A Climate Trend Analysis of Mali

Conclusions

- *Summer rains have remained relatively steady for the past 20 years, but are 12 percent below the 1920–1969 average.*
- *Temperatures have increased by 0.8° Celsius since 1975, amplifying the effect of droughts.*
- *Cereal yields are low but have been improving.*
- *Current population and agricultural trends indicate that increased yields have offset population expansion, keeping per capita cereal production steady.*

Food Security Context

Mali is a landlocked country (area: 1,240,278 square kilometers) with a 2011 population estimated at 14.2 million; it has an annual growth rate of 2.6 percent (CIA, 2011). Agricultural activities occupy 70 percent of Mali's labor force. This sector of the economy is dominated by small-scale traditional rainfall-dependent farming. The main crops are sorghum, millet, maize, and rice. In periods of adequate rainfall, Mali approaches food self-sufficiency. Unfortunately, droughts are recurrent and irrigated lands represent only 3 percent of total cropland and are limited to areas along the Niger River. Rains, as in much of the Sahel, have been marked by annual variability that increases northward.

This brief report, drawing from a multiyear effort by the U.S. Agency for International Development (USAID) Famine Early Warning Systems Network (FEWS NET), examines recent trends in rainfall and air temperatures. These analyses are based on quality controlled station observations.

Rainfall Recovery Stalled in the 2000s

Rainfall in Mali declined rapidly between 1950 and the mid-1980s, partially recovered in the 1990s, then declined slightly in the 2000s. The 2000–2009 average remained about 12 percent lower than the 1920–1969 mean (–1.1 standard deviations). Rainfall increases since the mid-1980s are probably caused by the warming of the north Atlantic Ocean (Hoerling and others, 2006).

These changes can be visualized in three ways: as a reduction of the region receiving adequate rainfall for viable agricultural livelihoods, as maps of anticipated changes in rainfall, and as time series plots.

Mali receives most of its rain between June and September, and rainfall totals of more than 500 millimeters (mm) during this season typically provide enough water for crops and livestock. Between 1960 and 1989, the region receiving (on average) this much rain during June–September is shown in light brown in the left panel of figure 1 and should be understood to lie beneath the dark brown and orange areas. During the past 20 years, this region has retreated slightly southward.

Rainfall reductions and temperature increases can be visualized by combining the observed 1960–2009 changes with predicted 2010–2039 changes, based on persistence of the observed trends (fig. 2, top panels). Rainfall decreases range from -150 to -10 mm across a large part of the country, with the largest decreases found in the west of the country. Observed changes (those between 1960 and 2009) account for 63 percent of the change magnitudes.

Smoothed time series (fig. 2, lower panel, 10-year running means) of 1900–2009 rainfall, extracted for crop growing regions in Mali, show that 2000–2009 rainfall has been, on average, about 12 percent lower than rainfall between 1920 and 1969. These time series were based on crop growing regions in southwestern Mali (Kayes and Koulikoro) and southeastern Mali (Mopti, Segou, Sikasso). In both southwestern and southeastern Mali (see map with region names in the "Objectives and Methods" section), rainfall has recovered since the mid-1980s, but has leveled off during the past decade, and 2000–2009 rainfall remains substantially below its 1920–1960 mean.

Much Warmer Air Temperatures

Since 1975, temperatures have increased by more than 0.8° Celsius (°C) across most of Mali, with typical

