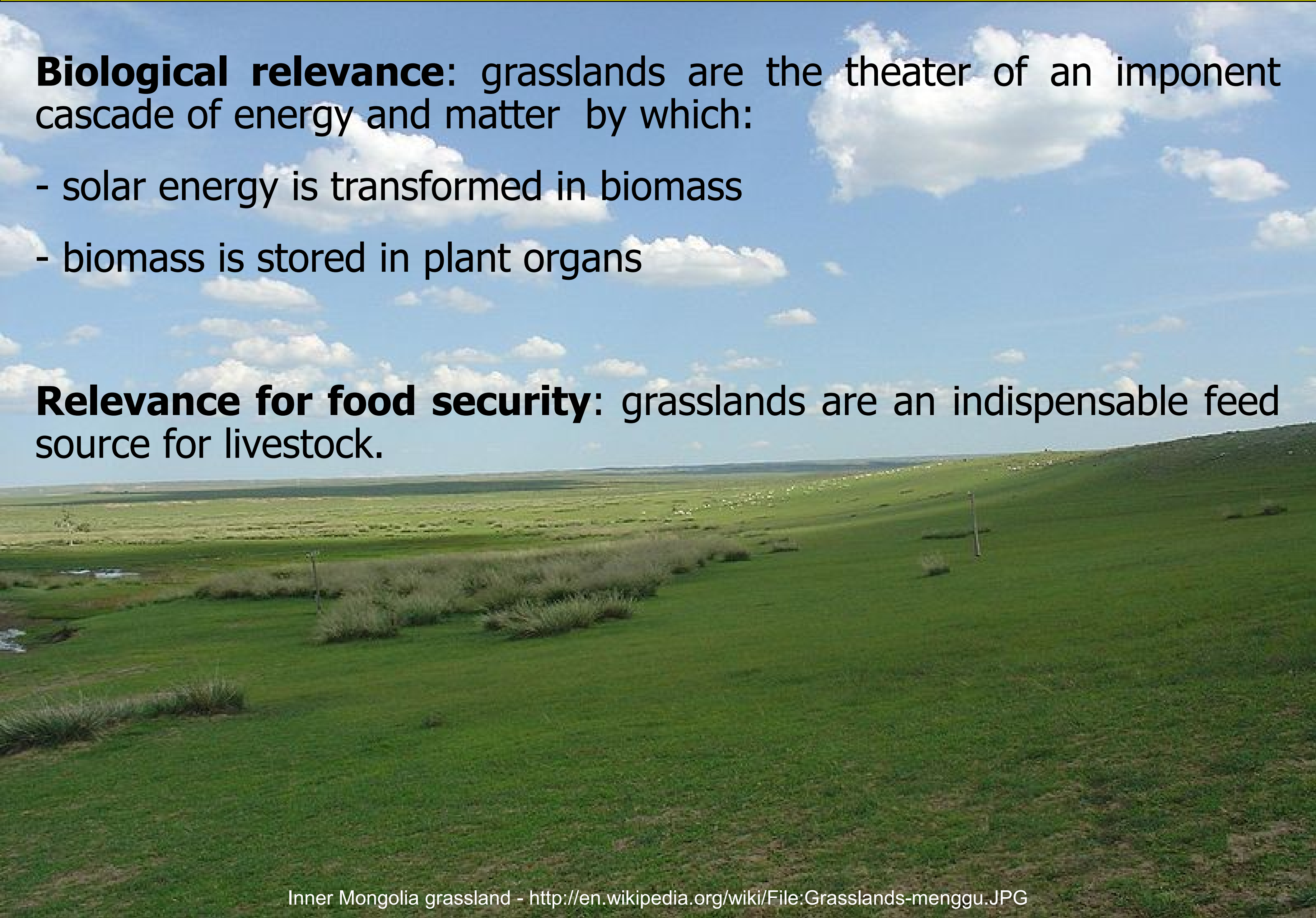
Pastures

Biological relevance: grasslands are the theater of an imponent cascade of energy and matter by which:

