Weather shocks, social upheaval and cash crops: Evidence from colonial tropical Africa.

Kostadis J. Papaioannou, Wageningen & Utrecht University
Michiel de Haas, Wageningen University

Abstract. This study investigates the effects of weather shocks on social upheaval among African smallholders in British colonial Africa. We collect data from annual administrative records and construct a panel dataset of 151 districts across west, south-central and east Africa in the Interwar Era (1920-1939). Our findings are twofold. First, we establish a robust U-shaped relation between rainfall deviation and annual imprisonment. We argue that the effect runs via harvest failures which increase levels of social tension and distress. Second, we review a long-standing and unsettled debate on the impact of agricultural commercialization on African smallholders' resilience to weather shocks, and find that areas where smallholders cultivated cash crops experienced lower levels of social upheaval in years of abnormal rainfall.

Keywords: Africa; economic history; colonialism; social conflict; social upheaval; tropical agriculture; agricultural commercialization; environmental history

JEL Codes: N17, N57, Q17, F54 , D74

Corresponding author: Kostadis J. Papaioannou, kostadis.papaioannou@wur.nl

Acknowledgments: We are indebted to Erwin Bulte, James Fenske and Ewout Frankema whose comments and suggestions substantially improved this study. For useful comments, we thank Felicitas Becker, Peter Bent, Cédric Chambru, William Collins, Daniel Curtis, Leigh Gardner, Jose Martinez-Gonzalez, Leander Heldring, Noel Johnson, Niek Koning, Paul Lane, Paolo Malanima, Pieter Woltjer, and the participants of the International Workshop in Historical Ecology at Uppsala University, Sweden (November 2014), the Thesis Workshop Series at the London School of Economics and Political Science (LSE), United Kingdom (February 2015), the seminar of Political Economy, Economic History, Growth and Development at Groningen University, Netherlands (February 2015), the Economic History Graduate seminar at Oxford University, United Kingdom (May 2015), the Datini-ESTER advanced seminar in Prato, Italy (May 2015), the ERSA Workshop at Stellenbosch University, South Africa (May 2015), the XII[th] World Economic History Congress in Kyoto, Japan (August 2015) and the Social Science History Association conference in Baltimore (November 2015). We are grateful for the financial support of the European Research Council under the European Community's Seventh Framework Programme (ERC Grant Agreement no. 313114) as part of the project *Is Poverty Destiny? A New Empirical Foundation for Long-Term African Welfare*. Any remaining mistakes are our own.

1. Introduction

Scholars and policy makers have become increasingly aware of the short-run and long-run impact of climatic factors on economic, social and political outcomes (Hsiang et al. 2013; Dell et al. 2015). The adverse impact of erratic rainfall on societies is particularly pronounced in developing countries, with sub-Saharan Africa being the most vulnerable region (Ahmed et al. 2009; Barrios et al. 2010; Bruckner & Ciccone 2011; Miguel et al. 2004). This is not surprising, as a large share of the population depends on rain-fed subsistence agriculture and less than 5% of the cultivated area is irrigated (Schlenker & Lobell 2010). Indeed, in an African context, harvest failures and food insecurity arising from climatic factors appear to be tightly related to social destabilization. Several studies have shown that climatic factors trigger social conflict (Fjelde & von Uexkull 2012; Hendrix & Salehyan 2012; Papaioannou 2016) and full-blown civil war (Blattman & Miguel, 2010), but also processes of democratization (Bruckner & Ciccone 2011). Rather than accepting a static link between weather and social outcomes, a key challenge is to understand which conditions aggravate or mediate the impact of exogenous environmental shocks. It is especially crucial to learn more about the local determinants of resilience to the vagaries of climate (Adger 2000; Folke 2006; Gallopin 2006). Africa's rising population densities, pervasive climate change and resurging socio-political instability contribute to making this a most pressing concern.

The contribution of this study to existing empirical analyses is fourfold. First, it provides novel evidence on the link between weather shocks and social outcomes in tropical Africa. While this link is subject to a wide range of studies, the number of data sources is relatively thin, and the debate far from settled (Dell et al. 2015; Hsiang et al. 2013; Klomp & Bulte 2013; Buhaug et al., 2014). Exploiting the extensive and consistent administrative records that remain from Britain's African empire, we provide new material on a region for which systematic data collection is notoriously difficult. Moreover, our focus on the interwar era (1920-1939) contributes to a considerable expansion of the time horizon (cf. Papaioannou 2016; Christian & Fenske 2015).

Second, our argument is based on both qualitative evidence and econometric analysis. We use colonial administrative accounts to expose the mechanisms that lead from extreme weather shocks to higher levels of social upheaval.[1] These accounts strongly suggest that extreme weather events bring about crop and harvest failures which, in turn, increase

[1] We conceptualize social upheaval as heightened levels of social tension and distress, which manifests itself in resource scarcity, reduced incomes and population displacements, which ultimately result in higher levels of crime, political unrest and poverty.

competition over scarce resources and ultimately lead to higher levels of social tension and distress (cf Homer-Dixon 1999, Kahl 2006). The qualitative accounts show that both *drought* and *excessive rainfall* adversely affect agricultural outcomes. To test the weather-to-upheaval link econometrically, we construct a novel panel dataset at the *sub-national level*[2], obtaining observations on annual rainfall and imprisonment. We argue that imprisonment rates are appropriate to proxy for social tension and distress, as colonial prisons were used to lock up *deviant* and *destitute* elements of society. Our dataset consists of *151 administrative units* for a *20 year period*. Our econometric estimates using fixed-effects models confirm the existence of a robust *U-shaped* effect of weather shocks on rising levels of social upheaval.

Third, this study investigates the extent to which social upheaval resulting from weather shocks is mitigated by smallholders' cash crop cultivation. The issue of whether the adoption of cash crops by African smallholders was beneficial or detrimental to vulnerable rural communities is the subject of a long-standing debate among policy makers and scientists (Hopkins 1973; Myint 1958; Rodney 1978; Maxwell & Fernando 1989; Austin 2014). A key issue at stake in this debate is the impact of cash crops on rural communities' ability to cope with exogenous shocks. Some maintain that the adoption of cash crops made rural communities more *vulnerable* to societal destabilization, by diverting attention away from subsistence production, undermining 'traditional insurance mechanisms' and facilitating exploitation and extraction (Vaughan 1987; Watts 1983). Others, instead, have argued that access to export markets made such communities more *resilient* to social upheaval, providing them with the ability to spread risk, smoothen consumption and profit from infrastructural and institutional investments (Bryceson, 1980, 1988; Fafchamps 1992b).

Fourth, we measure cash crop production on a sub-national level by constructing a new fine-grained indicator of smallholder cash crop production in British colonial Africa during the interwar era. We use this index to split our sample in halves and quartiles and control for outliers (the West African cocoa belt). Our indicator allows us to measure our variable of interest directly, rather than having to rely on a crude proxy (e.g. based on crop suitability). We demonstrate that districts with relatively higher levels of cash crop cultivation were significantly less affected by weather shocks than those with less cash crops. We perform a number of tests to refute alternative geographical, institutional and income-related explanations to determine that the link between cash crop cultivation and resilience to weather anomalies is causal.

[2] We collected the most disaggregated data consistently available: provinces in the case of Nigeria, districts in all other cases.

We justify our case study of interwar British colonial Africa on a number of grounds.[3] First, Britain administered a vast African empire. The colonial state's key preoccupations were related to law and order as well as agricultural production, coinciding with our key variables of interest. The extensive bureaucratic legacy has allowed us to construct a sub-national dataset (N=151) spanning approximately one fifth of Africa's landmass and one third of its population in this period. Second, our geographic scope provides us with the necessary variation to exploit, encompassing administrative units where cash crops were widely cultivated, as well as those where livelihoods were dominated by subsistence farming. Third, our temporal scope encompasses the interwar period, which is generally considered more tranquil and peaceful than the period of violent early-colonial conquest and the highly politicized post-war road to independence (Killingray 1986). Thus, this timeframe offers us a good framework to plausibly link levels of social tension and distress to harvest failures (rather than political turmoil).The remainder of the paper is organized as follows. Section two deals with the impact of weather shocks on social upheaval. It introduces the data and presents the main results on the robust curvilinear (U-shaped) relation between weather shocks and annual imprisonment rates. In section three, we test the relationship between cash crop cultivation and upheaval, and find that districts with cash crops were more resilient to weather-induced scarcities. Section four concludes and suggests directions for further research.

2. Do weather shocks lead to social upheaval?

2.1 Theory

Over the past decade, the scholarly debate on impact of weather anomalies on societal outcomes has expanded considerably. Weather variables have been linked to economic outcomes, health, agriculture, crime and conflict (for overviews see Hsiang et al. 2013; Dell et al. 2015). While some scholars dispute the evidence linking weather to conflict (Klomp & Bulte, 2013; Buhaug et al. 2014), most find support for the existence of a causal relation, especially in low-income settings (Hsiang et al. 2013). The link seems particularly pronounced in tropical Africa (Barrios et al. 2010; Bruckner & Ciccone 2011; Miguel et al. 2004). Scholars are divided on the mechanisms that explain the climate-to-conflict nexus (Buhaug 2010; Klomp & Bulte 2013). Harvest failure (leading to lower incomes and agricultural deficiencies) appears to be a

[3] Included are [name of colonial territory (name of present-day country)]: Gold Coast (Ghana), Nigeria Protectorate and Colony (Nigeria), The Gambia, Sierra Leone, Bechuanaland (Botswana), Northern Rhodesia (Zambia), Nyasaland (Malawi), Kenya Colony (Kenya), Tanganyika Territory (Tanzania) and Zanzibar (Tanzania). We did ot have sufficient prisoner data to include Uganda Protectorate (Uganda) in the analysis.

prime candidate, especially in low-income settings, where people's livelihoods tend to rely more heavily on (rain-fed) farming and where small deviations in crop yields can have devastating effects (Barrios et al. 2010; Bruckner & Ciccone 2011; Miguel et al. 2004; Schlenker & Lobell 2010). The literature would profit from more fine-grained analysis and an extension of the time period.

In an *African context*, numerous studies have found that weather extremes lead to tension and conflict (Almer & Boes 2012; Buhaug 2010; Burke et al. 2009; Couttenier et al 2011; Fjelde & von Uexkull 2012; Hendrix & Salehyan 2012; Miguel et al. 2004). Among those who take precipitation as the key independent variable, some find that drought is the prime driver of conflict (Maystadt & Ecker 2014; Christian & Fenske 2015), while others argue that extremes on both ends (drought and excessive rainfall) lead to higher conflict incidence (Papaioannou 2016; Fjelde & von Uexkull 2012; Hendrix & Salehyan 2012). Most studies use a binary indicator of conflict, for example based on the ACLED database which records conflict events in states affected with civil war (1960 – 2004), or the UCDP/PRIO Armed Conflict Dataset on armed conflict (1946 – present), which captures only large-scale outbreaks of unrest, violence or conflict, and omits subtler forms of social tension and distress. A number of recent contributions have begun to investigate different time periods (Papaioannou 2016, Christian & Fenske 2015), employ a more fine-grained, sub-national scope (Harari et al. 2013; Papaioannou 2016; Raleigh & Urdal 2007; cf. Jia 2014) and use more non-binary indicators of conflict intensity (Papaioannou 2016). Moreover, a number of studies have employed detailed case study analyses to uncover the key mechanisms leading from weather to conflict (Adano et al. 2012, Benjaminsen et al. 2012; Ember *et al.* 2012; Witsenburg & Adano 2009). We contribute to these new explorations by providing a new indicator on more subtle forms of social tension and distress.