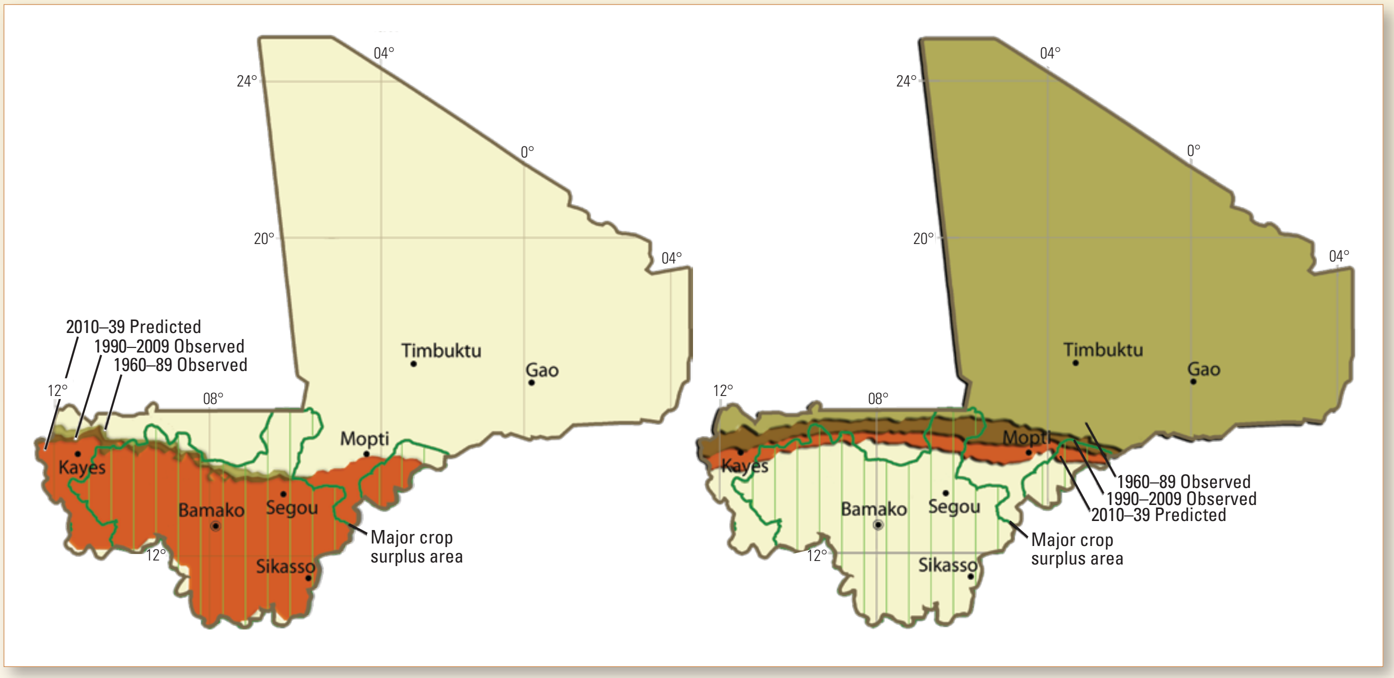

Figure 1. Climate change in Mali: The left map shows the average location of the June–September 500-millimeter rainfall isohyets for 1960–1989 (light brown), 1990–2009 (dark brown), and 2010–2039 (predicted, orange). The green polygons in the foreground show the main crop surplus regions for millet and maize. The right map shows analogous changes for the June–September 30°Celsius air temperature isotherms

rates of warming greater than 0.2°C per decade. This transition to an even warmer climate could reduce crop harvests and pasture availability, amplifying the impact of droughts. Assuming the observed trends persist, we can create a composite of observed and anticipated air temperature changes (fig. 2, top panel). Again, observed changes alone account for 63 percent of the change magnitudes. Mali is becoming significantly hotter. Time series of air temperature data (fig. 2, lower panel) indicate that the magnitude of recent warming is large and unprecedented within the past 110 years. We estimate that the 1975 to 2009 warming has been more than 0.7°C for Mali during the June–September rainy season. Given that the standard deviation of annual air temperatures in these regions is low (0.4°C), these increases represent a very large (+1.5 standard deviations) change from the climatic norm. Such warming, in regions with very high average air temperatures, can amplify the impact of water shortages.

Population Growth has been Matched by Agricultural Development

In 2011, the estimated population of Mali was 14.2 million (CIA, 2011). Mali has a population growth rate of 2.4 percent; at this rate the population will double every 29 years. Between 1990 and 2010, Mali's population increased by 74 percent, with the largest increases in population occurring in Sikasso (2.4 million), Koulikoro (1.7 million), and Tombouctou (0.8 million). This population expansion will place increasing stress on limited natural resources, especially in arid Tombouctou. Analysis of crop statistics from the Food and Agriculture Organization of the United Nations (FAO, 2011), however, suggests that increases in national crop yields have kept pace with population growth.

Between the 1960s and 2000s, Mali's average yields increased by 37 percent, whereas the amount of farmland expanded at the same rate as the population, resulting in the amount of farmland per person remaining steady at about 0.24 hectares per person. It may be difficult for Mali to continue this rapid expansion of farmland, and improved use of existing agricultural areas could provide a more sustainable and lower-risk path to food security.

