4th CGMS Expert Meeting (18-19 March 2009) – JRC ISPRA

Set-up of CGMS in Ethiopia and first user experiences

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A. Objective

Adaptation of the European CGMS to an African tropical region and improvement of the model with remote sensing integration or assimilation.

Extract a set of comprehensive crop growth parameters at sub-national level for early forecasting/warning purposes and agricultural productions estimates

B. Context

Activity included into the GLOBAM project (GLOBal Agricultural Monitoring systems by integration of earth observation and modelling techniques – Belgian Science Policy Funded Project)

B. GLOBAM Model selection

Four criteria were used to select the models :

- Model selection is directed by the number of biophysical variables calculated by these approaches that could be compared with RS derived ones.
- Possibility for the selected models to receive and valorise direct remote sensing information instead of intermediate calculated state or output variables. This requests an accessibility to the source codes.
- The selected models should also have ability to work both at (large) parcel and NUTS3 level. It should also work in the 3 different test sites.
- Finally, the model selection also depends on our own experience with process-oriented crop growth models. Indeed the three scientific teams implied in the selection process have a strong experience with the Mars Crop Yield forecasting System

B.1. Model selection : WOFOST (CGMS)

CGMS, the Crop Growth Monitoring System,

- used at European level since 1992.
- based on the photosynthesis process
- all the teams implied in the agrometeorological part of GLOBAM have a strong experience with this model.
- the model has got a calibration platform that allows, in principle, a robust calibration of the model for the three different test sites.

B.2. Possibilities for improving Agromet models

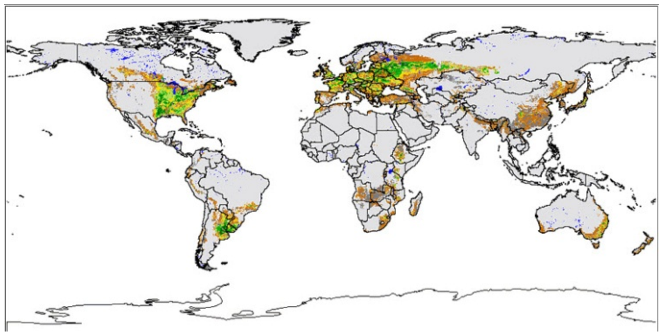
- Improving estimates of static parameter values
- Improving estimates of initial conditions in space and time
- Replacing state variables (LAI, ETa, Biomass) by input variable estimated by RS
- Applying sequential assimilation processes to update crop state variables
- Use spatio-temporal dispersion of RS-derived biophysical variables to produce probabilistic model outputs.

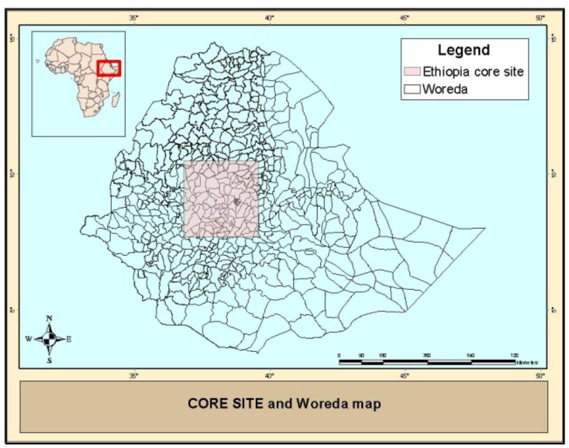
B.3. Model validation

- At parcel level, comparison between field biophysical variables observed and model outputs
- At NUTS 3 level, comparison between official stats figures (if available and reliable) and average values of fields biophysical variables in the same administrative unit.
- Comparison also with operational models running in the study site.