2.2 Rainfall shocks and harvest failures under British colonialism

Our sources provide a unique opportunity to engage with the different perspectives in the debate on the effects of weather anomalies on African societies. The British colonizers set up an extensive system of administration in their African dependencies. Territories were subdivided into provinces and districts. Local administration was left to African native rulers, who operated under supervision of British administrative officers. In this paper, we use annual administrative reports obtained from the departments of agriculture, native affairs, police, justice and prisons, as well as the annual *Blue Books of Statistics*. These reports are consistent in their coverage of issues over time and across colonies and give us a uniquely comprehensive insight into local conditions across a wide area and a timespan of 20 years. The reports are rich in relevant content, making regular notice of weather-induced agricultural failure, resulting in higher levels of distress, and in the more extreme cases, to subsistence crises and famines. Firstly, we discuss mechanisms leading from rainfall anomalies to harvest failures. Secondly we show how harvest failures led to social tension and distress.

Administrative accounts frequently mention how *droughts* led to crop damage and failure. In a context of rain-fed agriculture, lack of precipitation prevents seeds from germinating, slows down plant growth and diminishes yields. Droughts also affect livestock. Diminished supplies to wells, surface water sources and pastures negatively impacts upon the water and food supply of livestock. An administrative account discusses how these different drought effects struck Baringo District (Kenya): “The year 1933 has been one of the worst in living memory. A complete failure of the long rains caused enormous losses among stock, ruined the crops in the low-lying parts and made the harvest on Masop very late. It is safe to say 50 per cent of the cattle died” (Kenya, Native Affairs Report 1933)

Regular mention is also made of the adverse effects of *excessive rainfall* on agriculture. The adverse effects of excessive rainfall run via a number of mechanisms. Heavy precipitation and resulting inundation can damage crops and create adverse conditions for harvesting, storage and transportation of agricultural produce. In 1936, the Rufiji District (Tanganyika) suffered “a great flood”, which “ destroyed the main crops of one-third of the population.” (Tanganyika, Native Affairs Report 1936). In Gambia, as a result of abnormally heavy rainfall, the groundnut crop “suffered severely during the ripening and reaping period. [...] Fermentation was rapid and much damage was done to the nuts and to the quality of soil. The extent of this damage was widespread and felt throughout the country” (Gambia, Agricultural Report 1927).

Administrative accounts also link heavy rainfall to increased prevalence of plant diseases. In Ondo Province (Nigeria), ‘black pod disease’ destroyed an estimated 30 percent of the cocoa harvest during a year of heavy rainfall (Nigeria, Agricultural Report 1933). Reports also recount how parasitic organisms thrived under conditions of heavy rainfall. A serious increase in weevil infestation in the Trans Nzoia District (Kenya) was attributed to “abnormal weather conditions” (Kenya, Agricultural Report 1930). In some cases, humid conditions also favoured the propagation of human disease, which negatively affected the harvest. In Nyanza Province (Kenya), “the rainfall was much above the average with but a very slight break between the long and the short rains. Crops suffered as a consequence and yields have been low. Fever among the inhabitants restricted the amount of work done. These factors have reduced the output of marketable crops, and in some areas a food shortage may result." (Kenya, Agricultural Report 1926)

Examples of the negative impact of droughts as well as excessive rainfall can be found in both very wet and very dry regions. Dry soils can be incapable of absorbing the precipitation, resulting in run-off, floods and waterlogging. After a few years of drought, for example, Machakos (Kenya), a district with an average annual rainfall of only 40 inches, experienced an exceptionally wet year. The agricultural report notes that "despite the very heavy rain during the year, the condition of the Reserve has not improved; it has in fact degenerated further, particularly in regard to water supply. Owing to large areas being denuded of grass, the erosion caused by the heavy rains must have been enormous" (Kenya, Native Affairs 1930).

2.3 From harvest failures to social upheaval

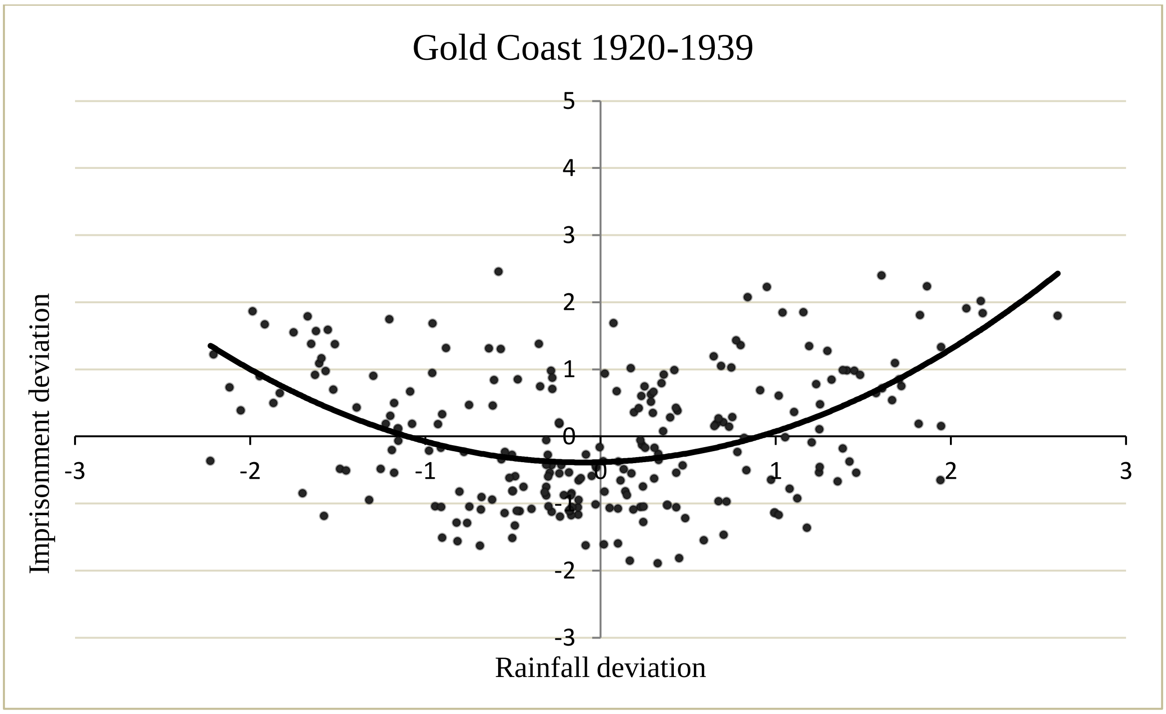
We proceed by illustrating how weather-induced harvest failures provoked social upheaval. The administrative record reveals how the negative impact of rainfall deviations on agricultural production resulted in *distress*. Firstly, harvest failures have been frequently reported to result in food price hikes and distress. In Northern Nigeria, 1927 the causal mechanism running from drought to harvest failure to food shortage and prices hikes was explicitly recognized: "the rainfall, which was considerably below the average, caused a partial failure of the guinea corn and yam crops in certain districts of the province. There was a definite shortage which caused the price of grain to soar to three or four times the normal price" (Nigeria, Provincial Report 1927). An episode of abnormally high rainfall in Saltpond and Winneba District (Gold Coast) resulted in crop damage, failure and 'resultant stress', 'shortage of the food supply' and high prices (Gold Coast, Agricultural Report 1925). Similarly, in Rufiji District (Tanganyika) 1930: "for a considerable period 15,000 natives were homeless owing to the floods and many lost their houses, stock and crop." (Tanganyika, Native Affairs 1930).

Secondly, the administrative accounts frequently link the adverse impact of rainfall to *social tension*, including increased frequency of petty crime as well as livestock raids and thefts. In 1933, severe drought and stock mortality in the Masai District (Kenya) "led to an increase in crime. Actual hunger caused many sheep thefts and raids into Tanganyika Territory" (Kenya, Native Affairs 1933). Similarly, "there was a series of stock thefts and armed raids by Masai. The probable cause of these was the drought conditions in Masai which resulted in heavy mortality among their stock." (Kenya Native Affairs 1934). The opposite was also true. Colonial officers sometimes explicitly attributed the absence of tension to low prices due to favourable weather. The Gambia police, for example noted that: "With such favourable weather conditions coupled with the low price of foodstuffs, it was only to be expected that the crime figures should be satisfactory and never in the past 30 years has the total number of reports of serious crime been so small as in 1934. It is too much to hope that such a peaceful state of affairs can become normal" (Gambia, Police Report 1934). Rainfall extremes have been associated with forcing people to get on the move. Drought-induced migration, carried an increased risk of clashes with neighbouring groups over grazing pastures and water. In Turkana District (Kenya), "a phenomenal drought" led to "famine and poverty" as well as a "constant anxiety of raids and massacres on the frontier. [...] The Turkana have been driven in unprecedented numbers to encroach on the grazing and water supplies of their more fortunate neighbours" (Kenya, Native Affairs 1933).

2.4 Expected result

An example of the expected curvilinear (U-shaped) impact of weather shocks on social upheaval is provided in Figure 1. In this example, based on Gold Coast data, we have scatter-plotted rainfall deviations against annual imprisonment deviations.

Figure 1. *Weather shocks and social upheaval in the Gold Coast (1920-1939)*



2.5 Data

To test the expected relationship econometrically, we use annual imprisonment deviation and rainfall deviation as our main variables. We include a set of *observable* and *unobservable* controls in the analysis. All variables are original and obtained directly from colonial sources, except if stated otherwise. The summary statistics are presented in Table 1 below.

2.5.a Imprisonment rates

While the administrative accounts are rich, a qualitative approach also suffer from considerable limitations. British colonial services tended to be understaffed. Local administrators had to operate on a shoestring and were hardly capable to control the vast territories they were supposed to administer. Moreover, their accounts reveal strong prejudice as well as paternalistic and derogatory attitudes towards local African populations, while civil servants, to brush up their achievements and benefit their own careers, also had incentives to focus on 'progress' and paint a rosy picture to superiors (Killingray 1986). Although we have few reasons to question the accuracy of administrators' observations concerning the weather and harvest failure, we are less confident about the ability of colonial officials to objectively and consistently assess levels of social tension and distress.

Rather than basing our indicator on an analysis of qualitative sources (cf. Huillery 2011), we collect annual, district-level data on imprisonment (panel (a) of Table 1). We argue that this indicator, rather than reflecting the preferences or reporting qualities of individual colonial officials, provides us with an accurate reflection of annual fluctuations in levels of social upheaval. Each district we include has at least one prison within its borders. If more than one was present, we take the sum. We standardize our imprisonment figures using the z-scores: $(x_{i,t} - \bar{x}_i) / \sigma_i$. We break down imprisonment in the robustness section into those admitted for debt, safe custody and penal imprisonment. The latter category is further refined by distinguishing penal imprisonment of up to three months, and above three months.