- solar energy is transformed in biomass

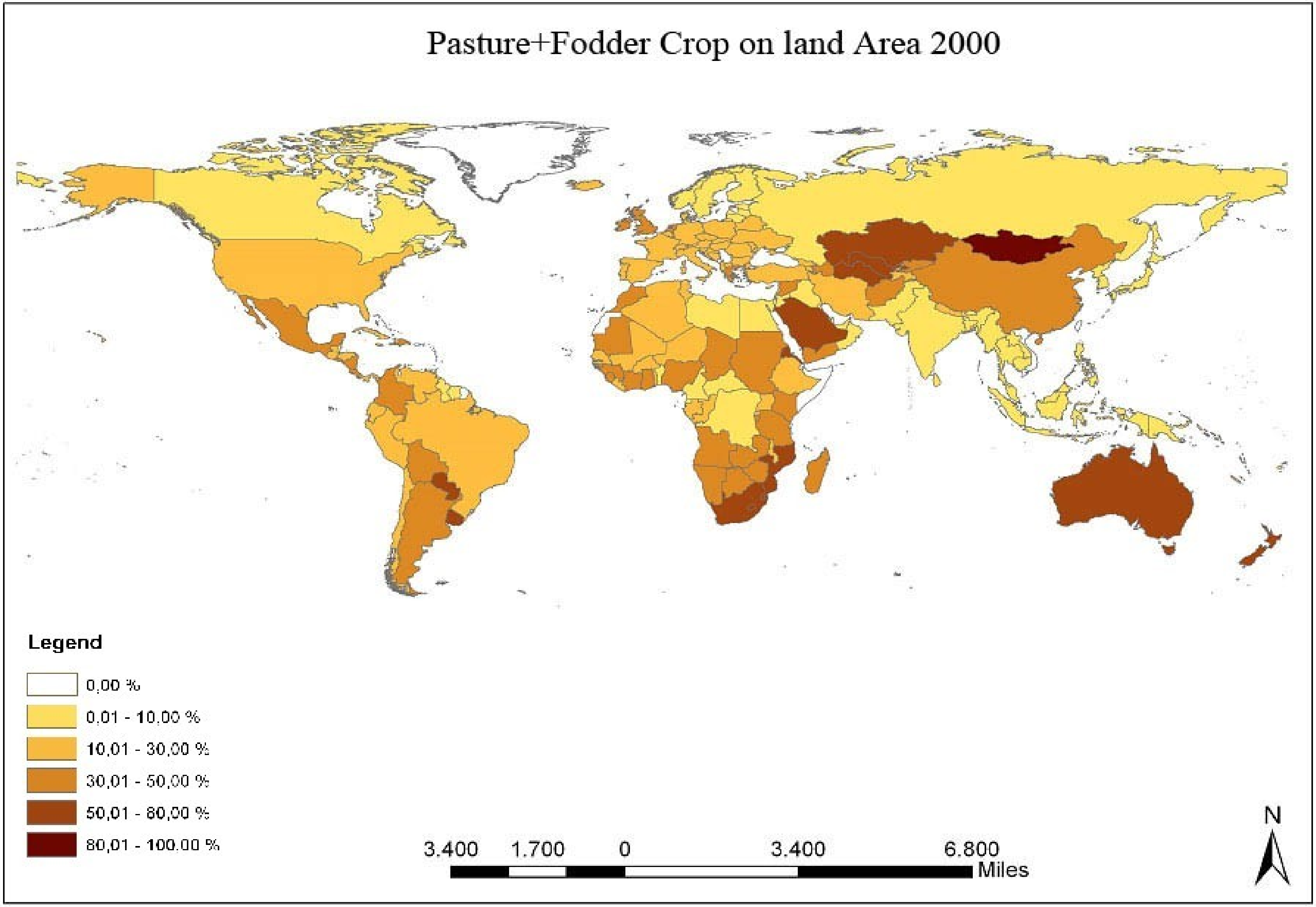
- biomass is stored in plant organs

Relevance for food security: grasslands are an indispensable feed source for livestock.



Inner Mongolia grassland - http://en.wikipedia.org/wiki/File:Grasslands-menggu.JPG

Pastures world statistics



http://engineering.dartmouth.edu/gsbproject/2-pasture-productivity.html
Source of data: Ramankutty, N., A.T. Evan, C. Monfreda, J.A. Foley. 2008. Farming the planet: 1. Geographic distribution of global agricultural lands in the year 2000. Global Biogeochem. Cycles 22:B1003, doi:10.1029/2007GB002952.

Pastures world statistics

COUNTRIES	LAND AREA (1000 Ha)	PASTURES (1000 Ha)			% PASTURE		
	2000	1980	1990	2000	1980	1990	2000
Africa	2,933,450	911,110	920,374	869,878	31.06	31.38	29.65
Asia	3,508,087	1,016,148	1,126,845	1,106,060	28.97	32.12	31.53
America	3,831,866	769,041	798,909	808,920	20.07	20.85	21.11
Europe	2,208,912	85,578	82,756	182,344	3.87	3.75	8.25
Oceania	848,729	453,465	430,511	419,455	53.43	50.72	49.42
World	13,004,202	3,244,404	3,368,403	3,442,078	24.95	25.90	26.47

(Source: FAOSTAT)

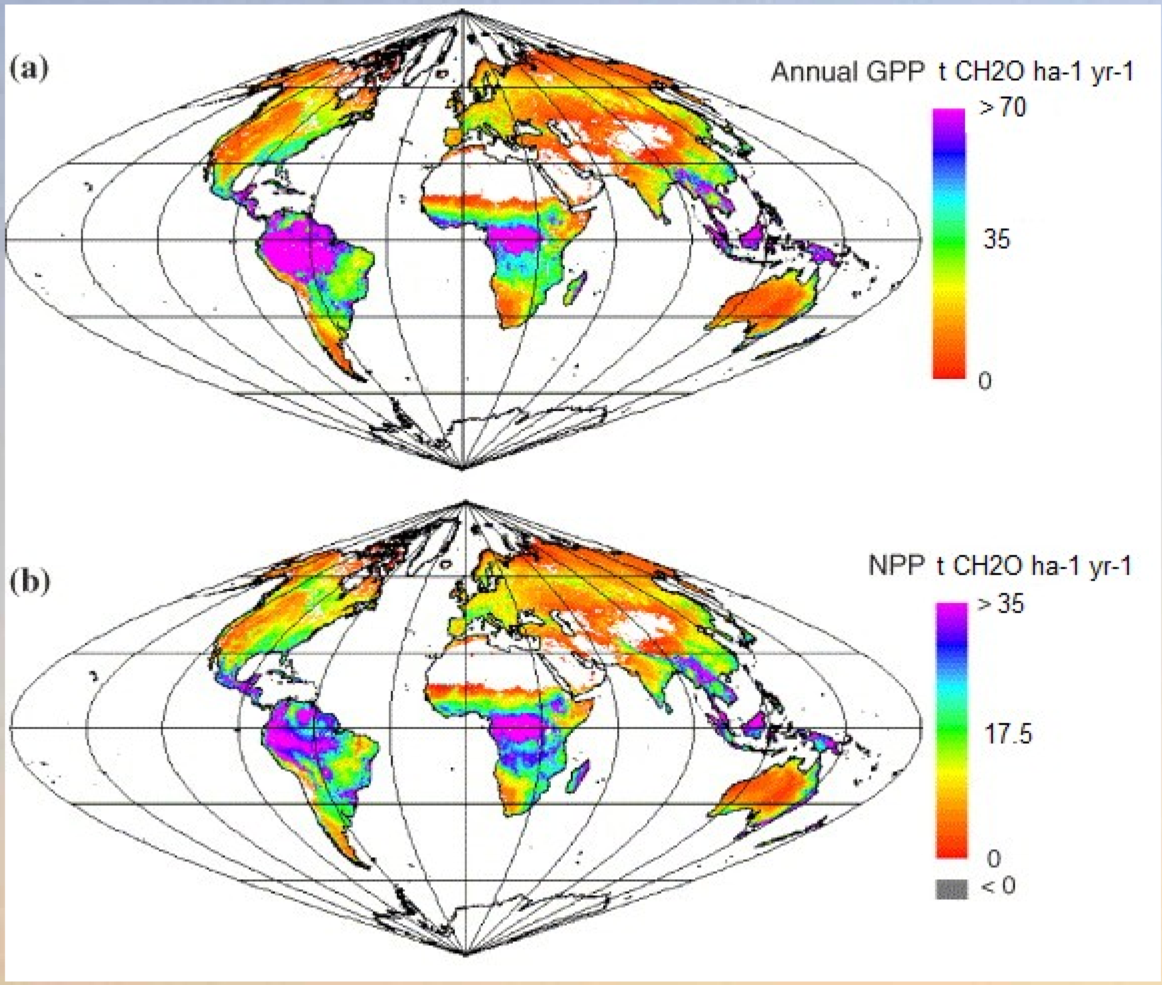
World Arable lands = 1.4 billions of ha
Pastures=3.4 billions of ha (the 25% is in Africa)

http://www.fao.org/ag/agp/agpc/doc/grass_stats/grass-stats.htm

Grasslands production

Remote sensing approach

Annual Gross assimilaton and Net production (t CH_2O ha^{-1} yr^{-1})