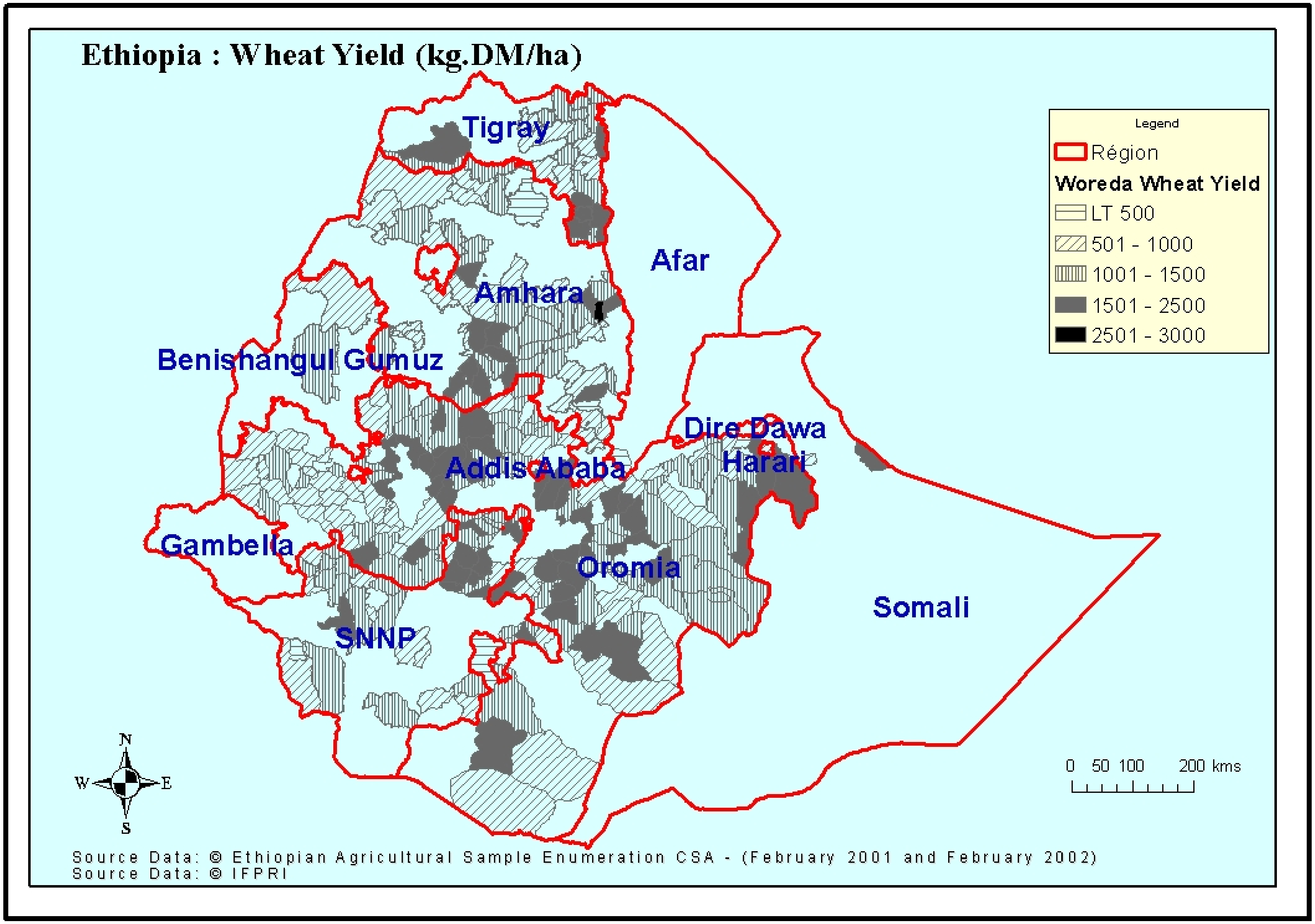
C. Study area

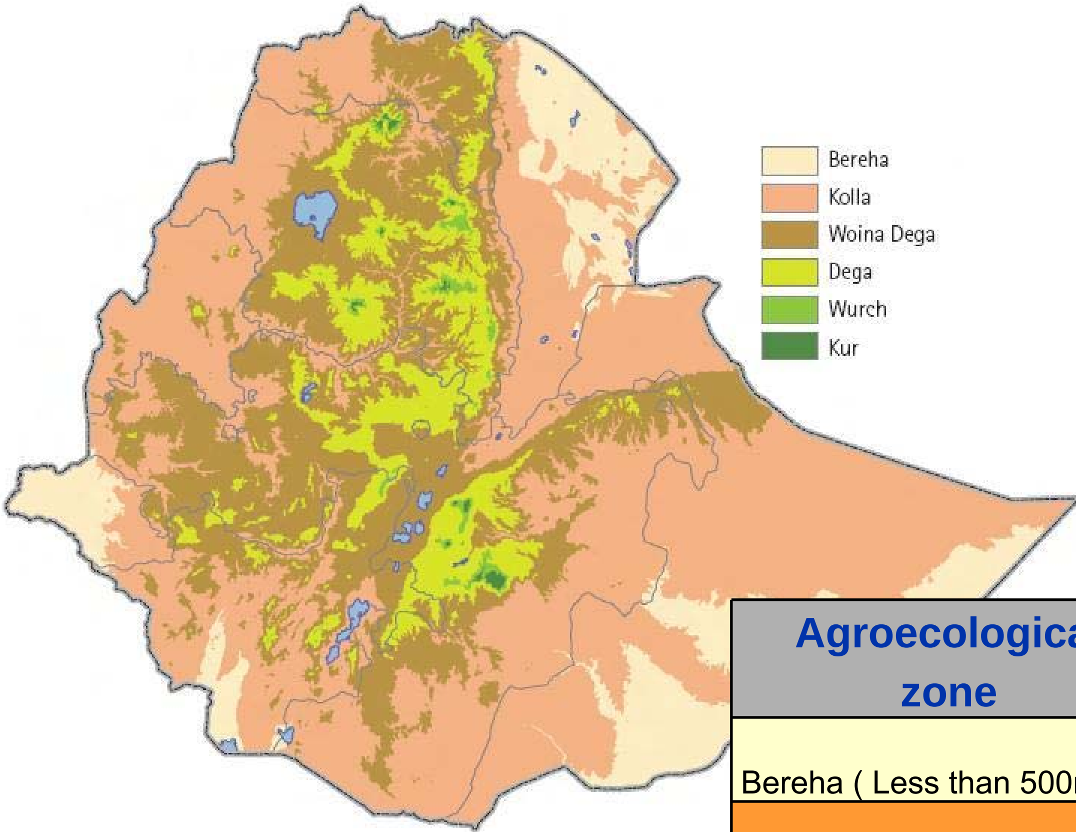
Area: 1 113 380 sq.km
Population: 77 million (2007)
Rural : 85%
Wheat area : 1.3 million ha





C.1. Wheat zone (CSA 2001 census)