Reasons for colonial imprisonment are contested (Kercher 1981; Branch 2005). Colonial penal institutions, grafted upon imported penal codes and using imprisonment, fines and, in some cases corporeal punishment as its major instruments, were essentially foreign to most parts of sub-Saharan Africa (Milner 1969; Killingray 1986; Bernault 2003; 2007). Colonial penal systems were established and served to increase the governability of the newly acquired territories (Bernault 2007; Hynd 2011; Killingray 1986). To that aim, prisons were used to incarcerate deviant and destitute elements of society. In most cases, administering justice (i.e. applying the penal code) happened at the discretion of the district officer (who had enjoyed only minor legal training) or, for minor breaches of law, native authorities (Milner 1969). According to the official statistics, most cases of imprisonment resulted from crimes related to theft or offences against the person. Significant shares of imprisonment cases resulted of debt, fine and tax defaulting, and transgressions of a range of colonial ordinances (Hynd 2011; McCracken 1986; Coldham 2000).

Table 1. Summary Statistics: District by Year Data

Variable	Obs.	Mean	Std. Dev.	Min	Max
Panel (a): Dependent variables					
Total prisoners	2730	412.74	521.62	0.00	5572
Prisoners st.dev.	2714	0.00	1.00	-2.60	3.70
Debt	2688	8.69	29.61	0.00	426
Safe custody	2688	109.88	172.28	0.00	3377
Penal imprisonment	2729	296.17	377.01	0.00	3523
Less than 3 months	2671	190.93	319.27	0.00	3335
More than 3 months	2672	106.68	169.28	0.00	1344
Panel (b): Independent variable of interest					
Rainfall long-term mean	2900	46.91	24.12	15.80	144.10
Rainfall st.dev. Stations	2529	0.00	1.00	-3.20	3.30
Rainfall st.dev. squared Stations	2529	1.00	1.32	0.00	10.89
Rainfall absolute st.dev. Stations (Linear)	2529	0.80	0.58	0.00	3.30
Rainfall st.dev. Grids	3200	0.00	1.00	-3.50	3.30
Rainfall st.dev. squared Grids	3200	1.00	1.33	0.00	12.25
Rainfall absolute st.dev. Grids (Linear)	3200	0.81	0.58	0.00	3.50
CashCropProduction value(£) per capita	3220	0.52	1.47	0.00	10.10
Positive rainfall shocks	1225	0.83	0.62	0.01	3.27
Negative rainfall shocks	1289	-0.79	0.56	-3.16	-0.01
Panel (c): Control variables (time-varying)					
Population density (persons per square mile)	3260	52.98	74.60	0.13	801.44
Whites per 1000 of the population	3240	5.28	20.37	0.00	395.10
World market prices of cash crops	2176	100.76	40.12	31.00	303.00
Panel (d): Control variables (time-invariant)					
Rainfall coefficient of variation (CV)	2900	0.22	0.01	0.10	0.40
Pre-colonial chiefdom or state	3180	2.45	0.94	1.00	4.00
Railway	3260	0.41	0.49	0.00	1.00
Settler agriculture	3260	0.17	0.37	0.00	1.00
Livestock units per 1000 of the population	3260	70.62	21.97	0.00	135.28
Cocoa cultivation	3260	0.07	0.26	0.00	1.00
Rainy season overlaps two years	3220	0.57	0.50	0.00	1.00
Consecutive shocks (>1 std. dev.)	3220	1.00	0.00	1.00	1.00

Notwithstanding the exact mix of criminals, rebels and the poor in colonial prisons, annual imprisonment fluctuation is a suitable indicator to test the impact of weather-induced harvest failures on social upheaval. If imprisonment rates reflect *crime rates,* imprisonment spikes in years of weather anomalies can be interpreted as resulting from increased property crimes, committed in an effort to mitigate food insecurity and compensate for lost income. If imprisonment rates reflect levels of *civil disobedience,* imprisonment spikes in years of weather anomalies can be interpreted as challenges to local authorities who have proven unable to avert distress. If imprisonment reflects *poverty rates*, imprisonment spikes in years of weather anomalies are likely to result from increased numbers of debt, fine and tax defaulters. Moreover, in such years, moreover, some destitute persons might seek out imprisonment as a last resort to obtain food and basic health care (Branch 2005: 259). Even if imprisonment reflects colonial *pre-emptive incarceration strikes*, imprisonment spikes in years of weather anomalies probably social instability and increased levels of vagrancy. In other words, notwithstanding the exact interpretation of colonial imprisonment statistics, they provide us with an indicator of social upheaval.

2.5.b Rainfall deviations

We collect annual precipitation data from meteorological stations, which were first introduced in British colonial Africa in the late 19th century. Each district we include has at least one meteorological station within its borders. If more than one was present, we took the average of them. To fit econometric purposes, we use the following formula (z-score) to construct our measure for weather anomalies:

$$(X_{i,t} - \bar{X}_i) / \sigma_i , \qquad (1)$$

where $\bar{X}_i$ is the long-term mean of each district, $X_{i,t}$ is the annual rainfall in time t for district i, and σ_i is the standard deviation of each panel, that is for every i.

On a cautionary note, both the quantity and distribution of rain are determinants of agricultural failure or success. Average annual rainfall may be close to the long term mean, but if the distribution was very abnormal, a weather-induced crop failure may have occurred nonetheless. In other cases the total rainfall was far off, but the distribution favourable. Similarly, if a rainfall excess or shortage was spread smoothly throughout the year, or occured outside the growing season, the effect may have been less severe than suggested by the annual figure. Annual rainfall figures, hence, may not fully capture the impact of rainfall on harvest. Nevertheless, we find their use highly defensible. Firstly, they are commonly used in the literature. Secondly, the crude nature of annual rainfall figures is unlikely to result in unduly significant results (i.e. finding a relation when there is none), but rather to underestimate the results. Thirdly, the selected model specification with the use of nearly 2,500 observations (n=151, T=20) substantially increases the reliability of our findings. The summary statistics of the weather conditions are presented in panel (b) of Table 1.

2.5.c Time-varying control variables

Next to our main dependent and independent variables, we construct time-varying controls. Annual total population is estimated on the basis of colonial 'native' census data, and expressed in terms of population density (per square mile). White population is estimated on the basis of 'non-native' censuses, and express per 1000 of the population. World market prices of relevant export commodities are taken from Wageningen African Trade Database (forthcoming) (see panel (c) of Table 1).

2.5.d Time-invariant control variables

In our estimation we distinguish between *observable* and *unobservable* time-invariant controls. With our observable time-invariant controls we control for the interaction of several *observable* district-specific characteristics (for example: the presence of livestock) with a linear time trend to take into account for their impacts over time. We would expect districts with high presence of livestock to be more resilient in 1939 than in 1920, due to stock accumulation. Livestock per 1000 of the population per district (average 1920-1939) is estimated on the basis of livestock censuses.[4] Coastal and railway dummies were created on the basis of colonial maps. Pre-colonial chiefdoms and states were measured using the classification proposed by G.P. Murdock (1967) for "Jurisdictional Hierarchy beyond Local Community" (Variable 33, Gray 1999). Pre-colonial chiefdoms and states are defined as places with more than one level of jurisdictional hierarchy beyond the local community.

With our unobservable time-invariant controls we control for any other *unobservable* characteristics that we would expect to change over time. This set of controls is estimated by interacting each district with a linear time trend. We label these unobservable controls as district-specific effects (*DSE*). In this way, we control for the possibility that (a) colonial authorities have become more efficient in inhibiting social tensions (or instead have extended their punitive capacity) over time and that (b) previous episodes of social upheaval have promoted distrust among certain social groups in a way that this distrust may affect future attitudes and upheaval between particular groups, (c) regions with higher incomes are better off over time because they are able to store wealth, (d) conflict may have been attenuated by the gradual expansion of public infrastructure such as roads and railways. The summary statistics for these variables are reported in panel (d) of Table 1.

[4] We use the concept of 'tropical livestock units' to weigh cattle (weight = 0.7), sheep (0.1) and goats (0.1).

2.6 Model

To test the effect of rainfall shocks on social upheaval, we estimate the following specification:

$$
\begin{aligned}
Y_{i,t} = \; & \beta_1 \, RainfallDeviation_{i,t} + \beta_2 \, RainfallDeviationSQ_{i,t} \\
& + \delta Z'_{i,t} + v_i + \mu_t \\
& + (observable \times time)_{i,t} + (unobservable \times time)_{i,t} + \varepsilon_{i,t} \,. \qquad (2)
\end{aligned}
$$

where $Y_{i,t}$ denotes the annual standard deviation of imprisonment. $Rainfall\_deviation_{i,t}$ denotes the annual rainfall deviation of each district i from the historical long-term mean of the same district. We included the square term of $RainfallDeviation_{i,t}$ (denoted in model (1) as $RainfallDeviationSQ_{i,t.}$) in order to estimate the hypothesized non-linear condition. This way we test for both linear and curvilinear relationships between rainfall shocks and the incidence of social upheaval. $Z'_{\mathrm{i,t}}$ denotes a vector of institutional and economic determinants of tension which we control for in order to avoid any potential omitted variable bias.

ν_i and μ_t are district and year fixed effects, respectively. We use these to control for omitted heterogeneity at the level of districts and time periods. These controls are crucial in controlling for factors that may affect the levels of prisoners across all districts in the same year. For example, we might expect higher levels of imprisonment in a given year with extremely low export prices (such as during the Great Depression). To address autocorrelation concerns of weather shocks the standard errors are clustered by district.

Moreover, $(observable \times time)_{i,t}$ denotes the *observable* district specific characteristics when interacted with a linear time trend (t). To give an example, we expect that a railway mitigates the impact of weather anomalies on social upheaval, because food supplies can be distributed to the affected district at a relatively faster pace. $(unobservable \times time)_{i,t}$ denotes district-specific effects (*DSE)*, i.e. an interaction term between *unobservable* district characteristics (ν_i) and a linear time trend (t). ε_{it} is the error term.

To further increase the robustness of the results, for each Table in the main text using the square term of rainfall deviation, we have added a corresponding Table in the Appendix using a linear form of rainfall deviation. The linear form was calculated by taking the absolute value of rainfall deviation. Since excluding the lagged dependent variable (Y_{t-1}) can bias the estimates (Dell et al. 2015), we re-estimate all the results by running a dynamic panel data model using the system Generalized Method of Moments (system-GMM) developed by Bond (2002). This method not only takes into account the inclusion of a lagged dependent variable among the explanatory variables, but it also allows for the time series dimension of the data (e.g. lagged

Rainfall$_{t-1}$), yielding consistent estimates. Finally, in all estimations we have controlled for spatial correlation (cross-sectional dependence) by adjusting standard errors following Hoechle (2007). This way we deal with the issue of migration and spatial spill-overs of upheaval. We control for any potential spillovers (e.g. 'hunger' migration across district borders) and allow this effect to decay smoothly with distance. In practice, we allow correlation to decay smoothly with distance.

2.7 Main Results

Table 2 presents our main results, which indicate a robust and significant curvilinear effect of weather shocks on social upheaval. The rainfall deviation square variable yields a positive sign and holds a highly statistical significant coefficient throughout all columns. Column 1 shows the baseline results without controlling for any fixed effects. Column 2 shows the results after controlling for district and year fixed effects. Column 3 shows the results after controlling for the interaction of *observable* district characteristics multiplied with a linear trend, whereas Column 4 yields a similar result after controlling for *unobservable* district-specific effects (*DSE*).[5] Column 5 reports the results after adding the time-varying controls. On average, a standard deviation increase (or decrease) in rainfall causes a 0.169 standard deviation increase in social upheaval.[6] This result is crucial not only for its statistical significance but also for its economic significance.

