Estimating *Meher* Crop Production Using Rainfall in the 'Long Cycle' Region of Ethiopia[1]

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Meher *season crop production is well correlated with April-May rainfall in the Ethiopian 'long cycle' crop growing region. This relationship is used to estimate 2003* Meher *small-holder gross production at 87 ± 10 million quintals (8.7 million MT ± 1 million MT) of cereals, pulses and other crops, using data from the Central Statistical Authority (CSA). Assuming recent levels of commercial and food aid imports,* Belg *production and population growth, this estimate will produce food deficits of about 23 million quintals (2.2 million MT) for 2003-04, smaller than those experienced during 2002-03 (34 million Qt, or 3.4 million MT), but similar to the deficits experienced in 1997-98. Large long-term negative trends in March-September precipitation totals (~23 mm/year) may be aggravating the situation. Data show an increasing aridity, adding a major additional threat to fragile rain fed farming. Increasing food requirements and decreasing precipitation point toward chronic food shortages in the near future.*

Highlights

- National *Meher* yield and production correlate well with April-May rainfall in the 'long cycle' crop growing region of Ethiopia.
- Rainfall in April-May 2003 suggests *Meher* production will be about average when compared with the last seven years.
- Population growth (1.8 million per year) adds 3.3 M Qt per year to the national consumption requirement, nearly half of annual food aid received.
- A coarse food balance shows that about 13 million people would meet none of their food needs at all in 2003-04, assuming equitable distribution.
- The 'long cycle' crop growing region has experienced a strongly negative rainfall trend since 1972, with adverse consequences for production.
- Ethiopia requires rapid changes in its rural landscape and national development.

Introduction

Despite massive relief operations, serious levels of food insecurity persist in Ethiopia, with recent assessments recommending an increase in the number of beneficiaries to 12.6 million[2] (18.2% of the nation's 69.1 million people). Recent Water Requirement Satisfaction Index (WRSI) anomaly images for the *Belg* season (approximately March-May) and field reports suggest that agroclimatic conditions in 2003 generally compared favorably with the past four years. While these results are reassuring, *Belg* production typically accounts for only 5-10% of total annual production, while *Meher* season (approximately June-September) crops harvested in September-December make up the bulk of food production (90-95%). Our study estimates the September-December 2003 *Meher* yields based on 2003 April-May rainfall[3] and uses an average area-planted figure to produce a rough estimate of national *Meher* production, using Central Statistical Authority (CSA) data.[4]

The *Meher* crop production in Ethiopia combines high yield 'long cycle' crops (planted in the *Belg* season in March and harvested in September-December, after the end of the Meher season in September), and lower-yield 'short cycle' (June-September) varieties. Long cycle maize crops with the recommended agricultural inputs (fertilizer and improved seeds) on average yield about 2.5 – 3.0 tons per hectare, but short cycle maize (improved or local varieties) yields about 0.8 – 1 tons. Long cycle sorghum varieties with the necessary inputs yield about 1.5 tons, while short maturing varieties yield about 0.9 tons/ha. The higher yielding long cycle crops contribute about 50% of national production, compared to about 40-44% for short cycle *Meher* crops. These results imply that *national Meher* production is strongly dependent on rainfall *within* the long cycle region.[5]

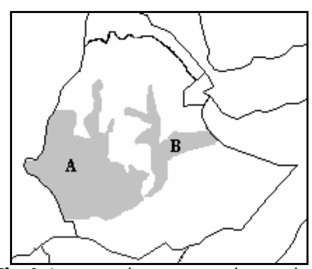

Fig 1. Long cycle crop growing region.

The significant production of long cycle crops, and the dependence of these crops on April-May rainfall, means that considerable information regarding prospective September-December *Meher* cereal

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[1] This report was prepared by Chris Funk, Alemu Asfaw, Phil Steffen, Gabriel Senay, Jim Rowland and Jim Verdin.

[2] Ethiopia Network on Food Security Monthly Report, May 20, 2003 and FEWS NET/Ethiopia Emergency Alert of May 23, 2003.