Map source : IFPRI Atlas

Agroecological zone	mean temperature (°C)	Annual rainfall (mm)
Bereha (Less than 500m)	28.4 ± 0.1	327.9 ± 17.9
Kolla (500 to 1500 m)	25.5 ± 0.2	555.6 ± 26.8
Woina Dega (1500 -2300m)	21.3 ± 0.3	1310.8 ± 60.8
Dega (2300 to 3200 m)	19.0 ± 0.4	1655.7 ± 83.0
Wurch (3200 to 3700)	19.3 ± 1.2	1217.9 ± 214.5

D. METHODOLOGY

D.1 Crop growth model

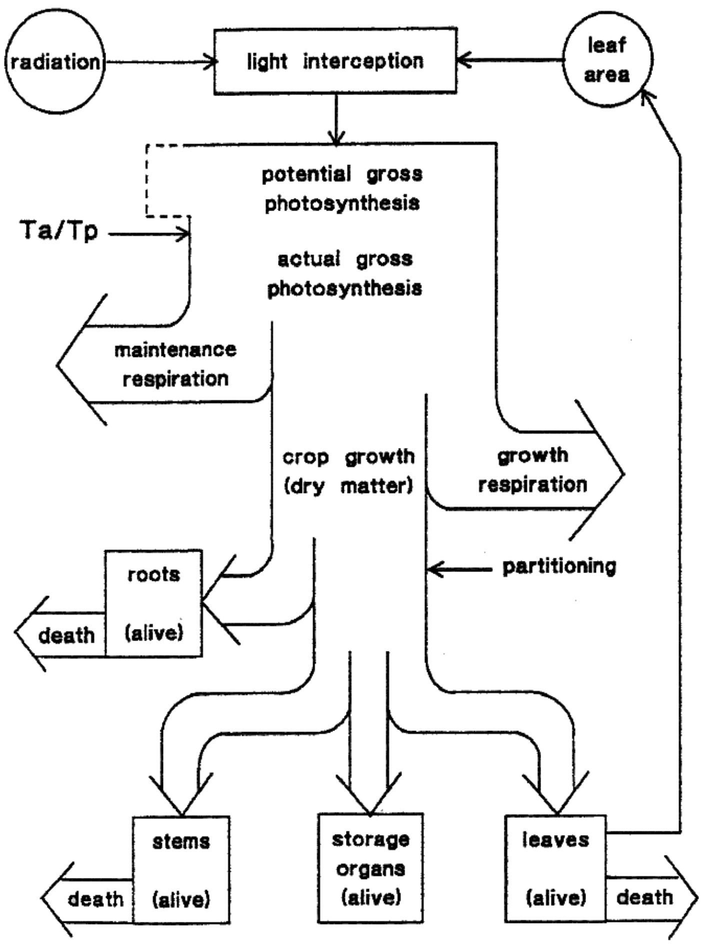
WOFOST crop simulation model (van Diepen, Rappold, Wolf, and van Keulen, 1989)

CGMS applications : CGMS version 9.2

CGMS has been chosen for :

- the database framework for model inputs and outputs;
- the facility for aggregation at differents administrative level;
- the facility to link with GIS and remote sensing data
- availability of differents complementary tools (CALPLAT, SANPLAT, CGMS-Statool, Pywofost)

