JOINT RESEARCH CENTRE
EUROPEAN COMMISSION

Crop Monitoring in Eastern Africa

Yield forecasting methodology

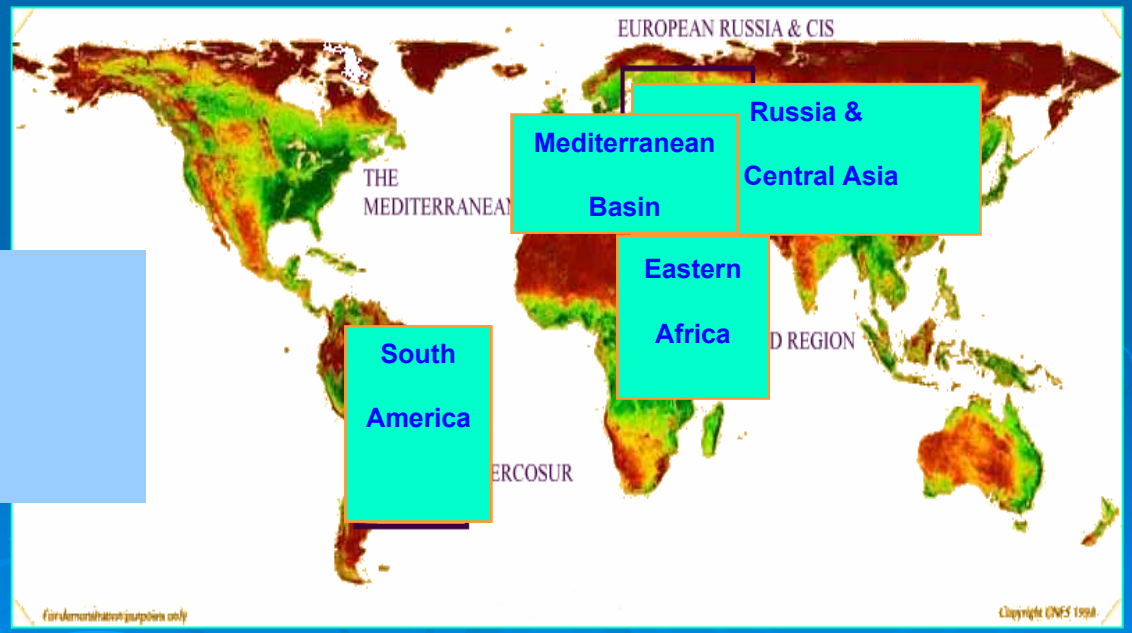
O. Rojas

MARS

MARS-FOODAID

➔ *To support the EU Food Aid and Food Security Policy (DG EuropeAid)*

➔ *Crop monitoring and Forecasting for Food Security*



4 Pilots areas

Intergovernmental Authority on Development, IGAD-Sub region

- *Area of 5.2 million square km with a total population of more than 160 million people.*
- *One of the most FOOD insecure regions due to recurrent severe droughts, coupled with rampant insecurity and other natural and man made disasters*

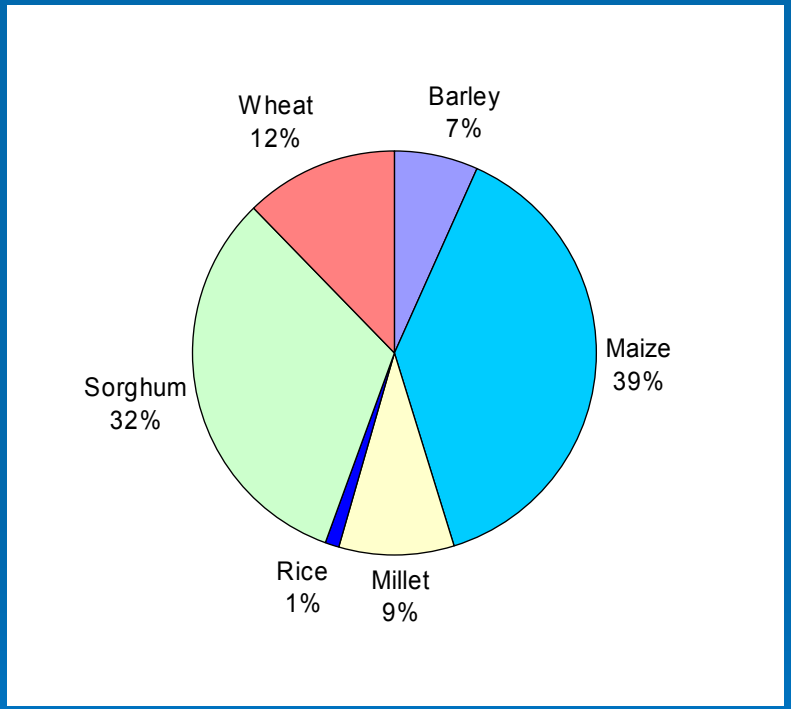
Table 1. Physiographic and Demographic Data of IGAD States

Country	Population Millions	Population Growth (annual in %)	Area (Km2)	GNP/ Inhab. (US$)	Rural Pop. (%)
Djibouti	0.6	4	23,200	880	16.7
Eritrea	4.1	2.7	117,600	170	81.3
Ethiopia	64.3	3	1,100,000	100	82.4
Kenya	30.1	3.6	580,400	350	66.9
Somalia	8.8	1.6	637,760	110	72.5
Sudan	31.1	2.9	2,500,000	310	63.9
Uganda	22.2	3.5	241,000	300	85.8
TOTAL	**161.2**	**Av. 2.5**	**5,199,960**	**Av. 317**	**Av. 67**

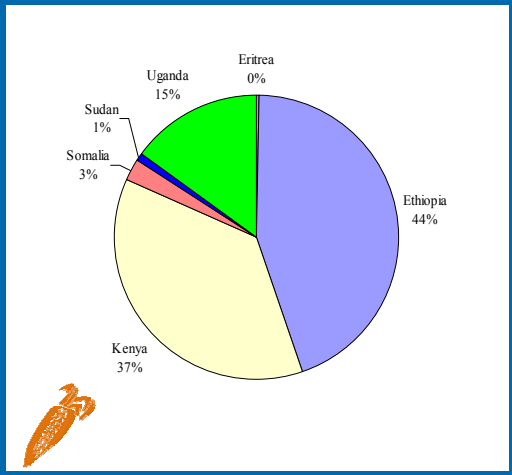
Source: The World Development Indicators Database of the World Bank as of April 2002