Zhao M., Heinscha F.A., Nemanib R.R. Runninga S.W., 2005. Improvements of the MODIS terrestrial gross and net primary production global data set, Remote Sensing of Environment, Volume 95, Issue 2, 30 March 2005, Pages 164–176

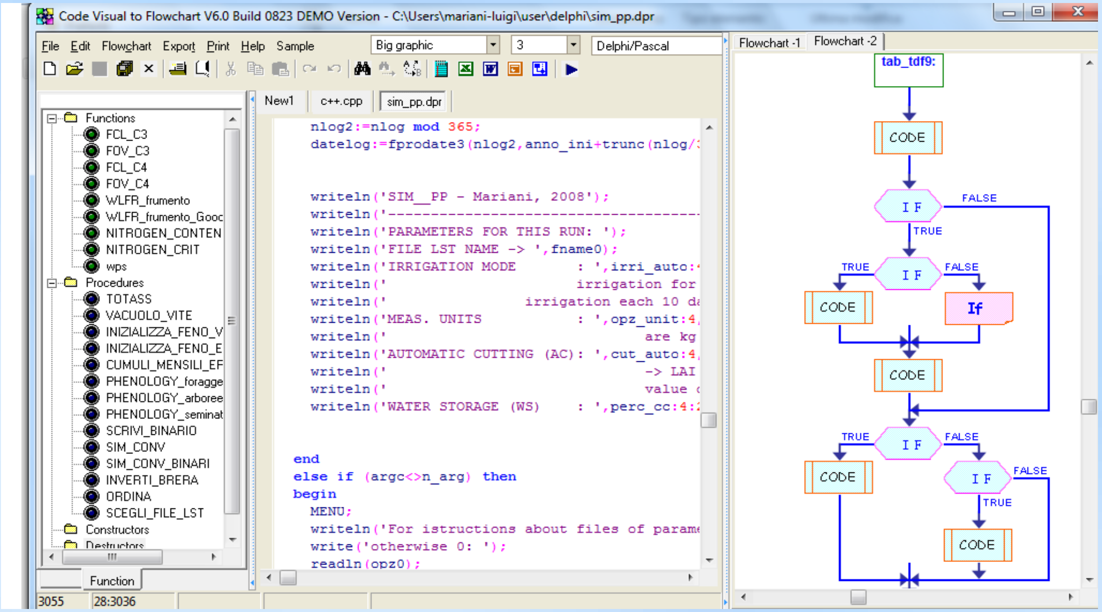
Approach based on mathematical models driven by meteorological variables

Many examples are present in bibliography

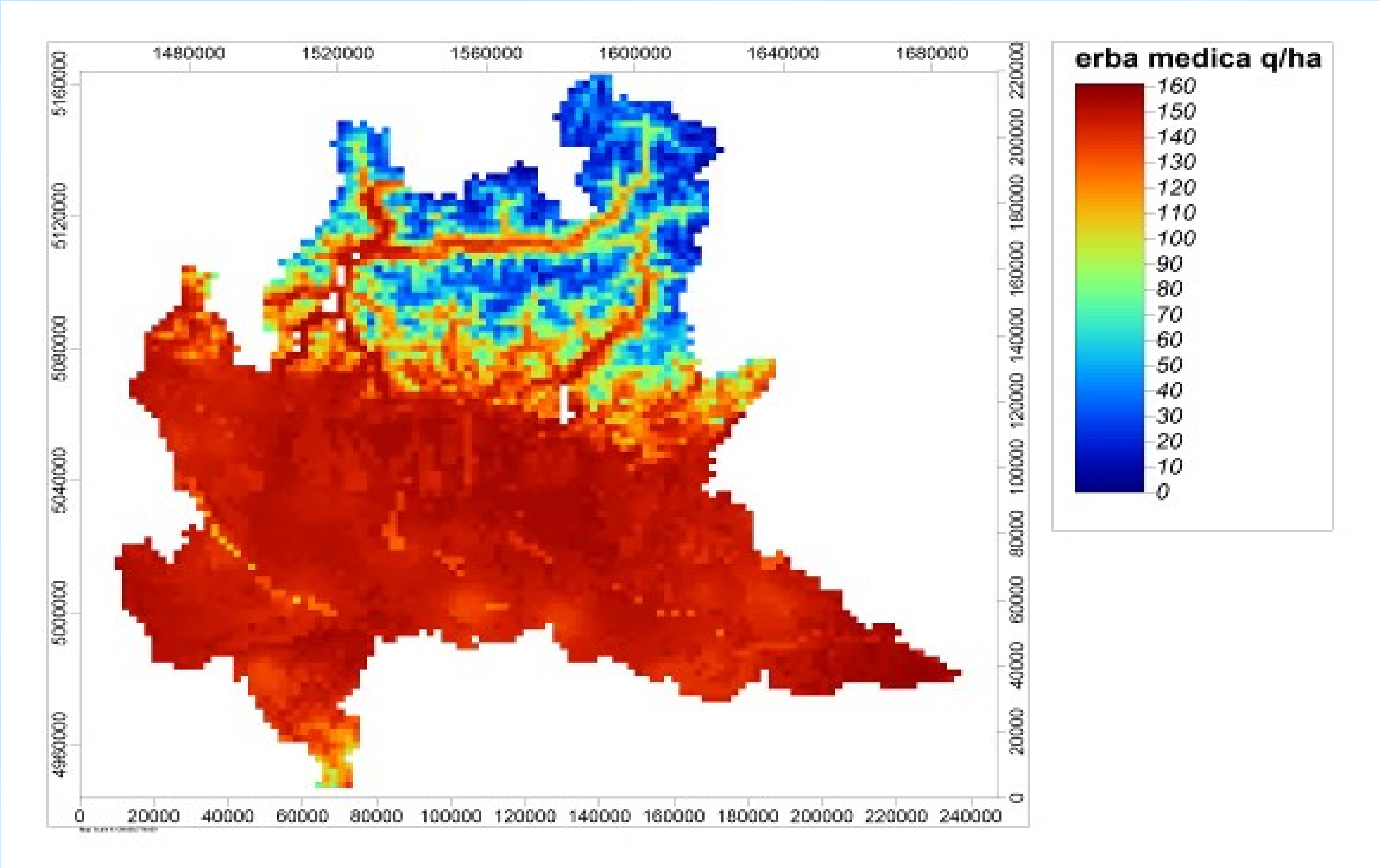
Our approach is based on SIM_PP → dynamic simulation model for many herbaceous and woody crops - maize, wheat, barley, rice, grapevine, grasslands, etc. - based on the scheme proposed by the de Wit school (Bouman et al., 1996)

SIM_PP able to carry out single point or territorial (raster) simulations.