2.8 Robustness checks of main results

We perform numerous robustness exercises which we report in the Appendix. First, we seek to investigate whether our results remain robust using alternative indicators of both our independent and dependent variables. In Table A-1, we show that replacing rainfall deviation obtained from meteorological stations with an alternative measure of rainfall, based on the Matsuura and Wilmott (2009) world rainfall database (0.5 x 0.5 grid), gives nearly identical results. In Table A-2, we modify our dependent variable by distinguishing among various reasons for imprisonment (debt, safe custody and penal imprisonment). Moreover, we distinguish between high and low intensity of upheaval by using the duration of imprisonment; our cut-off point was 3 months. The results point to a significant U-shape relation across all variables.

Second, we seek to explore whether our results are driven by the econometric specification. In Table A-3, we show that the results remain largely unchanged when a Probit

[5] Given that *observable* characteristics are redundant once district-specific effects (*DSE*) are included, in section 3 we present the results only after controlling for DSE. Including *observable* characteristics instead of DSE does not change the results.

[6] Calculated as follows: 0,1287 x 1.317 = 0.169

estimation was used. This model confirms a non-symmetrical (U-shaped) impact of weather shocks on social upheaval. The probability remains low when the deviation is moderate (one deviation point), and increases gradually and significantly when the deviation becomes severe (two deviation points).

Table 2. *Weather Shocks and Social Upheaval*

Dependent variable	(1)	(2)	(3)	(4)	(5)
Prisoners st.dev	OLS-FE	OLS-FE	OLS-FE	OLS-FE	OLS-FE
Rainfall st.dev.	0.0189	0.0108	0.0140	0.0139	0.0081
	[0.93]	[0.47]	[0.66]	[0.61]	[0.29]
Rainfall st.dev. squared	0.1287	0.1223	0.1179	0.1103	0.0763
	[8.41]***	[6.34]***	[6.06]***	[6.11]***	[3.63]***
Population density					0.0047
					[1.35]
Whites per 1000 of the population					0.0160
					[0.58]
World market prices					-0.0012
					[-0.57]
District FE	N	Y	Y	Y	Y
Time dummies	N	Y	Y	Y	Y
Observable controls × year	N	N	Y	N	N
District-specific effects (*unobservable* × year)	N	N	N	Y	Y
Number of Observations	2335	2335	2246	2335	1665
Number of Districts	143	143	143	137	104

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Similarly, in Table A-4 we show the baseline results with system-GMM. Besides providing an additional test to our main results, we are able to test whether the overall effect remains similar after controlling for the time-series dimension of the main explanatory variables (columns 1-5). Running this dynamic panel data model, two additional concerns are addressed; one is to control for any time-spillover effect from the lagged prisoners variable (t-1) to the following year (t) (all columns) and another one is to control for the impact of lagged rainfall shocks (t-1) on prisoners in year (t) (column 6).

Third, for comparability of the main effect with other findings in economic literature (Jia 2014; Hsiang et al. 2013; Dell et al. 2015), in Table A-5 we show that the results are largely similar to the baseline when we introduce a linear rainfall deviation term (taking the absolute value of *Rainfall st.dev*) and run an OLS-FE estimator. One standard deviation change in rainfall causes a 0.29 standard deviation increase in upheaval, or 16.9 percentage points; a finding which is slightly higher than the overall average climate-to-conflict effect reported in Hsiang et al.

(2013). Fourth, we include dummies of more than ±2.5 and ±3 standard deviations of rainfall in order to control for the scenario that severe weather shocks drag the whole U-shaped correlation upwards (results not reported).

Finally, the results are robust to clustering standard errors at different levels. Table A-6 presents the results of standard errors clustered at the year level, country level as well as two-way clustered at both the year and the country level.

3. Does agricultural commercialization mitigate the impact of shocks?

3.1 The debate

Whether the introduction of cash crops was beneficial, or detrimental to vulnerable rural communities is the subject of a multifaceted, heated and long-standing debate among policy makers and social scientists (Maxwell & Fernando 1989; Myint 1958; Rodney 1972). We take up one important aspect of the debate by exploring if districts with smallholder cash crop cultivation experienced different levels of social upheaval in the wake of annual weather anomalies, compared to areas relying primarily on subsistence agriculture.

Tropical Africa under British rule provides a suitable context to study the relationship between smallholder cash crop cultivation and societies' resilience to weather shocks. Cash crops dominated the colonial economy, and except for some small mining and settler farming areas, the role of expatriate enterprise was limited. Some of the areas in our dataset experienced considerable smallholder-based agricultural commercialization. Livelihoods in areas without cash crops tended to depend heavily on subsistence farming. Hence, a study of interwar British colonial Africa enables us to compare the heterogeneous impact of weather shocks on social upheaval between subsistence-based and commercialized rural economies.

While the production of cash crops in British Africa was certainly not free from abuses and coercion, it contrasts favourably with the extractive and coercive practices in French (Tadei 2013), Belgian (Frankema & Buelens 2013) and Portuguese Africa (Isaacman 1980), where cash crop cultivation went hand in hand with extensive forced labour schemes. Since the widespread adoption of cash crops among smallholders affected farming practices, household incomes and social relations, we expect cash crop cultivators to respond differently to weather anomalies and harvest failures. We investigate if they mitigate or aggravate weather-induced social tension and distress. Our study of the colonial administrative record highlights that the impact of cash crops on resilience in the wake of exogenous shocks is not only up for debate among scholars, but was a topic of discussion among colonial administrators as well. A southern Nigerian agricultural director expressed the concern that cocoa “considerably reduced the output of food”, and increased smallholders’ vulnerability to weather anomalies: an episode of “great shortage of food” was attributed “partially from the cocoa boom and partially to the drought” (Nigeria, Agriculture 1930). Others were more optimistic, highlighting the diversification of risk that came with the adoption of cash crops. A drought in Central Kavirondo (Kenya) “proved disastrous to food crops”, while the cotton crop “fared better [...]. The failure of the food crops accentuated the value of cotton, for those who had it to sell were able to subsist on their own resources” (Kenya, Agriculture 1937).

The ambiguous impact of cash crops is reflected in a literature which is highly divided. Firstly, cash crops affect agricultural practices. (non-edible) Cash crops can destabilize existing farming systems, and drain scarce labour and land resources away from food production, as such increasing the chances of food shortages and malnutrition (Hughes & Hunter 1970, MacKenzie 1999; Papaioannou 2016; Anderman et al. 2014). Farmers, however, tended to decide carefully how and to what extent a cash crop would fit into their farming systems (Berry, 1975; Tosh 1978; Bryceson 1988; Binswanger & McIntyre 1987; De Janvry et al. 1991; Omamo 1998). Adding a new cash crop to the existing crop-mix could even be an effective strategy to mitigate crop-specific risks, as newly introduced cash crops such as cocoa or cotton often react differently to weather fluctuations than local food crops (Maxwell & Fernando 1989).

Secondly, cash crops affect household incomes. The voluntary adoption of cash crops by smallholders should be seen as an attempt to raise income in reaction to new opportunities resulting from lower transport costs and access to new markets and technologies (Hill 1982; Hopkins 1973; Myint 1958; Szereszewski 1965; Von Braun & Kennedy 1986; Austin 2014). The (monetary) income from cash crops can enable households to store wealth and cushion the impact of shocks and smooth consumption (cf. Dearcon 2002; Morduch 1990). Increased trade openness, moreover, has the potential to stabilize food prices (Fafchamps 1992b; Burgess & Donaldson 2012). At the same time, production for volatile external markets introduces an additional dimension of income uncertainty and risk into already risk-prone environments (Sen 1981). One may also question the degree to which the benefits from trade trickled down to the majority of producers. Large producers with access to credit can profit disproportionately (Maxwell & Fernando 1989), or elites can extract the benefits through taxation, marketing boards and other means (Bates 1981; Falola 2009; Rodney 1978; Watts 1983).

Thirdly, cash crops affect societies’ collective resource management. Cash crop cultivation can result in land conflict (Fenske 2015) or lead to a breakdown of traditional communal insurance mechanisms, or ‘moral economy’ of fair prices, mutual aid and exchange of food in times of hardship (Fafchamps, 1992a; Raynaut, 1977; Richards, 1990; Vaughan, 1987; Watts, 1983). At the same time, the introduction of cash crops went hand in hand with new collective coping mechanisms, such as state investments which improved societies abilities to cope with exogenous shocks. The infrastructure necessary to open up areas to the world economy may also have led to more effective responses to food and income shortages (Herbst 2000; Bryceson 1980; 1981). Moreover, because cash crops contributed to the state's tax base and revenues, colonial states had an incentive to target food aid efforts first to areas with cash crops.

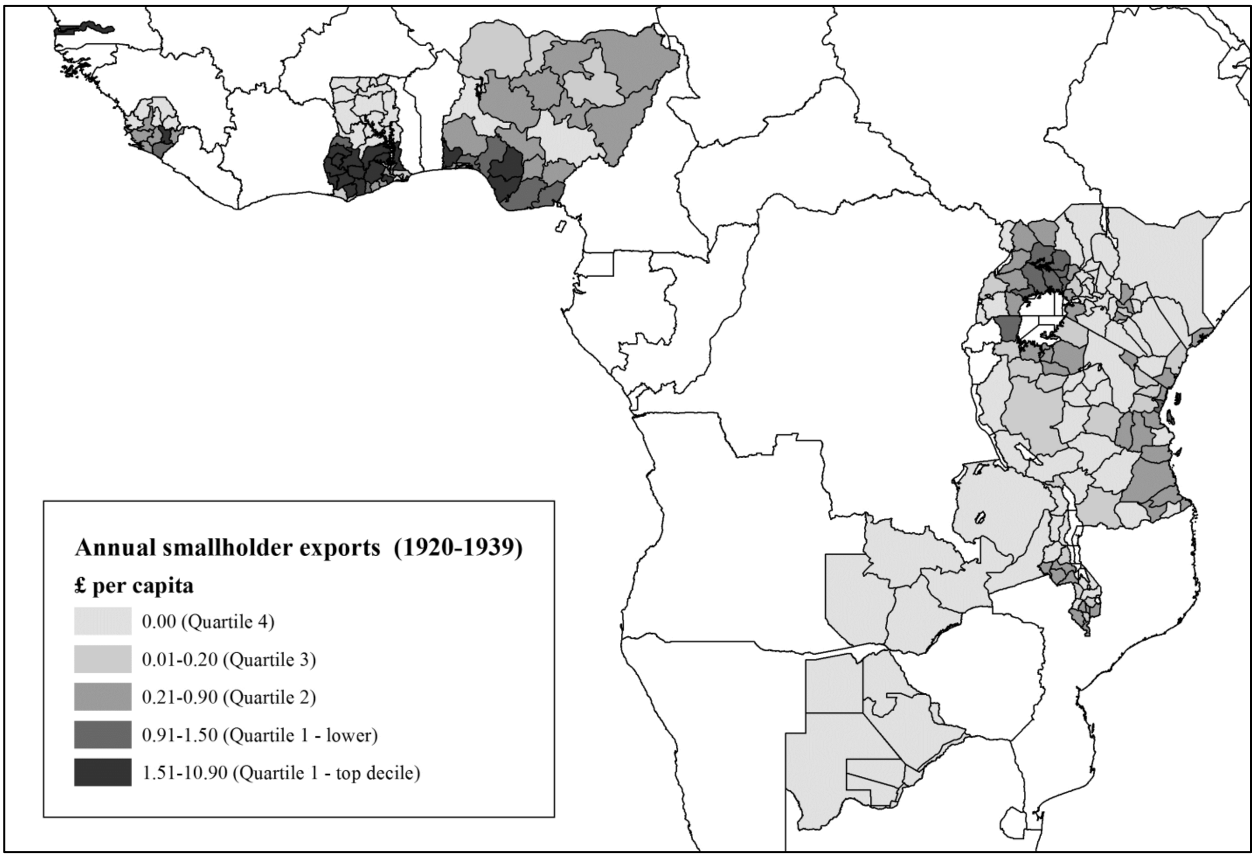
Rather than testing the validity of each of these individual arguments, our goal is to test the *overall treatment effect* of cash crops on weather-induced social upheaval in years of extreme weather shocks.

