Technical Paper 6. Building Rural Development in the Lake Chad Region

Brian Blankespoor (World Bank)

7.1 Introduction

Limited market accessibility, and more recently conflict, hinder agricultural production and therefore pose major challenges to the economic recovery and development of the Lake Chad region. More than 250 million people live in the four countries of the Lake Chad region, where the vast majority of the people depend on agricultural activities for their livelihoods. Compounding limited paved roads in agricultural areas is the occurrence of numerous violent events from the decade long insurgence of Boko Haram near Lake Chad. Displaced and conflict-affected households face limited market access and economic opportunities to earn income (FEWS NET, 2021). Therefore, it is very timely and crucial to understand the links between these challenges and agricultural activities.

The objective of this paper is to gain insight on the current state of rural development in the Lake Chad countries by examining the relation between road investments and cropland expansion over the past three decades following the framework in Berg et al. (2018) and then by investigating rural development in proximity to conflict events arisen by the insurgence of Boko Haram this past decade.

Over the past several years, roads have improved in the Lake Chad region (Magrin et al., 2018), yet limited paved roads and road maintenance continues to be a challenge. Nigeria has one of the largest road networks in West Africa in terms of length of roads. However, the percentage of national roads in a bad state increased from 23 percent in 1985 to 60 percent in 2010 (Federal Government of Nigeria, 2010). The other three countries have less paved roads. The concentration of roads in Niger is mainly in the south along the West-East route of Niamey to Nguime via Diffa as well as the a triangle including Agadez, Tahoua and Zinder. Chad has limited paved roads, which are mainly concentrated in the capital region. The roads in Cameroon connect the main port of Douala and the administrative cities including the capital Yaoundé. Unpaved roads continue to pose challenges during the rainy season.

Connectivity is very important to the local economy and cross-border trade. Previous literature demonstrates that road infrastructure is conducive to regional trade and growth where it can facilitate local economic growth with the reduction in input and transportation costs, while connecting the potential for higher prices of crops (Crawford et al., 2003; Redding and Turner, 2015; Berg et al., 2017; Aggarwal, 2018; Henderson et al., 2017; Jedwab and Storeygard, 2020; Storeygard, 2016; Jedwab and Storeygard, 2019). In Nigeria, roads can facilitate growth of the non-agricultural sector (Ali et al., 2015) and improve access to market that has been linked to the adoption of modern technologies (Damania et al., 2017). Even so, Chamberlin et al. (2014) show that suit able land remains uncultivated in Sub-Saharan Africa due to limited transport access. Using panel methods over which significant road development took place from 1970 to 2010 in Sub-Saharan Africa, Berg et al. (2018) demonstrate a modest impact of improved market access on cropland expansion and suggestive evidence of impacts on the local intensity of croplands.

Not only are roads crucial to the Lake Chad region, but these countries are also linked to the water resources of Lake Chad, which is a large area natural transboundary resource that supports local livelihoods including farming, livestock, and fisheries (Déby Itno et al., 2015). Due to environmental changes and human activities, Lake Chad has shrunk approximately 90 percent from 1960 levels, when it was the world's sixth largest inland water body. The region is subject to droughts as well as human activities have altered the hydrology of this endorheic lake by stream flow modification and water diversion (Lemoalle et al., 2012), which contributes to the water scarcity and fragility of the region (Okpara et al., 2015). Droughts can challenge agricultural production and correspond to an increase in violence

against civilians (Bagozzi et al. 2017). In addition to the administrative challenges of a transboundary resource, the fluctuations in interannual and seasonal water impede the development of stable resources exploitation rights (Sarch, 2001) and reduce groundwater discharge along with loss in biodiversity (Odada et al., 2003).

Along with the environmental changes over the past few decades, the fragility of the region has increased in the past decade due to the insurgency from Boko Haram in northern Nigeria that contributes to humanitarian challenges in the region. Conflict can drive population displacement, impede the normal activity of local markets, and constrain household access to livelihood, food and income. Conflict events from Boko Haram started in 2009 have caused massive displacement of people and disruption to the agricultural sector including market activities (Awodola and Oboshi, 2015; Van Den Hoek, 2017; Jelilov et al., 2018). The conflict has displaced a large number of individuals who have experienced significant income shocks with an increase of over 40 percent chance of having no income based on an analysis of Nigeria (UNHCR and World Bank, 2016). From a recent report by OCHA (2020), the Lake Chad region has 2.6 million Internally Displaced People with 256 thousand refugees, and 5.2 million people are severely food insecure as of 16 September 2020. FAO (2017) recently reported that nearly 50 percent of the 704,000 people in Niger are in dire need of humanitarian assistance and nearly 20 percent are facing issues of food security. For Nigeria, nearly 70 percent of the 12 million people are in need of humanitarian assistance with 43 percent facing issues of food insecurity. Employing a Difference in Differences framework with panel household survey data, Agwu (2020) finds that exposure of households to conflict events from Boko Haram is associated with significant downward movements in food security. In a study of Africa, Maystadt et al. (2020) find evidence of agricultural expansion near refugee-hosting areas, whereas Salemi (2021) finds evidence of small increases of forest loss (intensive margin and not extensive margin) in areas near refugee camps in Sub Saharan Africa.

Although an explicit strategy by Boko Haram to attack markets is not known, markets are still a key location to disrupt trade and target civilians. Using conflict event data Van Den Hoek (2017) reports 38 direct attacks on markets in Borno state, Nigeria, between November 2014 and December 2016, which is nearly two market attacks per month. The paper also finds seasonality in the timing of the attacks, which occur prior to the lean season and just after the harvest. Both of these periods have the potential to disrupt agricultural production and trade by various channels: impeding physical access, access to inputs, the timing of planting and harvesting, and abandoning of fields. Adelaja and George (2019) examine the effect of the Boko Haram conflict on agricultural productivity using a nationally representative panel dataset and micro data from the ACLED database.[358] They do not find a decrease in the total hectares of agricultural land harvested, however they do find a significant reduction in total output and productivity from the Boko Haram attacks. Adebisi et al. (2016) find negative impact on agribusiness in Borno state, Nigeria. Barra et al. (mimeo) examine the relationship between conflict and poverty in Nigeria considering the connectivity where they find that decreasing transportation costs with less multidimensional poverty. Ali et al. (2015) find that reducing transportation costs in Nigeria increase measures of welfare.

This paper examines the relationship between access to markets and land cultivation following Berg et al. (2018) using panel methods. Then, I contextualize these results within the broader recent development challenges of the Lake Chad region. The results provide evidence that an increase in market access is associated with an increase in cultivated land and is positively associated with an increase in local agricultural GDP. Even so, conflict from the rise of Boko Haram in the past decade can attenuate gains whereby the proximity to conflict events in the previous year is associated with less cropland across the entire region and less night time lights from over a hundred local markets nearby Lake Chad.

358 They use the Living Standard Measurement Study Integrated Study on Agriculture dataset with three waves: 2010–11, 2012–13 and 2015–16.

This paper makes two contributions. First, the importance of market access as part of economic development is well known, yet advancements in measurement of agricultural activity derived from satellite data and recent data are necessary to gain current insight given developments in the region. Following Berg et al. (2018) who examine Sub-Saharan Africa during the period 1970 to 2010, I examine market access for rural development in the Lake Chad countries over a period during which changes in cultivated area and modest road improvements took place. I provide contemporary insights with a higher spatial resolution measure of cropland derived from satellite data at 300m from 1992 to 2019 building on the findings in Berg et al. (2018).[359] In addition, I use a newly available data set on agricultural GDP (Blankespoor et al., forthcomingc) to examine the impact of market access on local agricultural GDP.[360] Similarly, I examine the local conditions in each grid cell to determine if areas of increased cultivated land are exposed to more suitable agricultural production conditions. I focus on the extensive margin of cropland expansion (rather than intensification) given the strong dependence on rainfed agriculture and the relatively small share of cropland that is classified as irrigated.

Second, this paper contextualizes the findings of market access with local conditions given the numerous conflict events in the past decade from Boko Haram. First, I examine the impact of proximity of conflict events on cropland expansion during the period 2009 to 2019 for the entire region. Second, I build on the market level analysis by Van DenHoek (2017) who examines agricultural market activity for 104 markets nearby Lake Chad. I examine the impact of conflict by adding more recent observations of market status in a new framework that includes local night time lights as a proxy for local economic activity and a measure of proximity to Boko Haram events.

The rest of this paper is structured as follows. Section 2 describes the data sources while section 3 presents the empirical framework, section 4 presents the results, and section 5 concludes.

359 Before 2000, the HYDE 3.2 database methodology uses a weighting algorithm to estimate cropland including slope where as the measure from ESA is the result of supervised and unsupervised methods using satellite time-series data.

360 Berg et al. (2018) examine the impact of market access on total GDP; they did not examine the impact on the agricultural sector.

7.2 Data and Sample

Given the challenges of data collection across multiple countries, geospatial methods integrate a variety of data at a consistent unit of 0.1 × 0.1 degrees (approximately 11km × 11km at the equator) covering the four countries surrounding the Lake Chad. I intersect these grids with the national border to create a total of 33,252 pixels along with the corresponding area. The number of observations depends on the locations and time-step included in the regression. The regional analyses with full geographic coverage includes all pixels times the number of years. The geographic definition of the Lake Chad area is from the World Bank Lake Chad Regional Recovery and Development (PROLAC) project.[361] The local market level analysis is limited to the pixels with field based observations of a 104 markets summarized at the pixel level by season. These datasets provide insight into agricultural activity given the limited official statistics and access to the field. Below is a description of the datasets.

7.2.1 Local conditions

Agricultural production is subject to the local variation in annual climate and initial conditions (Zaveri et al., 2020). Figure 1 illustrates the shared boundary of Lake Chad as well as major transboundary rivers including the Niger and Benue from the Global Lakes and Wetlands Database (Lehner and Döll, 2004). Lake Chad has extensive floodplains and wetlands (Odada et al., 2005).

I summarize mean annual precipitation and its square at the cell-year level from the CHIRPS dataset version 2 (Funk et al., 2015). FAO (2013) provides a measure of agricultural suitability based on soil and climate conditions for twelve major crops for the period 1981–2010 from the ClimAfrica project (WP4).[362] Another measure is a common drought index with the Standardized Precipitation Evapotranspiration Index (SPEI) algorithm (Beguería et al., 2014) using the monthly precipitation and evapotranspiration 1950–2019 data version 4 from the Climate Research Unit (Harris et al., 2020). I count the number of months in a cell that are considered severe drought with values below or equal to -1.5 (Guenang and Kamga, 2014). Given the time scale over which water deficits accumulate for agricultural is important and I run the 18 month lag.[363]

7.2.2 Land cover and agricultural activity

Land cover estimates from satellite data provide a geographically comprehensive and consistent measurement from which to identify trends in agricultural activity (Weiss et al., 2020). Previous work by Berg et al. (2018) examined cultivated area from 1970 to 2010 using cropland estimates in the History Database of the Global Environment (HYDE) 3.2 (Klein Goldewijk et al., 2017). A more recently released dataset is from the European Space Agency (2017, 2019) that provides annual estimates of land cover at 300m from 1992–2019 which are harmonized from two data products Land Cover Maps - v2.0.7 and Land Cover Maps - v2.1.1.[364] I aggregate the 38 categories into six: irrigated and rainfed cropland, cropland mosaic, grassland, urban, bare land and other.[365] I summarize these data by pixel into the share of cropland per pixel.[366] I also include another measure of

361 It includes the following administrative areas: Far North Region (Cameroon); Lac, Kanem, Hadjer Lamis, and Chari Baguirmi Regions (Chad); Diffa and Zinder Regions (Niger); and Borno, Adamawa and Yobe States (Nigeria). Notably, the definition excludes N'Djamena in Chad.