IGAD Cereal Production

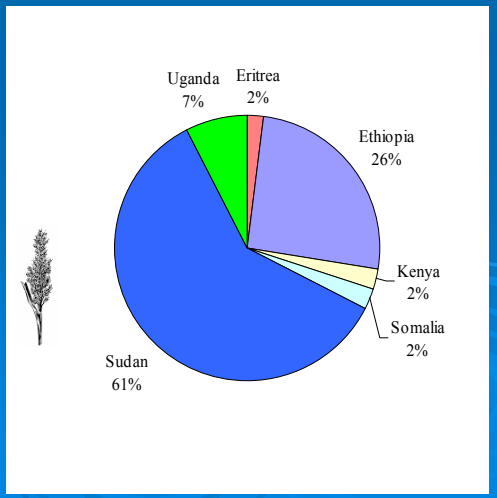
Cereals



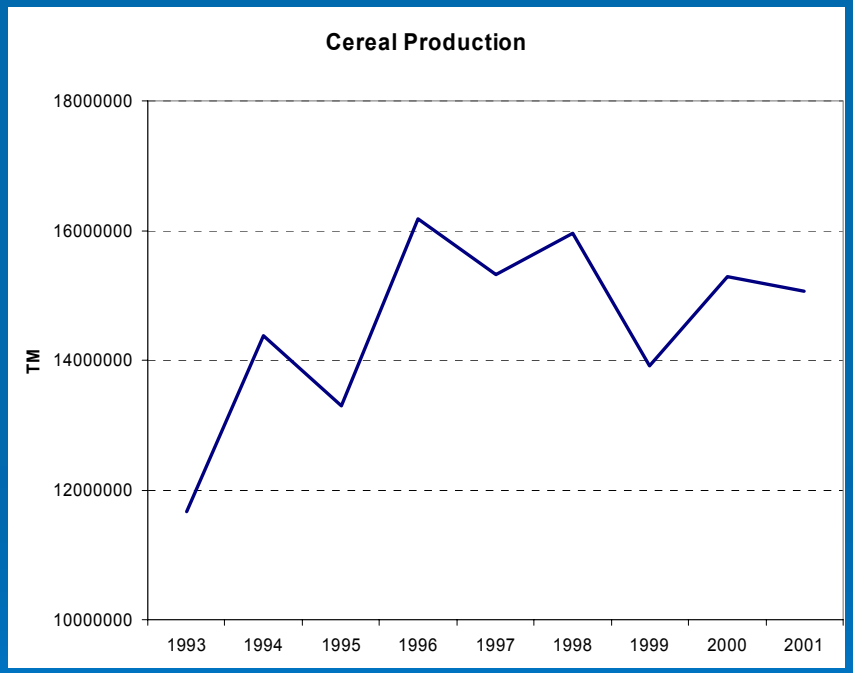
Maize

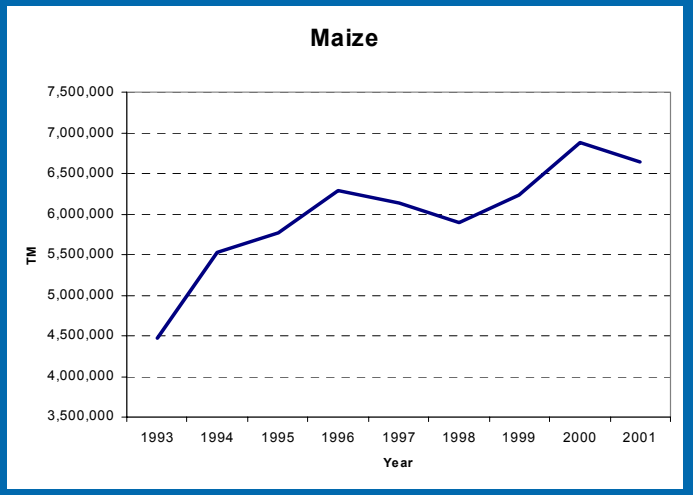


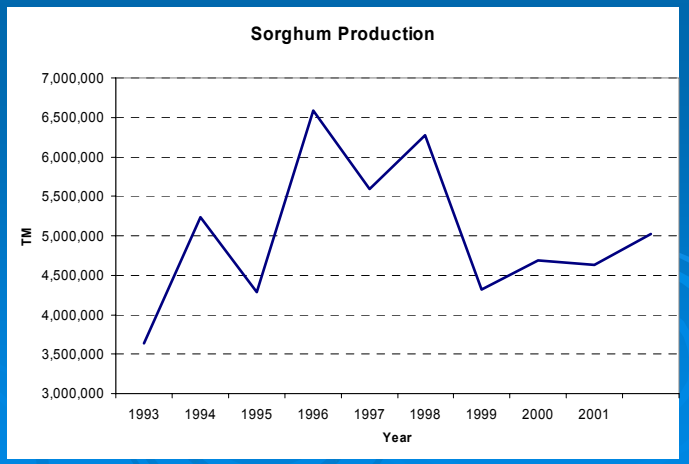
Sorghum



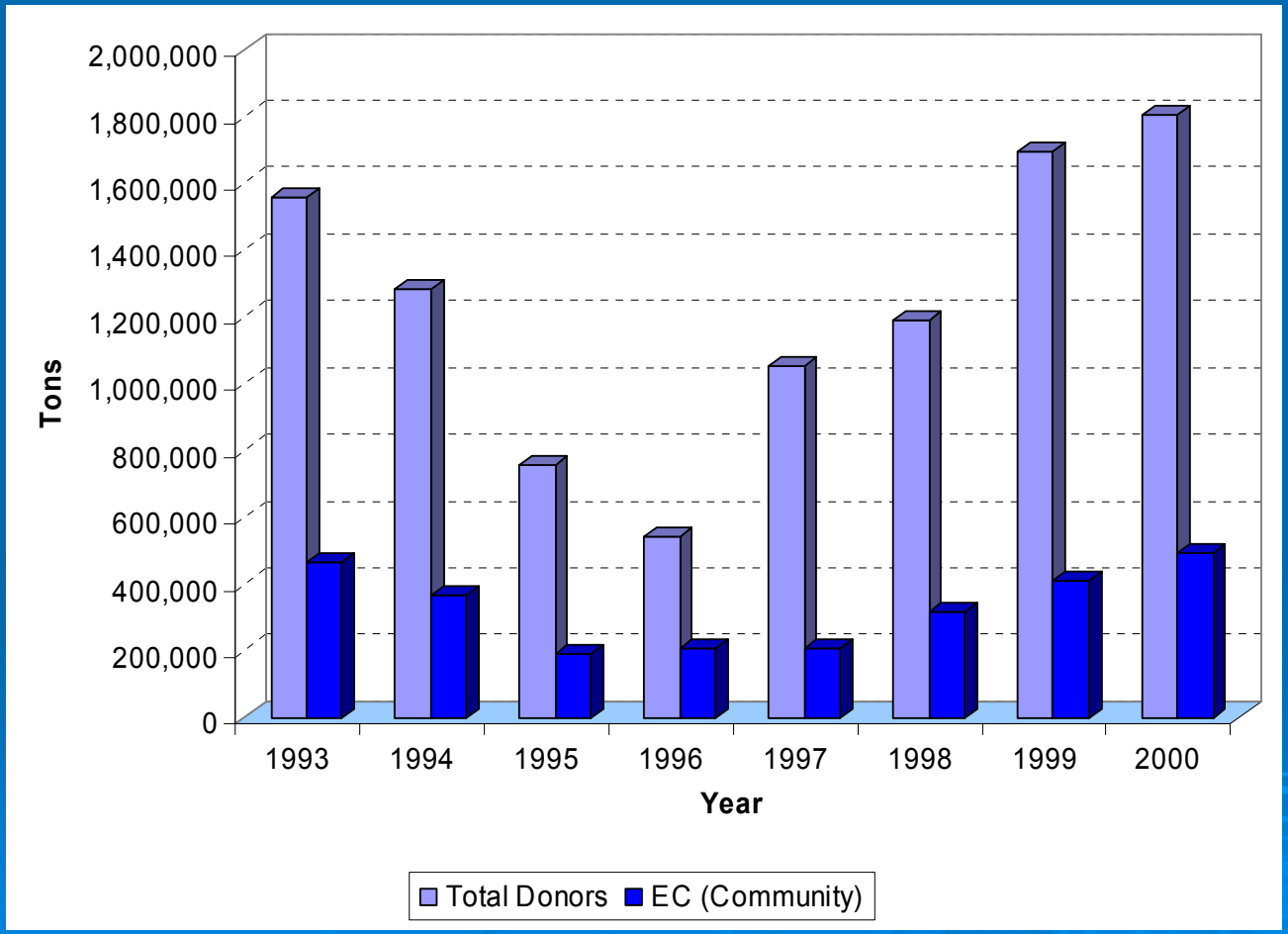
Cereal production





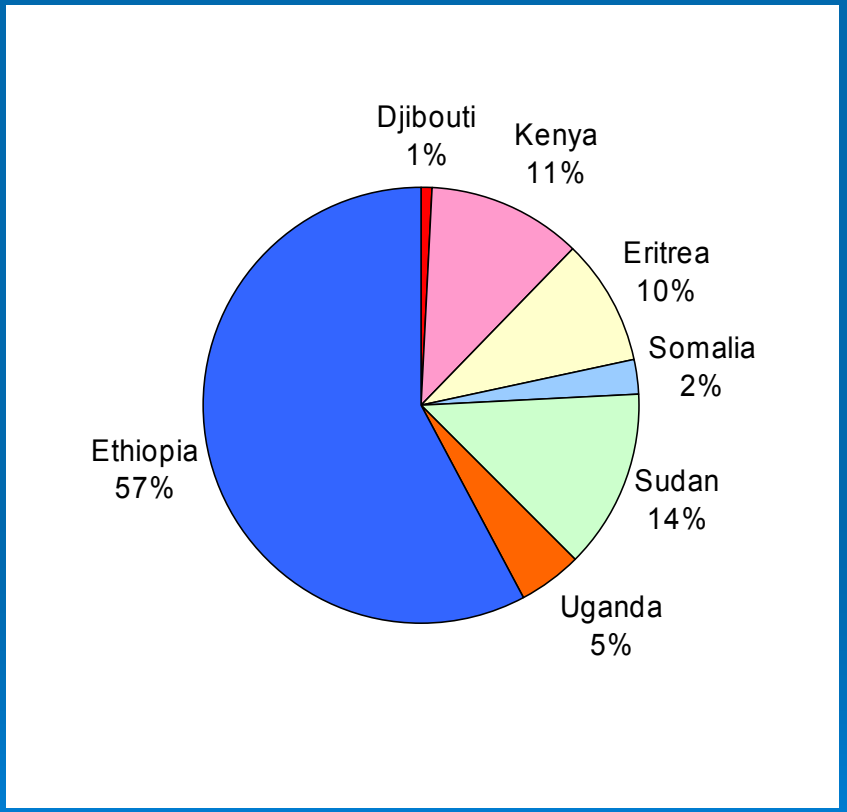


Cereal donation to IGAD

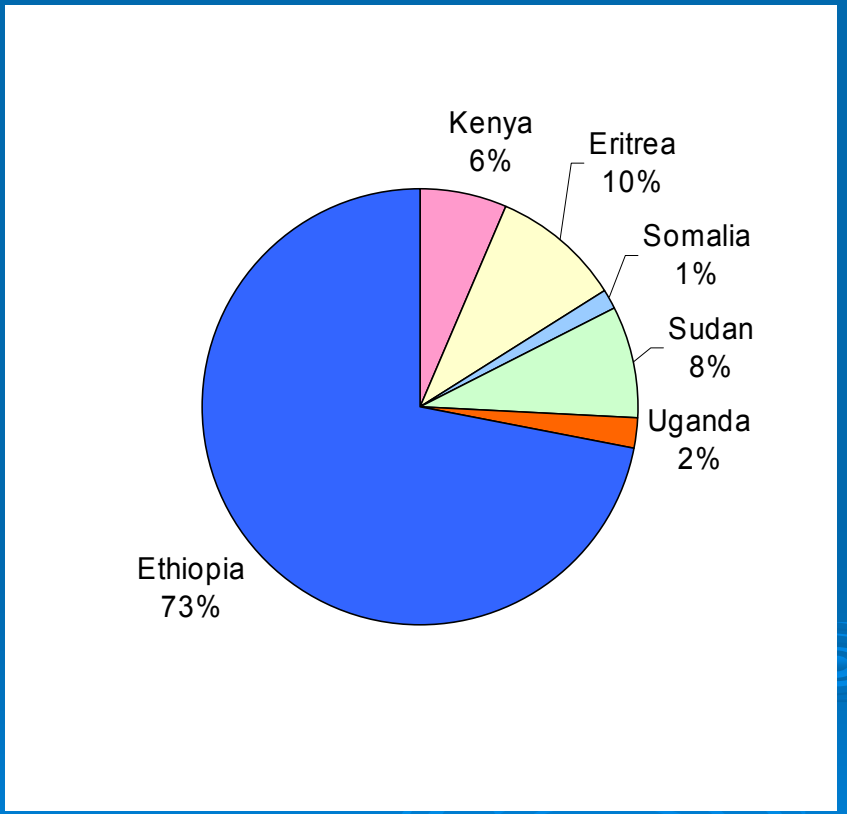


Cereal donation by country

International Community

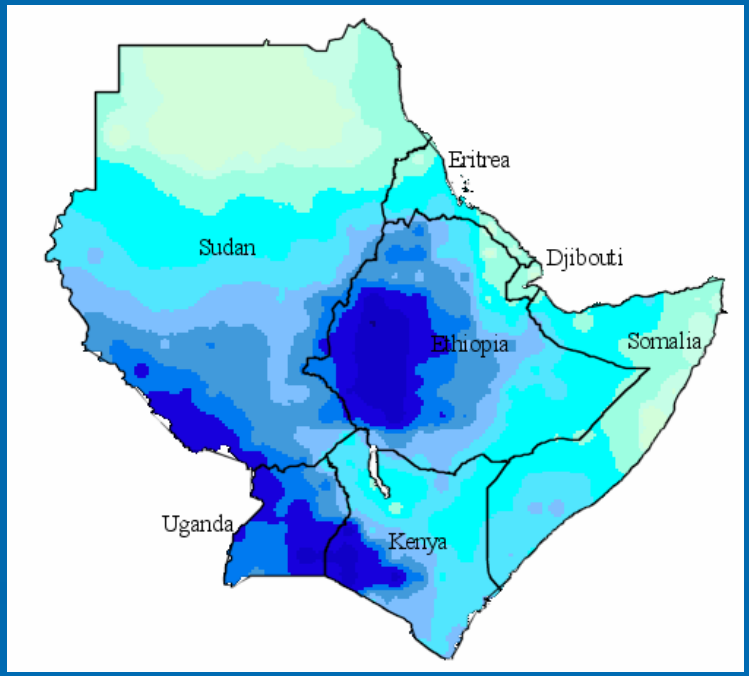


European Community

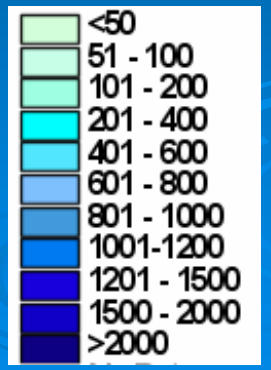


Physical and Agronomic Information

- *bi-modal distribution of the rainfall giving the opportunity to have two crop seasons per year.*
- *The climate variability goes from desert conditions to humid conditions in the highlands*
- *IGADD countries are not homogenous from the agro-ecological point of view; this implies a high temporal variability in crop seasons.*
- *Therefore it is rel;atively complex to monitor one crop at the same time for the whole region*

