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 farmer gross production at 87 ± 10 million quintals (8.7 million MT*[2] *± 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 a food deficit of about 23 million quintals (2.3 million MT) for 2003-04, smaller than the one experienced during 2002-03 (34 million Qt, or 3.4 million MT), but similar to the deficit experienced in 1997-98. A long-term negative rainfall trend in the southwestern highlands may be aggravating the situation. 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 to 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 the annual food aid received.
- A simple food balance shows that about 13 million people would meet none of their food needs at all in 2003-04, assuming equal distribution of all available supplies.
- Food balance projections suggest that 12.8 million Ethiopians will meet none of their food needs in the 2004-05 production year, increasing to 14.3 million in 2005-06, 15.8 million in 2006-07 and 17.3 million in 2007-08.
- The western portion of the 'long cycle' crop-growing region has experienced a strongly negative rainfall trend since 1961, with potentially adverse consequences for production.
- Ethiopia will need to refocus its national development goals to reduce reliance on rain fed agriculture.

Introduction

Despite massive relief operations and development efforts, serious levels of food insecurity persist in Ethiopia, with recent assessments recommending an increase in the number of beneficiaries to 13.2 million (or 22.6% of the nation's rural population).[3] Recent Water Requirement Satisfaction Index (WRSI) anomaly images for the *Belg* season (approximately March-May) and field reports suggest that agroclimatic conditions in 2003 were generally better than those over the past four years. While these improved conditions are reassuring, *Belg* production typically accounts for only 5-10% of total annual production, while *Meher* rainy season (approximately June-September) crops harvested in September-December make up the bulk of food production (90-95%). June-September imagery from the USGS shows near-median WRSI values across most of the country. Our study estimates the September-December 2003 *Meher* yields based on April-May 2003 rainfall.[4] Using average area-planted (CSA data), this study produces a rough estimate of national *Meher* production.[5] The estimated national yield is close to the seven-year average, and thus agrees fairly well with WRSI values based on data from June-September.

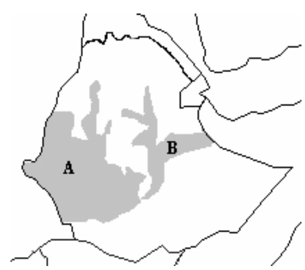

Fig 1. Long cycle crop growing regions of Ethiopia

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, see Figure 1), and lower-yield 'short cycle' (June-September) varieties. Long cycle maize crops with the recommended agricultural inputs (fertilizer and improved seeds) yield about 2.5 – 3.0 tons per hectare, but short cycle maize (improved or local varieties) yields about 0.8 – 1.0 tons. Long cycle sorghum varieties with the necessary inputs yield about 1.5 tons, while short maturing varieties yield about

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[1] This report was prepared by Chris Funk, Alemu Asfaw, Phil Steffen, Gabriel Senay, Jim Rowland and Jim Verdin. This document is an update of the original report (issued on June 21, 2003) and contains a revised estimate of precipitation trends in the western long cycle region, using interpolated rainfall station data, instead of a combination of station and satellite rainfall estimates.

[2] We use the following abbreviations for units in this report: Qt for quintal, MT for metric ton, M for million, mm for millimeter, kg for kilogram and ha for hectare.

[3] Ethiopia Network on Food Security Monthly Report, August 14, 2003 and FEWS NET/Ethiopia Emergency Alert of August 29, 2003.

[4] The study, therefore, explicitly ignores important factors such as agricultural inputs, the tendency to reduce production following a bumper harvest, and the year-to-year variation in area planted.

[5] 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). To help generalize our results, our findings are presented in percent deviations, as well as metric tons and quintals.

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[6].

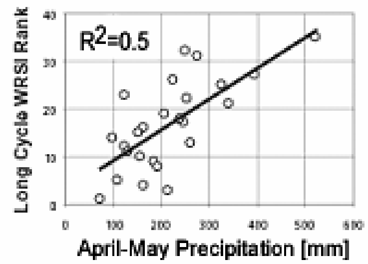


Fig 2. Scatter plot of ranked Ethiopia long cycle WRSI and April-May precipitation.

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 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 *Mehe*r production is the tendency for April-May precipitation anomalies to persist 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.

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. It should be noted that this national indicator might not represent zonal or regional variations that may arise. 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 – 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 yield for 2002 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[7] 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 climate forecasts for normal-to-above-normal rainfall during June-September from the International Research Institute (IRI) and Ethiopian National Meteorological Agency (NMSA) and normal-to-below-normal rainfall from the Drought Monitoring Center in Nairobi (DMCN).

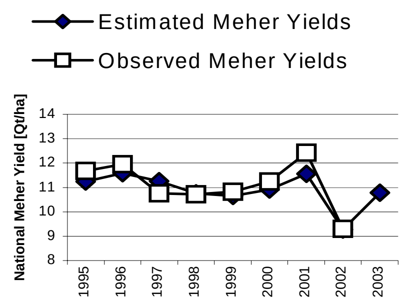


Fig 3. Cross-validated estimates and observed (CSA) Meher yields. Estimates based on April-May rainfall.

Table 1. Cross-validated estimates of *Meher* yield and production figures, 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.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003
Apr-May Long Cycle Precip [mm]	218	251	205	166	159	239	176	34	169
CV-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 Production [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 Production	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 use of 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

[6] 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).
[7] *Meher* yield in Qt/ha = 8.93 + 0.011(April-May precipitation).

