Estimating the effect of conflict on agricultural activity in the Central African Republic with remotely sensed data

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Ongoing armed conflict poses major challenges to the economic recovery and development of the Central African Republic. Although the conflict occurs in agricultural areas, little evidence exists on the magnitude of the effect of conflict on agricultural activity and the channels. We construct a geo-referenced monthly panel (2000-2018) during which numerous conflict events occurred. Exploiting the prevalent practice of burning fields as a measure of active land under preparation for cultivation, we find that the presence of a conflict event 12 months prior lowers fire presence during land preparation by 9% and lowers biomass by 8% during the sowing/growing season - particularly in areas where maize, millet and cassava are highly suitable. While the nature of this effect differs across crops that are driven largely by differences in production processes particularly during land preparation, these decreases are suggestive of the abandoning of farm lands due to conflict.

JEL code: Q10, Q34

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1. Introduction

Ongoing armed conflict poses major challenges to the economic recovery and development of the Central African Republic (CAR), where poverty incidence is among the highest in Africa. The link between conflict and agricultural activity is particularly important, since agricultural activity comprised 30-40 percent of GDP between 2008 and 2018 (see World Bank 2020). Agriculture is a major source of livelihood for households in CAR. About 80 percent of the population (i.e 4 million people out of a total of 4.9 million people) depend on agricultural activities (crop production, livestock rearing, fishing) as a major livelihood source. It is also an important source of foreign exchange accounting for 42 percent of exports. About 2 million hectares (3.2 percent of the total land area) is arable and under permanent crops, while 3 million hectares (4.8 percent of the total land area) is under permanent pasture. Key food crops include cassava, groundnuts, sorghum, millet, maize, sesame, plantains and the major export crops are cotton*,* coffee*,* and tobacco (FAOSTAT 2015).

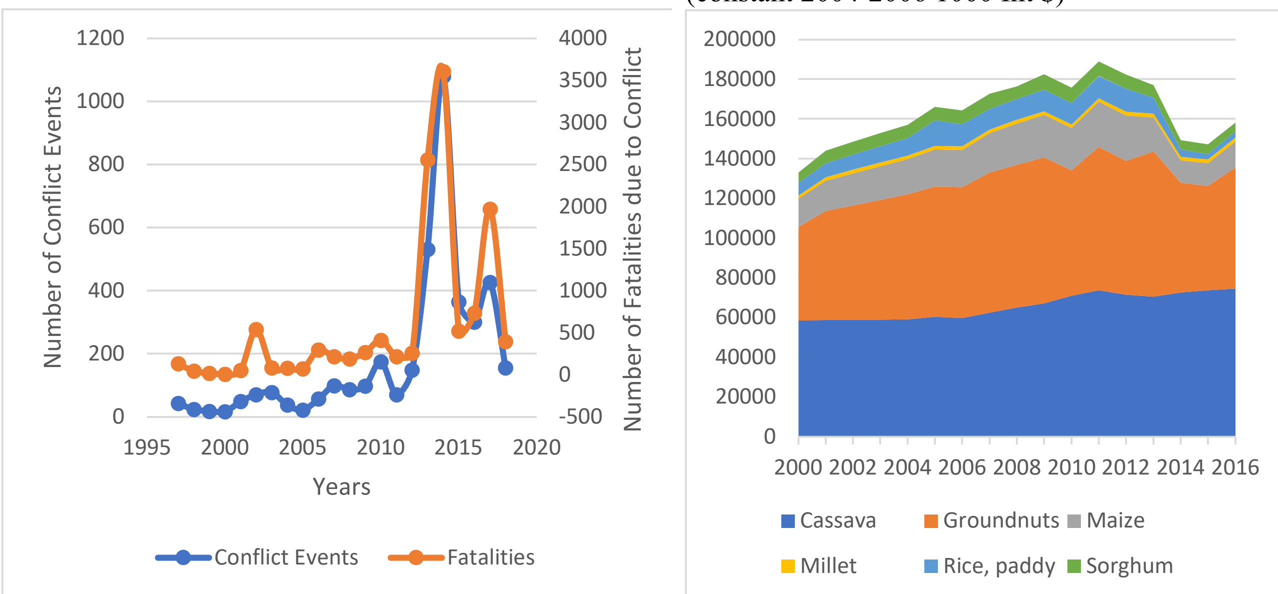
Despite the prevalence of agricultural activities, civil conflict continues to significantly affect agricultural production in the CAR. Displacements of households within the country and into neighboring countries has led the abandoning of fields. In 2015, 81 percent of farmers reported constraints to accessing their fields due to the ongoing conflict. Recent data shows a decline in access to farms from 81 to 71 percent in 2018 indicating that these constraints continue to significantly affect agricultural production.

Figure 1 below shows the number of conflict events (panel a) and the gross production value of major crops in the CAR over the years (panel b). The number of conflict events significantly increased during the 2013 and 2014 due to the civil conflict. During this period, the sum of the gross production value of key crops (except cassava) rapidly declined. This is perhaps because of the common practice of growing cassava near homes (often in backyards) rather than on farm plots which are often more distant and possibly inaccessible during conflict. This relationship between conflict and agricultural activity is also observed when other measures of agriculture such as harvest area is used. It can be observed that the harvested area of most crops decreased significantly after 2010 (see Annex Figure 10). For instance, between 2009 and 2010, area harvested decrease by 40 percent, 48 percent, 15 percent and 36 percent for groundnut, maize, millet and rice respectively. Given the level of civil insecurity in the country during this period, the decrease in area harvested was likely driven by the access constraints and/or the abandoning of fields. As levels of conflict decrease in the years which followed, crop production started to increase. A look at conflict events also shows a decrease in the number of conflict events in 2018 from a spike in 2017. As a result, crop production was estimated at over 1 million tonnes in 2018- 3 percent less than 2017 levels, but 18 percent above the previous five-year average. This increase in crop production is largely attributed to a 27 percent and 21 percent increase in maize and cassava production respectively. (FAO 2019).

Figure 1: Conflict events and Agricultural Output in the CAR

Panel a): Number of conflict Events and Fatality

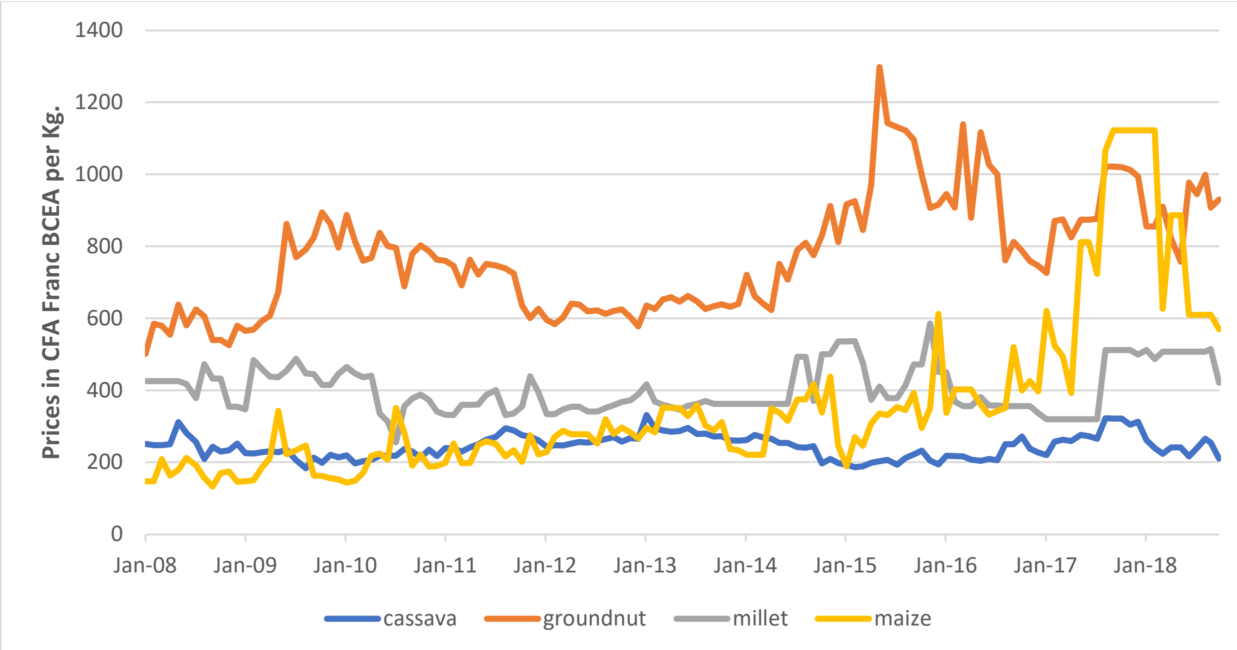
Panel b): Gross production value of key crops (constant 2004-2006 1000 Int $)



Source: Authors' calculation using data from ACLED and FAOSTAT (2020).