362 FAO GAEZ version 4 was unavailable at the time of analysis to measure high agricultural suitability following (Berg et al., 2018).

363 The 18 month SPEI provides information of precipitation patterns over a medium to long time scale.

364 Liu et al. (2018) examine the correlation between cropland area in FAOSTAT and ESA-CCI-LC.

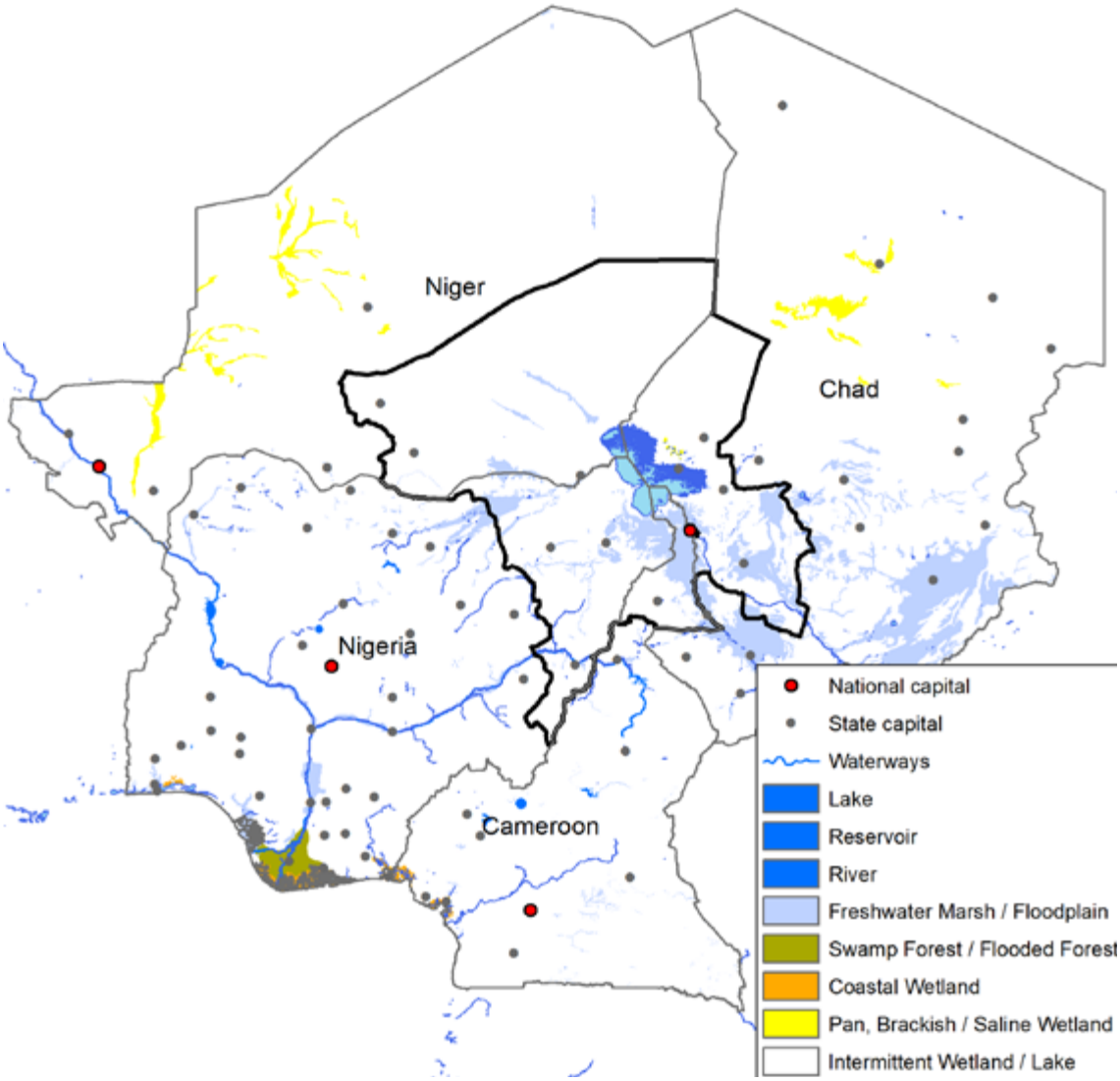
365 Specifically, I aggregate the landcover classes 10–12 into cropland; 20 as irrigated, 30 as mosaic cropland; 150 as grassland, 190 as urban and the remaining codes defined as other.

366 The area considered irrigated is significantly smaller than cropland.

cropland that includes more than 50 percent mosaic crop lands with less than 50 percent natural vegetation (tree, shrub, herbaceous cover) to include mixed land use with smallholder agriculture.

The land cover model provides an estimate of annual agricultural land use, however it aggregates any seasonal variation. So, following Blankespoor et al. (forthcomingb) and a calendar with the seasons of major crops for each country from FAO (2020a,b,c,d) I define each month into three seasons: (i) land preparation; (ii) sowing and growing; and (iii) harvest. I summarize the measures below at the season level. Another measure to gain insight on agricultural activity is from a measure of burned areas derived from satellite. Burning agricultural fields is a common practice in Central and West Africa and can reduce post-harvest fires as well as provide short-term nutrients (Bucini and Lambin, 2002; Kull and Laris, 2009). I summarize the area from the MODIS Burned Area data product (v6) in a cell, which provides a burned-area estimate per 500m pixel by month (NASA, 2020a). The intensity of land use is measured from a greenness measurement called Normalized Difference Vegetation Index (NASA, 2020b). Another measure of vegetation

Map 7.1: This map illustrates the distribution and type of waterbodies from Lehner and Döll (2004) and the Lake Chad area within the solid black line



growth is Net Primary Productivity that captures the solar energy absorbed by plants or other primary producers (Running et al., 2004). Previous work shows a strong positive correlation between these estimates and crop yields (e.g. Strobl and Strobl, 2011; Zaveri et al., 2018). The source is from the MODIS satellite product (MOD17A2H) as summarized by monthly mean of a cumulative 8-day composite with a 500m resolution (NASA, 2020c). Cross-sectional spatial distribution of crops such as cotton are from the Spatial Production Allocation Model (SPAM) (Yu et al., 2020).

In addition to cropland, the livestock and fishing trade are important activities in the Lake Chad region, especially near Lake Chad. The spatial distribution of livestock ca. 2010 is from Gilbert et al. (2018). They provide estimates livestock including cattle and goat based on agricultural census data with equal weights.[367] Lake Chad was once one of the great fisheries. Graaf et al. (2014) in FAO (2017) estimate of fishing activities in the region at a value of USD 54 to 220 million. However, current indiscriminate fishing practices are not sustainable, yet employed as a coping strategy for survival (Eriegha et al., 2019).

7.2.3 Market Access

Following Jedwab and Storeygard (2019) and Berg et al. (2018), I calculate the local market access for a given location as a function of the weighted sum of the populations of all other locations, with a weight that decreases with travel time. Formally, I define market access in a location i at time t:

$$M A_{i,t} = \sum_{j \neq i} P_{j,t} \, \tau_{i,j}^{-\sigma} \qquad (1)$$

where $P_{j,t}$ is the population in location j at time t, $\tau_{i,j}$ is the travel time between locations i and j at time t, and σ is a trade elasticity parameter. Market access depends on the road types and topography between locations i and j at time t through the values $\tau_{i,j}^{-\sigma}$ and excluding itself and cells within 20km. Following previous studies (Berg et al., 2018; Jedwab and Storeygard, 2020), I use the value for the elasticity of trade σ equal to 3.8 from Donaldson (2018) who derived it for the case of India. The travel time is calculated based on a time cost raster method using the Dijkstra algorithm as the minimum time result from the roads and offroad speeds. For the years 1983, 1992, 2001 and 2010, I assign a speed based on road categories similar to Berg et al. (2018); Jedwab and Storeygard (2020)[368] and offroad speed based on the hiking function from (Tobler, 1993).

$$Hiking = 6 * e^{-3.5*|s+0.05|} * 0.6$$

where s is mean slope from Verdin et al. (2007).

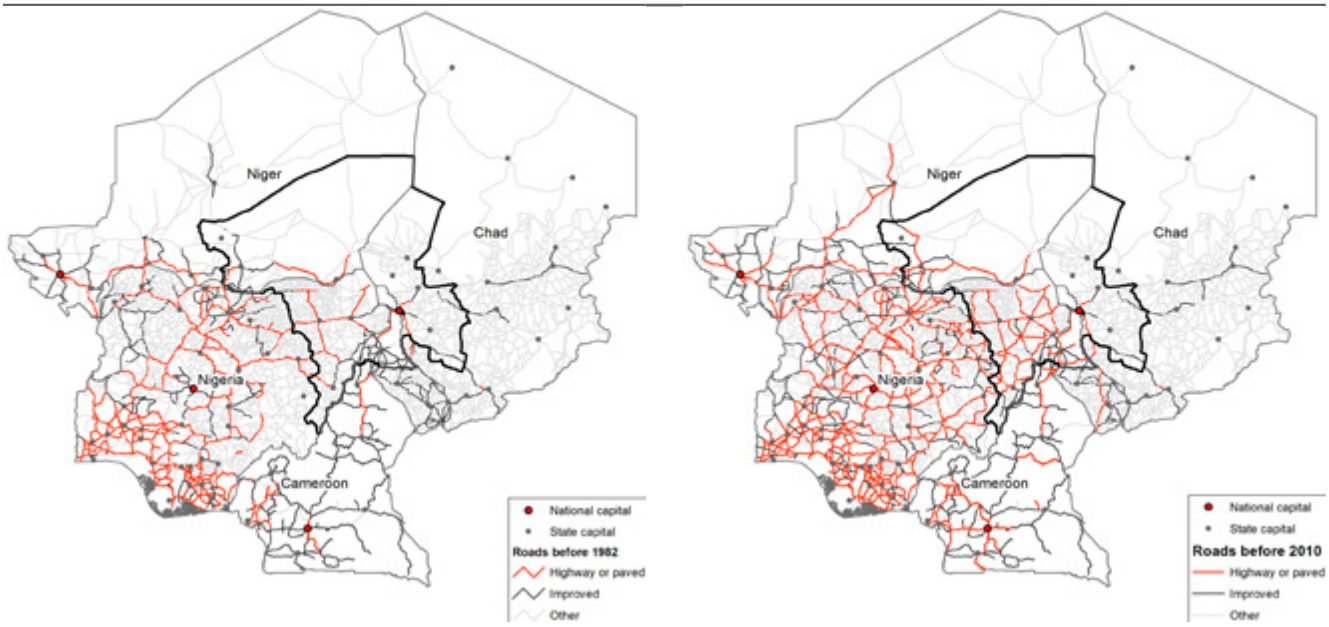
For panel roads, I use the georeferenced panel roads data from 1983 to 2010 from (Jedwab and Storeygard, 2019). The length of paved roads increased in Chad along with Cameroon, while Niger and Nigeria does not increase significantly (See Map 7.2).

The size of the market is based on urban population data from the consolidated urban population database (Blankespoor et al., 2017). The population has increased over the past decades. The distribution of population in the Lake Chad area has high variation, where Nigeria has much higher population than the other three countries.