D.2. WOFOST Crop Model

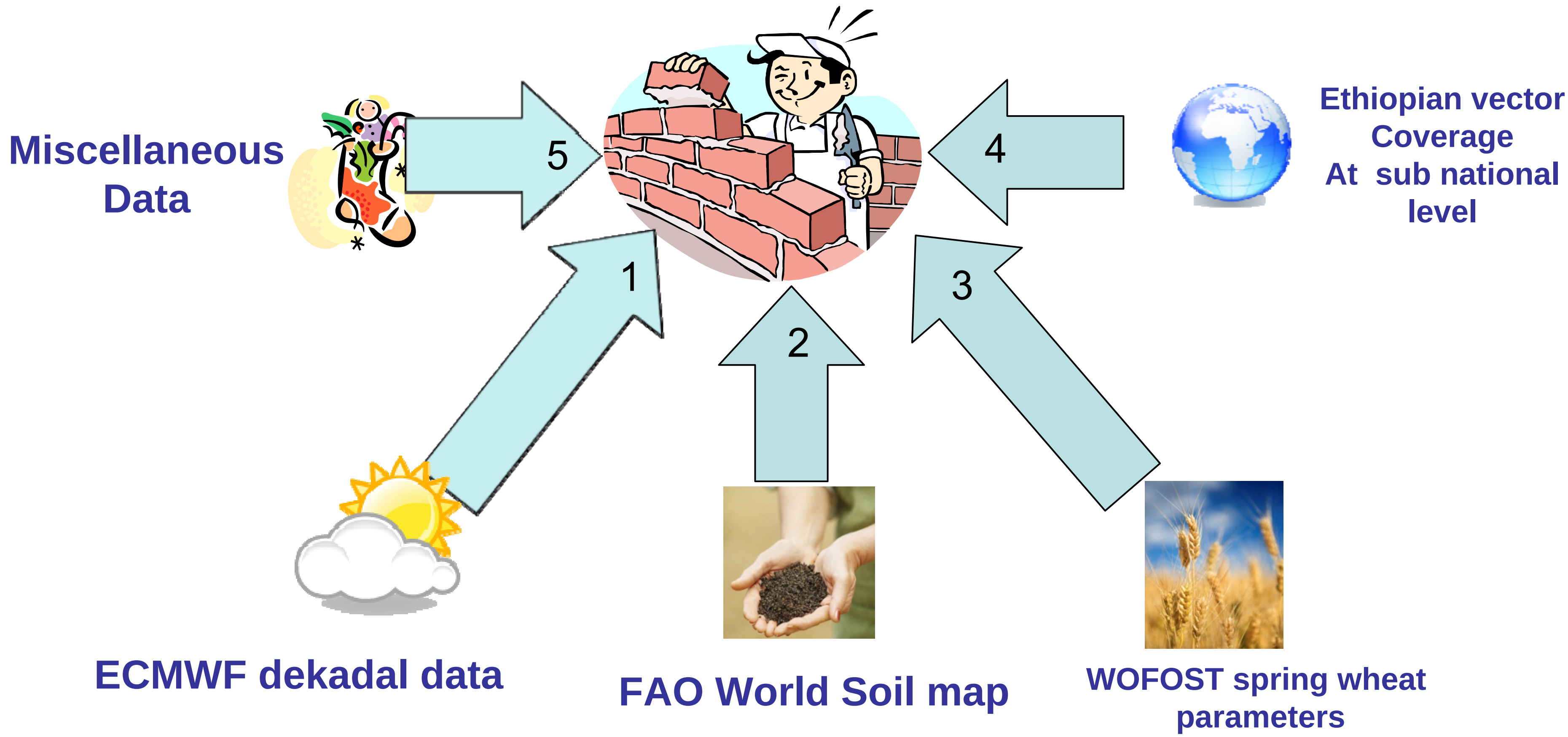


- conversion of daily weather data into daily growth of crop biomass

- many crops: Wheat, Barley, Maize, Rice, Sunflower, Rapeseed, Sugar Beet, Potato, Field Beans/Peas, Soy Beans, Pastures (Rye Grass)

- Energy balance, water availability, dry matter partitioning

D.3. Model input



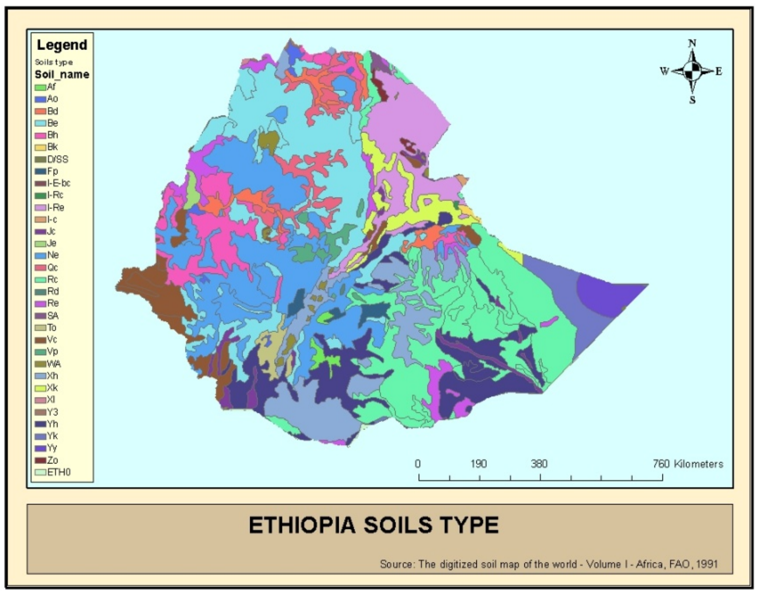
D.3.1. Weather data

- Source : FOODSEC Climatic database (CID portal)
- Parameters :
  - average temperature
  - maximum temperature
  - minimum temperature
  - precipitation sum
  - evapo-transpiration sum (ES0, bare soil)
  - evapo-transpiration sum (E0, over water)
  - evapo-transpiration sum (ET0, Penman-Monteith)
  - global radiation sum
- Spatial resolution : 0.5 degree grid (≈ 50 * 50 kms)
- Temporal resolution : 10-daily
- Temporal windows used : 1997 to 2007
- Others parameters : wind speed and vapour pressure **(FAO new-loclim database at monthly time scale)**

D.3.2. Soil database

- **Source : FAO-UNESCO soil database and map (Africa soils V.1)**
  Scale = 1:5000 000

- **Pedotranfer rule : Baruth et al (2006) and Altera Water holding capacity table**
  - **Soil database elements: 39 soil physical group**
    288 soils units
    26 major soil association



- **Other soil database :**
  Harmonized World soil database
  [HWSD, (Nachtergaele, 2008)]

D.3.3. CROP Parameters

- **Crop parameters :** Wofost spring wheat parameters provided by ALTERRA

- **Crop data**

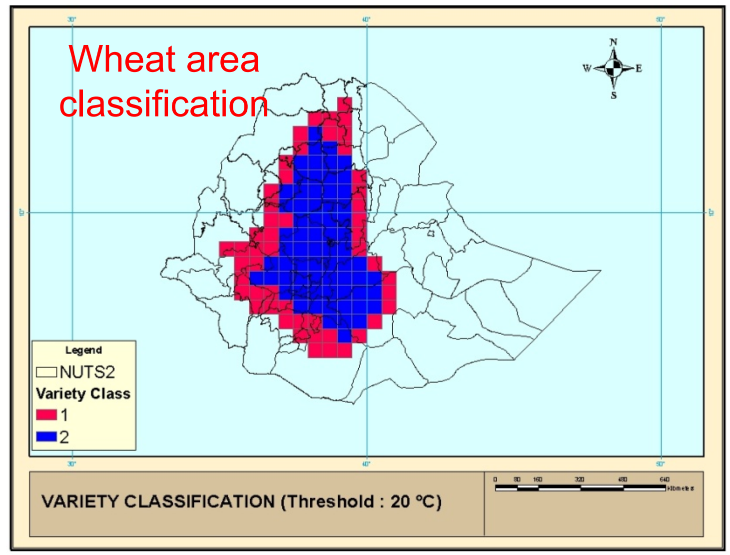
  - Phenology (sowing, anthesis, maturity) : Ethiopia NMA census