Another effect of conflict on agricultural activity is its effect on the functioning of institutions such as markets. The prevalence of civil insecurity creates disincentives for farmers to produce and sell agricultural products that resulted in shortages triggering a hike in prices. **Error! Reference source not found.**Figure 2 (see below) presents monthly prices of major crops in markets in Bangui. During the lean period of 2014 (between March to June), prices of major crops became volatile as the prices of groundnut, millet and maize began to increase. Low production and hence supply from the 2014 farming season due to ongoing conflict resulted in increased volatility in prices and a build up to a further increase in prices in early 2015. For instance, in March 2014, the price of maize was CFA Franc 220.51 per kg. By November 2014, it had nearly doubled in price at CFA Franc 437.73 per kg despite being post-harvest. Similarly, millet prices increased from CFA Franc 337.76 per kg in May 2014 to CFA Franc 499.69 per kg in November 2014 (FAOSTAT 2019).

Figure 2: Monthly Prices of major crops in Bangui- Jan 2008- Oct. 2018

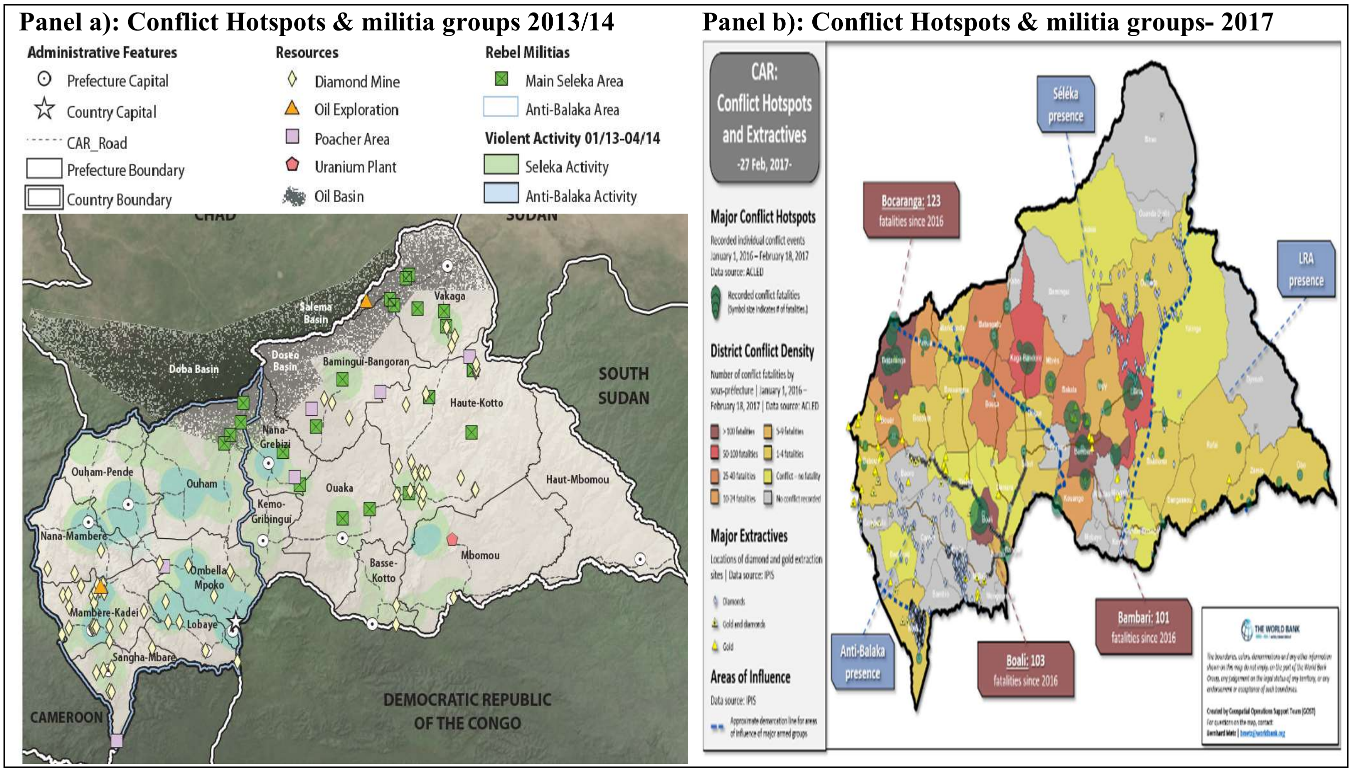


Source: FAOSTAT (2019)

Conflict data in the CAR also show a large concentration of conflict events in and around areas with natural resources.

Figure 3 (panel a) below shows that the West and South-Western parts of the country (in Mambere-Kadei, Ombella M'Poko, etc), which has an oil exploration site and several diamond mines, was a conflict hotpot in 2013 to 2014. Similarly, the recent shift in conflict towards the East is mostly occurring in Haute-Kotto, which also has several diamond mines and poacher areas. A decrease in conflict in these hotspots is generally associated with decrease in the overall number of conflict events in the country-as observed in 2015 following the increase in 2014; and 2018 following the peak in 2017. Another feature of conflict in the CAR is the spread of different militia groups across the country as shown in Figure 4 (panel b). The Lord Resistance Army (LRA) is mostly present in the South and South-East; the Séléka group is in the North; and the Anti-Balaka is in the East and South-East.

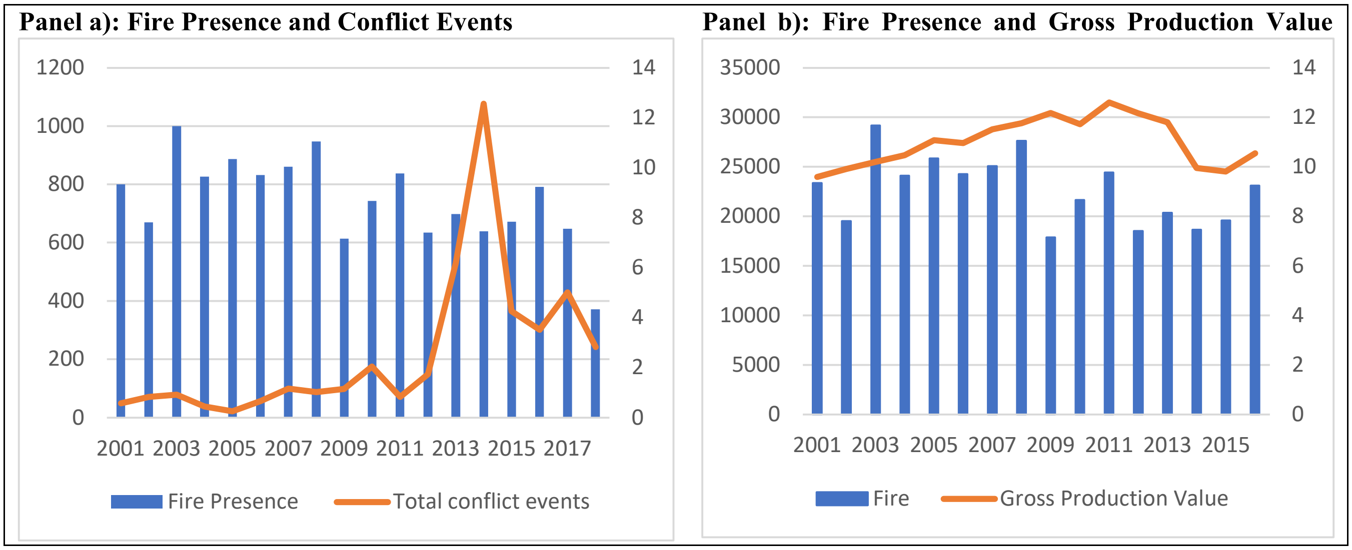
Figure 3: Conflict Hotspots and militia groups in the CAR



Source: panel (a) Central African Institute of Statistics, Economic and Social Studies (ICASEES) (2017) panel (b) Metz 2017.

Understanding the nature and size of the effect of conflict across space and sectors is particularly important. In a country such as the CAR, insights from these analyses will be useful for the post-conflict rebuilding process. However, empirical evidence of the effect of the civic conflict on agricultural activity in the CAR is limited. This is largely because of significant limitations in data to fill this gap and inform ongoing reforms. The objective of this paper is to estimate the effect of conflict on agricultural activity. Given the limitations in the availability of data in the CAR, we rely on remotely sensed data with geo-referenced grids/cells as cross-sectional units. We combine geo-referenced monthly data on conflict events including actors and fatalities along with measures of agricultural activity and additional controls such as rainfall, crop suitability, etc. for 520,425 cells of 0.1 x 0.1 degrees for the period February 2000 to June 2018. These grids allow us to better capture spatial and temporal variation in the data which would otherwise be overshadowed by aggregation at standard administrative units. Using this data, we examine the extent to which the presence of conflict affects agricultural activity. Typical measures of agricultural activity in settings where data is scare rely on measures of greenness, biomass, etc as a proxy for the extent of agricultural activity. We explore an additional approach which relies on the share of burned-area. In communities where land preparation for agricultural activity is done by burning remnants of crop vegetation from a previous farming period, the share of burned area can serve as a proxy for agricultural activity. In Figure 4 below, it can be observed that years of high conflict events such as 2013, are followed by a significant reduction in fire presence (see panel a). Similarly, reduced fire presence appears to be correlated with a reduced production value of major crops in the CAR. We rely on this relationship between conflict, fire presence and agricultural activity, to examine the extent to which conflict affects the intensity of agriculture and identify channels through which this effect may occur.