The regional analysis also considers other important infrastructure and markets. Ports provide an important connection to the international market. The location of marine ports is from the World Ports Index (National Geospatial-Intelligence Agency, 2014). The busiest marine port in Cameroon is Douala followed by Limbé. Nigeria has major ports including: Lagos, Calabar, Onne, Port Harcourt and Warri. I construct a variable estimating the minimum travel time to a port. The locations of

367 They also provide a version as the result of statistical models with dasymetric weighting.
368 Specifically, highway speed is 80kph; paved is 60kph; improved is 40kph and earthen is 12kph.

Map 7.2: Map illustrating highway (red), paved (black) and improved (pink) roads from (Jedwab and Storeygard, 2020)



cotton ginning factories are digitized from a map on *Cotton Zones, Ginning Factories and Exports of West Africa* in OECD (2006). The locations of regional livestock markets are from FEWS NET (2009) for Chad and Niger FEWS NET (2008) for Nigeria and from Motta et al. (2019) for Cameroon. Within the Lake Chad region, the trade routes depend on connectivity of infrastructure across borders, especially Chadian livestock along with the collection of Cameroonian livestock on the way to Nigeria (Magrin et al., 2018).

For local markets near Lake Chad, the Famine Early Warning Systems Network (FEWS NET) reports provide both time and place of the operational status, which are based on field-based investigations, into four qualitative categories: (i) normal activity/operating normally (ii) some disruption, reduced activity/operating slightly below normal, (iii) significant disruption, limited activity/operating well below normal or (iv) minimal or no activity/not operating. Following Van Den Hoek (2017) I use the closed and normal operational status and then I aggregate the well below normal status and below status into a combined below normal category for a total of three categories. They produced this report every few months starting with the earliest publicly available market activity report in January 2015, which focused on market activities in December 2014. I summarize the most restrictive category during the season and I exclude 32 missing observations during the six year period of record (N = 104 * 3 * 6 - 32 = 1840); including a one year lagged variable reduces the number of observations equal to 1533.

7.2.4 Economic activity

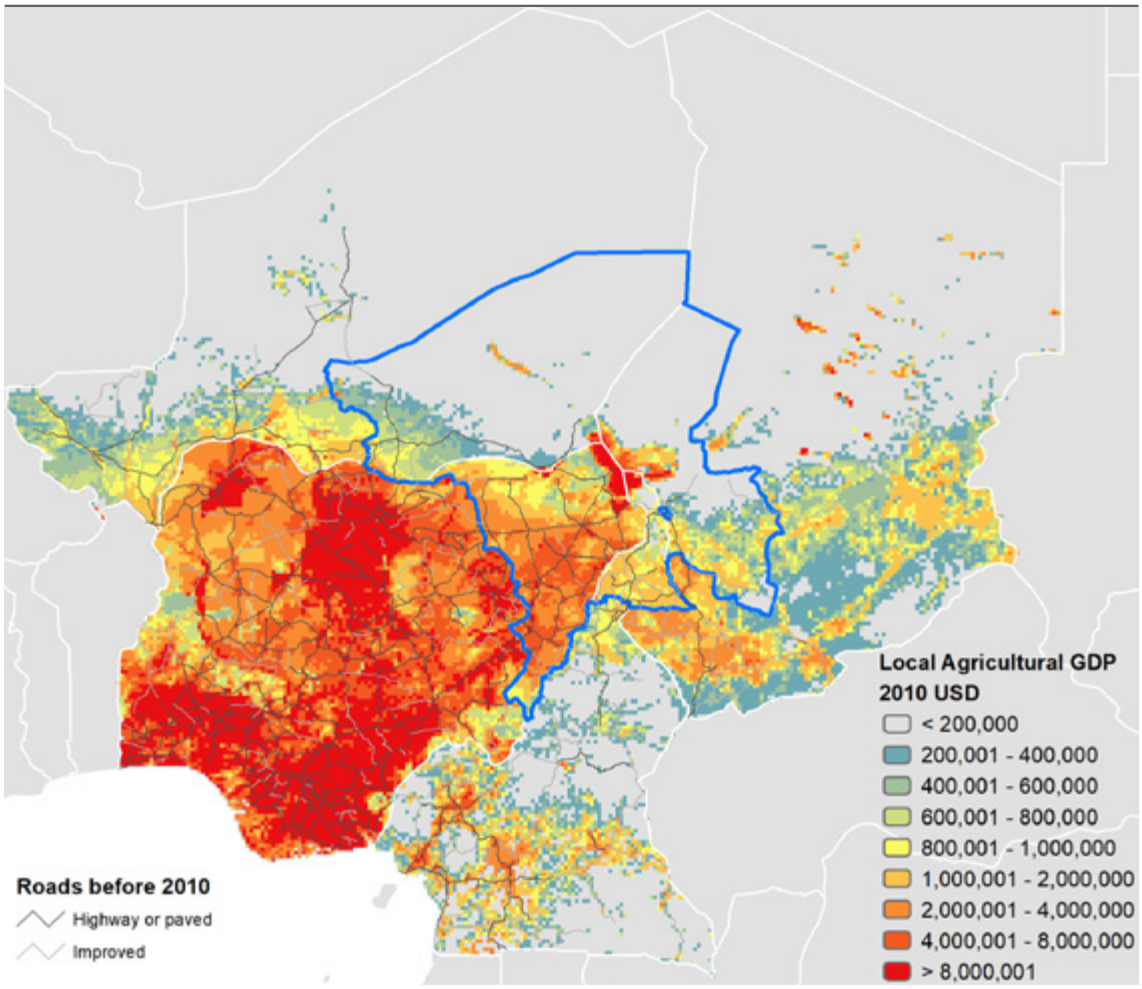
Night time lights can proxy total local economic activity (Henderson et al., 2011) **and human development** (Bruederle and Hodler, 2018). I use two night time lights datasets due to the time-step. For annual trends across the region from 1992–2018, I use the dataset that harmonizes two data sources DMSP-OLS and VIIRS data from Li et al. (2020).[369] The second source is the monthly data from VIIRS available from April 2012 until 2020.[370]

369 DMSP-OLS (1992–2013) is used for temporal calibration with a simulation of VIIRS data (2014–2018). These satellites measure light at night at different times of day.

370 I calculate these values using the Stray Light Corrected Nighttime Day/Night Band Composites Version 1 product.

After visual inspection and inline with previous work by Li et al. (2020), I calculate the sum of the radiance values above 0.3 by pixel.[371] Even with the striking correlation of night time lights and total GDP, these measures require areas to emit light at night to relate to economic activity, which is not prevalent in many rural areas (Thomas et al., 2019). So, it does not account well for a significant contribution to the economy from the agricultural sector. Over the past two decades, Chad, Niger and Nigeria have a higher share of agricultural GDP than the Sub-Saharan Africa regional aggregate.[372] To fill this local data gap, (Blankespoor et al., forthcomingc) employ a data fusion method based on cross-entropy optimization that disaggregates administrative level agricultural GDP into grids depending on satellite-derived indicators of the components that make up agricultural GDP, namely crop, livestock, fishery, hunting and timber production. Map 7.3 illustrates the distribution of agricultural GDP circa 2010. The cropland component takes advantage of the SPAM model to inform the prior allocation of cropland production value and does not directly use infrastructure data (Yu et al., 2020). The level of agricultural GDP in Nigeria is considerably higher compared to Cameroon, Chad and Niger.

Map 7.3: This map illustrates main roads along with the distribution of Agricultural GDP (2010) from (Blankespoor et al., forthcomingc), where darker red represents relatively higher agricultural GDP and light blue or transparent has little estimated value



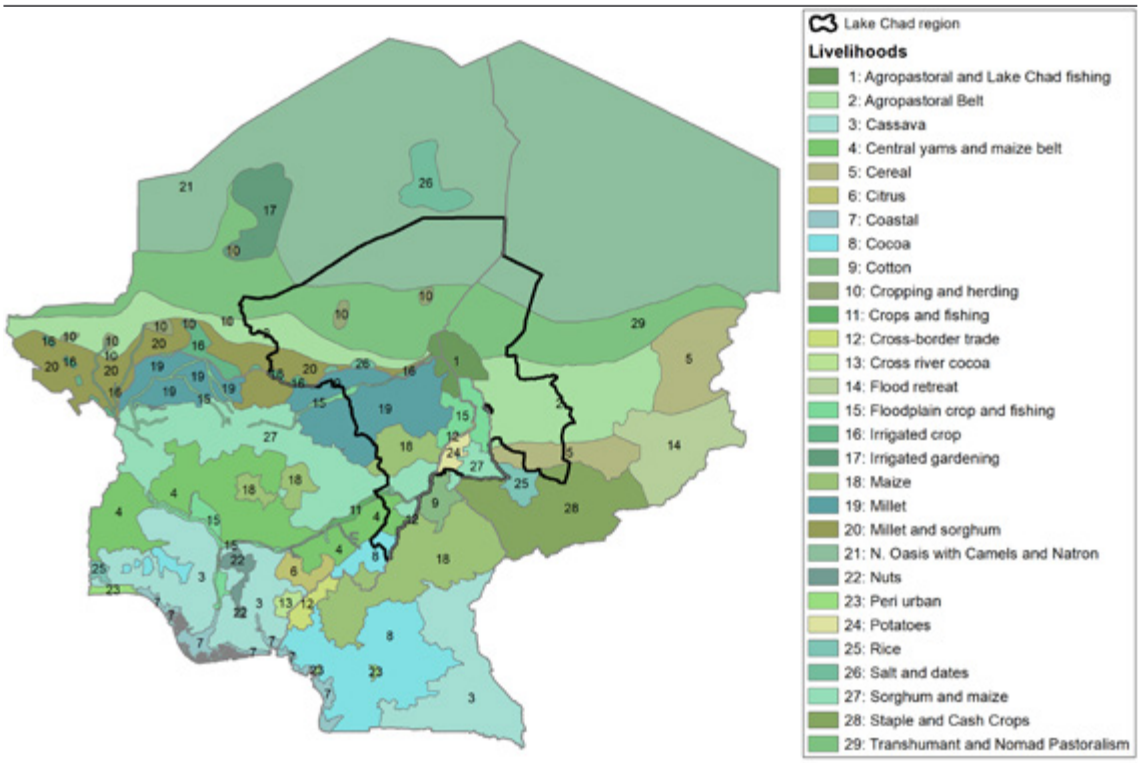
371 Values less than 0.3, which include negative values, are considered background noise such as large areas of the Sahara desert.
372 The World Bank World Development Indicators reports that the share of agricultural added-value GDP is in a range of 15–42 percent.

Livelihood zones for each country are from FEWS. NET. These geographic zones group people with similar patterns considering how people gain access to food and income as well as markets. The map data include the following number of zones: 36 in Nigeria (FEWS NET, 2018), 9 in Chad, (FEWS NET, 2011a), 15 in Niger (FEWS NET, 2011b) and 17 in Cameroon (FEWS NET, 2019a).[373] I aggregate these categories into 29 categories based on the first or dominant crop listed in the description with multiple crops (See Map 7.4).