Some Implications for Food Security and Adaptation

The results presented here depict a combination of modest rainfall decreases and rapid air temperature increases. Over the past 20 years, rainfall has remained relatively steady, but future variations seem likely. The sea surface temperature gradient of the Atlantic Ocean swings slowly from north to south on a time scale of decades, and a reversal of the current state could lead to another precipitous Sahelian rainfall decline, a decline augmented by the effects of warmer air temperatures. Given the potential

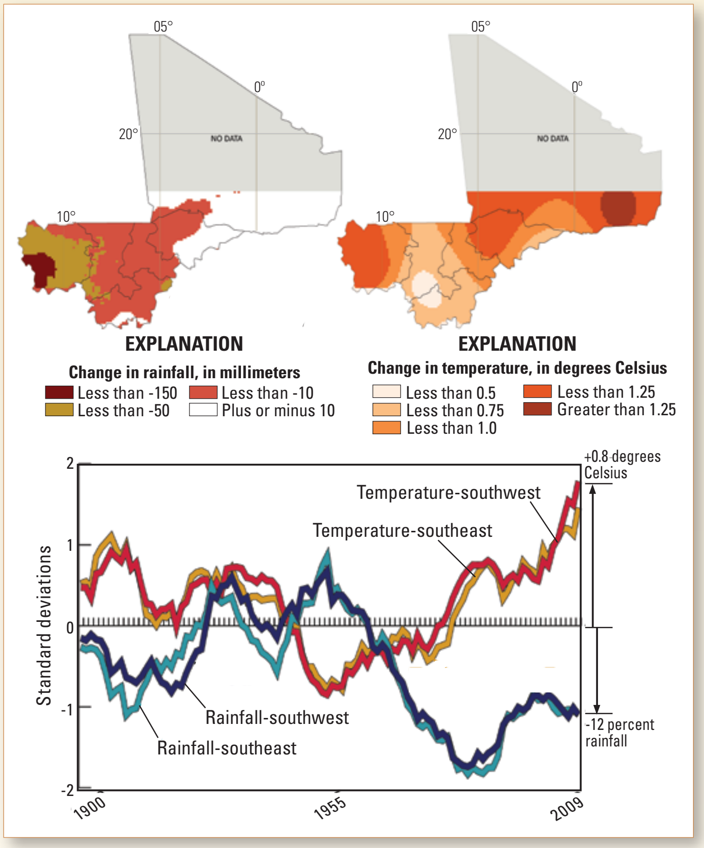

Figure 2. Observed and projected change in June–September rainfall and temperature for 1960–2039 (top), together with smoothed rainfall and air temperature time series for June–September for southwestern and southeastern Mali (bottom). Mean rainfall and temperature are based on the 1920–1969 time period.

for such a decline, raising yields in wetter areas may be a more viable option than extending agriculture into more marginal areas. Although it may be difficult to continue Mali's rapid expansion of farmland, the growth in yields appears promising. The expansion of cropland into more arid areas, and the increase in air temperatures, however, may make sustained yield growth difficult. The rapid population expansion in Koulikoro and Tombouctou could lead to enhanced food insecurity in these regions.

Objectives and Methods

The FEWS NET *Informing Climate Change Adaptation* series seeks to guide adaptation efforts by providing subnational detail on the patterns of climate trends already observed in an appropriately documented record. Whether these observed trends are related to natural climate variations, global warming, or some combination of the two is less important than knowing now where to focus adaptation efforts.

These FEWS NET reports rely on rigorous analysis of station data, combined with attribution studies using observed climate data. This brief report examines Mali rainfall and temperature trends over the last 110 years (1900–2009) using observations from 160 rainfall gauges and 17 air temperature stations for the primary rainy period, June–September. The data were quality controlled, and the mean 1960–1989 and mean 1990–2009 station values were calculated. The difference between these means was converted into 1960–2009 trend observations and interpolated using a rigorous geostatistical technique (kriging). Kriging produces standard error estimates, and these can be used to assess the relative spatial accuracy of the identified trends. Dividing the trends by the associated errors allows us to identify the relative certainty of our estimates (Funk and others, 2005; Verdin and others, 2005; Brown and Funk, 2008; Funk and Verdin, 2009; Funk and others, 2012). Readers interested in more information can find these publications at *http://earlywarning.usgs.gov/fews/reports.php*.

This report was written by Chris Funk and Jim Rowland (both USGS), Alkhalil Adoum (UCSB), Gary Eilerts (USAID), and Libby White (UCSB). It builds upon a multiyear research project (see references below) carried out under a USAID-funded FEWS NET agreement with USGS.