Figure 4: Fire Presence, Conflict and Agricultural Production in the CAR



Source: panel (a) Authors' calculation using ACLED and remotely sensed data panel (b) Authors' calculation using FAO and remotely sensed data.

Our main contribution is to quantify the effect of conflict on agriculture as well as identify the channels through which this effect occurs in the Central African Republic with spatially consistent measurements. We also make a contribution to the growing literature on using remotely sensed data- particularly in fragile states where limitations in access to data are all too common. We find that the presence of a conflict event 12 months prior lowers fire presence during land preparation and lowers biomass during the sowing/growing season - particularly in areas where maize, millet and cassava are highly suitable. The results from this paper will also provide useful insights to inform the ongoing rebuilding reforms. This paper is organized as follows: literature review, data section, methodology, results with discussion and the conclusion.

2. Literature Review

Several studies have examined the link between armed conflict and land use change (eg. Sato 2000, Baumann and Kuemmerle 2016). In particular, poor human and initial conditions for agricultural livelihoods may hold grave implications with regards to conflict, which can lead to abandonment of farms (e.g. De Soysa et al. 1999, Gorsevski et al. 2012). The FAO reports that the presence of armed conflict may lower agricultural production through destruction of agricultural infrastructure, reduced access to extension services and other inputs, lower access to markets, among others (FAO 2002 and FAO 2018). Likewise, a Brookings Institution report summarizes the impacts of conflict on agricultural value chains as follows: reduction in human mobility, reduction in market access and access to inputs, increase in the theft of cash, products and equipment, and an increase in prices of transportation, inputs and products (Kimenyi et al. 2014). Conflict can also influence the agricultural markets by armed actors engaging in predatory practices including: the coffee production and trade in CAR (Mangan et al. 2020) and bush meat trade (ICG 2014). Another strand of the literature considers the effect of uncertainty due to conflict on agricultural activity through the lens of production decisions such as land use (choice of crops and size of planted areas or abandoning the farm) and investments; as well as through the efficiency of agricultural production (see Rezek and Lukongo (undated), Arias et al. (2013), Eklund et al. (2017) among others).

Another set of studies have focused on examining the extent to which agricultural activities affect conflict. This strand of the literature is premised on the argument that poor agricultural production or harvest losses (particularly food production) is likely to result in armed conflict (or increase its severity where it is on-going) through higher prices and/or scarcity, for example see Wischnath and Bahaug (2014) and Raleigh et al (2015) for recent studies. By linking agricultural activities and conflict through production, the results from these studies have provided interesting insights into the extent to which climate change affects armed conflict. Warming due to climate change is likely to increase the likelihood of armed conflict (Burke et al. 2009).

Typically, these studies rely on agricultural production and activity data from administrative level data (e.g. Kimenyi et al. 2014; Wischnath and Bahaug 2014) or household surveys (e.g. Arias et al. 2013). However, in fragile and conflict environment, access to quality data is often limited. Studies of conflict increasingly use remotely sensed data to detect changes in landcover and land use (see review in Witmer 2015). For example, an analysis of the Islamic State uses satellite imagery from MODerate resolution Imaging Spectroradiometer (MODIS) data product to identify agriculture and they use normalized difference vegetation index (NDVI) as a greenness measure Eklund et al. (2017). Economic analysis also has increasingly used remotely sensed data (Donaldson and Storeygard 2016). For example, studies of economic development use a satellite-based proxy of Net Primary Productivity (e.g. Berg et al. 2018; Russ et al. 2020).

3. Data

The use of satellite data sources enables us to obtain consistently measured variables at geo-referenced grids (i.e areas of a certain dimension for which we obtain the number of conflict events, as well as values for other variables within administrative units in the CAR). This approach enables us to capture variation in the data, which would otherwise be overshadowed by the aggregation at standard administrative units as well as consider the uncertainty in the spatial precision of the conflict data (ie smoothing from the provided coordinates). We summarize the data at the grid cell level of 10 arc minutes x 10 arc minutes (approximately 20km). As a robustness check, we also produce the same data at the grid cell level of 0.5 x 0.5 degrees (approximately 50km), which is similar to other studies (Berman, N. and Couttenier 2015 or Berman et al. 2017).

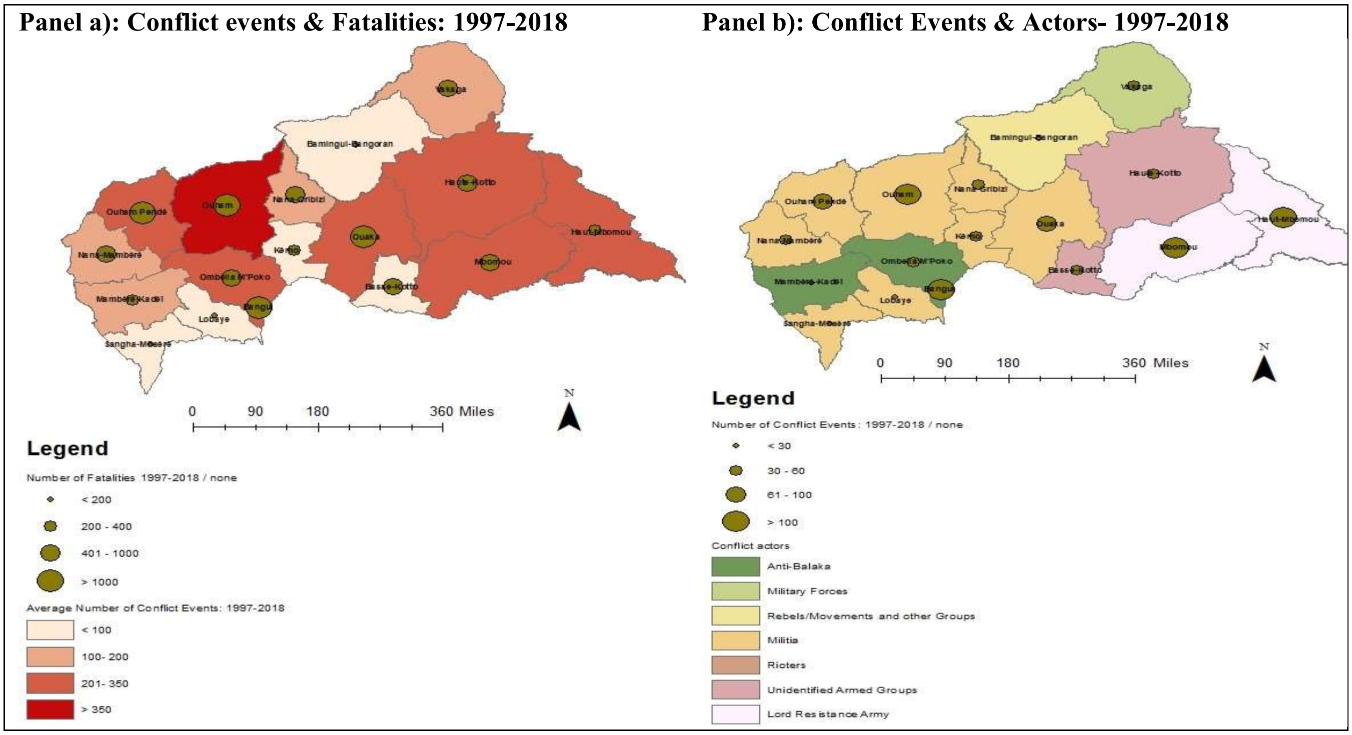
3.1. Conflict Events in the CAR- ACLED Data

The event and fatalities due to conflicts data are obtained from the Armed Conflict Location and Event Dataset (ACLED) (Raleigh et al. 2010). We extract the data for CAR for the period 1997-2018.

Figure 5 below shows the spatial distribution of conflict events, fatalities and actors in the CAR overtime. In the first panel (a), we map out the average number of conflict events and fatalities in each prefecture between 1997 and 2018. Most conflict appears to be concentrated in the North-West (in Ouham Pende and Ouham) and in the Capital City Bangui. In these areas, livestock breeding is the major household livelihood. The conflict in these areas are also quite fatal as indicated by the number of causalities. In parts of the South-East (in Mbomou and Haut- Mbomou), high incidence of conflict is also reported although comparatively less fatal. Low incidence of conflict is observed in the Western, South-Western and up Northern parts of CAR. However, despite low number of conflicts in prefectures such as Vakaga, high number of fatalities is observed. In these areas, forestry, hunting and tourism are the major sources of livelihood. The second panel (b) shows the most frequent conflict actors in each prefecture between

1997-2018. The map shows that overall, most of the conflict in the South-East are due to the Lord's Resistance Army (LRA). Towards the West, North-West and South-West, most conflicts involve militias and Rebel Groups- except in and around Bangui where the Anti-Balaka Group are responsible for most of the conflict.