    Sowing date : June
    harvest date : October

  - TSUM1 and TSUM2 calculation based on climatic data clustering

TSUM1 and TSUM2 values and coefficient of variation

Variety	TSUM1		TSUM2	
1 20°<T mean < 22°	1187	16%	1212	13%
2 15°<T mean < 20°	1041	13%	1071	11%



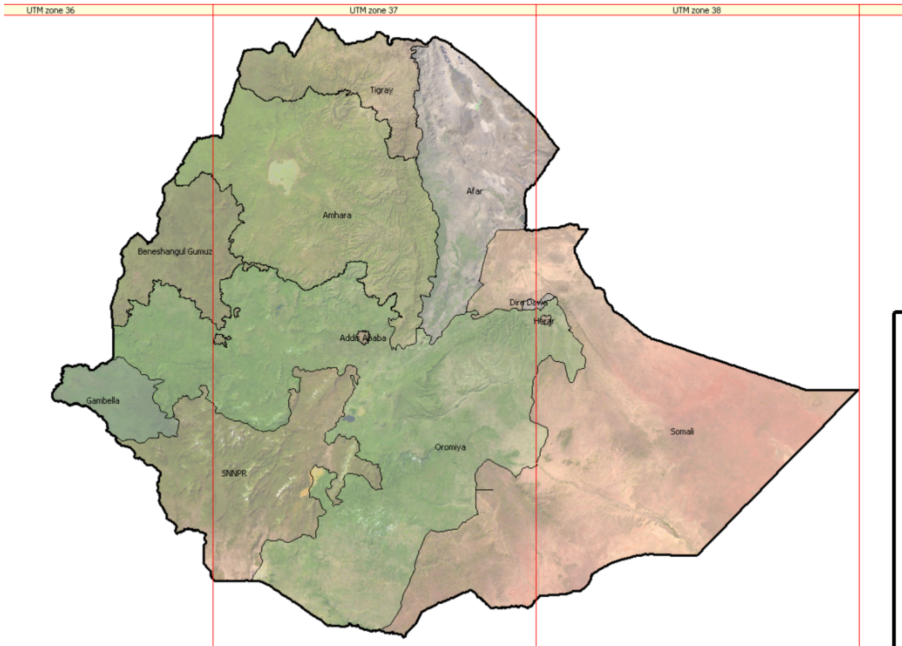
D.3. Model input

D.3.4. Ethiopia NUTS

NUTS LEVEL for CGMS	Ethiopia	Administrative Level	Number
0	Regions	1	9
1	Zones	2	68
2	Woreda	3	≈550