Bouman B.A.M., van Keulena H., van Laar H.H., Rabbinge R., 1996. The 'School of deWit' crop growth simulation models: A pedigree and historical overview, Agricultural Systems, Vol. 52, Issues 2–3, Pages 171–198

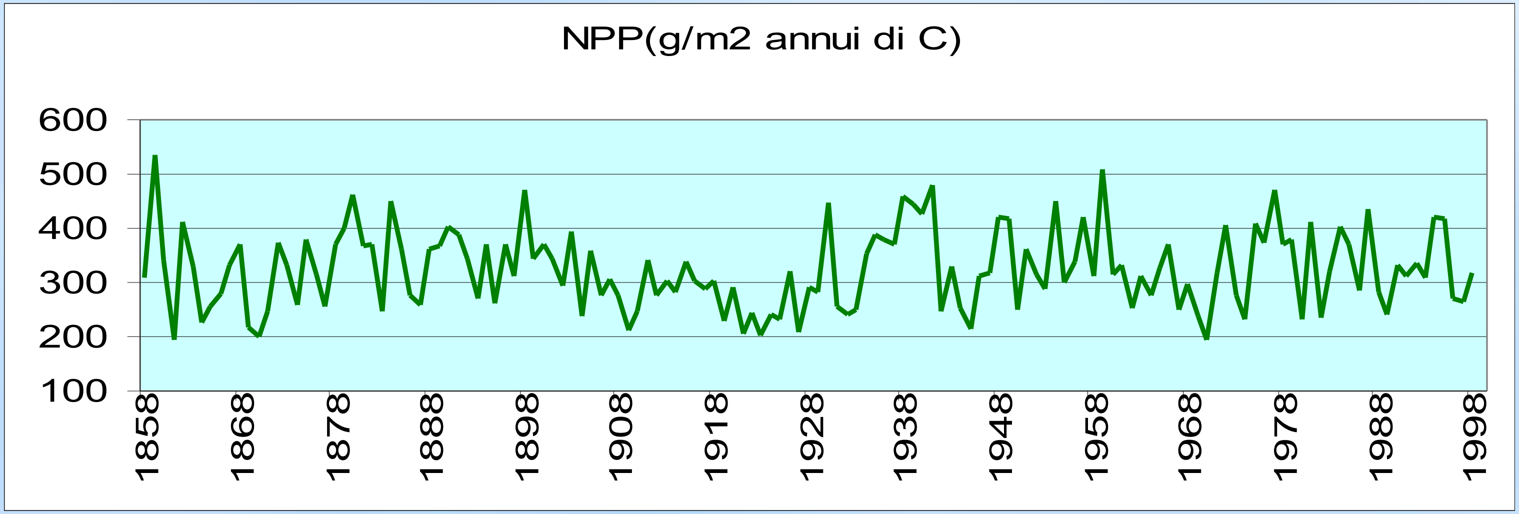


SIM_PP grassland model – example of territorial simulation

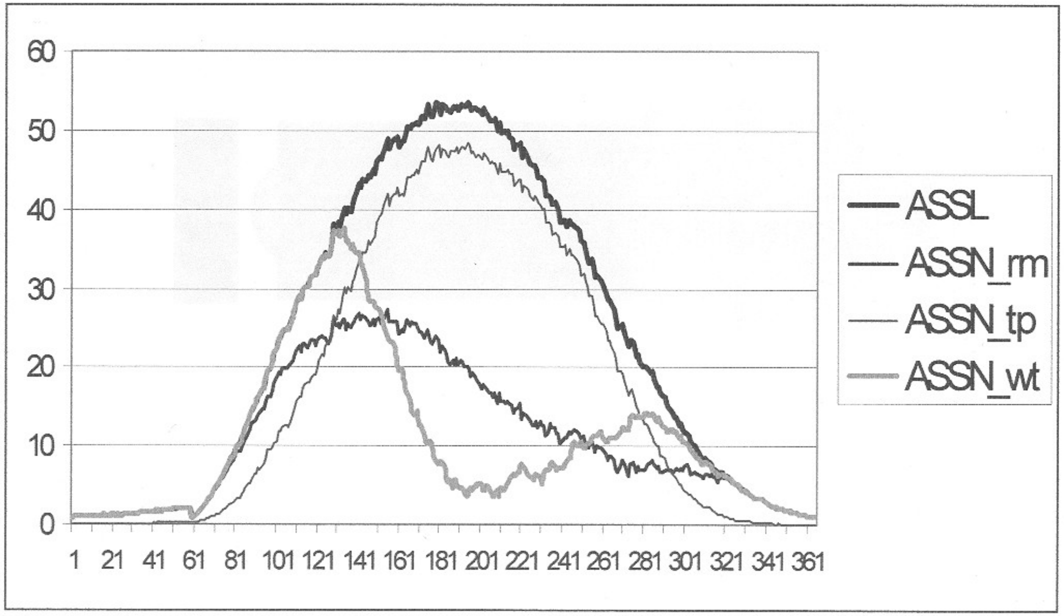


Medicago sativa L. with delayed irrigation – yearly final production (1951-2007 period)
Source: project RICLIC WARM (http://www.riclic.unimib.it/)

SIM_PP – example of single point approach - Milano Brera 1859-1998



Produzione giornaliera di un prato polifita (C assimilato in g/m2)
Valori medi stimati da un modello di produttività applicato alla serie storica 1859-1998 di Milano Brera (ASSL=assimilaz.lorda; ASSN_rm=assimilaz.al netto della sola respirazione di mantenimento, ASSN_tp= assimilaz.al netto della sola limitaz.termica, ASSN_rm=assimilaz.al netto della sola limitaz.idrica (Da Mariani, Maugeri e Bocchi, in corso di stampa).



SIM_PP - past simulations of grasslands

In the past this model has been applied to:

- grasslands of Italian Alps of Lombardy (Koeppen climate type H)
- grasslands of Po plain (transitional Csa - Cfb)
- grasslands of Sicily (Koeppen Climate type - Csa)
- grasslands of Himalayan area of Nepal (Koeppen climate type H).

Model run of SIM_PP for Ethiopia

Single point run

Model driven by meteorological data from Adiss Ababa airport.

