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The failure of cotton imperialism in Africa:

Did agricultural seasonality undermine colonial exports?

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Abstract: European colonizers sought to extract cotton from sub-Saharan Africa. However, while some African farmers generated substantial cotton output, most others did not. I revisit a thesis proposed by John Tosh (1980), to argue that patterns of agricultural seasonality played a crucial role in these heterogeneous outcomes. A comparison of widespread cotton adoption in British Uganda and persistent cotton failure in the French West African interior highlights the impact of rainfall seasonality on farmers' production possibilities and subsistence risks. Ugandan output was enabled by long rainy seasons, smoothing labor requirements and allowing farmers to assess the food harvest before committing to cotton planting. These combined effects resulted in an estimated 4 to 5 times larger capacity to grow cotton alongside food crops. A belated take-off in post-colonial Francophone West Africa illustrates how the observed historical seasonality constraint was contingent on technological stagnation and thin food markets, which characterized most parts of colonial Africa.

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1. Introduction

Securing access to raw materials was a key justification, if not a main driver, of European colonial rule in Africa. Colonial investments and policies often served to catalyse processes of cash crop specialization (Austen 1987; Martin 1989; Munro 1976). Considering the importance of European textile industries and volatile supply, cotton was particularly sought after by European colonizers (Isaacman & Roberts 1995; Johnson 1974; Beckert 2014). However, on an aggregate scale, European ambitions to extract a large supply of raw cotton from African dependencies remained largely unfulfilled. Moreover, African responses to the cotton growing proposition followed a spatial pattern that does not reflect levels of European investment or coercive effort. Most spectacularly, farmers French West Africa continually rejected the cotton proposition despite persistent colonial efforts, while their counterparts British Uganda widely adopted cotton with comparatively little compulsion (De Haas 2017; Bassett 2001; Roberts 1996). Moreover, despite their unpopularity, coercive cotton growing schemes in the Belgian Congo generated quick and hight returns, while those in Portuguese Mozambique took much longer to yield some returns and were more strongly resisted by the African rural population (Likaka 1997; Isaacman 1996).

African resistance to labor coercion, diversion of the cotton harvest to more lucrative local textile markets and preference for alternative cash crops are the most often invoked explanations of the failure of colonial cotton ventures (Isaacman & Roberts 1995; Beckert 2014). In this study, however, I argue that these dynamics, while historically important, were crucially underpinned by local environmental endowments, which we need to consider to understand the heterogeneity of African farmers' responses, as well their overall reluctance to engage with the 'premier colonial crop' (Isaacman & Roberts 1995:29). I build on an authoritative, but often overlooked and largely untested argument, originally proposed by John Tosh (1980), that seasonal labor constraints in savanna regions limited the ability of the majority of African farmers to adopt cash crops while also pursuing food security. I argue that this basic seasonal rainfall endowment had major repercussions for the way African farmers responded to the colonial cotton proposition, and was therefore a key determinant of cotton output in the colonial era.

After reviewing African cotton colonialism (Section 2), I unpack and extend Tosh's argument along several lines. First, I establish that the few African colonies that were well-endowed with smooth, bimodal rainfall patterns were responsible for the bulk of African cotton exports, and argue that this was not driven by their greater agro-climatic suitability for cotton (Section 3). Second, I contrast French West Africa (henceforth FWA), the most clear-cut case of persistent colonial cotton failure, with British Uganda, which had more favorable rainfall endowments and became the largest cotton exporter below the Sahara as soon as its potential was unlocked by a railway to the coast (Section 4). To measure the quantitative importance of rainfall seasonality, I analyze two mechanisms linking agricultural seasonality to cotton adoption in Uganda and FWA (Côte d'Ivoire and Mali). Using historical farm-level data, I simulate cotton production in the framework of a constrained optimization problem, showing that Ugandan farmers with equal labor endowments were able to grow almost four times as much cotton alongside their food crops as their counterparts in FWA, a difference confirmed by colonial-era statistics (Section 5). Next, I explore if long rainy seasons enabled Ugandan farmers to assess their food security before committing resources to cotton production, something their counterparts in FWA were not able to do. Using a district-level panel on seasonal rainfall fluctuation and subsequent cotton planting, I demonstrate that Ugandan farmers indeed increased cotton planting after a successful food crop harvest, further compounding their cotton production possibilities (Section 6).

Third, I engage alternative explanations for the observed difference in cotton output. I make the case that more forced labor (Van Waijenburg 2018), lower colonial investment in the cotton sector, and the existence of a thriving local textile sector (Roberts 1996) should each be understood in the context of seasonal labor constraints, and cannot alone explain the failure of cotton imperialism in FWA relative to Uganda (Section 7). Before concluding, I discuss the specific historical conditions in which agricultural seasonality became such a decisive factor informing African farmers' cotton adoption choices during the colonial era (Section 8). I highlight the importance of thin markets for food which inhibited specialization, and emphasize the failure of European colonizers to produce technological innovations to increase labor productivity and break the seasonal bottleneck. Using the belated but impressive 'peasant cotton revolution' in postcolonial FWA, I show that technological breakthroughs and improved market conditions, when finally in place, did remove the constraints posed by agricultural seasonality, and erased the conditions that shaped half a century of colonial failure.

The paper adds to various literatures. First, recent years have seen a surging interest in the history of globalizing cotton production chains, in which European states and capitalists have been framed as joining hands to effectively coerce colonial subjects to generate cheap fiber for metropolitan industries. Most influentially, Sven Beckert has argued that the "incorporation of land and labour in the global cotton nexus" effectuated through imperialism, "sharpened global inequalities and cemented them through much of the twentieth century" (Beckert 2014:377). His argument for Africa, following a sizeable body of case-based historical scholarship, focuses on the European coercive thrust to extract imperial cotton, while attributing this project's failure to local resistance and resilient local textile manufacturing sectors which diverted raw cotton supply away from export markets (Beckert 2014; Isaacman & Roberts, ed. 1995). I harness comparative analysis, case studies and various empirical strategies to interrogate this narrative, emphasizing European impotence in light of adverse local conditions, and exploring the rationale of African responses beyond a dichotomy of victimization and resistance. I show that the interaction of a mundane environmental factor, in a context of technological and market failures, explains much of the variation in outcomes observed during the colonial era, and in fact shaped the degree to which colonial coercion yielded the desired returns.

Second, this paper examines the determinants of the adoption of cash crops, which crucially underpinned African colonial economies: they made colonial states financially independent from the metropole, stimulated Africans to buy metropolitan manufactures and provided raw materials to European industries (Austin 2014b; Frankema, Woltjer and Williamson 2018). Recent studies have begun to show that specialization in and limited diffusion of cash crop production beyond concentrated production 'enclaves' has resulted in a high degree of spatial inequality of income, development, gender relations and education, which persists until today (Baten et al. 2020; Miotto 2019; Müller-Crepon 2020; Roessler et al. 2020; Tadei 2018; 2020). However, the empirical literature on the *drivers* of heterogeneous cash crop adoption in Africa is remarkably limited. Fenske (2013) has linked the failure of rubber in Benin to specific local dynamics of labor shortage and ineffective colonial policy. Moradi and Jedwab (2013) show that the spatial pattern of cocoa planting in Ghana was linked to railway location. Austin's (2014a) analysis of cocoa cultivation in Ghana is the only study that explicitly engages Tosh to evaluate the role of labor seasonality. Austin concludes that labor could be profitably redeployed into cocoa cultivation without compromising food security, but in an environmental context much more favorable than the one investigated here. Otherwise, most empirical studies have typically assumed that either soil suitability or agro-climatic suitability was the core determinant of spatial production patterns (Baten et al. 2020; Müller-Crepon 2020; Roessler et al. 2020; Tadei 2018; 2020). Such an approach, however, only considers the optimal growing conditions of crops themselves (in terms of soils, or temperature, radiation and moisture regimes), and does not account for important labour seasonality effects.

2. The African cotton puzzle: colonial effort and local output

As European nations partitioned Africa and imposed colonial administrative control in the half century before World War I, their textile industries were important, and output expanding (Isaacman & Roberts 1995: 6). However, during the interwar era, European textile sectors, facing increasing competition from the United States, India and Japan, were threatened by the specter of sectoral collapse and mass unemployment (Beckert 2014; Isaacman & Roberts 1995; Marseille 1975; Robins 2017). Throughout both periods, European statesmen and business interests vividly remembered the major disruption of supply during the American civil war and saw repeated boll weevil attacks in the American cotton fields threatening supply again (Lange, Olmstead & Rhode 2009). Britain's attempt to generate a large supply of high quality cotton from colonial India had proven largely unsuccessful (Robins 2017). All of these factors fueled anxieties about reliable and cheap raw cotton supplies and contributed to a widely held belief among statesmen and industrialists that Africa should be the next imperial cotton frontier (Beckert 2014: 340-79).

Initial assessments of Africa's cotton export potential were lyrical. British commentators, for example, hyperbolically branded West Africa as Lancashire's "promised land" (1860, in Dawe 1993:52), potential sole supplier (1871, Dawe 1993:24), "future salvation" (1904, in Ratcliffe 1982:113) and "new Mecca" (1907, in Hogendorn, 1995:54). Attempts to stimulate cotton export in colonial Africa indeed became widespread and persistent. Private European cotton projects in West Africa date back to the 17th century (Law, Schwarz & Stickrodt 2013), but serious, state-backed cotton growing initiatives throughout Africa took off in the early 20th century. To this aim, textile interests throughout Europe established organizations such as the *British Cotton Growing Association* (BCGA) in 1902 and the French *Association Cotonnière Coloniale* (ACC) in 1903, receiving substantial financial and moral support from the state (Dawe 1993; Roberts 1996; Sunseri 2001). Even Italy, a marginal player in Africa, established its own association, the *Societa per la Cotivatione del Cotone nella Colonia Eritrea* in 1903 (Dawe 1993:69). In the early 1920s, disappointed with the limited success of the state-funded but private BCGA, the British proceeded to establish the *Empire Cotton Growing Corporation*, a corporatist body devoted entirely to empire cotton and funded by mandatory levies on British textile producers (Dawe 1993:33-179; Roberts 1996:34-5; Robins 2017:72-115). In the long run, the French proved most determined to grow cotton in Africa, establishing the *l'Institut de recherches du coton et des textiles exotiques* (IRCT) in 1946 and *La compagnie française pour le développement des fibres textiles* (CFDT) in 1949, responsible for cotton research, and on the ground promotion and extension respectively (Bassett 2001:90-4). Deep French involvement in African cotton cultivation long outlived the era of colonial rule itself (Lele, van de Walle & Gbetibouo 1989).