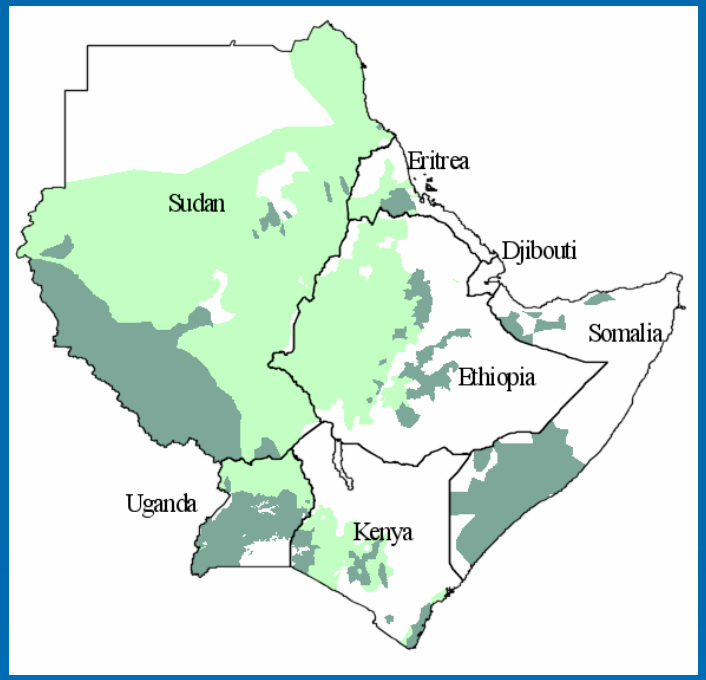


Annual Rainfall in mm

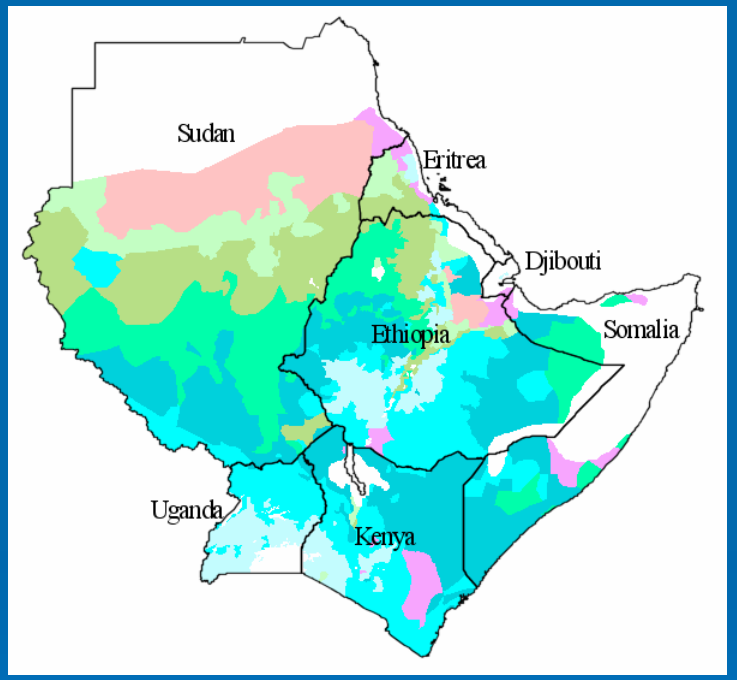


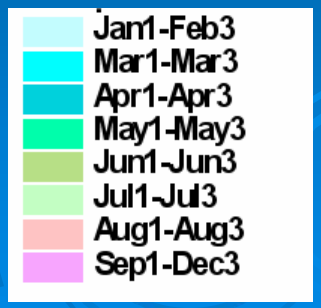
- *Eritrea: millet, maize, sorghum, wheat, barley and teff*
- *Ethiopia: millet, maize, sorghum, wheat, barley and teff*
- *Sudan: millet, rice and sorghum*
- *Somalia: maize, sorghum and rice*
- *Kenya: millet, maize, sorghum, wheat, barley and rice*
- *Uganda: millet, maize, rice, beans and sorghum*

Physical and Agronomic Information



Planting





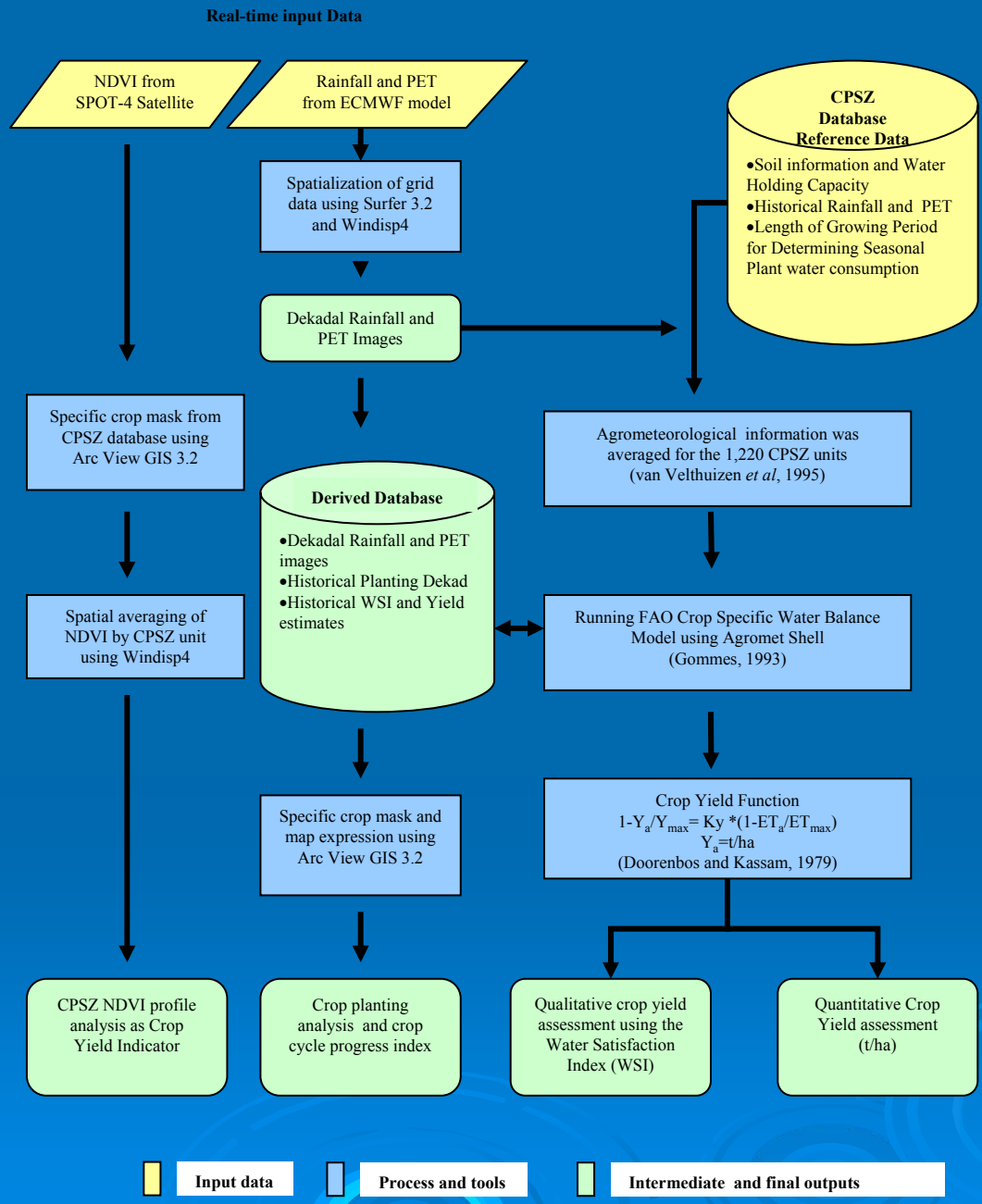
Model selection for Eastern Africa

- The main limiting factor is WATER
- The FAO Water balance model, already tested, is proven to be reliable in semiarid conditions
- It is adapted to available input data in Eastern Africa
- It is disseminated and used all over the region
- The focus is on areas of production

What infrastructure is there in the region?