3.2 Data: an indicator for district-level cash crop cultivation

We construct a new indicator to estimate cash crop production during the colonial-era at the district level. We follow a number of steps to arrive at this indicator, which expresses the value of exported produce in per capita terms (see Appendix B). We use this measure to split our sample in half in the subsequent analysis (and in quartiles in the robustness section). We argue that our indicator for cash crop cultivation is much more satisfactory than the use of a crude binary dummy, especially since cash crop cultivation is our main heterogeneous variable. Some studies have successfully exploited crop suitability indicators to proxy for adoption of crops (Nunn & Qian 2014; Jia 2014, Fenske & Kala 2015). We have two reasons not to use crop suitability to estimate the impact of cash crop production on resilience to weather shocks. First, we expect measures of cash crop suitability to correlate strongly with overall agricultural suitability. This is especially problematic since we want to include a range of different cash crops into our analysis (cocoa, coffee, cotton, tobacco, etc.). Secondly, we argue that the expected effect runs via 'actual' cultivation, rather than potential cultivation of cash crops. To establish that cash crop cultivation is exogenous to a geographical and institutional factors, we perform a range of robustness tests which refute alternative explanations (see section 3.5).

Map 1 reports the cash crop production estimates. The data is divided in quartiles, with the top quartile split in the top decile and the remainder, to highlight outliers. Smallholder cash crop exports in interwar British colonial Africa were concentrated in the Gambia (groundnuts), coastal Gold Coast (cocoa), coastal Nigeria (cocoa and palm oil), northern Nigeria (cotton and groundnuts), the Lake Victoria area (cotton and coffee), coastal Tanganyika and Zanzibar (cotton, copra and cloves) and southern Nyasaland (cotton and tobacco).

Map 1. *Cash crop production estimate*



Sources: constructed by the authors in ArcGIS on the basis of digitized colonial maps. See Appendix B for further information

3.3 Model

To test the mitigating effect of cash crop cultivation on weather-induced social upheaval, we estimate the following specification:

$$Y_{i,t} \;=\; \beta_1\, RainfallDeviationLinear_{i,t} + \pi\,(CashCropProduction \times RainfallDeviationLinear)_{i,t}$$
$$+\ \delta Z'_{i,t} + \nu_i + \mu_t$$
$$+\ (observable \times time)_{i,t} + (unobservable \times time)_{i,t} + \varepsilon_{i,t}\,. \qquad (3)$$

where $(CashCropProduction \times RainfallDeviation)_{i,t}$ denotes the interaction of above median cash crop production with *absolute rainfall deviation (linear)*.

3.4 Heterogeneous Results

The results in Table 3 suggest that access to cash crops mitigated the effect of weather shocks on social upheaval (columns 1-3). Overall, districts with cash crops were less severely affected, which is consistent with our hypothesis that the overall treatment effect of cash crops cultivation on resilience to weather shocks was positive.

Table 3. *The Mitigating Effect of Cash Crop Production*

Dependent variable	(1)	(2)	(3)
Prisoners st.dev.	OLS-FE	OLS-FE	OLS-FE
Rainfall Deviation Linear	0.3393	0.3416	0.3178
	[7.21]***	[7.41]***	[7.22]***
Cash Crop Production × *Rainfall Deviation Linear*	-0.2376	-0.2765	-0.2456
	[-2.80]***	[-3.26]***	[-3.02]***
District FE	Y	Y	Y
Time dummies	Y	Y	Y
Observable controls × year	N	Y	N
District-specific effects (*unobservable* × year)	N	N	Y
Number of Observations	2335	2246	2335
Number of Districts	143	137	143

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. The standard errors are clustered at the district level. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

3.5 Alternative explanations

The literature and the qualitative evidence have already provided a range of plausible channels suggesting that the presence of cash crops had a direct effect on communities' resilience. However, we cannot entirely rule out the possibility of some alternative explanations feeding into our findings. This section attempts to address the most plausible alternative explanations.

The first concern is that cash crops were adopted mostly in *specific institutional conditions*, which might, by themselves, explain societal reactions to shocks. For example, strong precolonial institutions or higher colonial presence may coincide with the establishment of infrastructure, the introduction of improved agricultural inputs and methods, and/or better provisioning of food. Each of these factors has the potential to *directly* increase a smallholder community's resilience to adverse weather conditions. Each of them may also contribute *indirectly* to resilience, providing the right conditions for the adoption of cash crops. Moreover, strong precolonial and colonial institutions may reduce outbreaks of social tension and distress in years of harvest failures because the cost of engaging in unrest is higher in areas with greater state capacity, leading to higher levels of obedience (Christian & Fenske 2015). If colonial rule broke down the ability to resist, less pronounced imprisonment peaks in years of rainfall deviation signify obedience or even lethargy rather than resilience (Watts 1983).

To disentangle the effect of cash crops on resilience from these alternative explanations, we create three dummy variables: one indicator for colonial presence (based on average whites per 1000 of the population), one for pre-colonial institutions (based on the absence/presence of consolidated chiefdoms and states), and one for the level of coercion (based on average annual imprisonments per 1000 of the population) which we interact with the *absolute rainfall deviation* (linear) variable. The estimated coefficients are presented in columns 1–3 of Table 4. These interaction terms do not enter the regression significantly, and do not take power away from our main interaction effect.

Secondly, one may hypothesize that cash crops were adopted in areas with specific *geographical conditions*, which by themselves explain (higher or lower) levels of social upheaval in years of harvest failures. For example, the adoption of cash crops might correlate strongly with the length of the rainy season(s) (long rainy seasons allowed for two harvests, hence a combination of food crops and cash crops without compromising on food security). At the same time, the length of the rainy season may also *directly* affect resilience to shocks (longer rains enabled farmers to replant food crops after a harvest failure). In a similar vein, it can be argued that areas with more generous average annual rainfall are both more resilient by themselves, and more suitable for cash crops as well. We would also expect that areas which had a higher degree of rainfall variability (i.e. high range of observations between min and max) to be more vulnerable (because continuous weather volatility made it more difficult for them to calibrate their farming systems and build buffers), while such areas can also be expected to be less suitable for cash crop cultivation. To test these alternative explanations, we use average annual rainfall (1920-1939), the coefficient of rainfall variation (CV) and length of the rainy season (average number of months with >60 mm of rainfall during 1920-1939) and interact them with *absolute rainfall deviation (linear)*. The results are reported in columns 4–6 of Table 4. None of the geographical explanations enter the analysis significantly or take power away from our main interaction effect.

Thirdly, it is important to take stock of a range of *alternative income earning opportunities* which might explain differential reactions to shocks. In interwar British colonial Africa, employment in the secondary and tertiary sector was limited, and urbanization rates low. Key alternative sources of income for smallholders consisted mainly of consuming or marketing livestock, or seeking agricultural employment (with African or expatriate ('settler') farmers) elsewhere. Access to alternative income could alleviate tension and distress arising from harvest failure. If cash crop areas also enjoyed higher levels of livestock ownership or settler agriculture, these could be alternative explanations of higher resilience. To test for these alternative explanations, we enter a livestock dummy (based on average livestock ownership per 1000 of the population) and a settler agriculture dummy and interact them with *absolute rainfall deviation* (linear). The results are reported in columns 7&8 of Table 4. The livestock variable does not affect our results, while settlers had a significant and strong mitigating effect on social upheaval, suggesting that it may not have mattered for resilience if cash crops were cultivated on smallholdings or large scale farms.

3.6 Further robustness checks

There are two methodological issues which may drive the mitigating impact of cash crop cultivation on social upheaval. Firstly, we want to know if our cash crop effect results from conditions that are specific to either the beginning or the end of our period of interest. One could argue that colonial officials, over time, invested more in districts with cash crops than ones without. The cultivation of cash crops might lead the colonial state to construct and expand a railway line or road network, which in turn could provide a collateral solution of food relief provision. We interact *absolute rainfall deviation* (linear) with a time trend and include this term in the regression. This procedure shows that the mitigating impact of cash crops was similar at the beginning and end of our period (column 9, Table 4). This finding provides some evidence to argue that cash crop production was not influenced by local context conditions during the Interwar era, allowing for reasoning that cash crop production was exogenously determined and based on climatological conditions.

Secondly, we were concerned that our results were driven by the overlap of the rainy season in two years of some districts. We reasoned that in districts which rely on rainfall at the end of year t, harvest failure might only lead to distress (hence more prisoners) in year $t + 1$. While the only possible effect of this data issue on our main effect would be that it would *reduce* the explanatory power of rainfall in year t on social upheaval in year t (hence biasing our results downwards), the anticipated problem for the interaction effect was that places with overlapping rainy seasons were also places with cash crops, which would imply that our interaction effect is driven by a data issue. We create a dummy for places with overlapping rainy seasons (significant rainfall in December) and interact with *absolute rainfall deviation* (linear). The results are presented in column 10 of Table 4.

We also performed additional robustness checks by creating sub-samples (results not reported). A *first issue* concerned the overrepresentation of livestock-dense districts in our below-median cash crop sample. One could argue that the presence of livestock intensifies social upheaval in years of weather shocks, for example because cattle can either be stolen with relative ease, and or in years of drought cattle herders may migrate in order to find water and pasture. To rule out the possibility that the higher spikes of social upheaval in our below-median cash crop sample were driven not by the absence of cash crops, but by the presence of livestock, we rerun the analysis, excluding districts with above median presence of livestock. We find that the results remain robust.

A *second*, analogous, *issue* concerned the possibility that higher spikes of social upheaval in our below-median cash crop sample were driven not by the absence of cash crops, but by the presence of settlers (all settler districts end up in the below-median cash crop sample). The argument would be that land alienation and extractive institutions could potentially have a negative impact on resilience to rainfall shocks. We excluded the settler districts from the analysis and re-estimated our model. We find that the main as well as the cash crop interaction effect remain unchanged.

A *third issue* would be that the mitigating effect of cash crops on resilience is driven by districts with cocoa, which are sometimes portrayed as an exceptional case of successful cash crop adoption. To rule out the possibility that our cash crop interaction effect is driven by cocoa, we created a sub-sample excluding the cocoa districts from the analysis, and find that our results remain robust.