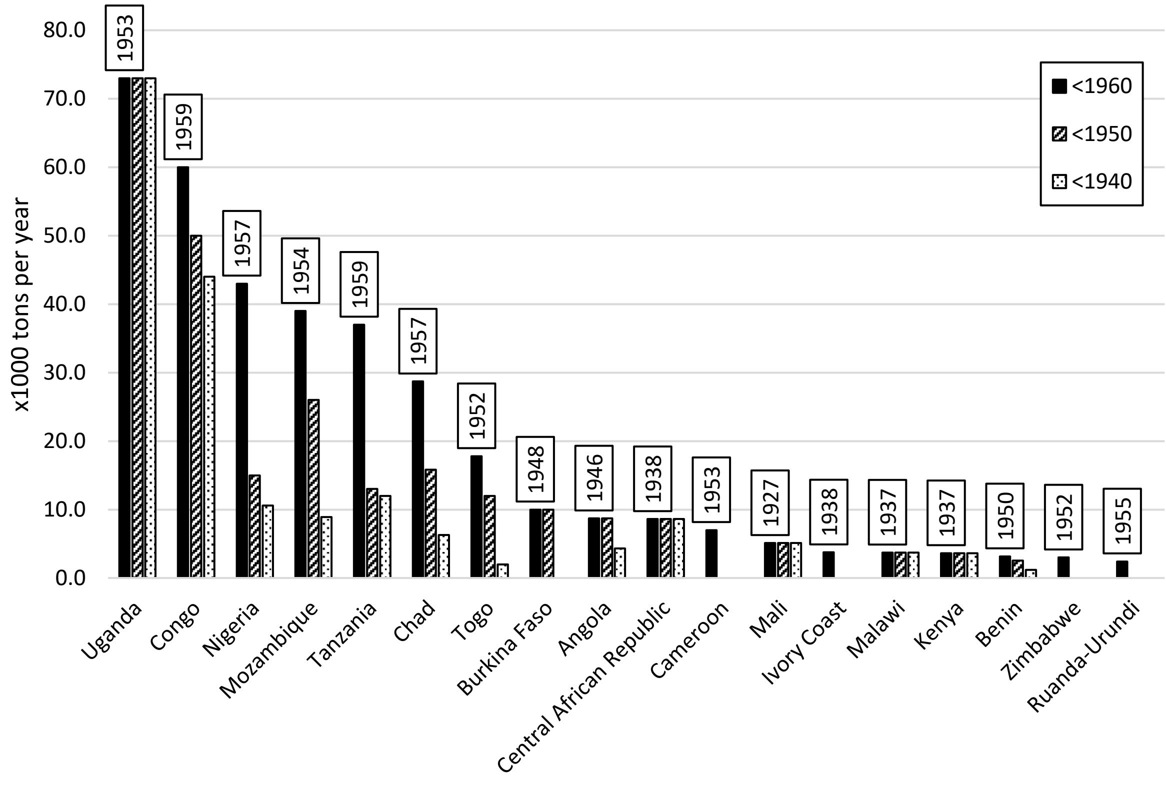
Measured against the ambitious rhetoric and persistent efforts, cotton imperialism in Africa failed. In the 1920s, cotton exports were less important in terms of volume than groundnuts, palm kernels and cocoa. In the decades after World War II, colonial Africa also exported substantially more coffee than cotton.[2] World cotton production was dominated by the United States, India, the Soviet Union, China and Egypt (in order of importance), which together produced 83 per cent of all cotton in 1938, and 75 per cent in 1951 (Atkinson 1953). Sub-Saharan Africa's share in 'free world' production (excl. communist countries) rose from a mere 0.3 percent in the 1910s, to a more substantial but still modest five percent during the first post-World War II decade (Dawe 1993: 431). With the exception of Portugal, a small textile producer (Pitcher 1993), after the Second World War, none of the European colonizers obtained a large (let alone majority) share of their raw cotton supplies from Africa possessions. After decades of failure, numerous disillusioned colonial officials concluded with resignation that their attempts to entice African farmers to grow the crop had failed (Robins 2017:29; Bassett 2001:81; Likaka 1997:89).

However, if we leave aside mounting expectations and excessive efforts, the proposition that cotton failed in Africa needs to be qualified more than some colonial officials and later scholars have done (Isaacman & Roberts 1995; Porter 1995). Figure 1 shows the maximum annual cotton output generated

[2] "1920s" based on the year 1925 from League of Nations *Yearbook*, and 1929 from Frankema, Woltjer and Williamson 'An economic rationale'. "Decades after World War II" based on the years 1947 and 1957 from Munro *Africa and the International economy*, p. 179. Austen incorrectly notes that all these other crops have "equal or greater value per ton" than cotton, which (if compared to cotton lint) is untrue for groundnuts and palm kernels. Still the volumes exported were so much greater than those of cotton that their total value easily surpassed that of cotton. See Austen "The premier colonial crop", p. 864.

in 19 African colonies in which cotton projects were persistently attempted by their respective colonizers before 1940, 1950 and 1960.[3] The British-Egyptian Sudan and the British Uganda Protectorate both emerged as substantial cotton exporters. Between 1920 and 1959, average annual cotton production in these two countries added up to 29.7 percent of the total production of Egypt (Mitchell 1995:244-5), a country that had invested a very large share of its resources into its cotton sector (Karakoc & Panza, 2020). In per capita terms, Ugandans produced 56.5 percent of their Egyptian counterparts, which is impressive considering that Uganda's cotton sector, unlike its irrigated counterpart in Egypt and Sudan, was capital-extensive and rainfed (De Haas 2017). The Belgian Congo generated substantial cotton output from the 1930s onwards, both for export and for use in Belgian textile firms established on Congolese soil (Brixhe 1953). French Chad (from the 1930s), and Portuguese Mozambique and French Togo (from the 1940s) also exported significant quantities of cotton, although not at the scale envisioned by their colonizers (Maier 1995; Pitcher 1993). British Tanzania and Nigeria saw a substantial expansion of raw cotton output during the colonial era, but only after World War II. On a smaller scale, cotton was adopted by African cultivators in early British colonial Malawi (Mandala 1990).

Figure 1. Maximum annual cotton output of African countries, denoting output in peak year before 1960



Sources: See Appendix 1.

[3] Evidence for colonial efforts in each of these countries is compiled in appendix 1.

The most successful cases of cotton adoption by African farmers hardly reflected colonial effort. The BCGA was heavily invested in establishing a cotton sector in Nigeria, and only peripherally involved in Uganda and Sudan, where cotton production was instead stimulated by Christian missionaries and American investors respectively (Robins 2017:159; Ehrlich 1958). Tellingly, the British cotton advocate J.A. Todd, reflecting decades of optimism about West Africa's cotton potential, asserted in 1915 that "the possible cotton crop of Nigeria is about 6,000,000 bales of 400 pounds." All the while, he stated that from Uganda, "it is doubtful whether any really large quantity of cotton, more than, say, 100,000 bales per annum, is likely to be raised for a good many years to come" (Todd 1915: 170). In reality, Nigeria came to export a meagre average of 70,000 bales annually between 1920 and 1960 (1.2 per cent of Todd's projected amount), while Uganda exported 260,000 bales annually in this period (260 per cent of his projection).

How do we explain this rift between European expectations and African realities of cotton cultivation? Most historians follow the assessment of late colonial officials, emphasizing the unattractiveness of the export cotton proposition from the African farmer's perspective. Cotton was labour intensive, yielded poorly close to the equator and faced competition from producers across a large latitudinal band, stretching into the American south and the steppes of central Asia (Isaacman & Roberts 1995; Porter 1996; Beckert 2014).[4] As a result, the argument goes, African farmers resisted, ignored or abandoned export cotton production for more lucrative pursuits, such as the cultivation of alternative cash crops like palm oil, rice, groundnuts or cocoa (Dumett 1977; Isaacman & Roberts, ed. 1995; Hogendorn 1978). To the extent that Africans did cultivate cotton, they diverted the crop into local textile markets, where higher prices were paid and lint quality standards were not as stringent (Roberts 1996). In some cases, the literature emphasizes, colonial states responded to farmers' reluctance to grow and market cotton with force, thus extracting cotton for export at the expense of farmers' freedom, food security and income (Likaka 1997; Isaacman 1996; Beckert 2014). Isaacman & Roberts (1995:34) go as far as stating that "the extent to which cotton impoverished rural Africans [is indicated by] the widespread malnutrition and hunger throughout colonial Africa."

However, the framing of cotton as an unattractive crop pushed onto African farmers by European colonialists squares poorly with actual patterns of cotton output. It does not help us answer the important question why compulsion yielded quicker and higher returns in some cases, notably Belgian Congo, than in others, such as Mozambique, where cotton, despite the territory's highly suitable soils and the crop's importance to the colonial state's revenues, was widely resisted and became known as the "mother of poverty" (Isaacman 1996). Moreover, this framing of repression and resistance struggles with counterfactual cases where cotton was widely adopted with comparatively limited colonial compulsion. Most notably, Uganda barely features in the comparative discussions of Isaacman and

[4] Some of whom, such as those in the United States south, also operated under much more favourable institutional conditions (Olmstead & Rhode 2003)

Roberts (1995) and Beckert (2014), even though Uganda's 'cotton revolution' took place in a context of comparatively limited compulsion and access to other crops, such as coffee, groundnuts and sesame seeds. To the extent that Uganda is discussed in the comparative literature, the focus is placed on Buganda, a kingdom in the southern part of the country, and emphasis is put on its purportedly exceptional characteristics – highly centralized pre-colonial institutions, its fertile soils and the cultivation of relatively undemanding bananas as the staple food – which are harnessed to prove the general rule of cotton's unattractiveness to African farmers (Austin 2008:597,601; De Haas 2017:610; Elliot 1969:136-7; Isaacman & Roberts 1995:23; McMaster 1962:44). However, the focus on the 'exceptional' case of Buganda is not warranted by Uganda's spatial pattern of cotton adoption: most cotton came to be grown *outside* of Buganda, in regions that had none of its distinctive 'cotton prone' features (De Haas & Papaioannou 2017; Vail 1977; Tosh 1978; Wrigley 1959).

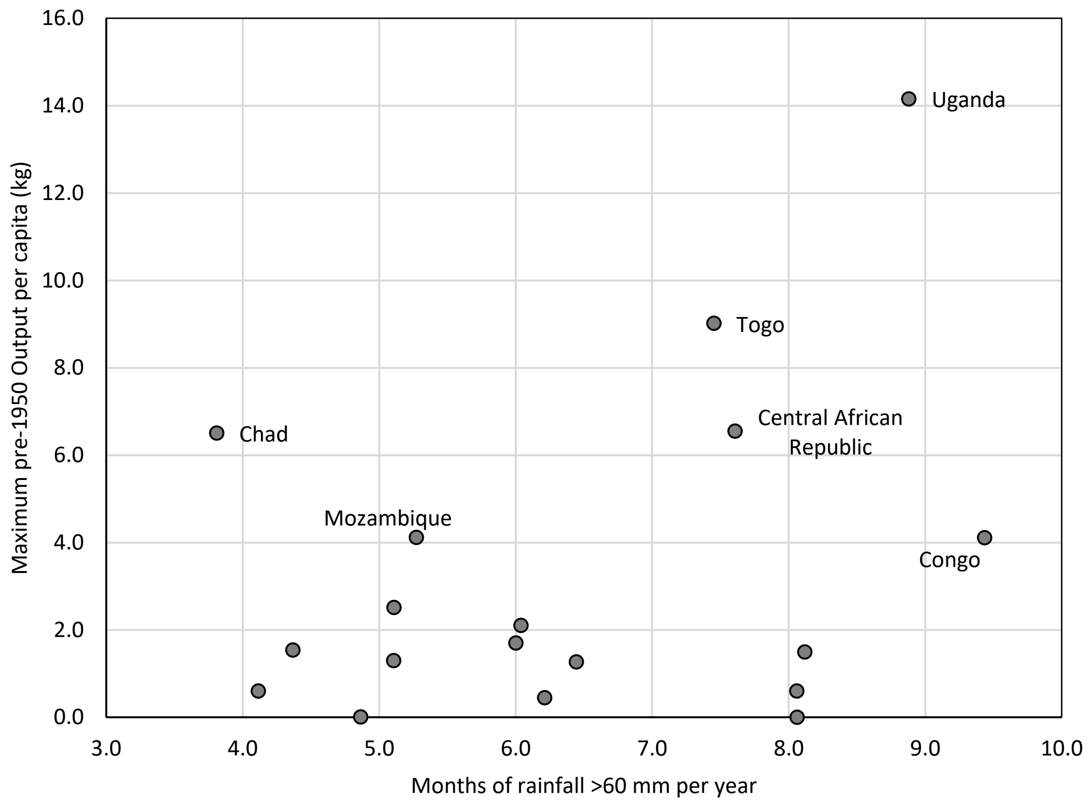
Other explanations, not prevalent in the historical literature but sensible for economic historians, also do not suffice. First, Cotton price differences and terms of trade cannot explain uneven adoption. Farmers in the Belgian Congo were particularly poorly paid, but still ended up generating substantial output (Brixhe 1953; Likaka 1997). World market prices trends did not have any consistent effect on the timing of cotton adoption either: farmers in Nyasaland and Uganda adopted cotton in the early 20th century, at a time of favourable market prices, but cotton also expanded rapidly in Uganda, the Belgian Congo and Chad during the 1930s and 1940s, at a time of depressed prices and worsening terms of trade (Frankema, Woltjer & Williamson 2017). Second, cotton adoption was not clearly linked to colonizer identity. In the British Empire, Uganda became a major cotton exporter, while Nigeria did not. In French Africa, Togo and the riverine valley of southern Chad generated sizeable cotton output, while the Soudan (Mali) and Côte d'Ivoire did not.