- There is no a formal structure to monitor the region as there is in Southern Africa (SADC) or in the Sahel (AGRHYMET)

- There is ADDS (Africa Data Dissemination Service) to support FEWS, produced by USGS-EROS-Data Center


Real-time input Data
NDVI from SPOT-4 Satellite
Rainfall and PET from ECMWF model
Spatialization of grid data using Surfer 3.2 and Windisp4
Dekadal Rainfall and PET Images
CPSZ Database Reference Data
•Soil information and Water Holding Capacity
•Historical Rainfall and PET
•Length of Growing Period for Determining Seasonal Plant water consumption
Specific crop mask from CPSZ database using Arc View GIS 3.2
Agrometeorological information was averaged for the 1,220 CPSZ units (van Velthuizen et al, 1995)
Derived Database
•Dekadal Rainfall and PET images
•Historical Planting Dekad
•Historical WSI and Yield estimates
Spatial averaging of NDVI by CPSZ unit using Windisp4
Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)
Specific crop mask and map expression using Arc View GIS 3.2
Crop Yield Function
1-Ya/Ymax= Ky *(1-ETa/ETmax)
Ya=t/ha
(Doorenbos and Kassam, 1979)
CPSZ NDVI profile analysis as Crop Yield Indicator
Crop planting analysis and crop cycle progress index
Qualitative crop yield assessment using the Water Satisfaction Index (WSI)
Quantitative Crop Yield assessment (t/ha)
Input data
Process and tools
Intermediate and final outputs

CPSZ Database Reference Data

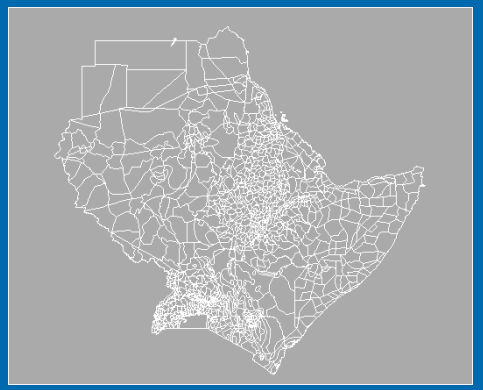
- Historical Rainfall and PET
- Length of Growing Period for Determining Seasonal Plant water consumption
- Soil information and Water Holding Capacity

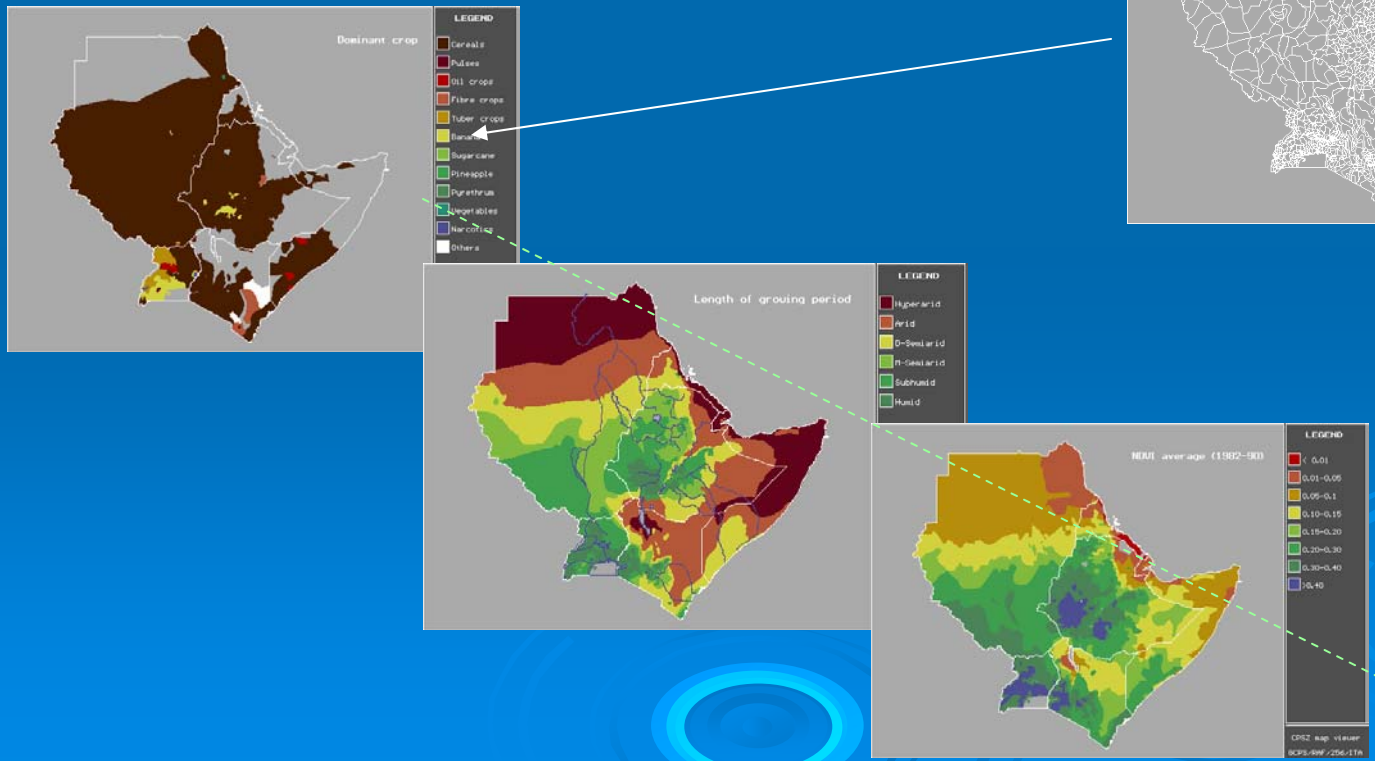
CPSZ Database

By:

Harry van Velthuizen, Luc Verelst and Paolo Santacroce,1995

- 1,220 homogeneous map units which correspond to administrative units, or subdivisions thereof whenever steep ecological gradients occur.





CPSZ Database Reference Data

- Historical Rainfall and PET
- Length of Growing Period for Determining Seasonal Plant water consumption
- Soil information and Water Holding Capacity

CPSZ Database

Table 1. Data availability and reliability

	Djibouti		Eritrea		Ethiopia		Kenya		Somalia		Sudan		Uganda	
	A	R	A	R	A	R	A	R	A	R	A	R	A	R
Crop occurrence data	-	g	+	m	+ +	g	+	m	-	p	+	m	+	m
Physical environment data	+ +	g	+ +	g	+ +	g	+ +	g	+ +	g	+ +	g	+ +	g
Agronomic data	-	p	+	m	+ +	g	+	m	-	p	+	m	+	m
Livestock	-	p	+	m	+	m	+	m	-	p	+	m	+	m
Environmental hazard data	--	n.a.	-	m	+	m	-	m	--	n.a.	+	m	+	m
Pest and disease hazard data	--	n.a.	-	m	+	m	+	m	--	n.a.	+	m	+	m

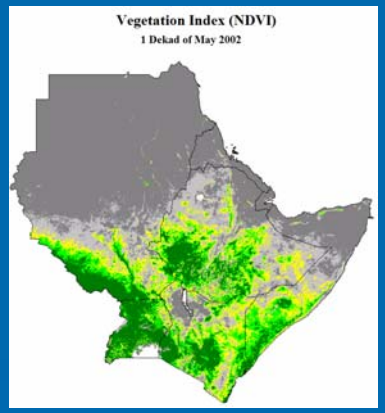
A = Data availability
+ + : complete
+ : almost complete
- : incomplete
--: no data
m : moderate

R = Data Reliability
g : good
p : poor
n.a. : not applicable

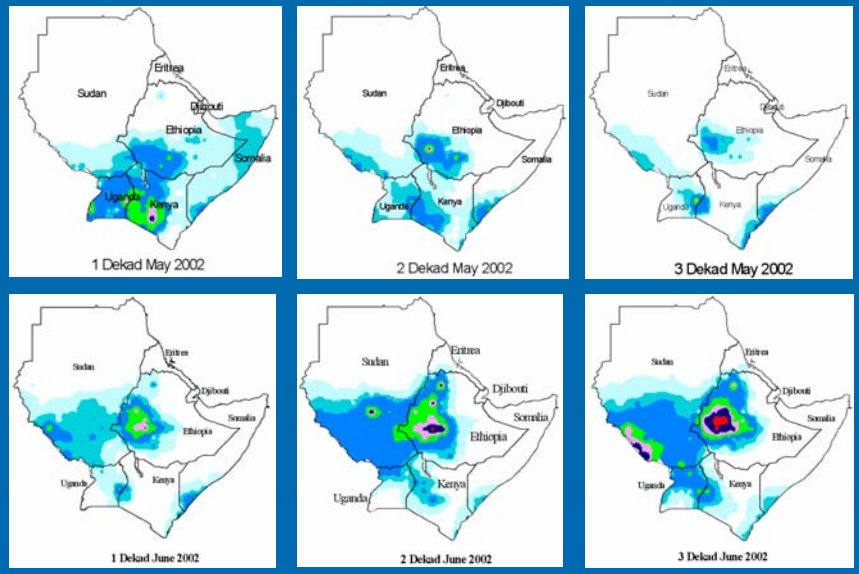
Source: Van Velthuizen et al 1995. Crop production system zones of the IGAD sub-region

Real Time Input Data

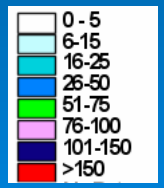
NDVI from
SPOT-4 Satellite



Rainfall and PET
from ECMWF model



mm



Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)

Mathematical expression of the FAO Water balance model

$$Wa = Wp + Ra - ETA - (Losses)$$

Wa: amount of water stored in the soil
Wp: amount of water stored in the soil at the end of the previous period
Ra: actual rainfall
ETA: amount of water actually evapotranspired by the crop
Losses: runoff and deep infiltration ("water excess")

Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)

Information needed to run the FAO Water Balance Model

- Planting dekad
- Actual rainfall by dekad
- Actual PET
- Length of the crop cycle
- Soil water holding capacity

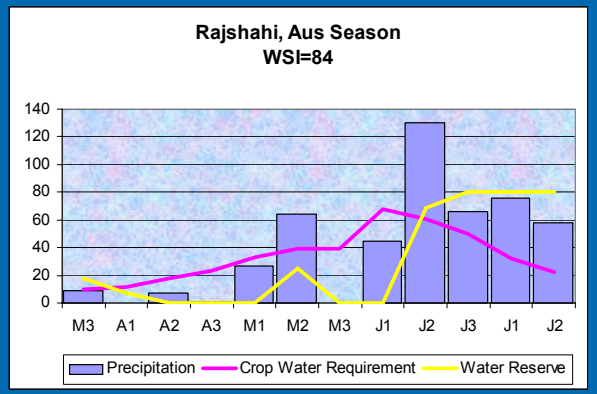
Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)

Outputs of the FAO Water balance model

- Soil water storage in millimetres
- Actual evapotranspiration
- Water satisfaction index
- Soil water surplus or deficit
- Summary file with all parameters
- Plain text detailed output tables

Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)