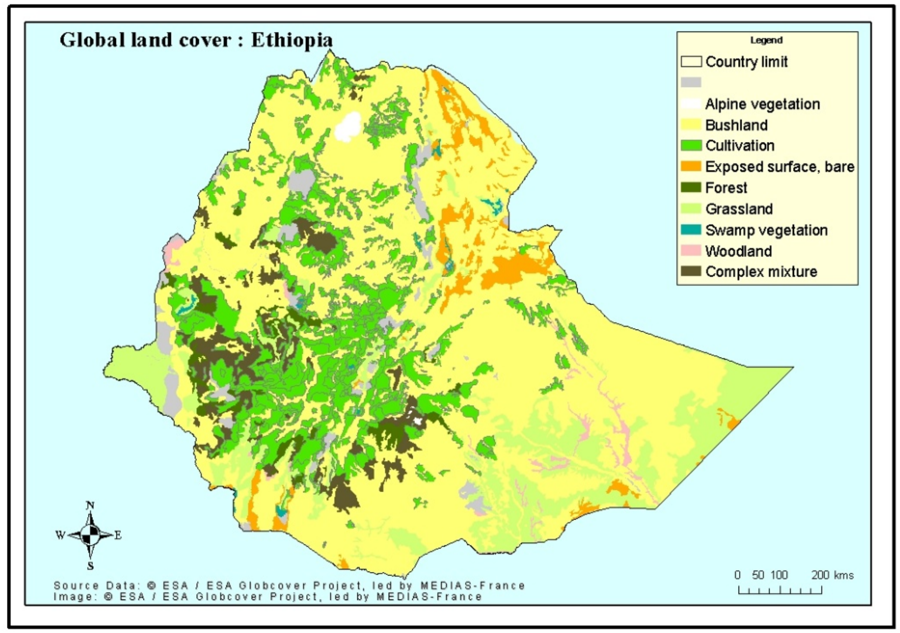
D.3. Model input

D.3.5. Ethiopia NUTS 0 and 1 maps



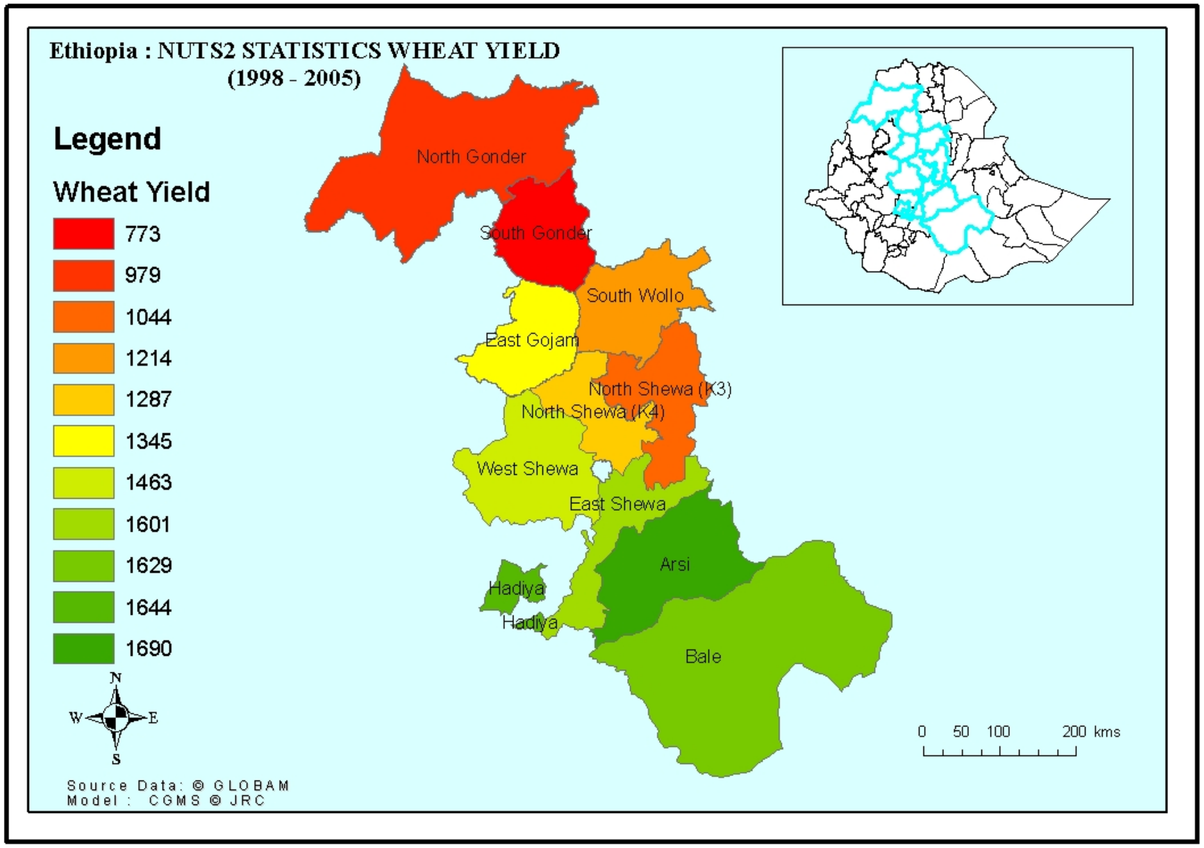
D.4. Miscellanous data

- GLOBCOVER image : Check land suitability
- Official statistics yields : 1997 to 2005 for Zone Level
- Official statistics yield, area : 2001 CSA census for Woreda level



D.4. Miscellanous data

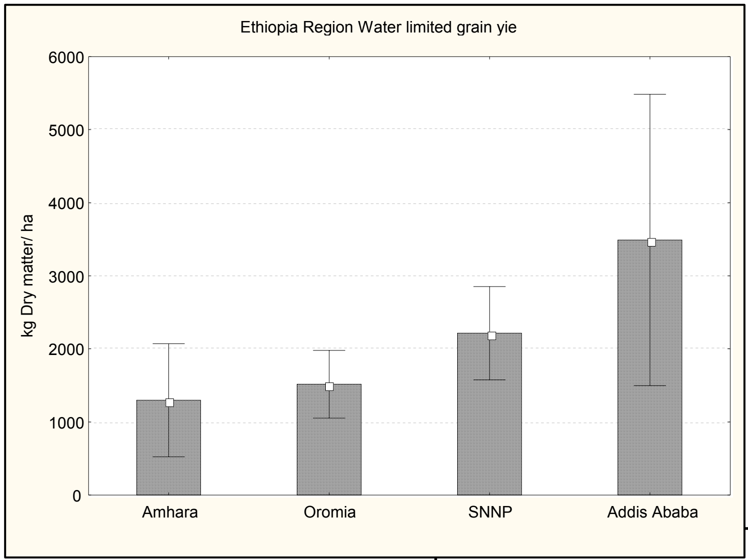
Official statistics: wheat Yield (kg / ha)



Zone	Mean	C.Interval
Arsi	1690	243
Hadiya	1644	139
Bale	1629	203
East Shewa	1601	117
West Shewa	1494	221
South West Shewa	1431	173
East Gojam	1346	179
North Shewa	1287	226
South Wello	1214	184
North West Shewa	1045	156
North Gonder	979	218
South Gonder	773	113
Mean	1345	142