3. Rainfall seasonality and cotton output

Tosh (1980) argued that African historians, seeking to explain patterns of rural commercialization and broader economic development, focused too narrowly on the political economy of colonialism and overlooked basic agricultural factors, such as crops, weather and seasonality. He took issue with the widely held presumption that rural producers could simply tap into surplus resources when a road or railroad arrived in their region, substituting productive activities for leisure, and cultivate previously idle land (Austin 2014b:300-5; Myint 1958). Tosh argued that abundant availability of labor, while perhaps present in Africa's *forest zones*, certainly did not characterize farming in its *savanna zones*, which was constrained by seasonal labor bottlenecks, erratic rainfall patterns, and concomitant food insecurity concerns, limiting farmers' ability to branch out into export crop cultivation. Favorable environmental conditions were not a sufficient, but certainly close to a necessary condition for a 'cash crop revolution' to take place. Tosh applied his argument to all cash crops but in particular to cotton, which grew well in savanna climates, but is inedible (unlike groundnuts which also grow well in the savanna) and highly labor intensive under rain-fed and low-input conditions.

To what extent does rainfall seasonality correlate with heterogenous cotton adoption outcomes? Figure 2a shows the colony-level correlation between maximum cotton output before 1950 and the number of rainy months (<60 mm of rainfall) for 18 African territories were colonizers persistently attempted to introduce the crop. Figure 2b links output to cotton suitability, another environmental variable that is often invoked in recent literature.[5] The two figures confirm that the far majority of cotton output in colonial Africa was generated in territories with long rainy seasons, while there were very few countries with high cotton output and short rainy seasons.[6] Cotton suitability does not seem related to output.

Figure 2a. Length of the rainy season and maximum annual cotton output per capita before 1950

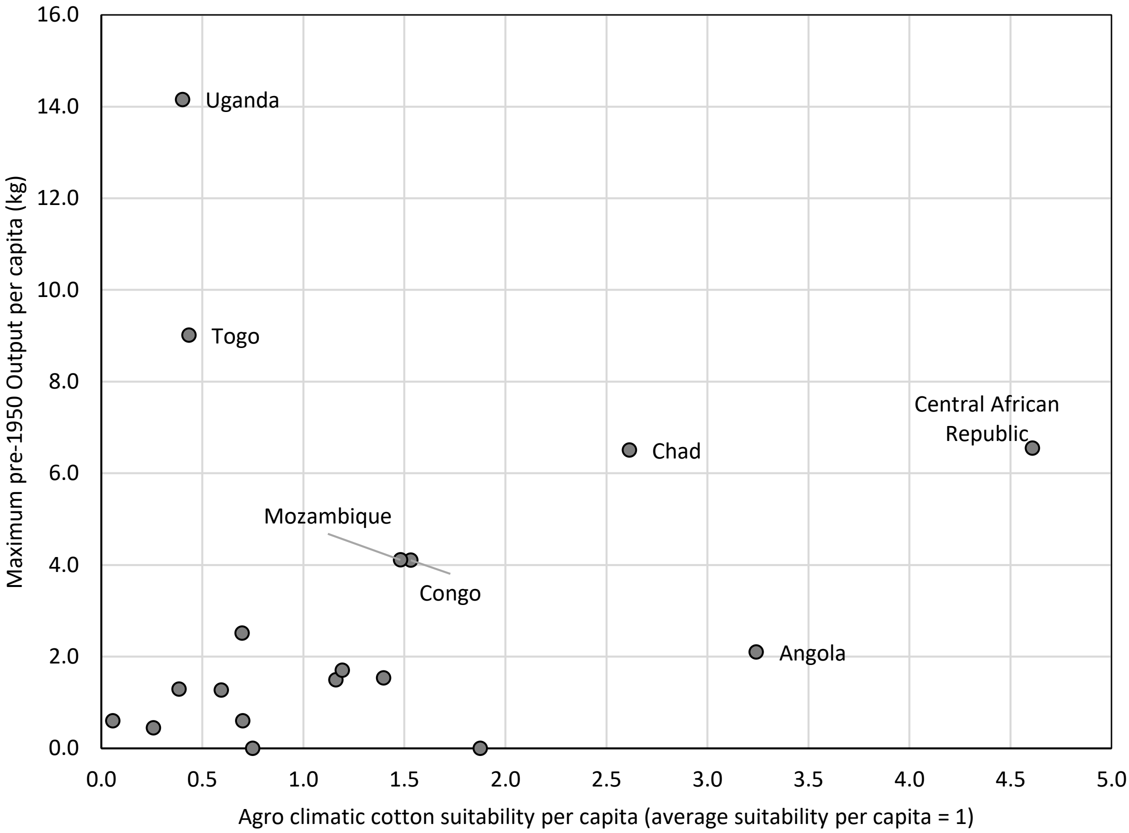


Sources: See Appendix 1.

[5] Sudan and Eritrea, where irrigation eliminated the importance of rainfall seasonality, and South Africa, which did not have a tropical climate and was no longer a colony since 1910 are excluded.

[6] Chad appears to be the exception here, perhaps because it had an extensive riverine system which allowed farmers to practice riverbed agriculture and broaden their subsistence activities to fishing, which is a largely non-seasonal activity. For more on Chad see Cabot (1957).

Figure 2b. Agro-climatic cotton suitability and maximum annual cotton output per capita before 1950



Sources: See Appendix 1.

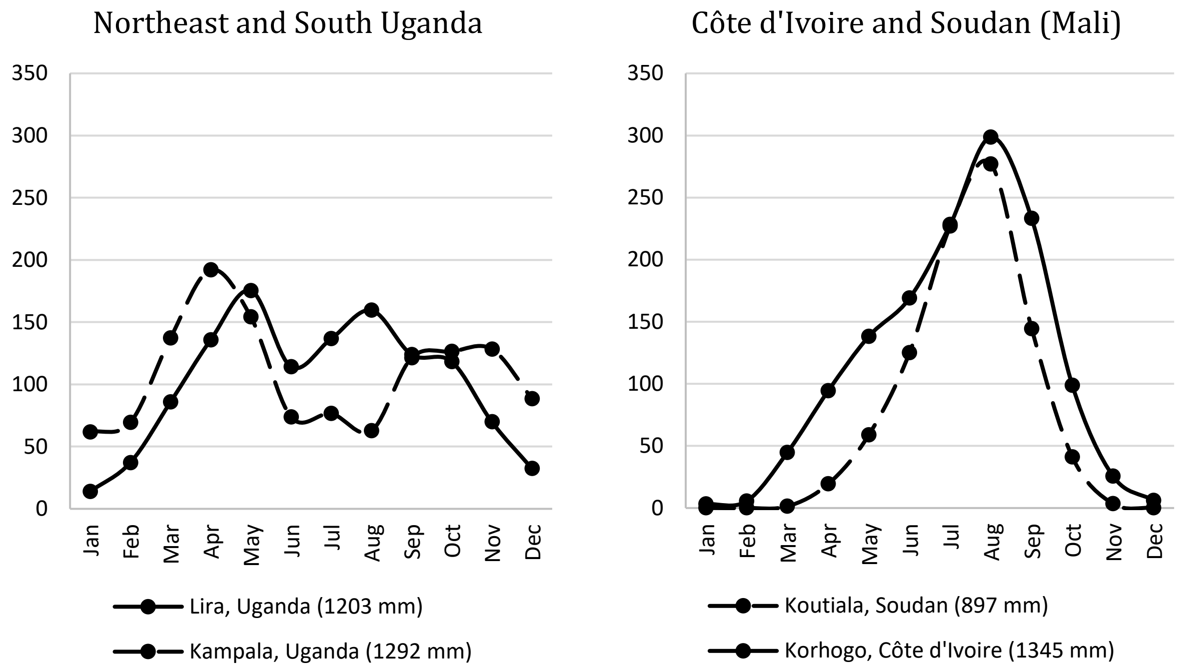
While country-level differences suggest a plausible role of seasonal rainfall endowments, it reveals no more than a tentative relationship between rainy season length and cotton output. It should be noted, furthermore, that cotton output is affected by a range of other factors which cannot be properly tested in a statistical framework with less than 20 cases. Such factors include access to alternative crops, the presence of European settlers, the quality of transportation infrastructure, levels of colonial effort and coercion, the potential of river irrigation, etc. Moreover, many of these forces operated on a sub-national level, and are hot revealed by country-level comparisons. Therefore, to further examine the relationship between seasonality and cotton adoption, we must zoom in further and pinpoint specific mechanisms. The remainder of the paper elaborates a comparison between British colonial Uganda, where cotton was widely adopted with only a limited degree of compulsion, and the interior savannas of French West Africa (specifically northern Côte d'Ivoire and Mali) where persistent French attempts to push for increased output of the crop failed. I analyse various potential factors contributing to these different outcomes and conclude that they must all be understood in the context of the fundamental constraints imposed by the intra-annual distribution of rainfall.

4. Divergent cotton outcomes in Uganda and French West Africa

Uganda and FWA make for a suitable comparison to study the impact of rainfall seasonality for several reasons. In particular, they have very similar agro-climatic conditions, which allow us to single out the effect of rainfall seasonality. Uganda is located on the equator in the Great Lakes Region of central-east Africa, on the border of what Tosh refers to as ‘forest’ and ‘savanna’ zones. The key staple of southern Uganda is the green banana, while northern and eastern Uganda mainly rely on grains. Colonial-era observers and later scholars have stressed environmental differences between Uganda’s ‘north’ and ‘south’, but recent research in ecology does not confirm the existence of a strict north-south divide in environmental zones. According to Staver, Archibald and Levin (2011), for example, almost all of Uganda classifies as a ‘bistable savanna’ (i.e. a savanna that also has the potential to be forested). The spatial contrast in cropping choices within Uganda, then, derived not primarily from environmental features, but rather from linguistic and cultural differences, reinforced by colonial policies (Wrigley 1959:6). Like Uganda, Northern Côte d’Ivoire qualifies as a ‘bistable savanna’, while Mali is a ‘deterministic savanna’, not suitable for forest growth (Staver, Archibald and Levin (2011). Annual rainfall quantities (1900-1960) line up with this categorization: similar annual totals of 1345 mm in Korhogo (northern Côte d’Ivoire), 1292 mm in Kampala (Buganda) and 1203 mm in Lira (North/East Uganda), and a considerable lower annual total of 897 mm in Koutiala (Mali) (World Bank 2018). Aside from Uganda’s banana farmers, cropping patterns and agricultural practices in Uganda and FWA were similar, revolving around annual crops such as grains, oil crops and beans, supplemented by some cassava and yams (McMaster 1962; Parsons 1960a:14-67; Parsons 1960b;1-45; Tothill 1940; Jameson 1970). Notably, both regions also have very similar degrees of cotton soil suitability (FAO/IIASA 2011).

What separates environmental conditions in Uganda and FWA are their very different patterns of rainfall *seasonality*. As shown in Figure 3 below, Uganda’s rainfall was evenly distributed throughout the year and had a bimodal pattern. Both northern Côte d’Ivoire and Mali, on the other hand, had rainfall patterns that sharply spiked during a relatively short rainy season. As argued by Tosh, the intra-annual distribution of rainfall set the seasonal rhythm of agriculture, which in turn had a major impact on agricultural production possibilities. Farmers in northern Côte d’Ivoire had to make do with a fairly short rainy season, which lasted from April to October (7 months), during which they had to procure all of their food and cash crops. The rainy season in Mali was even shorter, running from May to September (5 months). Ugandan farmers, instead, could smooth their agricultural production quite evenly throughout the year, because of a fairly even and bimodal rainfall distribution, with 9 or 10 months of high rainfall (>60 mm).