Cropping season: 1995-96
Station number: 1. Crop 1
Station Name: Rajshahi"
Crop type: Rice(upland)
Cycle length: 12 dekads (C)
Total water requirements: 408mm (TWR)
Normal water requirements: 403mm (TWRNor)
Planting dekad: 9 (P)
Maximum soil water storage: 80mm (H or WHC)
Effective/Total rain: 100% (E or EfRain)
Pre-season Kcr : .15



DEK	NOR	ACT	WRK	PET	KCR	WR	AvW	SW	S/D	INDEX
1	5	17	17	32	.15	5	13	13		
2	1	0	0	32	.15	5	-4	8		
3	5	0	0	32	.15	5	-4	4		
4	6	2	2	24	.15	4	-1	3		
5	2	10	10	24	.15	4	7	10		
6	3	19	19	24	.15	4	16	25		
7	1	0	0	25	.15	4	-3	22		
8	7	0	0	25	.15	4	-3	19		
9	18	9	9	25	.4	10	-1	18	0	100
10	2	0	0	27	.44	12	-12	7	0	100
11	22	7	7	27	.64	18	-11	0	-4	100
12	22	1	1	27	.85	23	-22	0	-22	94
13	31	27	27	31	1.05	33	-6	0	-6	93
14	33	64	64	31	1.25	39	25	25	0	93
15	120	0	0	31	1.25	39	-39	0	-13	90
16	62	45	45	54	1.25	68	-23	0	-23	84
17	97	130	130	54	1.13	61	69	69	0	84
18	120	66	66	54	.92	50	16	80	6	84
19	88	76	76	44	.71	32	44	80	44	84
20	105	58	58	44	.5	22	36	80	36	84

Surplus: 87mm (EXWT) Deficit: 66mm (DEFWT)
ETA: 341mm % data avail: 100% (%AVAIL)
Norm.index: 100% (IndxNor)

Running FAO Crop Specific Water Balance Model using Agromet Shell (Gommes, 1993)

Water Satisfaction Index (WSI)

- Reflects the cumulative water stress endured by the crop, dekad after dekad: the higher the final index, the smaller the water stress

% of yield in relation to the average of 3 best yields	Category	WSI
>100%	Very good	100
90-100	good	95-99
50-90	average	80-94
20-50	mediocre	60-79
10-20	poor	50-59
<10%	complete failure	<50

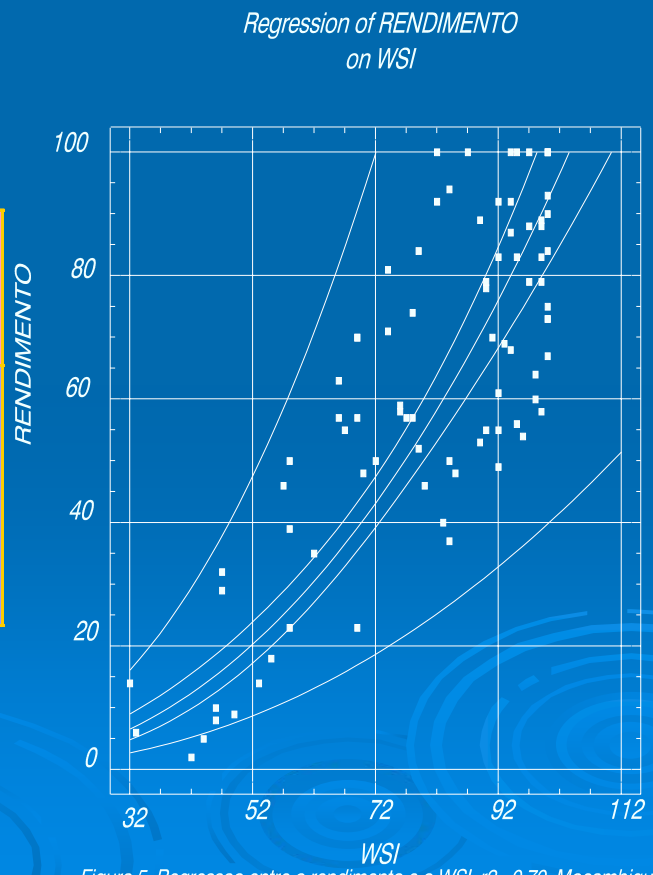


Figura 5. Regressao entre o rendimento e o WSI. r2=0.70. Mocambique

Crop Yield Function

$1-Y_a/Y_{max} = Ky * (1-ET_a/ET_{max})$

Y_a=t/ha

(Doorenbos and Kassam, 1979)

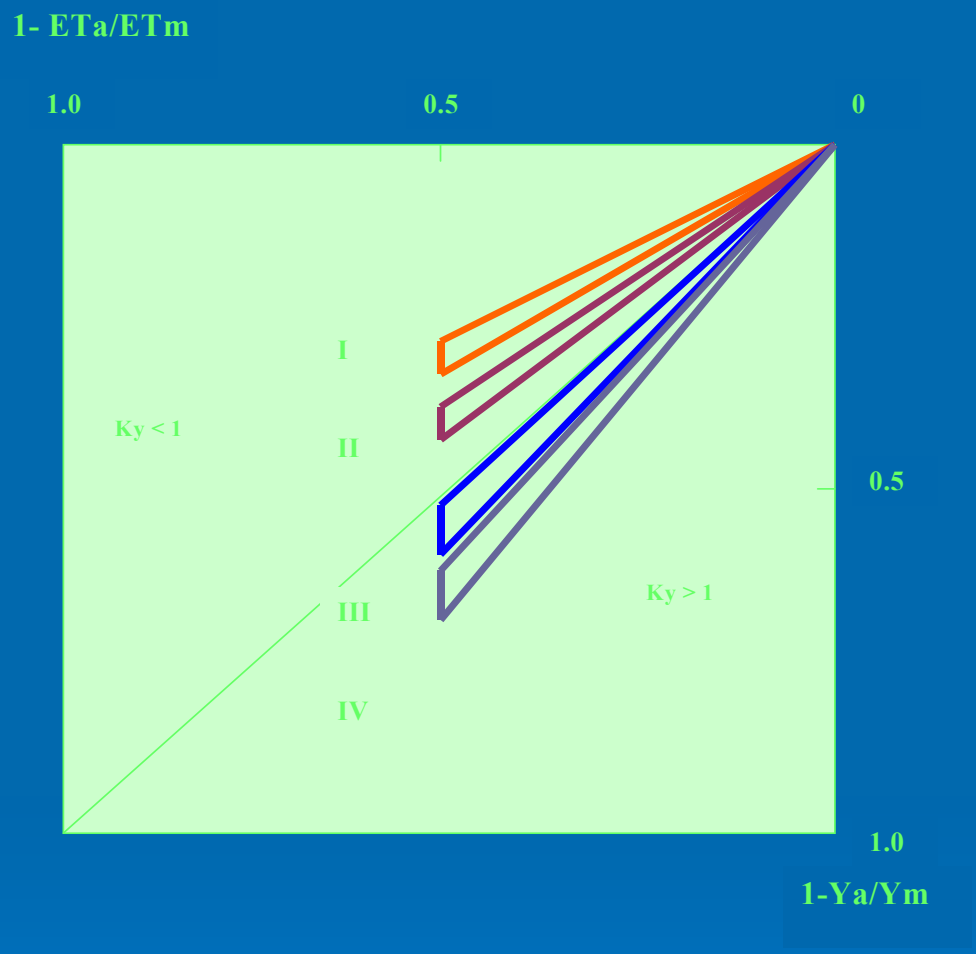


Figura 1. Relación general entre la disminución del rendimiento relativo (1-Ya/Ym) y la evapotranspiración relativa (1-ETa/ETm). Cultivos Grupo I: alfalfa, maní, remolacha, Grupo II: cítricos, repollo, algodón, sorgo, soya, girasol, tabaco, trigo Grupo III : frijol, cebolla, papa, tomate, sandía. GrupoIV: banano, maíz, caña de azúcar. (Fuente: Doorenbos y Kassam, 1986)

Spatialization of grid data using Surfer 3.2 and Windisp4

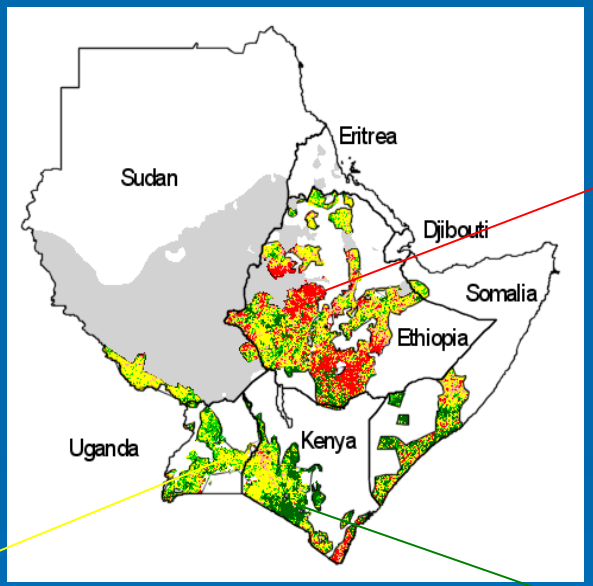
File preparation

- Rainfall and PET data (1 degree resolution) from the ECMWF model were interpolated using the nearest neighbor method in SURFER (avoiding extra modifications of the original estimation of rainfall).
- The resulting grid has a spatial resolution of 0.083 degree (approximately 10 km) with grid limits from 10° to 60° Latitude and -10° to 40° Longitude.
- An image was produced using the applications on Windisp4 from the SURFER GRD files of Surfer and for each CPSZ the rainfall and the ETP were spatially averaged.
- The information of each CPSZ was imported into AgrometShell given the longitude and latitude of the center of the polygon.
- Crop information (WHC, Planting dekad, Cycle length) was exported from the CPSZ database.