7.2.5 Conflict data

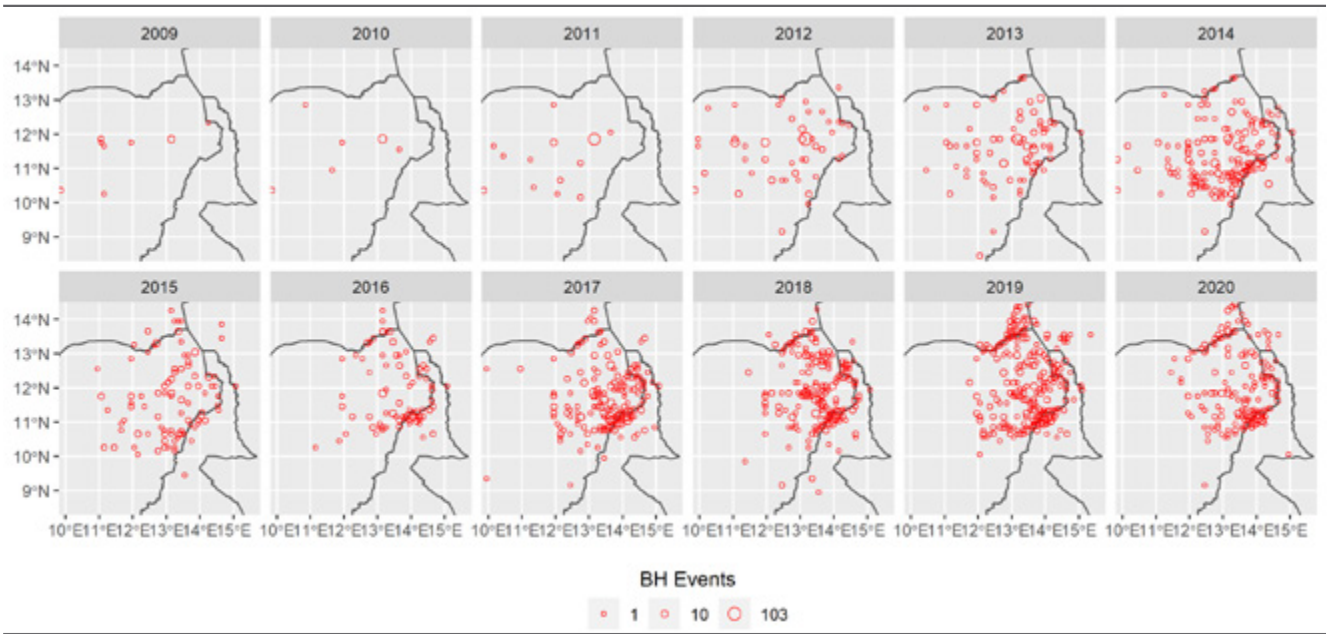
The insurgency by Boko Haram in the Lake Chad area has led to an increase in the number of conflict events and fatalities since 2009 with a notable concentration in the three states of Northeastern Nigeria (See Map 7.5).[374] The ACLED database includes over 4,800 events with more than 35,000 fatalities that are associated with Boko Haram as an actor from 2009 to December 2020. Many conflict events are in close proximity to Maiduguri, which is the state capital of Borno and major commercial center in the Lake Chad region. According to a news source in 2013, approximately 5,000 hectares of agricultural plots with wheat and rice were abandoned near Marte in Borno state, Nigeria. This translated to roughly 200 metric tonnes of wheat according to Abubakar Gabra Iliya, head of the Lake Chad Basin Development Agency.[375] After 2013, conflict events continued to increase in occurrence and spread to include the area across the Nigerian border in the Lake Chad area (See Map 7.5). In Niger, Boko Haram activities target Diffa, Bosso and the small villages along the river Komadougou. In Chad, Boko Haram is present in the islands of Lake Chad as well as attacks in N'Djamena, Guitté, Bo and

Map 7.4: This map illustrates the livelihoods of the four countries, which clusters similar livelihood patterns into a zone



373 The zones for Cameroon were digitized given the lack of response of FEWS NET to provide the georeferenced data and may include small digitizing errors.
374 Violence from Boko Haram increased most notably after the execution of its leader Mohammed Yusuf in July 2009.
375 https://www.pmnewsnigeria.com/2014/03/25/food-supply-crisis-imminent-in-nigeria/

Map 7.5: These maps in the panel show the evolution of the number of events from 2009–2020 defined as Boko Haram



Source: ACLED (Raleigh et al., 2010) (downloaded 2020-05) and author's calculations.

Baga Sola. More recently, Boko Haram has taken refuge in the Sambisa forest, which is South East of Maiduguri, and the swamps of Lake Chad (Magrin et al., 2018). Conflict has taken place, especially in the area in close proximity to Lake Chad. I use the location of conflict events from the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al., 2010). I summarize the number of events and fatalities by cell.

7.3 Empirical Framework

In a framework following Berg et al. (2018), I first explore the links between market access and two measure of agriculture: cropland area and a local measure of agricultural economic activity. I examine the impact of market access on cropland area using a panel framework and a second model exploring the association between cropland area and local agricultural activity (Agricultural GDP). Given numerous conflict events have occurred in the past decade, I also examine agriculture activity amidst conflict in a panel framework examining the association of the proximity of conflict on cropland area across the entire region as well as night time lights for a sample of local markets nearby Lake Chad.

7.3.1 Cropland expansion across the region

The cropland regression in levels is defined as follows:

$$InCrop_{i,t} = \alpha_0 InM\,A_{i,t-9} + X'_{i,t-9}\theta + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (3)$$

where $InCrop_{i,t}$ is natural logarithm of the area of cropland in pixel i for time period t, $InMA_{i,t-9}$ is the lagged natural logarithm of the market access indicator is the result of Equation (1), $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term.

Using the same approach to address concerns of reverse causality I employ a lag in the market access index by one period (9 years) as cultivation may influence the placement of new road investments as well as the changes in local population. To account for the local level of population, I include population density estimated by UNEP-GRID Geneva and The World Bank. The travel time to the nearest major port is a measure of proximity to the international market. To account for heterogeneous effects, I include an interaction of the natural logarithm of the market access index with a measure of agricultural suitability and a measure of shrinking land. The regressions include country fixed effects, time dummies, and the interaction between the two as a control for any remaining unobserved heterogeneity.

7.3.2 Local agricultural activity across the region

I also explore the association between cropland area and a measure of local agricultural activity (local agricultural GDP) at the grid cell level with the following regression estimated in levels. The regression is defined as follows:

$$lnAgGDP_{i,t} = \beta_0 lnCrop_{i,t-9} + \beta_1 lnM\,A_{i,t-9} + X'_{i,t-90} + D'_i\pi + \delta_t + \epsilon_{it} \qquad (4)$$

where $InAgGDP_{i,t}$ is natural logarithm of the local agricultural GDP in pixel i for time period t (2010), $InCrop_{i,t-9}$ is natural logarithm of the area of cropland in the previous period of 9 years, $InMA_{i,t-9}$ is the lagged natural logarithm of the market access indicator is the result of Equation (1), $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term.

The other controls are similar to Equation (3). The travel time to livestock markets accounts for proximity to livestock trading. The regressions include country dummies given the agricultural GDP dataset is only available for one time step. A cautionary note is the local agricultural GDP is the result of a cross-entropy model that leverages spatial detail in the subcomponents of agricultural GDP.[376]

376 See Thomas et al. (2019) for more details and model comparisons.

7.3.3 Agriculture amidst conflict nearby Lake Chad

The previous analyses examine the impact of market access over the past three decades; this framework does not account for the lived reality of access to markets given the insurgency of violence on an annual or seasonal basis. The next section focuses on examining agricultural activity amidst conflict.

7.3.3.1 Cropland expansion amidst conflict

I examine the association of distance to nearest conflict event or fatality on local cropland extent during the period 2009 to 2019 for the entire region.

$$lnCrop_{i,t} = \alpha_0 lnDistConf_{i,t-1} + lnDistConf_{i,t-1} \times Y_i + lnNTL_{i,t-1} + lnNTL_{i,t-1} \times S_{i,t-1} + lnNTL_{i,t-1} \times lnM\,A_{i,2008} + X'_{i,t-1}\theta + X'_{i,t-1}0 + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (5)$$

where $lnCropi,t$, is the natural logarithm of the cropland area in pixel i for time period t in years, $lnDistConf$ is the natural logarithm of the nearest distance to a conflict event or an event with a fatality from pixel i in the previous year $t-1$, $X_{i,t-9}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term. I use a lag in the conflict variables to address reverse casualty. I address the concern about modeling error of local population estimates due to displacement by taking advantage of the annual frequency and high correlation of night time lights with population density. I include lagged night time lights variables to control for size effects. Then, I interact night time lights with shrinking cropland, market access in the previous base year (2008) and natural logarithm of the travel time to nearest livestock market in 2008.

7.3.3.2 Operational status of markets amidst conflict

For a set of markets in the area nearby Lake Chad with reported operational status, I examine the impact of the market operational status on the natural logarithm of night time lights. Then, I introduce a distance to the nearest conflict event from the previous year into the regressions as follows:

$$lnNTL_{i,t} + \alpha_0 Market_{i,t} + \alpha 1 distConflict_{i,t-3} + X'_{i,t-1}\theta + D'_i\pi + \delta_t + \epsilon_{i,t} \qquad (6)$$

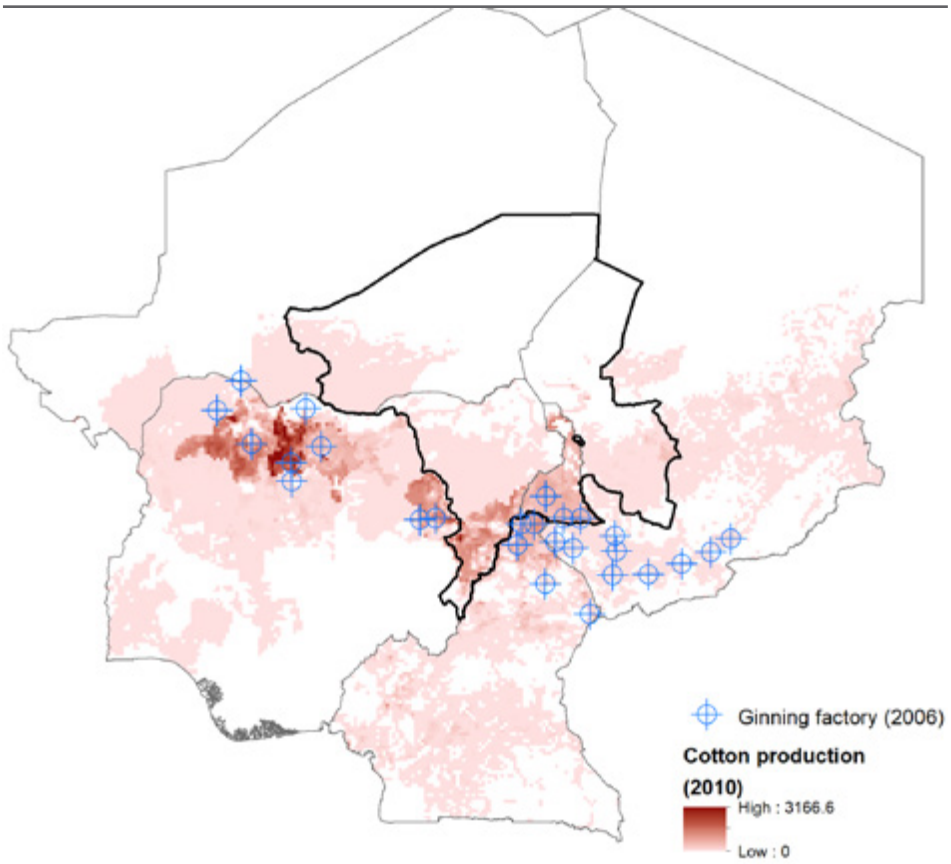
where $InNTL_{i,t}$, is natural logarithm of the sum of night time lights in pixel i for time period t, which is defined as a season of the year (land preparation, sowing and growing, or harvest). $Market$ is the operational status of the local market as normal, below normal or closed. $distConflict$ is the distance to the nearest conflict event in pixel i during the same season of the previous year, $X_{i,t}$ is a vector of control variables at time t, D'_i is a vector of time invariant dummies, and $\epsilon_{i,t}$ is the error term. I include the mean precipitation and its square along with mean greenness during the season as a control, which is used as a proxy for local agricultural productivity.