Grasslands located near Adiss Ababa with the following reference genders: Andropogon, Avena, Eragrostis, Eleusine, Cynodon, Cyperus, Digitaria, Hyparrhenia, Pennisetum, Setaria, Trifolium and Medicago (Zewdu, 2005).

Zewdu T., 2005. Identification of indigenous pasture and the effect of time of harvesting and nitrogen fertilizer in the northwestern Ethiopian highlands, Trop.Sci., 2005, 45, 28-32.

Meteorological data

NOAA GSOD daily data of maximum / minimum temperature ad precipitation for 1981-2011 period.

The quality of these data is generally low

The % of missing data for the year 1989 and the period 1997-2005 was too high → these years has been excluded from processing.

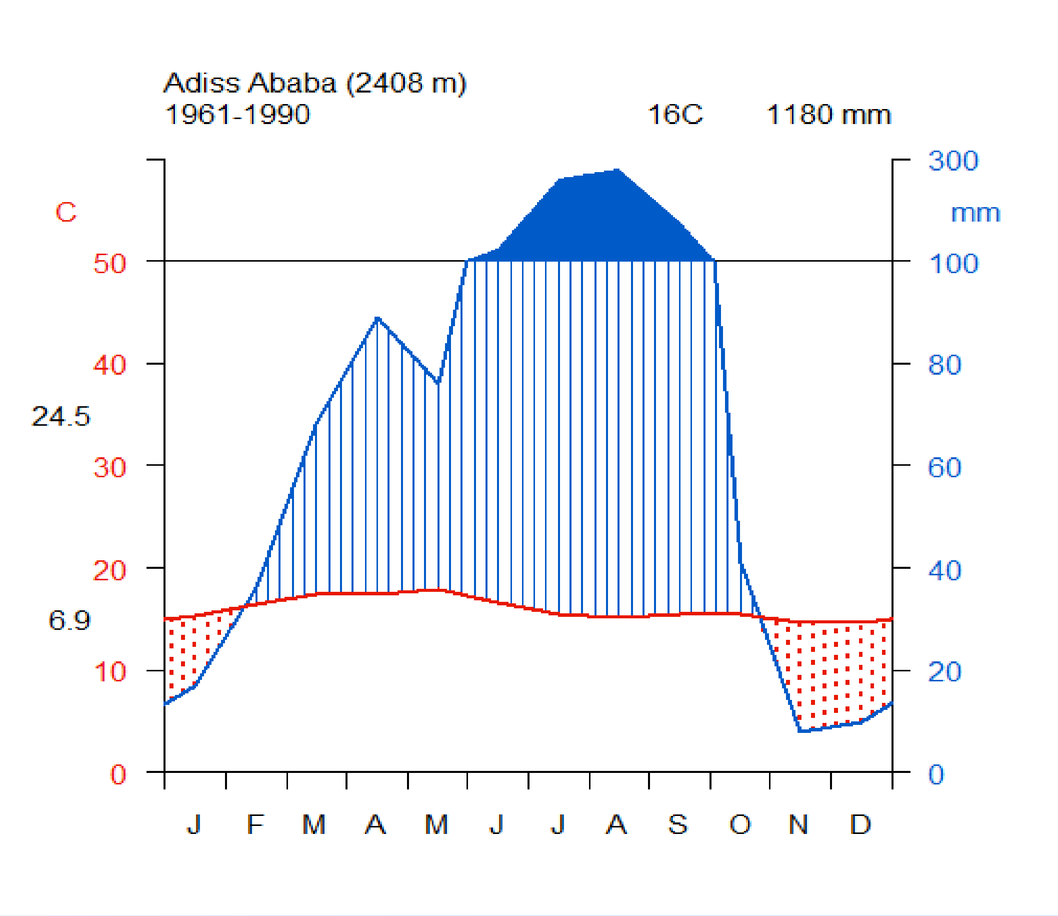
Processed periods :
1981-1988
1990-1996
2006-2011

1990-1996 = is probably the period with the best data quality → this presentation is mainly founded on this period.

Ethiopia environment

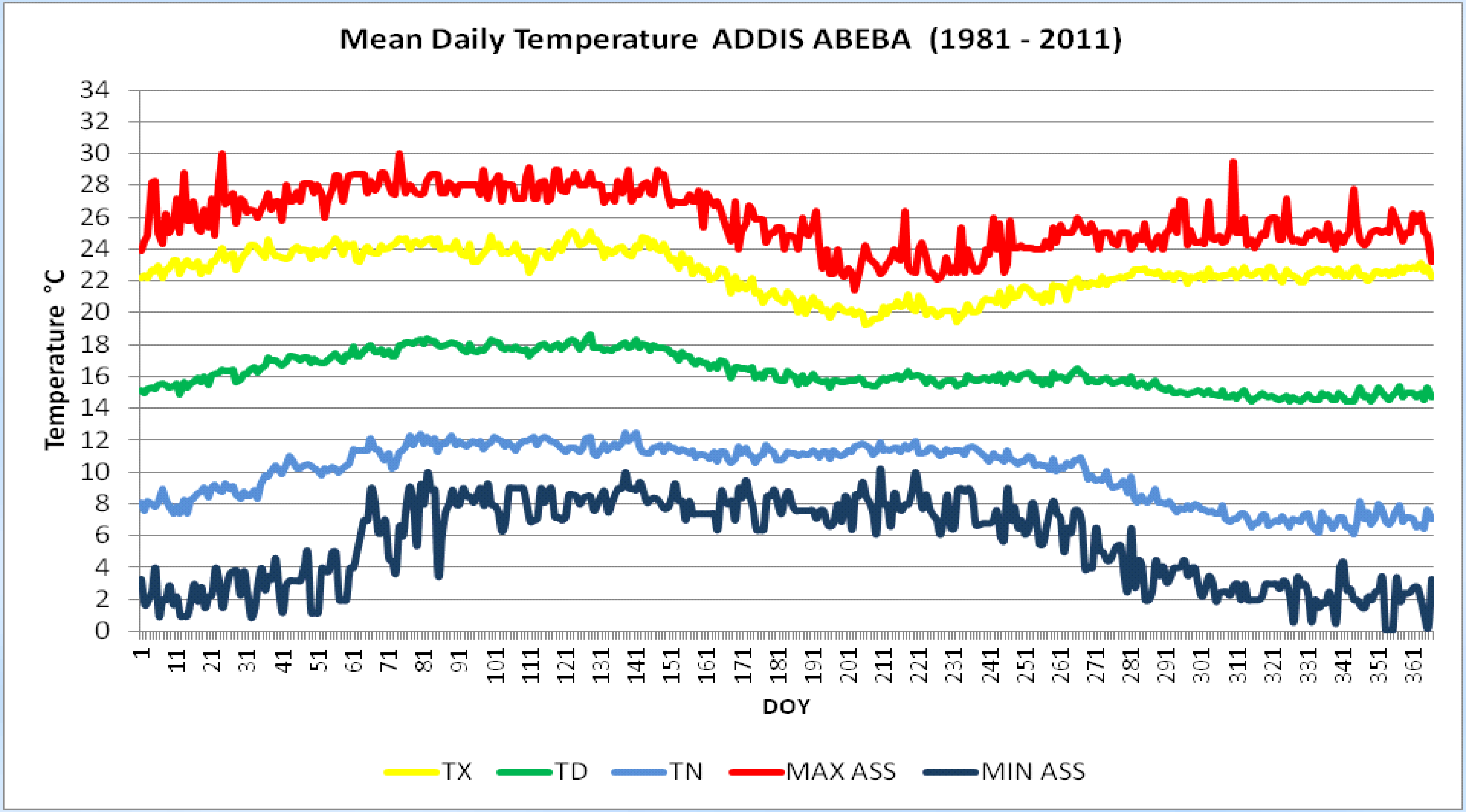
Thermal-pluviometric diagram of Lieth for Adiss Ababa