[3] The study, therefore, explicitly ignores important factors such as agricultural inputs, area planted, and the tendency of farmers to reduce production following a bumper harvest.

[4] National yields are calculated by dividing national production by national area planted, and thus will not always be representative of yields at the zonal or *woreda* level. Gross production figures are used in our estimates, and net production figures will be typically about 17% lower. CSA production figures are typically lower than FAO/WFP figures (e.g. 20% lower for 2002 *Meher* production), in part because commercial and state farms are not enumerated. To help generalize our results, findings are presented in percent deviations in Table 2, as well as metric tons/quintals.

[5] We mapped the long cycle region (shaded in Figure 1) by using climatological ratios of precipitation and potential evaporation, aided by reference to FAO Crop Production System Zones (CPSZ).

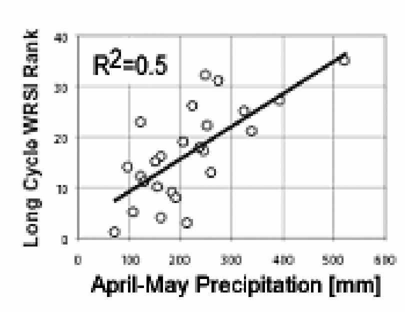

Fig 2. Scatterplot of ranked Ethiopia long cycle WRSI and April-May precipitation.

and pulse production becomes available as soon as May rainfall estimates are processed in early June. April-May rainfall totals can explain about half the variance (R^2=0.5) of end-of-season long cycle maize Water Requirement Satisfaction Index values (Figure 2), strongly suggesting that rainfall deficits at this critical stage can negatively impact yields of crops harvested in September-December. Another factor linking April-May rainfall to *Meher* production is the tendency for precipitation anomalies to persist from April-May into August-September (R^2~0.4) in long cycle growing areas. In short, these factors suggest that April-May rainfall in the long cycle crop region of Ethiopia is a good indicator of national *Meher* production, allowing us to forecast total *Meher* production this year.

Statistical Estimates of *Meher* Yields Based on April-May Rainfall Totals

Table 1 summarizes cross-validated estimates of national CSA *Meher* yields for 1995 through 2002, based on regression analysis with April-May rainfall from the long cycle region in Figure 1. The CSA yields represent a weighted average of cereal, pulse and other crop categories. The regression estimates varied from year-to-year because each year's actual yield was omitted from the calculation. This cross-validation procedure mimics a real forecast, in which the estimated value is not known, and allows the forecast accuracy to be assessed. The yield estimation procedure performed well (Figure 3), with a cross-validated R^2 of 0.7, and a standard error of 0.5 quintal per hectare – which is equivalent to 5% of the mean yield (11.1 Qt/ha). This R^2 value is in part attributable to the correct estimation of the particularly low 2002 value and could be artificially high. April-May rainfall thus appears to give a fair indication of September-December *Meher* yields – including both long and short cycle crops. Rainfall observed in April-May 2003 (169 mm) can be used to estimate yields[6] for the 2003 *Meher* season at 10.8 Quintals/hectare, with a standard error of 0.4 Qt/ha. This projection, about average for recent years, falls in between forecasts for normal-to-above-normal rainfall during June-September from the International Research Institute for Climate Prediction (IRI) and Ethiopian National Meteorological Service Agency (NMSA) and normal-to-below-normal rainfall from the Drought Monitoring Center in Nairobi (DMCN).

Table 1. Cross-validated estimates of *Meher* yield and gross production figures for small-holders, assuming average area planted. The area was kept fixed at the recent average (8.06 M Ha) to simulate a forecast scenario in which the area under cultivation is unknown.