7.4 Results

7.4.1 Trends in Agriculture

Agriculture is the main sector of economic activity for households and individuals living in the Lake Chad region. For the four countries, Map 7.4 illustrates dominant livelihoods with similar patterns considering how people gain access to food and income as well as markets. The northern areas of Niger and Chad are sparsely populated with activities including salt, dates and trading activities in oases along with nomad pastoralism and transhumance. In southern Niger, where most of the population lives, is an agropastoral belt with millet and sorghum as well as irrigated crops such as Komadougou Irrigated Peppers and Violet de Galmi onions (FEWS NET, 2011b). Northern Nigeria has cultivated areas with diverse crops including millet and sorghum as well as livestock. The area nearby Lake Chad includes flood retreat cultivation and fishing activities. Major cash crops include cotton in the Sahel region where many cotton ginn factories are located (See Map 7.6). Other rainfed cash crops such as bananas and coconuts are located near the ports outside of the Lake Chad area. Maize, cassava, sorghum and millet provide staple crops and are among the highest production in the Lake Chad region.[377]

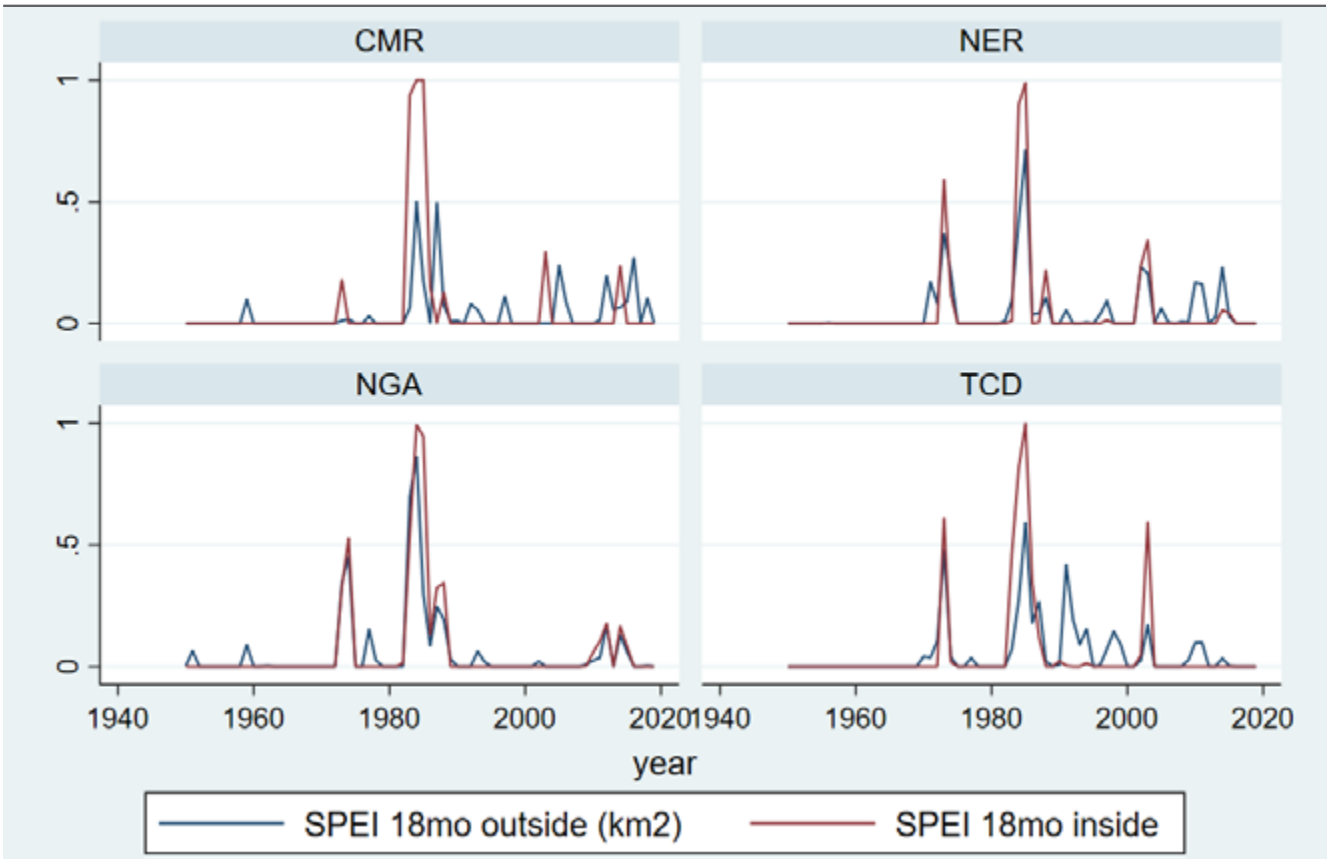
Map 7.6: This map illustrates cotton production from SPAM ca. 2010 (Yu et al., 2020) and ginning factories (OECD, 2006)



377 These results are summarized from the SPAM circa 2017.

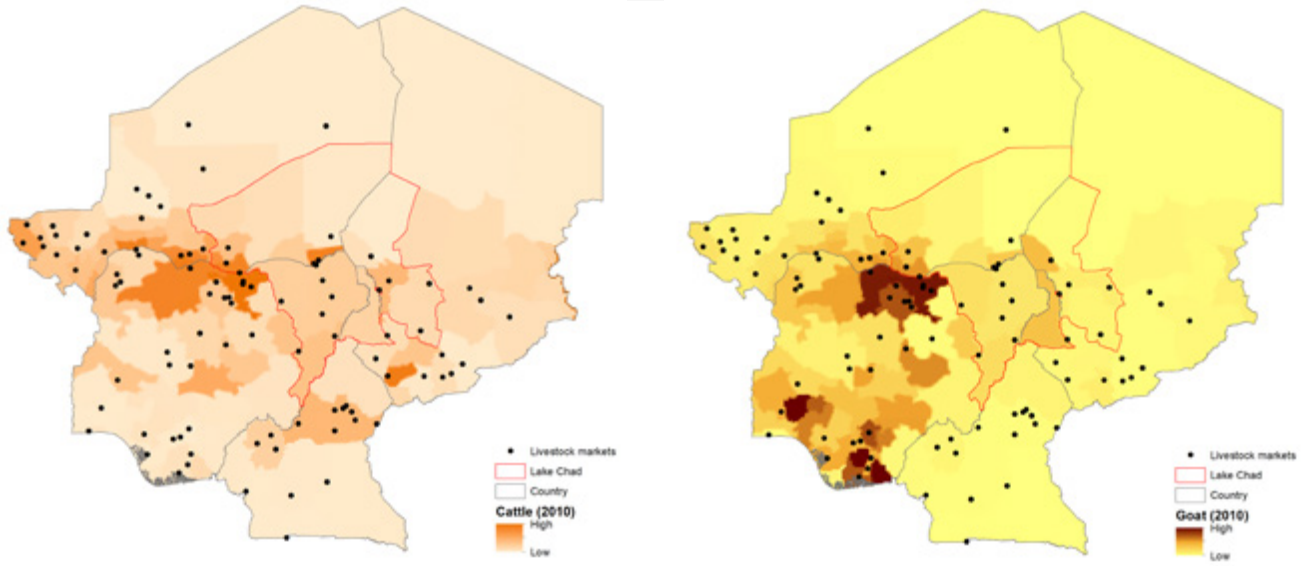
In the region, agricultural production is typically rain-fed and thus dependent on the climate. The levels of rainfall have varied over the past several decades. One can consider three periods of climate since 1960 in the Lake Chad area: a period of high rainfall in the 1960's, low rainfall in 70s to the 90s and the recent period with more variability than the two previous periods. Droughts can impact food availability and timing and a households' ability to consume. Figure 7.1 displays the share of area that exceeds a drought threshold, which is measured by SPEI with 18 month lag, for the Lake Chad study region "inside" and the remaining area in the country "outside". One can see the major drought in the 70s and 80s[378] and the lesser intensity one in the 00s, where the Lake Chad area typically has a higher share of drought compared to the remaining are in the country. However, the period from the 1980s until present has seen some greenness growth as measured from satellite (e.g. Dardel et al., 2014). As shown above, some seasons drought persists, however the opposite case is also true. In 2019, flooding occurred in an area with approximately 220,000 people as the result of heavier-than average rainfall in the fall of 2019. USAID (2020) reported the damage from the floods included infrastructure, crops and restricted access. The area nearby Lake Chad is rural and dependent on hydro-climatic conditions (Nilsson et al., 2016).

Figure 7.1: This graph shows the share of area considered a drought identified from the Standardized Precipitation Evapotranspiration Index (SPEI) at an 18 month time lag (with a value less than or equal to -1.5). This is the result of the algorithm provided by Begueria et al. (2014) using the monthly precipitation and evapotranspiration data version 4 from the Climate Research Unit (Harris et al., 2020)

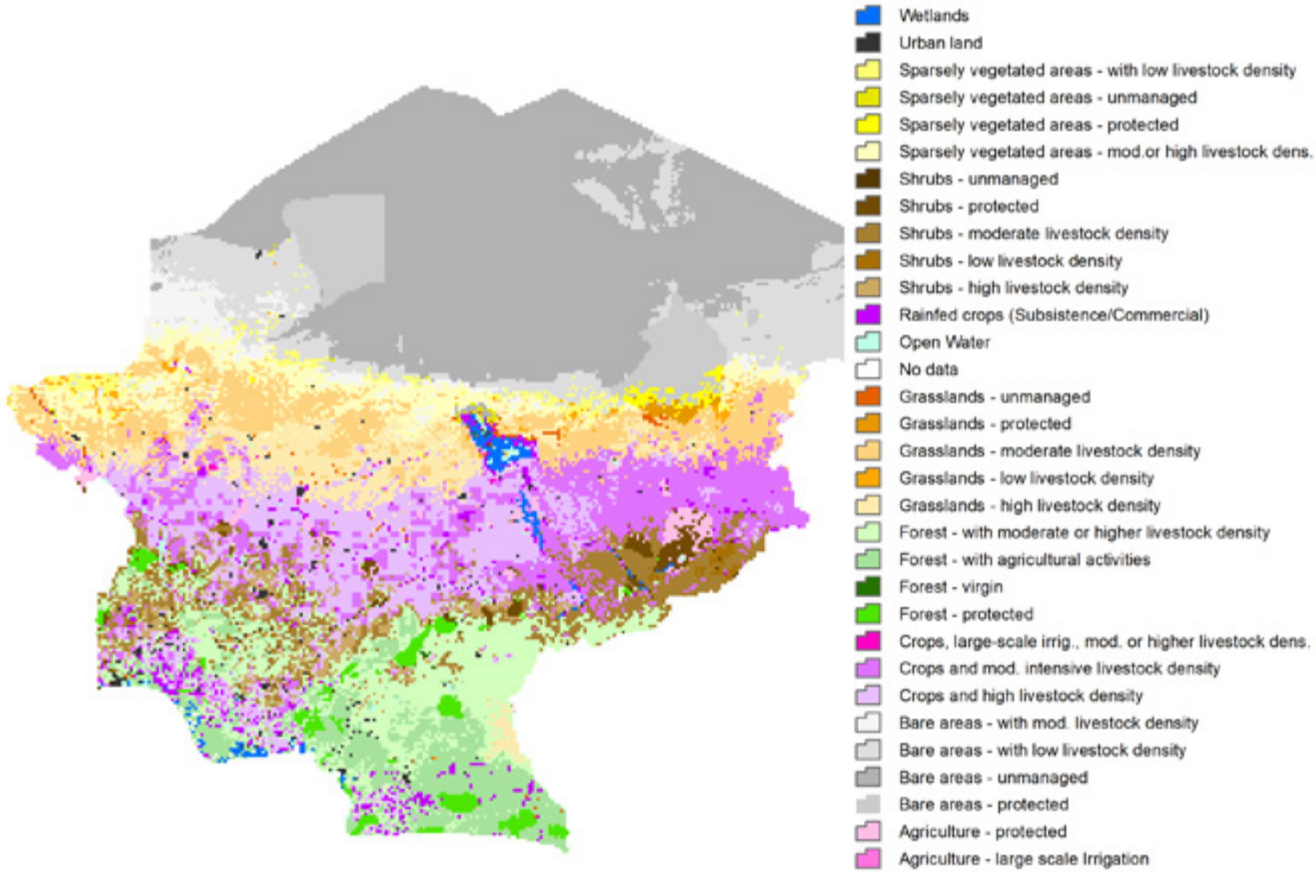


378 Rivers did not flow into the lake in 1973 and 1984 as the result of Sahelian drought (Raji, 1993).

Map 7.7: These maps illustrate the location of livestock markets (black dots) from FEWS NET (2009); Motta et al. (2017) and distribution of cattle from Gilbert et al. (2018) (left) and goat (right) in 2010 from Gilbert et al. (2018) where a darker shade represents higher livestock density