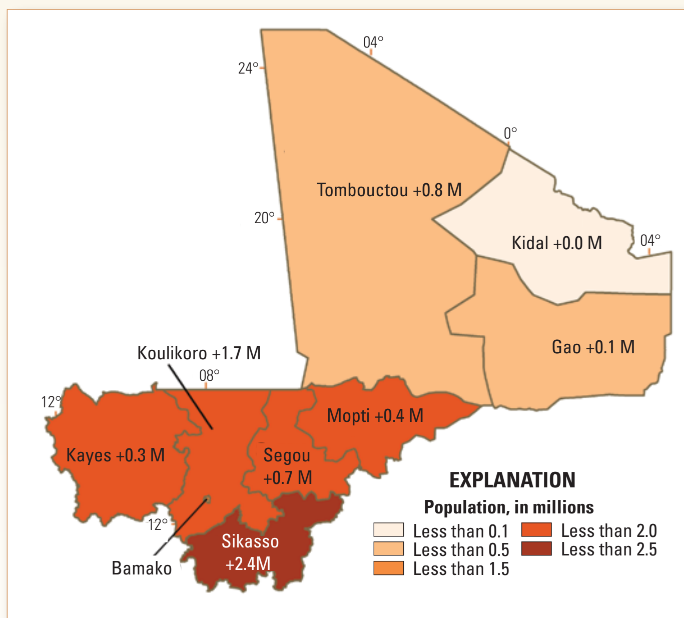

Figure 3. Landscan 2008 population (ORNL, 2010) for Mali as well as Gridded Population of the World estimates (CIESIN, 2010) of 1990 to 2010 population change.

References

Brown, M.E., and Funk, C.C., 2008, Food security under climate change: Science, v. 319, p. 580–581. (Also available at *http://earlywarning.usgs.gov/fews/pubs/Science_2008.pdf*.)

CIA (Central Intelligence Agency), 2011, The World Factbook, accessed December 15, 2011, at *https://www.cia.gov/library/publications/the-world-factbook/geos/ml.html*.

CIESIN (Center for International Earth Science Information Network), 2010, Gridded population of the world, version 3, accessed May 5, 2010, at *http://sedac.ciesin.columbia.edu/gpw/*.

FAO, 2011 (Food and Agriculture Organization of the United Nations), FAOSTAT: Accessed December 15, 2011, at *http://faostat.fao.org*.

Funk, C., Senay, G., Asfaw, A., Verdin, J., Rowland, J., Korecha, D., Eilerts, G., Michaelsen, J., Amer, S., and Choularton, R., 2005, Recent drought tendencies in Ethiopia and equatorial-subtropical eastern Africa: Washington D.C., U.S. Agency for International Development. (Also available at *http://earlywarning.usgs.gov/fews/pubs/FEWSNET_2005.pdf*.)

Funk, C., and Verdin, J.P., 2009, Real-time decision support systems—The famine early warning system network, in Gebremichael, M., and Hossain, F., eds., Satellite rainfall applications for surface hydrology: Netherlands,Springer, p. 295–320. (Also available at *http://earlywarning.usgs.gov/fews/pubs/SatelliteRainfallApplications_2010.pdf*.)

Funk, C., Michaelsen, J., and Marshall, M., 2012, Mapping recent decadal climate variations in precipitation and temperature across Eastern Africa and the Sahel, chap. 14 *in* Wardlow, B., Anderson, M., and Verdin, J., eds., Remote sensing of drought—Innovative monitoring approaches: Taylor and Francis, 25 pgs. (Also available at *http://earlywarning.usgs.gov/fews/pubs/mapping_decadal_variations.pdf*.)

Hoerling, M., Hurrell, J., Eischeid, J., and Phillips, A., 2006, Detection and attribution of twentieth-century northern and southern African rainfall change: Journal of Climatology, v. 19, p. 3,989–4,008.

ORNL (Oak Ridge National Laboratory), 2010, Landscan 2008 population: accessed May 5, 2010, at *http://www.ornl.gov/sci/landscan/*.

Verdin, J.P., Funk, C.C., Senay, G.B., and Choularton, R., 2005, Climate science and famine early warning: Philosophical Transactions of the Royal Society B—Biological Sciences, v. 360, no. 1463, p. 2,155–2,168. (Also available at *http://earlywarning.usgs.gov/fews/pubs/RoyalSociety.pdf*.)

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