Table 4. *Alternative Explanations, Absolute Rainfall Deviation (Linear)*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Dependent variable	Institutions			Geography			Income		Specification Issues	
Prisoners std	Colonial presence	Pre-colonial chiefdoms	Coercion index	Length of rainy season	Rainfall zones	Rainfall variability (CV)	Livestock	Settler farming	Rainfall×Trend	Season overspill
Rainfall Deviation Linear	0.3629	0.3825	0.3389	0.2728	0.3278	0.2744	0.3372	0.3674	0.4270	0.4021
	[6.15]***	[7.32]***	[6.84]***	[4.27]***	[6.36]***	[4.49]***	[6.18]***	[7.99]***	[5.22]***	[7.64]***
Cash crop dummy × Rainfall Deviation Linear	-0.2488	-0.2086	-0.2537	-0.2274	-0.0646	-0.2510	-0.2405	-0.2514	-0.2355	-0.2069
	[-3.09]***	[-2.45]**	[-3.15]***	[-2.80]***	[-3.02]***	[-3.12]***	[-2.93]***	[-3.20]***	[-2.94]***	[-2.47]**
Alternative explanations	-0.0759	-0.1436	-0.0767	0.0773	-0.0419	0.0800	-0.0462	-0.2573	-0.0103	-0.1649
	[-1.02]	[-1.90]*	[-0.91]	[1.02]	[-0.52]	[1.07]	[-0.61]	[-2.87]***	[-1.52]	[-2.08]**
District FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observable controls × year	N	N	N	N	N	N	N	N	N	N
District-specific effects (*unobservable* × year)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Number of Observations	2322	2256	2335	2335	2335	2335	2335	2335	2335	2317
Number of Districts	142	138	143	143	143	143	143	143	143	142
R^2	0.421	0.433	0.421	0.424	0.423	0.424	0.422	0.417	0.428	0.428

Notes: OLS-FE estimation. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. The standard errors are clustered at the district level. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Each alternative specification is an interaction term of absolute rainfall deviation × an alternative explanation dummy (the above median is used, unless stated otherwise). Settler farming is a dummy variable.

4. Conclusion

This study has investigated two questions. First, to what extent did weather-induced scarcities cause higher levels of social upheaval? Second, to what extent did the introduction of cash crops mitigate the impact of these shocks? Building on various original source materials, the analysis has yielded two contributions. First, it presents consistent qualitative and quantitative evidence about the impact of weather shocks on levels of social tension and distress. While some previous papers in the climate-economy literature have modelled rainfall in a linear way, or have argued that high precipitation is associated with abundance, our analysis of colonial sources indicate that both drought and excessive rainfall have increased scarcity and created conditions that generated social upheaval. Our econometric analysis confirms this relationship, showing a strong and robust *U-shaped* relation between annual rainfall deviation and imprisonment rates.

Second, this study builds on the link between weather shocks and social upheaval to take up a long-standing debate on the impact the introduction of cash crops had on resilience to shocks in tropical Africa. Based on a new and fine-grained indicator, we find that the cultivation of cash crops increased farmers' resilience against erratic weather anomalies; regions with more cash crops displayed less pronounced spikes of social upheaval in years of weather shocks than regions with few to no cash crops. We find that these results survive a wide range of robustness tests, suggesting that the impact of cash crops on resilience is causal.

We suggest a number of directions for future research. First, it would be of particular interest to see if the effect of cash crops on resilience is primarily channelled through higher private (household) income or through public investments in infrastructure and food aid programs. Second, it would be valuable to zoom in on the actual adoption of (different types of) cash crops and identify conditions that determine successful adoption. Third, while this study finds a short term mitigating effect of cash crops on resilience, it does not address long-term positive or negative effects that have been proposed in the literature; for instance, the underdevelopment of African living standards, the disruption of traditional insurance mechanisms or the environmental impact of agricultural commercialization. A more complete understanding of the impact of cash crops would benefit from studies that attempt to empirically study the *long-run effects* and *legacies* of cash crops on resilience. Finally, while cash crops were the main gateway to more open, monetized economies in large parts of Africa, it would be worthwhile to identify alternative 'roads to openness' (such as settler agriculture, mining or industrialization) and test their impact on resilience in the short and long-run.

References

Adano, W. R., Dietz, T., Witsenburg, K., & Zaal, F. (2012). 'Climate change, violent conflict and local institutions in Kenya's drylands'. Journal of Peace Research, 49(1): 65-80.

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in human geography*, 24(3), 347-364.

Ahmed, S. A., Diffenbaugh, N. S., & Hertel, T. W. (2009). Climate volatility deepens poverty vulnerability in developing countries. *Environmental Research Letters*, 4(3), 034004.

Almer, C., & Boes, S. (2012). "Climate (change) and conflict: Resolving a puzzle of association and causation, " Discussion Papers, Department of Economics, University of Bern.

Anderson, D. M. (1993). Black mischief: crime, protest and resistance in colonial Kenya. The Historical Journal, 36(04), 851-877

Anderson, D., & Killingray, D. (1991*). Policing the empire : government, authority, and control, 1830-1940*. Manchester, UK; New York; New York: Manchester University Press

Austin, G. (2014). Explaining and evaluating the cash crop revolution in the "peasant" colonies of tropical Africa, ca. 1890-ca. 1930: beyond "vent for surplus". In E. Akyeampong, R. H. Bates, N. Nunn, & J. Robinson, A. (Eds.), *Africa's development in historical perspective* (pp. 295-320). Cambridge: Cambridge University Press.

Bates, R. H. (1981). *Markets and states in tropical Africa: the political basis of agricultural policies.* Berkeley, CA: University of California Press.

Benjaminsen, T. A., Alinon, K., Buhaug, H., & Buseth, J. T. (2012). 'Does climate change drive land-use conflicts in the Sahel?'. Journal of Peace Research, 49(1): 97-111.

Bernault, F. (Ed.). (2003). *A history of prison and confinement in Africa*. Portsmouth, N.H.: Heinemann.

Bernault, F. (2007). The Shadow of Rule: Colonial Power and Modern Punishment in Africa. *Cultures of Confinement: A History of the Prison in Africa, Asia and Latin America*, 55-94.

Berry, S. (1975). Cocoa, Custom and Socio-Economic Change in Rural Western Nigeria: Oxford University Press.

Binswanger, H. P., & McIntire, J. (1987). Behavioral and Material Determinants of Production Relations in Land-Abundant Tropical Agriculture. *Economic Development and Cultural Change, 36*(1), 73-99

Blattman, C., & Miguel, E. (2010). "Civil war," *Journal of Economic Literature*, 3-57.

Bond, S. R. (2002). 'Dynamic panel data models: a guide to micro data methods and practice'. Portuguese Economic Journal, 1(2): 141-162.

Branch, D. (2005). Imprisonment and Colonialism in Kenya, c.1930-1952: Escaping the Carceral Archipelago. *The International Journal of African Historical Studies*, 38(2), 239-265

Brückner, M., & Ciccone, A. (2010). 'International Commodity Prices, Growth and the Outbreak of Civil War in Sub-Saharan Africa*'. The Economic Journal, 120(544): 519-534.

Brückner, M., & Ciccone, A. (2011). ‘Rain and the democratic window of opportunity’. Econometrica, 79(3): 923-947.

Brunnschweiler, C. N., & Bulte, E. H. (2009). ‘Natural resources and violent conflict: resource abundance, dependence, and the onset of civil wars’. Oxford Economic Papers, 61(4): 651-674.

Bryceson, D. (1980). Changes in peasant food production and food supply in relation to the historical development of commodity production in pre-colonial and colonial Tanganyika. *The Journal of Peasant Studies,* 7(3), 281-311.

Bryceson, D. (1981). Colonial famine responses: the Bagamoyo district of Tanganyika 1920-1961. *Food Policy*(May), 91-104.

Bryceson, D. (1988). Peasant cash cropping versus self-sufficiency in Tanzania: a historical perspective. *IDS Bulletin, 192,* 37-46.

Buhaug, H. (2010). Climate not to blame for African civil wars. *Proceedings of the National Academy of Sciences, 107*(38), 16477-16482.

Burke, M. B., Miguel, E., Satyanath, S., Dykema, J. A., & Lobell, D. B. (2009). Warming increases the risk of civil war in Africa. *Proceedings of the National Academy of Sciences, 106*(49), 20670-20674

Burgess, R., & Donaldson, D. (2010). Can openness mitigate the effects of weather shocks? Evidence from India's famine era. *The American Economic Review*, 449-453.

Burgess, R. & Donaldson, D. (2012) *Can openness to trade reduce income volatility? Evidence from colonial India's famine era*. The London School of Economics and Political Science, London, UK.

Coldham, S. (2000). Criminal justice policies in commonwealth Africa: trends and prospects. *Journal of African Law*, 44(2), 218-238.

Couttenier, M., & Soubeyran, R. (2011). Drought and civil war in Sub-Saharan Africa. *FEEM Working Paper No. 150*.

Christian, C., & Fenske, J. (2015). Economic shocks and unrest in French West Africa. *CSAE Working Paper WPS/2015-01*.

Crost, B., Duquennois, C., Felter, J., & Rees, D. I. (2015). *Climate Change, Agricultural Production and Civil Conflict: Evidence from the Philippines*. Institute for the Study of Labor (IZA).

De Janvry, A., Fafchamps, M., & Sadoulet, E. (1991). Peasant household behavior with missing markets: Some paradoxes explained. *Economic Journal, 101*(409), 1400-1417.

Deflem, M. (1994). Law enforcement in British Colonial Afdrica: A comparative analysis of imperial policing in Nyasaland, the Gold Coast and Kenya. *Police Studies*, 17(1), 45-68.

Dell, M. (2012). Path dependence and development: evidence from the Mexican Revolution. *Working Paper*.

Dell, M., Jones, F. B. & Olken, B. (2015) “What do we learn from the weather? The new climate-economy literature”, *Journal of Economic Literature* (Forthcoming)..

Dercon, S. (2002). “Income risk, coping strategies, and safety nets.” *The World Bank Research Observer*, 17(2), 141-166.

Ellis, F. (1993). *Peasant economics: farm households in agrarian development*. Cambridge: Cambridge University Press.

Ember, C. R., Adem, T. A., Skoggard, I., & Jones, E. C. (2012). Livestock raiding and rainfall variability in Northwestern Kenya. *Civil Wars, 14*(2), 159-181.

Fafchamps, M. (1992a). ‘Solidarity networks in preindustrial societies: Rational peasants with a moral economy’. Economic Development and Cultural Change: 147-174.

Fafchamps, M. (1992b). Cash Crop Production, Food Price Volatility, and Rural Market Integration in the Third World. *American Journal of Agricultural Economics*, 74(1), 90-99.

Falola, T. (2009). Colonialism and violence in Nigeria: Indiana University Press.

Fenske, J. (2014). Trees, tenure and conflict: Rubber in colonial Benin. *Journal of Development Economics*, 110, 226-238

Fenske, J. and Kala, N. (2015). Climate and the slave trade. *Journal of Development Economics*

Fjelde, H., & von Uexkull, N. (2012). ‘Climate triggers: Rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa’. *Political Geography*, 31(7): 444-453.

Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, 16(3), 253-267.

Frankema, E. H. P., & Buelens, F. (Eds.). (2013). Colonial exploitation and economic development: The Belgian Congo and the Netherlands Indies compared: Routledge.

Frankema, E. and M. Jerven (2014). Writing history backwards or sideways: towards a consensus on African population, 1850–2010. *The Economic History Review* 67(4): 907-931.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. Global environmental change, 16(3), 293-303

Gray, J. P. (1999). A corrected ethnographic atlas. *World Cultures*, 10(1), 24-85.

Harari, M., & La Ferrara, E. (2013). Conflict, climate and cells: a disaggregated analysis. *CEPR Discussion Paper No DP9277*.