Figure 3. Average monthly rainfall in Uganda, Côte d'Ivoire and the Soudan in millimeters, 1900-1960

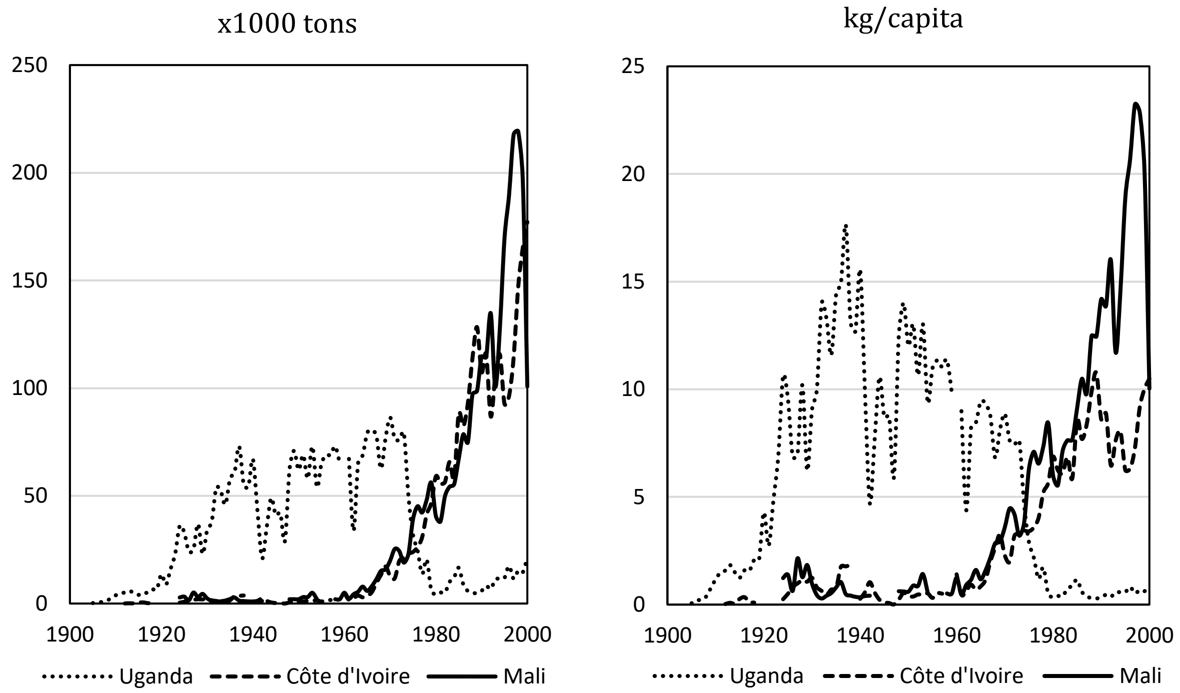


Sources: World Bank *Climate Knowledge Portal* (climateknowledgeportal.worldbank.org) based on Harris et al. (2014)

Landlocked Uganda's cotton take-off started soon after the completion of a coastal railway in 1902 (Ehrlich 1965). By the 1950s, cotton production had diffused to a region of ca. 135,000 Ha, inhabited by approximately 4.5 million people (Uganda 1960). During the 1950s, smallholder grown coffee took over as Uganda's most valuable export crop, but cotton production was maintained on a large scale, especially in areas were coffee did not grow well (De Haas 2017). Uganda's cotton exports declined precipitously during the 1970s under the Amin regime, in the context of collapsing institutions and the expulsion of Uganda's commercially important Asian minority (Jamal 1976). Cotton production recovered somewhat later on, but never bounced back to pre-crisis levels.

French efforts to generate export cotton from the West African savanna started in earnest when a railway reached Bamako (Mali) in 1904 and Bouaké (Côte d'Ivoire) in 1912 (Bassett 2001:56-8; Roberts 1996:80). Despite high expectations and a persistent *politique cotonnière*, the volume and quality of smallholder grown cotton disappointed enormously (Figure 4). The French attempted to generate cotton exports in other ways. In the Niger River Valley in Mali, they established a highly capitalized, irrigated cotton growing scheme, known as the "Office du Niger" (Roberts 1996:118-144, 223-248; Van Beusekom 2002). In Côte d'Ivoire, they attempted to entice European planters (who already dominated coffee ad cocoa production in country's southern forest regions) to establish themselves in the northern regions as well (Bassett 2001:77). However, these projects struggled to secure sufficient labor and incurred heavy losses, which made the French colonizers stick to the promise of rain-fed cotton cultivation by African smallholders.[7] After independence, this promise was finally delivered through a belated but impressive 'peasant cotton revolution' (Bassett 2001). From 1961-65 to 1995-99, Benin, Burkina Faso, Côte d'Ivoire, Mali and Togo recorded staggering annual compound cotton output growth rates of 9.5 to 13.7 per cent (compared to 1.6 per cent worldwide). Over these same years, these five countries significantly expanded their collective share in sub-Saharan cotton production from 2.8 to 35.4 per cent, and in world market production from 0.2 to 2.8 per cent (FAOSTAT).[8] I will discuss the technological and market changes that enabled this post-colonial take off in a final section of the paper.

Figure 4. Cotton production in Uganda, Côte d'Ivoire and Mali, 1900-2000



Note: Before 1960, data from Côte d'Ivoire and Uganda pertain to *production*, Mali to *export*.
***Sources*:** Data post-1960 from the FAOStat database, earlier data from Mitchell (1995), and Côte d'Ivoire before 1948 from Bassett (2001), using a 3:1 seed cotton:cotton lint conversion, and Mali before 1948 from Roberts (1996).

5. Labor seasonality and cotton adoption

Can we quantify the maximum amount of cotton that farmers in colonial Uganda and FWA were able to grow without endangering their food security? I develop a simple constrained optimization problem, where farmers have a choice to assign labor inputs to the cultivation of either food crops or cotton, must grow enough food crops to feed their family, and cannot exceed their total amount of labor available in

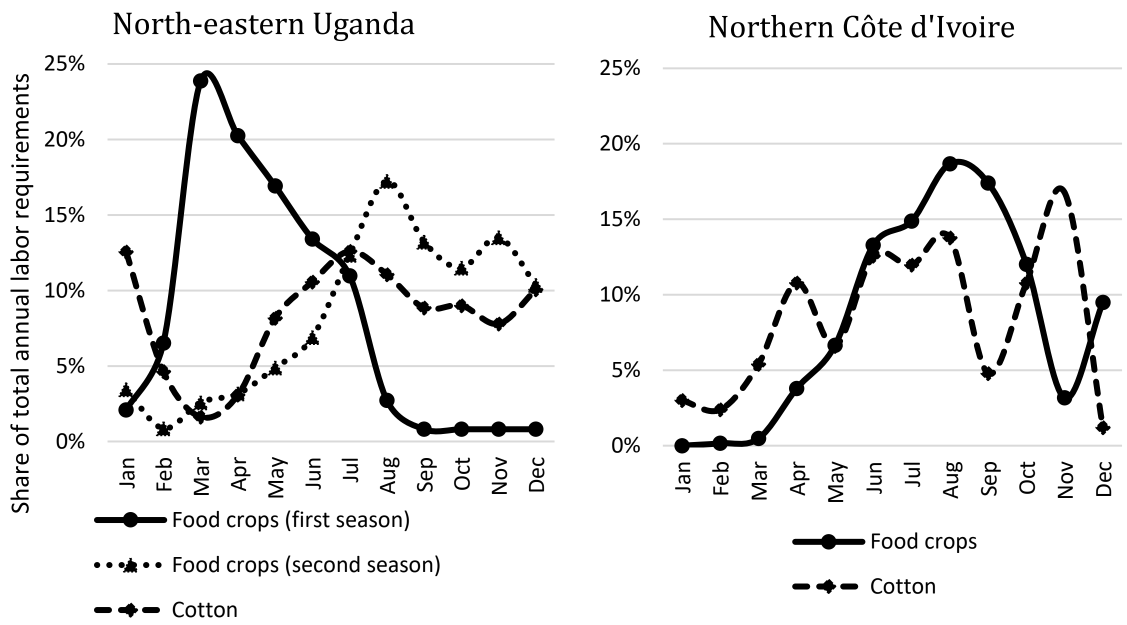
[7] The continued promotion of smallholder cotton in Northern Côte d'Ivoire thus contrasts with the strategy of backing settler interests and expatriate cocoa plantations in the Southern part of the territory (Frankema, Green & Hillbom 2016:258-9).
[8] I used the first (1961-65) and last (1995-1999) five-year-average to calculate annual compound growth rates (i.e. over a 34 year period from 1963 to 1997)

their household at any time of the year. These assumptions reflect that first priority of farmers in both Uganda and FWA was to use the agricultural season to procure a sufficient supply of food to feed the family. Cotton was grown to obtain cash income, for example to pay taxes and acquire imports. To simulate seasonal labor requirements, I collect data on monthly labor inputs in food crops and cotton among farmers in Uganda and northern Côte d'Ivoire (Figure 5). For Uganda, I use two samples of grain farmers observed in the 1964-5, 30 farmers in Aboke (Lango district) and Koro (Acholi district) respectively, and one experimental farm observed ca. 1970 in Teso district (Cleave 1974:87,121; Vail 1977:104). For northern Côte d'Ivoire and Mali, I rely on data from Katiali (northern Côte d'Ivoire), collected by Bassett in 1981 (Bassett 2001:126).

As can be seen in the right panel of Figure 5 below, Ivorian labor demands for food crops and cotton peaked jointly in a single agricultural cycle, from April to November. In their writings, French colonial administrators espoused a clear awareness that cotton and food crops directly competed for labor during the agricultural season. According to Bassett (2001:126, cf. 59), "[Ivoirian] colonial officials observed as early as 1912 that it would be difficult to expand cotton cultivation ... without improving labor productivity. Otherwise, there simply was not enough time in the agricultural calendar if farmers gave priority to food security." One official in Soudan remarked in 1924 that "the increase in cotton production in this colony will have as its corollary the reduction in the volume of grains [...]. The agricultural labor of the black will be thus allocated differently, but will not vary" (Roberts 1996:167).

In Uganda (left panel), labor demands were more equally spread throughout the year, which reflects that Uganda's food crops could be sown and harvested twice during the year, while cotton was typically relegated to the second rainy season (Tothill 1940:42-52). Because labor demands for Uganda's two seasons overlapped, farmers had to adjust their cropping choices in the first and second season to accommodate for the parallel tasks of harvesting first season crops and planting second season crops. Indeed, Ugandan grain farmers typically faced their most serious labor bottleneck during the interseason period (May to August). To allow for the harvest of first season food crops and mitigate the impact of adverse weather events (such as a hailstorm or short drought which interfered with the germination of seeds), cotton planting was 'staggered' over a four month period (May to August). Early cotton was sown in newly opened fields, while late cotton was planted in freshly harvested fields.

Figure 5. Monthly labor requirements (share of total annual labor inputs per crop category)



Sources: Uganda: Author's calculations (see text) based on Cleave (1974:87,121); Vail 1977:104). Northern Côte d'Ivoire: Bassett (2001:126).

To get from an intra-annual distribution of labor requirements to a simulated estimate of food crop and cotton output, we need to know the annual labor inputs and the output per labor unit (labor productivity) for both crop categories. De Haas (2017:609) estimates millet labor inputs at 99 man days per hectare. Various studies report millet yields in both colonial Uganda and Mali of 600 to 800 kg/ha (De Haas 2017; Benjaminson 2001:264; Labouret 1941:211-6). Followign De Haas (2017:615). I estimate yields of 606 kg/ha after accounting for on-farm waste and losses and seed retention, and caloric returns of 3417 kcal/kg (De Haas 2017:615). I assume that a farm supports a household of five consumers with an average nutritional requirement of 2100 kilocalories (kcal) per day (De Haas 2017). The simulation focuses solely on millet, the central crop in farmers' diet in both FWA and northern and eastern Uganda. I assume that holdings routinely produced a surplus of 25 per cent above the household's nutritional needs to hedge against partial harvest failures or post-harvest losses. Based on these assumptions, a farmer needs to cultivate 2.31 hectares of food crops to fulfil the family's caloric requirements.