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Apr-May Precip [mm]	218	251	205	166	159	176	239	34	169
Estimated *Meher* Yield [Qt/ha]	11.4	11.5	11.2	10.8	10.6	11.0	11.6	9.2	10.8
Actual *Meher* Yield [Qt/ha]	11.7	11.9	10.8	10.7	10.8	11.2	12.4	9.3	
Average Area [M ha]	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06	8.06
Actual Area [M ha]	7.95	8.07	6.85	8.01	8.22	9.44	8.00	7.93	
Estimated Production [M Qt]	91.9	92.7	90.3	87.0	85.4	88.7	93.5	74.2	87.0
Percent deviation from 8 year average	3%	4%	1%	-3%	-5%	-1%	4%	-17%	-3%
Actual *Meher* Prod [M Qt]	92.8	96.4	73.6	85.8	88.9	106.2	99.4	73.7	
Percent deviation from 8 year average	4%	8%	-18%	-4%	-1%	19%	11%	-18%	
Percent deviation from Actual Prod	1.0%	3.8%	22.7%	-1.4%	3.9%	16.5%	5.9%	-0.7%	

In order to use our yield estimate to project production, we have to assume a value for area planted (and ignore the effects of factors such as agricultural inputs). Yearly percent deviations in area planted (±5%) are similar in magnitude to percent variations in yields (±6%). Thus, area planted is as important as yields in estimating production. Lack of early information regarding 2003 area planted contributes uncertainty to our projection. Assuming average area planted based on 1995-2002 CSA statistics (8.06 million hectares), we estimate production for the upcoming *Meher* season at 87 million quintals (8.7 M MT). There is substantial uncertainty in this estimate, however, with an R^2 value of 0.4 and a standard error of 10 million quintals (1 M MT).

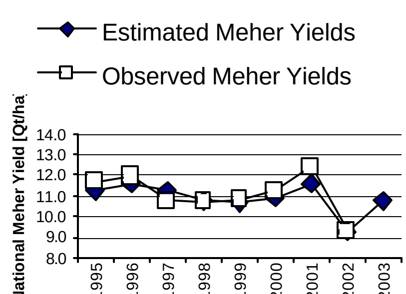

Fig 3. Cross-validated estimates and observed (CSA) Meher yields. Estimates based on April-May rainfall.

[6] *Meher* yield in Qt/ha = 8.93 + 0.11xApril-May precipitation

The variance explained for yield (70%) is greater than for production (40%) because uncertainty in area planted reduces the accuracy of our assessment.

Projected Food Needs

While the *Meher* cereals and pulses production forecast (87 M Qt, or 8.7 M MT) is typical of recent production figures, it will likely be insufficient to prevent food shortages in 2003-04, unless commercial and food aid imports are substantially above recent amounts. A simple food balance sheet using modified[8] CSA crop production and population figures, actual and projected Customs Authority and projected commercial food imports and DPPC and WFP food aid imports (Table 2) suggests that Ethiopia experienced modest (6 M Qt, or 600,000 MT) and large (36 M Qt, or 3.6 M MT) food deficits during 2001-02 and 2002-03, respectively. Food balance calculations for 2003-04 using estimated population growth (~2.9% a year) and average values for *Belg* production (5 M Qt, or 500,000 MT) and food aid (6 M Qt, or 600,000 MT), result in a considerable food deficit of 23 M Qt (2.3 M MT). To aid contingency planners, the deficit crop production values associated with a ± 1 standard error of 10 million quintals are 13 M Qt (1.3 M MT) and 33 M Qt (3.3 M MT). Thus, considerable food shortages appear likely.

Table 2. Approximate food balance calculations based on population, net food production and food aid. Food aid values for 1995-2002 were obtained from (DPPC and WFP). The average of these values was used for 2003-04 to 2007-08. The' theoretical population without food' was estimated by dividing the food deficits by the required consumption (kg) per year per capita and should only serve as reference for comparison between years.