E. RESULTS

E.1. Region level

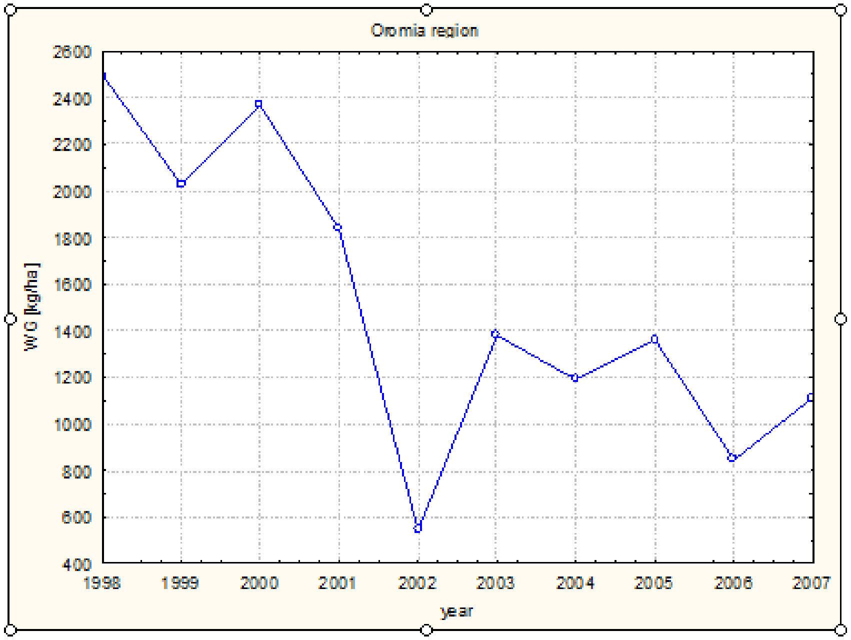


Except Addis Ababa where no real agriculture exists, CGMS water limited grain yield reaches the same level of yield as observed in official statistics and other models (CERES) at regions level

Regions	Potential Biomass	Potential grain yield	Water limited biomass	Water limited grain yield
Addis Ababa	16594 ± 535	8740 ± 174	9051 ± 1,404	3490 ± 881
Amhara	14127 ± 315	6895 ± 144	5275 ± 704	1298 ± 342
Oromia	14382 ± 496	7493 ± 243	5406 ± 343	1517 ± 205
SNNP	15930 ± 415	8271 ± 196	7885 ± 507	2216 ± 282
All	**15258 ± 272**	**7850 ± 146**	**6904 ± 481**	**2130 ± 278**

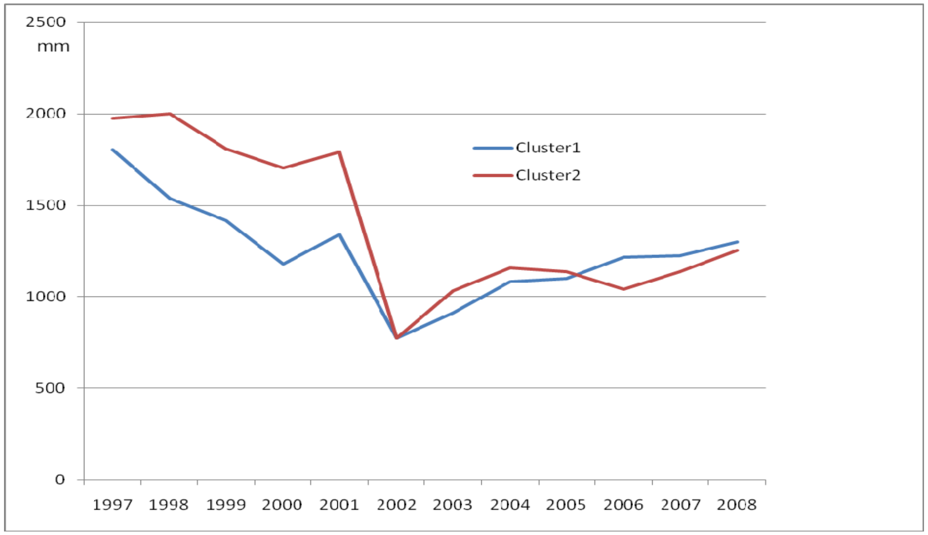
E.1. Region level

Oromia region water limited grain yield



Weak link with official stats data !

ECMWF rainfall data as a probable main reason of this discrepancy



E.2. Zone level

Regression analyses per region over all years

Simple linear regression between official statistics and CGMS outputs are significant in 4 zones over 12, and water limited grain and biomass, potential grain yield and biomass explain 20 to 58% of the variability of official statistics.