The key question of interest here is how much labor was left to grow cotton after feeding the family. Within the household, various members traditionally had different roles in agriculture. Men were most involved in clearing fields and cash crop cultivation, while women did most of the weeding and took care of food crops. During the colonial era, many of these distinctions quickly faded, so we can assume that households efficiently coordinated their farming duties, especially during the peak-season (Boserup 1970:16-24; De Haas 2017:622; Summers 2002). Women often spent at least as many hours in agriculture as men during the year as a whole. During the agricultural peak season, however, men could devote all their productive efforts to agriculture, while women had to continue to combine agricultural work with rearing children, preparing food and gathering water and firewood (Bassett 2001:134; Cleave 1974:191; Vail 1977:37). Children, even those not going to school, generally performed little hard agricultural labor (Cleave 1974:191), although they made valuable contributions by chasing away wild animals, looking after livestock, sorting cotton post-harvest, and by freeing up some women's labor by looking after younger siblings and fetching supplies. Overall then, I estimate that households were able to provide up to 1.6 adult male equivalents of agricultural field labor per day, every single day of the month.[9]

In the case of Côte d'Ivoire, we can multiply the monthly shares of total labour requirements from the survey data (Figure 5) with our estimate of annual millet labour requirements. This allows us to see what share of the 1.6 labor units is left every month for cotton cultivation. In the case of Uganda, we first have to establish what share of their food supplies farmers' grew in the first and second season respectively. In our simulation, this decision depended solely on what allows for most cotton output. Following De Haas (2017:615), I estimate that cotton labor inputs in Uganda were 148 to 297 man-days/ha (average 198 man-days/ha). As with food crops, I multiply the monthly shares of total labor requirements (Figure 5) with the estimated annual labor requirements. The amount of cotton that can be grown annually, then, is constrained by the month in which the combined labor requirement for food crops and cotton reaches its limit, i.e. when the full 1.6 labor units are engaged every day of that month.

Figure 6 visualizes the result of this simulation, showing large differences. While farmers in FWA (bottom panel) were capable of cultivating only 0.25 Ha of cotton while retaining food self-sufficiency, farmers in Uganda (upper panel) could cultivate close to a fourfold: 0.96 Ha. It is worth noting that Ugandan households could more effectively deploy their labor in agriculture than their Ivorian-Malian counterparts. If we assume that adults worked a total of 312 days a year, Ugandan households would only have 82 working days left for non-agricultural productive activities (16 per cent of their total labor capacity), while Ivorian households retained 223 days for off-farm work (45 per cent). The implication of this finding is that the colonial strategy of cash crop specialization was more consistent with Uganda's seasonal resource endowments than it was with FWA's.

Admittedly, the data on which these results are based are far from perfect. First, the seasonal labor distributions date from the 1960s-1980s, and pertain to farmers who had better access to labor saving innovations such as ploughs and herbicides than their colonial-era predecessors. This issue is especially pertinent in the case of Côte d'Ivoire which had undergone a major 'technology breakthrough' (discussed in the final section of this paper). We have to assume that the labor saving effects of newly adopted innovations was evenly spread throughout the year. This assumption does not hold entirely, because cotton picking could not be mechanized and required *more* labor inputs as yields increased.

[9] Although this would certainly not apply to the year as a whole, it is reasonable to assume that during the peak season people did not take days off.

However, in both Uganda and Côte d'Ivoire, cotton picking was concentrated outside the agricultural peak seasons (October and November in Côte d'Ivoire, and December and January in Uganda, as shown in Figure 5), so we can safely assume it not to have constrained farmers' agricultural production possibilities. Second, the case of colonial FWA is based on a single sample of farms. Bassett (2001:120) notes that the 1981 season was unusually dry throughout, and that rainfall tapered off early, in August and September instead of October and November. As such, that years' rainfall patterns were more like those observed in the drier northern parts of the FWA cotton zone. Still, the effects of the drought in 1981 on the production-constraining seasonal labor bottleneck were probably fairly minimal, since labor demands peaked in June, July and August – that is before farmers knew that the year's rainy season was coming to a premature end.

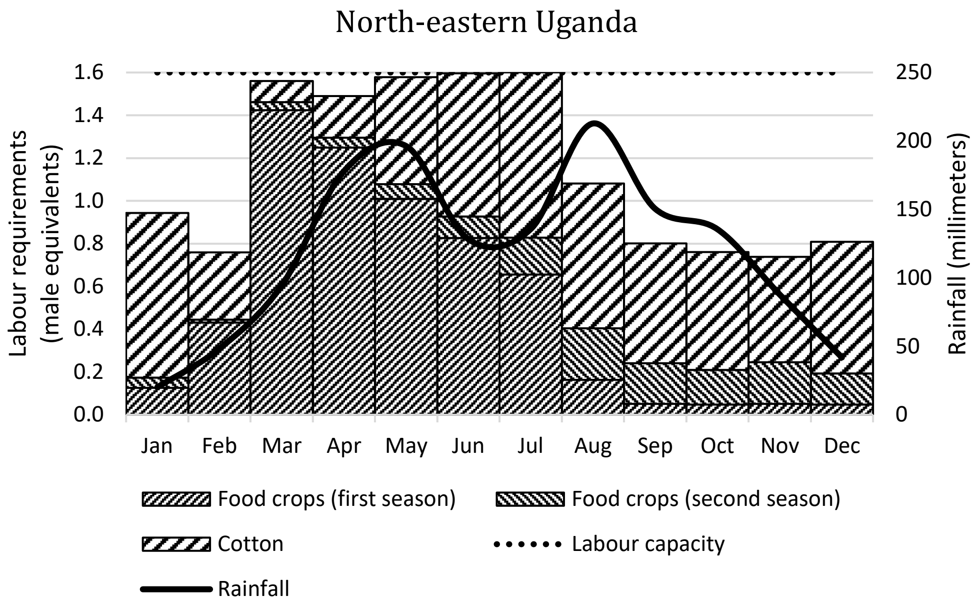
It is reassuring that the simulated results are consistent with the actual cropping choices of Ugandan farmers found in farm survey data from the 1930s and 1950s (Table 1). Acreage data from colonial FWA are not as detailed, but to the extent that they are available, are also reassuringly consistent with the simulation. A household surveyed in Mali in 1937 contained 8 adults (4 men, 4 women) and 7 children. This unit cultivated 10.84 hectares, including 7 hectares of millet, 3.14 hectares of secondary food crops and 0.7 hectares of cotton (Labouret 1941, pp. 211-6). On average, each adult pair cultivated 2.54 hectares of food crops and 0.18 hectares of cotton, which is close to the simulated acreage estimates.

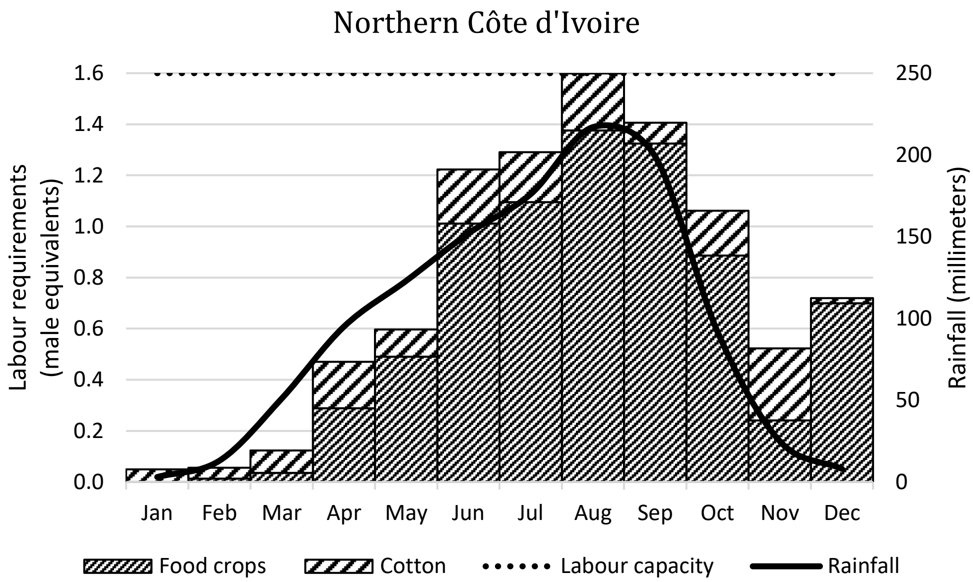
6. Food crop harvest fluctuations and cotton planting in Uganda

Rainfall seasonality also impacted African farmers' ability to cultivate cotton through a second mechanism. In cases of short rainy seasons, farmers had to plant, tend and harvest all of their subsistence crops and cotton simultaneously. This created a risk assessment problem. As noted by Roberts (1980:53) for Mali: "where a farmer has devoted a significant portion of his energy to the cultivation of nonedible cash crops, a poor harvest may result in a reduced capacity to survive." Not being able to anticipate fluctuations in harvest outcomes, farmers had to hedge against the possibility of partial harvest failure and plan for a 'normal surplus' (Allan 1965). Effectively, this insecurity and resultant hedging strategy meant that farmers allocated their resources inefficiently: they had to overinvest in subsistence crop planting to reduce risk, at the expense of cotton planting and cash income. The longer the growing season, the better farmers were able to avoid growing a surplus, as they could assess expected harvest outcomes for their early planted food crops *before* having to decide if they would have to grow additional food crops or could focus on cotton instead. In the case of Uganda, farmers were even able to postpone cotton planting decisions altogether until their first season grain harvest was secured.[10] As such, farmers could allocate labor more efficiently later during the year (second season), choosing either to supplement a poor food crop harvest, or to cultivate more cotton in case of a good food crop harvest.

[10] Which, to the frustration of colonial officials, they often did, resulting in what they referred to as 'late planting' of cotton

Figure 6. Optimized simulation of monthly food crop and cotton labor inputs





Sources: Labour requirements: Authors' calculations (see text). Rainfall: see Figure 4.

Table 1. Ugandan household sizes and crop acreages: simulation versus actual farm survey data

Sample	Date	Household size	Food crops (Ha)	Cotton (Ha)
6 villages (village average)	1933-37	4.6	2.4	1.1
2 villages (village average)	1953-55	5.1	2.5	1.1
2790 households	1963	5.8	3.1	1.0
This study's simulation	*Colonial era*	*5.0*	*2.3*	*1.0*

Sources: De Haas (2017: Online Appendix Tables).

In the optimized cropping simulation illustrated in Figure 6, Ugandan households cultivated 81 per cent of their food crops (1.87 Ha) in the first season, and 19 per cent (0.44 Ha) in the second season, alongside cotton. We assumed that this included a planned surplus of 25 percent above family subsistence needs. However, as long as crop yields were close to or above average, households had already fulfilled their subsistence requirement in the first season, which obviated the need to cultivate additional subsistence crops in the second season. Not having to grow the 25 percent food surplus equates to a gain of 0.16 Ha of cotton, added to the 0.96 Ha they were already capable of cultivating.

If Ugandan farmers indeed adjusted their cotton planting annually based on their food position, we should find that they modified their crop mix in each year's second season on the basis of their harvest outcomes in the preceding first rainy season. To test this hypothesis, I exploit annual data from 10 districts in Uganda (including both the banana and grain regions) over 35 time periods (1925-26 to 1959-60). The key variables are rainfall during the first rainy season (independent) and subsequently planted cotton acreages (dependent).[11] If long (bimodal) rainy seasons gave farmers better knowledge of their food security position and enabled them to make a more informed decision on how much labor they could afford to allocate to cotton cultivation, we should observe a positive association between the (second season) cotton acreage and the preceding (first season) food crop yield.

The acreage statistics for cotton in Uganda are arguably the best of their kind in colonial Africa. Since cotton was so crucial to Uganda's colonial economy, and output so dependent on farmers' annual planting decisions, the administration devised a system to closely monitor acreage. Each cotton season, chiefs were required to count the number of cotton 'gardens' in their administrative area. A standardized conversion (established based on a sample of representative fields) was used to turn this count into an acreage estimate. Acreage returns were accumulated at the district level and recorded annually in the colonial *Blue Books* (until 1945), and the *Report of the Department of Agriculture*.[12] This system was not without its flaws. Chiefs were known to inflate cotton acreages to please their superiors and meet performance expectations. Moreover the conversion rates and measuring practices were altered several times.[13] Nonetheless, the acreage statistics did emerge from systematic and bottom-up data collection, and although the overall *levels* might be inflated, we have no reason to believe that the annual *fluctuations* observed at the district level are compromised by non-random bias.

Unfortunately, colonial era annual data on food crop yields, or even acreages, is of very poor quality and reliability, if available at all. However, we can use rainfall, measured monthly at numerous locations using precipitation gauges, as a workable proxy for harvest outcomes. In tropical conditions, both the amount and distribution of rainfall during the growing season may be expected to affect yield outcomes.