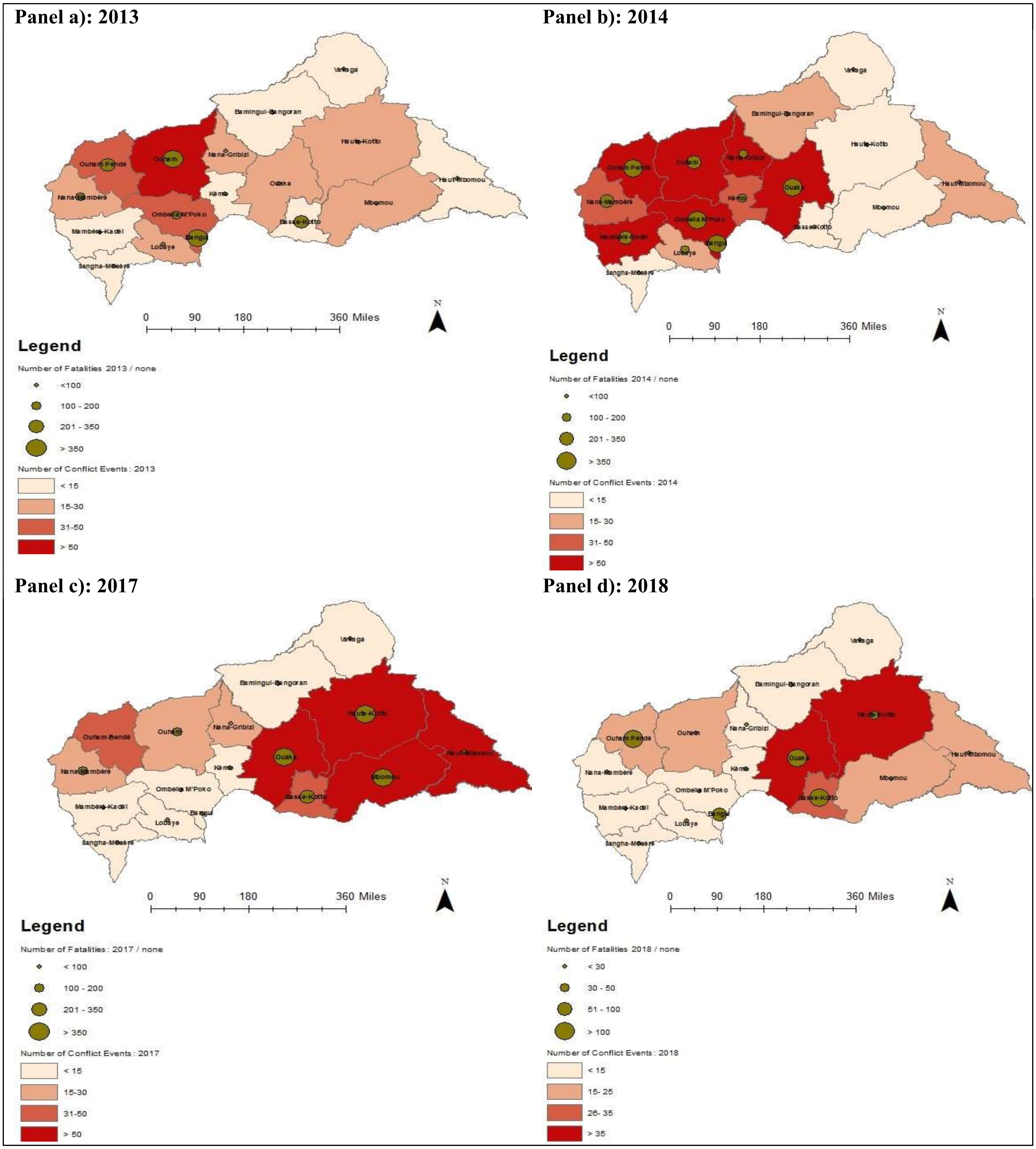
Figure 5: Conflict events, fatalities and Actors in CAR overtime



Source: Authors' calculation using ACLED Data.

In the panel figure below, we describe the spatial distribution of conflict in 2013-2014 when the highest number of conflict events were recorded as well as recent trends in 2017 and 2018 (see Figure 6). The conflict events of 2013 were predominantly concentrated in the North-West (in Ouham and Ouham Pende) and parts of the South-West (in and around the capital city Bangui) (panel a). A further increase in conflict in these areas (particularly in Ombella M'Poko) in 2014 perhaps spilled-over to neighboring prefectures resulting in a gradual accumulation to the increase in conflict in the South and parts of the West (panel b). For instance, the increase in conflict in Kemo and Ouaka was perhaps due to a spill-over from neighboring Ouham and Ombella M'Poko. By 2015, the number of conflict events in the country decreased overall despite a slight increase in the number of events in parts of the East (in Haute-Kotto) perhaps due to a spill-over from Ouaka. Recent trends in conflict illustrate a shift in the spatial concentration of conflict events from the West towards the East and South East. For instance, in 2017, Haute-Kotto and its neighbors, Ouaka and Mbomou registered the highest number of conflict events (panel c). A similar trend is also observed in 2018 (based on data obtained between January and June) (panel d).

Figure 6: Spatial Distribution of Conflict in the CAR- Recent Trends



Source: Authors' calculation using ACLED Data.

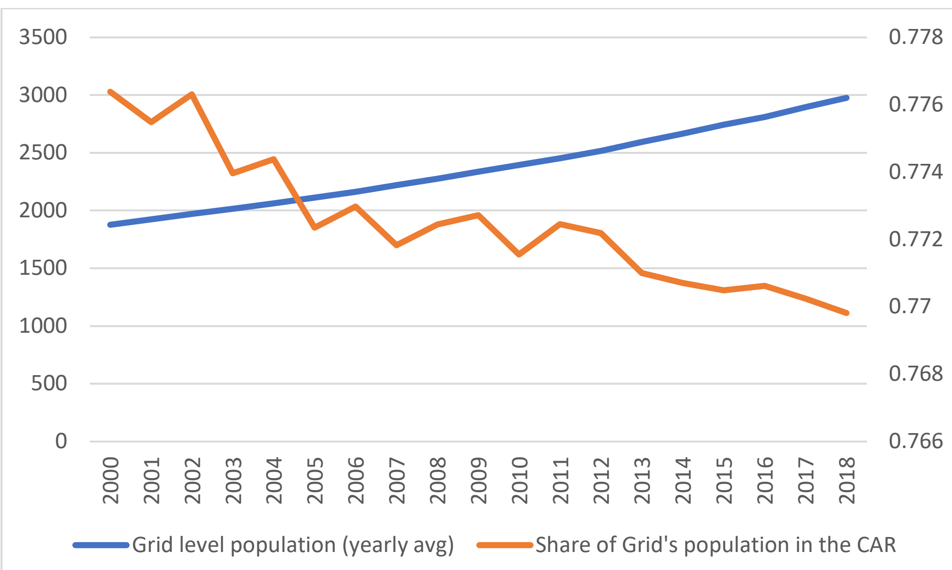
3.2. Natural conditions

Much of the geography of a country relates to a fixed set of natural endowments or agro-ecological conditions. These biophysical conditions are especially important in a country such as the CAR where most of the population is involved in rainfed and low input agricultural activities (World Bank, 2017b). Precipitation varies greatly with an increasing gradient of precipitation from North to South. However, soil nutrient quality is relatively higher in the North with smaller areas in the West and South compared to the remainder of the country. We extract information on precipitation and temperature using Google Earth Engine. We summarize pentad precipitation from CHIRPS Pentad (version 2.0 final) into a monthly time-step: *precip*. We summarize the mean daily land surface temperature from MODIS (MOD11A1.006) into a monthly time-step: *lst*.

3.3. Population

We extract an estimate of the population in each grid cell by summing the population from WorldPop (Linard et al. 2012): *pop*. For each grid, an estimation of total population as well as share of population in the CAR (as well as other countries) is calculated for each month. On average, as shown in figure 7 below, more than 70 percent of the population in the grids in the data are in the CAR.

Figure 7: Population estimates overtime



Source: Authors' Calculation using WorldPop estimates

3.4. Agricultural production and crop suitability

The GAEZ database provides crop-specific suitability for low input (IIASA/FAO 2012). We assign a crop based on the maximum suitability across the selected crops. We consider the following crops based on their prevalence in CAR: cassava, groundnut, maize, pearl millet and sorghum (FAO 2019).

3.5. Fire presence

Many farmers clear the fields by fire after the harvest anticipating the next season, which is a common practice in Central Africa (e.g. Kull and Laris 2009, NASA 2018)[5]. Bucini and Lambin (2002) provide a variety of reasons including: nutrient-rich soil layer for crops and reduction in late-season fires. They find evidence that areas near human settlements have a skewed distribution of early fires compared to areas far from human settlement that exhibit a more even distribution of fire dates. Kahui and Hanan (2018) find that burnt areas are most common in Sub-Saharan Africa in areas with lower population density[6]. In Africa, Archibald et al. (2013) classify many fire areas into pyromes as "frequent–cool–small". Given the paucity of agricultural area data, we use this logic of human presence as a proxy/identification of cultivated area. We use the MODIS Burned Area data product (version 6), which provides a burned-area estimate per 500m pixel by month (NASA 2018): *fire*.