Map 7.8: This map illustrates land use (Nachtergaele et al., 2010) (Version 1.1)



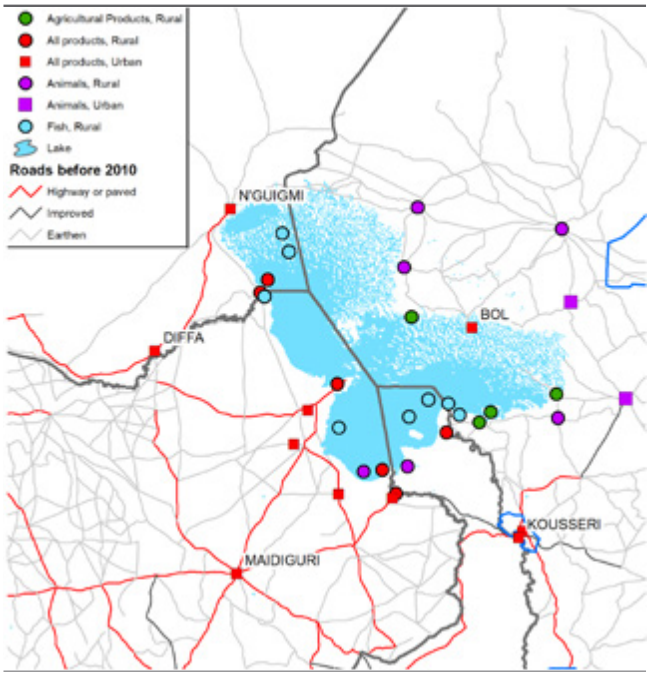
Over the past two decades, arable or cropland areas increased although irrigated lands are limited as measured from satellite imagery. Total cropland area has increased by almost 43,000 km^2 between 1992–2019, where Cameroon and Nigeria have the most relative gain in cropland area compared to Chad and Niger. Irrigated areas represent approximately 5 percent of the cropland area during this period with little growth, which is the likely result of little new investment. The annual growth rate of cropland area for the four countries started at 0.42 percent during the 1992–2001, lessened at 0.31 percent during 2001–2010, and was lower at 0.03 during 2010–2019.The annual growth rate of cropland area for the four countries inside the area nearby Lake Chad started at 0.29 percent during the 1992–2001, lessened at 0.24 percent during 2001–2010, and was slightly negative during 2010–2019.

In addition to cropland, the livestock trade is vital for the region and cross-border trade has long played a role in trade in livestock markets in Africa (de Haan et al., 1999). The distribution of livestock markets and a subnational estimate of cattle is notable in the Lake Chad area (See Map 7.7). Over half of the livestock markets are within 100km of the border and 16 of the 97 livestock markets are located in the Lake Chad area. Nearby Lake Chad, agricultural activities benefit from the connection to markets. Fish routes supply several tonnes of fish everyday to regional hubs of N'Djamena and Maiduguri with an annual estimate of 50,000 to 100,000 tonnes of fish per year (Lemoalle and Abdullahi, eds, 2017). Similarly, livestock trade routes from Chad and Niger pass through Maiduguri onto regional markets and are an important part of the goat and millet trade (WFP, 2016).

Mapping the cropland, livestock, forestry, fishing across the landscape illustrates a mosaic of agricultural activity and management of land (See Map 7.8). The agricultural economy of Nigeria is notably higher than the other three countries. The development of highways in Nigeria coincides with the area with relatively higher agricultural GDP circa 2010; they are the three corridors of Kaduna-Kano (North Central), Lagos-Benin City (South West) and the delta region corridor of Port Harcourt-Enugu (See Map 7.3). The natural logarithm of the distance to nearest paved road in 2008, which is constrained by country, has a negative correlation with natural logarithm of local agricultural GDP of 0.70.

In closer proximity to Lake Chad, road transport connects key local agricultural markets of (i) Bol and N'Djamena in Chad, (ii) Kousseri in Cameroon, (iii) N'guigmi and Diffa in Niger and (iv) Bosso, Niger along with Marte and Monguno via Madiguri in Nigeria. Maiduguri is an important connection for the trade corridors between Nigeria and Cameroon (Kousseri or Maroua) (See Map 7.9). This was especially important in the commercialisation of fishing in Lake Chad linked to the development of road infrastructure (Stauch, A., 1960). For the fishing trade, a number of fish markets exist; the largest fish market was Baga Kawa in Nigeria (prior to Boko Haram), which is a key market town in close proximity of Lake Chad (Magrin et al., 2018).

Map 7.9: This map illustrates local markets in close proximity to Lake Chad by type



Source: Déby Itno et al. (2015).

7.4.2 Market Access

Table 7.1 presents the panel results of market access on cropland area (in levels). The baseline estimation of equation (3) of market access does have a significant positive effect on an increase in cropland across OLS (Columns 1–3) and FE specifications (Columns 4–6) during the period from 1992 to 2019.[379]

The results from new and updated measurements with a focus on the Lake Chad region are in line with previous research by Berg et al. (2018). Given the modest gain in length of paved road, the growth in population, which is a proxy for the size of the market, is the main driver for the increase in market access. A 1 percent increase in market access is associated with a 3.9 per cent increase in cropland area. Given the approximate total of cropland in the four countries is nearly 600,000 km^2, this result implies a growth of around 23,400 km^2 given a 1 percent increase in market access over 9 years. Following Berg et al. (2018), I examine spatial heterogeneity with interactions of market access with yield and a shrinking cropland dummy. The sign of the yield interaction is positive, providing a positive association of the growth in cropland where the land has higher yield of cotton.[380] Also, it is important to note that the area near Lake Chad is landlocked. The results show a connection of cropland area to external markets measured in travel time to the nearest port that are located in Nigeria and Cameroon.

Table 7.1: Estimates of the impact of market access on cropland area

	(1)	(2)	(3)	(4)	(5)	(6)
Ln MA_{t-9}	0.317***	0.0420**	0.0374	0.274***	0.0385*	0.0434*
	(18.96)	(2.72)	(1.80)	(16.50)	(2.39)	(1.99)
Ln MA_{t-9} × Yield			0.0701**			0.0630*
			(2.71)			(2.31)
Shrinking		-0.0920***	-0.0841***		-0.0826***	-0.0706***
		(-14.04)	(-11.65)		(-12.65)	(-9.83)
Ln MA_{t-9} × Shrinking			-0.0322*			-0.0486***
			(-2.43)			(-3.58)
Ln time to $port_{t-9}$		-0.109***	-0.107***		-0.0355***	-0.0332***
		(-14.97)	(-14.75)		(-4.40)	(-4.09)
Ln pop $density_{t-9}$		0.359***	0.359***		0.135***	0.133***
		(97.01)	(97.03)		(36.73)	(36.34)
Mean $Precipitation_t$		-0.114***	-0.111***		-0.187***	-0.182***
		(-6.33)	(-6.16)		(-10.42)	(-10.21)
(Mean $precipitation_t)^2$		-0.0119*	-0.0114*		0.0269***	0.0274***
		(-2.22)	(-2.13)		(5.12)	(5.18)
Country x Year dummies	Y	Y	Y	Y	Y	Y
Observations	133,008	133,008	133,008	133,008	133,008	133,008
R-squared	0.0528	0.532	0.533	0.0528	0.449	0.450

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents estimates of OLS (column 1-3) and FE (column 4-6) regressions of the natural logarithm of the sum of rainfed and irrigated cropland area at time t on the natural logarithm of the lagged market access index during the period between 1992 and 2019. The controls included in the OLS regressions (column 3-4 and 5-6) include a dummy variable indicating a decrease in cropland during the previous period (***shrinking***$_{t-9}$), the lagged natural logarithm of time to nearest major port (***Ln time to major port***$_{t-9}$), the average rainfall over the previous five years / 1000 (***Mean precipitation***$_t$) and its square, and country × year dummies. Constants are not shown.

379 Specifically, the panel includes the following years: 1983, 1992, 2001, 2010 and 2019.

380 The yield of cotton is a constant value circa 2010 from the SPAM model. Regressions (not shown) of market access on cropland provide similar results with a positive and significant interaction with the agricultural suitability.

A 1 percent decrease in this time is associated with a 3.6 percent increase in cropland area.

Next, Table 7.2 presents the results examining the association of cropland expansion on local agricultural GDP from the Equation (4). As mentioned earlier, this result is a descriptive association due to potential endogeneity concerns about the modeling of the local agricultural GDP measure. Cropland does have a significant positive effect on an increase in local agricultural GDP in OLS specifications.[381] Following Berg et al. (2018), I examine the relationship with and without market access. I find a positive and significant coefficient for market access even beyond the effect of cropland expansion controlling for time to port and time to nearest livestock market.

Table 7.2: Estimates of the impact of market access on Agricultural GDP

	(1)	(2)	(3)
Ln crop$_{t-9}$	0.950***	0.342***	0.342***
	(245.43)	(71.44)	(71.50)
Ln MA$_{t-9}$			0.0872***
			(3.92)
Ln time to port$_{t-9}$		-0.312***	-0.302***
		(-21.67)	(-20.46)
Ln time to livestock markets$_{t-9}$		-0.0232***	-0.0242***
		(-3.27)	(-3.41)
Ln population density$_{t-9}$		0.316***	0.315***
		(41.44)	(41.19)
Mean precipitation$_t$		1.234***	1.245***
		(37.78) (37.74)	
(Mean precipitation$_t$)^2		-0.259***	-0.261***
		(-27.54)	(-27.54)
Country x Year dummies	Y	Y	Y
Observations	33,252	33,252	33,252
R-squared	0.602	0.878	0.878

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: This table presents estimates of OLS (column 1–3) regressions of the natural logarithm of Agricultural GDP (ca. 2010) on the natural logarithm of the sum of rainfed and irrigated cropland area (*Ln cropland*$_{t-9}$) and the lagged market access index (*Ln MA*$_{t-9}$). The controls included in the OLS regressions include the lagged natural logarithm of time to nearest major port (*Ln time to major port*$_{t-9}$), the lagged natural logarithm of time to nearest livestock market (*Ln time to livestock*$_{t-9}$), the lagged natural logarithm of time to nearest ginn factory (*Ln time to ginn factory*$_{t-9}$), the average rainfall over the previous 5 years * 1000 (*Mean precipitation*$_t$) and its square, population density (*Ln pop density*$_{t-9}$), and country × year dummies. Constants are not shown.