Climate type:
Koeppen Cwb (mesothermal climate - mild with dry winter).



Three main seasons:
Spring rainy season (march-april): due to the migrating ITCZ
Summer rainy season (june-sept): due to the Indian Ocean monsoon
Winter dry season (october-february): lack of forcings

Temperature daily diagram



A mild climate without thermal extremes (maximum always below 30°C and minimum always above 0°C. **Thermal limitation for pastures is reduced**

Dry season

Cattle grazing - northwest of Addis Ababa (1 march 2008 - G.Cola)

Rainy season

Cattle grazing near Sululta-north of Addis Ababa
(http://www.panoramio.com/photo/55105162)

Rainy season

North Ethiopia (Tigray) - Abergelle bull grazing in the early rainy season (June)
http://www.fao.org/docrep/008/a0070t/a0070t06.htm

Rainy season

North Ethiopia (Tigray) - Abergelle cow grazing in the early rainy season (June)

http://www.fao.org/docrep/008/a0070t/a0070t06.htm

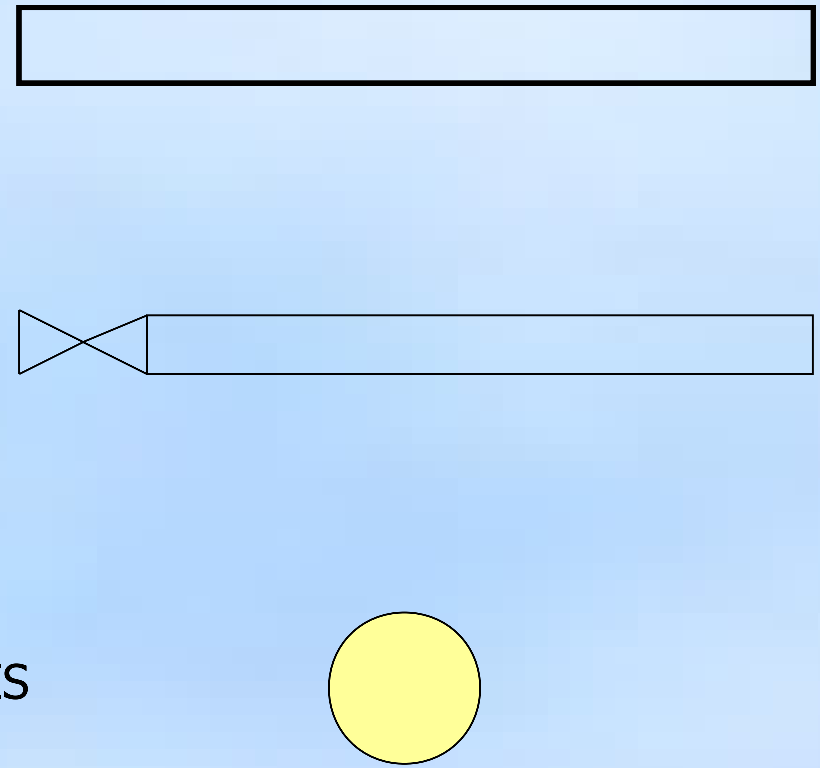
SIM_PP model description

FLOWCHART OF THE MODEL - Symbols

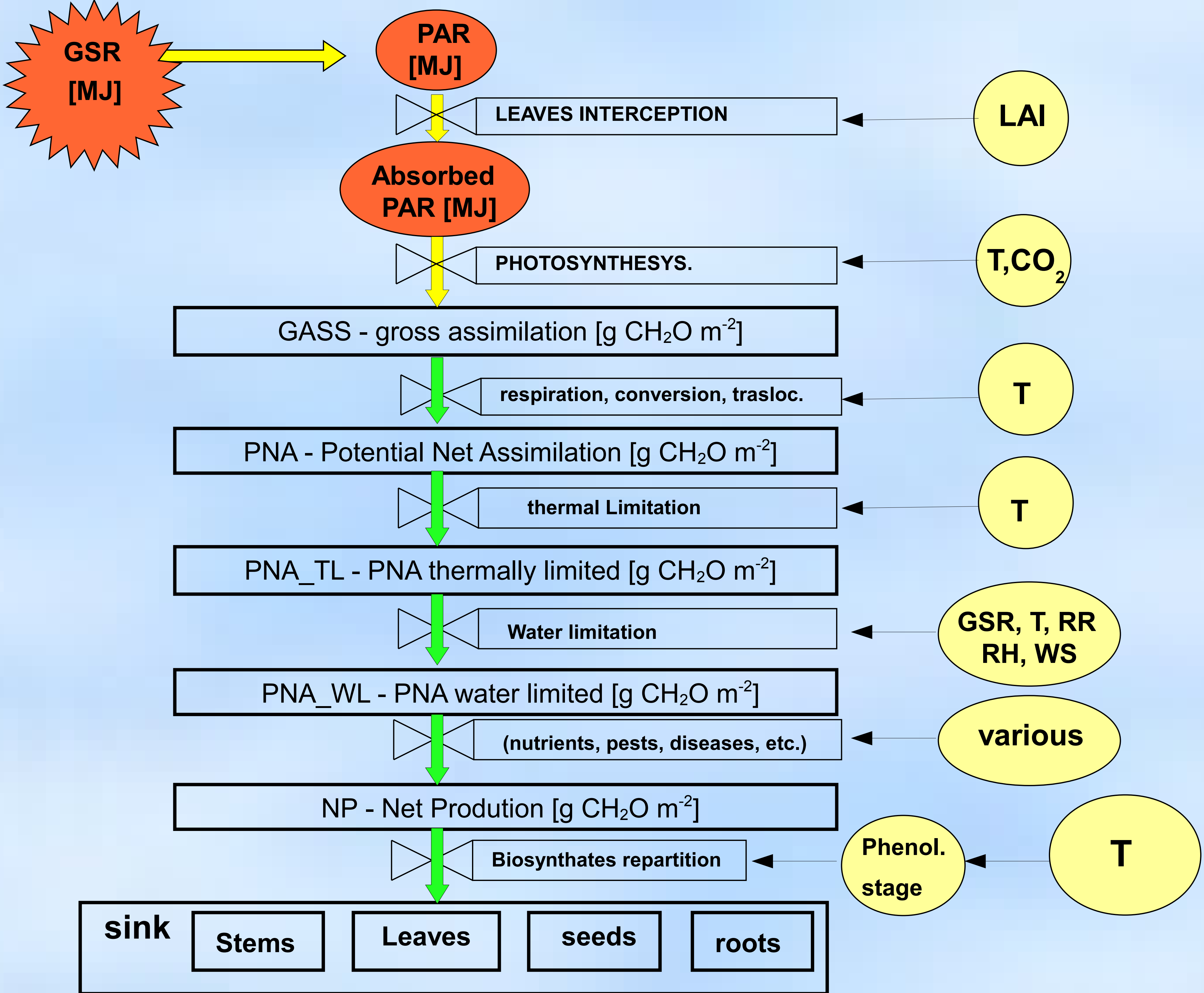
STATE VARIABLES

RATE VARIABLES

DRIVING VARIABLES



Grassland - a generalized physiological model



Main SIM_PP features

Model step: fast loop (horly) and slow loop (daily). The fast loop is applied only to thermal limitation.

Algorithms:
PAR= 50% of the GSR
LAI =obtained applying a specific leaf weight of 1500 g m^{-2} per LAI unit