3.6. Gross Primary Productivity and Net Primary Productivity

One of our other main outcome variables is Gross Primary Productivity, which provides a consistent measure of gross biomass. We use the Gross Primary Productivity (GPP) MODIS data product (MOD17A2H) at 500m per pixel and sum the 8-day composite by month (see Figure 8). A related measure, Net Primary Productivity, is also available from MODIS and has been used in other studies (e.g. Strobl and Strobl 2011; Russ et al. 2020), however studies have shown yield estimates are relatively low (Xin et al. 2013 and Reeves et al. 2005).[7] The MODIS-GPP algorithm tends to underestimate GPP in irrigated areas due to the sensitivity of transpiration rates from cooler leaves (Xin et al. 2013), yet irrigated area in CAR is a relatively small share of agricultural land. Also, greenness measures tend to be highly correlated (see Tucker et al. 1985, Pricope et al. 2015). We calculate GPP per month, but also by season into three seasons (sowing, harvest and lean).[8]

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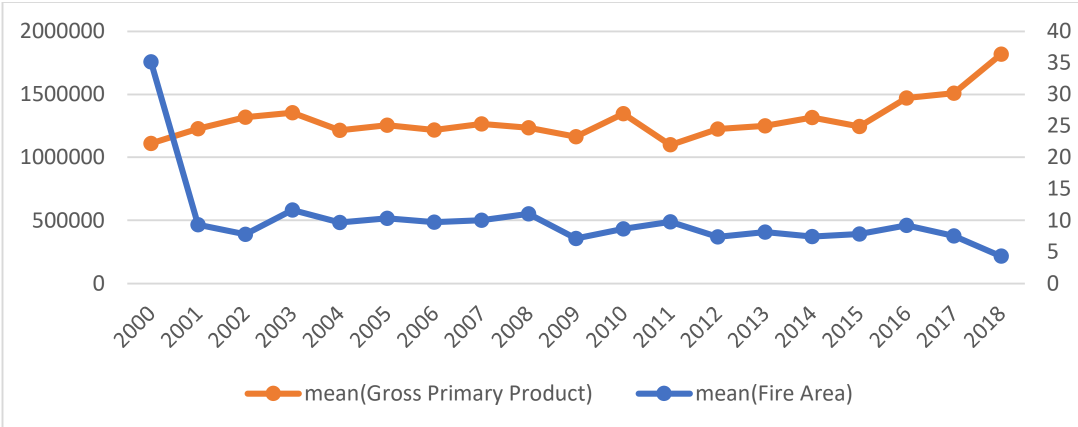
[5] Burned areas is also a practice in other countries such as Central China (e.g. Wang et al. 2018).

[6] More specifically, they find a steep gradient increasing in areas with approximately 50 people per km^2 where burnt areas are common up to 200 people per km^2 with little fire activity. In Africa, Archibald (2016) finds that a nearly linear positive relationship between fire ignition numbers and population density until a maximum near 10 people per km2, then the relationship is negative with increasing population density.

[7] The measure is likely to underestimate due to lack of accounting of below ground elements: litterfall, roots, etc. Monfreda et al. (2008) discuss limitations using Net Primary Productivity including: the difficulty to distinguish cropland from other vegetation from remote sensing measurements. Although crop specific RUE may improve estimates (Xin et al. 2013), Lobell et al. 2002 observe that the yield predictions at the regional level are insensitive to RUE.

[8] We define the seasons at crop level based on agricultural calendar information provided by the FAO (http://www.fao.org/giews/countrybrief/country.jsp?code=CAF)

Figure 8: Fire presence and GPP overtime



Source: Authors' Calculation using MODIS satellite data.

3.7. Summary statistics

Table 1: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Fire	494,982	9.06	33.62	0	340.55
Log (GPP)	511,916	13.38	1.83	-2.08	15.63
Total Conflict events	1,717	2.30	4.40	1	105
Total Fatal events	1,717	7.43	28.54	0	847
Conflict (=1)	520,425	0.003	0.06	0	1
Fatal event (=1)	520,425	0.002	0.04	0	1
Share of Grid's population in CAR	520,425	0.77	0.40	0	1
Precipitation	518,112	19.58	15.96	7E-09	1E+02
Temperature	506,936	29.45	4.66	2E+00	5E+01
Main Crop					
Cassava	520,425	0.62	0.48	0	1
Maize	520,425	0.10	0.30	0	1
Sorgum	520,425	0.22	0.41	0	1
Groundnut	520,425	0.00	0.07	0	1
Millet	520,425	0.06	0.24	0	1
Seasons:					
Land Preparation	520,425	0.33	0.47	0	1
Sowing/Growing	520,425	0.37	0.48	0	1
Harvesting	520,425	0.29	0.45	0	1

Note: Each observation is a grid/month of a year
Source: Authors' calculation using ACLED data, FAO, WorldPop, CHIRPS and MODIS (LST)

The table above (Table 1) shows the summary statistics of the variables at grid level. On average, conflict occurred 2.8% of the months which is equivalent to 1,717 times in the period under review. Fatalities are reported 1.5% of the months or 843 times in the same period. In the periods for which there was conflict, on average there was 2.3 conflict and 7.43 fatalities. Overall, average measure of agricultural activity and rainfall are below historical average calculated between the period 2000-2018. Regarding the suitability of crops, cassava is the most suitable crop in 62% of the grids; followed by sorghum in 22% of the grids. These pattern matches with FAOSTAT data on most common crops in the CAR.

4. Methodology

We combine several sources of remotely sensed data into spatially consistent measures at a grid level. For purposes of presentation, we present the results of 0.1 by 0.1 degree grid similar to Jedwab and Storeygard (2019), but we also run the method at a larger size grid of 0.5 by 0.5, which is the size of other studies (e.g. Berman et al. 2017).

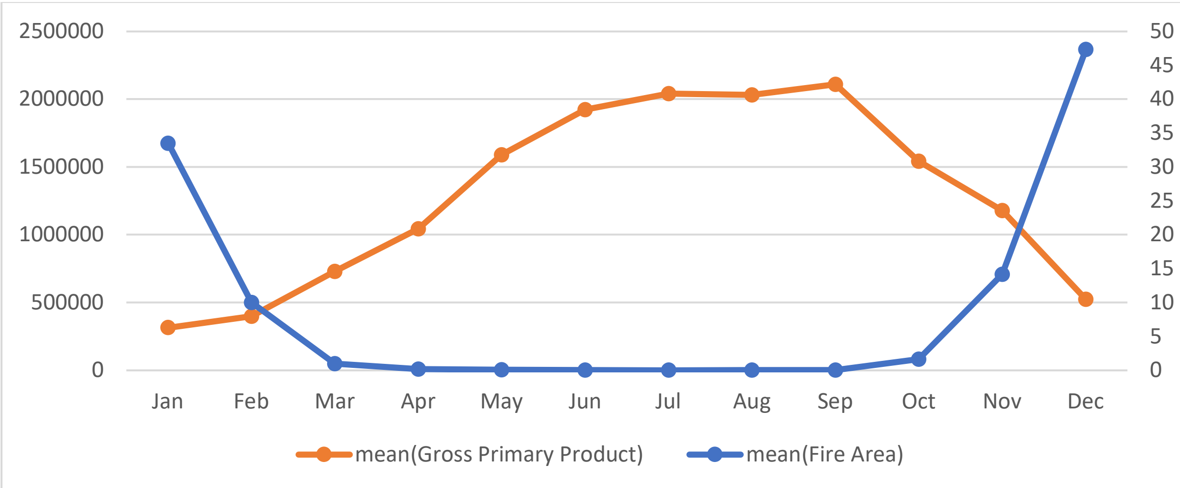
4.1. Identification strategy

We rely on the common practice of burning the agricultural lands as our identification of agricultural areas (Kull and Laris 2009). According to FEWSNET the agricultural calendar in the CAR comprises of a land preparation period beginning November to February the following year during which farmers prepare their land for sowing. This is followed by a wet season between March- September[9]. As shown in Figure 9 below, our data follows similar pattern. During months for land preparation, significant amount of fire presence is observed - perhaps due to the burning of farm land in preparation for sowing/growing. As the wet season approaches, fire presence starts to decrease as the wet season advances until it reaches zero. During the wet season, Gross Primary Product (GPP) increases substantially indicating increased agricultural activity as farmers advance into sowing and growing of their crops.

Our identification strategy exploits this pattern in agricultural activity in the CAR. The presence of conflict may affect agricultural activity by disrupting land preparation activities and abandoning of fields/plots- either because of safety concerns, lower incentives from farming as farmers anticipate continued disruptions to sowing/growing, harvesting and marketing of farm produce; or limited access to farm land. In communities where land is typically prepared by burning, we can expect to observe a negative effect of conflict on fire area during land preparation. Where land does not require burning, the abandoning of farmland for the reasons mentioned above will result in a decrease in the intensity of agricultural activity (proxied by GPP) during sowing/growing. Based on this strategy, we examine the channels through which conflict affects agricultural activity in the CAR and identify the main crops which are most affected.