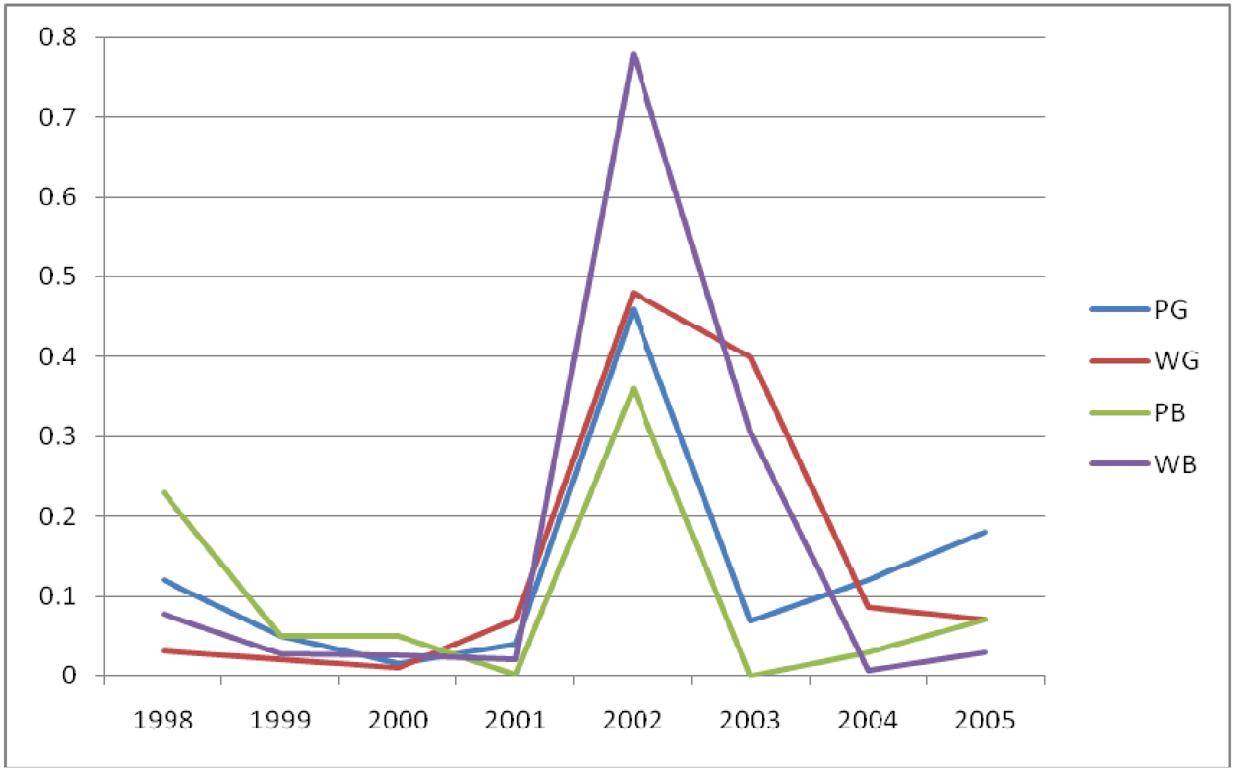
NUTS NAME	Model	RMSE	R^2	Intercept	slope	p
Arsi	WB	246	0.58	543	0.26	0.029
	WG	272	0.48	814	0.9	0.056
North Gonder	WB	234	0.53	581	0.08	0.042
South Gonder	WG	114	0.58	924	-0.1	0.029
West Shewa	PB	259	0.2	-943	0.15	0.087
	PG	250	0.25	-2662	0.48	0.049
	WB	215	0.45	2062	-0.06	0.005
	WG	188	0.58	1852	-0.11	0.001

E.2. Zone level

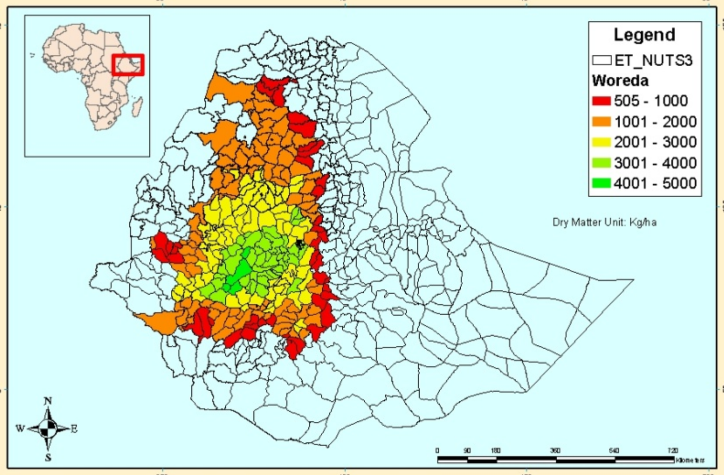
Regression analyses for one year over all regions

High R-square has been obtained with spatial trend analysis in 2002.

R-Square



E.3.Woreda level



NUTS3 (Woreda) Water limited grain yield (1998-2007)

At woreda level , only one year (2001) figures has been compared and the variability observed in water limited grain and biomass are greater than what is observed in official statistics and the spatial concordance rank percentage is only 40%.

	N	Mean±s		CV	Median
W.L. Biomass	209	6885	± 263	55%	8146
WL grain yield	209	2068	± 113	79%	2081
P. Biomass	209	12932	± 291	32%	13887
P. Grain yield	209	6579	± 159	35%	6973
Statistics yield	209	1245	± 28	32%	1206

F. Preliminary analysis

1. Trend observed in CGMS outputs times series is different from official statistics trend at national and zone levels.
2. CGMS outputs trends are very similar to ECMWF rainfall trend
3. Spatial ranks show a high correspondence between CGMS outputs and Official statistics in 2002, which is the year with lower total rainfall, statistics yield and CGMS outputs
4. A comprehensive database has been built for wheat in Ethiopia

G. Next step

Model improvements by:

- Checking rainfall data by using an interpolated source from raingauge data
- Sensitivity analysis to refine phenology spatial distribution and TSUM1,TSUM2 calculation
- Replace the soil data with the existing 1:1.000.000 scale data from SOTER database
- Combine R.S. data with CGMS outputs
- Compare CGMS outputs with other well-established models (AMS)

H. Conclusions and perspectives

- First trial of CGMS in Ethiopia : possible but data accessibility remains a key problem

- CGMS framework offers for the African region an interesting tool to build historical databases for crop growth indicators and yield database. This database can improve identification of vulnerable zone to enhance early warning systems assessments.

- Model can be improved by updating parameters with actual field data and remote sensing data

- Wheat, millet, sorghum and maize, the most important crops in food insecure African regions, have been tested in Wofost and this experience should be used through CGMS tools to serve as crop monitoring tools also for food security and early warning purposes