PAR interception= LAI based Lambert Beer law I=I0*exp(-Ke*LAI)
Photosynthesis: Goundrian and Van Laar model.

Main SIM_PP features

Thermal limitation: a response curve applied to hourly temperatures (cardinal temperatures are Cmin=12°C, Copt=22/28°C, Cmax=35°C)

Water limitation: approached with a water balance based on the mass conservation equation applied to the soil reservoir (AWC=150 mm).

Evapotranspiration: ET0 is calculated with the Hargeaves and Samani equation. ETR obtained applying a crop coefficient obtained from LAI. A suitable response curve is applied to daily water content to obtain water limitation (for shortage or excess).

Final dry matter partition between above and below ground: an Harvest index approach is adopted to subdivide between aerial organs and roots (HI=0.7).

Green matter senescence – a two stages approach

Gradual senescence: is expressed by the index HS (function of mean daily temperature Tm and soil water content WC) used to multiply the daily final production (Romera etal, 2010).

HS=sigma*G*SW

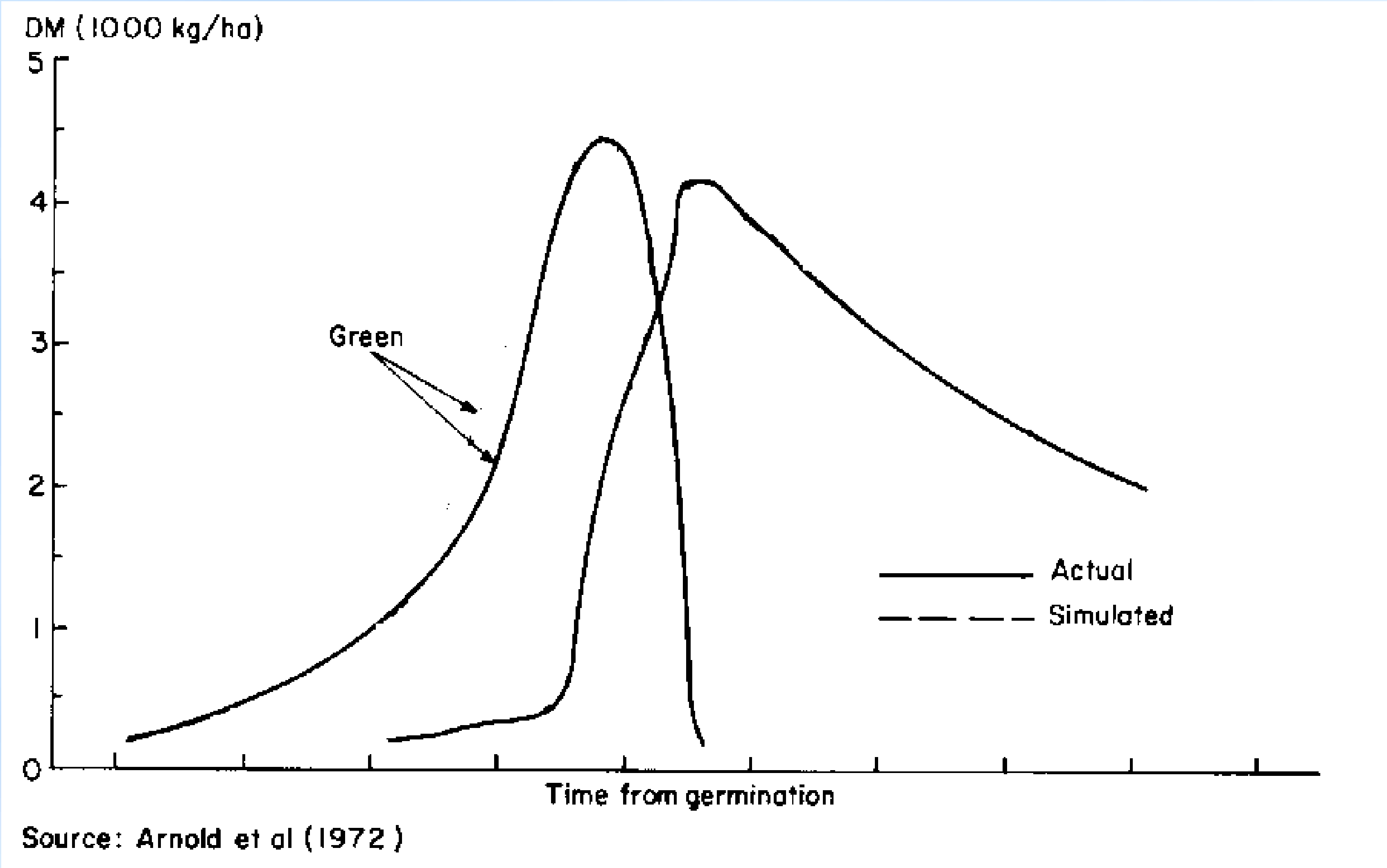
where SW=1 for water content between 1 and 0.2 AWC and grows linearly from 1 to 3 for for water contents between 0.2 and 0 AWC; G=green pasture mass in kg/ha; sigma=(Tm/LLS)*(1-rem) where LLS=mean life of leaves expressed as GDD on 0°C base (LLS=700 GDD) and rem=remobilization coefficient (=0.3)