[9] See https://fews.net/west-africa/central-african-republic

Figure 9: Monthly averages of fire presence and GPP



Source: Authors' calculation using MODIS satellite data.

4.2. Model

Our empirical model seeks to estimate the extent to which conflict affects agricultural activity at the grid level.

Suppose that grids/cell are indexed by i, the administrative unit (such as a commune or sous-prefecture) in which the grid falls under is indexed by c and months are indexed by t, the following specification is proposed:

$$y_{ict} = \beta_0 + \beta_1 K_{ict-1} + \beta_2 S_{ict} + \beta_3 S_{ict} * K_{ict-1} + R_{ict}'\beta_4 + \beta_5 X_i + \rho_c + \gamma_t + \varepsilon_{ict}$$

Where

- $y_{ict} =$ measure of agricultural activity-GPP for cluster i in administrative unit c in time t.
- $K_{ict-1} =$ Lag of the measure of conflict in cluster i . Two definitions are used: a dummy variable to estimate the effect of *occurrence* of conflict (=1 for grids with at least one conflict related event in a given month;); a count of the number of conflict related events to estimate the effect of conflict *intensity*. We also use several lag periods, 1, 3, 6, 9 and 12 months.
- S_{ict} = crop specific definition of seasons- land preparation, sowing/growing and harvesting.
- $X_i =$ Other time invariant characteristics of the grid- suitability of key crops.
- $R_{ict} =$ Vector of additional controls include: Rainfall using precipitation data, temperature, population (based on estimates provided by WorldPop).
- ρ_c and γ_t are administrative unit (such as sous-prefecture or commune) and time fixed effects.
- $\varepsilon_{ict} =$ idiosyncratic error term

We estimate the specification above using panel data econometric techniques, mainly the Fixed Effects Estimator. We estimate separate specifications for fire presence and GPP as well as crop-specific regressions. In order to examine the heterogeneous effects on crops, we examine the spatial distribution of each crop based on their biophysical suitability. Given that the effect of conflict on agriculture may be influenced by spatial spillovers of conflict events, we fit a spatial econometric model onto the data.

5. Results and Discussion

In this section, we present the main findings from our analysis and discuss its implications in the CAR. In the first part, we discuss the results from using fire presence as a measure of activity on cultivated land. Results from using GPP as an alternative indicator of agricultural production are discussed in the second part. Having two measures of agricultural activity allows us to backout the channel through which conflict affects agricultural activity in the CAR. As discussed above, our identification strategy relies on the practice of using fire to prepare land for agriculture. Thus, by examining the effect of conflict on fire presence, we highlight the extent to which conflict affects agriculture during the land preparation stage. GPP on the other hand measures the intensity of the biomass on the land and hence allow us to examine the extent to which conflict affects post-land preparation agricultural production.

In both measures of agricultural activity, we use different lag periods of the presence of conflict including: 6, 9 and 12 months[10]. Also, we use two definitions of conflict: a binary indicator for the presence or absence of conflict; and a count of the number of conflict events in a month in each grid.

[10] Other lag periods such as 1 and 3 were also examined.

Table 2: Effect of Conflict on cultivated land area with activity (fire presence)

	Using Conflict presence dummy			Using # of conflict events		
VARIABLES	6 months lag	9 months lag	12 months lag	6 months lag	9 months lag	12 months lag
Lag of Presence of conflict.	3.654**	1.585	2.438*	0.221	0.0220	0.206
	(1.551)	(1.345)	(1.331)	(0.259)	(0.0660)	(0.158)
Seasons[1]:						
Land Preparation	11.95***	11.95***	11.82***	11.93***	11.92***	11.79***
	(4.184)	(4.186)	(4.160)	(4.181)	(4.181)	(4.157)
Sowing	-6.934***	-6.935***	-6.953***	-6.925***	-6.929***	-6.949***
	(0.989)	(0.989)	(0.993)	(0.987)	(0.987)	(0.992)
Interactions of conflict dummy & seasons						
Conflict * Land preparation	**-9.683*** **	**-9.303*** **	**-9.047*** **	**-1.359** **	**-1.240* **	**-0.548**
	(3.211)	(3.164)	(2.868)	(0.671)	(0.680)	(0.424)
Conflict * Sowing	1.851	3.210***	2.482**	0.0993	0.665***	0.613***
	(1.312)	(0.988)	(1.138)	(0.127)	(0.223)	(0.186)
Constant	18.63***	18.61***	-4.060	18.62***	18.65***	-4.009
	(6.577)	(6.567)	(6.797)	(6.570)	(6.567)	(6.796)
Additional controls[2]	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Administrative Unit[3] Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Admin * Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	415,215	415,215	409,248	415,215	415,215	409,248
R-squared	0.083	0.083	0.074	0.083	0.083	0.073
Number of grids	1,989	1,989	1,989	1,989	1,989	1,989
Adjusted R-squared	0.0800	0.0800	0.0708	0.0799	0.0799	0.0707

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

Notes:

1) Crop-specific seasonal definitions based on CAR's agricultural calendar are used from FAO (2019). The base category for seasons is Harvesting.
2) This include: population (including share of population in CAR), precipitation, crop suitability index and temperature.
3) This corresponds to prefectures in the CAR.

The presence of conflict is associated with a significant reduction in fire presence during the land-preparation period. We observe this effect using both the binary and count definitions of conflict. In particular, we find that in grids in which at least one conflict event occurred 6, 9 or 12 months prior, fire presence during land preparation decreased by 9.7, 9.3 and 9.0 respectively on average. Similarly, using the total number of conflict events in a month instead of a binary indicator, we find that on average, an additional conflict event in a grid 6, 9 or 12 months prior lowers fire presence during land preparation by 1.4, 1.2 and 0.5 respectively.

It can also be observed from the results above that more recent conflict events appear to have a larger effect on activity on cultivated lands. Using different lag periods, it is observed that the decrease in fire presence is larger in shorter lag periods- fire presence decreased by a larger magnitude when conflict occurred in the previous 6 months to a land preparation season than when it occurred in the previous 9 or 12 months.

Typically, a larger share of fire presence in the grid cell is observed during the land preparation period relative to other periods such as sowing/growing and harvesting. This is in line with our identification strategy which relies on the common practice of burning to prepare land for agricultural activity. However, the results show that all else equal, the presence of conflict during the months leading up to land preparation is associated with lower fire presence. Several factors may explain this effect of conflict on agricultural activity. For instance, the occurrence of conflict may limit farmers' access to their farm lands thereby affecting their land preparation activities. In the absence of constraints to accessing farm lands, the occurrence of conflict may also lower anticipated economic gains from agriculture through disruptions in growing, harvesting and/or marketing of agricultural produce. Bearing this in mind and its implication on returns from farming, the incentives to clear farm land in preparation for sowing may be lowered and hence less land preparation activities.

The second observation from the results discussed above may offer some insight which may be useful for disentangling the possible explanations for the effect of conflict on agriculture through land preparation. Under the assumption that the decision to prepare (or not) farm land for sowing is determined early on in the agricultural calendar, one would expect that longer lag effects of conflict will have a larger effect on land preparation. However, given that we observe a larger effect from more recent conflict, it may be the case that in the CAR, conflict effects on agriculture through land preparation is driven by limited access to farm land.

Table 3: Effect of Conflict on the biomass on cultivated land (Log (Gross Primary Product))

	Using Conflict presence dummy			Using # of conflict events		
VARIABLES	6 months lag	9 months lag	12 months lag	6 months lag	9 months lag	12 months lag
Lag of conflict	-0.0657	-0.0169	-0.0332	-0.00659	-0.00284	-0.0127***
	(0.0515)	(0.0472)	(0.0503)	(0.00744)	(0.00229)	(0.00421)
Seasons[1]:						
Land Preparation	-1.351***	-1.338***	-1.315***	-1.351***	-1.338***	-1.315***
	(0.0949)	(0.0933)	(0.0946)	(0.0949)	(0.0933)	(0.0945)
Growing/Sowing	0.312***	0.320***	0.319***	0.312***	0.320***	0.318***
	(0.0303)	(0.0299)	(0.0301)	(0.0303)	(0.0299)	(0.0301)
Interactions of conflict & seasons						
Conflict * Land preparation	0.261**	0.0994	0.0420	0.0718***	0.0335*	0.0195**
	(0.113)	(0.142)	(0.140)	(0.0171)	(0.0201)	(0.00914)
Conflict * Sowing/Growing	-0.0196	-0.0531	-0.0831*	-0.00255	-0.0140*	-0.0164**
	(0.0508)	(0.0548)	(0.0475)	(0.00586)	(0.00777)	(0.00779)
Constant	18.19***	17.51***	18.69***	18.19***	17.51***	18.69***
	(0.257)	(0.282)	(0.273)	(0.257)	(0.282)	(0.273)
Additional controls[2]	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Administrative Unit[3] Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Admin * Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	416,741	410,909	405,170	416,741	410,909	405,170
R-squared	0.497	0.499	0.497	0.497	0.499	0.497
Number of grids	1,989	1,989	1,989	1,989	1,989	1,989
Adj. R-squared	0.495	0.498	0.496	0.495	0.498	0.496

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

Notes:

1) Crop-specific seasonal definitions based on CAR's agricultural calendar are used from FAO (2019). The base category for seasons is Harvesting.
2) This include: population (including share of population in CAR), precipitation, crop suitability index and temperature.
3) This corresponds to prefectures in the CAR.