[11] An early version of this analysis is presented in De Haas & Papaioannou (2017). The analysis presented here is based on the same data but uses an adapted and improved empirical strategy and presents additional robustness tests.

[12] A revision for the years 1945-58 was published in Uganda, *Revised crop acreage estimates.*

[13] Uganda, *Annual Report of the Department of Agriculture*, 1930, pp. 8, 13; 1934, pp. 6 and 24; 1938, p. 8; Uganda, *Revised crop acreage estimates.*

While any aggregate measures of deviation remain imprecise and may hide specific shocks such as hailstorms (Fishman 2016), the strength of rainfall measures is that it is exogenous, so the direction of causality is not at stake. An extensive econometrics literature has demonstrated that, especially in rain-fed agricultural economies, *annual* or *seasonal rainfall variability* correlates strongly to output, and explains a variety of economic and social outcomes (Carleton & Hsiang 2016; Dell et al. 2014; Miguel et al. 2004). The effects of rainfall variability are most pronounced during extreme events in both directions – droughts or floods – but smaller annual deviations from the expected rainfall pattern have also shown to matter for output (Lobell & Burke 2008; Nicholson et al. 2018).

For this analysis, I take the aggregate of rainfall during the first season only (January-June). I express rainfall deviation in z-scores, and transform to absolute (non-negative) values to capture the expectation that deviation from the long-run mean has an adverse, linear impact on harvest outcomes (3):

$$AbsoluteRainfallDeviation_{i,t} = |(x_{i,t} - \bar{x}_i) / \sigma_i,| \qquad (3)$$

where $\bar{x}_i$ is the long-term mean (1925-60) of each district, $x_{i,t}$ is the annual observation in time t for district i, and σ_i is the standard deviation of each panel, that is for every i

I use observations from one meteorological station per district, choosing the station for which most data points are available.[14] One small cotton-growing district (Mubende) has been dropped from the analysis, since consistent rainfall observations are lacking. Although some rainfall and acreage statistics are available before 1925, I confine the analysis to 1925-60 because (i) we have almost complete data for all districts during these years,[15] (ii) by 1925 the acreages were substantial enough to produce reliable and economically meaningful growth rates in all major cotton districts,[16] (iii) by 1925 cotton was widely diffused and annual fluctuations were not driven primarily by government cotton campaigns[17] and (iv) starting in 1925 excludes sharp acreage fluctuations related to a currency realignment that took place in the early 1920s. To assess farmers' investment in cotton, I take the log growth of the cotton acreage relative to the previous year[18] and estimate the following specification:

$$CottonAcresLogGrowth_{i,t} = \beta_0 + \beta_1\, AbsoluteRainfallDeviation_{i,t} + \nu_i + \mu_t +$$

$$(District\ dummy \times Time\ Trend)_{i,t} + \varepsilon_{i,t}\,. \qquad (4)$$

---

[14] See Appendix 2.

[15] Except for the war years 1940-43, for which I impute district level acreages on the basis of four province-level annual data points.

[16] The problem with using growth rates is that a district level increase from 121 to 3237 and back to 41 hectares looks like an enormous fluctuations, even though this volatility applies to minor acreages, and probably arose from a measurement error. After 1925, there is only one such obvious outlier (West Nile, 1927-29). I exclude the years 1925-30 for West Nile from the dataset. Excluding the West Nile district from the analysis altogether does not affect the results.

[17] For example, cotton expanded rapidly in Busoga district between 1908 and 1912, despite a major famine. This development was solely attributable to a very forceful government campaign (Nayenga 1981). 0

[18] Ln(cottonacres$_t$) – Ln(cottonacres$_{t-1}$). The results are robust to using other measures of growth, such as the first difference ($\frac{Acres\ t - Acres\ (t-1)}{Acres\ (t-1)}$), the difference compared to the three previous periods or absolute cotton acreages including lags of the dependent variable on the right hand side. These results are shown in Appendix Table A2.1. columns (1) to (3) respectively.

where

$i = 1,2,3,....,10$

$t = 1,2,3...,35$

and where $CottonAcresLogGrowth_{i,t}$ denotes the log growth of total acreages of cotton planted per capita in district *i* and year *t*. v_i and μ_t are district and year fixed effects, respectively. $(District\ dummy \times Time\ trend)_{i,t}$ captures unobservable district characteristics (v_i) interacted with a linear time trend (t). In all estimations, I cluster standard errors at the district level (no. of clusters = 10) to avoid any autocorrelation concerns of rainfall deviations and the possibility of measurement errors, which are most likely to be correlated within districts across time. The coefficient of interest, β_1, is the estimated effect of a one-standard-deviation-change (either positive or negative) in rainfall on the log growth of the cotton acreage. A negative sign, $\beta_1 < 0$, indicates that, on average, first season rainfall deviations are associated with a decrease in the second season cotton acreage.

The results are reported in Table 2 (below). As shown in Column 1 and 2, a one-standard-deviation-change of first season rainfall is associated with a subsequent decrease in the acreage of cotton of 7 per cent. In Column 3, I split out dry and wet seasons, taking 1.25 st. dev. as the cut-off point. Both dry and wet shocks had a significant adverse impact on subsequent cotton acreage.[19] In Column 4 and 5, I include rainfall indicators for the first and second season of the previous year, which had no effect on cotton planting. Next, I perform several falsification tests where I include rainfall deviation during the first season of the *next* year (Column 6) and rainfall deviation during the *second* rainy season from July to December (Column 7). That these results are insignificant is reassuring. Column 8 shows the results with annual rather than seasonal rainfall, yielding a negative but non-significant coefficient, which can plausibly be attributed to the noise introduced by the inclusion of second season rainfall in the variable, which had no effect on cotton planting.[20] The results are robust to excluding individual districts and specific categories of districts.[21] They are also robust to using Wild Bootstrap standard errors.[22]

[19] Results for a cut-off at 1.0 std. dev. (33 percent of all years) are shown in Appendix Table A2.1., column (8). Results for a cut-off at 1.5 std. dev. (10 percent of all years) are shown in column (9). As expected, drought shocks become more severe at larger deviations. This is not the case for excessive rainfall shocks, possibly because the adverse impact of excessive rainfall shocks is more sudden (e.g. a hailstorm or flooding) and is therefore a not captured as consistently by seasonal precipitation totals. Further exploration of this issue lies beyond the scope of this paper.

[20] There is only a very mild positive bivariate correlation between the standard deviations of rainfall in the periods January-June and July-December (coefficient of 0.10, p-value of 0.025 and R^2 of 0.01).

[21] I exclude three coffee growing districts in Appendix Table A2.1. column (4), two districts with large outliers of the dependent variable in column (5) and three districts with the smallest per capita cotton acreage in column (6). In column (7), I exclude the war years (1939-45).

[22] Wild Bootstrap P-values for each of the results in Table 2 are reported in Appendix Table A2.2.

Table 2. Effect of first season absolute rainfall deviation from long-term mean on second season cotton acreage (log growth)

Dependent variable: cotton acreage	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
Rainfall deviation t (Jan.-June)	-0.062***	-0.063***		-0.076***	-0.062***	-0.059***	-0.061***		
	(0.015)	(0.015)		(0.023)	(0.013)	(0.012)	(0.016)		
Drought shock t (Jan.-June)			-0.116**						
			(0.043)						
Excessive rain shock t (Jan.-June)			-0.083**						
			(0.034)						
Rainfall deviation t-1 (Jan.-June)				0.006					
				(0.029)					
Rainfall deviation t-1 (July-Dec.)					0.024				
					(0.016)				
Rainfall deviation t+1 (Jan.-June)						0.016			
						(0.019)			
Rainfall deviation t (July-Dec.)							-0.001		
							(0.032)		
Rainfall deviation t (Jan.-Dec.)								-0.017	
								(0.027)	
Rainfall deviation t (Jan.-April)									-0.079**
									(0.023)
Rainfall deviation t (May-Aug.)									-0.035
									(0.022)
Rainfall deviation t (Sep.-Dec.)									0.025
									(0.032)
District & year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District-specific effects	N	Y	Y	Y	Y	Y	Y	Y	Y
No. observations	334	334	334	324	327	315	331	331	330
No. districts	10	10	10	10	10	10	10	10	10

Notes: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

7. Uganda versus FWA: Alternative explanations

Forced labor

Were forced labor policies in Uganda more geared towards cotton production than in FWA? In both contexts, colonial officials initially applied various forms of pressure and compulsion to increase cotton output, using local chiefs, whose tenure often depended on their ability to extract cotton from their taxpayers, or other local agents to enforce certain acreage or output requirements (Bassett 2001:61-2,77,197fn; Ehrlich 1958:79,88; Jørgensen 1981:52-4; Roberts 1995:221-46; Roberts 1996:92,98, 124; Robins 2017:120; Summers 2002; Vail 1977:63; Wrigley 1959:16). In Uganda, most forms of agricultural and non-agricultural labor compulsion had been phased out by the 1930s, when the cotton export sector was already firmly established, while in FWA it persisted into the late 1940s (Powesland 1957:13-34; Roberts 1996:246-8; Van Waijenburg 2018). Did French labor requisition policies undermine cotton output by diverting labor away from farming? This does not seem plausible for several reasons, First, there would only be such direct substitution if labor was called for during the agricultural season, which was typically not the case. Moreover, forced labor was typically used for infrastructural development, which should have, in the long run, benefited cotton exports, obviating the need for labor intensive porterage to distant processing facilities (Bassett 2001:64; Ehrlich 1958:91-2; Roberts 1996:228; Vincent 1982:220). We should also remember that off-farm labor requisition in Uganda was intense during the 1900s and 1910s, when cotton was already expanding rapidly (Nayenga 1981). One could even argue that the causality ran the other way: as the French colonizers failed to establish a successful agricultural export sector from which to derive tax revenues, they continued to rely on the more costly alternative of labor taxes.

Infrastructural investment

Did farmers in Uganda have better opportunities to market their crop? In both regions, the first ginning facilities were erected in 1904, by the ACC in Soudan, and by the Uganda Company, a commercial offshoot of the Christian Missionary Society, in Uganda (Ehrlich 1958:69; Roberts 1996:81-2). Eventually, the ginnery infrastructure in Uganda would become much more fine grained than in colonial FWA, especially after the entry of South Asians into the market in 1910 (Ramchandani 1976:124). In FWA, in the meanwhile, the ginnery sector continued to be dominated by large European trading firms. By 1926, there were 12 mechanized ginneries in the Soudan compared to 177 in Uganda, of which the far majority was owned by South Asians (Ehrlich 1958:176; Ramchandani 1976:128; Roberts 1996:170). A landscape dotted with small ginneries was a great advantage to growers, who no longer had to headload their cotton to far away markets. However, in 1914, when Uganda's cotton production already far exceeded Ivoirian and Soudanese levels, there were only 20 ginneries in Uganda, most of them concentrated on the coast of Lake Victoria. In the Eastern Province, where about half of Uganda's cotton was cultivated, transporting the harvest to processing facilities still required a staggering half million porter loads annually (Ehrlich 1958:90-2). Uganda's fine-grained ginnery infrastructure, then, was primarily a *consequence* rather than a *cause* of widespread cotton adoption: when output increased, the establishment of new ginneries became more attractive

West Africa's local textile industry?