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). 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 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 CSA crop production and population figures and DPPC and WFP food aid import values (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 deficits 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 DPCC 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 [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 implies that about 13 million people *would meet none of their food needs at all* – assuming perfectly equal food distribution. In reality, no one would go completely without food, 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 of about 1.8 million people a year (1995-2002) adds about 3.3 M Qt (330,000 MT) a year to the national cereals and pulses consumption requirement, or nearly 60% 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 production techniques that are based almost entirely on unreliable rainfall. Population increases simply aggravate the already substantial crop production deficit.

Trends in Ethiopian Precipitation

In addition to increasing population, it appears that the western portion of the long cycle growing region in Ethiopia (A in Figures 1& 4) has been experiencing a fairly consistent drying trend, when evaluated over the 1961-1996 period. Evaluation of April-September

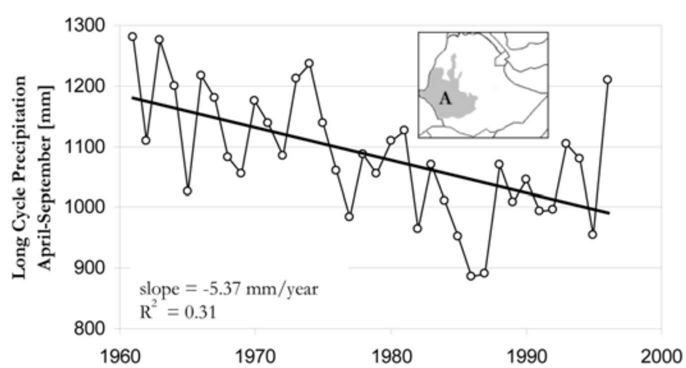
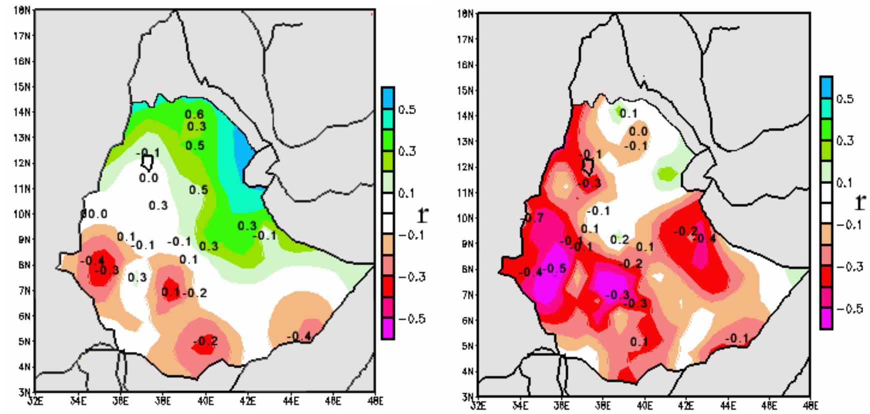


Fig 4. Average April-September precipitation in the western long cycle crop-growing region (shaded region on map).

precipitation[8] in the long cycle region (Figure 4) reveals a negative trend of 5.4 mm per year. FEWS NET is working with colleagues in Ethiopia to analyze up to date rain gauge data (1997-2003) for comparison with the historical data (1961-1996).

One way of examining the strength of trends is to examine maps of the correlation of rainfall and time. In places where this correlation value is close to zero, trends are negligible. The observed correlation patterns, calculated over 1961-1996, are weak throughout most of the *Belg* crop growing regions for the months of March through May (Figure 5, left panel). The correlations can vary from –1 to 1, and indicate the relative strength of the rainfall change over time. Correlation values between -0.3 and 0.3 represent trends that explain less than 10% of the rainfall variability. Most of the March-May correlations fall within this range. For the months of June through September (Figure 5, right), however, portions of the western highlands exhibit fairly strong negative correlations (<-0.4) over the 1961-1996 period. This pattern suggests that the southwestern highlands have been experiencing a drying trend during the height of their rainy season.



March-May, 1961-1996 CAI Correlation with Time June-September, 1961-1996 CAI Correlation with Time

Fig 5. Correlation [r] between seasonal CAI precipitation totals and time, calculated over the 1961-1996 period. Correlations are calculated at selected stations with near continuous periods of record. Note that interpolated fields are weighted averages of multiple stations, and that more stations than those plotted here were used to derive the interpolated fields.

Summary

April-May rainfall in the long cycle region is a good predictor of national CSA *Meher* yields, and this relationship was used 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 moderate decline in precipitation in the western long cycle region may be hampering attempts to increase production. Slowly decreasing precipitation and steadily increasing food requirements suggest that Ethiopia needs to reduce its reliance on low-input, low-yield rain fed agriculture and create new livelihood opportunities for its rural population.

To counteract these ominous trends of growing deficits and declining rainfall, Ethiopia requires urgent changes in its rural development priorities – 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 improve food availability and access while helping to solve the pervasive problem of rural hunger and poverty.

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[8] The Climatologically Aided Interpolated (CAI) fields produced by Cort Willmott at the University of Delaware. International Journal of Climatology, 15, 221-229.