Based on the alternative definition of agricultural activity- i.e GPP, the presence of conflict also has a negative effect on biomass of the land, which captures the intensity of agricultural production. Typically, GPP values are higher during the growing/sowing seasons as can be seen in the seasonal dummies in the table above. Therefore, reductions in GPP during the growing/sowing season in areas where conflict occurred may reflect a reduction in the intensity of agricultural activity due to conflict. We find a negative effect of conflict on GPP during the sowing/growing seasons and statistically significant when a longer lag period is used. Using the binary indicator of conflict and controlling for other factors such as precipitation, temperature, population, the presence of conflict in the 12 months prior lowers GPP during sowing/growing season by 8 percent. Similarly, statistically significant effect from using the count of number of conflict events is observed during the sowing seasons and with longer lag periods. All else equal, an additional conflict event 9 months and 12 months prior to a sowing/growing season is expected to decrease GPP by 1.4 and 1.6 percent respectively. This implies that in areas where conflict occurred in the past (particularly in the distant past), biomass of the land (which is typically intense during the sowing/growing seasons for agricultural activity) is observed to be less intense.

It is interesting to observe that unlike fire presence, statistically significant effect of conflict on GPP occurs after a longer lag period. Larger effects of conflict on fire presence during land preparation season are observed when a lag period of 6 months is used. On the other hand, decreases in GPP during sowing/growing periods in areas where conflict occurred are only statistically significant when a lag period of 9 or 12 months is used. Given that sowing/growing follows land preparation in the agricultural calendar, this result is perhaps not surprising- when farmers are unable clear their farm land (either because of access constraints or they choose to abandon it) due to conflict, agricultural activity is likely to be less intense- an uncleared farm land is less likely to be used for sowing/growing. As a result, a weaker effect of conflict on the intensity of agricultural activity will be observed- particularly when more recent conflict events are considered. This in line with the results found from using fire and GPP as indicators of agricultural activity.

Implication of the results on Agriculture in the CAR

The negative effect of conflict on agricultural activity is widely documented in the empirical literature. Understanding the channel through which this effect occurs often requires further analysis. For instance,

Figure 1 shows large reductions in production in the CAR- especially in the years following periods of intense conflict. What is unclear is the channel through which this occurs. The results from this analysis make a contribution in this regard. The effect of conflict on land preparation appears to be the main channel through which conflict affects agricultural activity in the CAR. Weak effects are observed in the case of GPP. The presence of conflict in the 6 months prior to land preparation season is often large enough to discourage farmers from clearing their land for farming. This large effect on land preparation perhaps explains the weak effect of conflict on GPP- because less land is cleared for farming due to conflict, subsequently less biomass is observed.

To some extent, this effect also explains the large negative effect of conflict on agriculture in the CAR- see figure on yields and conflict. When conflict significantly affect farmers' land preparation activities leading to the abandoning of farm lands, large reductions in agricultural produce are expected. In instances where conflict does not prevent land clearing (either by not limiting access to land and/or lowering incentives for agricultural activity), much lower effect on agricultural produce is more likely. Thus, the observed larger effect of conflict on land clearing relative to the intensity of agricultural activity explains the significant decrease in agricultural in the years following a rise in conflict events. For the CAR, understanding these patterns will be particularly useful for identifying policies to boost post-conflict agricultural production.

In what follows, we examine crop-specific effects of conflict on agricultural activity. In the results above, we examined the overall effect of conflict on agricultural activity. These effects are likely to be overshadowed by variation across crops. Given that much of the observed effect of conflict on agriculture is seasonal and hence likely to vary across crops, it will be interesting to examine crop-specific effects of conflicts.

Table 4: Crop-Specific Regressions using fire presence

VARIABLES	(1) Cassava	(1) Maize	(1) Groundnut	(1) Millet	(1) Sorghum
Lag of conflict (6 months)	0.981	10.11***	2.968	2.927***	12.05***
	(1.635)	(3.133)	(5.671)	(0.558)	(1.599)
Seasons[1]					
Land Preparation	-0.873	25.63***	28.76	39.60***	41.46***
	(2.974)	(6.086)	(17.46)	(0.648)	(5.523)
Growing/Sowing	-8.549***	-5.163***	3.491	6.121*	4.300***
	(1.014)	(0.691)	(2.327)	(2.657)	(1.485)
Interactions of conflict & seasons					
Conflict * Land preparation	-2.288	-26.79***	-16.95	-0.197	-20.62***
	(3.229)	(7.187)	(13.93)	(1.631)	(3.580)
Conflict * Sowing/Growing	2.302	0.689	5.446***	2.614**	-3.558*
	(1.685)	(1.031)	(0.617)	(0.899)	(1.863)
Constant	-15.94***	-25.68***	18.47**	79.17***	77.17***
	(5.473)	(8.895)	(5.727)	(3.417)	(10.14)
Additional controls[2]	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Administrative Unit[3] Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes
Admin * Year FE	Yes	Yes	Yes	Yes	Yes

Observations	262,620	42,725	2,095	18,726	89,049
R-squared	0.072	0.145	0.115	0.149	0.144
Number of grids	1,254	206	10	91	428
Adj. R-squared	0.0680	0.136	0.0793	0.144	0.140

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

Notes:

1) Crop-specific seasonal definitions based on CAR's agricultural calendar are used from FAO (2019). The base category for seasons is Harvesting.
2) This include: population (including share of population in CAR), precipitation, crop suitability index and temperature.
3) This corresponds to prefectures in the CAR.

Table 5: Crop-Specific Regressions using log (Gross Primary Product)

VARIABLES	(3) Cassava	(3) Maize	(3) Groundnut	(3) Millet	(3) Sorghum
Lag of conflict (12 months)	0.0268	0.111	0.145	-0.0533***	-0.0614
	(0.0464)	(0.0845)	(0.0862)	(0.00698)	(0.0775)
Seasons[1]					
Land Preparation	-1.116***	-1.357***	-1.575***	-1.469***	-2.431***
	(0.0886)	(0.150)	(0.211)	(0.0337)	(0.170)
Growing/Sowing	0.440***	0.0424	-0.00543	0.403**	0.0889***
	(0.0398)	(0.0344)	(0.0744)	(0.135)	(0.0237)
Interactions of conflict & seasons					
Conflict * Land preparation	-0.0524	-0.621***	-0.858	0.165***	0.206
	(0.122)	(0.150)	(0.414)	(0.0321)	(0.286)
Conflict * Sowing/Growing	-0.147***	0.0140	0	0.0621	-0.0239
	(0.0545)	(0.199)	(0)	(0.0931)	(0.0677)
Constant	16.88***	21.37***	20.27***	19.57***	17.49***
	(0.382)	(0.439)	(0.273)	(0.0484)	(0.306)
Additional controls[2]	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Administrative Unit[3] Fixed Effects	Yes	Yes	Yes	Yes	Yes
Grid Fixed Effects	Yes	Yes	Yes	Yes	Yes
Admin * Year FE	Yes	Yes	Yes	Yes	Yes
Observations	259,308	41,693	2,068	18,240	83,861
R-squared	0.449	0.542	0.676	0.648	0.571
Number of grids	1,254	206	10	91	428
Adj. R-squared	0.447	0.538	0.664	0.646	0.570

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

Notes:

1) Crop-specific seasonal definitions based on CAR's agricultural calendar are used from FAO (2019). The base category for seasons is Harvesting.
2) This include: population (including share of population in CAR), precipitation, crop suitability index and temperature.
3) This corresponds to prefectures in the CAR.

In the analysis above, we examined crop-specific effects of conflict on agriculture using fire area and GPP. In the analysis using fire area, we present the results with a 6 months lag for the incidence of conflict since more recent conflict events have a larger effect on agriculture when measured by fire presence. Similarly, in the analysis using GPP, the results from using a 12 months lag for the incidence of conflict is used since it is observed that longer lags of conflict have larger effects when agricultural activity is measured by GPP. These observations are consistent with results from using 6, 9 and 12 month lags in the crop-specific regressions. We also only present the results from using the binary indicator for the presence or not of conflict in both the fire and GPP regressions.

Using fire presence, we observe large negative effects of conflict on maize and sorghum during land preparation. The effect on millet is also negative but only statistically significant when longer lag periods are used (such as 9 and 12 months). The presence of at least one conflict event 6 months prior to land preparation significantly lowers fire presence in areas where maize and cassava are most suitable.