These two analyses provide suggestive evidence for the positive impact of market access on cropland expansion and local agricultural economic activity in the countries comprised of the Lake Chad region. Given the conceptual framework, these results used a lagged approach with a period of 9 years. Remarkably, the current development status in the region has changed since the onset of Boko Haram in 2009. In the next section, I examine the association of the location of conflict events on cropland and the association of operational status of markets on night time lights.

7.4.3 Market status and conflict nearby Lake Chad

Recent developments with the variation in environmental conditions and conflict pose challenges for agricultural activity. From the suggestive evidence above, market access is associated with an increase in cropland area (extensive margin), however this result does not incorporate short-term shocks or the uncertainty to travel to market, especially related to the proximity of conflict events.[382] The discussion below focuses on the Boko Haram conflict regionally and then geographically on an area in close proximity to Lake Chad with more detailed data (e.g. market data) to contextualize current development with remotely sensed measures.

7.4.3.1 Cropland amidst conflict

As stated above, the Boko Haram insurgency started near Maiduguri in 2009 (see Map 7.5). Numerous reports state the destruction of cropland and infrastructure as

381 The local agricultural GDP data are only available circa 2010.

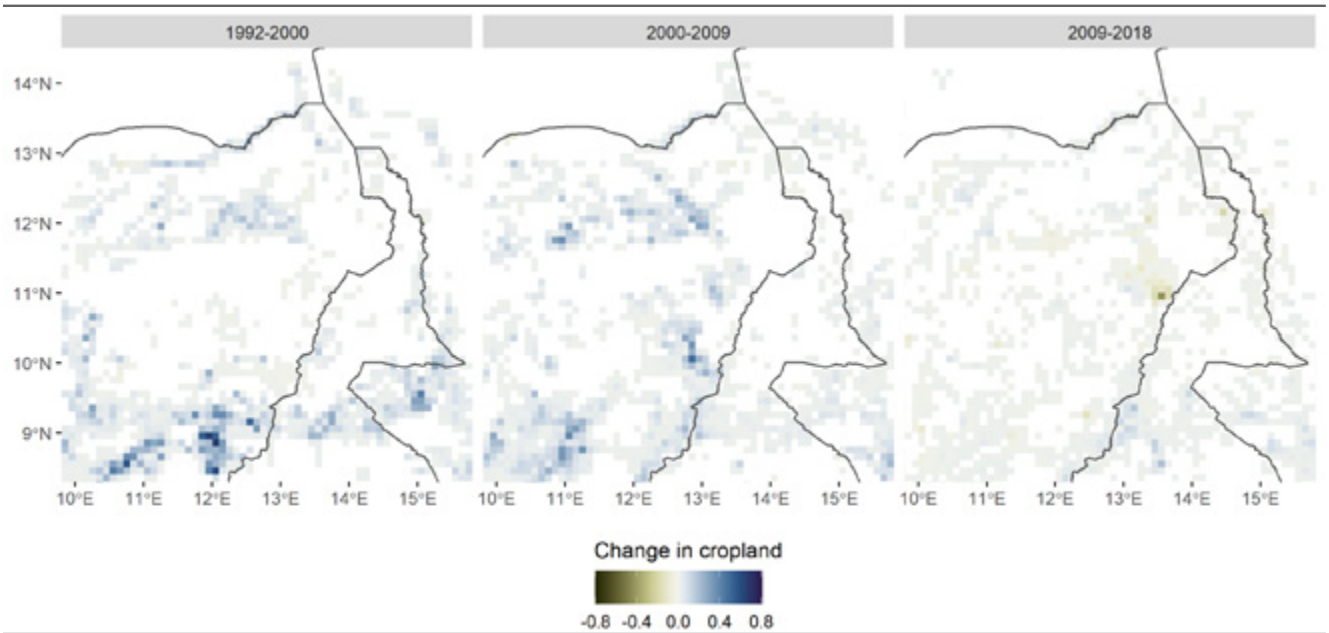
382 The travel time assumes fastest route and does not include any measures of delays or road blocks. For example, Van Der Weide et al. (2018) incorporate road closure obstacles in the travel time analysis to quantify the impact of market access on local GDP in the West Bank.

Table 7.3: Estimates of the impact of the proximity of conflict on cropland area

	(1)	(2)	(3)	(4)
Ln NTL_{t-1}	0.0154***	0.0176***	0.0139***	0.0163***
	(4.50)	(5.12)	(4.04)	(4.73)
Ln dist to $event_{t-1}$		0.00413***		0.00576***
		(9.60)		(13.38)
Ln dist to $event_{t-1}$ × Yield		0.00237***		0.00162***
		(17.26)		(12.04)
Ln NTL_{t-1} × $Shrinking_{t-1}$	-0.0223***	-0.0222***	-0.0225***	-0.0223***
	(-15.70)	(-15.63)	(-15.77)	(-15.71)
Ln NTL_{t-1} × Ln MA_{2008}	0.00711*	0.00721*	0.00686*	0.00688*
	(2.50)	(2.54)	(2.40)	(2.42)
Ln NTL_{t-1} × Ln time to $livestock_{2008}$	-0.00250***	-0.00289***	-0.00223***	-0.00262***
	(-4.06)	(-4.68)	(-3.62)	(-4.25)
Mean $precipitation_t$	0.0126*	0.0182***	-0.0127**	-0.00844
	(2.55)	(3.66)	(-2.65)	(-1.75)
$(Mean\ precipitation_t)^2$	-0.00551***	-0.00724***	0.00113	0.000184
	(-3.54)	(-4.62)	(0.74)	(0.12)
Country x Year dummies	Y	Y	Y	Y
Observations	365772	365772	365772	365772
R-Squared	0.326	0.327	0.180	0.199

t statistics in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Notes: This table presents estimates of OLS (1-2) and FE (3-4) regressions of the natural logarithm of cropland area at time ***t*** (in years) on the natural logarithm of the distance to the nearest conflict event ($Ln\ dist\ to\ event_{t-1}$), night time lights ($Ln\ NTL_{t-1}$), the average rainfall ($Mean\ precipitation_t$) and its square. Constants are not shown.

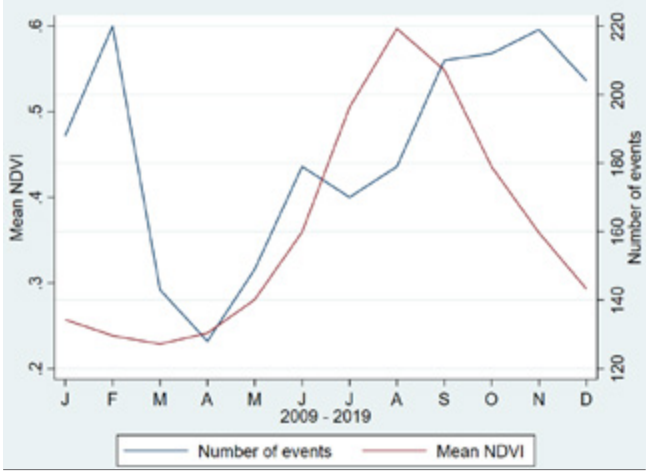
Map 7.10: This panel set of maps shows the evolution of cropland for three distinct periods: 1992–2000 (left map); 2000–2009 (center map); 2009–2018 (right map)



Source: ESA.

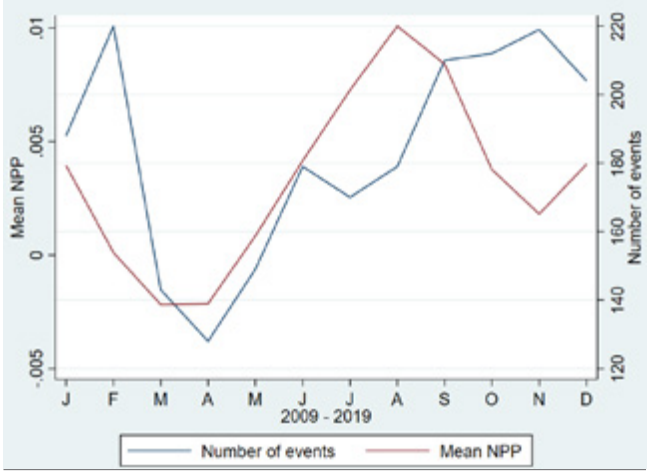
Figure 7.2: Two figures illustrating the seasonality of the number of conflict events with NDVI (a) and NPP (b)

(a) This graph displays the monthly frequency of conflict events from Boko Haram and the mean level of greenness of vegetation, as measured by NDVI.



Sources: Raleigh et al. (2010); NASA (2020b) and author's calculations.

(b) This graph displays the monthly frequency of conflict events from Boko Haram and the mean level of Net Primary Productivity, as measured by NPP.



Sources: Raleigh et al. (2010); NASA (2020c) and author's calculations.

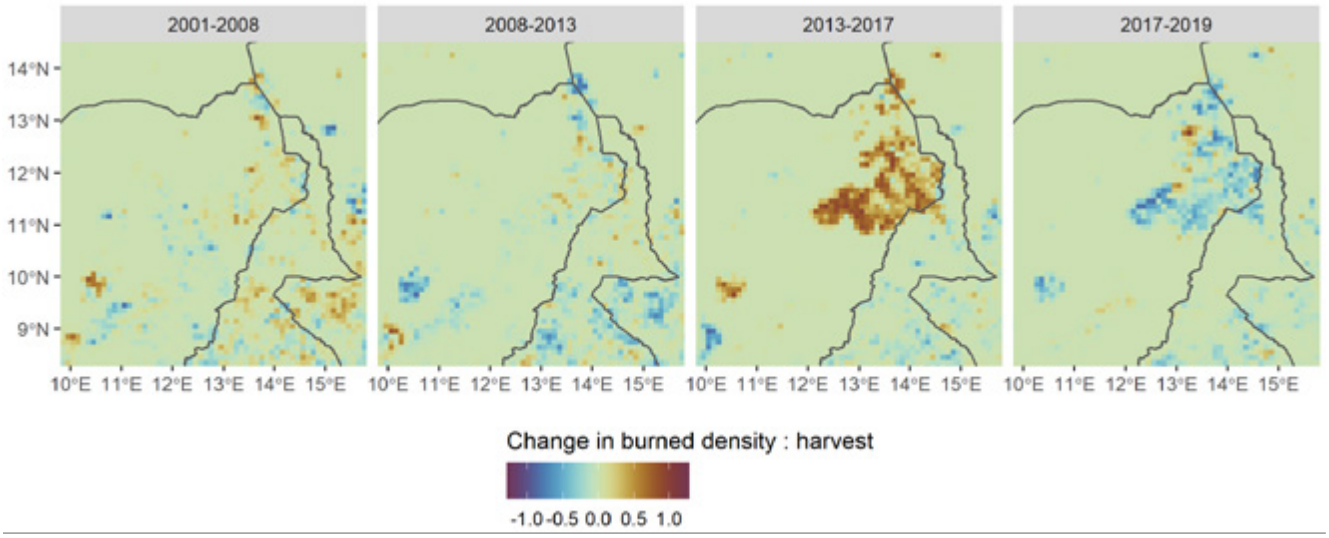
well as the undermining the supply routes of agricultural inputs (e.g. FAO, 2017; Jelilov et al., 2018). I find suggestive empirical evidence of the decrease in cropland as derived from satellite land use classification in areas near conflict events. During the period 2009 to 2018, cropland area in North East Nigeria decreased, even though the previous two periods indicated some growth in cropland area (See Map 7.10). Table 7.3 presents the results of the OLS and FE regression of the impact of the proximity of conflict from Boko Haram on cropland area from 2009 to 2019. The results highlight an association of an increase of cropland area away from the natural logarithm distance to the nearest event or fatality during the previous year.