Hendrix, C. S., & Salehyan, I. (2012). Climate change, rainfall, and social conflict in Africa. *Journal of Peace Research, 49*(1), 35-50. doi: 10.1177/0022343311426165

Hill, P. (1982). Dry Grain Farming Families: Hausalund (Nigeria) and Karnataka (India) Compared: Cambridge University Press.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. Stata Journal, 7(3), 281.

Homer-Dixon, T. F. (1999). *Environment, scarcity and violence*. Princeton: Princeton University Press.

Hopkins, A. G. (1973). An economic History of West Africa: Longman Group Ltd., London.

Hsiang, S. M., Burke, M., & Miguel, E. (2013). ‘Quantifying the influence of climate on human conflict’. Science, 341(6151): 53-67.

Hughes, C. C., & Hunter, J. M. (1970). Disease and "development" in Africa. *Social Science & Medicine*.

Huillery, E. (2011). The Impact of European Settlement within French West Africa: Did pre-colonial prosperous areas fall behind? *Journal of African Economies*, 20(2):263–311.

Hynd, S. (2008). Killing the Condemned: the Practice and Process of Capital Punishment in British Africa, 1900-1950s. *The Journal of African History*, *49*(03), 403-418

Hynd, S. (2011). Law, violence and penal reform: state responses to crime and disorder. *Journal of Southern African Studies, 37*(1), 431-447.

Isaacman, A. (1980). *"Cotton is the mother of poverty": peasant resistance to forced cotton production in Mozambique, 1938-1961*. London: James Currey.

Jia. R. (2014). “Weather shocks, sweet potatoes and peasant revolts in historical China”, *The Economic Journal*, *124*(575), 92-118.

Kahl, C. H. (2006). States, scarcity, and civil strife in the developing world. Princeton: Princeton University Press.

Killingray, D. (1986). The Maintenance of Law and Order in British Colonial Africa. *African Affairs, 85*(340), 411-437

Klomp, J., & Bulte, E. (2013). ‘Climate change, weather shocks, and violent conflict: a critical look at the evidence’. Agricultural Economics, 44(s1): 63-78.

MacKenzie, A. F. D. (1999). Betterment and the gendered politics of maize production, Murang'a district, Central Province, Kenya, 1880-1952. *Canadian Journal of African Studies*, 33(1), 64-97.

Matsuura, K. and Willmott, C. J. (2009). *Terrestrial precipitation: 1900–2008 gridded monthly time series.* Centre for Climatic Research Department of Geography, Centre for Climatic Research, University of Delaware.

Maxwell, S., & Fernando, A. (1989). Cash crops in developing countries: The issues, the facts, the policies. *World Development*, 17(11), 1677-1708

Maystadt, J. F., & Ecker, O. (2014). Extreme weather and civil war: does drought fuel conflict in Somalia through livestock price shocks?. *American Journal of Agricultural Economics*, 96(4), 1157-1182.

McCracken, J. (1986). Coercion and Control in Nyasaland: Aspects of the History of a Colonial Police Force. *Journal of African History, 27*(1), 127-147.

Meredith, M. (2005). *The state of Africa : a history of fifty years of independence*. London: Free.

Miguel, E., Satyanath, S., & Sergenti, E. (2004). ‘Economic shocks and civil conflict: An instrumental variables approach’. Journal of Political Economy, 112(4): 725-753.

Milner, A. (1969). *African penal systems*. London: Routledge & Kegan Paul.

Morduch, J. (1995). Income smoothing and consumption smoothing. *The journal of economic perspectives*, 103-114.

Murdock, G. P. (1967). *Ethnographic atlas*. Pittsburgh: University of Pittsburgh Press.

Myint, H. (1958). The classical theory of international trade and the underdeveloped countries. *Economic Journal, 68*, 317-337.

Omamo, S. W. (1998). Farm-to-market transaction costs and specialisation in small-scale agriculture: Explorations with a non-separable household model. *The Journal of Development Studies, 35*(2), 152-163.

Papaioannou, K. J. (2016). 'Climate Shocks and Conflict: Evidence from colonial Nigeria'. *Political Geography*, 50(1): 33-47

Raleigh, C., & Urdal, H. (2007). 'Climate change, environmental degradation and armed conflict'. Political Geography, 26(6): 674-694.

Raynaut, C. (1977). 'Lessons of a crisis'. Drought in Africa, 2: 17.

Reid, R. J. (2012). *A history of modern Africa: 1800 to the present*: John Wiley & Sons.

Richards, P. (1990). 'Local strategies for coping with hunger: central Sierra Leone and northern Nigeria compared'. African Affairs: 265-275.

Rodney, W. (1978). How Europe Underdeveloped Africa: Bogle-L'Ouverture Publications, Howard University Press.

Roodman, D. (2006). 'How to do xtabond2: An introduction to difference and system GMM in Stata'. Center for Global Development working paper(103).

Roodman, D. (2009). 'A note on the theme of too many instruments*'. Oxford Bulletin of Economics and Statistics, 71(1): 135-158.

Szereszewski, R. (1965). *Structural changes in the economy of Ghana, 1891-1911*. London: Weidenfeld and Nicolson.

Tadei, F. (2013). Extractive institutions and gains from trade: Evidence from colonial Africa. *Working Paper*, California Institute of Technology.

Theisen, O. M. (2012). 'Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989–2004'. Journal of Peace Research, 49(1): 81-96.

Tosh, J. (1978). Lango agriculture during the early colonial period: land and labour in a cash-crop economy. *The Journal of African History, 19*, 415-439.

Vaughan, M. (2007[1987]). The story of an African famine: Gender and famine in twentieth-century Malawi: Cambridge University Press.

Watts, M. (1983). Silent Violence: Food Famine and Peasantry in Northern Nigeria (Vol. 18). Berkeley. Cal.: University of California Press.

Windmeijer, F. (2005). 'A finite sample correction for the variance of linear efficient two-step GMM estimators'. Journal of econometrics, 126(1): 25-51.

Witsenburg, K. M., & Adano, W. R. (2009). 'Of rain and raids: Violent livestock raiding in northern Kenya'. Civil Wars, 11(4): 514-538.

Appendix A. Robustness Tests

Table A-1. *Main results with Grid rainfall deviations*

Dependent variable	(1)	(2)	(3)	(4)	(5)
Prisoners st.dev	OLS-FE	OLS-FE	OLS-FE	OLS-FE	OLS-FE
Rainfall st.dev. Grids	0.0429	0.0157	0.0280	0.0095	0.0248
	[0.19]	[0.71]	[1.26]	[0.46]	[1.01]
Rainfall st.dev. squared Grids	0.0741	0.0843	0.0777	0.0767	0.0785
	[5.08]***	[5.13]***	[4.65]***	[4.92]***	[3.82]***
Population density					0.0045
					[1.35]
Whites per 1000 of the population					0.0117
					[0.45]
World market prices					-0.0010
					[-0.52]
District FE	N	Y	Y	Y	Y
Time dummies	N	Y	Y	Y	Y
Observable controls × year	N	N	Y	N	N
District-specific effects (unobservable × year)	N	N	N	Y	Y
Number of Observations	2680	2680	2422	2680	1827
Number of Districts	156	156	137	156	105

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Table A-2. *Results with alternative dependent variables*

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Debt	Safe custody	Penal Imprisonment	Convictions above 3 months	Convictions below 3 months
Rainfall st.dev. Stations	0.0591	-0.0073	0.0280	-0.0019	-0.0147
	[3.15]***	[-0.33]	[1.26]	[-0.08]	[-0.63]
Rainfall st.dev. squared Stations	0.0490	0.0555	0.0955	0.0835	0.0675
	[2.99]***	[3.09]***	[5.53]***	[4.41]***	[3.59]***
District FE	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y
Observable controls × year	N	N	N	N	N
District-specific effects (unobservable × year)	Y	Y	Y	Y	Y
Number of Observations	1797	2318	2328	2250	2280
Number of Districts	109	142	143	142	144

Notes: OLS-FE estimator. Sample period: 1920–1939. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Table A-3. *Testing the Symmetrical Impact of Weather Shocks on Imprisonment Rates*

	Probit	Probit
Dependent variable	(1)	(2)
	Binary Prisoners	Binary Prisoners
Positive rainfall deviation	0.2148	
	[3.33]***	
Negative rainfall deviation		0.3065
		[4.26]***
District FE	Y	Y
Time dummies	Y	Y
Observable controls × year	N	N
District-specific effects (unobservable × year)	Y	Y
Number of Observations	1019	1032
Number of Districts	143	143
R^2	0.49	0.53

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Table A-4. *The impact of Lagged Imprisonment and Rainfall Deviations*

Dependent variable	(1)	(2)	(3)	(4)	(5)
Prisoners st.dev	GMM	GMM	GMM	GMM	GMM
Prisoners st.dev. lagged (t-1)	0.4556	0.4449	0.6557	0.4808	0.4871
	[11.10]***	[6.33]***	[9.86]***	[9.92]***	[11.17]***
Rainfall st.dev.	-0.0103	0.0020	0.0522	-0.0256	0.0079
	[-0.43]	[0.07]	[0.70]	[-0.80]	[0.29]
Rainfall st.dev. squared	0.0865	0.0969	0.1216	0.0521	0.1006
	[4.61]***	[3.75]***	[2.18]**	[2.08]**	[4.48]***
Rainfall st.dev. lagged (t-1)					0.0218
					[0.71]
Rainfall st.dev. squared lagged (t-1)					-0.0208
					[-0.78]
Rainfall st.dev. lagged (t-2)					-0.0214
					[-0.86]
Rainfall st.dev. squared lagged (t-2)					0.0250
					[1.21]
Population density				0.0003	
				[1.41]	
Whites per 1000 of the population				0.0001	
				[0.22]	
World market prices				-0.0030	
				[-1.23]	
District FE	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y
Observable controls × year	N	Y	N	N	N
District-specific effects (unobservable × year)	N	N	Y	Y	Y
Number of Observations	2216	2131	2216	1589	1995
Number of Districts	143	137	137	104	143
Number of Instruments	169	172	311	233	182
AR1 statistics (p-value)	0.000	0.000	0.000	0.000	0.000
AR2 statistics (p-value)	0.216	0.381	0.220	0.314	0.814
Hansen test (p-value)	0.987	0.942	0.299	0.998	0.996

Notes: System-GMM estimation for dynamic panel data-model. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Second (and latter) lags were used as instruments in the first-differenced equations, and their once-lagged first differences were used in the levels equation. Two-step results using robust standard errors corrected for finite samples using Windmeijer (2005) correction. We adjust standard errors for spatial dependency following Conley (1999).

Table A-5. *Results with Linear Rainfall Deviation*

Dependent variable	(1)	(2)	(3)	(4)	(5)
Prisoners st.dev	OLS-FE	OLS-FE	OLS-FE	OLS-FE	OLS-FE
Rainfall Deviation Linear	0.2919	0.2744	0.2700	0.2509	0.1698
	[8.55]***	[6.71]***	[6.66]***	[6.41]***	[3.74]***
Population density					0.0024
					[0.82]
Whites per 1000 of the population					0.0059
					[0.31]
World market prices					-0.0015
					[-0.71]
District FE		Y	Y	Y	Y
Time dummies		Y	Y	Y	Y
Observable controls × year		N	Y	N	N
District-specific effects (unobservable × year)		N	N	Y	Y
Number of Observations	2335	2335	2246	2335	1665
Number of Districts	143	143	137	143	104
R^2	0.031	0.163	0.216	0.699	0.734

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. We adjust standard errors for spatial dependency following Conley (1999).