Using GPP, we observe large reductions in biomass during the sowing/growing seasons in areas where cassava is most suitable. In these areas, the occurrence of at least one conflict event in the previous 12 months is associated with a 14.7 percent decrease in GPP during sowing/growing seasons.

The crop-specific analysis provides another insight into the effect of conflict on agricultural activity in the CAR. The first set of results presented showed the channel through which conflict affects agricultural activity. These results highlight the differences in the effect of conflict across crops and by extension across space- since crop suitability is linked to space. In areas where maize and sorghum are suitable crops, it appears conflict results in the abandoning of farm lands- whether by imposing access constraints and/or lowering incentives for farming; thereby affecting agricultural activity. On the other hand, in areas where cassava is the most suitable crop, less sowing/growing of farm land due to conflict may explain large reductions in agricultural activity.

This is perhaps to be expected. Farm lands on which maize, millet and sorghum are most suitable to grow are likely to be cleared by burning; whereas roots and tubers such as cassava may not require the use of fire for land clearing since they are uprooted at the time of harvest. Hence most of the land-preparation activities will involving leveling the plot in preparation for sowing/planting. As a result, the effect of conflict on agricultural activity during land preparation in the case of crops such as cassava, groundnuts, etc; is likely to be weaker than the effect during sowing/growing. This is because less effort is required for land preparation for these crops in general (particularly the use of fire). As a result, the observed decrease in agricultural activity during sowing/growing for these crops reflects the abandoning of farm land (whether because of access constraints and/or lower incentives) due to conflict.

Given the impact of the conflict on agriculture and numerous rural livelihoods, the agricultural sector has the potential to become a major source of employment and a pathway for economic recovery. Development projects in CAR could include an improvement to infrastructure, which is among the lowest 25% of transport index from 2016-2018 (ADB 2018) and labour intensive agricultural projects that could reconnect farms to markets with attention to re-establishing agricultural value chains.

6. Conclusion

Agricultural activity is important part of the economy in CAR that provides livelihoods to a large share of the population. Although the conflict occurs in agricultural areas, little is known about the effect of conflict on agricultural activity in the CAR given the limitations in access to data in the CAR. Demonstrating the utility of data fusion to overcome issues of access, consistency, currency and lack of information, we combine several sources of remotely sensed data along with conflict data at the 0.1 x 0.1 degree grid cell level to obtain a spatially consistent panel of monthly measures to examine the effect of conflict events on agricultural activity including: conflict events, fire presence, Gross Primary Product (a measure of biomass), precipitation, population, temperature, crop suitability. Our identification strategy relies on the unique practice of burning remnants of farm land in preparation for sowing/planting of crops. Given that this is a common practice in Sub-Saharan Africa, especially Central Africa, we explore the extent to which conflict events affect agricultural activity by disrupting farmers' land preparation activities which precede sowing/growing. We also complement this analysis by using Gross Primary Product (GPP) a measure of biomass to examine the effect of conflict on the intensity of agricultural activity while controlling for precipitation, temperature among other controls.

In general, we find that the presence of conflict lowers agricultural activity in the CAR- particularly in areas where maize, millet and cassava are produced. While the nature of this effect differs across crops that are driven largely by differences in production processes particularly during land preparation, the abandoning of farm lands due to conflict is also a likely common characteristic. For crops which require significant efforts in land preparation, more recent conflict events are associated with significant reductions in these activities leaving farm land unprepared for sowing/planting and possibly abandoned. On the other hand, for crops which require less land preparation, we still observe significant decrease in the intensity of the biomass of cultivated land following conflict events suggesting an absence of sowing/growing and possibly abandoning of farm land. Possible explanations for the abandoning of cultivated land following conflict events include: limited access to farms, safety concerns, lower incentives from farming since conflict events may be prolonged disrupting harvesting and/or marketing of agricultural produce.

7. References

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ANNEX

Figure 10: Internally Displaced Population (UNHCR)

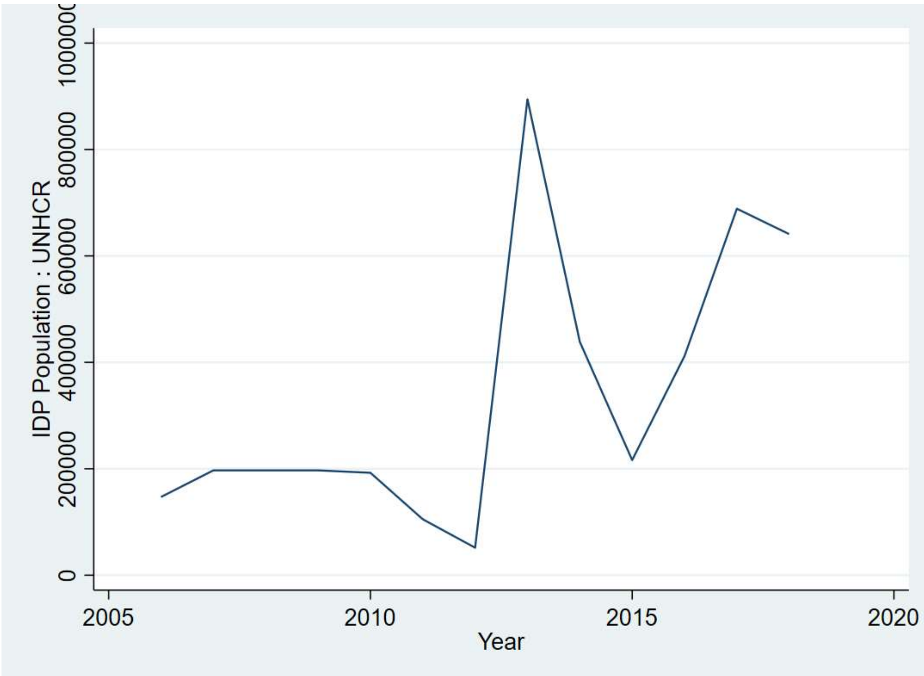

Figure 11: Crop production (FAOSTAT 2019)

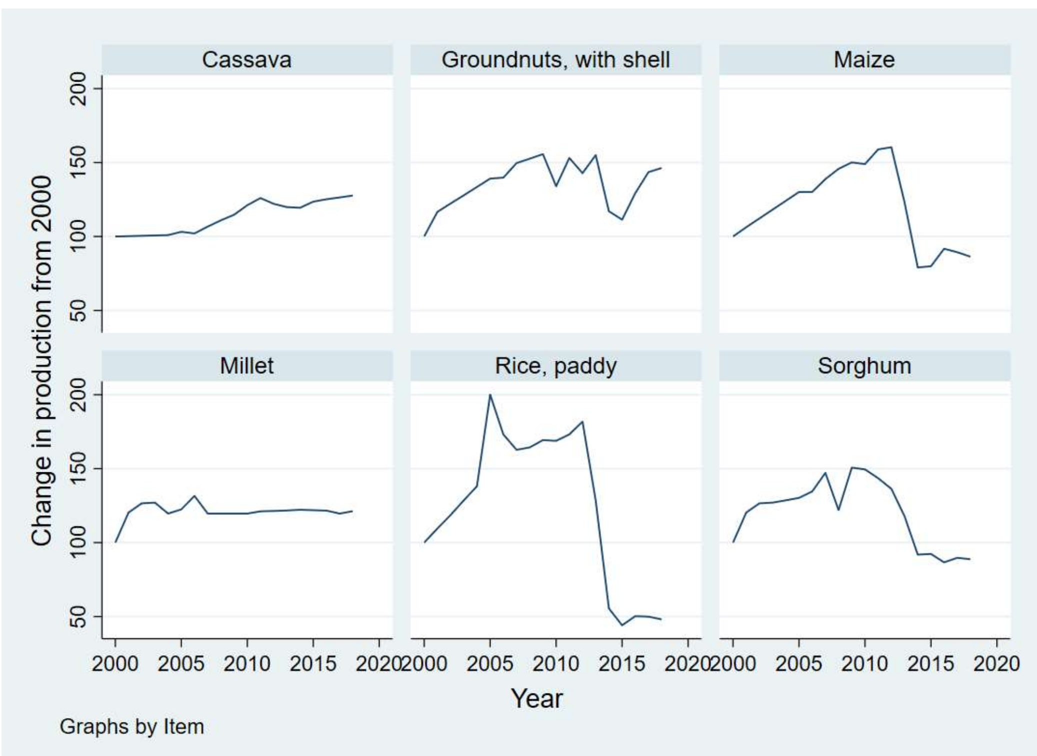

Table 6: CAR food production from 2012 to 2015 in tonnes (source Direction des Statistiques, de la Documentation et de l'Information cited in WFP 2018)

Production	**2012**	**2013**	**2014**	**2015**
Cassava chips	708771	455494	488700	485216
Maize	84365	67514	79595	80455
Rice Paddy	14249	10147	12822	10180
Millet /sorghum	54681	27279	30723	30871
Peaunut	131520	91727	101794	96834
Sesame	28923	17374	27513	34466
Squash seeds	19305	14673	18275	19020
Total	**1041814**	**684208**	**759422**	**757042**