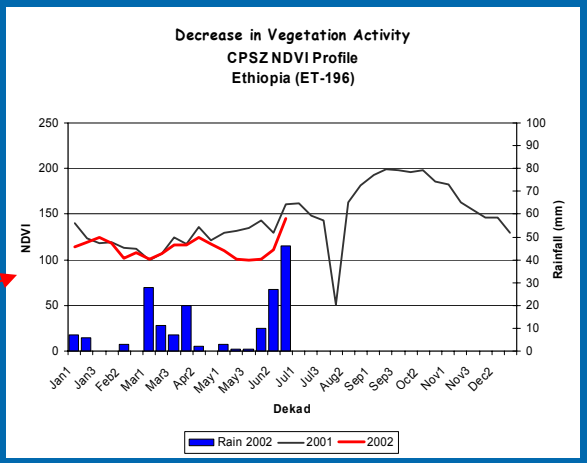
CPSZ NDVI profile analysis as Crop Yield Indicator

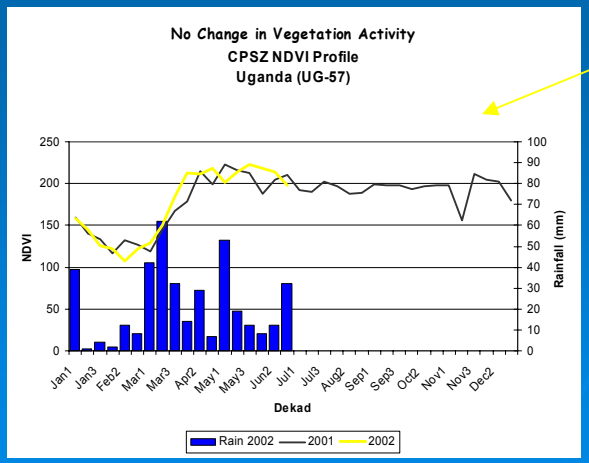
Vegetation index analysis

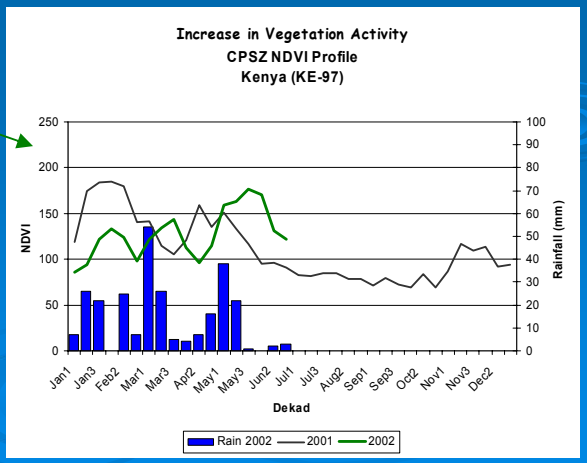
- It is expected to define some specific areas from the point of view of food security in the near future



3 dekad of May 2002



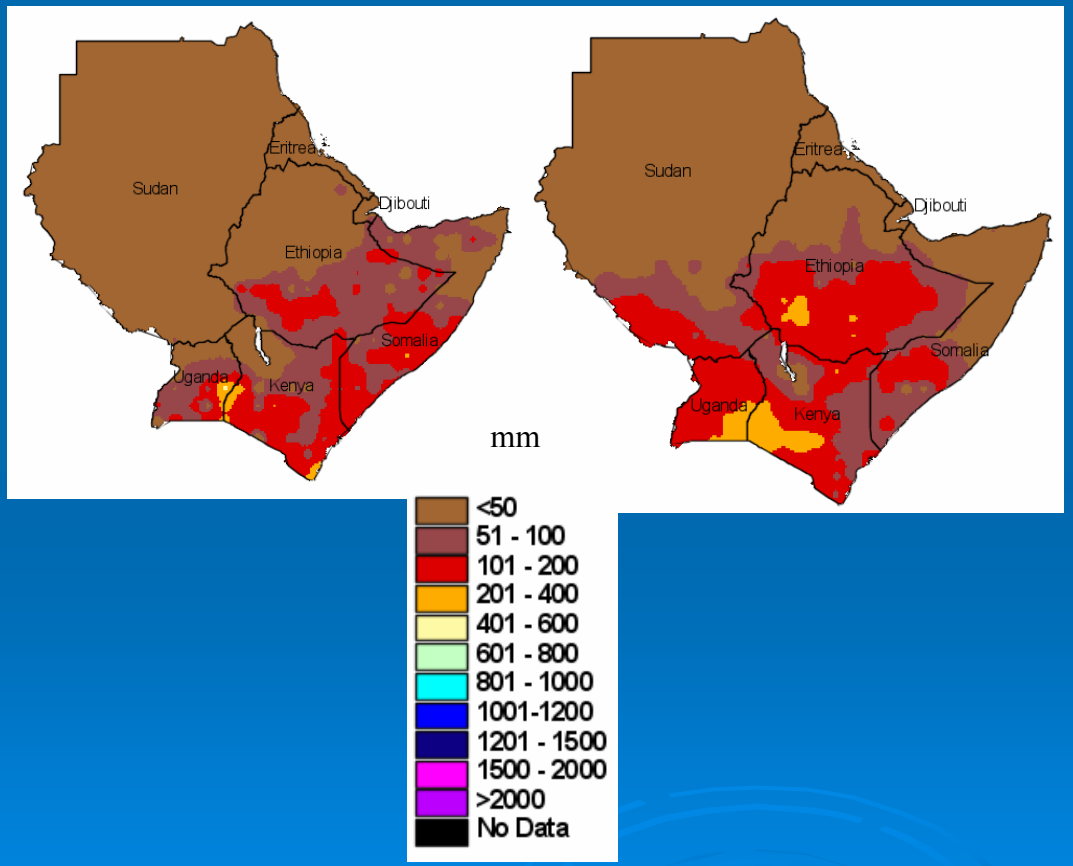




Dekadal Rainfall and PET Images

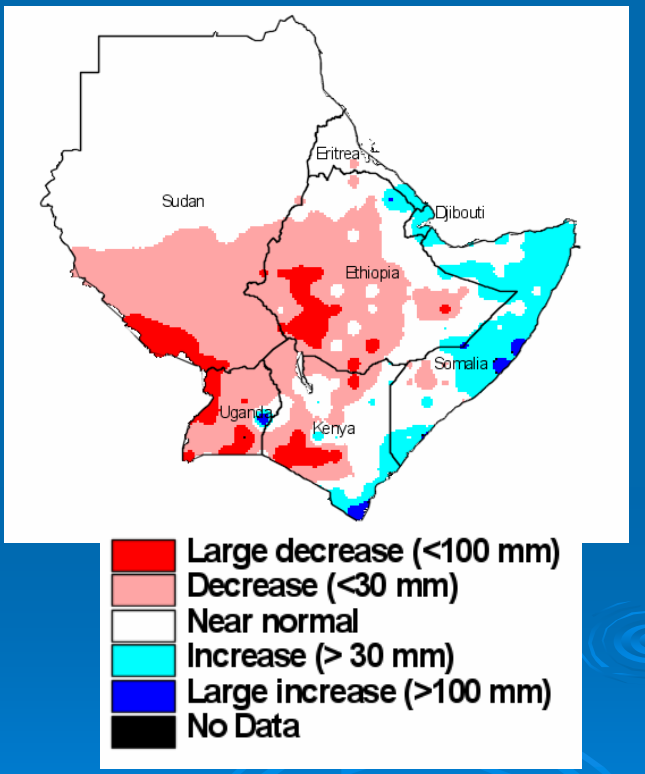
IGAD
Rainfall Analysis

Cumulative Actual Rainfall
(1 Dek April to 1 Dek May 2002)



Cumulative Normal Rainfall
(1 Dek April to 1 Dek May)

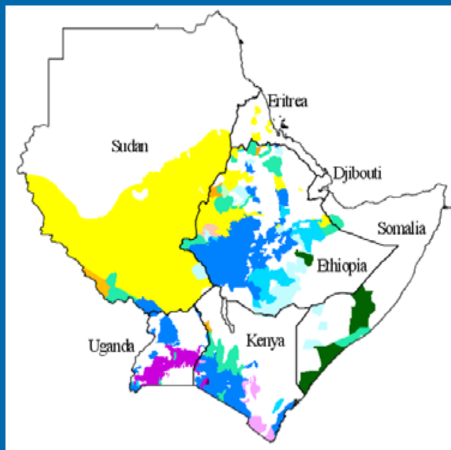
Rainfall Difference

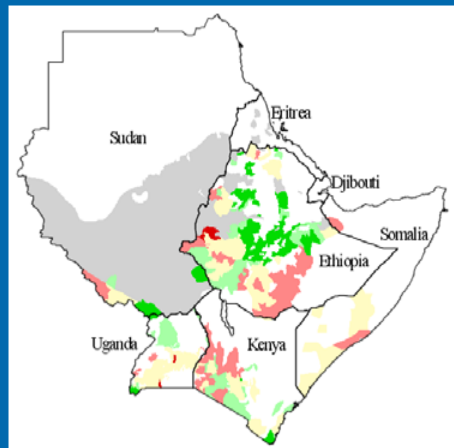


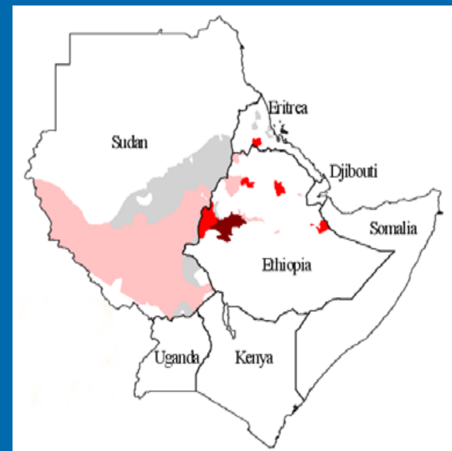
Crop planting analysis and crop cycle progress index

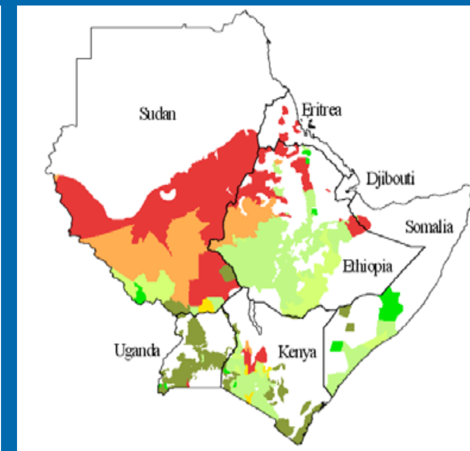
Crop planting analysis and crop cycle progress index

3 dekad of May 2002 | 3 dekad of July 2002









Planting dekad

- <Feb 1
- Feb 2
- Feb 3
- Mar 1
- Mar 2
- Mar 3
- Apr 1
- Apr 2
- Apr 3
- May 1
- May 2
- May 3
- Jun 1
- Jun 2
- Jun 3
- Jul 1
- Jul 2
- > Jul 3
- No planted yet