Production Year	Pop[1] [M]	Human Needs[1] [MQt]	Est Net Prod[1] [MQt]	Import[1] [MQt]	Food Aid [MQt]	Prod + Imp + Aid [MQt]	Food Surplus [MQt]	Theoretical population without food [M]
1995-96	56.4	101.5	97.6	0.7	6.8	105.2	3.7	-2.1
1996-97	58.1	104.6	103.6	0.8	3.5	107.9	3.3	-1.8
1997-98	59.9	107.8	80.7	2.5	3.9	87.0	-20.8	11.5
1998-99	61.7	111.0	88.6	4.7	5.7	99.1	-11.9	6.6
1999-00	63.5	114.3	91.6	2.2	5.0	98.9	-15.4	8.6
2000-01	65.3	117.6	109.6	9.6	10.0	129.1	11.5	-6.4
2001-02	67.2	121.0	103.6	5.5	5.8	114.8	-6.2	3.4
2002-03	69.1	124.4	78.7	5.8	3.9	88.3	-36.1	20.1
2003-04	***70.8***	**127.5**	**91.6**	***6.9***	***5.6***	**104.1**	***-23.3***	**13.0**
2004-05	*72.6*	130.7	94.6	*7.5*	*5.6*	107.7	*-23.0*	12.8
2005-06	*74.4*	134.0	94.6	*8.0*	*5.6*	108.2	*-25.7*	14.3
2006-07	*76.2*	137.2	94.6	*8.6*	*5.6*	108.8	*-28.4*	15.8
2007-08	*78.0*	140.5	94.6	*9.2*	*5.6*	109.3	*-31.1*	17.3

A sense of the dimension of the potential human impact of these estimated production deficits may be obtained by dividing the deficits by the baseline cereals and pulses requirement of 180 kg per capita per year. This coarse calculation, not a proper vulnerability assessment, implies that about 13 million people *would meet none of their food needs at all* – assuming perfectly equitable food distribution. In reality, no one would completely go without, but many impoverished Ethiopians without adequate access to food will face debilitating hunger and malnutrition, as seen in the high rate of stunting in children, and increased susceptibility to disease. Population growth plays a significant role in these food shortage projections. Average population growth has been about 1.8 million people a year from 1995 through 2002, adding about 3.3 M Qt (330,000 MT) a year to the national cereals and pulses consumption requirement, or about 59% of the average recent annual food aid amounts (558,000 MT). Even in a year of 'average' crop production, Ethiopia is unable to meet its own cereals and pulses consumption requirements with present production techniques, based almost entirely on unreliable rainfall. The increasing population simply aggravates this already substantial crop production deficit.

Trends in Ethiopian Precipitation

In addition to increasing population, it appears that the long cycle growing region in Ethiopia has been experiencing a strong and consistent drying trend. Evaluation of April-September precipitation in the long cycle region (Figure 4), reveals a negative trend of 23 mm per year. This trend accounts for roughly 23% of the 1,000 mm interval (500 mm-1,500 mm) of seasonal rainfall observed since 1972. Figures 5 and 6 present spatial maps of the correlation between seasonal rainfall with a trend, with the correlation at

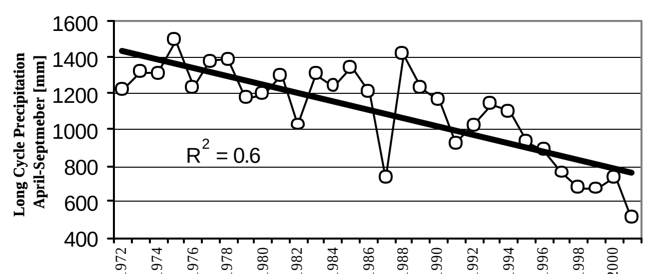

Fig 4. April-September precipitation in the long cycle crop growing region.

selected stations super-imposed. The negative trends tend to occur where and when they will have large potential impacts on crops. This implies that even a 'good' rainfall year in the present decade will tend to be drier than any year in the 1970s or 80s.

