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Climate warming causes declines in crop yields and lowers school attendance rates in Central Africa

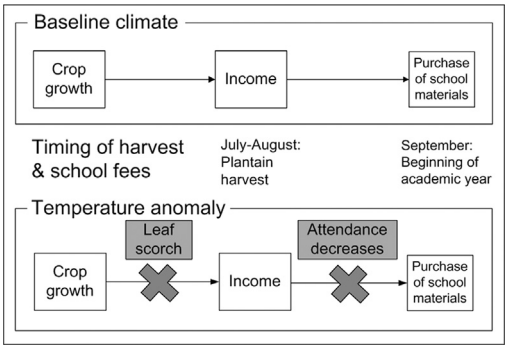
Trevon L. Fuller [a,*], Paul R. Sesink Clee [b], Kevin Y. Njabo [a], Anthony Tróchez [c], Katy Morgan [d], Demetrio Bocuma Meñe [b], Nicola M. Anthony [d], Mary Katherine Gonder [b], Walter R. Allen [c], Rachid Hanna [e], Thomas B. Smith [a,f]

[a] Center for Tropical Research, Institute of the Environment and Sustainability, University of California, Los Angeles, 619 Charles E. Young Dr. East, Los Angeles, CA 90095, United States
[b] Department of Biology, Drexel University, 3245 Chestnut Street, PISB 503, Philadelphia, PA 19104, United States
[c] Graduate School of Education and Information Studies, 290 Charles E. Young Dr. N, Los Angeles, CA 90095, United States
[d] Department of Biology, University of New Orleans, 2000 Lakeshore Dr, New Orleans, LA, United States
[e] International Institute of Tropical Agriculture-Cameroon, 1st Main Road IRAD, Nkolbisson, PO Box 2008 (Messa), Yaoundé, Cameroon
[f] Department of Ecology and Evolutionary Biology, University of California, Los Angeles, 612 Charles E. Young Drive East, P.O. Box 957246, Los Angeles, CA 90095, United States

HIGHLIGHTS

- Plantain yield in Cameroon declined 43% from 1991 to 2011.
- Climatic variables explained the reduction in productivity ($R^2 = 0.68$).
- Education levels in rural households correlated with crop productivity ($R^2 = 0.82$).
- By 2080 we predict a 39% decrease in plantain yields and 51% in education outcomes.
- Farmer training could enhance the adaptive capacity of food production systems.

GRAPHICAL ABSTRACT



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ABSTRACT

Although a number of recent studies suggest that climate associated shifts in agriculture are affecting social and economic systems, there have been relatively few studies of these effects in Africa. Such studies would be particularly useful in Central Africa, where the impacts of climate warming are predicted to be high but coincide with an area with low adaptive capacity. Focusing on plantain (*Musa paradisiaca*), we assess whether recent climate change has led to reduced yields. Analysis of annual temperature between 1950 and 2013 indicated a 0.8 °C temperature increase over this 63-year period - a trend that is also observed in monthly temperatures in the last twenty years. From 1991 to 2011, there was a 43% decrease in plantain productivity in Central Africa, which was explained by shifts in temperature ($R^2 = 0.68$). This decline may have reduced rural household wealth and decreased parental investment in education. Over the past two decades, there was a six month decrease in the duration of school attendance, and the decline was tightly linked to plantain yield ($R^2 = 0.82$). By 2080, mean annual temperature is expected to increase at least 2 °C in Central Africa, and our models predict a concomitant decrease of 39% in plantain yields and

* Corresponding author.
E-mail addresses: fullertl@ucla.edu (T.L. Fuller), psesinkclee@drexel.edu (P.R. Sesink Clee), kynjabo@ucla.edu (K.Y. Njabo), kmorgan4@uno.edu (K. Morgan), db525@drexel.edu (D.B. Meñe), nanthony@onu.edu (N.M. Anthony), mkg62@drexel.edu (M.K. Gonder), wallen@ucla.edu (W.R. Allen), r.hanna@cgiar.org (R. Hanna), tbsmith@ucla.edu (T.B. Smith).

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51% in education outcomes, relative to the 1991 baseline. These predictions should be seen as a call-to-action for policy interventions such as farmer training programs to enhance the adaptive capacity of food production systems to mitigate impacts on rural income and education.

1. Introduction

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) outlined hypotheses about the impacts of climate change on agriculture, disease, ecosystems, and water resources in Africa (Niang et al., 2014). Regarding agriculture, the Fifth Assessment hypothesized that with warmer temperatures and decreased rainfall, crop yields will decline. Since the Fifth Assessment was published, the effects of climate change on yield have been predicted for cocoa in West Africa. By the 2050s, increases in maximum temperature are forecast to cause declines in areas suitable for cocoa production in countries along the Gulf of Guinea (Schroth et al., 2016). In addition to effects on agriculture, the Fifth Assessment hypothesized that the geographic ranges of vector-borne and water-borne diseases will expand and that the geographic boundaries of ecosystems will shift affecting wildlife and natural resources (Niang et al., 2014).