Table A-6. *Clustering Standard Errors at Different Levels*

Dependent variable	Prisoners Deviation			
	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
Rainfall Deviation Stations	0.2919	0.2744	0.2700	0.2509
	(0.0437)	(0.0408)	(0.0405)	(0.0391)
		<0.0930>	<0.0854>	<0.0834>
		[0.0905]	[0.0825]	[0.0759]
Rainfall Deviation Grids	0.1632	0.1739	0.1636	0.1695
	(0.0371)	(0.0355)	(0.0353)	(0.0336)
		<0.0865>	<0.0752>	<0.0725>
		[0.0793]	[0.0716]	[0.0667]
District FE	N	Y	Y	Y
Time dummies	N	Y	Y	Y
Observable controls x year	N	N	Y	N
District-specific effects (unobservable x year)	N	N	N	Y
Number of Observations	2335	2680	2422	2680

Notes. The specifications and the estimated coefficients in this Table are the same as in Table A-5. The standard errors in columns 2–4 are clustered at the district level (in parentheses), the country level (in angle brackets) as well as two-way clustered both the country and the year level (in square brackets).

Appendix B. Cash crop production calculation

We proceed in the following steps:

(i) We obtain *annual, crop-specific, country-level cash crop export values*, compiled in the Wageningen African Trade Database, for the years 1920 to 1939;

(ii) We collect *annual, crop-specific, district-level, smallholder cash crop production estimates* for the years 1920 to 1939. We use a range of sources, including colonial maps, annual statistics and agricultural censuses. We inter-/extrapolate if production data is not available for all years. The data is rough but suffices to estimate the shares of different districts in total country production.

(iii) We use (ii) to distribute (i) over the individual districts, for each of the countries in our dataset.

(iv) We add up the value of all cash crops grown in a district to arrive at an indicator of *annual, district-level cash crop export values per district*.

(v) We divide (iv) over *annual, district-level population figures* to arrive at an indicator of *annual, district-level, smallholder cash crop export value per capita*. We inter-/extrapolate if population data is not available for all years.

(vi) We take the average of (v) for the years 1920-1939 to arrive our indicator of *cash crop intensity (average annual value of cash crops in pounds per capita).*

A simple example is given below. We have followed a similar procedure for all the districts in our dataset.

(i) The total value of Nyasaland's cotton production in the years 1920-1939, following the Wageningen African Trade Database, fluctuated between a minimum of £35 thousand in 1932 and a maximum of £205 thousand in 1935.

(ii) The colonial Bluebooks of Nyasaland report annual estimates of district-level native cotton production. The *Lower Shire District*'s contribution, according to these estimates, fluctuated between 21 and 65 per cent of the country's total cotton production between 1920 and 1939.

(iii) By multiplying the annual value (i) with the Lower Shire's production share (ii), we find that the value of cotton produced in the Lower Shire district fluctuated between a minimum of £14 thousand and a maximum of £67 thousand.

(iv) The Lower Shire District only produces cotton so we can use the cotton figures, without having to add up values of different cash crops.

(v) We deflate these annual district-level values with district-level population numbers to obtain an estimate of *gross-export-crop-income per capita,* which in the case of the Lower Shire varies between £0.2 (during the depression years), and £0.8 per capita.

(vi) Because both the district-level production estimates and population figures can only be considered rough proxies of reality, we discard annual fluctuations and take the average of the entire 20-year period as our indicator for cash crop intensity. The average gross annual per capital export income for the Lower Shire district is £0.4.

Gold Coast

District borders are the administrative borders from 1930 reported in Gold Coast 'Administration Report 1930'. District-level, smallholder production shares for cocoa, cola nuts, copra and palm oil are estimated using maps in Cardinall (1932) and Kaplan et al. (1971). No panel data on cash crop production is used. The 1931 map-based production shares are used for the entire period (1920-1939). District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder cash crop production values are obtained by multiplying the 1931 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Gold Coast Blue Books (1920-1939). For some districts, only data for 1930 is available. Missing years are extrapolated using a nearby district. Note that the maps only indicate the area in which cash crops were produced, and do not indicate the intensity of production or yields. Hence, the assigned shares are a rough approximation of reality.

Nigeria

District level data for Nigeria is not available. Instead, we use provinces. Borders are obtained from Papaioannou (2014). Province-level, smallholder production shares for cocoa, cotton, groundnuts and palm oil are estimated using maps cited in Papaioannou 'Climate shocks and conflict'. No panel data on cash crop production is used. The map-based production shares are used for the entire period (1920-1939). District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder cash crop production values are obtained by multiplying the map-based production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Nigeria Blue Books (1920-1939). Note that the maps only indicate the area in which cash crops were produced, and do not indicate the intensity of production or yields. Hence, the assigned shares are a rough approximation of reality.

Sierra Leone

District borders are administrative borders from 1920-30, reported in Abraham (1978). District-level, smallholder production shares for ginger and palm oil are estimated using production estimates for 1938, reported on a map in Sierra Leone 'Administration Reports'. No panel data on cash crop production is used. The 1938 production shares are used for the entire period (1920-1939). District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder cash crop production values are obtained by multiplying the 1938 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Sierra Leone Blue Books (1920-1939). Note that the districts in Sierra Leone shifted somewhat between the interwar period and today. The graphical representation on the map, hence, is not fully accurate.

Gambia

Gambia is treated as one district. Cash crop production (groundnuts) in that district can be equated to the total annual export figure in the WTD. Population figures from Gambia Blue Books (1920-1939). Note that considerable numbers of migrants ('strange farmers') came annually to the Gambia to produce groundnuts. Since these migrants are not counted in the population figures, the cash crop intensity may be biased slightly upwards.

Tanganyika

District borders are the administrative borders from 1933 reported in Berry (1972). District-level, smallholder production estimates for coffee, copra, cotton, groundnuts, sesame and tobacco are obtained from the Tanganyika Blue Books (1926, 1927, 1929, 1930, 1932, 1933, 1935, 1937, 1938 and 1939). District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced cash crops, crops (coffee) produced by expatriate farmers are included into this country sum. Production shares for missing years are interpolated. The shares for 1920-1925 are set equal to the average share of 1926 and 1927. Annual, district-level smallholder cash crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Tanganyika Blue Books (1928, 1931, 1939). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that some of the crops included (copra, groundnuts and sesame) were both consumed locally and exported. We are forced to assume that exports are equally divided over the producing districts, but this assumption has only a minor effect on the eventual cash crop intensity estimates.

Zanzibar

District borders coincide with Pemba Island and Zanzibar Island. District-level, smallholder production estimates for cloves and copra are obtained by estimating the relative contribution of the two Islands based on production figures in Zanzibar 'Administration Reports'. District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced cash crops, we roughly estimate expatriate-plantation clove production at 50% and copra production at 20% and include the crops produced by expatriate farmers into the country sum. Annual, district-level smallholder cash crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Zanzibar Blue Books (1920-1939).

Kenya

District borders are from Kenya 'Administration Reports 1931'. District-level, smallholder production estimates for cotton, wattle, sesame, groundnuts and coconuts are obtained from Kenya 'Agricultural Census 1930'. No panel data on cash crop production is used. The 1930 production shares are used for the entire period (1920-1939). District-level, cash crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. As the WTD does not distinguish between smallholder- and expatriate-produced cash crops, crops (maize and wattle) the total reported value of smallholder produced crops is taken as a share of total production, including production at expatriate farms. This share is applied to the entire period. Annual, district-level smallholder cash crop production values are obtained by multiplying the 1930 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Kenya Colony Blue Books (1927, 1929, 1934, 1938). Missing years are inter-/extrapolated using a procedure analogous to the production estimates under ‘Tanganyika’. Note that the district-level production figures are based on sales rather than production. Note that some of the crops included (maize, sesame, groundnuts, coconuts) were both consumed locally and exported. We are forced to assume that exports are equally divided over the producing districts, but this assumption has only a minor effect on the eventual cash crop intensity estimates.

Uganda

District borders are from Uganda ‘Administration Reports 1948’, with some modifications based on Wrigley (1959). District-level, smallholder production estimates for coffee and cotton are obtained from the Uganda Blue Books (1920, 1923, 1926, 1929, 1932, 1935 and 1938). District-level, cash crop production shares are obtained by dividing the district’s production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced cash crops, crops (coffee) produced by expatriate farmers are included into this country sum. Production shares for missing years are set equal to the closest available year. Annual, district-level smallholder cash crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the Uganda Bluebooks (the WTD does not break down export data for Kenya and Uganda). All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Uganda Blue Books (1920, 1923, 1926, 1929, 1932, 1935 and 1938). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that the district shares, as well as the smallholder versus expatriate shares are based on acreage rather than production, meaning that yield differences between provinces is not taken into account. This may slightly diminish the accuracy of the cash crop intensity estimates.

Nyasaland

District borders are from Nyasaland ‘Administration Reports 1933’. District-level, smallholder production estimates for cotton and tobacco are obtained from the Nyasaland Blue Books (1923, 1925, 1927, 1929, 1931, 1933, 1935, 1937 and 1939). District-level, cash crop production shares are obtained by dividing the district’s production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced cash crops, crops (both cotton and tobacco) produced by expatriate farmers are included into this country-sum. Production shares for missing years are inter-/extrapolated (analogous to procedure described under ‘Tanganyika’ above). Annual, district-level smallholder cash crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Nyasaland Blue Books (1920-1938). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that the district-level production figures are based on sales rather than production. The Blue Books explicitly note that this way of measuring diminishes the accuracy of production estimates, as ‘many natives grow their tobacco and cotton in one district and sell in another’.

Bechuanaland

Districts borders based on a map kindly provided by Ellen Hillbom. No smallholder cash crops were exported from Bechuanaland. All districts are set at 0.

Northern Rhodesia

No map from the interwar period was available. Instead we used district borders based Northern Rhodesia ‘Administration Reports 1948’. No smallholder cash crops were exported from Northern Rhodesia. All districts are set at 0.

General notes

Population figures are obtained from the Blue Books. These official population figures are generally considered to be much too low (see Frankema & Jerven (2014). However, we are still very far from revising these official colonial population figures on the district level. Hence, we consistently use the colonial figures, taking stock of the possibility that our per capita estimates are too high all across the board and that some inaccuracy may enter the dataset as some districts may have been more accurately counted than others.

Country-level exports of each of the crops are obtained from Wageningen Trade Database (WTD). These figures are generally considered highly accurate and hence serve as the basis of our estimates. However, we do not account for the possibility that a share of the export value did not accrue to others in the production chain.

Additional references

Abraham, A. (1978). *Mende government and politics under colonial rule : a historical study of political change in Sierra Leone, 1890-1937.* Freetown, Sierra Leone; Oxford: Sierra Leone University Press ; Distributed by Oxford University Press.

Berry, L. (1972). *Tanzania in maps: graphic perspectives of a developing country.* New York, Africana Pub. Corp

Cardinall, A. W. (1932). *The Gold Coast, 1931 : a review of conditions in the Gold Coast in 1931 as compared with those of 1921, based on figures and facts collected by the chief census officer of 1931, together with a historical, ethnographical, and sociological survey of the people of that country.* Accra, Government Printer.

Kaplan, I. (ed.) (1971). *Area handbook of Ghana.* Washington, D.C., U.S. Government Printing Office.

Wrigley, C. C. (1959). *Crops and wealth in Uganda, a short agrarian history*. Kampala: East African Institute of Social Research.