While some (expected) differences between the weather station and gridded precipitation correlations exist, the general consistency of station and gridded precipitation trends strongly suggest that the rainfall decrease depicted in Figure 4 is an ominously real feature of the climate, and not a figment of sampling error. These negative trends also tend to occur when and where they will most negatively impact crop production – in the *Belg* growing regions of Southern Ethiopia during March-April-May (Figure 5), and in the long cycle crop growing regions during June-July-August (Figure 6). If we multiply the slope of the regression between recent *Meher* CSA yields and long cycle region April-September precipitation (0.0023 Qt/ha per mm)[7] and the slope of long cycle precipitation per year (-23 mm/year), we can sketch out an anticipated precipitation-based decline in *Meher* yields of about -0.06 Qt/ha per year. Assuming that a constant 8 million hectares are under production, we can roughly estimate a decrease in *Meher* production of -0.48 million Qt/year. While this estimate of year-to-year decline in production is relatively small, the cumulative effect over 10 years (-4.8 million quintals, or 480,000 MT) starts to approach the amount of average annual food aid.

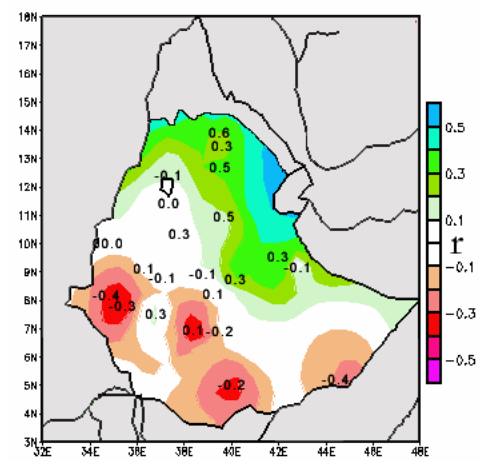

Fig 5. Shading shows the correlation between each grid cell's March-May rainfall and a linear trend over the 1961-1996 time period. Super-imposed numbers denote correlations with a trend calculated at quality-controlled stations over the same range of years.

Summary

We found that April-May rainfall in the long cycle region is a good predictor of national CSA *Meher* yields, and used this relationship to estimate yield for the 2003 *Meher* season at roughly 10.8 ± 0.4 M Qt/ha. This value is very close to the average for recent years, and agrees well with forecasts by the NMSA and DMC for normal climate conditions during the June-September season. The annual population increase of approximately 1.8 million creates an associated 3.3 M Qt (330,000 MT) increase in food requirements per year. The decline in precipitation in the long cycle region may be hampering attempts to increase production, with an estimated negative trend of roughly –0.48 M Qt per year (48,000 MT). These values correspond to roughly 59% and 9% of the average food aid values in recent years (558,000 MT).

The implication of these rainfall and crop production trends is that projected food shortages in Ethiopia may soon pass beyond chronic into tragic, exceeding the ability of food aid to make up the difference. To halt and reverse these ominous trends, Ethiopia will require urgent changes in its rural landscape and national development – security of land holdings, improvements in crop yields and production technologies, restoration of the environment, more efficient markets, protection of livelihoods and entitlements, and reductions in population growth. A more diversified and trade-oriented economy can help reduce reliance on low-input, low-yield rain fed agriculture on small plots and solve the pervasive problem of rural poverty and hunger.

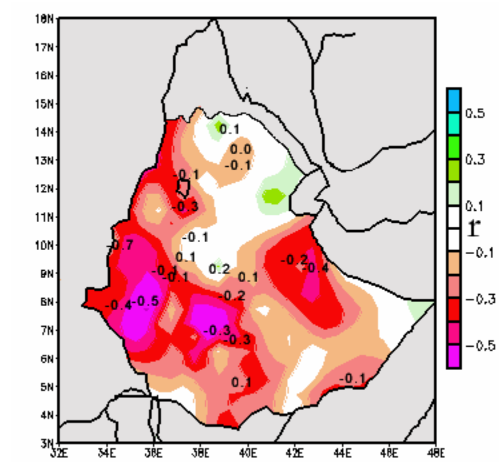

Fig 6. Shading shows the correlation between each grid cell's June-September rainfall and a linear trend over the 1961-1996 time period. Super-imposed numbers denote correlations with a trend calculated at quality-controlled stations over the same range of years.

[7] Yield = 0.0023x + 9.5763