Perhaps the most powerful explanation for divergent outcomes in colonial FWA and Uganda that competes with Tosh' environmental endowment explanation, revolves around the domestic cotton handicraft industry. In Uganda before the export take-off, cotton was grown and used only on a very small scale 'to manufacture small articles of clothing and adornment' (Nye & Hosking 1940:183). Clothing was more typically made from tree bark or animal hides, while cotton textiles were imported. This situation persisted throughout the period studied, although during the 1950s and 1960s a small share of Ugandan cotton was taken up by a local mechanized textile factory (De Haas 2017:610). In Mali and Côte d'Ivoire, in contrast, substantial textile handicraft sectors existed that survived deep into the 20th century, despite competition from imports (Bassett 2001:84; Roberts 1987; Roberts 1996:274-8).[23]

Did French cotton policies fail simply because farmers preferred to sell their crops locally rather than to export traders? Roberts (1996:22) builds this case, arguing that "the failure of colonial cotton development in the French Soudan is directly attributable to the persistence of the precolonial handicraft textile industry." He claims that "the Soudan produced vast amounts of cotton", which, instead of being channeled towards the export market, were fed into the local handicraft industry (Roberts 1996:278). He substantiates this argument by referring to ginnery statistics and various statements by colonial officials and merchants about the absorption of cotton by local producers. Upon close inspection, however, Roberts' argument is unconvincing. Colonial officials, keen to jumpstart cotton exports from very low levels, were indeed frustrated to see their efforts undermined by competition from local producers, whom, by metropolitan guidelines, they were not allowed to suppress (Roberts 1996:223-6). However, the source of frustration was not that they lost the competition with local merchants over 'vast amounts' of cotton.

In precolonial west Africa, cotton cultivation was widespread, but individual farmers grew *small quantities* using various techniques to minimize the required labor inputs. They cultivated hardy and often perennial varieties, and intercropped cotton with food crops (Bassett 2001:57). That the aggregate raw cotton production continued to be limited during the colonial period is suggested by available quantitative data and anecdotal evidence from archival sources. In 1925-26, only 34 per cent of all cotton ginned in seven districts of colonial Mali (which together made up 64 per cent of all ginned cotton in

[23] This was the case in most of West Africa (Frederick 2020:1-35)

the territory) was consumed by the local industry (Roberts 1996:206-7). Between 1924 and 1938, approximately 37 per cent of total cotton output in Côte d'Ivoire was marketed locally (Bassett 2001:65-6). Some cotton was ginned manually (an extremely labor intensive process) and thus not recorded in the ginnery statistics (Roberts 1996:206), so let us assume that we should *double* Ivorian production statistics and *triple* Malian export statistics reported in Figure 2 to account for an unrecorded domestic economy. Even applying such large mark-ups, which is the conservative strategy in view of the argument, cotton production in Côte d'Ivoire and Mali remains unimpressive relative to Uganda: 7 per cent and 14 per cent respectively for all years in which production statistics are available for all three territories up to 1960.

The characteristics of West Africa's handicraft sector itself also testify to the scarcity of raw cotton. European capital-intensive bulk production of cheap cloth relied on abundant fiber inputs. In contrast, West Africa's textile manufacturers converted a limited and irregular supply of cotton lint into cloth of high quality and durability. This was a labor intensive process, which relied on the abundant supply of labor, which was mobilized outside the agricultural season (Austin 2008:603-4). That the profit margins of domestic handicraft producers were determined less by cheap inputs of raw material, and more by the low dry season opportunity costs of spinners and weavers,[24] helps to explain the curious situation that local buyers were willing and able to substantially outbid cotton exporters, sometimes by a factor three or even five (Roberts 1996:196). While local textile production was important for local livelihoods and trade, its focus on labor-intensive, input-saving production techniques, as well as its limited scale, suggests that it would not have absorbed more than a fraction of cotton output, even if it had increased to the levels that colonial officials aspired to. Colonial officials themselves were very aware of the limited capacity of the local textile producers to absorb large amounts of cotton (Bassett 2001:51-80; Roberts 1996:260-3,280). Their frustration, then, resided in the fact that the domestic sector, which proved remarkably resilient, absorbed what were *marginal increases* of cotton output from a very low level.

8. Breaking the seasonal bottleneck

In this final section, I expand the scope of the analysis to evaluate *why* rainfall seasonality was a key constraint for African farmers in the colonial era. Not in all times and places did short rainy seasons prevent farmers from adopting cotton in rain-fed conditions. Most strikingly, the same regions in French West Africa which had been constrained by a short rain season in the colonial period did realize a major cotton take-off in the post-colonial period. This diachronic comparison suggests that the constraining role of agricultural seasonality was contingent on temporally delineated contextual factors, of which I

[24] Although they also began to circumvent the labor-intensive process of carding and spinning cotton by using imported ginning techniques and yarn (Frederick 2020; Roberts 1987; Roberts 1996:101,200, 215,271-2).

identify two: poorly developed markets for food which inhibited specialization, and the absence of yield-enhancing and labor-saving technological breakthroughs which constrained total agricultural output.

First, both in Uganda and in colonial FWA cotton specialization beyond the levels simulated in Section 5 was hampered by thin food markets. In an initial situation of high self-sufficiency and poor infrastructure, a large gap existed between farm-gate and consumer prices, which made surplus food production non-rewarding, and food shortages very costly. In interwar Uganda, for example, food prices were about twice as high in urban as in rural markets (De Haas 2017). Infrastructural and food-market development during the colonial era was not sufficient to obviate these very large price differences. Colonial authorities were mainly interested in the export of a limited range of cash crops that required 'dendritic' infrastructure to evict produce to a coastal harbor, and did not stimulate food trade between African regions (Austen 1988; Roessler et al. 2020). In the absence of external markets for food crops, an inverse relationship existed between quantity and price: in years of surplus, prices drop sharply, while in years of shortage, prices spike (Binswanger & McIntire 1987). In short, without access to well-functioning food crop markets, farmers were "trapped in subsistence" (de Janvry et al. 1991:1401-3).[25]

It is telling that, in the late 1940s, the share of the total food crop acreage that was devoted to production for the market was as low as 5 to 15 per cent in FWA, and under 10 percent in Uganda (United Nations 1954:11-3). If crops were marketed locally, this was typically in areas close to cities (Mukwaya 1962; Brandt et al. 1972; Roberts 1980), or particularly well-connected to railroads and waterways (Roberts 1996:99). In Uganda, interregional trade in food crops was of a very small scale until the 1960s (MacKenzie 1971). Fearing the social, economic and reputational consequences of famine, colonial authorities reinforced household and regional level self-sufficiency (McMaster 1962:96; Roberts 1996:150; Vail 1977:110). Only in specific circumstances did food trade reach a larger scale, for example to supply neighboring famine areas (e.g. Soudanese farmers supplying Senegal in 1925) and to support the war effort during World War II (Roberts 1996:99,165,264; Wrigley 1959:67).

Third, crop yields during the colonial era were low and largely stagnant. Various scholars have argued that African farmers faced distinct productivity challenges, such as erratic rainfall patterns, thin soils, tsetse infestation, and climatological variety, which hampered the diffusion of standardized crop varieties and widely applicable agricultural technologies (Frankema 2015; Rönnback & Theodoridis 2018). Others have stressed that African agriculture was dynamic and diversified, and that extensive farming methods were not necessarily a sign of constrained productivity potential, but rather signified a rational preference in a context of land abundance and the wider portfolio of on-farm and off-farm economic activities (Austin 2008; Platteau & Hayami 1998; Widgren 2017). Either dynamic may

[25] Even if food crop markets had functioned better, it is questionable if farmers would have abandoned their 'safety first' strategies, since specializing in a non-edible cash crop carries additional risk. For smallholders in the 19th century southern United States with substantially more developed food markets, Wright (1978:64) points out that "using cotton as a means of meeting food requirements involved the combined risks of cotton yields, cotton prices and corn prices. The man who grows his own corn need only worry about yields."

explain why farmers faced labor constraints during the agricultural peak season when confronted with the proposition to cultivate cotton for export.

During the colonial period, agricultural innovation had marginal and incremental impacts on labor productivity at best. Yield enhancing inputs such as fertilizers and herbicides were rarely used. Most colonial state interventions regulated growing practices (spaced planting, post-harvest crop burning) and the organization of markets (fixed prices for various qualities, regulated seed supplies). European colonizers focused their research efforts on cash crops and experimented extensively with cotton varieties (Schnurr 2011), but despite concerted efforts nowhere did this result in substantial increases of yields per hectare (Arnold 1970:155-64; Dawe 1993:149-59; Roberts 1996:224; 253-4). One potential labor-saving innovation, the plough, had only a marginal effect on peak-season labor productivity. Ox-ploughs were almost universally adopted in the Teso region of Uganda, but only *after* cotton was widely adopted there (Vail 1977:71). In other cotton-growing regions of Uganda they hardly played a role in the adoption of cotton (Tosh 1978:435). Ploughs were also introduced in Mali, but did not have much impact, until after the colonial era (Roberts 1996:147,176-7). Typically, then, simple hand hoes were used to open up and cultivate the fields.

In light of these constraints to specialization and productivity, the cotton take-off in post-colonial French West Africa is truly remarkable. How were farmers, suddenly, able to overcome the seasonality bottleneck that had prevented cotton adoption and frustrated colonial officials for over a half century?[26] The answer to this question largely resides in persistent research and extension efforts by the French former-colonizers in collaboration with post-colonial governments (Lele, van de Walle & Gbetibouo 1989). Even though they were unable to effectuate their ambitions, some colonial officials had understood at a very early stage that only by transforming labor productivity through higher yields and more efficient farming practices could cotton become the desired success (Roberts 1996:168). From the 1960s onwards, in a context of a global 'Green Revolution', the renewed concerted efforts to generate export cotton finally produced a well-rounded package of new technologies and inputs which increased crop yields and reduced labor requirements per hectare. That farmers in FWA proved willing and able to adopt these technologies testifies to their effectiveness (Bassett 2001; Benjaminson 2001; Bosc & Hanak Freud 1995; Lele, van de Walle & Gbetibouo 1989).

As a result of the introduction of improved varieties and the application of mineral fertilizers, grain yields in Côte d'Ivoire and Mali rose from an initial 600-800 kg/ha to over 1000 kg/ha for millet and sorghum, and over 1700 kg/ha for maize by the early 1980s (Benjaminson 2001:264), before stagnating at this higher level. Seed cotton yield gains over the same period were even more impressive, rising three to six fold, from an initial 200-400 kg/ha to an average of ca. 1200 kg/ha (Bassett 2001:186; Fok

[26] The colonial-era correlation between cotton output and seasonality, observed in Figure 2a and 2b, breaks down entirely when we consider post-1959 maximum annual output.

et al. 2000:14).[27] Various innovations were adopted to a greater or lesser extent in different parts of FWA, substantially increasing labor productivity (Bosc & Hanak Freud 1995). Animal traction reduced labor inputs early in the season, while the application of pesticides reduced the need for mid-season weeding (Bassett 2001:107-45). As noted earlier (Section 5), only the harvest of cotton bolls may have ended up requiring more labor due to increased picking demands resulting from higher yields, but because picking fell outside of the peak season this did not limit production possibilities (Bosc & Hanak Freud 1995:282).

We can run the same simulation introduced earlier in the paper (Section 5), but now based on the higher labor productivity in the post-colonial era. In terms of food crop, production shifted away from millet towards maize, which has a similar caloric value per kg, but higher yields (Bassett 2001:127-9; Bosc & Hanak Freud 1995:290). I conservatively estimate that food crop yields doubled, and that labor demands per Ha in both food crop and cotton cultivation halved. In these new conditions, farmers were able to cultivate 2.7 Ha of food crops, more than a tenfold increase compared to the colonial era. Cotton yields per Ha also increased, threefold. As a consequence, smallholders' cotton production possibilities had risen over thirtyfold. This gain may appear extreme, but between the 1930s-60s and the 1970s-90s, per capita cotton production in Côte d'Ivoire (and probably Mali) did rise over ten fold. Moreover part of the increased production possibilities were shifted towards surplus grain production, which became more attractive as food markets developed. Indeed, the region's cotton zones now also produced substantial grain surpluses for domestic and international export (Bingen 1998:271; Benjaminson 2001:264).

9. Conclusion

To understand why cotton imperialism in Africa was an overall failure, and produced unanticipated spatial patterns of output, we should look beyond the dynamics colonial labor coercion, colonial investments, and diversion to indigenous textile producers, and instead consider how environmental constraints underpinned the choices of African farmers, and thwarted colonial designs. Validating a hypothesis proposed by John Tosh (1980), this study has shown that most African savanna farmers, at prevailing levels of technology and market access, were unable to combine substantial involvement in cotton production with sustaining food security. In a context of short rainy seasons, farmers did not have enough labor at their disposal in the agricultural peak season, and could not assess their food security before committing resources to an inedible cash crop. Colonial states, despite their persistent efforts to generate cotton output, were unable to mitigate this bottleneck. As a result, cotton only took off on a large scale in regions with comparatively long rainy seasons, most notably Uganda. Only after

[27] In terms of lint, the yield gain was even greater, since the lint:seed ratio improved as well (Bosc & Hanak Freud 1995:269-70).

independence, did the introduction of labor saving technologies in the former French territories of West Africa enable widespread and large scale cotton adoption among savanna smallholders, alongside their food crops.