The sensitivity of crop yields to climate change is often complex encompassing both direct biophysical effects, such as the impact of shifts in temperature and precipitation on plant growth, as well as indirect effects, such as the impact of climate on the abundance of pathogens, vectors, and their predators (Ye et al., 2015). Examples of reduced yields attributed to climate change include rice and wheat in India (Burney and Ramanathan, 2014) and the productivity of a variety of staple food crops in Sub-Saharan Africa (Blanc, 2012). Banana (*Musa* spp.) and plantain (*Musa paradisiaca*) are predicted to be highly sensitive to the direct effects of climate change due to their narrow temperature and water tolerance (Jarvis et al., 2012). In Cameroon in Central Africa (Fig. 1(A)), plantain is expected to be sensitive to climate change because the predicted increase in temperature could delay flower development and bunch emergence causing yields to decline (Turner et al., 2007). Furthermore, the irrigation requirements of banana are 1200 mm in tropical climates and declines in precipitation below this threshold could induce water stress (FAO, 2015). As discussed below, adaptation via changes in management such as genetic improvement of *Musa* might partially mitigate the impacts of climate change on plantain yield, but will not eliminate them entirely due to the significant time and investment required to establish crop breeding programs.

As most farmers in Central and West Africa rely on rain for irrigation, the vulnerability of the region's agricultural production systems to drought is high. Over the last 40 years, one of the strategies that rural populations have adopted in response to drought is to abandon agriculture and migrate away from farming areas (Njock and Westlund, 2010). For example, in 1972 and 1983–4 droughts prompted major migration events involving millions of people who relocated from dry ecosystems in the Sahel to humid coastal ecosystems along the Gulf of Guinea (Gautier et al., 2016; Mertz et al., 2010; Ouedraogo et al., 2010). Future droughts and demographic shifts such as substantial growth of the population under 15 years of age are predicted to result in increased population vulnerability and migration in northern Nigeria, western Cameroon, and coastal areas of the Republic of Congo and the Democratic Republic of Congo (Lopez-Carr et al., 2014).

Understanding the impacts of climate change on crop productivity in Central Africa is vital due to the economic importance of the region's agricultural sector. For example, in Cameroon >70% of the rural population works on small farms (Yengoh, 2012). Given the importance of crop production, the negative effects of climate change on food crop yields could impact the dynamics of supply and demand in the plantain sector. A decrease in the supply of plantain would increase demand due to shortages, but whether this would affect prices would depend on buyers' willingness and ability to pay more for plantain. The most recently-available price data from Cameroonian markets is from 2009 to 2011 and indicates that the price per kilogram rose 55% over this period, increasing from 100 to 150 Central African Francs per kilogram (Institut National de la Statistique, 2012). However, over longer periods, climate change may reduce consumer income, making buyers unable to match increased plantain prices.

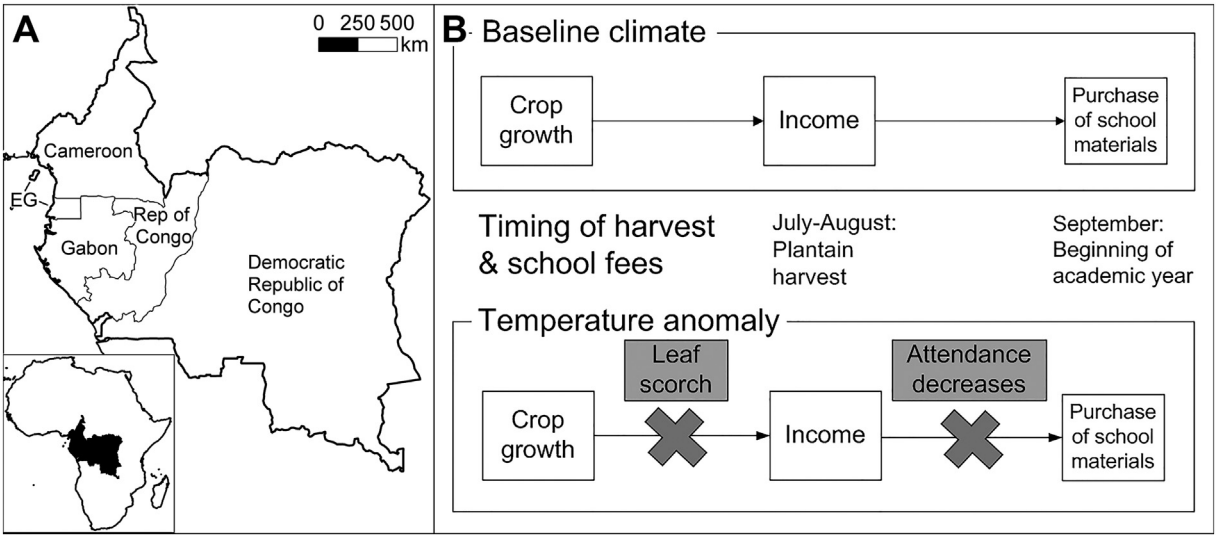

Fig. 1. Study area and schematic of climate change impacts on crops: (A) countries of Central Africa. EG = Equatorial Guinea; (B) mechanisms by which climate change could affect plantain yields and school attendance in Cameroon.