Acute senescence: is activated when Wilting Point WP is attained (AWC=0). In these conditions the 20% of the green matter is converted in dead matter for each day.

In its turn the 1% of the dead matter disappears daily due to physical (e.g.: wind action) and biological factors (cattle trampling, micro-organisms, etc).

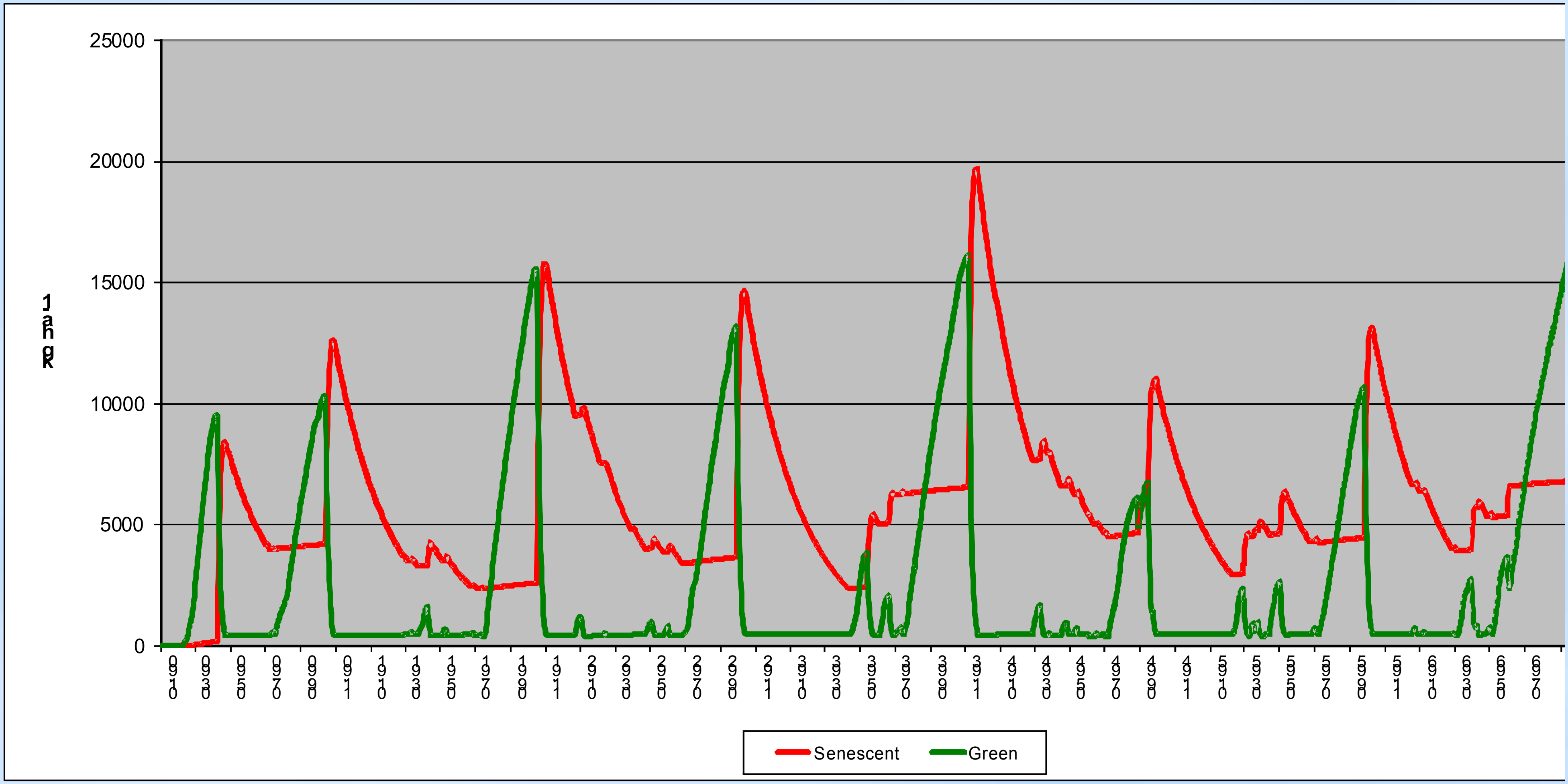
Romera etal, 2010. Improving the McCall herbage growth model, New Zealand J. of Agric. Research, 52:4, 477-494

Green matter senescence – theoretical behaviour



Effects of grazing management on pasture/animal production: use of simulation model.
http://www.ilri.org/InfoServ/Webpub/fulldocs/Modellin/ILCA%27s%20.htm

Green matter senescence – SIM_PP results (1990-1996)



Nitrogen limitation estimate

YEARLY NITROGEN RESTITUTION TO THE SOIL		
Tropical livestock units (TLU)	n ha^{-1}	3
Weight of a TLU (kg)	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

Validation of our approach

parcel	Unfertilized	fertilized	unfertilized vs fertilized (%)
1	6.7	22.5	0.30
2	3.5	19.3	0.18
3	2.8	15.8	0.18
4	4.3	19.2	0.22
5	5.8	20.9	0.28
6	4.3	16.7	0.26
7	3.6	14.5	0.25
8	4.6	17.4	0.26
9	6.6	21.7	0.30
10	3.9	18	0.22
11	3.2	15.2	0.21
12	4.5	18.3	0.25
mean	**4.5**	**18.3**	**0.24**

Result of the trials of Nitrogen fertilization carried out in four locations of Ethiopian highlands (Zewdu T., 2005. Identification of indigenous pasture and the effect of time of harvesting and nitrogen fertilizer in the northwestern Ethiopian highlands, Trop.Sci., 2005, 45, 28-32).

Example of a daily modelization