Acknowledging the role of rainfall seasonality in the specific technological and marketing context that prevailed in colonial Africa has wider repercussion for the way in which we evaluate the dynamics of colonial rule. Farmers in Uganda adopted cotton unlike their West African counterparts not because the former experienced more coercion or resisted less, but because they had access to two rainy seasons per year. Colonial coercion and African resistance were certainly important *outcomes* of cotton imperialism, as shown for the cases of the Belgian Congo (Likaka 1997) and Mozambique (Isaacman 1996) among others, but they do not decisively *explain* its relative success and failure, which instead were mainly linked to environmental constraints, technology and markets. As such, this study affirms the points made by Olmstead and Rhode (2018) and Wright (2020), albeit in the very different context of antebellum cotton slave plantations in the United States, that the study of labor coercion, while important in its own right, does not always hold the key to understanding the magnitude of and changes in cotton output, but that seemingly mundane factors, such as seasonality and biological innovation (or the lack thereof) deserve close scrutiny as well, not in the least because they determine the returns on coercive efforts.

Some of the dynamics studied for cotton will also apply to other savanna cash crops in Africa, most notably oil crops. Hance, Kotschar and Peterec (1961:494) noted that in 1957, only 6.4 percent of all export value in tropical Africa was generated from rain-fed agriculture in “the savanna proper” (Tosh’ savanna zones), compared to 43.2 percent from “rainy and adjacent savanna areas” (Tosh’ forest zones). There are important exceptions to this pattern. Savanna farmers, operating in a context of short rainy seasons, were able to cultivate substantial amounts of groundnuts around Kano in Northern Nigeria, and in coastal Senegal and Gambia. Although these cases can only be addressed briefly here, it is important to note that their success relied on very specific conditions which were not (yet) present in other parts of colonial Africa. Coastal Senegal and Gambia benefited from large-scale rice imports, which enabled farmers to specialize in groundnuts (Swindell & Jeng 2006; Van Beusekom 2002). The areas surrounding Kano were characterized by exceptional levels of agricultural productivity and dense trade networks, which are linked to the region’s historically high population densities and pre-colonial processes of state formation (Hill 1977; Hogendorn 1978). These cases, then, foreshadow the breaking of environmental bottlenecks that colonial states were unable to effectuate, but would eventually occur in Francophone West Africa after independence.

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Appendix 1: Country analysis

Criteria of country inclusion: I include countries for which I found evidence of serious and persistent attempts by the colonial government to bolster cotton production and stimulate cotton export during the period from 1900 to 1959, for example by experimenting with cotton varieties, establishing ginneries and instructing or forcing cultivators to grow cotton. This criterion narrows down my sample of countries to 21. Next, I exclude Ghana, where attempts to establish a cotton sector were abandoned early, before 1920 (Dumett 1975). I also exclude Sudan (Bernal 1995) from the final analysis because cotton was grown under irrigated conditions and therefore not subject to the local rainfall regime. I exclude South Africa, Basutoland and Swaziland because of their very different climate, and South Africa's non-colonial status for most of the period. I include the following countries (listing one or multiple references to the existence of serious and persistent colonial cotton projects): Angola (Pitcher 1993), Benin (Manning 1990), Burkina Faso (Cordell & Gregory 1982), Burundi (Leurquin 1963), Cameroon (Austen & Headrick 1983:60), Central African Republic (De Dampierre 1960); Chad (Stürzinger 1983), Belgian Congo (Likaka 1997), Côte d'Ivoire (Bassett 2001), Kenya (Fearn 1961), Malawi (Mandala 1990), Mali (Roberts 1996), Mozambique (Isaacman 1996), Nigeria (Hinds 1996; Hogendorn 1995; Vincent 1976), Togo (Maier 1995), Uganda (Wrigley 1959), Tanzania (Austen 1968; Monson 1995; Sunseri 2001), and Zimbabwe (Nyambara 2000).

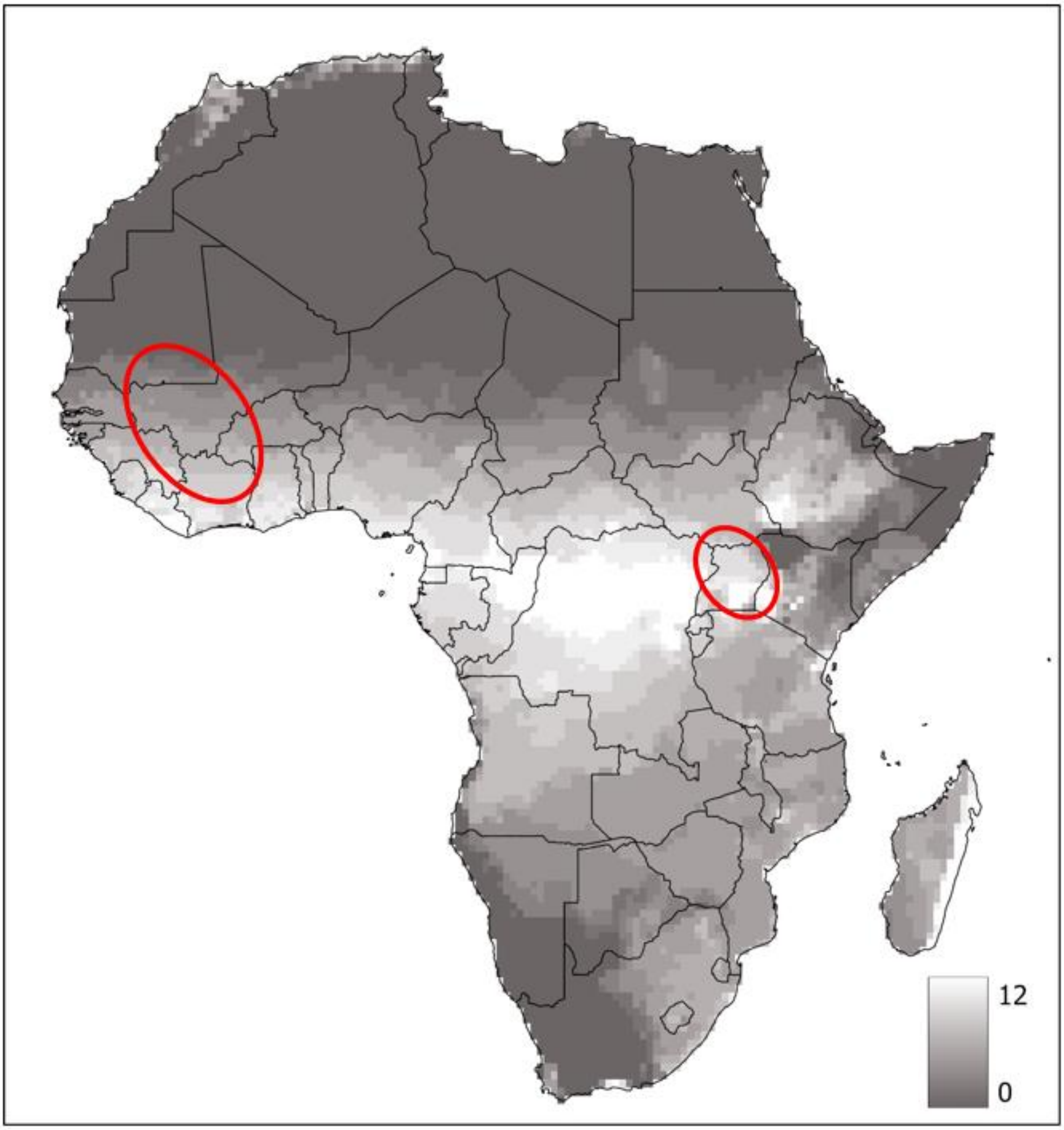
Cotton output in metric tons: I take cotton output from Mitchell (1993), supplemented with additional data for Benin (Manning 1990), Burundi (*Verslag van het Belgisch Bestuur van Ruanda-Urundi*), Côte d'Ivoire (Bassett 2001), Kenya (Fearn 1961), Mali (Roberts 1996), Malawi (Frankema, Woltjer & Williamson 2017), Mozambique (Bravo 1963:81) and Togo (*Tableau Général du Commerce Extérieur*). I consider the year with the largest annual production, which is likely to be recorded in the above sources. In this way, I avoid having to estimate averages on the basis of incomplete series (doing so, however, would not majorly change the reported ranking of countries).

Rainy season**:** The length of the rainy season is defined as the number of months with 60 millimeter of rainfall or more, which is the standard threshold for tropical wet months in the Köppen climate classification system. Monthly rainfall (pertaining to the period 1900-59) is obtained from the World Bank *Climate Change Knowledge Portal* (Harris et al. 2014) on a fine-grained grid-level. The length of the rainy season could differ substantially within territories (see Figure A1). I obtain a weighted country-level average by multiplying the grid-cell-level length of the rainy season by that cell's contribution to country level cotton suitability. In that way, the length of the rainy season in cotton suitable areas weighs in more in the country average (and cotton unsuitable areas, for example the large parts of Chad that are situated in the Sahara desert, are not considered).

Cotton suitability: Cotton agro-climatic suitability is derived from the *Global Agro-Ecological Zones (GAEZ)* portal of the Food and Agriculture Organization of the United Nations (FAO/IIASA 2011), taking suitability for rain-fed agriculture at a low input level for the FAO's baseline period (1961-1990).

The suitability of all grid-cells within a country is aggregated at the country-level. Using the agro-ecological (soil) suitability indicator of FAO instead of agro-climatic suitability does not change the results (the indicators are highly correlated).

Figure 5. Average length of the rainy season, 1900-1959 per grid-cell, main study areas indicated in red



Sources: World Bank *Climate Change Knowledge Portal* (Harris et al. 2014)

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Appendix 2: Rainfall and cotton planting

The rainfall stations selected for each of the districts are located in Gulu (Acholi district), Mbarara (Ankole district), Masindi (Bunyoro district), Namasagali (Busoga district), Mbale (Central district), Lira (Lango district), Masaka (Masaka district), Entebbe (Mengo district), Ngora (Teso district), Fort Portal (Toro district) and Arua (West Nile district).

Table A2.1. Additional specifications testing the effect of rainfall deviation on cotton acreage (see main text for context)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Rainfall deviation t	-0.052**	-0.046**	-0.016***	-0.077***	-0.065***	-0.049**	-0.044*		
(Jan.-June)	(0.018)	(0.017)	(0.005)	(0.017)	(0.019)	(0.019)	(0.020)		
Drought shock t								-0.047	-0.165**
(Jan.-June)								(0.032)	(0.082)
Excessive rain shock t								-0.087**	-0.059
(Jan.-June)								(0.038)	(0.040)
Cotton acreage 1st lag			0.814***						
			(0.147)						
Cotton acreage 2nd lag			-0.017						
			(0.115)						
Cotton acreage 3rd lag			-0.001						
			(0.057)						
District & year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District-specific effects	Y	Y	N	Y	Y	Y	Y	Y	Y
No. observations	334	334	315	229	264	242	254	334	334
No. districts	10	10	10	7	8	7	10	10	10

Table A2.2. Wild Bootstrap P-values (only significant coefficients for the main results in table 2 are reported)

Dependent: cotton acreage	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS	(6) OLS	(7) OLS	(8) OLS	(9) OLS
Rainfall deviation t (Jan.-June)	0.0050	0.0020		0.0000	0.0020	0.0000	0.0020		
Drought shock t (Jan.-June)			0.0100						
Excessive rain shock t (Jan.-June)			0.0470						
Rainfall deviation t (Jan.-April)									0.0100
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y
District & year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
District-specific effects	N	Y	Y	Y	Y	Y	Y	Y	Y
No. observations	334	334	334	324	327	315	331	331	330
No. districts	10	10	10	10	10	10	10	10	10

Notes: The results are obtained using the “boottest” Stata package, null imposed with 999 replications