Dekads of delay of the units that already planted

- Delay (more than 4)
- Slight Delay (2 or 3)
- Normal (+-1)
- Slight Early (2 or 3)
- Early (more than 4)
- No planted yet

Dekads of delay of the units that not planted yet

- 6-8 Dekads of delay
- 3-5 Dekads of delay
- 1-2 Dekads of delay
- It is not time to plant yet

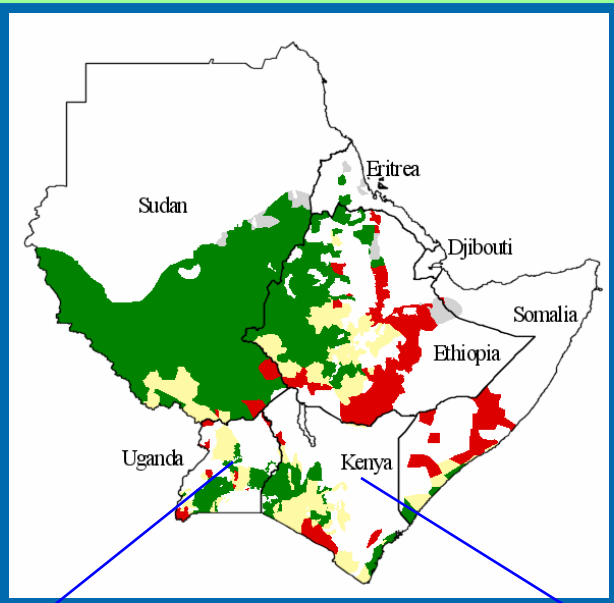
Percentage

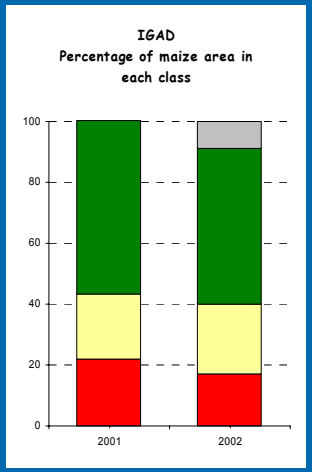
- 0 (No planted yet)
- 1 - 25
- 25 - 45
- 45 - 65
- 65 - 85
- 85 - 99
- 100 (crop cycle completed)

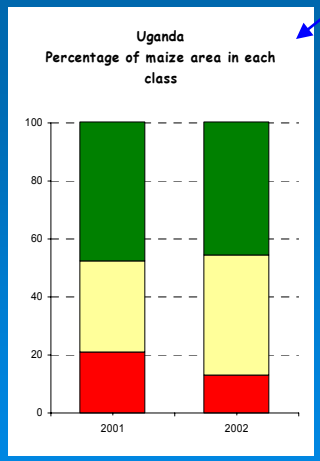
Products ⟷ Crop calendar

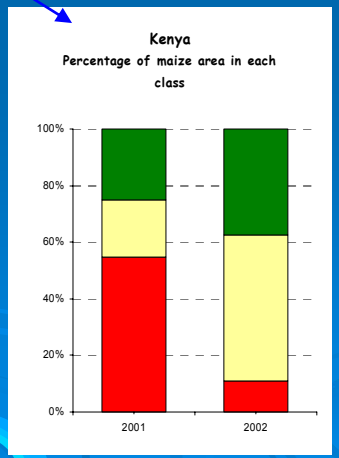
Qualitative crop yield assessment using the Water Satisfaction Index (WSI)

Qualitative crop yield assessment using the WSI







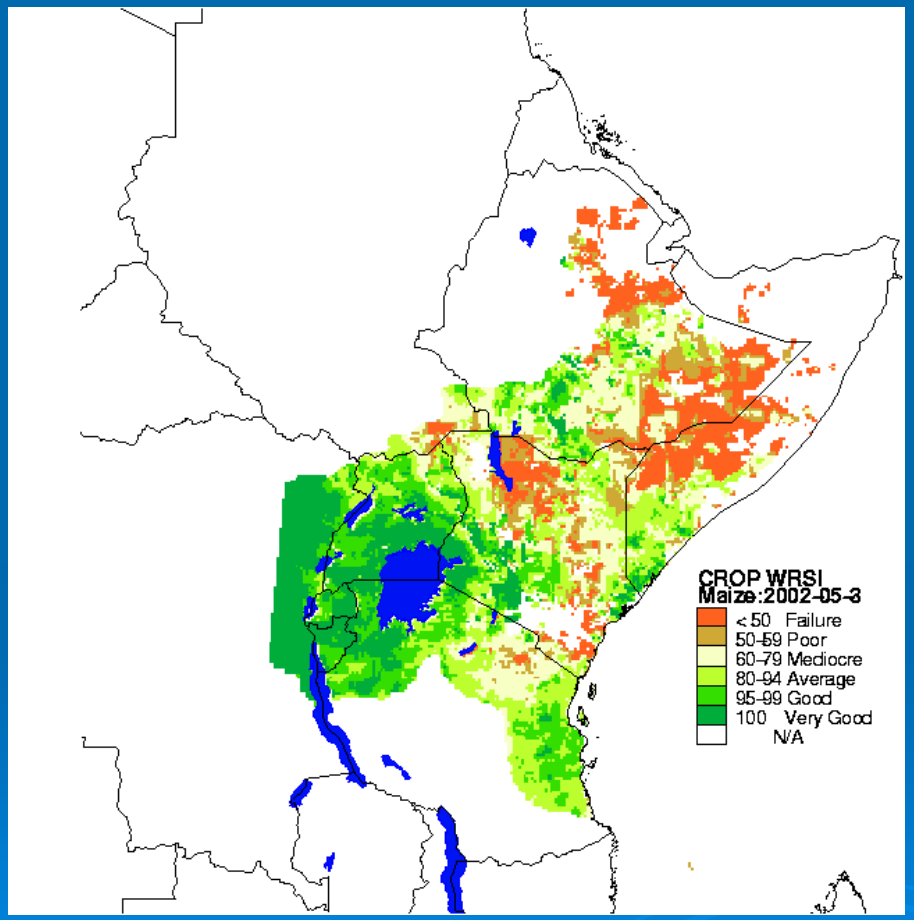


WSI for Maize

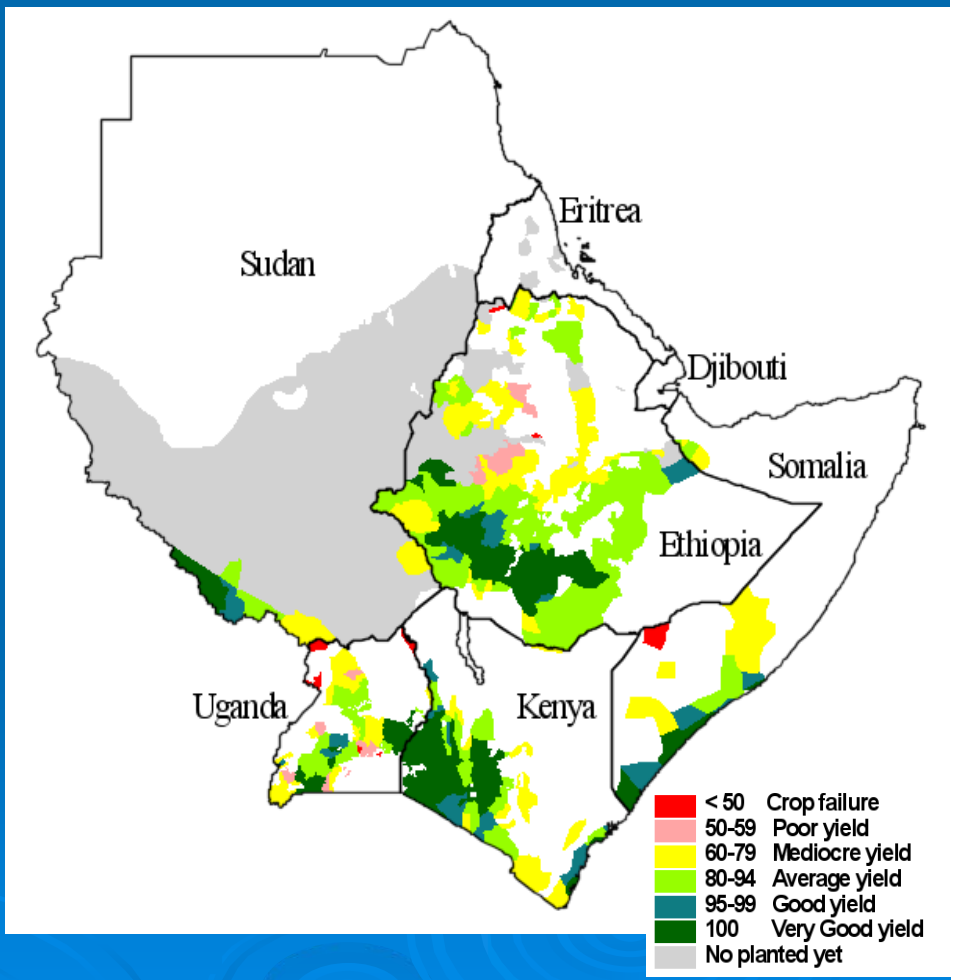
< 50	Crop failure
50-79	Poor/Mediocre
80-100	Average /Very Good
	Not planted yet

Products comparison

EROS-Data Center (USA)