Given the seasonality of agricultural production, Figure 7.2 shows measures of crop phenology along with the frequency of Boko Haram conflict events. Focusing on the three Northeastern states in Nigeria, these events have two peaks: one during the harvest and another in the land preparation stage.

Recent research finds that the rise of Boko Haram results in more agricultural burning (Jedwab et al., forthcoming), which has been associated with agricultural activity due to the common practice of burning fields for clearing and (short-term) nutrients (Blankespoor et al., forthcomingb). Map 7.11 shows the change in burning activity since 2001 in four time periods. The first period shows the variation in burned areas before Boko Haram, whereas the second panel map illustrates a reduction in burned density. Notably, the third panel shows a concentration of burned area nearby Maiduguri and Dikwa in Nigeria that may be attributable to both clearing of fields and conflict events (e.g. the burning of buildings), whereas Northern Cameroon indicates reduction in activity relative to 2013. The last panel of data (2017–2019) shows an attenuation of these burned areas. So, it is important to note that this measure can capture both agricultural activity and conflict, so it is necessary to examine the description of the conflict events.[383]

383 The ACLED database include a description of conflict events that note burning of buildings or razing village(s).

Map 7.11: This panel map illustrates the distribution of burned density during the harvest season



Source : MODIS.

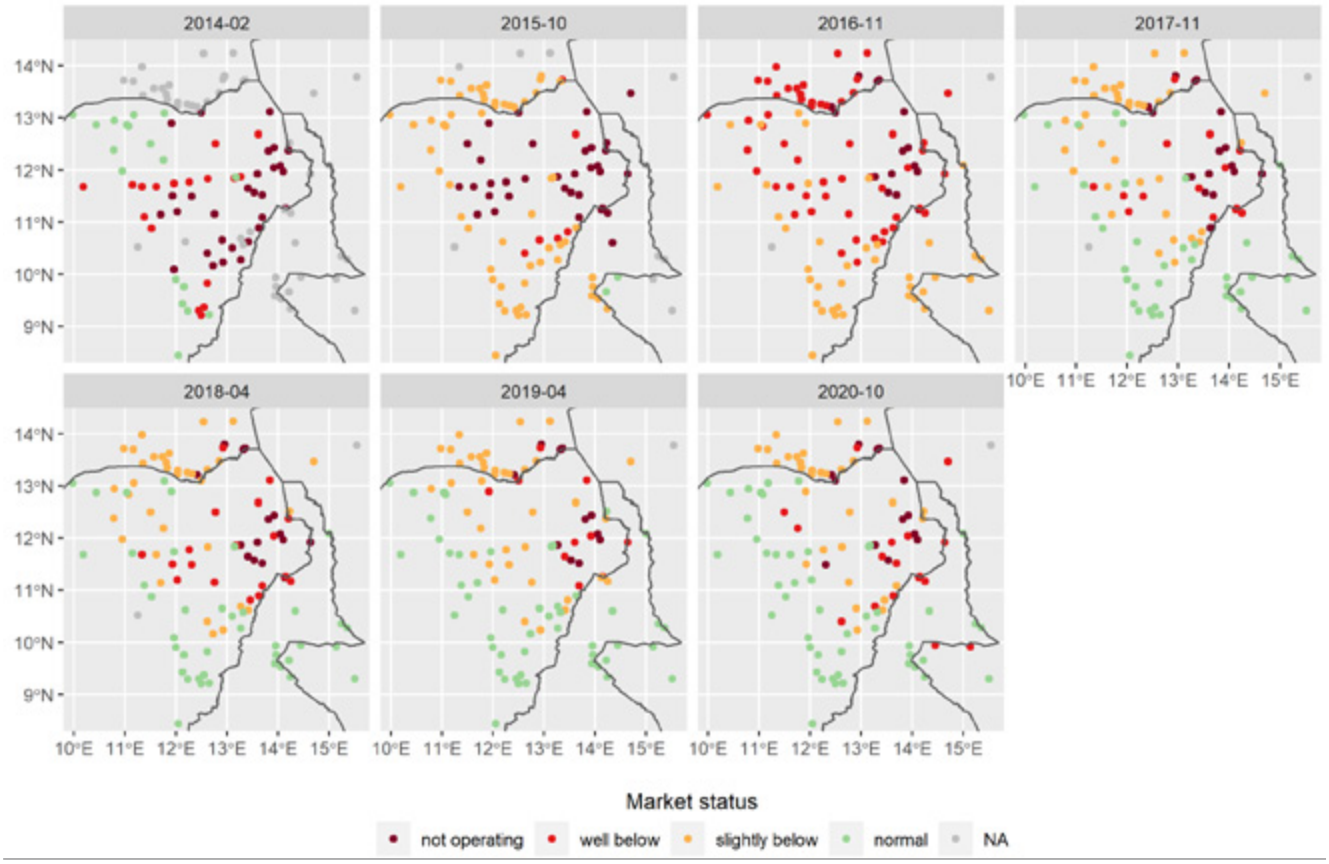
7.4.3.2 Markets amidst conflict

Previous analysis associated the impact of Boko Haram on the operational status of local markets (Van Den Hoek, 2017). The spatial concentration of Boko Haram events was primarily in Northeast Nigeria. Although the monitoring of the markets from FEWS NET started only in 2014, conflict events already took place by Boko Haram at local markets in Nigeria, especially in Borno state (Awodola and Oboshi, 2015).[384] Map 7.12 illustrates the evolution of market status using market data from 2014–2020 based on FEWS NET in Van Den Hoek (2017) with additional digitized time periods from FEWS NET (2019b, 2020).[385] Before 2014, nearly all of the conflict events from Boko Haram took place in Nigeria (Raleigh et al., 2010; Jedwab et al., forthcoming). Many markets were not operating from 2014 to 2016 despite regained territory from some recovery efforts in 2015 from West African troops. Physical damage also took place to market infrastructure, for example, over 650 shops were reported as damaged in Damaturu, Yobe, Nigeria (Mercy Corps et al., 2017). In addition to the indirect and direct impacts of Boko Haram, the Nigerian government made recommendations for some markets to close given the sites are targets for attacks (on civilians) (FEWS NET, 2015). Markets in the Diffa region were officially shut down to impede supply routes to the insurgents and markets in the Far North of Cameroon closed in response to repeated suicide bomber attacks (FAO, 2017). From 2017–2020, several markets on the fringe operated with a slightly below or normal status. Notably, markets in close proximity to Lake Chad were well below or not operating. More recently in 2020, markets in Chad near the border with Cameroon and Nigeria were not operating. Food and Agriculture Organization of the United Nations (FAO) reports that the conflict situation continue to pose challenges for household to access land and agricultural inputs.

Table 7.4 presents the panel results of operational status on the natural logarithm of the mean of monthly night time lights during the season of the year. The baseline estimation of equation (6) of the operational market status compared to the reference closed market does have a significant positive effect on an increase in night time lights for both normal and below normal

384 ACLED database has 23 events with "market" in the notes between 2012 and 2013.
385 The first available year is 2014 along with updates at irregular intervals.

Map 7.12: This panel set of maps shows the evolution of market status in and near Northeast Nigeria with a selection for each year from 2014 to present with the month that the report was published



Source : Van Den Hoek (2017); FEWS NET (2019b, 2020) and author's calculations.

Table 7.4: Estimates of the operational status of local markets on night time lights

	(1)	(2)	(3)	(4)
Market : below$_t$	0.0122**	0.00699	0.0117**	0.00670
	(0.00484)	(0.00487)	(0.00483)	(0.00472)
Market : normal$_t$	0.0182**	0.0155**	0.0171**	0.0147*
	(0.00799)	(0.00727)	(0.00825)	(0.00757)
Ln dist. to conflict event$_{t-3}$		0.00784*		0.00781*
		(0.00418)		(0.00451)
Mean NDVI$_t$	0.170***	0.195***	0.176***	0.202***
	(0.0308)	(0.0331)	(0.0318)	(0.0332)
Precipitation$_t$	-0.531***	-0.677***	-0.532***	-0.676***
	(0.0870)	(0.107)	(0.0911)	(0.111)
(Mean precipitation$_t$)^2	0.662	1.224*	0.619	1.149
	(0.643)	(0.673)	(0.674)	(0.713)
Country x Year dummies	Y	Y	Y	Y
Observations	1,840	1,533	1,840	1,533
R-Squared	0.189	0.180	0.189	0.181

Standard errors in parentheses; * p<0.10, ** p<0.05, *** p<0.010

Notes: This table presents estimates of OLS regressions (column 1-2) and FE (column 3-4) regressions of the natural logarithm of night time lights at time t (a season in a year) on the operational status of the local market *Market: Normal* and *Market : below* with the reference group defined as closed during the period between 2015 and 2020. The controls included in the regression include: greenness as measured by the mean Normalized Difference Vegetation Index *Mean ndvi*, precipitation *Mean precipitation* and its square *Mean precipitation*^{2} and country × year dummies. Constants are not shown.

market status across the OLS (Columns 1–2) and FE specifications (Columns 3–4). The normal market status has a higher coefficient than below normal market status, which is inline with expectations.

These results show that a normal operation status is associated with a 1.8 percent higher night time lights compared to the reference closed status. The natural logarithm to the nearest conflict event in the same season of the previous year is positive, whereby market locations farther from the conflict have on average higher night time lights. I find similar results for a one year lagged market status (results not shown). A report by Mercy Corps et al. (2017) stated that destroyed market outlets can typically take 9 to 12 months to reopen. Furthermore, findings from the report include 80 percent of interviewed farmers responded that their preferred or most frequented market closed during the insurgency where women and IDP and returnee farmers experienced a slightly higher incidence of market closures compared to the overall average. At the time of writing, the number of conflict events nearby Lake Chad continues at high levels and limits economic opportunities of displaced and conflict-affected households to earn income and now typically include firewood sales, petty trade, and construction labor (FEWS NET, 2021).

7.5 Conclusion

Agriculture is important for the economies of the countries in the Lake Chad region. Farming, herding and fishing provide essential economic activity for many households. Using over three decades of remotely sensed and geospatial panel data to gain insight on agricultural activities, these results provide evidence that an increase in market access is associated with an increase in cultivated land and local agricultural economic activity. Given the modest increase in length of paved road during this period, I find the increase in market access is mainly driven by the growth in population rather than an improvement in roads, which is suggestive that growth in cultivated land is responsive to local demand similar to the findings in Berg et al. (2018). The findings of heterogeneous effects that an increase in market access in areas of shrinking cropland will further reduce cropland area is inline with Berg et al. (2018). Similarly, I find a positive association of market access with agricultural GDP using newly available local estimates.

Although more land is under cultivation, the satellite derived measures of rainfed and irrigated cropland show little gains in irrigated land since 1992. It remains an important question to investigate for further examination whether or not gains in yield have corresponded commensurately with the increase in cultivated land.

Even so, conflict can attenuate gains with negative impacts whereby the proximity of conflict events in the previous year lessens cropland expansion over the entire region and lessens night time lights in local markets. I find that the normal and below normal operational status of markets is associated with higher night time lights compared to closed markets.

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