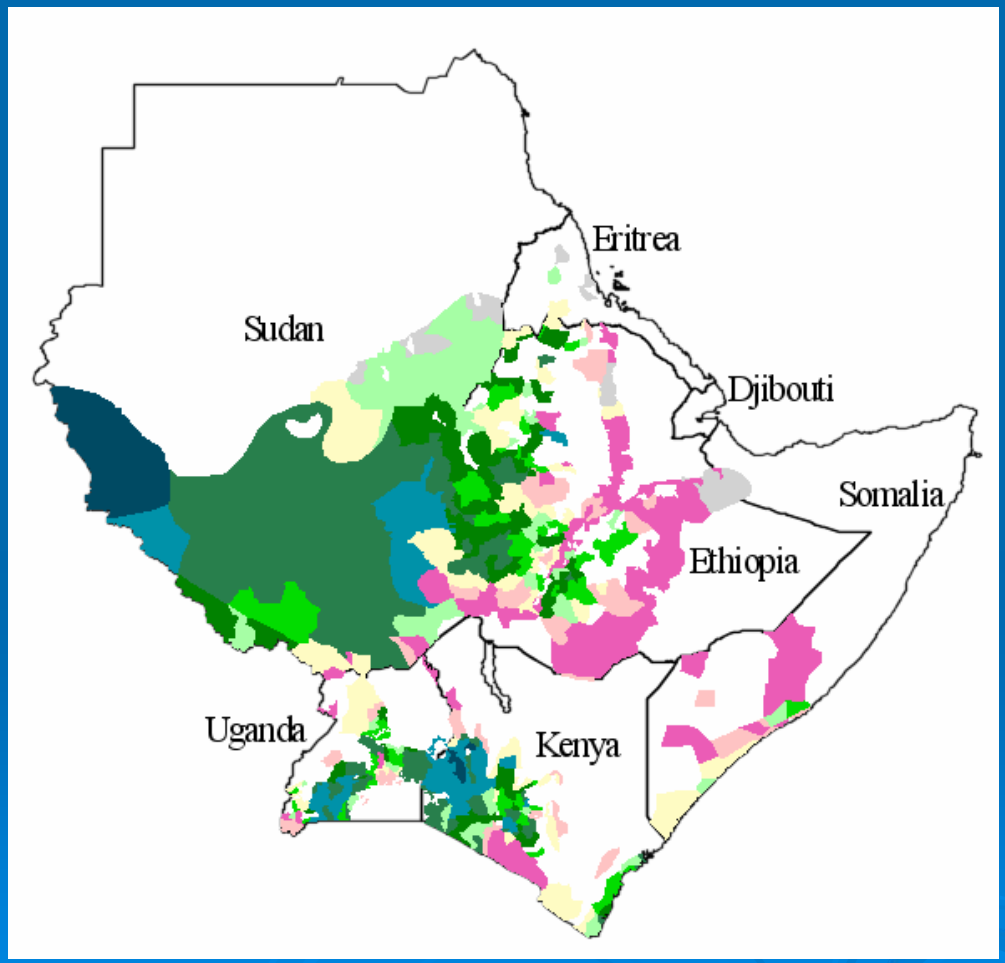


JRC/FAO product



Quantitative Crop Yield assessment (t/ha)

Quantitative crop yield assessment (t/ha)



Maize Yield Estimate

(t/ha)

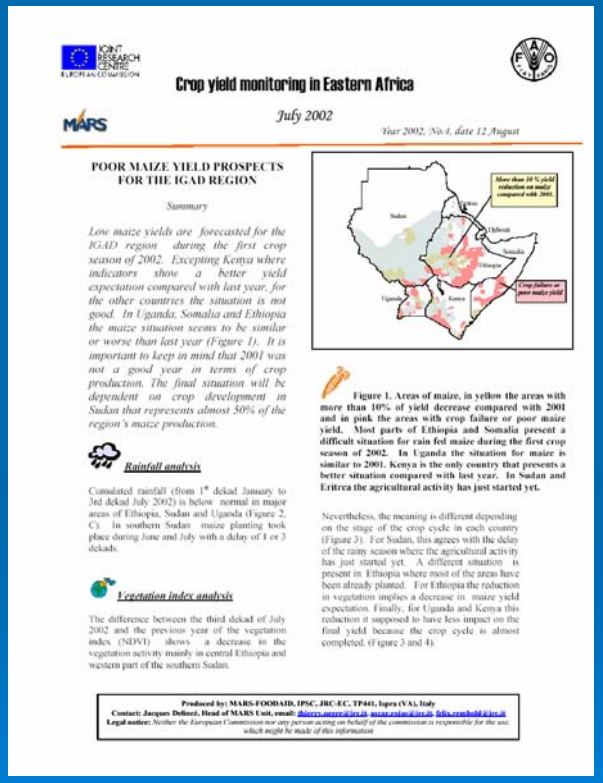
- < 0.20
- 0.20-0.50
- 0.51-0.80
- 0.81-1.00
- 1.01-1.20
- 1.21 - 1.50
- 1.51 - 2.00
- 2-4
- >4
- No planted yet

(Not calibrated yet)

Table 6. Summary of the support products for crop monitoring and yield forecasting in Eastern Africa.

Product	Derived product	Type of analysis	What is it used for?
Vegetation Index (NDVI)	NDVI Difference	Spatial distribution of biomass production. (Map)	NDVI images describe the amount of green vegetation present. The difference in vegetation types result in different values, hence the dekadal NDVI images are compared with the long-term average (or the previous year) of the same dekad to give an indication of the status of the potential biomass production of the growing season.
Vegetation Index (NDVI)	CPSZ-NDVI profile on going year with reference year.	Temporal evolution of crop biomass. (Profile graph)	The CPSZ-NDVI profile is the extraction of the spatial average NDVI values for a specific administrative level from a series of images. This analysis gives the aspect temporal of the behavior of the vegetation and agricultural area. Overview of the campaing (start, growing, senescence, water stress)
Planting date	Comparison (delay or advance planting dekad)	Spatial-temporal planting front. (Map)	The current planting dekad compared with the normal planting dekade can be a good indicator of possible yield reduction or crop failure when to a long delay is observed from the onset of the rainy season.
Crop cycle stage	Indicator of crop cycle progress	Spatial analysis of crop stage (Map)	The crop cycle progress is an index expressed in percentage derived from the CSWB model. The index gives an indication of the percentage already completed of the length crop cycle.
Water Satisfaction Index (WSI)	Comparison with previous year or long-term average.	Geographical and temporal distribution. (Map + Profile graph)	The WSI is a crop water stress indicator. It expresses the percentage of the crop water requirements which has been met. Difference in WSI with the long-term average (or previous year) gives an indication of the current crop yield situation.
Yield estimates	Comparison (better or below than reference yield)	Spatial distribution of yield. (Map)	The yield forecast is obtained by using the crop yield functions. Comparison with historical estimates gives an assessment of the present growing season.

Monthly Eastern Africa Bulletin



JOINT RESEARCH CENTRE
EUROPEAN COMMISSION

MARS

Crop yield monitoring in Eastern Africa

July 2002

Year 2002, No 3, date 12 August

POOR MAIZE YIELD PROSPECTS FOR THE IGAD REGION

Summary

Low maize yields are forecasted for the IGAD region during the first crop season of 2002. Excepting Kenya where indicators show a better yield expectation compared with last year, for the other countries the situation is not good. In Uganda, Somalia and Ethiopia the maize situation seems to be similar or worse than last year (Figure 1). It is important to keep in mind that 2001 was not a good year in terms of crop production. The final situation will be dependent on crop development in Sudan that represents almost 50% of the region's maize production.

More than 10 % yield reduction on maize compared with 2001

Crop failure or poor maize yield

Sudan
Eritrea
Djibouti
Somalia
Ethiopia
Uganda
Kenya

Figure 1. Areas of maize, in yellow the areas with more than 10% of yield decrease compared with 2001 and in pink the areas with crop failure or poor maize yield. Most parts of Ethiopia and Somalia present a difficult situation for rain fed maize during the first crop season of 2002. In Uganda the situation for maize is similar to 2001. Kenya is the only country that presents a better situation compared with last year. In Sudan and Eritrea the agricultural activity has just started yet.

Rainfall analysis

Cumulated rainfall (from 1st dekad January to 3rd dekad July 2002) is below normal in major areas of Ethiopia, Sudan and Uganda (Figure 2, C). In southern Sudan maize planting took place during June and July with a delay of 1 or 3 dekads.

Vegetation index analysis

The difference between the third dekad of July 2002 and the previous year of the vegetation index (NDVI) shows a decrease in the vegetation activity mainly in central Ethiopia and western part of the southern Sudan.

Nevertheless, the meaning is different depending on the stage of the crop cycle in each country (Figure 3). For Sudan, this agrees with the delay of the rainy season where the agricultural activity has just started yet. A different situation is present in Ethiopia where most of the areas have been already planted. For Ethiopia the reduction in vegetation implies a decrease in maize yield expectation. Finally, for Uganda and Kenya this reduction it supposed to have less impact on the final yield because the crop cycle is almost completed. (Figure 3 and 4).

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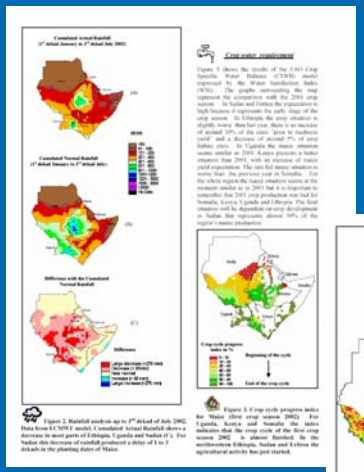
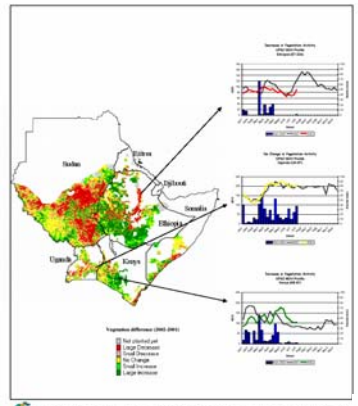
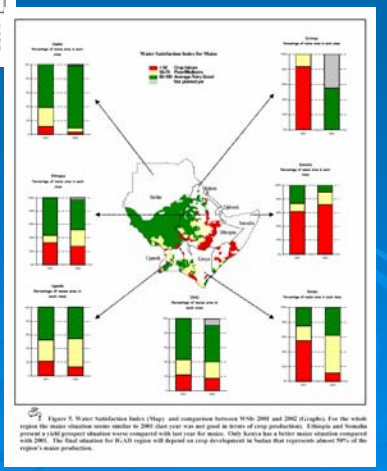




Real-time agro-meteorological crop yield monitoring in Eastern Africa



News

BBCi

Tuesday, 19 November, 2002, 09:25 GMT
Ethiopia: The warning signs that lead to famine

The Economist Newspaper

Hunger in Ethiopia
Africa's horn of famine
Nov 14th 2002
From The Economist print edition

Facing famine, Ethiopia appeals urgently for food aid

Next steps

- To calibrate yield estimates when the historical meteo data will be available at the JRC.
- To refine and improve the system (DG-AIDCO, EU delegations, FAO, Regional and national food security units, etc.)
- To develop an “automatic” data production chain to simplify the process of bulletin elaboration
- To develop an interactive user interface to facilitate access and interpretation of the information produced.